INTEGRATED CIRCUITS FOR COMMUNICATIONS PRODUCTS

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A TDK Group Company

1995 Data Book

The Company

Silicon Systems specializes in the design and manufacture of application-specific, mixed-signal integrated circuits (MSICs®). It offers a sophisticated line of custom and standard ICs aimed primarily at the storage, communications and industrial marketplace.

The company, which is headquartered in California, 30 miles south of Los Angeles, was founded in 1972 as a design center. It soon entered into manufacturing and today has fabrication sites in California and approximately 2,000 employees worldwide. Additional operations include assembly and test facilities in California and Singapore, and design engineering centers in California, Colorado, Tokyo and Singapore.

Reliability and quality are built into Silicon Systems' products through the use of statistical problem solving techniques, analytical controls, and other quantitative methods. Silicon Systems has successfully met quality standards established by the International Organization of Standardization that governs ISO 9000 certification regulations. Silicon Systems' domestic facilities have received ISO 9001 certification for Quality Management Systems applicable to design and manufacture, and, Silicon Systems' Singapore facility has achieved ISO 9002 certification which is pertinent to production and installation.

The company is committed to the goal of customer satisfaction through the on-time delivery of defect-free products that meet or exceed the customer's expectations and requirements. Listed in the back of this publication is a worldwide network of sales representatives and distributors ready to serve you.

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ISO 9001

Silicon Systems, Inc.
Quality Management Systems

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4,691,172 / 4,777,453 / 4,847,868 / 4,866,739 / 4,870,370 / 4,789,995

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Target, Advanced and Preliminary Information
In this data book the following conventions are used in designating a data sheet "Target," "Advanced" or "Preliminary":

Target Specification–
The target specification is intended as an initial disclosure of specification goals for the product. Product is in first stages of design cycle.

Advance Information–
Indicates a product still in the design cycle, undergoing testing processes, and any specifications are based on design goals only. Do not use for final design.

Preliminary Data–
Indicates a product not completely released to production. The specifications are based on preliminary evaluations and are not guaranteed. Small quantities are available, and Silicon Systems should be consulted for current information.

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*Data Sheet available upon request.

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73D2240
73D2247F
73D2404
73D2420/2421
73D246
73D2950
73K212 (12V Version)
73K221 (12V Version)
73K222 (12V Version)
73K312L
73M214
73M376
73M450L/1450/2450
73M650/1650

Part #
75T957
75T981
75T982
78A093A/B
78P233A
78P234
78P8050
78P8060
78Q8330
78Q8360
78Q8370

Communications Products Selector Guide

Device Number	B212 B103	B202	CCITT V.21	CCITT V.23	CCITT V.22	CCITT V.22bis	Description	Power Supply	Available Packages
K-SERIES SINGLE CHIP MODEM FAMILY									
SSI 73K212L	✗						low power, integrated single-chip modem	+5V	28 DIP, 28 PLCC
SSI 73K212SL	✗						73K212L with serial interface only	+5V	22 DIP
SSI 73K221L			✗		✗		low power, integrated single-chip modem	+5V	22, 28 DIP, 28 PLCC
SSI 73K221SL			✗		✗		73K221L with serial interface only	+5V	22 DIP
SSI 73K222L	✗		✗		✗		low power, integrated single-chip modem	+5V	22, 28 DIP, 28 PLCC
SSI 73K222SL	✗		✗		✗		73K222L with serial interface only	+5V	22 DIP
SSI 73K222U	✗		✗		✗		73K222L with 16C450 UART	+5V	40 DIP, 44 PLCC
SSI 73K224L	✗		✗		✗	✗	Bell 212A/103, CCITT V.22bis/V.22/V.21	+5V	28 DIP, 28, 32 PLCC, 52 QFP, 64 TQFP
SSI 73K224SL	✗		✗		✗	✗	73K224L with serial interface	+5V	22 DIP
SSI 73K302L	✗	✗					Bell 212A/202/103	+5V	28 DIP, 28 PLCC
SSI 73K302SL	✗	✗					Bell 212A/202/103; serial interface only	+5V	22 DIP
SSI 73K321L			✗	✗			CCITT V.23/V.21	+5V	28 DIP, 28 PLCC
SSI 73K321SL			✗	✗			73K321L with serial interface only	+5V	22 DIP
SSI 73K322L			✗	✗	✗		CCITT V.23/V.22/V.21	+5V	28 DIP, 28 PLCC
SSI 73K322SL			✗	✗	✗		73K322L with serial interface only	+5V	22 DIP
SSI 73K324L	B212		✗	✗	✗	✗	CCITT V.22bis/V.22/V.23/V.21	+5V	28 DIP, 28, 32 PLCC, 52 QFP, 64 TQFP
CONTROLLERS AND SPECIAL MODEM PRODUCTS									
SSI 73D2248/2348				✗	✗	✗	modem device set w/ AT, MNP	+5V	Various QFP & TQFP
SSI 73M223							1200 bit/s modem IC, compact HDX V.23 modem	+5V	16 DIP, 16 SOL
SSI 73M550							16C550 pin compatible UART Receive and Transmit FIFOs	+5V	40 DIP, 44 PLCC, 48 GT
SSI 73M1550							28-pin version of 73M550, full UART in 28-pin package	+5V	28 DIP, PLCC
SSI 73M2550							28-pin version of 73M550 adds µPRST function	+5V	28 DIP, PLCC
SSI 73M2910/2910A							Microcontroller device	+3V/+5V	Various QFP & TQFP
SSI 73M2918/2918A							Plug & Play Microcontroller & UART	+3.3V/+5V	100 QFP

Communications Products Selector Guide

Device Number	Circuit Function	Features	Power	Available Packages
ANALOG SIGNALLING AND SWITCHING PRODUCTS				
SSI 75T201	Integrated DTMF Receiver	binary coded 2-of-8 output	+12V	22 DIP
SSI 75T202	Integrated DTMF Receiver	low power, binary output	+5V	18 DIP
SSI 75T203	Integrated DTMF Receiver	early detect, binary output	+5V	18 DIP
SSI 75T204	Integrated DTMF Receiver	low power, binary output	+5V	14 DIP, 16 SO
SSI 75T2089	Integrated DTMF Transceiver	generator & receiver, µP interface	+5V	22 DIP
SSI 75T2090	Integrated DTMF Transceiver	like 75T2089 w/ call progress detect	+5V	22 DIP
SSI 75T2091	Integrated DTMF Transceiver	like 75T2090 w/ early detect	+5V	28 DIP, PLCC
SSI 75T980	Imprecise Call Progress Detector	energy detect in 305-640 Hz band, Teltone	+5V	8 DIP
SSI 78A207	Integrated MF Receiver	detects central office toll signals	+5V	20 DIP
PCM PRODUCTS				
SSI 78P236	DS-3 Line Interface	T3 clock & data recovery, transmit equalization	+5V	28 DIP, PLCC
SSI 78P2361	STS-1 Line Interface Transceiver	STS-1 clock & data recovery, transmit equalization	+5V	28 DIP, PLCC
SSI 78P2362	CEPT E-3 Line Interface Transceiver	E3 clock & data recovery, transmit equalization	+5V	28 DIP, PLCC
SSI 78P300	T1/E1 Short Haul Transceiver	receive jitter attenuation	+5V	28 DIP, PLCC
SSI 78P304A	Low-Power 38P300	receive jitter attenuation	+5V	28 DIP, PLCC
SSI 78P7200	DS-3/E3 Line Interface Transceiver	DS-3/E3 transceiver w/receive equalization & higher transmitter drive	+5V	28 DIP, PLCC
LAN PRODUCTS				
SSI 78Q902	10BaseT MAU Transceiver	direct interface to twisted pair and AUI	+5V	28 DIP, PLCC
SSI 78Q2250	ISS Mbit/s ATM Transceiver for NRZ	on-chip clock/data recovery	+5V	48 TQFP
SSI 78Q8373	Single-chip Ethernet IC for PCMCIA	on-chip PCMCIA bus logic, 10BaseT Transceiver	3V or 5V	100 TQFP
SSI 78Q8377	Single-chip Ethernet for ISA/PnP	on-chip Plug & Play logic, 10BaseT transceiver	+5V	128 QFP
SSI 78Q8378	Single-chip Ethernet for PCMCIA	on-chip PCMCIA multi-function logic	3V or 5V	100 TQFP
SSI 78Q8392	802.3 Coax Transceiver	pin-compatible w/NSC 8392	-9V	16 DIP, 28 PLCC
SSI 78Q8392L	Low-power Coax Transceiver	pin-compatible w/NSC 8392	-9V	16 DIP, 28 PLCC

Communications Products Selector Guide

Device Number	Circuit Function	Features
PROGRAMMABLE FILTERS		
SSI 32F8001/8002	Low Power Prog. Elect. Filter	7-Pole Equiripple Active Filter, Prog. *fc* /Pulse Slimming, 9 - 27 MHz (8001), 6-18 MHz (8002)
SSI 32F8003	Prog. Electronic Filter	7-Pole Equiripple Active Filter, Prog. *fc* /Pulse Slimming, 5 - 13 MHz
SSI 32F8011/8012	Prog. Electronic Filter	7-Pole Bessel Active Filter, Prog. *fc* /Pulse Slimming, (5 - 13 MHz, 8011) (6-15 MHz, 8012)
SSI 32F8020/8022	Low Power Prog. Elect. Filter	7-Pole Equiripple Active Filter, Prog. *fc* /Pulse Slimming, 1.5 - 8 MHz
SSI 32F8030	Prog. Electronic Filter	7-Pole Equiripple Active Filter, Prog. *fc* /Pulse Slimming, 250 kHz - 2.5 MHz
SSI 32F8101/02/03/04	Low Power Dgtl. Prog. Filter	(8101/02/03) - 8001/02/03 w/Serial Port & DACs, 95 mW, (8004) - Similar to 8103, *fc* range 3-9 MHz
SSI 32F8120	Low Power Dgtl. Prog. Filter	32F8020 with serial port and DACs
SSI 32F8130/31	Low Power Dgtl. Prog. Filter	32F8030 with serial port and DACs / 32F8131 = 150 kHz < *fc* < 1.5 MHz
SSI 32F8144	Low Power Dgtl. Prog. Filter	2 zero/7-pole linear phase filter, 7-bit serial shift register, 7-27 MHz

Section 1

CUSTOM SOLUTIONS

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CUSTOM SOLUTIONS

SILICON SYSTEMS LEADS THE WAY DEVELOPING MIXED-SIGNAL CUSTOM PRODUCTS.

This is a story about leadership. Silicon Systems is dedicated to taking the point in the creation of high-performance, application-specific custom, mixed-signal integrated circuits (MSICs®).

Such dedication means we bring a lot to the party. Including truly innovative analog, digital, and mixed analog/digital ICs. A full complement of mixed-signal CMOS, BiCMOS and Bipolar wafer fabrication processes, state-of-the-art automated design tools, production, assembly, test, and QA capability.

No one's more experienced

More than 20 years of successful IC design work makes us the most experienced engineering team in the MSICs field. Add it all up and you get a company that saves you time and money while delivering you the most sophisticated mixed-signal custom ICs you can get.

Faster to market for mixed-signal applications

Whatever your mixed-signal design application, Silicon Systems gives you a competitive advantage. In communications, disk drives, other storage products, automotive control systems, or other analog/digital signal processing applications, you can depend on our technical know-how to do the job right and turn your design around faster.

CMOS. Bipolar. BiCMOS. Analog. Digital. We've done it

Our designers are an experienced bunch. They're uniquely able to take a look at your specific application problem and move quickly to the right IC solution.

Our team is particularly adept at identifying key issues such as power, cost and performance trade-offs. So we can gear our efforts toward delivering you an optimized solution, manufactured with the appropriate fab process.

Technique	Application	Silicon Systems Designed Examples
CMOS Analog Processing	For analog continuous time, sampled data (switched-capacitor implementation), and high-current power transistor applications. Low power, high density capability also supports inclusion of ROMs, RAMs, and other analog/digital subsystems.	• Complete single-chip 2400 bit/s modem • 14.4 kbps modem chip set • Direct-broadcast satellite descrambler • Servo and spindle motor controllers with 1.0 Amp motor interfaces • High-resolution analog data acquisition • Cellular baseband processor
BiCMOS Signal Processing	For high-performance, low noise, wideband signal acquisition and processing applications. Offers TTL, CMOS and/or ECL logic interfaces with high current drive.	• Sub 1 nV/√Hz HDD R/W amplifiers • AGC, pulse detection amplifiers • High-speed data separators • Wideband transceivers • PLLs (phase locked loops) • Optical signal processing • Digital cellular, PCS IF circuits
Digital CMOS	For ASIC controllers, digital signal processors, sequencers and data path applications with on-board ROM, RAM, and PLA sub-systems. Offers standard TTL and/or CMOS logic interfaces.	• Digital communications LAN devices • Hard disk drive controllers • SCSI interface controllers • UARTs • Digital signal processors for hard disk servo and telecommunications

The right mix of analog and digital

Providing total analog/digital systems on a chip allows you to meet your cost and performance objectives whether you're designing the next generation of communication, computer peripheral, or industrial control systems.

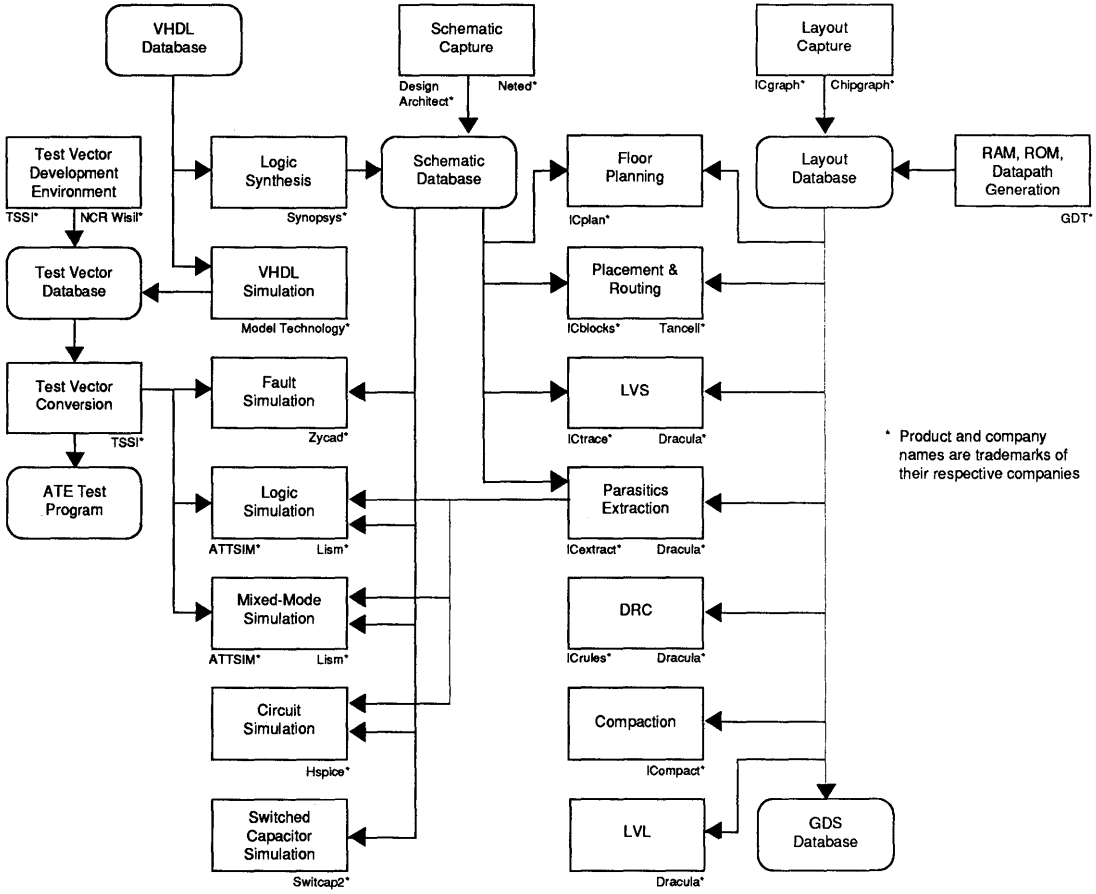
We've turned to CMOS to effectively implement low-power, highly integrated systems solutions for everything from modems and cellular phones to hard disk drive controllers and digital signal processors.

We've gone the BiCMOS route to meet the high-performance needs of products like wideband transceivers, wireless IF modems, R/W amplifiers, low-noise amplifiers, pulse detectors, high-speed data separators and high-performance, low-power combo devices.

SOPHISTICATED TOOLS FOR STRUCTURED CUSTOM DESIGN

At each of six design centers capable of worldwide service – Tustin, San Jose and Nevada City, California; Longmont, Colorado; Tokyo and Singapore – Silicon Systems employs PEGASYS, any internal design automation system developed from carefully selected vendor tools and our own proprietary software. Using Mentor Graphics workstations of both electrical and physical design, PEGASYS helps create complex designs while significantly reducing schedules, costs and errors.

By integrating third-party tools and custom software, we're better able to design and analyze mixed-signal integrated circuits in all CMOS, Bipolar and BiCMOS technologies. It's an approach that has given us the edge in mixed-signal design and helped put Silicon Systems' customers in a favorable position in the marketplace.



PEGASYS Design System

Specifically, PEGASYS brings the following to each design:

- Fully integrated design environment
- Methodology for precision circuit design
- Integrated electrical and physical design
- Unique blend of full-custom and automated layout techniques
- Complete layout verification
- Full mixed-signal parasitic extraction

Our design automation staff integrates the third-party tools and optimizes their use on the Mentor platform. This framework can easily accommodate new tools when needed, and it enables us to support a combination of analog and digital design techniques in all CMOS, Bipolar and BiCMOS chip designs. By mixing design methodologies, we can achieve optimum systems performance, even when schedules are tight.

Electrical design

A single CAE (computer aided engineering) environment provides for schematic capture, synthesis, simulation, and fault grading. We support this software with extensive libraries of pre-designed cells and components. Highly specialized cells or components can be designed and enhanced where required. We simulate each circuit to meet precise performance specifications using:

- Analog circuit simulation
- Digital logic simulation
- VHDL simulation
- Mixed-mode simulation
- Switched-capacitor filter simulation
- Analog and mixed-mode behavioral simulation

Admittedly, simulation alone is not the key to perfecting performance. That's why we work aggressively to refine our understanding of models to make them work with simulation. Inside our progressive device modeling and characterization (DMC) laboratory, we develop accurate circuit simulation models and parameters. The DMC lab provides complete device model data for our processes using capabilities such as AC measurement, statistical analysis and worst-case modeling. Accurate models are a cornerstone of our design-for-quality approach.

To ensure high quality test vectors, production test vectors are derived from simulation vectors using the TSSI tools early in the design process. The industry-standard Zycad fault simulator is then used to determine fault coverage.

Physical design

Our PEGASYS layout system aids the mask designer through all physical design phases, ensuring consistency throughout the design cycle. This flexible, fully integrated environment supports a broad range of layout techniques, from full-custom to full-automation.

Capabilities include:

- Chip floor planning
- Analog device generators
- Schematic driven layout
- On-line point-to-point routing
- Compaction
- Automatic place and route
- Support of custom cells, standard cells, and compiled blocks in any combination
- Design rule checking (drc)
- Layout-versus-schematic verification (lvs)
- Parasitic extraction/back annotation
- Output in industry standard GDS format

In the first generation Pegasys system, Silicon Systems pioneered a device-generator based approach to precision analog layout. In partnership with Mentor Graphics, we have enhanced this technique for our current system, based on Mentor Graphics V8 ICstation® tools. ICstation® provides tremendous flexibility, combined with ease of customization, to fully support analog and mixed-signal designs. A variety of layout styles and techniques are combined to meet each chip's specific requirements. Rigorous verification checks ensure the quality and accuracy of the layout, for both physical and electrical properties. Post-layout simulation uses true parasitic modeling to handle remaining problems before first silicon fabrication.

STATE OF THE ART CMOS DIGITAL AND ANALOG PROCESSES

Silicon Systems offers four proven CMOS process technologies for creating cost effective, highly integrated systems solutions. These processes combine small geometry digital circuit capability with high performance analog capability. Table 1 summarizes Silicon Systems' CMOS process capabilities.

Our newest CK process is designed to support high breakdown, high current power FETs, 15V NPNs for specialized analog needs, poly capacitors and resistors, low noise differential amplifiers and high performance A/D and D/A converters. It also includes highly optimized and silicon area efficient digital cells including DSPs, microcontrollers, sequencers, memory managers and data paths.

The CJ process provides high performance analog and digital cells and includes the same analog and digital complex devices in our CK process.

Our CG process supports high-performance analog circuitry with precision poly-poly capacitors. Complex analog circuitry includes 1.25 Amp power FETs, 12-bit switched capacitor analog to digital converters and low distortion operational amplifiers and filters. Complex digital circuitry includes DSPs, microcontrollers, sequencers, memory mangers and data paths.

BIPOLAR & BICMOS PROCESS TECHNOLOGIES

Our bipolar MSICs take advantage of a high-performance Bipolar process, BN (for 5V applications).

BN - Low-power/ 8 GHz Bipolar at 5 volts

Because we employ full oxide isolation in our BN process, we can fabricate very fast, very small transistors and reduce sidewall capacitances. This supports not only high speed, but low power.

The BN process features high-performance NPN transistors to support mixing high-performance emitter coupled logic (ECL) with analog circuitry. To provide for strict TTL I/O compatibility, we use superior PtSi Schottky diodes.

The resulting speed and packing density allows you to effectively implement dense high-performance, low-power Bipolar analog/digital capability into your system designs.

For a feature-by-feature comparison of Silicon Systems' BN Bipolar process, see Table 3.

BiCMOS process technologies

Our BiCMOS process portfolio is expanding to support the evolving demands of the mixed-signal IC market. Now in production is our BCA process which combines 13 GHz NPNs with 1.0μ CMOS features to support the design of efficient, high performance, mixed-signal circuits. High bandwidth analog circuits can be combined with dense digital logic to support the development of 5V data channels with transfer rates into the 120+ Mbit/s range, while maintaining low power consumption. The BCA technology has also allowed our designers to develop 3V only circuits to address very low power applications.

Our second generation BiCMOS process, BCB, will provide the next step in performance with a parallel improvement in circuit density. BCB advances our BiCMOS with 0.8μ CMOS feature sizes and improved interconnect capability resulting in a significant performance step for CMOS logic. This will allow implementation of mixed-signal circuits that support data transfer rates well beyond 200 Mbit/s, while maintaining very low power dissipation. The dense digital advantages of BCB will also expand the possibilities for cost effective customization and programmability in both 5V and 3V environments.

For a summary of our BiCMOS processes see Table 2.

Process	Type	Application Voltage	BVDSS	Drawn Gate Length	Interconnect Pitches Poly 1	Metal 1	Metal 2	Features
CG	Si-Gate, dual metal, dual poly, PWell	5V	7V	1.5µ	3.0µ	4.5µ	6.0µ	• DDD S/D structure • Poly-poly capacitors • Shrinkable to 1.2µ
CJ	Si-Gate, dual metal, dual poly, NWell	5V	7V	1.0µ	2.0µ	3.0µ	3.3µ	• Ldd S/D structure • Poly-poly capacitors • Shrinkable to 0.8µ
CK	Si-Gate, dual metal, dual poly, NWell	5V	7V	0.8µ	1.6µ	2.0µ	2.4µ	• Ldd S/D structure • Poly-poly capacitors • Shrinkable to 0.5µ • High voltage FETs • 15V NPNs

TABLE 1: CMOS Process Chart

Process	Appl. Voltage	BVDSS	Drawn Gate Length	Interconnect Pitches Poly	M0	M1	M2	BV_{CEO}	NPN Ft	Emitter	Features
BCA:	5V	10V	1.0µ	2.6µ	3.2µ	3.8µ	5.0µ	8V	13 GHz	1.0µ	**Bipolar:** • High Performance NPNs • Polysilicon emitters • PtSi Schottky Diodes • Poly resisters
BCB:	5V	8V	0.8µ	1.6µ	2.4µ	2.0µ	2.4µ	8V	15 GHz	0.8µ	• Gate Oxide Capacitors • Poly Capacitors • Sidewall Oxide Isolation • Fuses **CMOS:** • Lightly Doped Drains

TABLE 2: BiCMOS Process Chart

Process	Type	BV_{CEO}	NPN Ft	Emitter Size	M1 Pitch	M2 Pitch	Features
BN	Oxide-isolated	6V	8 GHz	2.0µ	4.5µ	8.0µ	• High performance NPNs • PtSi Schottky diodes • Nitride capacitors • Ion implanted resistors • Sidewall oxide isolation • Collector/base plugs

TABLE 3: Bipolar Process Chart

A SUPERIOR FINISH FOR CMOS, BIPOLAR AND BICMOS

You might say this is the payoff window. The benefits of our process technologies, design tools and our unique custom approach all come together during wafer fabrication, test and assembly.

Our two manufacturing centers, located in Tustin and Santa Cruz, California, can offer specialized capabilities to match your particular fabrication requirements. Both facilities provide you with high resolution stepper photolithography technology, positive resist, dry plasma etch systems, high current ion implantation and automatic sputtering.

Fabrication sites in both Tustin and Santa Cruz accommodate 4- and 6-inch wafer fabrication and Bipolar, CMOS and BiCMOS processes.

The right package

Silicon Systems offers a wide range of packages to meet the small footprint requirements of advanced storage and communication products. We continue to be innovative in surface mount technology by providing PLCC, SO, VSOP, VTSOP, QFP, TQFP, VTQFP and UTQFP packages. At our ISO 9002-certified Singapore assembly & test facility we have the full capability to support high quality automated packaging while also maintaining rapid cycle times.

Promis. Quality through CAM

Process and Management Information System (PROMIS) underscores our commitment to computer-aided manufacturing (CAM). And to delivering you a superior quality product on time.

We use PROMIS to facilitate the data required in our manufacturing, monitoring and statistical process control (SPC) systems.

With PROMIS we more effectively manage our inventory, accurately track wafers in process, and closely monitor the clean room environment.

PROMIS also assists our SPC efforts, as does our commitment to fully train all of our manufacturing personnel in SPC basics.

We design for quality

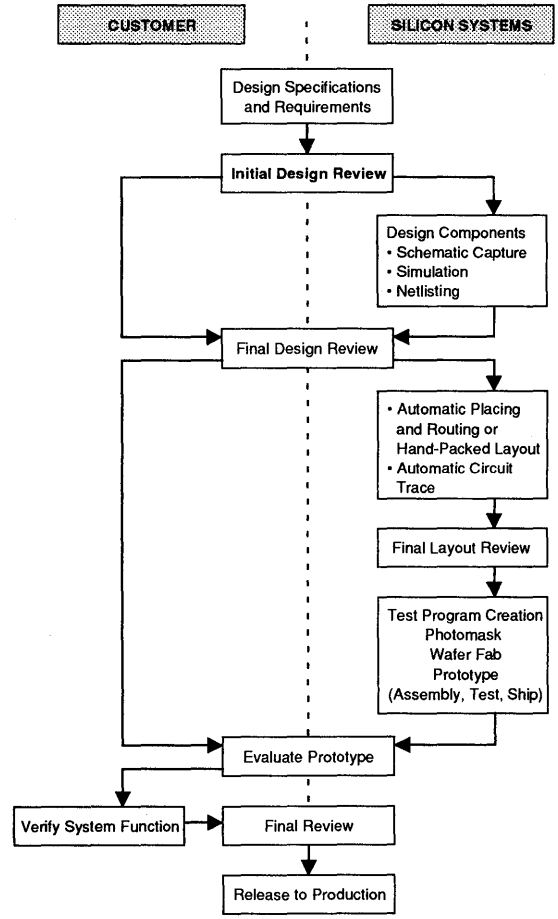
It's our view that quality is nothing less than absolute customer satisfaction. To achieve it, we begin far "upstream" in the product development process. Our design-for-quality approach scrutinizes the design itself with statistically based models, comprehensive simulation tools and vigorous design reviews.

The results of such an effort are IC products that boast lower defect rates, higher parametric performance and far fewer redesigns. Moreover, our persistence in improving quality keeps us focused on finding better and faster ways to satisfy future customer demands.

Quality that delivers

With effective systems such as PROMIS and our design-for-quality approach in place, Silicon Systems is prepared to deliver you finished products you can really depend on. On time. And within budget.

For details on how you can take best advantage of Silicon Systems' custom mixed-signal IC solutions, see your nearest Silicon Systems representative, or contact us. Silicon Systems, Inc. 14351 Myford Road, Tustin, CA 92680-7022. 714-573-6000. FAX: (714) 573-6914.



Customer Interface for Full-Custom and Cell-Based Designs

Section 2

RELIABILITY & QUALITY ASSURANCE

CONTINUOUS IMPROVEMENT MISSION & OBJECTIVE STATEMENT

Mission

Be the supplier of choice by exceeding customer expectations through continuous improvements in our products, systems and services.

Objectives

Provide world class quality in our products and services through focus on:

Customer Partnering
Cycle Time Improvement
Process and System Improvements

Develop a culture that ensures the consistent use of continuous improvement tools and fact based decision methodology by:

Senior Management Leadership
Employee Empowerment
Aggressive Goal Setting and Performance Measurement
Communication and Celebration of Successes

silicon systems®
A TDK Group Company

SECTION 1

1.1 INTRODUCTION

Silicon Systems is committed to the goal of customer satisfaction through the on-time delivery of defect free products that exceed the customer's expectations and requirements. This section outlines Silicon Systems' ongoing activities for the control and continual improvement of quality in every aspect of our organization.

Silicon Systems is diligently working to maintain and improve its position as a world-class provider of mixed-signal integrated circuits (MSICs®).

We realize and practice the concept that quality and reliability must be designed and built into our products. In addition, Silicon Systems utilizes rigid inspections and data analysis to evaluate the acceptability and variation existing in incoming materials and performs stringent outgoing quality verification. The manufacturing process flow is encompassed by an effective system of test/inspection checks and in-line monitors which focus on the control and reduction of process variation. These gates and monitors ensure precise adherence to prescribed standards and procedures.

Silicon Systems also incorporates the use of statistical process control techniques into company operations. The control and reduction of the process variation by the use of statistical problem solving techniques, analytical controls and other quantitative methods ensures that Silicon Systems' products maintain the highest levels of quality and reliability.

Our Reliability and Quality Assurance organizations are committed to working closely with our customers to provide assistance and a continually improving level of product quality.

1.2 SILICON SYSTEMS' QUALITY MANDATE: CONTINUOUS IMPROVEMENT

Continuous improvement is Silicon System's strategic thrust for the 1990's. In order to ensure that all aspects of our business are encompassed by this mandate, Corporate Reliability & Quality Assurance has been chartered with the responsibility for developing, educating and overseeing the worldwide continuous improvement process. The continuous improvement initiative will lead to developing a new organizational culture, changing attitudes and stronger ownership and accountability for total customer satisfaction.

1.3 CHARACTERISTICS OF SILICON SYSTEMS' CONTINUOUS IMPROVEMENT PROCESS

- Executive Steering Committee leadership and direction - defines the right things to do and provides guidance - the right way to do them.
- Continuous improvement is measured everywhere and by everyone. Metrics that reflect pride in accomplishment are celebrated.
- Benchmarking is employed as a method to shorten learning curves and ensure successful ventures.
- Quality management and employee empowerment are encouraged at all levels.

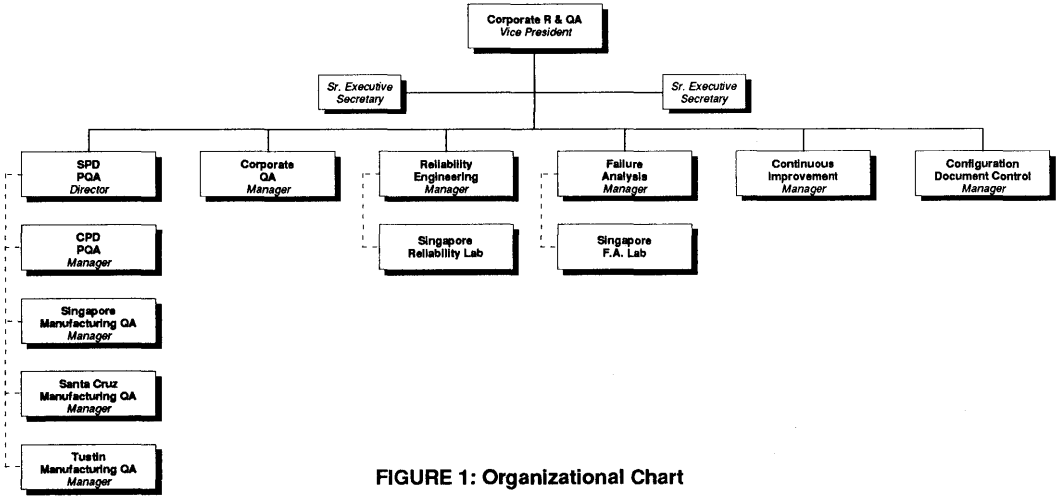


FIGURE 1: Organizational Chart

- Supplier partnership is a critical element of our quality strategy.

This is the essence of Silicon Systems - a total quality involved company - forward looking and immersed in the goal of customer satisfaction and best-in-class business pursuits.

1.4 CORPORATE RELIABILITY AND QUALITY ASSURANCE

It is the objective of the Corporate Reliability and Quality Assurance organization to ensure that proactive quality systems are in place to ensure that Silicon Systems' products will meet or exceed customer requirements and expectations. In addition, the Reliability and Quality Assurance organization works to facilitate the timely implementation of solutions and monitors the effectiveness of corrective actions. These organizational strategies support the continuing enhancement of quality consciousness throughout Silicon Systems.

1.5 ISO 9000 CERTIFICATION

Silicon Systems has determined that ISO 9000 certification is an important strategy for achieving total customer satisfaction. Our Singapore assembly and test operations facility has been ISO 9002 certified through SISIR and our domestic facilities' quality systems have been ISO 9001 certified through Intertek. We believe strongly that ISO 9000 certification proves that Silicon Systems is doing the right things to do things right.

SECTION 2: QUALITY ASSURANCE

2.1 QUALITY OBJECTIVES

While all Silicon Systems employees have direct responsibility for quality in their functions, the Quality Assurance Organizations have the ultimate responsibility for the reliable performance of our products. This is accomplished through the development, administration and assessment of formal quality systems which assure Silicon Systems' management, as well as our customers, that products will fulfill the requirements of customer purchase orders and all other specifications.

Corporate Quality Assurance supports, coordinates and actively participates in the formal qualification of suppliers, material, processes, and products, and the administration of quality systems to assure that our products meet Silicon Systems quality standards. Product Quality Assurance provides the liaison between Silicon Systems and the customer for all product quality related concerns. Manufacturing Quality Assurance administers the manufacturing quality systems and reports quality monitor data to the factory.

It is the practice of Silicon Systems to have corporate quality and reliability objectives encompass all of its activities. This starts with a strong commitment of support from the corporate level and continues with exceptional customer support long after the product has been shipped.

Silicon Systems emphasizes the belief that quality and reliability must be built into all of its products by ensuring that all employees are educated in the quality philosophy of the company. Some of the features built into Silicon Systems quality culture include:

1. Structured training programs directed at wafer fabrication, test, process control personnel and supporting organizations.
   - Team-based problem solving methodologies.
   - Corporate-wide training of quality philosophy and statistical methods.
2. Stringent in-process inspections, gates, and monitors.
3. Rigorous evaluation of designs, materials, and processing procedures.
4. Stringent electrical testing (100% and QC AQL/Sample testing).
5. Ongoing reliability monitors and process verifications.
6. Real-time use of statistical process control methodology.
7. Corporate level audits of manufacturing, subcontractors, and suppliers.
8. Timely corrective action system.
9. Control of non-conforming material.

These focused quality methods result in products which deliver superior performance and reliability in the field.

2.2.1 INCOMING INSPECTIONS

Incoming inspection plays a key role in Silicon Systems' quality efforts. Small variations in incoming material can traverse the entire production cycle before being detected much later in the process. By paying strict attention to the monitoring of materials at the earliest possible stage, variation can be reduced, resulting in a stable uniform process.

2.2.2 IN-PROCESS INSPECTIONS

Silicon Systems has established key inspection monitors in the following strategic areas: wafer fabrication, wafer probe, assembly, and final test.

Quality control monitors have been integrated throughout the manufacturing flow, so that data may be collected and analyzed to verify the results of intermediary manufacturing steps. This data is used to document quality trends or long term improvements in the quality of specific operations.

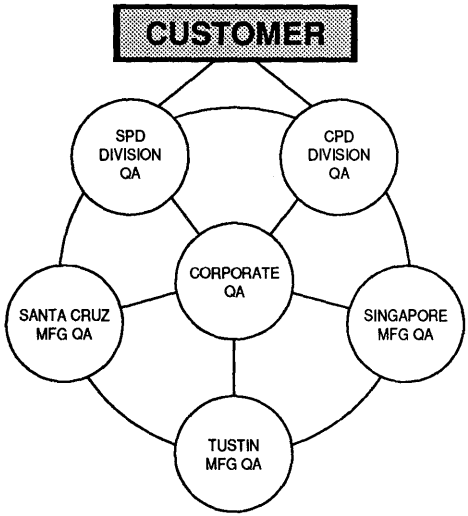


FIGURE 2
Quality Assurance Relationships
Quality Steering Committee

Abnormality control is being used to enhance the effectiveness of this process. In process monitors such as oxide integrity, electromigration immunity and other parameters monitor long term reliability as well as circuit performance.

2.3 QUALITY STEERING COMMITTEE

The Corporate, Product and Manufacturing Quality Assurance organizations work closely together to provide leadership in the development, integration and assessment of Silicon Systems' worldwide quality systems and procedures.

This team approach ensures that policies and procedures are standardized and facilitates rapid improvement in products, processes and services.

2.4 DESIGN FOR QUALITY

Since the foundation of a reliable product is rooted in the design process, the Reliability and Quality Assurance organizations actively participate in comprehensive cross-functional reviews of design stages prior to the product's transition to production status. These review stages assure a predictable and effective development cycle. Other important design-related functions include ensuring that process specification revisions are translated into updated design parameters and the translation of manufacturing process capability into design guidelines. This is accomplished through the identification and monitoring of critical process and device parameters. Wafer level test at the early stages of process development also plays a critical role. These elements, included in Silicon Systems design for quality effort, support the development of robust design rules which are as insensitive as possible to inherent manufacturing variation. The result is a product that delivers predictable and reliable long term performance.

2.5 PPM REDUCTION PROGRAM

The primary purpose of a PPM reduction program is to provide a formalized feedback system in which data from nonconforming products can be used to improve future product consistency and reliability. The action portion of this program is accomplished in three stages:

1. Identification of defects by failure mode.
2. Identification of defect causes and initiation of corrective action.
3. Measurement of results and setting of improved goals.

The data summarized from the established PPM program is compiled as a ratio of units rejected/tested. This ratio is then expressed in terms of defective parts per million (PPM). Founded on a statistically valid database of PPM data and an established five-year strategic plan identifying PPM improvement goals, Silicon Systems has consistently achieved excellent quality standards and will continue to progressively improve PPM standards.

2.6 COMPUTER AIDED MANUFACTURING CONTROL

Computer Aided Manufacturing (CAM) is used throughout Silicon Systems for the identification, control, collection and dissemination of timely information for logistics control. Silicon Systems also uses this type of computerized system for statistical process control and manufacturing monitoring. PROMIS, (PROcess Management and Information System), displays approved/controlled recipes, processes, and procedures; tracks work-in-process; reports accurate inventory information; allows continuous recording of facilities data; contains statistical analysis capabilities; and much more. PROMIS allows for a paperless facility, a major element in minimizing contamination of clean room areas.

Reliability and Quality Assurance

TEST	CONDITIONS	PURPOSE OF EVALUATION
Biased temperature/humidity	85°C/85° %RH	Resistance to high humidity with bias
Highly accelerated stress test (HAST)	JDEC A110	Evaluates package integrity
High temperature operating life (HTOL)	Mil 883D, Method 1005	Resistance to electrical and thermal stress
Early Failure Rate	Mil 883D, Method 1005	Detect infant mortality
Steam pressure	121°C/15PSI	Resistance to high humidity
Temperature cycling	Mil 883D, Method 1010	Resistance to thermal excursion (air)
Thermal shock	Mil 883D, Method 1011	Resistance to thermal excursion (liquid)
Salt atmosphere	Mil 883D, Method 1009	Resistance to corrosive environment
Constant acceleration	Mil 883D, Method 2001	Resistance to constant acceleration
Mechanical shock	Mil 883D, Method 2002	Resistance to mechanical shocks
Solderability	Mil 883D, Method 2003	Evaluates solderability of leads
Lead integrity	Mil 883D, Method 2004	Evaluates lead integrity before board assembly
Vibration, variable frequency	Mil 883D, Method 2007	Resistance to vibration
Thermal resistance	Silicon Systems Method	Evaluates thermal dissipation
Electrostatic damage	Mil 883D, Method 3015	Evaluates ESD susceptability
Latch-up	Silicon Systems Method	Evaluates latch-up susceptibility
Seal fine and gross leak	Mil Std 883D, Method 1014	Evaluates hermeticity of sealed packages

TABLE 1: Reliability Stress Tests

SECTION 3: RELIABILITY

3.1 RELIABILITY PROGRAM

A primary objective at Silicon Systems is to improve the reliability of our products through characterization of our manufacturing operations. The identification of specific failure mechanisms occuring in the wafer fabrication and assembly processes is a prerequisite to effective corrective action aimed at reducing defects and improving quality and reliability.

Silicon Systems has defined various programs that will characterize product reliability levels on a continuous basis. These programs can be categorically described by:

1. Qualifications
2. Production monitors
3. Evaluations
4. Failure analysis
5. Wafer level reliability
6. Data collection and presentation for improvement projects

3.2 QUALIFICATIONS

Extensive qualification testing and data collection ensures that all new product designs, processes, and packaging configurations meet the absolute maximum ratings of design and the worst case performance criteria for end users. A large database generated by means of accelerated stress testing results in a high degree of confidence in predicting final use performance. The qualification criteria used are periodically reviewed to be consistent with Silicon Systems' increasing quality and reliability goals in support of our customers.

3.3 PRODUCTION MONITORS

This program has been established to randomly select a statistically significant sample of production products for subjection to maximum stress test levels in order to evaluate the useful life of the product in a field use environment.

Table 1 lists reliability test methods that are in use at Silicon Systems. This analysis of production monitor at Silicon Systems provides valuable information on possible design/process changes which assure continued improved reliability. The monitors are periodically reviewed for effectiveness and improvements.

3.4 EVALUATIONS

The evaluation program at Silicon Systems is an ongoing effort that defines standards which address the reliability assessment of the circuit design, process parameters, and package of a new product. This program continuously analyzes updated performance characteristics of product as they undergo improvement efforts at Silicon Systems.

3.5 FAILURE ANALYSIS

The failure analysis function is an integral part of the Quality and Reliability department at Silicon Systems. Silicon Systems has assembled a highly technical and sophisticated failure analysis laboratory and staff. This laboratory provides visual analysis, electrical reject mode analysis, and both destructive and non-destructive data to aid the engineers in developing corrective action for improvement. These test analyses may include metallurgical, optical, chemical, electrical, SEM with X-ray dispersive analysis, and E-Beam non-contact analysis as needed.

These conclusive in-house testing and analysis techniques, are complemented by outside support, such as scanning acoustic microscopy, focused ion beam, and complete surface and material analysis. This allows Silicon Systems to monitor all aspects of product manufacturing to ensure that the product of highest quality is shipped to our customers.

3.6 WAFER LEVEL RELIABILITY PROGRAM

The primary advantage of wafer level reliability testing is the speed at which results can be derived, thereby providing additional response time and an early warning of process changes. This tool provides Silicon Systems with a very rapid analysis tool which allows for the early identification of possible problems and a determination of their origin.

The continuous improvement approach taken at Silicon Systems uses wafer level reliability tests as tools to improve the process, identify potential problems, determine the sources of any process weakness and eliminate problems upstream in the process. This results in a focus on reliability improvement that goes well beyond merely determining the projected lifetime of a product to a detailed characterization, measurement and control of the specific parameters which actuallly determine product lifetime.

3.7 DATA COLLECTION AND PRESENTATION FOR IMPROVEMENT PROJECTS

Data collected from each element of the Reliability program is summarized for scope and impact and distributed among all engineering disciplines in the company. This data facilitates improvement and provides our customers an opportunity to review the performance of our product.

3.8 RELIABILITY METHODS

The Reliability Program utilizes a number of stress tests that are presently being used to define performance levels of our products. Many of these stress tests are per MIL-STD-883D as shown in Table 1.

3.9 RELIABILITY PREDICTION METHODOLOGY

At Silicon Systems, the Arrhenius model is used to relate a failure rate at an accelerated temperature test condition to a normal use temperature condition.

The model basically states FR = A exp(-Ea/KT)

Where:

FR = Failure rate

A = Constant

Ea = Activation Energy (eV)

K = Boltzmann's constant 8.62×10^{-5} eV/ degree K

T = Absolute temperature (degree K)

SECTION 4: ELECTROSTATIC DISCHARGE PROGRAM

4.1 ESD PREVENTION

Silicon Systems recognizes that the protection of Electrostatic Discharge (ESD) sensitive devices from damage by electrical transients and static electricity is vital. ESD safe procedures are incorporated throughout all operations which come in contact with these devices. Continuous improvement in the ESD protection levels is being accomplished through the incorporation of increasingly robust protection devices during the circuit design process as well as work area improvements.

Silicon Systems' quality activity incorporates several protection measures for the control of ESD. Some of the preventive measures include handling of parts at static safe-guarded workstations, the wearing of wrist straps during all handling operations, the use of conductive lab coats in all test areas and all areas which handle parts and the packaging of components in conductive or anti-static containers.

NOTES

Section 3

K-SERIES SINGLE-CHIP MODEM FAMILY

Introduction

Silicon Systems' K-Series Family of One-Chip Modems

Silicon Systems is a leader in the design and manufacturing of CMOS VLSI modems. Currently, Silicon Systems offers the most extensive line of one-chip modem ICs available, with high-performance, cost-effective designs suitable for a wide range of applications. Silicon Systems' fully compatible modem IC family has redefined the modem IC as a universal component which can be easily integrated into any system. Designs can be upgraded to meet different standards and speeds by simply substituting one K-Series IC for another. Using a K-Series family modem IC in your application eliminates product obsolesence, and minimizes development costs.

The Silicon Systems modem IC family consists of four basic products:

1. The SSI 73K222L, a multi-mode device which combines both Bell 212A/103 and V.22/V.21 capability in one chip, with operating modes at 0 - 30, 600 and 1200 bit/s.

2. The SSI 73K222U which combines the functionality of the 73K222L with the industry standard 16C450 UART.

3. The SSI 73K224L, a major technological breakthrough which provides 2400 bit/s V.22bis operation in addition to V.22/V.21 and Bell 212A/103 modes in a single IC.

4. The SSI 73K322L provides CCITT V.22/V.21 plus V.23 Videotex modes.

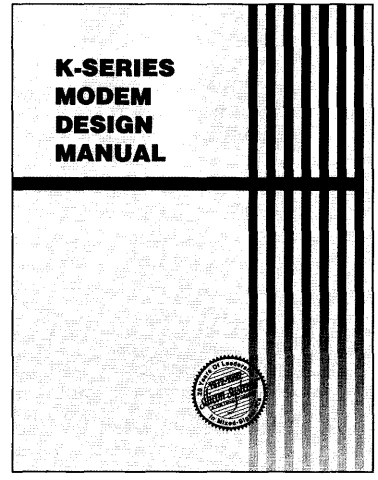
New additions to Silicon Systems' modem IC family extend the available operating modes and provide features which greatly simplify integral modem design. The SSI 73K324L offers V.22bis, V.22/V.21 and V.23 operating modes on one chip. These products dramatically reduce external circuitry required for dedicated integral modem designs.

Silicon Systems' one-chip modem IC products represent technical achievements unmatched in the industry. An advanced Digital Signal Processor resides on the same chip with sophisticated analog circuitry in the SSI 73K224L and SSI 73K324L products. "U" versions of the K-Series devices integrate an industry standard UART with full modem capability on a single chip. In addition, an innovative bus structure makes a separate controller unnecessary in dedicated integral designs. All K-Series devices are available in low-power versions. This feature allows optimal performance with single +5V supply operation and is unique to Silicon Systems' products.

Silicon Systems' single-chip modem IC family is designed to be the most effective solution for a wide variety of modem applications. The products provide for a full range of communications standards and speeds up to 2400 bit/s. Moreover, features can be extended to include additional modes and higher operating speeds without impacting existing designs. Take advantage of these capabilities. Design for tomorrow's needs today by using Silicon Systems' K-Series modem IC family.

K-Series Modem Design Manual

The Silicon Systems K-Series Modem Design Manual contains a large body of application literature for the K-Series family of single chip modem products. This manual is intended as a tutorial for those users who may be designing with modems for the first time, and also as a helpful guide for more experienced modem designers.



The K-Series Modem Design Manual is available through our worldwide network of representatives and distributors.

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SSI 73K212L
Bell 212A/103
Single-Chip Modem

January 1994

DESCRIPTION

The SSI 73K212L is a highly integrated single-chip modem IC which provides the functions needed to construct a typical Bell 212A full–duplex modem. Using an advanced CMOS process that integrates analog, digital and switched–capacitor filter functions on a single substrate, the SSI 73K212L offers excellent performance and a high level of functional integration in a single 28-Lead PLCC, 28- or 22-pin DIP configuration. The SSI 73K212L operates from a single +5V supply.

The SSI 73K212L includes the DPSK and FSK modulator/demodulator functions, call progress and handshake tone monitor test modes and a DTMF dialer. This device supports all Bell 212A modes of operation allowing both synchronous and asychronous communications.

Test features such as analog loop, digital loop, and remote digital loopback are provided. Internal pattern generators are also included for self-testing. The SSI 73K212L is designed to appear to the systems designer as a microprocessor peripheral, and will easily interface with popular one-chip microprocessors

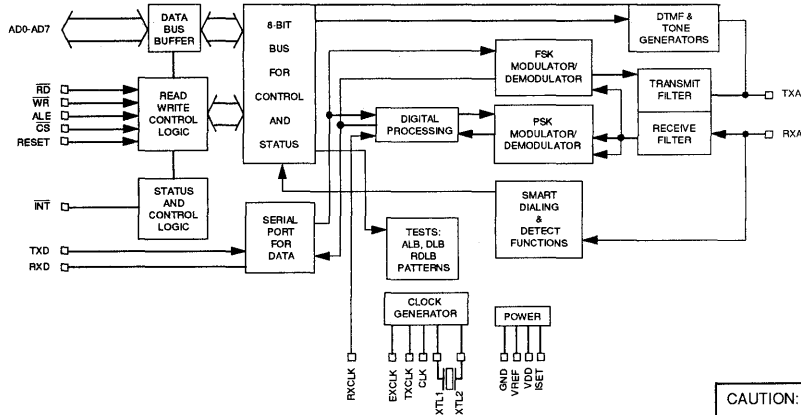
(Continued)

FEATURES

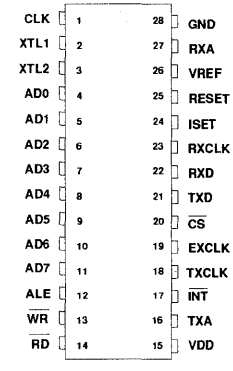
- **One-chip Bell 212A and 103 standard compatible modem data pump**
- **Full-duplex operation at 0-300 bit/s (FSK) or 1200 bit/s (DPSK)**
- **Pin and software compatible with other SSI K-Series 1-chip modems**
- **Interfaces directly with standard microprocessors (8048, 80C51 typical)**
- **Serial or parallel microprocessor bus for control**
- **Serial port for data transfer**
- **Both synchronous and asynchronous modes of operation**
- **Call progress, carrier, precise answer tone and long loop detectors**
- **DTMF generators**
- **Test modes available: ALB, DL, RDL, Mark, Space, Alternating bit patterns**
- **Precise automatic gain control allows 45 dB dynamic range**
- **CMOS technology for low power consumption using 30 mW @ 5V**
- **Single +5V supply**

3

BLOCK DIAGRAM



PIN DIAGRAM



CAUTION: Use handling procedures necessary for a static sensitive component.

DESCRIPTION (Continued)

(80C51 typical) for control of modem functions through its 8-bit multiplexed address/data bus or serial control bus. An ALE control line simplifies address demultiplexing. Data communications occurs through a separate serial port only.

The SSI 73K212L is ideal for use in either free standing or integral system modem products where full-duplex 1200 bit/s data communications over the 2-wire switched telephone network is desired. Its high functionality, low power consumption and efficient packaging simplify design requirements and increase system reliability. A complete modem requires only the addition of the phone line interface, a control microprocessor, and RS-232 level convertor for a typical system. The SSI 73K212L is part of SSi's K-Series family of pin and function compatible single-chip modem products. These devices allow systems to be configured for higher speeds and Bell or CCITT operation with only a single component change.

OPERATION

ASYNCHRONOUS MODE

Data transmission for the DPSK mode requires that data ultimately be transmitted in a synchronous fashion. The SSI 73K212L includes ASYNC/SYNC and SYNC/ASYNC converters which delete or insert stop bits in order to transmit data within a 0.01% rate. In asynchronous mode the serial data comes from the TXD pin into the ASYNC/SYNC converter. The ASYNC/SYNC converter accepts the data provided on the TXD pin which normally must be 1200 bit/s +1.0%, - 2.5%. The rate converter will then insert or delete stop bits in order to output a signal which is 1200 bit/s ± .01% (±.01% is the required synchronous data rate accuracy).

The serial data stream from the ASYNC/SYNC converter is passed through the data scrambler and onto the analog modulator. The data scrambler can be bypassed under processor control when unscrambled data must be transmitted. The ASYNC/SYNC rate converter and the data scrambler are bypassed in all FSK modes. If serial input data contains a break signal through one character (including start and stop bits) the break will be extended to at least $2 \cdot N + 3$ bits long (where N is the number of transmitted bits/character). Serial data from the demodulator is passed first through the data descrambler and then through the SYNC/ASYNC rate converter. The SYNC/ASYNC convertor will reinsert any deleted stop bits and transmit output data at an intra-character rate (bit-to-bit timing) of no greater than 1219 bit/s. An incoming break signal (low through two characters) will be passed through without incorrectly inserting a stop bit.

SYNCHRONOUS MODE

The Bell 212A standard defines synchronous operation only at 1200 bit/s. Operation is similar to that of the asynchronous mode except that data must be synchronized to a provided clock and no variation in data transfer rate is allowable. Serial input data appearing at TXD must be valid on the rising edge of TXCLK.

TXCLK is an internally derived 1200 Hz signal in internal mode and is connected internally to the RXCLK pin in slave mode. Receive data at the RXD pin is clocked out on the falling edge of RXCLK. The ASYNCH/SYNCH converter is bypassed when synchronous mode is selected and data is transmitted out at the same rate as it is input.

DPSK MODULATOR/DEMODULATOR

The SSI 73K212L modulates a serial bit stream into dibit pairs that are represented by four possible phase shifts as prescribed by the Bell 212A standard. The baseband signal is then filtered to reduce intersymbol interference on the bandlimited 2-wire telephone line. Transmission occurs using either a 1200 Hz (originate mode) or 2400 Hz carrier (answer mode). Demodulation is the reverse of the modulation process, with the incoming analog signal eventually decoded into di-bits and converted back to a serial bit stream. The demodulator also recovers the clock which was encoded into the analog signal during modulation. Demodulation occurs using either a 1200 Hz carrier (answer mode or ALB originate mode) or a 2400 Hz carrier (originate mode or ALB answer mode). The SSI 73K212L uses a phase locked loop coherent demodulation technique for optimum receiver performance.

FSK MODULATOR/DEMODULATOR

The FSK modulator produces a frequency modulated analog output signal using two discrete frequencies to represent the binary data. In the Bell 103, the standard frequencies of 1270 and 1070 Hz (originate, mark and

space) or 2225 and 2025 Hz (answer, mark and space) are used. V.21 mode uses 980 and 1180 Hz (originate, mark and space) or 1650 and 1850 Hz (answer, mark and space). Demodulation involves detecting the received frequencies and decoding them into the appropriate binary value. The rate converter and scrambler/descrambler are bypassed in the 103 mode.

PASSBAND FILTERS AND EQUALIZERS

High and low band filters are included to shape the amplitude and phase response of the transmit and receive signals and provide compromise delay equalization and rejection of out-of-band signals in the receive channel. Amplitude and phase equalization are necessary to compensate for distortion of the transmission line and to reduce intersymbol interference in the bandlimited receive signal. The transmit signal filtering approximates a 75% square root of raised Cosine frequency response characteristic.

AGC

The automatic gain control maintains a signal level at the input to the demodulators which is constant to within 1 dB. It corrects quickly for increases in signal which would cause clipping and provides a total receiver dynamic range of >45 dB.

PARALLEL BUS INTERFACE

Four 8-bit registers are provided for control, option select and status monitoring. These registers are addressed with the AD0, AD1, and AD2 multiplexed address lines (latched by ALE) and appear to a control microprocessor as four consecutive memory locations. Two control registers and the tone register are read/write memory. The status detect register is read only and cannot be modified except by modem response to monitored parameters.

SERIAL COMMAND INTERFACE

The serial command mode allows access to the SSI 73K212L control and status registers via a serial command port (22-pin version only). In this mode the A0, A1 and A2 lines provide register addresses for data passed through the data pin under control of the $\overline{RD}$ and $\overline{WR}$ lines. A read operation is initiated when the $\overline{RD}$ line is taken low. The next eight cycles of EXCLK will then transfer out eight bits of the selected address location LSB first. A write takes place by shifting in eight bits of data LSB first for eight consecutive cycles of EXCLK. $\overline{WR}$ is then pulsed low and data transferred into the selected register occurs on the rising edge of $\overline{WR}$.

SPECIAL DETECT CIRCUITRY

The special detect circuitry monitors the received analog signal to determine status or presence of carrier, call-progress tones, answer tone and weak received signal, (long loop condition). An unscrambled mark request signal is also detected when the received data out of the DPSK demodulator before the descrambler has been high for 165.5 ms ± 6.5 ms minimum. The appropriate detect register bit is set when one of these conditions changes and an interrupt is generated for all purposes except long loop. The interrupts are disabled (masked) when the enable interrupt bit is set to 0.

DTMF GENERATOR

The DTMF generator will output one of 16 standard tone pairs determined by a 4-bit binary value and TX DTMF mode bit previously loaded into the tone register. Tone generation is initiated when the DTMF mode is selected using the tone register and the transmit enable (CR0 bit D1) is changed from 0 to 1.

PIN DESCRIPTION

POWER

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
GND	28	1	I	System Ground.
VDD	15	11	I	Power supply input, 5V ± 10% (73K212L). Bypass with .1 and 22 µF capacitors to ground.
VREF	26	21	O	An internally generated reference voltage. Bypass with 0.1 µF capacitor to GND.
ISET	24	19	I	Chip current reference. Sets bias current for op-amps. The chip current is set by connecting this pin to VDD through a 2 MΩ resistor. ISET should be bypassed to GND with a 0.1 µF capacitor.

PARALLEL MICROPROCESSOR INTERFACE

ALE	12	-	I	Address latch enable. The falling edge of ALE latches the address on AD0-AD2 and the chip select on $\overline{CS}$.
AD0-AD7	4-11	-	I/O	Address/data bus. These bidirectional tri-state multiplexed lines carry information to and from the internal registers.
$\overline{CS}$	20	-	I	Chip select. A low during the falling edge of ALE on this pin allows a read cycle or a write cycle to occur. AD0-AD7 will not be driven and no registers will be written if $\overline{CS}$ (latched) is not active. The state of $\overline{CS}$ is latched on the falling edge of ALE.
CLK	1	2	O	Output clock. This pin is selectable under processor control to be either the crystal frequency (for use as a processor clock) or 16 x the data rate for use as a baud rate clock in DPSK modes only. The pin defaults to the crystal frequency on reset.
$\overline{INT}$	17	13	O	Interrupt. This open drain output signal is used to inform the processor that a detect flag has occurred. The processor must then read the detect register to determine which detect triggered the interrupt. $\overline{INT}$ will stay low until the processor reads the detect register or does a full reset.
$\overline{RD}$	14	-	I	Read. A low requests a read of the SSI 73K212L internal registers. Data cannot be output unless both $\overline{RD}$ and the latched $\overline{CS}$ are active or low.

PARALLEL MICROPROCESSOR INTERFACE (Continued)

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
RESET	25	20	I	Reset. An active high signal on this pin will put the chip into an inactive state. All control register bits (CR0, CR1, Tone) will be reset. The output of the CLK pin will be set to the crystal frequency. An internal pull down resistor permits power on reset using a capacitor to VDD.
$\overline{WR}$	13	-	I	Write. A low on this informs the SSI 73K212L that data is available on AD0-AD7 for writing into an internal register. Data is latched on the rising edge of $\overline{WR}$. No data is written unless both $\overline{WR}$ and the latched $\overline{CS}$ are low.

SERIAL MICROPROCESSOR INTERFACE

A0-A2	-	5-7	I	Register Address Selection. These lines carry register addresses and should be valid during any read or write operation.
DATA	-	8	I/O	Serial Control Data. Data for a read/write operation is clocked in or out on the falling edge of the EXCLK pin. The direction of data flow is controlled by the $\overline{RD}$ pin. $\overline{RD}$ low outputs data. $\overline{RD}$ high inputs data.
$\overline{RD}$	-	10	I	Read. A low on this input informs the SSI 73K212L that data or status information is being read by the processor. The falling edge of the $\overline{RD}$ signal will initiate a read from the addressed register. The $\overline{RD}$ signal must continue for eight falling edges of EXCLK in order to read all eight bits of the referenced register. Read data is provided LSB first. Data will not be output unless the $\overline{RD}$ signal is active.
$\overline{WR}$	-	9	I	Write. A low on this input informs the SSI 73K212L that data or status information has been shifted in through the DATA pin and is available for writing to an internal register. The normal procedure for a write is to shift in data LSB first on the DATA pin for eight consecutive falling edges of EXCLK and then to pulse $\overline{WR}$ low. Data is written on the rising edge of $\overline{WR}$.

Note: In the serial, 22-pin version, the pins AD0-AD7, ALE and $\overline{CS}$ are removed and replaced with the pins; A0, A1, A2, DATA, and an unconnected pin. Also, the $\overline{RD}$ and $\overline{WR}$ controls are used differently.

The Serial Control mode is provided in the parallel control versions by tying ALE high and $\overline{CS}$ low. In this configuration AD7 becomes DATA and AD0, AD1 and AD2 become A0, A1 and A2, respectively.

DTE USER INTERFACE

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
EXCLK	19	15	I	External Clock. This signal is used in synchronous transmission when the external timing option has been selected. In the external timing mode the rising edge of EXCLK is used to strobe synchronous DPSK transmit data applied to the TXD pin. Also used for serial control interface.
RXCLK	23	18	O	Receive Clock. The falling edge of this clock output is coincident with the transitions in the serial received data output. The rising edge of RXCLK can be used to latch the valid output data. RXCLK will be valid as long as a carrier is present.
RXD	22	17	O	Received Data Output. Serial receive data is available on this pin. The data is always valid on the rising edge of RXCLK when in synchronous mode. RXD will output constant marks if no carrier is detected.
TXCLK	18	14	O	Transmit Clock. This signal is used in synchronous transmission to latch serial input data on the TXD pin. Data must be provided so that valid data is available on the rising edge of the TXCLK. The transmit clock is derived from different sources depending upon the synchronization mode selection. In Internal Mode the clock is generated internally. In External Mode TXCLK is phase locked to the EXCLK pin. In Slave Mode TXCLK is phase locked to the RXCLK pin. TXCLK is always active.
TXD	21	16	I	Transmit Data Input. Serial data for transmission is applied on this pin. In synchronous modes, the data must be valid on the rising edge of the TXCLK clock. In asynchronous modes (1200 bit/s or 300 baud) no clocking is necessary. DPSK data must be 1200 bit/s +1%, -2.5%.

ANALOG INTERFACE AND OSCILLATOR

RXA	27	22	I	Received modulated analog signal input from the telephone line interface.
TXA	16	12	O	Transmit analog output to the telephone line interface.
XTL1 XTL2	2 3	3 4	I I	These pins are for the internal crystal oscillator requiring a 11.0592 MHz parallel mode crystal and two load capacitors to Ground. Consult crystal manufacturer for proper valves. XTL2 can also be driven from an external clock.

REGISTER DESCRIPTIONS

Four 8-bit internal registers are accessible for control and status monitoring. The registers are accessed in read or write operations by addressing the A0, A1 and A2 address lines in serial mode, or the AD0, AD1 and AD2 lines in parallel mode. In parallel mode the address lines are latched by ALE. Register CR0 controls the method by which data is transferred over the phone line. CR1 controls the interface between the microprocessor and the SSI 73K212L internal state. DR is a detect register which provides an indication of monitored modem status conditions. TR, the tone control register, controls the DTMF generator, answer and guard tones and RXD output gate used in the modem initial connect sequence. All registers are read/write except for DR which is read only. Register control and status bits are identified below:

REGISTER BIT SUMMARY

	ADDRESS	DATA BIT NUMBER							
REGISTER	AD2 - AD0	D7	D6	D5	D4	D3	D2	D1	D0
CONTROL REGISTER 0 CR0	000			TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE
CONTROL REGISTER 1 CR1	001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTERRUPT	BYPASS SCRAMBLER	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0
DETECT REGISTER DR	010			RECEIVE DATA	UNSCR. MARKS	CARRIER DETECT	ANSWER TONE	CALL PROGRESS	LONG LOOP
TONE CONTROL REGISTER TR	011	RXD OUTPUT CONTROL		TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF3	DTMF2	DTMF1	DTMF0
CONTROL REGISTER 2 CR2	100				THESE REGISTER LOCATIONS ARE RESERVED FOR				
CONTROL REGISTER 3 CR3	101				USE WITH OTHER K-SERIES FAMILY MEMBERS				
ID REGISTER ID	110	ID	ID	ID	ID				

NOTE: When a register containing reserved control bits is written into, the reserved bits must be programmed as 0's.

REGISTER ADDRESS TABLE

REGISTER	ADDRESS AD2 - AD0	DATA BIT NUMBER D7	D6	D5	D4	D3	D2	D1	D0
CONTROL REGISTER 0 CR0	000			TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ORIGINATE/ ANSWER
				0000=PWR DOWN 0001=INT SYNCH 0010=EXT SYNCH 0011=SLAVE SYNCH 0100=ASYNCH 8 BITS/CHAR 0101=ASYNCH 9 BITS/CHAR 0110=ASYNCH 10 BITS/CHAR 0111=ASYNCH 11 BITS/CHAR 1100=FSK				0=DISABLE TXA OUTPUT 1=ENABLE TXA OUTPUT	0=ANSWER 1=ORIGINATE
CONTROL REGISTER 1 CR1	001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTERRUPT	BYPASS SCRAMBLER	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0
		00=TX DATA 01=TX ALTERNATE 10=TX MARK 11=TX SPACE		0=DISABLE 1=ENABLE	0=NORMAL 1=BYPASS SCRAMBLER	0=XTAL 1=16 X DATA RATE OUTPUT AT CLK PIN IN DPSK MODE ONLY	0=NORMAL 1=RESET	00=NORMAL 01=ANALOG LOOPBACK 10=REMOTE DIGITAL LOOPBACK 11=LOCAL DIGITAL LOOPBACK	
DETECT REGISTER DR	010			RECEIVE DATA	UNSCR. MARKS	CARRIER DETECT	ANSWER TONE	CALL PROGRESS	LONG LOOP
				OUTPUTS RECEIVED DATA STREAM	0=CONDITION NOT DETECTED 1=CONDITION DETECTED				
TONE CONTROL REGISTER TR	011	RXD OUTPUT CONTROL		TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF3	DTMF2	DTMF1	DTMF0
		RXD PIN 0=NORMAL 1=TRI STATE		0=OFF 1=ON	0=DATA 1=TX DTMF	4 BIT CODE FOR 1 OF 16 DUAL TONE COMBINATIONS.			
ID REGISTER 10	110	ID	ID	ID	ID				

00XX=73K212L, 322L, 321L
01XX=73K221L, 302L
10XX=73K222L
1100=73K224L
1110=73K324L
1101=73K312L

CONTROL REGISTER 0

	D7	D6	D5	D4	D3	D2	D1	D0
CR0 000			TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	Answer/ Originate	0	Selects answer mode (transmit in high band, receive in low band).
		1	Selects originate mode (transmit in low band, receive in high band).
D1	Transmit Enable	0	Disables transmit output at TXA.
		1	Enables transmit output at TXA.
			Note: Answer tone and DTMF TX control require TX enable.
D5, D4, D3, D2	Transmit Mode	D5 D4 D3 D2	
		0 0 0 0	Selects power down mode. All functions disabled except digital interface.
		0 0 0 1	Internal synchronous mode. In this mode TXCLK is an internally derived 1200 Hz signal. Serial input data appearing at TXD must be valid on the rising edge of TXCLK. Receive data is clocked out of RXD on the falling edge of RXCLK.
		0 0 1 0	External synchronous mode. Operation is identical to internal synchronous, but TXCLK is connected internally to EXCLK pin, and a 1200 Hz clock must be supplied externally.
		0 0 1 1	Slave synchronous mode. Same operation as other synchronous modes. TXCLK is connected internally to the RXCLK pin in this mode.
		0 1 0 0	Selects DPSK asynchronous mode - 8 bits/character (1 start bit, 6 data bits, 1 stop bit).
		0 1 0 1	Selects DPSK asynchronous mode - 9 bits/character (1 start bit, 7 data bits, 1 stop bit).
		0 1 1 0	Selects DPSK asynchronous mode - 10 bits/character (1 start bit, 8 data bits, 1 stop bit).
		0 1 1 1	Selects DPSK asynchronous mode - 11 bits/character (1 start bit, 8 data bits, Parity and 1 stop or 2 stop bits).
		1 1 0 0	Selects FSK operation.
D6		0	Not used, must be written as "0."

CONTROL REGISTER 1

	D7	D6	D5	D4	D3	D2	D1	D0
CR1 001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTER.	BYPASS SCRAMB	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D1, D0	Test Mode	D1 D0	
		0 0	Selects normal operating mode.
		0 1	Analog loopback mode. Loops the transmitted analog signal back to the receiver, and causes the receiver to use the same center frequency as the transmitter. To squelch the TXA pin, transmit enable bit must be low.
		1 0	Selects remote digital loopback. Received data is looped back to transmit data internally, and RXD is forced to a mark. Data on TXD is ignored.
		1 1	Selects local digital loopback. Internally loops TXD back to RXD and continues to transmit data carrier at the TXA pin.
D2	Reset	0	Selects normal operation.
		1	Resets modem to power down state. All control register bits (CR0, CR1, Tone) are reset to zero. The output of the CLK pin will be set to the crystal frequency on reset.
D3	CLK Control (Clock Control)	0	Selects 11.0592 MHz crystal echo output at CLK pin.
		1	Selects 16 X the data rate, output at CLK pin in DPSK modes only.
D4	Bypass Scrambler	0	Selects normal operation. DPSK transmit data is passed through scrambler.
		1	Selects Scrambler Bypass. Bypass DPSK data is routed around scrambler in the transmit path.
D5	Enable Detect Interrupt	0	Disables interrupt at $\overline{INT}$ pin.
		1	Enables $\overline{INT}$ output. An interrupts will be generated with a change in status of DR bits D1-D4. The answer tone and call progress detect interrupts are masked when the TX enable bit is set. Carrier detect is masked when TX DTMF is activated. All interrupts will be disabled if the device is in power down mode.

CONTROL REGISTER 1 (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
CR1 001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTER.	BYPASS SCRAMB	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D7, D6	Transmit Pattern	D7 D6	
		0 0	Selects normal data transmission as controlled by the state of the TXD pin.
		0 1	Selects an alternating mark/space transmit pattern for modem testing.
		1 0	Selects a constant mark transmit pattern.
		1 1	Selects a constant space transmit pattern.

DETECT REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
DR 010			RECEIVE DATA	UNSCR. MARK	CARR. DETECT	ANSWER TONE	CALL PROG.	LONG LOOP

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	LONG LOOP	0	Indicates normal received signal.
		1	Indicates low received signal.
D1	CALL PROGRESS DETECT	0	No call progress tone detected.
		1	Indicates presence of call progress tones. The call progress detection circuitry is activated by energy in the 350 to 620 Hz call progress band.
D2	ANSWER TONE DETECT	0	No answer tone detected.
		1	Indicates detection of 2225 Hz answer tone. The device must be in originate mode for detection of answer tone.
D3	CARRIER DETECT	0	No carrier detected in the receive channel.
		1	Indicated carrier has been detected in the received channel.
D4	UNSCRAM-BLED MARK	0	No unscrambled mark.
		1	Indicates detection of unscrambled marks in the received data. A valid indication requires that unscrambled marks be received for > 165.5 ± 6.5 ms.

DETECT REGISTER (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
DR 010			RECEIVE DATA	UNSCR. MARK	CARR. DETECT	ANSWER TONE	CALL PROG.	LONG LOOP

BIT NO.	NAME	CONDITION	DESCRIPTION
D5	RECEIVE DATA		Continuously outputs the received data stream. This data is the same as that output on the RXD pin, but it is not disabled when RXD is tri-stated.
D6, D7			Not used.

TONE REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.		TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2	DTMF 1	DTMF 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D3, D2, D1, D0	DTMF	D3 D2 D1 D0 0 0 0 0 - 1 1 1 1	Programs 1 of 16 DTMF tone pairs that will be transmitted when TX DTMF and TX enable bit (CR0, bit D1) are set. Tone encoding is shown below:

KEYBOARD EQUIVALENT	DTMF CODE D3	D2	D1	D0	TONES LOW	HIGH
1	0	0	0	1	697	1209
2	0	0	1	0	697	1336
3	0	0	1	1	697	1477
4	0	1	0	0	770	1209
5	0	1	0	1	770	1336
6	0	1	1	0	770	1477
7	0	1	1	1	852	1209
8	1	0	0	0	852	1336
9	1	0	0	1	852	1477
0	1	0	1	0	941	1336
*	1	0	1	1	941	1209
#	1	1	0	0	941	1477
A	1	1	0	1	697	1633
B	1	1	1	0	770	1633
C	1	1	1	1	852	1633
D	0	0	0	0	941	1633

TONE REGISTER (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.		TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2	DTMF 1	DTMF 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D4	TRANSMIT DTMF	0	Disable DTMF.
		1	Activates DTMF. The selected DTMF tones are transmitted continuously when this bit is high (with Transmit Enable, CR0-D1). TX DTMF overrides all other transmit functions.
D5	TRANSMIT ANSWER TONE	0	Disables answer tone generator.
		1	Enables answer tone generator. A 2225 Hz answer tone will be transmitted continuously when the Transmit Enable bit is set in CR0. The device must be in answer mode.
D7	RXD OUTPUT CONTROL	0	Enables RXD pin. Receive data will be output on RXD.
		1	Disables RXD pin. The RXD pin reverts to a high impedance with internal, weak pull-up resistor.

ID REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
ID 110	ID	ID	ID	ID	ID			

BIT NO.	NAME	CONDITION	DESCRIPTION
D7, D6, D5 D4	Device Identification Signature	D7 D6 D5 D4	Indicates Device:
		0 0 X X	SSI 73K212L, 73K321L or 73K322L or 73K321L
		0 1 X X	SSI 73K221L or 73K302L
		1 0 X X	SSI 73K222L
		1 1 0 0	SSI 73K224L
		1 1 1 0	SSI 73K324L
		1 1 0 1	SSI 73K312L

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

PARAMETER	RATING
VDD Supply Voltage	14 V
Storage Temperature	-65 to 150°C
Soldering Temperature (10 sec.)	260°C
Applied Voltage	-0.3 to VDD + 0.3 V
Note: All inputs and outputs are protected from static charge using built-in, industry standard protection devices and all outputs are short-circuit protected.	

RECOMMENDED OPERATING CONDITIONS

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
VDD Supply Voltage		4.5	5	5.5	V
TA, Operating Free-Air Temperature		-40		+85	°C
Clock Variation	(11.0592 MHz) Crystal or external clock	-0.01		+0.01	%
External Components (Refer to Application section for placement.)					
VREF Bypass capacitor	(External to GND)	0.1			µF
Bias setting resistor and ISET pins)	(Placed between VDD	1.8	2	2.2	MΩ
ISET Bypass capacitor	(ISET pin to GND)	0.1			µF
VDD Bypass capacitor 1	(External to GND)	0.1			µF
VDD Bypass capacitor 2	(External to GND)	22			µF
XTL1 Load Capacitor	Depends on crystal characteristics;			40	pF
XTL2 Load Capacitor	from pin to GND			20	

ELECTRICAL SPECIFICATIONS (Continued)

DC ELECTRICAL CHARACTERISTICS

(TA = -40°C to 85°C, VDD = recommended range unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
IDD, Supply Current	ISET Resistor = 2 MΩ				
IDDA, Active	CLK = 11.0592 MHz		8	12	mA
IDD1, Power-down	CLK = 11.0592 MHz			4	mA
IDD2, Power-down	CLK = 19.200 kHz			3	mA
Digital Inputs					
VIH, Input High Voltage					
Reset, XTL1, XTL2		3.0		VDD	V
All other inputs		2.0		VDD	V
VIL, Input Low Voltage		0		0.8	V
IIH, Input High Current	VI = VIH Max			100	µA
IIL, Input Low Current	VI = VIL Min	-200			µA
Reset Pull-down Current	Reset = VDD	1		50	µA
Input Capacitance	All Digital Input Pins			10	pF
Digital Outputs					
VOH, Output High Voltage	IOH MIN = -0.4 mA	2.4		VDD	V
VOL, Output Low Voltage	IO MAX=1.6 mA			0.4	V
VOL, CLK Output	IO = 3.6 mA			0.6	V
RXD Tri-State Pull-up Curr.	RXD = GND	-1		-50	µA
CMAX, CLK Output	Maximum Capacitive Load			15	pF

ELECTRICAL SPECIFICATIONS (Continued)

DYNAMIC CHARACTERISTICS AND TIMING

(TA = -40°C to + 85°C, VDD = recommended range unless otherwise noted.)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
PSK Modulator					
Carrier Suppression	Measured at TXA	55			dB
Output Amplitude	TX scrambled marks	-11	-10.0	-9	dBm0
FSK Mod/Demod					
Output Freq. Error	CLK = 11.0592 MHz	-0.35		+.35	%
Transmit Level	Transmit Dotting Pattern	-11	-10.0	-9	dBm0
Harmonic Distortion in 700-2900 Hz band	THD in the alternate band DPSK or FSK		-60	-50	dB
Output Bias Distortion	Transmit Dotting Pattern In ALB @ RXD		±8		%
Total Output Jitter	Random Input in ALB @ RXD	-15		+15	%
DTMF Generator					
Freq. Accuracy		-.25		+.25	%
Output Amplitude	Low-Band, DPSK Mode	-10	-9	-8	dBm0
Output Amplitude	High-Band, DPSK Mode	-8	-7	-6	dBm0
Twist	High-Band to Low-Band, DPSK mode	1.0	2.0	3.0	dB
Long Loop Detect	DPSK or FSK	-38		-28	dBm0
Dynamic Range	Refer to Performance Curves		45		dB
Call Progress Detector					
Detect Level	2-Tones in 350-600 Hz band	-34		0	dBm0
Reject Level	2-Tones in 350-600 Hz band			-41	dBm0
Delay Time	-70 dBm0 to -30 dBm0 STEP	27		80	ms
Hold Time	-30 dBm0 to -70 dBm0 STEP	27		80	ms
Hysteresis		2			dB

Note: Parameters expressed in dBm0 refer to the following definition:

0 dB loss in the Transmit path to the line.
2 dB gain in the Receive path from the line.

Refer to the Basic Box Modem diagram in the Applications section for the DAA design.

ELECTRICAL SPECIFICATIONS (Continued)

DYNAMIC CHARACTERISTICS AND TIMING (Continued)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Carrier Detect					
Threshold	DPSK or FSK receive data	-49		-42	dBm0
Delay Time	-70 dBm0 to -30 dBm0 STEP	15		45	ms
Hysteresis	Single tone detected	2	3		dB
Hold Time	-30 dBm0 to -70 dBm0 STEP	10		24	ms
Answer Tone Detector					
Detect Level	In FSK mode	-49		-42	dBm0
Delay Time	-70 dBm0 to -30 dBm0 STEP	20		45	ms
Hold Time	-30 dBm0 to -70 dBm0 STEP	10		30	ms
Detect Freq. Range		-2.5		+2.5	%
Output Smoothing Filter					
TXA pin Output Impedance			200	300	Ω
Output load	TXA pin; FSK Single Tone out for THD = -50 db in .3 to 3.4 KHz	10		 50	kΩ pF
Spurious Freq. Comp.	Frequency = 76.8 KHz			-39	dBm0
	Frequency = 153.6 KHz			-45	dBm0
Clock Noise	TXA pin; 76.8 KHz			1.0	mVrms
Carrier VCO					
Capture Range	Originate or Answer	-10		+10	Hz
Capture Time	-10 Hz to +10 Hz Carrier Freq. Change Assum.		40	100	ms
Recovered Clock					
Capture Range	% of frequency center frequency (center at 1200 Hz)	-625		+625	ppm
Data Delay Time	Analog data in at RXA pin to receive data valid at RXD pin		30	50	ms

3

ELECTRICAL SPECIFICATION (Continued)

DYNAMIC CHARACTERISTICS AND TIMING (Continued)

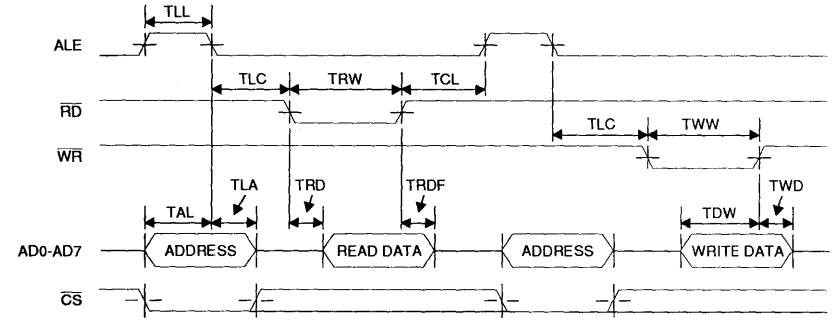
PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Timing (Refer to Timing Diagrams)					
TAL	$\overline{CS}$/Addr. setup before ALE low	30			ns
TLA	$\overline{CS}$/Addr. hold after ALE low	20			ns
TLC	ALE low to $\overline{RD}/\overline{WR}$ low	40			ns
TCL	$\overline{RD}/\overline{WR}$ Control to ALE high	10			ns
TRD	Data out from $\overline{RD}$ low	0		160	ns
TLL	ALE width	60			ns
TRDF	Data float after $\overline{RD}$ high	0		80	ns
TRW	$\overline{RD}$ width	200		25000	ns
TWW	$\overline{WR}$ width	140		25000*	ns
TDW	Data setup before $\overline{WR}$ high	150			ns
TWD	Data hold after $\overline{WR}$ high	20			ns
TCKD	Data out after EXCLK low			200	ns
TCKW	$\overline{WR}$ after EXCLK low	150			ns
TDCK	Data setup before EXCLK low	150			ns
TAC	Address setup before control**	50			ns
TCA	Address hold after control**	50			ns
TWH	Data Hold after EXCLK	20			ns

* Maximum time applies to parallel version only.

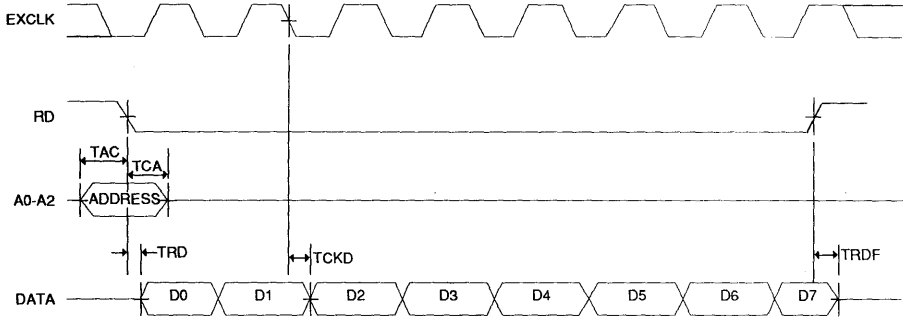
** Control for setup is the falling edge of $\overline{RD}$ or $\overline{WR}$.
Control for hold is the falling edge of $\overline{RD}$ or the rising edge of $\overline{WR}$.

TIMING DIAGRAMS

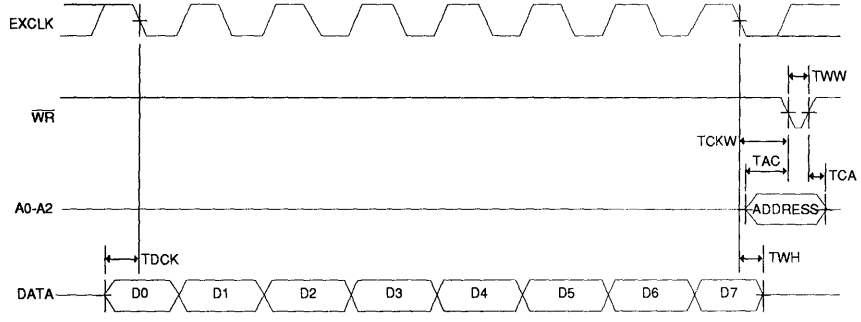
BUS TIMING DIAGRAM (PARALLEL VERSION)



READ TIMING DIAGRAM (SERIAL VERSION)



WRITE TIMING DIAGRAM (SERIAL VERSION)



3

SSI 73K212L
Bell 212A/103
Single-Chip Modem

APPLICATIONS INFORMATION

GENERAL CONSIDERATIONS

Figures 1 and 2 show basic circuit diagrams for K-Series modem integrated circuits. K-Series products are designed to be used in conjunction with a control processor, a UART or RS-232 serial data interface, and a DAA phone line interface to function as a typical intelligent modem. The K-Series ICs interface directly with Intel 8048 and 80C51 microprocessors for control and status monitoring purposes. Two typical DAA arrangements are shown: one for a split ±5 or ±12 volt design and one for a single 5 volt design. These diagrams are for reference only and do not represent production-ready modem designs.

K-Series devices are available with two control interface versions: one for a parallel multiplexed address/data interface, and one for a serial interface. The parallel version is intended for use with 8039/48 or 8031/51 microcontrollers from Intel or many other manufacturers. The serial interface 22-pin version can be used with other microcontrollers or in applications where only a limited number of port lines are available or the application does not lend itself to a multiplexed address/data interface. The parallel versions may also be used in the serial mode, as explained in the data sheet pin description.

In most applications the controller will monitor the serial data for commands from the DTE and the received data for break signals from the far end modem. In this way, commands to the modem are sent over the same line as the transmitted data. In other applications the RS-232 interface handshake lines are used for modem control.

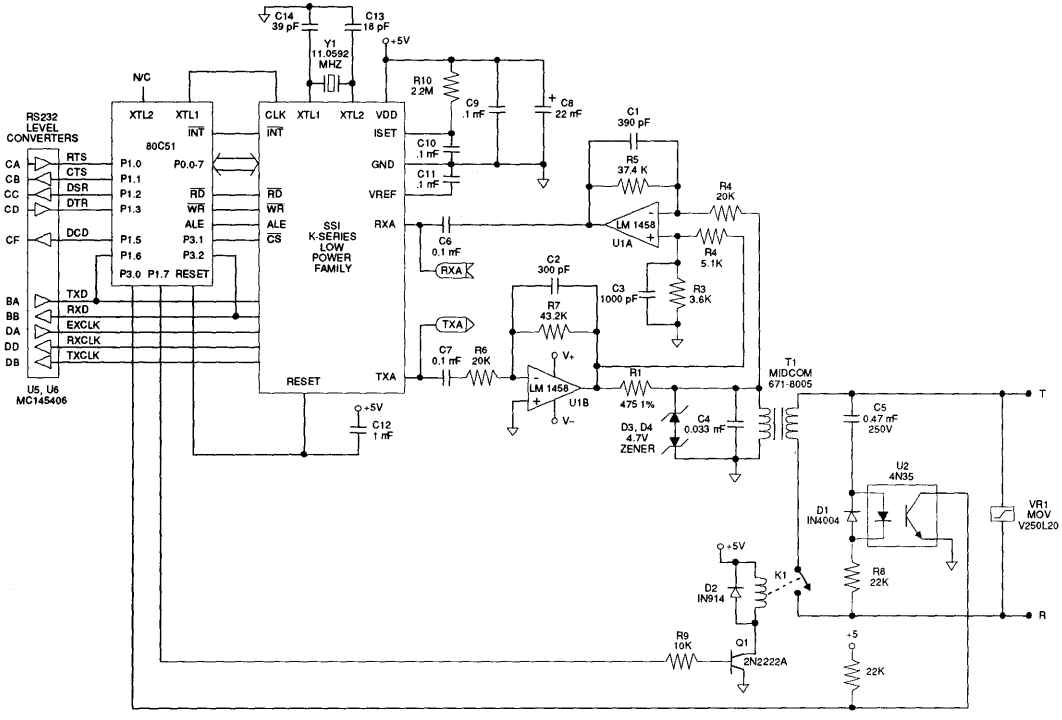


FIGURE 1: Basic Box Modem with Dual-Supply Hybrid

DIRECT ACCESS ARRANGEMENT (DAA)

The telephone line interfaces show two examples of how the "hybrid" may be implemented. The split supply design (Figure 1) is a typical two op-amp hybrid. The receive op-amp serves two purposes. It supplies gain to amplify the receive signal to the proper level for the modem's detectors and demodulator, and it removes the transmitted signal from the receive signal present at the transformer. This is done by supplying a portion of the transmitted signal to the non-inverting input of the receive op-amp at the same amplitude as the signal appearing at the transformer, making the transmit signal common mode.

The single-supply hybrid is more complex than the dual-supply version described above, but its use eliminates the need for a second power supply. This circuit (Figure 2) uses a bridged drive to allow undistorted signals to be sent with a single 5V supply. Because DTMF tones utilize a higher amplitude than data, these signals will clip if a single-ended drive approach is used. The bridged driver uses an extra op-amp (U1A) to invert the signal coming from the gain setting op-amp (U1B) before sending it to the other leg of the transformer. Each op-amp then supplies half the drive signal to the transformer. The receive amplifier (U1C) picks off its signal at the junction of the impedance matching resistor and the transformer. Because the bottom leg of the transformer is being driven in one direction by U1A and the resistor is driven in the opposite direction at the same time by U1B, the junction of the transformer and resistor remains relatively constant and the receive signal is unaffected.

DESIGN CONSIDERATIONS

Silicon Systems 1-chip modem products include all basic modem functions. This makes these devices adaptable for use in a variety of applications, and as easy to control as conventional digital bus peripherals.

3

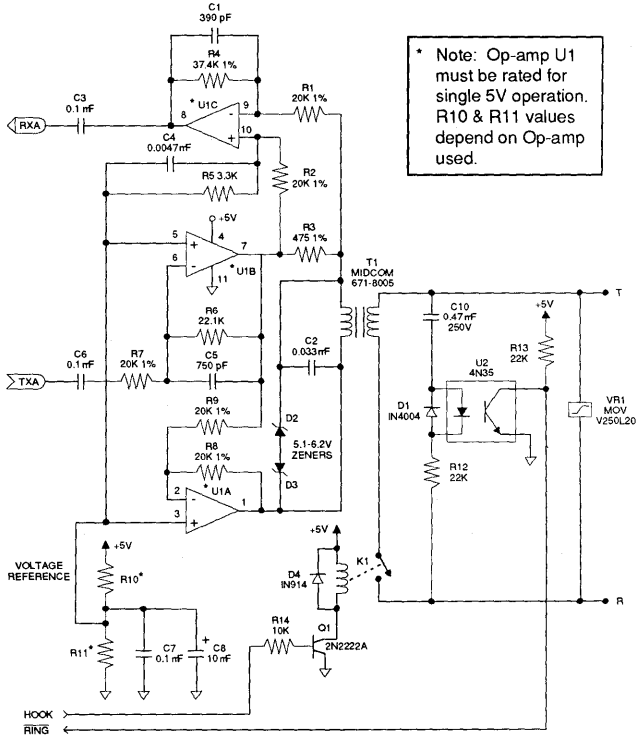


FIGURE 2: Single 5V Hybrid Version

Unlike digital logic circuitry, however, modem designs must properly contend with precise frequency tolerances and very low level analog signals, to ensure acceptable performance. Using good analog circuit design practices will generally result in a sound design. Following are additional recommendations which should be taken into consideration when starting new designs.

CRYSTAL OSCILLATOR

The K-Series crystal oscillator requires a parallel mode (antiresonant) crystal which operates at 11.0592 MHz. It is important that this frequency be maintained to within ±0.01% accuracy.

In order for a parallel mode crystal to operate correctly and to specification, it must have a load capacitor connected to the junction of each of the crystal and internal inverter connections, terminated to ground. The values of these capacitors depend primarily on the crystal's characteristics, and to a lesser degree on the internal inverter circuit. The values used affect the accuracy and start up characteristics of the oscillator.

LAYOUT CONSIDERATIONS

Good analog/digital design rules must be used to control system noise in order to obtain highest performance in modem designs. The more digital circuitry present on the PC board, the more this attention to noise control is needed. The modem should be treated as a high impedance analog device. A 22 mF electrolytic capacitor in parallel with a 0.1 mF ceramic capacitor between VDD and GND is recommended. Liberal use of ground planes and larger traces on power and ground are also highly favored. High speed digital circuits tend to generate a significant amount of EMI (Electro-Magnetic Interference) which must be minimized in order to meet regulatory agency limitations. To accomplish this, high speed digital devices should be locally bypassed, and the telephone line interface and K-Series device should be located close to each other near the area of the board where the phone line connection is accessed. To avoid problems, power supply and ground traces should be routed separately to the analog and digital functions on the board, and digital signals should not be routed near low level or high impedance analog traces. The analog and digital grounds should only connect at one point near the K-Series device ground pin to avoid ground loops. The K–Series modem IC's should have both high frequency and low frequency bypassing as close to the package as possible.

MODEM PERFORMANCE CHARACTERISTICS

The curves presented here define modem IC performance under a variety of line conditions while inducing disturbances that are typical of those encountered during data transmission on public service telephone lines. Test data was taken using an AEA Electronics' "Autotest I" modem test set and line simulator, operating under computer control. All tests were run full-duplex, using a Concord Data Systems 224 as the reference modem. A 511 pseudo-random-bit pattern was used for each data point. Noise was C-message weighted and all signal-to-noise (S/N) ratios reflect total power measurements similar to the CCITT V.56 measurement specification. The individual tests are defined as follows.

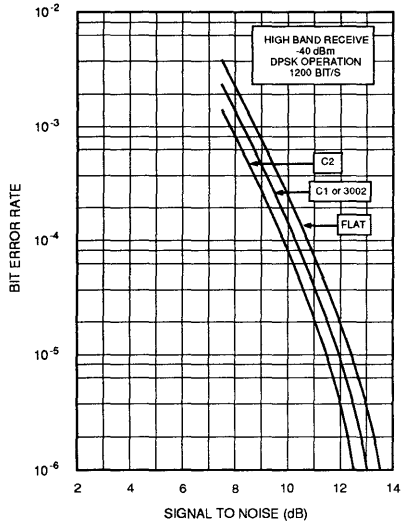
BER vs. S/N

This test measures the ability of the modem to operate over noisy lines with a minimum of data-transfer errors. Since some noise is generated in the best of dial-up lines, the modem must operate with the lowest S/N ratio possible. Better modem performance is indicated by test curves that are closest to the BER axis. A narrow spread between curves representing the four line parameters indicates minimal variation in performance while operating over a range of aberrant operating conditions. Typically, a DPSK modem will exhibit better BER-performance test curves receiving in the low band than in the high band.

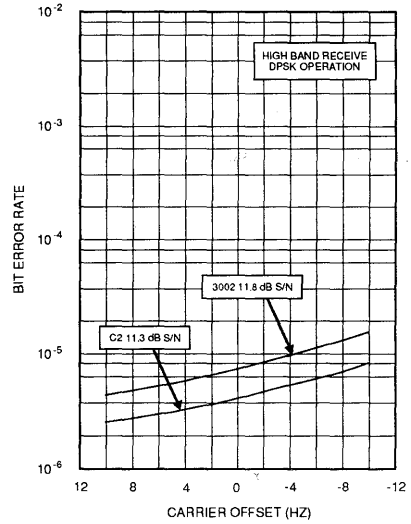
BER vs. Receive Level

This test measures the dynamic range of the modem. Because signal levels vary widely over dial-up lines, the widest possible dynamic range is desirable. The minimum Bell specification calls for 36 dB of dynamic range. S/N ratios are held constant at the indicated values while the receive level is lowered from a very high to very low signal levels. The width of the "bowl" of these curves, taken at the BER point, is the measure of dynamic range.

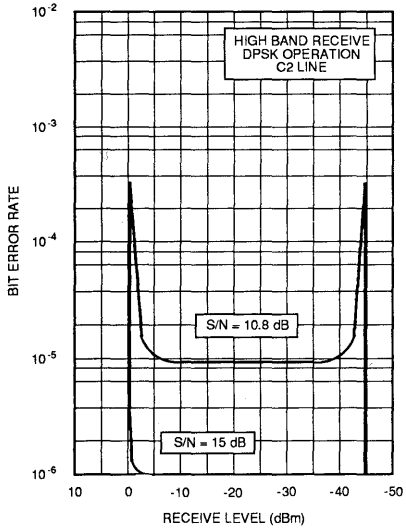
SSI 73K212L
BER vs SIGNAL TO NOISE



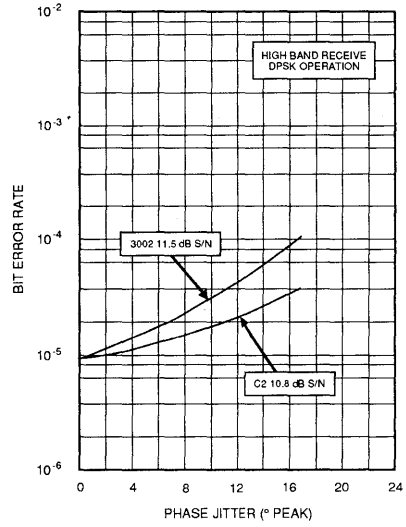
SSI 73K212L
BER vs CARRIER OFFSET



***SSI 73K212L**
BER vs RECEIVE LEVEL



***SSI 73K212L**
BER vs PHASE JITTER

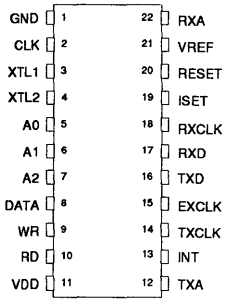


* = "EQ On" Indicates bit CR1 D4 is set for additional phase equalization.

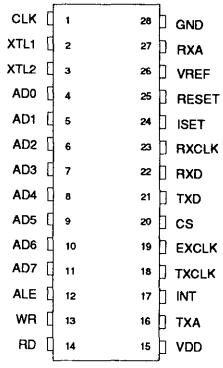
SSI 73K212L
Bell 212A/103
Single-Chip Modem

PACKAGE PIN DESIGNATIONS
(Top View)

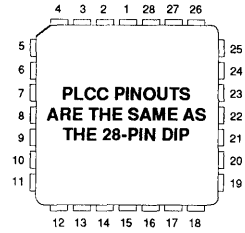
CAUTION: Use handling procedures necessary for a static sensitive component.



400-Mil
22-Pin DIP



600-Mil
28-Pin DIP



28-Pin
PLCC

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
28-pin		
Plastic Dual-In-Line	73K212L – IP	73K212L – IP
Plastic Leaded Chip Carrier	73K212L – IH	73K212L – IH
22-pin		
Plastic Dual-In-Line	73K212SL – IP	73K212SL – IP
Ceramic Dual-In-Line	73K212SL – IC	73K212SL – IC

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SSI 73K221L
CCITT V.22, V.21
Single-Chip Modem

January 1994

DESCRIPTION

The SSI 73K221L is a highly integrated single-chip modem IC which provides the functions needed to construct a CCITT V.22 and V.21 compatible modem, capable of 1200 or 0-300 bit/s full-duplex operation over dial-up lines. The SSI 73K221L is an enhancement of the SSI 73K212L single-chip modem with performance characteristics suitable for European and Asian telephone systems. The SSI 73K221L produces either 550 or 1800 Hz guard tone, recognizes and generates a 2100 Hz answer tone, and allows V.21 for 300 Hz FSK operation. The SSI 73K221L integrates analog, digital, and switched-capacitor array functions on a single substrate, offering excellent performance and a high level of functional integration in a single 28- or 22-pin DIP configuration. The SSI 73K221L, operates from a single +5 volt supply.

The SSI 73K221L includes the DPSK and FSK modulator/demodulator functions, call progress and handshake tone monitor test modes, and a tone generator capable of producing DTMF, answer and 550 or 1800 Hz guard tone. This device supports V.22 (Except mode v) and V. 21 modes of operation,

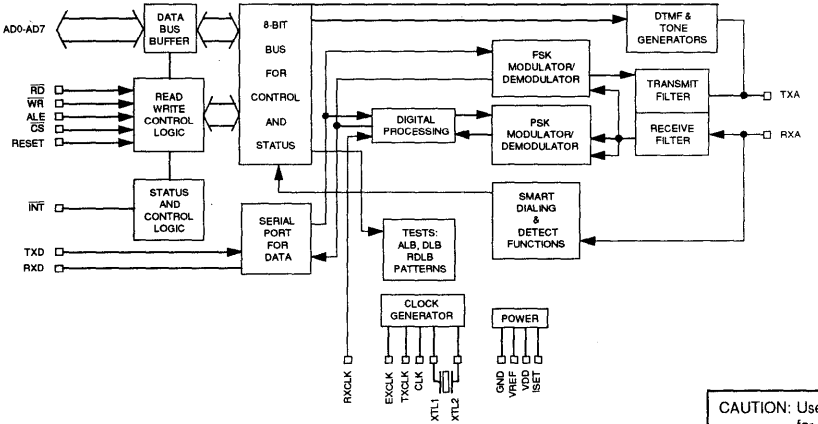
(Continued)

FEATURES

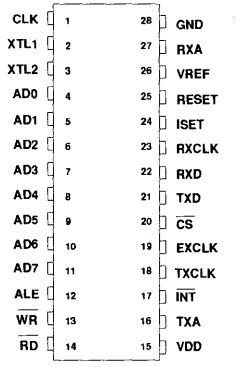
- **One-chip CCITT V.22 and V.21 standard compatible modem data pump**
- **Full-duplex Operation at 0-300 bit/s (FSK) or 600 and 1200 bit/s (DPSK)**
- **Pin and software compatible with other SSI K-Series 1-chip modems**
- **Interfaces directly with standard microprocessors (8048, 80C51 typical)**
- **Serial (22-pin DIP) or parallel (28-pin DIP or PLCC) microprocessor bus for control**
- **Serial port for data transfer**
- **Both Synchronous and Asynchronous modes of operation**
- **Call progress, carrier, precise answer tone (2100 Hz), and long loop detectors**
- **DTMF, and 550 or 1800 Hz guard tone generators**
- **Test modes available: ALB, DL, RDL, Mark, Space, Alternating bit patterns**
- **Precise automatic gain control allows 45 dB dynamic range**
- **Space efficient 22- or 28-pin DIP or 28 Pin PLCC packages**
- **CMOS technology for low power consumption using 30 mW @ 5V**
- **Single +5 volt supply**

3

BLOCK DIAGRAM



PIN DIAGRAM



CAUTION: Use handling procedures necessary for a static sensitive component.

DESCRIPTION (Continued)

allowing both synchronous and asynchronous communications. The SSI 73K221L is designed to appear to the systems designer as a microprocessor peripheral, and will easily interface with popular one-chip microprocessors (80C51 typical) for control of modem functions through its 8-bit multiplexed address/data bus or alternatively via the serial control bus. An ALE control line simplifies address demultiplexing. Data communications occurs through a separate serial port only.

The SSI 73K221L is ideal for use in either free standing or integral system modem products where full-duplex 1200 bit/s data communications over the 2-wire switched telephone network is desired. Its high functionality, low power consumption and efficient packaging simplify design requirements and increase system reliability. A complete modem requires only the addition of the phone line interface, a control microprocessor, and RS-232 level converter for a typical system. The SSI 73K221L is part of Silicon Systems' K-Series family of pin and function compatible single-chip modem products. These devices allow systems to be configured for higher speeds and Bell or CCITT operation with only a single component change.

OPERATION

ASYNCHRONOUS MODE

Data transmission for the DPSK mode requires that data ultimately be transmitted in a synchronous fashion, The SSI 73K221L includes ASYNC/SYNC and SYNC/ASYNC converters which delete or insert stop bits in order to transmit data at a regular rate. In Asynchronous mode the serial data comes from the TXD pin into the ASYNC/SYNC rate converter. The ASYNC/SYNC rate converter accepts the data provided on the TXD pin which normally must be 1200 or 600 bit/s +1.0%, - 2.5%. The rate converter will then insert or delete stop bits in order to output a signal which is 1200 or 600 bit/s ± 0.01%.

The serial data stream from the ASYNC/SYNC converter is passed through the data scrambler and onto the analog modulator. The data scrambler can be bypassed under processor control when unscrambled data must be transmitted. The ASYNC/SYNC rate converter and the data scrambler are bypassed in all FSK modes. If serial input data contains a break signal through one character (including start and stop bits) the break will be extended to at least 2 • N + 3 bits long (where N is the number of transmitted bits/character).

Serial data from the demodulator is passed first through the data descrambler and then through the SYNC/ASYNC rate converter. The SYNC/ASYNC convertor will reinsert any deleted stop bits and transmit output data at an intra-character rate (bit-to-bit timing) of no greater than 1219 bit/s. An incoming break signal (low through two characters) will be passed through without incorrectly inserting a stop bit.

The SYNC/ASYNC converter also has an extended Overspeed mode which allows selection of an output range of either +1% or +2.3%. In the extended Overspeed mode, stop bits are output at 7/8 the normal width.

SYNCHRONOUS MODE

The CCITT V.22 standard defines synchronous operation at 600 and 1200 bit/s. The Bell 212A standard defines synchronous operation only at 1200 bit/s. Operation is similar to that of the Asynchronous mode except that data must be synchronized to a provided clock and no variation in data transfer rate is allowable. Serial input data appearing at TXD must be valid on the rising edge of TXCLK.

TXCLK is an internally derived signal in Internal mode and is connected internally to the RXCLK pin in Slave mode. Receive data at the RXD pin is clocked out on the falling edge of RXCLK. The ASYNC/SYNC converter is bypassed when Synchronous mode is selected and data is transmitted at the same rate as it is input.

DPSK MODULATOR/DEMODULATOR

The SSI 73K221L modulates a serial bit stream into dibit pairs that are represented by four possible phase shifts as prescribed by the V.22 standard. The baseband signal is then filtered to reduce intersymbol interference on the bandlimited 2-wire telephone line. Transmission occurs on either a 1200 Hz (Originate mode) or 2400 Hz carrier (Answer mode). Demodulation is the reverse of the modulation process, with the incoming analog signal eventually decoded into di-bits and converted back to a serial bit stream. The demodulator also recovers the clock which was encoded into the analog signal during modulation. Demodulation

occurs using either a 1200 Hz carrier (Answer mode or ALB Originate mode) or a 2400 Hz carrier (Originate mode or ALB Answer mode). The SSI 73K221L uses a phase locked loop coherent demodulation technique for optimum performance.

FSK MODULATOR/DEMODULATOR

The FSK modulator produces a frequency modulated analog output signal using two discrete frequencies to represent the binary data. V.21 mode uses 980 and 1180 Hz (originate, mark and space) or 1650 and 1850 Hz (answer, mark and space). Demodulation involves detecting the received frequencies and decoding them into the appropriate binary value. The rate converter and scrambler/descrambler are bypassed in the V.21 mode.

PASSBAND FILTERS AND EQUALIZERS

High and low band filters are included to shape the amplitude and phase response of the transmit and receive signals and provide compromise delay equalization and rejection of out-of-band signals in the receive channel. Amplitude and phase equalization are necessary to compensate for distortion of the transmission line and to reduce intersymbol interference in the bandlimited receive signal. The transmit signal filtering approximates a 75% square root of raised Cosine frequency response characteristic.

AGC

The automatic gain control maintains a signal level at the input to the demodulators which is constant to within 1 dB. It corrects quickly for increases in signal which would cause clipping and provides a total dynamic range of >45 dB.

PARALLEL BUS INTERFACE

Four 8-bit registers are provided for control, optionselect and status monitoring. These registers are addressed with the AD0, AD1, and AD2 multiplexed address lines (latched by ALE) and appear to a control microprocessor as four consecutive memory locations. Two control registers and the tone register are read/write memory. The detect register is read only and cannot be modified except by modem response to monitored parameters.

SERIAL COMMAND INTERFACE

The serial Command mode allows access to the SSI 73K221L control and status registers via a serial command port (22-pin version only). In this mode the A0, A1 and A2 lines provide register addresses for data passed through the data pin under control of the $\overline{RD}$ and $\overline{WR}$ lines. A read operation is initiated when the $\overline{RD}$ line is taken low. The first bit is available after $\overline{RD}$ is brought low and the next seven cycles of EXCLK will then transfer out the remaining seven bits of the selected address LSB first. A write takes place by shifting in eight bits of data LSB first for eight consecutive cycles of EXCLK. $\overline{WR}$ is then pulsed low and data transferred into the addressed register on the rising edge of $\overline{WR}$.

SPECIAL DETECT CIRCUITRY

The special detect circuitry monitors the received analog signal to determine status or presence of carrier, call-progress tones, answer tone and weak received signal (long loop condition). An unscrambled mark signal is also detected when the received data out of the DPSK demodulator before the descrambler has been mark for 165.5 ms ± 6.5 ms minimum. The appropriate detect register bit is set when one of these conditions changes and an interrupt is generated for all conditions except long loop. The interrupts are disabled (masked) when the enable interrupt bit is set to 0.

DTMF GENERATOR

The DTMF generator will output one of 16 standard tone pairs determined by a 4-bit binary value and TX DTMF mode bit previously loaded into the tone register. Tone generation is initiated when the DTMF mode is selected using the tone register and the transmit enable (CR0 bit D1) is changed from 0 to 1.

PIN DESCRIPTION

POWER

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
GND	28	1	I	System Ground.
VDD	15	11	I	Power supply input, 5V ±10%. Bypass with 0.1 and 22 µF capacitors to ground.
VREF	26	21	O	An internally generated reference voltage. Bypass with 0.1 µF capacitor to GND.
ISET	24	19	I	Chip current reference. Sets bias current for op-amps. The chip current is set by connecting this pin to VDD through a 2 MΩ resistor. ISET should be bypassed to GND with a 0.1 µF capacitor.

PARALLEL MICROPROCESSOR INTERFACE

ALE	12	-	I	Address latch enable. The falling edge of ALE latches the address on AD0-AD2 and the chip select on $\overline{CS}$.
AD0-AD7	4-11	-	I/O	Address/data bus. These bidirectional tri-state multiplexed lines carry information to and from the internal control registers.
$\overline{CS}$	20	-	I	Chip select. A low on this pin during the falling edge of ALE allows a read cycle or a write cycle to occur. AD0-AD7 will not be driven and no registers will be written if $\overline{CS}$ (latched) is not active. The state $\overline{CS}$ is a latched on the falling edge of ALE.
CLK	1	2	O	Output clock. This pin is selectable under processor control to be either the crystal frequency (for use as a processor clock) or 16 x the data rate for use as a baud rate clock in DPSK modes only. The pin defaults to the crystal frequency on reset.
$\overline{INT}$	17	13	O	Interrupt. This open drain output signal is used to inform the processor that a detect flag has occurred. The processor must then read the detect register to determine which detect triggered the interrupt. $\overline{INT}$ will stay low until the processor reads the detect register or does a full reset.
$\overline{RD}$	14	-	I	Read. A low requests a read of the SSI 73K221L internal registers. Data cannot be output unless both $\overline{RD}$ and the latched $\overline{CS}$ are active or low.
RESET	25	20	I	Reset. An active high signal on this pin will put the chip into an inactive state. All control register bits (CR0, CR1, Tone) will be reset. The output of the CLK pin will be set to the crystal frequency. An internal pull down permits power on reset using a capacitor to VDD.

PIN DESCRIPTION (Continued)

PARALLEL MICROPROCESSOR INTERFACE (Continued)

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
$\overline{WR}$	13	-	I	Write. A low on this pin informs the SSI 73K221L that data is available on AD0-AD7 for writing into an internal register. Data is latched on the rising edge of $\overline{WR}$. No data is written unless both $\overline{WR}$ and the latched $\overline{CS}$ are low.

SERIAL MICROPROCESSOR INTERFACE

A0-A2	-	5-7	I	Register Address Selection. These lines carry register addresses and should be valid during any read or write operation.
DATA	-	8	I/O	Serial Control Data. Data for a read/write operation is clocked in or out on the falling edge of the EXCLK pin. The direction of data flow is controlled by the $\overline{RD}$ pin. $\overline{RD}$ low outputs data. $\overline{RD}$ high inputs data.
$\overline{RD}$	-	10	I	Read. A low on this input informs the SSI 73K221L that data or status information is being read by the processor. The falling edge of the $\overline{RD}$ signal will initiate a read from the addressed register. The $\overline{RD}$ signal must continue for eight falling edges of EXCLK in order to read all eight bits of the referenced register. Read data is provided LSB first. Data will not be output unless the $\overline{RD}$ signal is active.
$\overline{WR}$	-	9	I	Write. A low on this input informs the SSI 73K221L that data or status information has been shifted in through the DATA pin and is available for writing to an internal register. The normal procedure for a write is to shift in data LSB first on the DATA pin for eight consecutive falling edges of EXCLK and then to pulse $\overline{WR}$ low. Data is written on the rising edge of $\overline{WR}$.

Note: In the serial, 22-pin version, the pins AD0-AD7, ALE and $\overline{CS}$ are removed and replaced with the pins; A0, A1, A2, DATA, and an unconnected pin. Also, the $\overline{RD}$ and $\overline{WR}$ controls are used differently.

The Serial Control mode is provided in the parallel control versions by tying ALE high and $\overline{CS}$ low. In this configuration AD7 becomes DATA and AD0, AD1 and AD2 become A0, A1 and A2, respectively.

PIN DESCRIPTION (Continued)

DTE USER INTERFACE

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
EXCLK	19	15	I	External Clock. This signal is used in synchronous transmission when the external timing option has been selected. In the External Timing mode the rising edge of EXCLK is used to strobe synchronous DPSK transmit data applied to the TXD pin. Alternately used for serial control interface.
RXCLK	23	18	O	Receive Clock. The falling edge of this clock output is coincident with the transitions in the serial received data output. The rising edge of RXCLK can be used to latch the valid output data at RXD. RXCLK will be valid as long as a carrier is present in DPSK synchronous modes.
RXD	22	17	O	Received Digital Data Output. Serial receive data is available on this pin. The data is always valid on the rising edge of RXCLK when in Synchronous mode. RXD will output constant marks if no carrier is detected.
TXCLK	18	14	O	Transmit Clock. This signal is used in DPSK synchronous transmission to latch serial input data on the TXD pin. Data must be provided so that valid data is available on the rising edge of the TXCLK. The transmit clock is derived from different sources depending upon the Synchronization mode selection. In Internal Mode the clock is generated internally. In External Mode TXCLK is phase locked to the EXCLK pin. In Slave Mode TXCLK is phase locked to the RXCLK pin. TXCLK is always active.
TXD	21	16	I	Transmit Data Input. Serial data for transmission is applied to this pin. In Synchronous modes, the data must be valid on the rising edge of the TXCLK. In Asynchronous modes (1200/600 bit/s or 300 baud) no clocking is necessary. DPSK data must be 1200/600 bit/s +1%, -2.5% or +2.3%, -2.5 % in extended Overspeed mode.

ANALOG INTERFACE AND OSCILLATOR

RXA	27	22	I	Received modulated analog signal input from the telephone line interface.
TXA	16	12	O	Transmit analog output to the telephone line interface.
XTL1 XTL2	2 3	3 4	I I	These pins are for the internal crystal oscillator requiring an 11.0592 MHz Parallel mode crystal. Load capacitors should be connected from XTL1 and XTL2 to Ground. XTL2 can also be driven from an external clock.

REGISTER DESCRIPTIONS

Four 8-bit internal registers are accessible for control and status monitoring. The registers are accessed in read or write operations by addressing the A0 and A1 address lines in Serial mode, or the AD0 and AD1 lines in Parallel mode. In Parallel mode AD0 and AD1 lines are latched by ALE. Register CR0 controls the method by which data is transferred over the phone line. CR1 controls the interface between the microprocessor and the SSI 73K221L internal state. DR is a detect register which provides an indication of monitored modem status conditions. TR, the tone control register, controls the DTMF generator, answer and guard tones and RXD output driver used in the modem initial connect sequence. All registers are read/write except for DR which is read only. Register control and status bits are identified below:

REGISTER BIT SUMMARY

	ADDRESS	DATA BIT NUMBER							
REGISTER	AD2 - AD0	D7	D6	D5	D4	D3	D2	D1	D0
CONTROL REGISTER 0 CR0	000	MODULATION OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE
CONTROL REGISTER 1 CR1	001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTERRUPT	BYPASS SCRAMBLER	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0
DETECT REGISTER DR	010			RECEIVE DATA	UNSCR. MARKS	CARRIER DETECT	ANSWER TONE	CALL PROGRESS	LONG LOOP
TONE CONTROL REGISTER TR	011	RXD OUTPUT CONTROL	TRANSMIT GUARD TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF3	DTMF2	DTMF1/ OVERSPEED	DTMF0/ GUARD/
CONTROL REGISTER 2 CR2	100				THESE REGISTER LOCATIONS ARE RESERVED FOR				
CONTROL REGISTER 3 CR3	101				USE WITH OTHER K-SERIES FAMILY MEMBERS				
ID REGISTER ID	110	ID	ID	ID	ID				

NOTE: When a register containing reserved control bits is written into, the reserved bits must be programmed as 0's.

REGISTER ADDRESS TABLE

REGISTER	ADDRESS AD2 - AD0	DATA BIT NUMBER D7	D6	D5	D4	D3	D2	D1	D0
CONTROL REGISTER 0 CR0	000	MODULATION OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ORIGINATE/ ANSWER
		0=1200 BIT/S DPSK 1=600 BIT/S DPSK		0000=PWR DOWN 0001=INT SYNCH 0010=EXT SYNCH 0011=SLAVE SYNCH 0100=ASYNCH 8 BITS/CHAR 0101=ASYNCH 9 BITS/CHAR 0110=ASYNCH 10 BITS/CHAR 0111=ASYNCH 11 BITS/CHAR 1100=FSK				0=DISABLE TXA OUTPUT 1=ENABLE TXA OUTPUT	0=ANSWER 1=ORIGINATE
CONTROL REGISTER 1 CR1	001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTERRUPT	BYPASS SCRAMBLER	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0
		00=TX DATA 01=TX ALTERNATE 10=TX MARK 11=TX SPACE		0=DISABLE 1=ENABLE	0=NORMAL 1=BYPASS SCRAMBLER	0=XTAL 1=16 X DATA RATE OUTPUT AT CLK PIN IN DPSK MODE ONLY	0=NORMAL 1=RESET	00=NORMAL 01=ANALOG LOOPBACK 10=REMOTE DIGITAL LOOPBACK 11=LOCAL DIGITAL LOOPBACK	
DETECT REGISTER DR	010			RECEIVE DATA	UNSCR. MARKS	CARRIER DETECT	ANSWER TONE	CALL PROGRESS	LONG LOOP
				OUTPUTS RECEIVED DATA STREAM	0=CONDITION NOT DETECTED 1=CONDITION DETECTED				
TONE CONTROL REGISTER TR	011	RXD OUTPUT CONTROL	TRANSMIT GUARD/ TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF3	DTMF2	DTMF1/ OVERSPEED	DTMF0/ GUARD/ TONE
		RXD PIN 0=NORMAL 1=TRI STATE	0=OFF 1=ON	0=OFF 1=ON	0=DATA 1=TX DTMF	4 BIT CODE FOR 1 OF 16 DUAL TONE COMBINATIONS.			0=1800 Hz G.T. 1=550 Hz G.T.
ID REGISTER 10	110	ID	ID	ID	ID				

00XX=73K212L, 322L, 321L
01XX=73K221L, 302L
10XX=73K222L
1100=73K224L
1110=73K324L
1101=73K312L

CONTROL REGISTER 0

	D7	D6	D5	D4	D3	D2	D1	D0
CR0 000	MODUL. OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	Answer/ Originate	0	Selects Answer mode (transmit in high band, receive in low band).
		1	Selects Originate mode (transmit in low band, receive in high band).
D1	Transmit Enable	0	Disables transmit output at TXA.
		1	Enables transmit output at TXA. Note: TX Enable must be set to 1 to allow Answer Tone and DTMF transmission.
D5, D4,D3, D2	Transmit Mode	D5 D4 D3 D2	
		0 0 0 0	Selects Power Down mode. All functions disabled except digital interface.
		0 0 0 1	Internal Synchronous mode. In this mode TXCLK is an internally derived 1200 Hz signal. Serial input data appearing at TXD must be valid on the rising edge of TXCLK. Receive data is clocked out of RXD on the falling edge of RXCLK.
		0 0 1 0	External Synchronous mode. Operation is identical to internal synchronous, but TXCLK is connected internally to EXCLK pin, and a 1200 Hz ± 0.01% clock must be supplied externally.
		0 0 1 1	Slave Synchronous mode. Same operation as other Synchronous modes. TXCLK is connected internally to the RXCLK pin in this mode.
		0 1 0 0	Selects DPSK Asynchronous mode - 8 bits/character (1 start bit, 6 data bits, 1 stop bit).
		0 1 0 1	Selects DPSK Asynchronous mode - 9 bits/character (1 start bit, 7 data bits, 1 stop bit).
		0 1 1 0	Selects DPSK Asynchronous mode - 10 bits/character (1 start bit, 8 data bits, 1 stop bit).
		0 1 1 1	Selects DPSK Asynchronous mode - 11 bits/character (1 start bit, 8 data bits, Parity and 1 stop bit).
		1 1 0 0	Selects FSK operation.
D6		0	Not used; must be written as a "0."

CONTROL REGISTER 0 (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
CR0 000	MODUL. OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE

BIT NO.	NAME	CONDITION	DESCRIPTION
D7	Modulation Option	D7 D5 D4	Selects:
		0 0 X	DPSK mode at 1200 bit/s.
		1 0 X	DPSK mode at 600 bit/s. X = Don't care

CONTROL REGISTER 1

	D7	D6	D5	D4	D3	D2	D1	D0
CR1 001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTER.	BYPASS SCRAMB	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D1, D0	Test Mode	D1 D0	
		0 0	Selects normal Operating mode.
		0 1	Analog Loopback mode. Loops the transmitted analog signal back to the receiver, and causes the receiver to use the same center frequency as the transmitter. To squelch the TXA pin, transmit enable must be forced low.
		1 0	Selects remote digital loopback. Received data is looped back to transmit data internally, and RXD is forced to a mark. Data on TXD is ignored.
		1 1	Selects local digital loopback. Internally loops TXD back to RXD and continues to transmit carrier from TXA pin.
D2	Reset	0	Selects normal operation.
		1	Resets modem to power down state. All control register bits (CR0, CR1, Tone) are reset to zero. The output of the CLK pin will be set to the crystal frequency.
D3	CLK Control (Clock Control)	0	Selects 11.0592 MHz crystal echo output at CLK pin.
		1	Selects 16 X the data rate, output at CLK pin in DPSK modes only.

CONTROL REGISTER 1 (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
CR1 001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTER.	BYPASS SCRAMB	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D4	Bypass Scrambler	0	Selects normal operation. DPSK data is passed through scrambler.
D5	Enable Detect Interrupt	1	Selects Scrambler Bypass. Bypass DPSK data is routed around scrambler in the transmit path.
		0	Disables interrupt at $\overline{INT}$ pin.
		1	Enables $\overline{INT}$ output. An interrupts will be generated with a change in status of DR bits D1-D4. The answer tone and call progress detect interrupts are masked when the TX enable bit is set. Carrier detect is masked when TX DTMF is activated. All interrupts will be disabled if the device is in Power Down mode.
D7, D6	Transmit Pattern	D7 D6	
		0 0	Selects normal data transmission as determined by the state of the TXD pin.
		0 1	Selects an alternating mark/space transmit pattern for modem testing.
		1 0	Selects a constant mark transmit pattern.
		1 1	Selects a constant space transmit pattern.

DETECT REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
DR 010			RECEIVE DATA	UNSCR. MARK	CARR. DETECT	ANSWER TONE	CALL PROG.	LONG LOOP

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	Long Loop	0	Indicates normal received signal.
		1	Indicates low received signal level.
D1	Call Progress Detect	0	No call progress tone detected.
		1	Indicates presence of call progress tones. The call progress detection circuitry is activated by energy in the 350 to 620 Hz call progress band.

DETECT REGISTER (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
DR 010			RECEIVE DATA	UNSCR. MARK	CARR. DETECT	ANSWER TONE	CALL PROG.	LONG LOOP

BIT NO.	NAME	CONDITION	DESCRIPTION
D2	Answer Tone Detect	0	No answer tone detected.
		1	Indicates detection of 2100 Hz answer tone. The device must be in Originate mode for detection of answer tone.
D3	Carrier Detect	0	No carrier detected in the receive channel.
		1	Indicates carrier has been detected in the received channel.
D4	Unscrambled Mark	0	No unscrambled mark.
		1	Indicates detection of unscrambled marks in the received data. This may be used in the V.22 connect sequence or for requesting a remote modem to configure itself for remote digital loopback. A valid indication means that unscrambled marks have been received for > 165.5 ± 6.5 ms.
D5	Receive Data		Continuously outputs the received data stream. This data is the same as that output on the RXD pin, but it is not disabled when RXD is tri-stated.
D6, D7			Not used.

TONE REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.	TRANSMIT GUARD TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2	DTMF 1/ OVER-SPEED	DTMF 0/ GUARD

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	DTMF 0/ Guard Tone	D6 D4 D0	D0 interacts with bits D6, D5, and D4 as shown.
		X 1 X	Transmit DTMF tones.
		X 0 0	Transmits 1800 Hz guard tone.
		X 0 1	Transmits 550 Hz guard tone.
D1	DTMF 1/	D4 D1	D1 interacts with D4 as shown.
		0 0	Asynchronous DPSK 1200 or 600 bit/s +1.0% - 2.5%
		0 1	Asynchronous DPSK 1200 or 600 bit/s +2.3% -2.5%.

TONE REGISTER (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.	TRANSMIT GUARD TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2	DTMF 1/ OVER-SPEED	DTMF 0/ GUARD

BIT NO.	NAME	CONDITION	DESCRIPTION
D3, D2, D1, D0	DTMF 3, 2, 1, 0	D3 D2 D1 D0 0 0 0 0 - 1 1 1 1	Programs 1 of 16 DTMF tone pairs that will be transmitted when TX DTMF and TX enable bit (CR0, bit D1) is set. Tone encoding is shown below:
D4	Transmit DTMF	0	Disable DTMF.
		1	Activates DTMF. The selected DTMF tones are transmitted continuously when this bit is high. TX DTMF overrides all other transmit functions. Modem must be in DPSK mode during DTMF transmission.
D5	Transmit Answer Tone	0	Disables answer tone generator.
		1	Enables answer tone generator. A 2100 Hz answer tone will be transmitted continuously when the Transmit Enable bit is set in CR0. The device must be in Answer mode.

KEYBOARD EQUIVALENT	DTMF CODE D3	D2	D1	D0	TONES LOW	HIGH
1	0	0	0	1	697	1209
2	0	0	1	0	697	1336
3	0	0	1	1	697	1477
4	0	1	0	0	770	1209
5	0	1	0	1	770	1336
6	0	1	1	0	770	1477
7	0	1	1	1	852	1209
8	1	0	0	0	852	1336
9	1	0	0	1	852	1477
0	1	0	1	0	941	1336
*	1	0	1	1	941	1209
#	1	1	0	0	941	1477
A	1	1	0	1	697	1633
B	1	1	1	0	770	1633
C	1	1	1	1	852	1633
D	0	0	0	0	941	1633

TONE REGISTER (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.	TRANSMIT GUARD TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2	DTMF 1/ OVER-SPEED	DTMF 0/ GUARD

BIT NO.	NAME	CONDITION	DESCRIPTION
D6	TX Guard (Transmit Guard Tone)	0	Disables guard tone generator.
		1	Enables guard tone generator (See D0 for selection of guard tones).
D7	RXD Output Control	0	Enables RXD pin. Receive data will be output on RXD.
		1	Disables RXD pin. The RXD pin becomes a high impedance with internal weak pull-up resistor.

ID REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
ID 110	ID	ID	ID	ID				

BIT NO.	NAME	CONDITION	DESCRIPTION
D7, D6, D5 D4	Device Identification Signature	D7 D6 D5 D4	Indicates Device:
		0 0 X X	SSI 73K212L, 73K321L or 73K322L or 73K321L
		0 1 X X	SSI 73K221L or 73K302L
		1 0 X X	SSI 73K222L or 73K321L
		1 1 0 0	SSI 73K224L
		1 1 1 0	SSI 73K324L
		1 1 0 1	SSI 73K312L

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

PARAMETER	RATING	UNIT
VDD Supply Voltage	14	V
Storage Temperature	-65 to 150	°C
Soldering Temperature (10 sec.)	260	°C
Applied Voltage	-0.3 to VDD+0.3	V
Note: All inputs and outputs are protected from static charge using built-in, industry standard protection devices and all outputs are short-circuit protected.		

RECOMMENDED OPERATING CONDITIONS

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
VDD Supply voltage		4.5	5	5.5	V
TA, Operating Free-Air Temperature		-40		+85	°C
Clock Variation	(11.0592 MHz) Crystal or external clock	-0.01		+0.01	%
External Components (Refer to Application section for placement.)					
VREF Bypass Capacitor	(External to GND)	0.1			µF
Bias setting resistor	(Placed between VDD and ISET pins)	1.8	2	2.2	MΩ
ISET Bypass Capacitor	(ISET pin to GND)	0.1			µF
VDD Bypass Capacitor 1	(External to GND)	0.1			µF
VDD Bypass Capacitor 2	(External to GND)	22			µF
XTL1 Load Capacitor	Depends on crystal characteristics;			40	pF
XTL2 Load Capacitor	from pin to GND			20	

ELECTRICAL SPECIFICATIONS (Continued)

DC ELECTRICAL CHARACTERISTICS

(TA = -40°C to 85°C, VDD = recommended range unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
IDD, Supply Current	ISET Resistor = 2 MΩ				
IDDA, Active	CLK = 11.0592 MHz		8	12	mA
IDD1, Power-down	CLK = 11.0592 MHz			4	mA
IDD2, Power-down	CLK = 19.200 KHz			3	mA
Digital Inputs					
VIH, Input High Voltage					
Reset, XTL1, XTL2		3.0		VDD	V
All other inputs		2.0		VDD	V
VIL, Input Low Voltage		0		0.8	V
IIH, Input High Current	VI = VIH Max			100	µA
IIL, Input Low Current	VI = VIL Min	-200			µA
Reset Pull-down Current	Reset = VDD	1		50	µA
Input Capacitance	All Digital Input Pins			10	pF
Digital Outputs					
VOH, Output High Voltage	IOH MIN = -0.4 mA	2.4		VDD	V
VOL, Output Low Voltage	IO MAX = 1.6 mA			0.4	V
VOL, CLK Output	IO = 3.6 mA			0.6	V
RXD Tri-State Pull-up Curr.	RXD = GND	-1		-50	µA
CMAX, CLK Output	Maximum Capacitive Load			15	pF

ELECTRICAL SPECIFICATIONS (Continued)

DYNAMIC CHARACTERISTICS AND TIMING

(TA = -40°C to +85°C, VDD = recommended range unless otherwise noted.)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
PSK Modulator					
Carrier Suppression	Measured at TXA	55			dB
Output Amplitude	TX scrambled marks	-11	-10	-9	dBm0
FSK Mod/Demod					
Output Freq. Error	CLK = 11.0592 MHz	-0.35		+ 0.35	%
Transmit Level	Transmit Dotting Pattern	-11	-10	-9	dBm0
Harmonic Distortion in 700-2900 Hz band	THD in the alternate band DPSK or FSK		-60	-50	dB
Output Bias Distortion	Transmit Dotting Pattern In ALB @ RXD		±8		%
Total Output Jitter	Random Input in ALB @ RXD	-15		+15	%
DTMF Generator (Modem must be in DPSK mode to meet specifications)					
Freq. Accuracy		- 0.25		+ 0.25	%
Output Amplitude	Low Group, DPSK Mode	-10	-9	-8	dBm0
Output Amplitude	High Group, DPSK Mode	-8	-7	-6	dBm0
Twist	High-Group to Low-Group	1.0	2.0	3.0	dB
Long Loop Detect	DPSK or FSK	-38		-28	dBm0
Dynamic Range	Refer to Performance Curves		45		dB
Call Progress Detector					
Detect Level	2-Tones in 350-600 Hz band	-34		0	dBm0
Reject Level	2-Tones in 350-600 Hz band			-41	dBm0
Delay Time	-70 dBm0 to -30 dBm0 STEP	27		80	ms
Hold Time	-30 dBm0 to -70 dBm0 STEP	27		80	ms
Hysteresis		2			dB

Note: Parameters expressed in dBm0 refer to the following definition:

5V Version
0 dB loss in the Transmit path to the line.
2 dB gain in the Receive path from the line.

Refer to the Basic Box Modem diagram in the Applications section for the DAA design.

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ELECTRICAL SPECIFICATIONS (Continued)

DYNAMIC CHARACTERISTICS AND TIMING (Continued)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Carrier Detect					
Threshold	DPSK or FSK receive data	-49		-42	dBm0
Delay Time	-70 dBm0 to -30 dBm0 STEP	15		45	ms
Hysteresis	Single tone detected	2	3.0		dB
Hold Time	-30 dBm0 to -70 dBm0 STEP	10		24	ms
Answer Tone Detector					
Detect Level	Not in V.21 mode	-49.5		-42	dBm0
Delay Time	-70 dBm0 to -30 dBm0 STEP	20		45	ms
Hold Time	-30 dBm0 to -70 dBm0 STEP	10		30	ms
Detect Freq. Range		-2.5		+2.5	%
Output Smoothing Filter					
Output load	TXA pin; FSK Single	10			kΩ
	Tone out for THD = -50 db in 0.3 to 3.4 KHz			50	pF
Spurious Freq. Comp.	Frequency = 76.8 kHz			-39	dBm0
	Frequency = 153.6 kHz			-45	dBm0
Output Impedance	TXA pin		200	300	Ω
Clock Noise	TXA pin; 76.8 kHz			1.0	mVms
Carrier VCO					
Capture Range	Originate or Answer	-10		+10	Hz
Capture Time	-10 Hz to +10 Hz Carrier Frequency Change		40	100	ms
Recovered Clock					
Capture Range		-625		+625	ppm
Data Delay Time	Analog data in at RXA pin to receive data valid at RXD pin		30	50	ms

ELECTRICAL SPECIFICATIONS (Continued)

DYNAMIC CHARACTERISTICS AND TIMING (Continued)

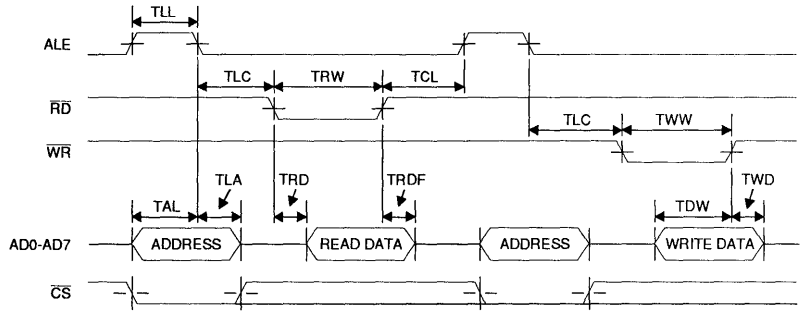
PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Guard Tone Generator					
Tone Accuracy	550 or 1800 Hz	-20		+20	Hz
Tone Level	550 Hz	-4.0	-3.0	-2.0	dB
(Below DPSK Output)	1800 Hz	-7.0	-6.0	-5.0	dB
Harmonic Distortion	550 Hz			-50	dB
700 to 2900 Hz	1800 Hz			-60	dB
Timing (Refer to Timing Diagrams)					
TAL	$\overline{CS}$/Addr. setup before ALE low	30			ns
TLA	$\overline{CS}$/Addr. hold after ALE low	20			ns
TLC	ALE low to $\overline{RD}/\overline{WR}$ low	40			ns
TCL	$\overline{RD}/\overline{WR}$ Control to ALE high	10			ns
TRD	Data out from $\overline{RD}$ low	0		160	ns
TLL	ALE width	60			ns
TRDF	Data float after $\overline{RD}$ high	0		80	ns
TRW	$\overline{RD}$ width	200		25000	ns
TWW	$\overline{WR}$ width	140		25000*	ns
TDW	Data setup before $\overline{WR}$ high	150			ns
TWD	Data hold after $\overline{WR}$ high	20			ns
TCKD	Data out after EXCLK low			200	ns
TCKW	$\overline{WR}$ after EXCLK low	150			ns
TDCK	Data setup before EXCLK low	150			ns
TAC	Address setup before control**	50			ns
TCA	Address hold after control**	50			ns
TWH	Data hold after EXCLK	150			ns

* Maximum time applies to parallel version only.

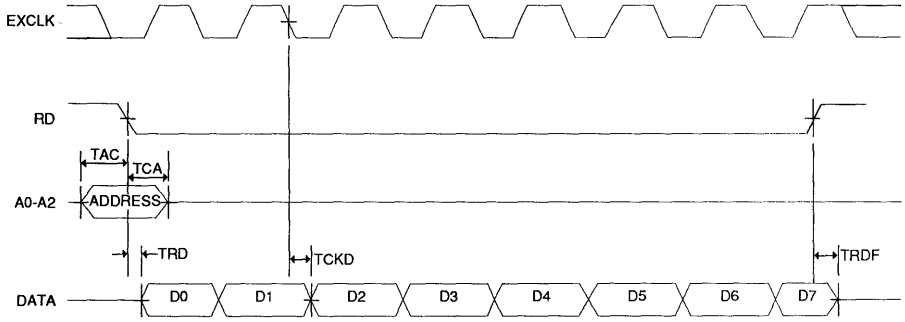
** Control for setup is the falling edge of $\overline{RD}$ or $\overline{WR}$.
Control for hold is the falling edge of $\overline{RD}$ or the rising edge of $\overline{WR}$.

TIMING DIAGRAMS

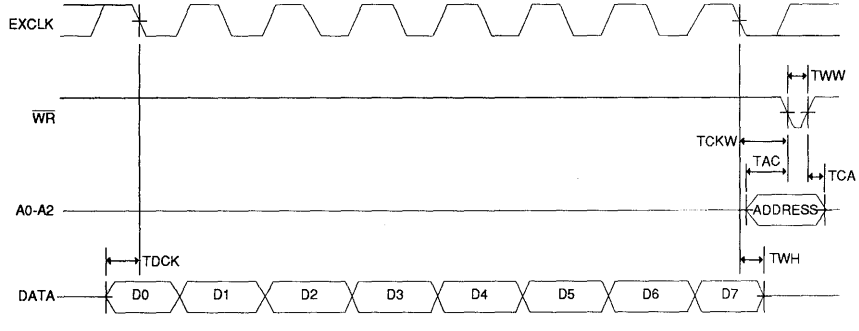
BUS TIMING DIAGRAM (PARALLEL VERSION)



READ TIMING DIAGRAM (SERIAL VERSION)



WRITE TIMING DIAGRAM (SERIAL VERSION)



APPLICATIONS INFORMATION

GENERAL CONSIDERATIONS

Figures 1 and 2 show basic circuit diagrams for K-Series modem integrated circuits. K-Series products are designed to be used in conjunction with a control processor, a UART or RS-232 serial data interface, and a DAA phone line interface to function as a typical intelligent modem. The K-Series ICs interface directly with Intel 8048 and 80C51 microprocessors for control and status monitoring purposes. Two typical DAA arrangements are shown: one for a split ±5 or ±12 volt design and one for a single 5 volt design. These diagrams are for reference only and do not represent production-ready modem designs.

K-Series devices are available with two control interface versions: one for a parallel multiplexed address/data interface, and one for a serial interface. The parallel version is intended for use with 8039/48 or 8031/51 microcontrollers from Intel or many other manufacturers. The serial interface 22-pin version can be used with other microcontrollers or in applications where only a limited number of port lines are available or the application does not lend itself to a multiplexed address/data interface. The parallel versions may also be used in the Serial mode, as explained in the data sheet pin description.

In most applications the controller will monitor the serial data for commands from the DTE and the received data for break signals from the far end modem. In this way, commands to the modem are sent over the same line as the transmitted data. In other applications the RS-232 interface handshake lines are used for modem control.

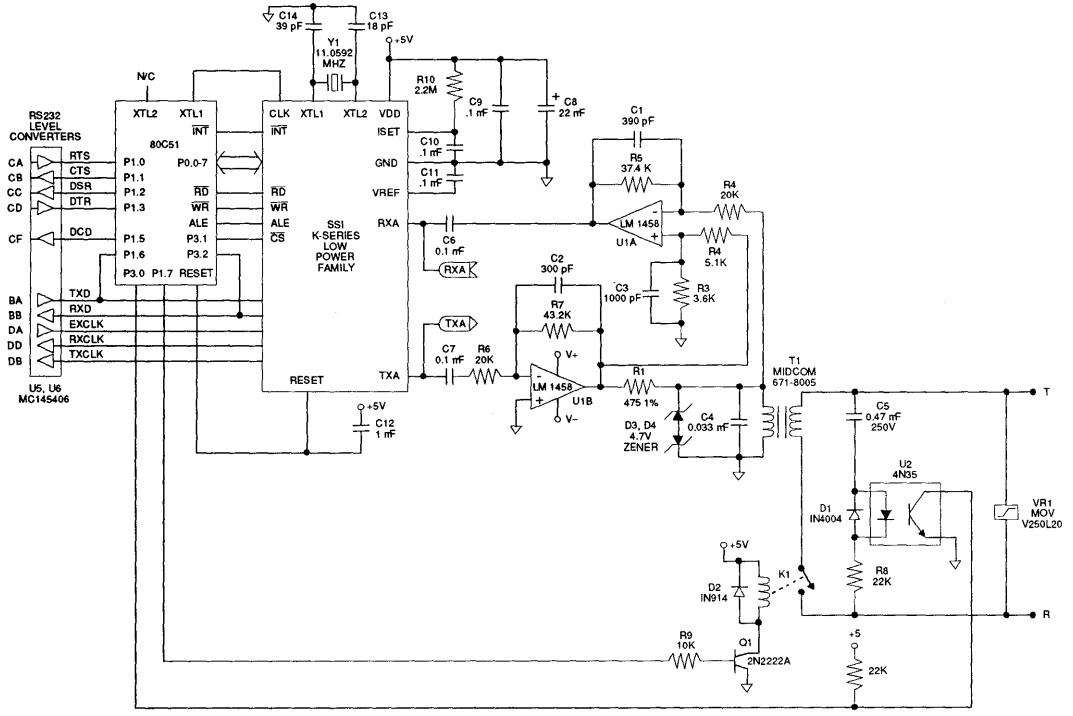


FIGURE 1: Basic Box Modem with Dual-Supply Hybrid

DIRECT ACCESS ARRANGEMENT (DAA)

The telephone line interfaces show two examples of how the "hybrid" may be implemented. The split supply design (Figure 1) is a typical two op-amp hybrid. The receive op-amp serves two purposes. It supplies gain to amplify the receive signal to the proper level for the modem's detectors and demodulator, and it removes the transmitted signal from the receive signal present at the transformer. This is done by supplying a portion of the transmitted signal to the non-inverting input of the receive op-amp at the same amplitude as the signal appearing at the transformer, making the transmit signal Common mode.

The single-supply hybrid is more complex than the dual-supply version described above, but its use eliminates the need for a second power supply. This circuit (Figure 2) uses a bridged drive to allow undistorted signals to be sent with a single 5 volt supply. Because DTMF tones utilize a higher amplitude than data, these signals will clip if a single-ended drive approach is used. The bridged driver uses an extra op-amp (U1A) to invert the signal coming from the gain setting op-amp (U1B) before sending it to the other leg of the transformer. Each op-amp then supplies half the drive signal to the transformer. The receive amplifier (U1C) picks off its signal at the junction of the impedance matching resistor and the transformer. Because the bottom leg of the transformer is being driven in one direction by U1A and the resistor is driven in the opposite direction at the same time by U1B, the junction of the transformer and resistor remains relatively constant and the receive signal is unaffected.

DESIGN CONSIDERATIONS

Silicon Systems 1-chip modem products include all basic modem functions. This makes these devices adaptable for use in a variety of applications, and as easy to control as conventional digital bus peripherals.

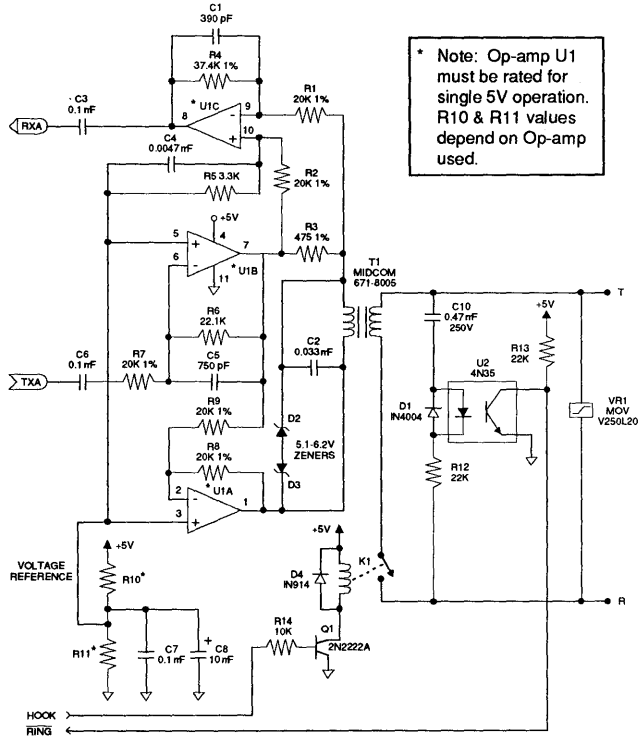


FIGURE 2: Single 5V Hybrid Version

Unlike digital logic circuitry, however, modem designs must properly contend with precise frequency tolerances and very low level analog signals, to ensure acceptable performance. Using good analog circuit design practices will generally result in a sound design. Following are additional recommendations which should be taken into consideration when starting new designs.

CRYSTAL OSCILLATOR

The K-Series crystal oscillator requires a Parallel mode (antiresonant) crystal which operates at 11.0592 MHz. It is important that this frequency be maintained to within ±0.01% accuracy.

In order for a Parallel mode crystal to operate correctly and to specification, it must have a load capacitor connected to the junction of each of the crystal and internal inverter connections, terminated to ground. The values of these capacitors depend primarily on the crystal's characteristics, and to a lesser degree on the internal inverter circuit. The values used affect the accuracy and start up characteristics of the oscillator.

LAYOUT CONSIDERATIONS

Good analog/digital design rules must be used to control system noise in order to obtain highest performance in modem designs. The more digital circuitry present on the PC board, the more this attention to noise control is needed. The modem should be treated as a high impedance analog device. A 22 mF electrolytic capacitor in parallel with a 0.1 mF ceramic capacitor between VDD and GND is recommended. Liberal use of ground planes and larger traces on power and ground are also highly favored. High speed digital circuits tend to generate a significant amount of EMI (Electro-Magnetic Interference) which must be minimized in order to meet regulatory agency limitations. To accomplish this, high speed digital devices should be locally bypassed, and the telephone line interface and K-Series device should be located close to each other near the area of the board where the phone line connection is accessed. To avoid problems, power supply and ground traces should be routed separately to the analog and digital functions on the board, and digital signals should not be routed near low level or high impedance analog traces. The analog and digital grounds should only connect at one point near the K-Series device ground pin to avoid ground loops. The K–Series modem IC's should have both high frequency and low frequency bypassing as close to the package as possible.

MODEM PERFORMANCE CHARACTERISTICS

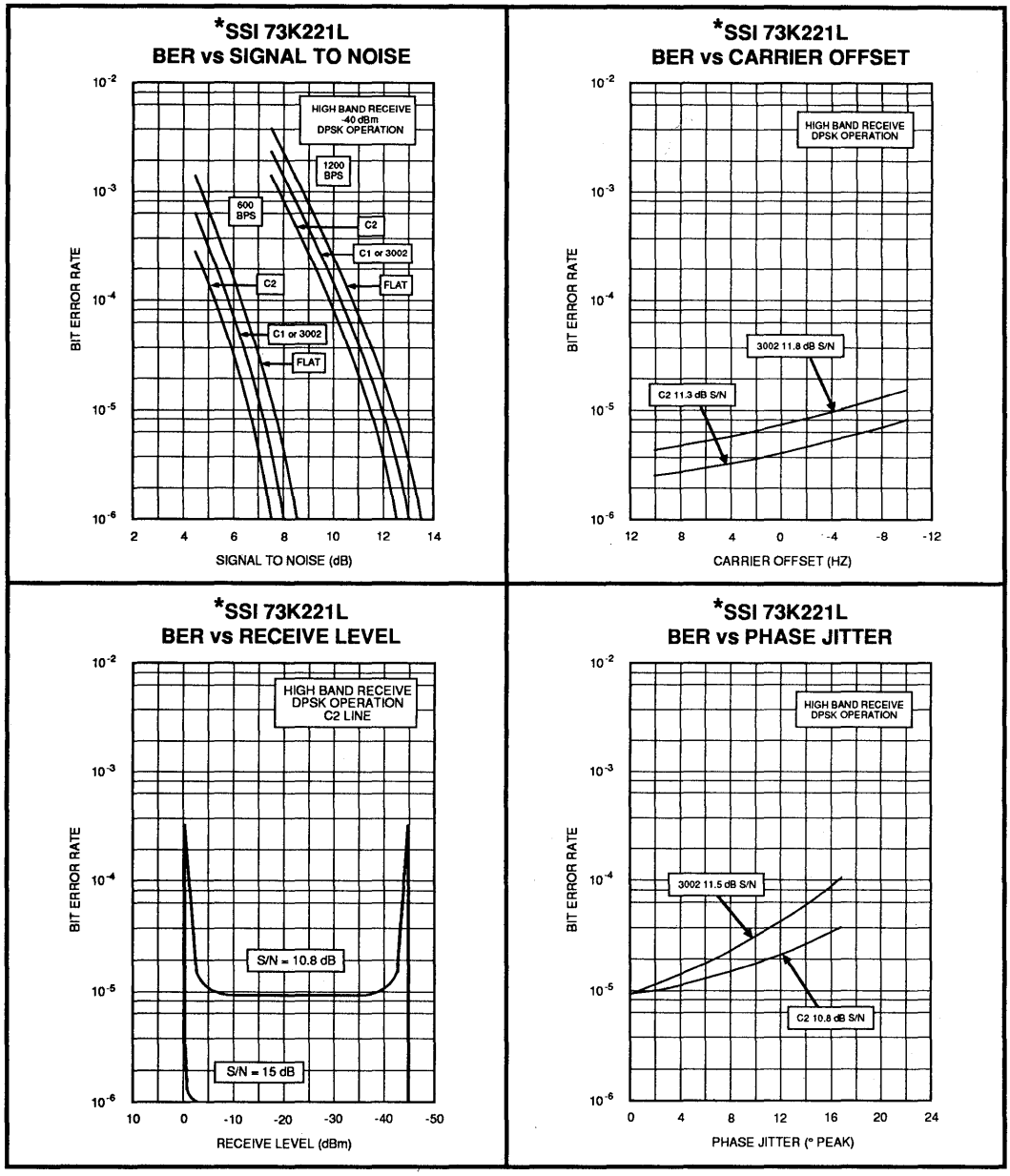
The curves presented here define modem IC performance under a variety of line conditions while inducing disturbances that are typical of those encountered during data transmission on public service telephone lines. Test data was taken using an AEA Electronics' "Autotest I" modem test set and line simulator, operating under computer control. All tests were run full-duplex, using a Concord Data Systems 224 as the reference modem. A 511 pseudo-random-bit pattern was used for each data point. Noise was C-message weighted and all signal-to-noise (S/N) ratios reflect total power measurements similar to the CCITT V.56 measurement specification. The individual tests are defined as follows.

BER vs. S/N

This test measures the ability of the modem to operate over noisy lines with a minimum of data-transfer errors. Since some noise is generated in the best of dial-up lines, the modem must operate with the lowest S/N ratio possible. Better modem performance is indicated by test curves that are closest to the BER axis. A narrow spread between curves representing the four line parameters indicates minimal variation in performance while operating over a range of aberrant operating conditions. Typically, a DPSK modem will exhibit better BER-performance test curves receiving in the low band than in the high band.

BER vs. Receive Level

This test measures the dynamic range of the modem. Because signal levels vary widely over dial-up lines, the widest possible dynamic range is desirable. The minimum Bell specification calls for 36 dB of dynamic range. S/N ratios are held constant at the indicated values while the receive level is lowered from a very high to very low signal levels. The width of the "bowl" of these curves, taken at the BER point, is the measure of dynamic range.

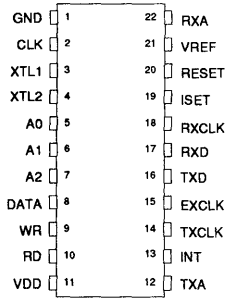


* = "EQ On" Indicates bit CR1 D4 is set for additional phase equalization.

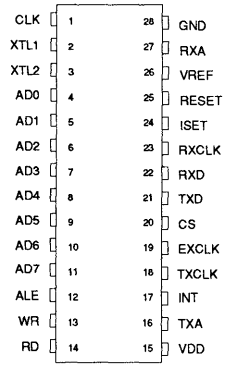
PACKAGE PIN DESIGNATIONS

(Top View)

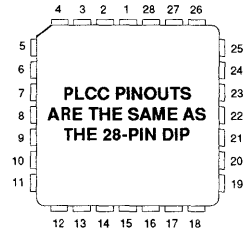
CAUTION: Use handling procedures necessary for a static sensitive component.



400-Mil 22-Pin DIP



600-Mil 28-Pin DIP



28-Pin PLCC

3

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 73K221L with Parallel Bus Interface		
28-Pin DIP	73K221L – IP	73K221L – IP
28-Pin PLCC	73K221L – IH	73K221L – IH
SSI 73K212L with Serial Interface		
22-Pin DIP	73K221SL – IP	73K221SL – IP

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SSI 73K222L
V.22, V.21, Bell 212A Single-Chip Modem

January 1994

3

DESCRIPTION

The SSI 73K222L is a highly integrated single-chip modem IC which provides the functions needed to construct a CCITT V.22, V.21 and Bell 212A compatible modem, capable of 1200 bit/s full–duplex operation over dial-up lines. The SSI 73K222L is an enhancement of the SSI 73K212L single-chip modem which adds V.22 and V.21 modes to the Bell 212A and 103 operation of the SSI 73K212L. In Bell 212A mode, the SSI 73K222L provides the normal Bell 212A and 103 functions and employs a 2225 Hz answer tone. The SSI 73K222L in V.22 mode produces either 550 or 1800 Hz guard tone, recognizes and generates a 2100 Hz answer tone, and allows 600 bit/s V.22 or 0-300 bit/s V.21 operation. The SSI 73K222L integrates analog, digital, and switched-capacitor array functions on a single substrate, offering excellent performance and a high level of functional integration in a single 28- or 22-pin DIP configuration. The SSI 73K222L operates from a single +5V supply.

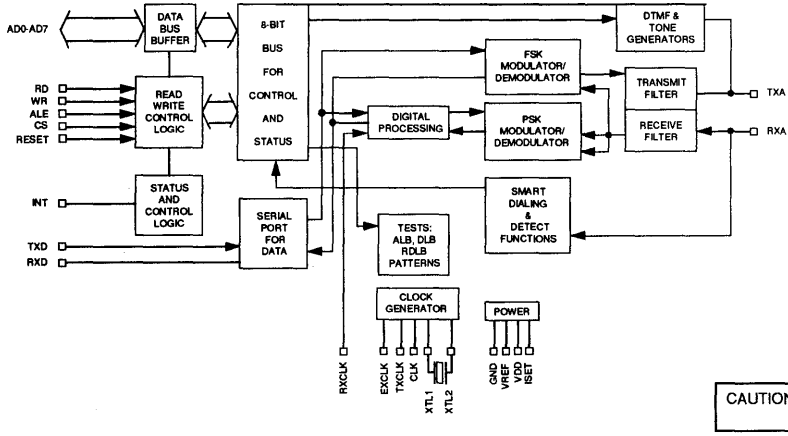
The SSI 73K222L includes the DPSK and FSK modulator/demodulator functions, call progress and handshake tone monitor and a tone generator capable of

(Continued)

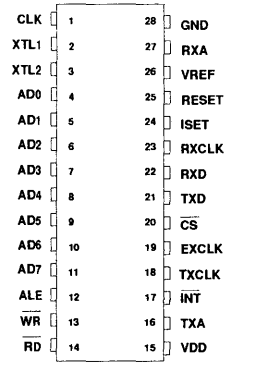
FEATURES

- **One-chip CCITT V.22, V.21, Bell 212A and 103 standard compatible modem data pump**
- **Full-duplex operation at 0-300 bit/s (FSK) or 600 and 1200 bit/s (DPSK)**
- **Pin and software compatible with other SSI K-Series 1-chip modems**
- **Interfaces directly with standard microprocessors (8048, 80C51 typical)**
- **Serial or parallel microprocessor bus for control**
- **Serial port for data transfer**
- **Both synchronous and asynchronous modes of operation including V.22 extended overspeed**
- **Call progress, carrier, precise answer tone (2100 or 2225 Hz), and long loop detectors**
- **DTMF, and 550 or 1800 Hz guard tone generators**
- **Test modes available: ALB, DL, RDL, Mark, Space, Alternating bit patterns**
- **Precise automatic gain control allows 45 dB dynamic range**
- **CMOS technology for low power consumption using 30 mW @ 5V**
- **Single +5 volt supply**

BLOCK DIAGRAM



PIN DIAGRAM



CAUTION: Use handling procedures necessary for a static sensitive component.

DESCRIPTION (Continued)

tone required for European applications. This device supports V.22 (except mode v) and V. 21 modes of operation, allowing both synchronous and asynchronous communications. Test features such as analog loop, digital loop, and remote digital loopback are supported. Internal pattern generators are also included for self-testing. The SSI 73K222L is designed to appear to the systems designer as a microprocessor peripheral, and will easily interface with popular one-chip microprocessors (80C51 typical) for control of modem functions through its 8-bit multiplexed address/data bus or serial control bus. An ALE control line simplifies address demultiplexing. Data communications occurs through a separate serial port only.

The SSI 73K222L is ideal for use in either free standing or integral system modem products where full-duplex 1200 bit/s data communications over the 2-wire switched telephone network is desired. Its high functionality, low power consumption and efficient packaging simplify design requirements and increase system reliability. A complete modem requires only the addition of the phone line interface, a control microprocessor, and RS-232 level converter for a typical system. The SSI 73K222L is part of Silicon Systems' K-Series family of pin and function compatible single-chip modem products. These devices allow systems to be configured for higher speeds and Bell or CCITT operation with only a single component change.

OPERATION

ASYNCHRONOUS MODE

Data transmission for the DPSK mode requires that data ultimately be transmitted in a synchronous fashion. The SSI 73K222L includes ASYNC/SYNC and SYNC/ASYNC converters which delete or insert stop bits in order to transmit data within a ±0.01% rate. In asynchronous mode the serial data comes from the TXD pin into the ASYNC/SYNC converter. The ASYNC/SYNC converter accepts the data provided on the TXD pin which normally must be 1200 or 600 bit/s +1.0%, -2.5%. The converter will then insert or delete stop bits in order to output a signal which is 1200 or 600 bit/s ± 0.01% (± 0.01% is required synchronous data rate accuracy).

The serial data stream from the ASYNC/SYNC converter is passed through the data scrambler and onto the analog modulator. The data scrambler can be bypassed under processor control when unscrambled data must be transmitted. The ASYNC/SYNC converter and the data scrambler are bypassed in all FSK modes. If serial input data contains a break signal through one character (including start and stop bits) the break will be extended to at least 2 • N + 3 bits long (where N is the number of transmitted bits/character).

Serial data from the demodulator is passed first through the data descrambler and then through the SYNC/ASYNC converter. The SYNC/ASYNC convertor will reinsert any deleted stop bits and transmit output data at an intra-character rate (bit-to-bit timing) of no greater than 1219 bit/s. An incoming break signal (low through two characters) will be passed through without incorrectly inserting a stop bit.

The SYNC/ASYNC converter also has an extended overspeed mode which allows selection of an overspeed range of either +1% or +2.3%. In the extended overspeed mode, stop bits are output at 7/8 the normal width.

SYNCHRONOUS MODE

The CCITT V.22 standard defines synchronous operation at 600 and 1200 bit/s. The Bell 212A standard defines synchronous operation only at 1200 bit/s. Operation is similar to that of the asynchronous mode except that data must be synchronized to a provided clock and no variation in data transfer rate is allowable. Serial input data appearing at TXD must be valid on the rising edge of TXCLK.

TXCLK is an internally derived signal in internal mode and is connected internally to the RXCLK pin in slave mode. Receive data at the RXD pin is clocked out on the falling edge of RXCLK. The ASYNCH/SYNCH converter is bypassed when synchronous mode is selected and data is transmitted out at the same rate as it is input.

DPSK MODULATOR/DEMODULATOR

The SSI 73K222L modulates a serial bit stream into di-bit pairs that are represented by four possible phase shifts as prescribed by the Bell 212A or V.22 standards. The baseband signal is then filtered to reduce intersymbol interference on the bandlimited 2-wire

telephone line. Transmission occurs using either a 1200 Hz (originate mode) or 2400 Hz carrier (answer mode). Demodulation is the reverse of the modulation process, with the incoming analog signal eventually decoded into di-bits and converted back to a serial bit stream. The demodulator also recovers the clock which was encoded into the analog signal during modulation. Demodulation occurs using either a 1200 Hz carrier (answer mode or ALB originate mode) or a 2400 Hz carrier (originate mode or ALB answer mode). The SSI 73K222L uses a phase locked loop coherent demodulation technique for optimum receiver performance.

FSK MODULATOR/DEMODULATOR

The FSK modulator produces a frequency modulated analog output signal using two discrete frequencies to represent the binary data. In Bell 103, the standard frequencies of 1270 and 1070 Hz (originate, mark and space) or 2225 and 2025 Hz (answer, mark and space) are used. V.21 mode uses 980 and 1180 Hz (originate, mark and space), or 1650 and 1850Hz (answer, mark and space). Demodulation involves detecting the received frequencies and decoding them into the appropriate binary value. The rate converter and scrambler/descrambler are bypassed in the 103 or V.21 modes.

PASSBAND FILTERS AND EQUALIZERS

High and low band filters are included to shape the amplitude and phase response of the transmit and receive signals and provide compromise delay equalization and rejection of out-of-band signals in the receive channel. Amplitude and phase equalization are necessary to compensate for distortion of the transmission line and to reduce intersymbol interference in the bandlimited receive signal. The transmit signal filtering approximates a 75% square root of raised Cosine frequency response characteristic.

AGC

The automatic gain control maintains a signal level at the input to the demodulators which is constant to within 1 dB. It corrects quickly for increases in signal which would cause clipping and provides a total receiver dynamic range of >45 dB.

PARALLEL BUS INTERFACE

Four 8-bit registers are provided for control, option select and status monitoring. These registers are addressed with the AD0, AD1, and AD2 multiplexed address lines (latched by ALE) and appear to a control microprocessor as four consecutive memory locations. Two control registers and the tone register are read/write memory. The detect register is read only and cannot be modified except by modem response to monitored parameters.

SERIAL COMMAND INTERFACE

The serial command interface allows access to the SSI 73K222L control and status registers via a serial command port (22-pin version only). In this mode the A0, A1 and A2 lines provide register addresses for data passed through the data pin under control of the $\overline{RD}$ and $\overline{WR}$ lines. A read operation is initiated when the $\overline{RD}$ line is taken low. The first bit is available after $\overline{RD}$ is brought low and the next seven cycles of EXCLK will then transfer out seven bits of the selected address LSB first. A write takes place by shifting in eight bits of data LSB first for eight consecutive cycles of EXCLK. $\overline{WR}$ is then pulsed low and data transferred into the addressed register occurs on the rising edge of $\overline{WR}$. This interface mode is also supported in the 28-pin packages. See serial control interface pin description.

SPECIAL DETECT CIRCUITRY

The special detect circuitry monitors the received analog signal to determine status or presence of carrier, call-progress tones, answer tone and weak received signal (long loop condition). An unscrambled mark request signal is also detected when the received data out of the DPSK demodulator before the descrambler has been high for 165.5 ms ± 6.5 ms minimum. The appropriate detect register bit is set when one of these conditions changes and an interrupt is generated for all purposes except long loop. The interrupts are disabled (masked) when the enable interrupt bit is set to 0.

DTMF GENERATOR

The DTMF generator will output one of 16 standard tone pairs determined by a 4-bit binary value and TX DTMF mode bit previously loaded into the tone register. Tone generation is initiated when the DTMF mode is selected using the tone register and the transmit enable (CR0 bit D1) is changed from 0 to 1.

PIN DESCRIPTION

POWER

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
GND	28	1	I	System Ground.
VDD	15	11	I	Power supply input, 5V ±10% (73K222L). Bypass with .1 and 22 µF capacitors to GND.
VREF	26	21	O	An internally generated reference voltage. Bypass with .1 µF capacitor to ground.
ISET	24	19	I	Chip current reference. Sets bias current for op-amps. The chip current is set by connecting this pin to VDD through a 2 MΩ resistor. ISET should be bypassed to GND with a .1 µF capacitor.

PARALLEL MICROPROCESSOR INTERFACE

ALE	12	-	I	Address latch enable. The falling edge of ALE latches the address on AD0-AD2 and the chip select on $\overline{CS}$.
AD0-AD7	4-11	-	I/O	Address/data bus. These bidirectional tri-state multiplexed lines carry information to and from the internal registers.
$\overline{CS}$	20	-	I	Chip select. A low on this pin during the falling edge of ALE allows a read cycle or a write cycle to occur. AD0-AD7 will not be driven and no registers will be written if $\overline{CS}$ (latched) is not active. The state of $\overline{CS}$ is latched on the falling edge of ALE.
CLK	1	2	O	Output clock. This pin is selectable under processor control to be either the crystal frequency (for use as a processor clock) or 16 x the data rate for use as a baud rate clock in DPSK modes only. The pin defaults to the crystal frequency on reset.
$\overline{INT}$	17	13	O	Interrupt. This open drain output signal is used to inform the processor that a detect flag has occurred. The processor must then read the detect register to determine which detect triggered the interrupt. $\overline{INT}$ will stay low until the processor reads the detect register or does a full reset.
$\overline{RD}$	14	-	I	Read. A low requests a read of the SSI 73K222L internal registers. Data cannot be output unless both $\overline{RD}$ and the latched $\overline{CS}$ are active or low.
RESET	25	20	I	Reset. An active high signal on this pin will put the chip into an inactive state. All control register bits (CR0, CR1, Tone) will be reset. The output of the CLK pin will be set to the crystal frequency. An internal pull down resistor permits power on reset using a capacitor to VDD.

PIN DESCRIPTION (Continued)

PARALLEL MICROPROCESSOR INTERFACE (Continued)

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
$\overline{WR}$	13	-	I	Write. A low on this informs the SSI 73K222L that data is available on AD0-AD7 for writing into an internal register. Data is latched on the rising edge of $\overline{WR}$. No data is written unless both $\overline{WR}$ and the latched $\overline{CS}$ are low.

SERIAL MICROPROCESSOR INTERFACE

A0-A2	-	5-7	I	Register Address Selection. These lines carry register addresses and should be valid during any read or write operation.
DATA	-	8	I/O	Serial Control Data. Data for a read/write operation is clocked in or out on the falling edge of the EXCLK pin. The direction of data flow is controlled by the $\overline{RD}$ pin. $\overline{RD}$ low outputs data. $\overline{RD}$ high inputs data.
$\overline{RD}$	-	10	I	Read. A low on this input informs the SSI 73K222L that data or status information is being read by the processor. The falling edge of the $\overline{RD}$ signal will initiate a read from the addressed register. The $\overline{RD}$ signal must continue for eight falling edges of EXCLK in order to read all eight bits of the referenced register. Read data is provided LSB first. Data will not be output unless the $\overline{RD}$ signal is active.
$\overline{WR}$	-	9	I	Write. A low on this input informs the SSI 73K222L that data or status information has been shifted in through the DATA pin and is available for writing to an internal register. The normal procedure for a write is to shift in data LSB first on the DATA pin for eight consecutive falling edges of EXCLK and then to pulse $\overline{WR}$ low. Data is written on the rising edge of $\overline{WR}$.

Note: In the serial, 22-pin version, the pins AD0-AD7, ALE and $\overline{CS}$ are removed and replaced with the pins; A0, A1, A2, DATA, and an unconnected pin. Also, the $\overline{RD}$ and $\overline{WR}$ controls are used differently.

The serial control mode is provided in the parallel control versions by tying ALE high and $\overline{CS}$ low. In this configuration AD7 becomes DATA and AD0, AD1 and AD2 become A0, A1 and A2, respectively.

PIN DESCRIPTION (Continued)

DTE USER

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
EXCLK	19	15	I	External Clock. This signal is used in synchronous transmission when the external timing option has been selected. In the external timing mode the rising edge of EXCLK is used to strobe synchronous DPSK transmit data applied to on the TXD pin. Also used for serial control interface.
RXCLK	23	18	O	Receive Clock. The falling edge of this clock output is coincident with the transitions in the serial received data output. The rising edge of RXCLK can be used to latch the valid output data. RXCLK will be valid as long as a carrier is present.
RXD	22	17	O	Received Data Output. Serial receive data is available on this pin. The data is always valid on the rising edge of RXCLK when in synchronous mode. RXD will output constant marks if no carrier is detected.
TXCLK	18	14	O	Transmit Clock. This signal is used in synchronous transmission to latch serial input data on the TXD pin. Data must be provided so that valid data is available on the rising edge of the TXCLK. The transmit clock is derived from different sources depending upon the synchronization mode selection. In Internal Mode the clock is generated internally. In External Mode TXCLK is phase locked to the EXCLK pin. In Slave Mode TXCLK is phase locked to the RXCLK pin. TXCLK is always active.
TXD	21	16	I	Transmit Data Input. Serial data for transmission is applied on this pin. In synchronous modes, the data must be valid on the rising edge of the TXCLK clock. In asynchronous modes (1200/600 bit/s or 300 baud) no clocking is necessary. DPSK data must be 1200/600 bit/s +1%, -2.5% or +2.3%, -2.5 % in extended overspeed mode.

ANALOG INTERFACE AND OSCILLATOR

RXA	27	22	I	Received modulated analog signal input from the telephone line interface.
TXA	16	12	O	Transmit analog output to the telephone line interface.
XTL1 XTL2	2 3	3 4	I I	These pins are for the internal crystal oscillator requiring a 11.0592 MHz parallel mode crystal. Load capacitors should be connected from XTL1 and XTL2 to Ground. XTL2 can also be driven from an external clock.

REGISTER DESCRIPTIONS

Four 8-bit internal registers are accessible for control and status monitoring. The registers are accessed in read or write operations by addressing the A0, A1 and A2 address lines in serial mode, or the AD0, AD1 and AD2 lines in parallel mode. In parallel mode the address lines are latched by ALE. Register CR0 controls the method by which data is transferred over the phone line. CR1 controls the interface between the microprocessor and the SSI 73K222L internal state. DR is a detect register which provides an indication of monitored modem status conditions. TR, the tone control register, controls the DTMF generator, answer and guard tones and RXD output gate used in the modem initial connect sequence. All registers are read/write except for DR which is read only. Register control and status bits are identified below:

REGISTER BIT SUMMARY

	ADDRESS	DATA BIT NUMBER							
REGISTER	AD2 - AD0	D7	D6	D5	D4	D3	D2	D1	D0
CONTROL REGISTER 0 CR0	000	MODULATION OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE
CONTROL REGISTER 1 CR1	001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTERRUPT	BYPASS SCRAMBLER	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0
DETECT REGISTER DR	010			RECEIVE DATA	UNSCR. MARKS	CARRIER DETECT	ANSWER TONE	CALL PROGRESS	LONG LOOP
TONE CONTROL REGISTER TR	011	RXD OUTPUT CONTROL	TRANSMIT GUARD TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF3	DTMF2	DTMF1/ OVERSPEED	DTMF0/ GUARD/ ANS TONE
CONTROL REGISTER 2 CR2	100				THESE REGISTER LOCATIONS ARE RESERVED FOR				
CONTROL REGISTER 3 CR3	101				USE WITH OTHER K-SERIES FAMILY MEMBERS				
ID REGISTER ID	110	ID	ID	ID	ID				

NOTE: When a register containing reserved control bits is written into, the reserved bits must be programmed as 0's.

REGISTER ADDRESS TABLE

REGISTER	ADDRESS AD2 - AD0	DATA BIT NUMBER D7	D6	D5	D4	D3	D2	D1	D0
CONTROL REGISTER 0 CR0	000	MODULATION OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ORIGINATE/ ANSWER
		0=1200 BIT/S DPSK 1=600 BIT/S DPSK 0=BELL 103 FSK 1=V.21 FSK		0000=PWR DOWN 0001=INT SYNCH 0010=EXT SYNCH 0011=SLAVE SYNCH 0100=ASYNCH 8 BITS/CHAR 0101=ASYNCH 9 BITS/CHAR 0110=ASYNCH 10 BITS/CHAR 0111=ASYNCH 11 BITS/CHAR 1100=FSK				0=DISABLE TXA OUTPUT 1=ENABLE TXA OUTPUT	0=ANSWER 1=ORIGINATE
CONTROL REGISTER 1 CR1	001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTERRUPT	BYPASS SCRAMBLER	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0
		00=TX DATA 01=TX ALTERNATE 10=TX MARK 11=TX SPACE		0=DISABLE 1=ENABLE	0=NORMAL 1=BYPASS SCRAMBLER	0=XTAL 1=16 X DATA RATE OUTPUT AT CLK PIN IN DPSK MODE ONLY	0=NORMAL 1=RESET	00=NORMAL 01=ANALOG LOOPBACK 10=REMOTE DIGITAL LOOPBACK 11=LOCAL DIGITAL LOOPBACK	
DETECT REGISTER DR	010			RECEIVE DATA	UNSCR. MARKS	CARRIER DETECT	ANSWER TONE	CALL PROGRESS	LONG LOOP
				OUTPUTS RECEIVED DATA STREAM	0=CONDITION NOT DETECTED 1=CONDITION DETECTED				
TONE CONTROL REGISTER TR	011	RXD OUTPUT CONTROL	TRANSMIT GUARD/ TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF3	DTMF2	DTMF1/ OVERSPEED	DTMF0/ GUARD/ ANSWER/ TONE
		RXD PIN 0=NORMAL 1=TRI STATE	0=OFF 1=ON	0=OFF 1=ON	0=DATA 1=TX DTMF	4 BIT CODE FOR 1 OF 16 DUAL TONE COMBINATIONS.			0=2225 Hz A.T. 1800 Hz G.T. 1=2100 Hz A.T. 500 Hz G.T.
ID REGISTER 10	110	ID	ID	ID	ID				

00XX=73K212L, 322L, 321L
01XX=73K221L, 302L
10XX=73K222L
1100=73K224L
1110=73K324L
1101=73K312L

CONTROL REGISTER 0

	D7	D6	D5	D4	D3	D2	D1	D0
CR0 000	MODUL. OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	Answer/ Originate	0	Selects answer mode (transmit in high band, receive in low band).
		1	Selects originate mode (transmit in low band, receive in high band).
D1	Transmit Enable	0	Disables transmit output at TXA.
		1	Enables transmit output at TXA. Note: TX Enable must be set to 1 to allow Answer Tone and DTMF Transmiission.
D5, D4,D3, D2	Transmit Mode	D5 D4 D3 D2	
		0 0 0 0	Selects power down mode. All functions disabled except digital interface.
		0 0 0 1	Internal synchronous mode. In this mode TXCLK is an internally derived 1200 Hz signal. Serial input data appearing at TXD must be valid on the rising edge of TXCLK. Receive data is clocked out of RXD on the falling edge of RXCLK.
		0 0 1 0	External synchronous mode. Operation is identical to internal synchronous, but TXCLK is connected internally to EXCLK pin, and a 1200 Hz ± 0.01% clock must be supplied externally.
		0 0 1 1	Slave synchronous mode. Same operation as other synchronous modes. TXCLK is connected internally to the RXCLK pin in this mode.
		0 1 0 0	Selects PSK asynchronous mode - 8 bits/character (1 start bit, 6 data bits, 1 stop bit).
		0 1 0 1	Selects PSK asynchronous mode - 9 bits/character (1 start bit, 7 data bits, 1 stop bit).
		0 1 1 0	Selects PSK asynchronous mode - 10 bits/character (1 start bit, 8 data bits, 1 stop bit).
		0 1 1 1	Selects PSK asynchronous mode - 11 bits/character (1 start bit, 8 data bits, Parity and 1 or 2 stop bits).
		1 1 0 0	Selects FSK operation.
D6		0	Not used; must be written as a "0."

CONTROL REGISTER 0 (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
CR0 000	MODUL. OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE

BIT NO.	NAME	CONDITION	DESCRIPTION
D7	Modulation Option	D7 D5 D4	Selects:
		0 0 X	DPSK mode at 1200 bit/s.
		1 0 X	DPSK mode at 600 bit/s.
		0 1 1	FSK Bell 103 mode.
		1 1 1	FSK CCITT V.21 mode.
			X = Don't care

CONTROL REGISTER 1

	D7	D6	D5	D4	D3	D2	D1	D0
CR1 001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTER.	BYPASS SCRAMB	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D1, D0	Test Mode	D1 D0	
		0 0	Selects normal operating mode.
		0 1	Analog loopback mode. Loops the transmitted analog signal back to the receiver, and causes the receiver to use the same center frequency as the transmitter. To squelch the TXA pin, transmit enable must be forced low.
		1 0	Selects remote digital loopback. Received data is looped back to transmit data internally, and RXD is forced to a mark. Data on TXD is ignored.
		1 1	Selects local digital loopback. Internally loops TXD back to RXD and continues to transmit carrier from TXA pin.
D2	Reset	0	Selects normal operation.
		1	Resets modem to power down state. All control register bits (CR0, CR1, Tone) are reset to zero. The output of the CLK pin will be set to the crystal frequency.
D3	CLK Control (Clock Control)	0	Selects 11.0592 MHz crystal echo output at CLK pin.
		1	Selects 16 X the data rate, output at CLK pin in DPSK modes only.

CONTROL REGISTER 1 (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
CR1 001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTER.	BYPASS SCRAMB	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D4	Bypass Scrambler	0	Selects normal operation. DPSK data is passed through scrambler.
		1	Selects Scrambler Bypass. Bypass DPSK data is routed around scrambler in the transmit path.
D5	Enable Detect	0	Disables interrupt at $\overline{INT}$ pin.
		1	Enables $\overline{INT}$ output. An interrupts will be generated with a change in status of DR bits D1-D4. The answer tone and call progress detect interrupts are masked when the TX enable bit is set. Carrier detect is masked when TX DTMF is activated. All interrupts will be disabled if the device is in power down mode.
D7, D6	Transmit Pattern	D7 D6	
		0 0	Selects normal data transmission as controlled by the state of the TXD pin.
		0 1	Selects an alternating mark/space transmit pattern for modem testing.
		1 0	Selects a constant mark transmit pattern.
		1 1	Selects a constant space transmit pattern.

DETECT REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
DR 010			RECEIVE DATA	UNSCR. MARK	CARR. DETECT	ANSWER TONE	CALL PROG.	LONG LOOP

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	Long Loop	0	Indicates normal received signal.
		1	Indicates low received signal level.
D1	Call Progress Detect	0	No call progress tone detected.
		1	Indicates presence of call progress tones. The call progress detection circuitry is activated by energy in the 350 to 620 Hz call progress band.

DETECT REGISTER (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
DR 010			RECEIVE DATA	UNSCR. MARK	CARR. DETECT	ANSWER TONE	CALL PROG.	LONG LOOP

BIT NO.	NAME	CONDITION	DESCRIPTION
D2	Answer Tone Detect	0	No answer tone detected.
		1	Indicates detection of 2225 Hz answer tone in Bell mode or 2100 Hz in CCITT mode. The device must be in originate mode for detection of answer tone. For CCITT answer tone detection, bit D0 of the Tone Register must be set to a 1.
D3	Carrier Detect	0	No carrier detected in the receive channel.
		1	Indicates carrier has been detected in the receive channel.
D4	Unscrambled Mark Detect	0	No unscrambled mark.
		1	Indicates detection of unscrambled marks in the received data. A valid indication requires that unscrambled marks be received for > 165.5 ± 6.5 ms.
D5	Receive Data		Continuously outputs the received data stream. This data is the same as that output on the RXD pin, but it is not disabled when RXD is tri-stated.
D6, D7			Not used.

TONE REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.	TRANSMIT GUARD TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2	DTMF 1/ OVER-SPEED	DTMF 0/ ANSWER/ GUARD

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	DTMF 0/ Answer/ Guard Tone	D6 D5 D4 D0	D0 interacts with bits D6, D5, and D4 as shown.
		X X 1 X	Transmit DTMF tones.
		X 0 0 0	Detects 2225 Hz in originate mode.
		X 1 0 0	Transmits 2225 Hz in answer mode (Bell).
		X 0 0 1	Detects 2100 Hz in originate mode.
		X 1 0 1	Transmits 2100 Hz in answer mode (CCITT).
		1 0 0 0	Select 1800 Hz guard tone.
		1 0 0 1	Select 550 Hz guard tone.
D1	DTMF 1/ Overspeed	D4 D1	D1 interacts with D4 as shown.
		0 0	Asynchronous DPSK +1.0% -2.5%.
		0 1	Asynchronous DPSK +2.3% -2.5%.

TONE REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.	TRANSMIT GUARD TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2	DTMF 1/ OVER-SPEED	DTMF 0/ ANSWER/ GUARD

BIT NO.	NAME	CONDITION	DESCRIPTION
D3, D2, D1, D0	DTMF 3, 2, 1, 0	D3 D2 D1 D0 0 0 0 0 - 1 1 1 1	Programs 1 of 16 DTMF tone pairs that will be transmitted when TX DTMF and TX enable bit (CR0, bit D1) are set. Tone encoding is shown below:

KEYBOARD EQUIVALENT	DTMF CODE D3 D2 D1 D0	TONES LOW HIGH
1	0 0 0 1	697 1209
2	0 0 1 0	697 1336
3	0 0 1 1	697 1477
4	0 1 0 0	770 1209
5	0 1 0 1	770 1336
6	0 1 1 0	770 1477
7	0 1 1 1	852 1209
8	1 0 0 0	852 1336
9	1 0 0 1	852 1477
0	1 0 1 0	941 1336
*	1 0 1 1	941 1209
#	1 1 0 0	941 1477
A	1 1 0 1	697 1633
B	1 1 1 0	770 1633
C	1 1 1 1	852 1633
D	0 0 0 0	941 1633

BIT NO.	NAME	CONDITION	DESCRIPTION
D4	Transmit DTMF	0	Disable DTMF.
		1	Activates DTMF. The selected DTMF tones are transmitted continuously when this bit is high. TX DTMF overrides all other transmit functions.
D5	Transmit Answer Tone	D5 D4 D0	D5 interacts with bits D4 and D0 as shown.
		0 0 X	Disables answer tone generator.
		1 0 0	Enables answer tone generator. A 2225 Hz answer tone will be transmitted continuously when the Transmit Enable bit is set in CR0. The device must be in answer mode.
		1 0 1	Likewise a 2100 Hz answer tone will be transmitted.

3

TONE REGISTER (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.	TRANSMIT GUARD TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2	DTMF 1/ OVER-SPEED	DTMF 0/ ANSWER/ GUARD

BIT NO.	NAME	CONDITION	DESCRIPTION
D6	Transmit Guard Tone	0	Disables guard tone generator.
		1	Enables guard tone generator (See D0 for selection of guard tones).
D7	RXD Output Control	0	Enables RXD pin. Receive data will be output on RXD.
		1	Disables RXD pin. The RXD pin reverts to a high impedance with internal weak pull-up resistor.

ID REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
ID 110	ID	ID	ID	ID				

BIT NO.	NAME	CONDITION	DESCRIPTION
D7, D6	Device Identification Signature	D7 D6 D5 D4	Indicates Device:
		0 0 X X	SSI 73K212(L), 73K321L or 73K322L or 73K321L
		0 1 X X	SSI 73K221(L) or 73K302L
		1 0 X X	SSI 73K222(L)
		1 1 0 0	SSI 73K224L
		1 1 1 0	SSI 73K324L
		1 1 0 1	SSI 73K312L

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

PARAMETER	RATING
VDD Supply Voltage	14V
Storage Temperature	-65 to 150°C
Soldering Temperature (10 sec.)	260°C
Applied Voltage	-0.3 to VDD+0.3V
Note: All inputs and outputs are protected from static charge using built-in, industry standard protection devices and all outputs are short-circuit protected.	

RECOMMENDED OPERATING CONDITIONS

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
VDD Supply voltage		4.5	5	5.5	V
TA, Operating Free-Air Temperature		-40		+85	°C
Clock Variation	(11.0592 MHz) Crystal or external clock	-0.01		+0.01	%
External Components (Refer to Application section for placement.)					
VREF Bypass Capacitor	(External to GND)	0.1			µF
Bias setting resistor	(Placed between VDD and ISET pins)	1.8	2	2.2	MΩ
ISET Bypass Capacitor	(ISET pin to GND)	0.1			µF
VDD Bypass Capacitor 1	(External to GND)	0.1			µF
VDD Bypass Capacitor 2	(External to GND)	22			µF
XTL1 Load Capacitor	Depends on crystal characteristics;			40	pF
XTL2 Load Capacitor	from pin to GND			20	

ELECTRICAL SPECIFICATIONS (Continued)

DC ELECTRICAL CHARACTERISTICS

(TA = -40°C to 85°C, VDD = recommended range unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
IDD, Supply Current	ISET Resistor = 2 MΩ				
IDDA, Active	CLK = 11.0592 MHz		8	12	mA
IDD1, Power-down	CLK = 11.0592 MHz			4	mA
IDD2, Power-down	CLK = 19.200 KHz			3	mA
Digital Inputs					
VIH, Input High Voltage					
Reset, XTL1, XTL2		3.0		VDD	V
All other inputs		2.0		VDD	V
VIL, Input Low Voltage		0		0.8	V
IIH, Input High Current	VI = VIH Max			100	µA
IIL, Input Low Current	VI = VIL Min	-200			µA
Reset Pull-down Current	Reset = VDD	1		50	µA
Input Capacitance	All Digital Input Pins			10	pF
Digital Outputs					
VOH, Output High Voltage	IOH MIN = -0.4 mA	2.4		VDD	V
VOL, Output Low Voltage	IO MAX = 1.6 mA			0.4	V
VOL, CLK Output	IO = 3.6 mA			0.6	V
RXD Tri-State Pull-up Curr.	RXD = GND	-1		-50	µA
CMAX, CLK Output	Maximum Capacitive Load			15	pF

ELECTRICAL SPECIFICATIONS (Continued)

DYNAMIC CHARACTERISTICS AND TIMING

(TA = -40°C to +85°C, VDD = recommended range unless otherwise noted.)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
PSK Modulator					
Carrier Suppression	Measured at TXA	55			dB
Output Amplitude	TX scrambled marks	-11	-10.0	-9	dBm0
FSK Mod/Demod					
Output Freq. Error	CLK = 11.0592 MHz	-0.35		+.35	%
Transmit Level	Transmit Dotting Pattern	-11	-10.0	-9	dBm0
Harmonic Distortion in 700-2900 Hz band	THD in the alternate band DPSK or FSK		-60	-50	dB
Output Bias Distortion	Transmit Dotting Pattern in ALB @ RXD		±8		%
Total Output Jitter	Random Input in ALB @ RXD	-15		+15	%
DTMF Generator					
Freq. Accuracy		-.25		+.25	%
Output Amplitude	Low Band, DPSK Mode	-10	-9	-8	dBm0
Output Amplitude	High Band, DPSK Mode	-8	-7	-6	dBm0
Twist	High-Band to Low-Band, DPSK Mode	1.0	2.0	3.0	dB
Long Loop Detect	DPSK or FSK	-38		-28	dBm0
Dynamic Range	Refer to Performance Curves		45		dB
Call Progress Detector					
Detect Level	2-Tones in 350-600 Hz band	-34		0	dBm0
Reject Level	2-Tones in 350-600 Hz band			-41	dBm0
Delay Time	-70 dBm0 to -30 dBm0 STEP	27		80	ms
Hold Time	-30 dBm0 to -70 dBm0 STEP	27		80	ms
Hysteresis		2			dB

Note: Parameters expressed in dBm0 refer to the following definition:

0 dB loss in the Transmit path to the line.
2 dB gain in the Receive path from the line.

Refer to the Basic Box Modem diagram in the Applications section for the DAA design.

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ELECTRICAL SPECIFICATIONS (Continued)

DYNAMIC CHARACTERISTICS AND TIMING (Continued)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Carrier Detect	DPSK or FSK				
Threshold	receive data	-49		-42	dBm0
Delay Time	-70 dBm0 to -30 dBm0 STEP	15		45	ms
Hysteresis	Single tone detected	2	3.0		dB
Hold Time	-30 dBm0 to -70 dBm0 STEP	10		24	ms
Answer Tone Detector					
Detect Level	Not in V.21 mode	-49.5		-42	dBm0
Delay Time	-70 dBm0 to -30 dBm0 STEP	20		45	ms
Hold Time	-30 dBm0 to -70 dBm0 STEP	10		30	ms
Detect Freq. Range		-2.5		+2.5	%
Output Smoothing Filter					
Output load	TXA pin; FSK Single	10			kΩ
	Tone out for THD = -50 db in .3 to 3.4 KHz			50	pF
Spurious Freq. Comp.	Frequency = 76.8 kHz			-39	dBm0
	Frequency = 153.6 kHz			-45	dBm0
TXA pin Output Impedance			200	300	Ω
Clock Noise	TXA pin; 76.8 KHz			1.0	mVrms
Carrier VCO					
Capture Range	Originate or Answer	-10		+10	Hz
Capture Time	-10 Hz to +10 Hz Carrier Freq. Change Assum.		40	100	ms
Recovered Clock					
Capture Range	% of frequency center frequency (center at 1200 Hz)	-625		+625	ppm
Data Delay Time	Analog data in at RXA pin to receive data valid at RXD pin		. 30	50	ms

ELECTRICAL SPECIFICATIONS (Continued)

DYNAMIC CHARACTERISTICS AND TIMING (Continued)

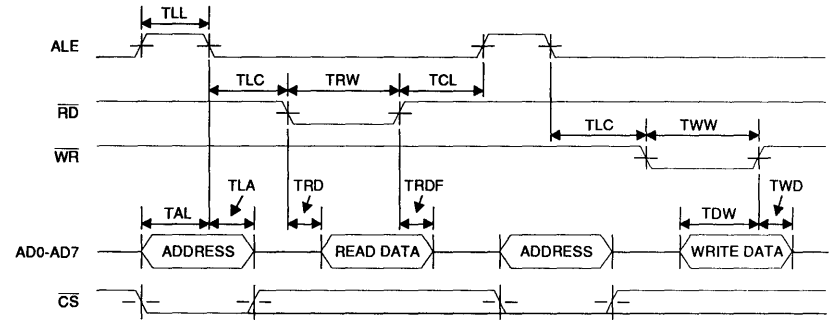
PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Guard Tone Generator					
Tone Accuracy	550 Hz				
	1800 Hz	-20		+20	Hz
Tone Level	550 Hz	-4.0	-3.0	-2.0	dB
(Below DPSK Output)	1800 Hz	-7.0	-6.0	-5.0	dB
Harmonic Distortion	550 Hz			-50	dB
700 to 2900 Hz	1800 Hz			-60	dB
Timing (Refer to Timing Diagrams)					
TAL	$\overline{CS}$/Addr. setup before ALE Low	30			ns
TLA	$\overline{CS}$/Addr. hold after ALE Low	20			ns
TLC	ALE Low to $\overline{RD}/\overline{WR}$ Low	40			ns
TCL	$\overline{RD}/\overline{WR}$ Control to ALE High	10			ns
TRD	Data out from $\overline{RD}$ Low	0		140	ns
TLL	ALE width	60			ns
TRDF	Data float after $\overline{RD}$ High	0		200	ns
TRW	$\overline{RD}$ width	200		25000	ns
TWW	$\overline{WR}$ width	140		25000	ns
TDW	Data setup before $\overline{WR}$ High	150			ns
TWD	Data hold after $\overline{WR}$ High	20			ns
TCKD	Data out after EXCLK Low			200	ns
TCKW	$\overline{WR}$ after EXCLK Low	150			ns
TDCK	Data setup before EXCLK Low	150			ns
TAC	Address setup before control*	50			ns
TCA	Address hold after control*	50			ns
TWH	Data Hold after EXCLK	20			

* Control for setup is the falling edge of $\overline{RD}$ or $\overline{WR}$.
Control for hold is the falling edge of $\overline{RD}$ or the rising edge of $\overline{WR}$.

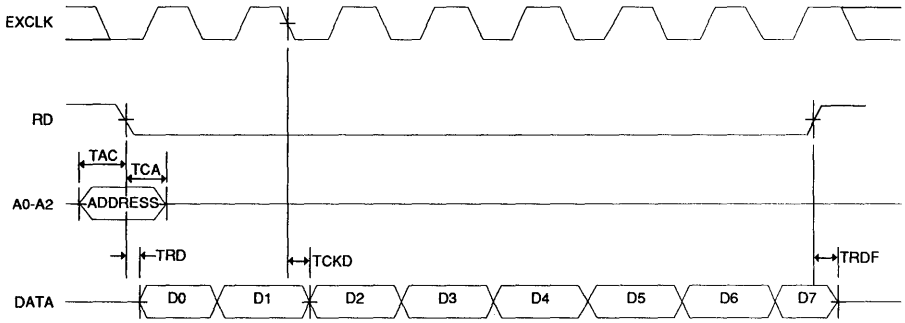
3

TIMING DIAGRAMS

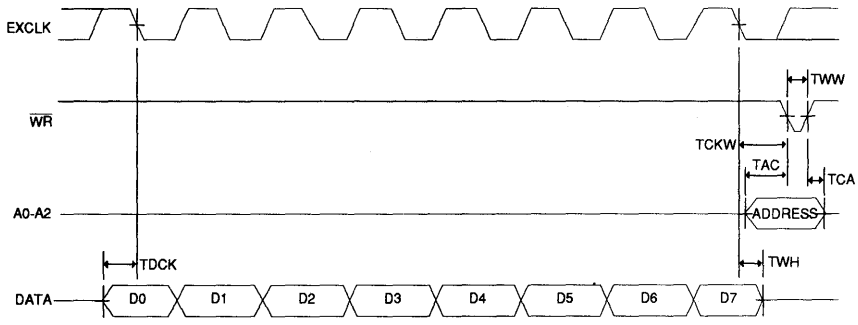
BUS TIMING DIAGRAM (PARALLEL VERSION)



READ TIMING DIAGRAM (SERIAL VERSION)



WRITE TIMING DIAGRAM (SERIAL VERSION)



APPLICATIONS INFORMATION

GENERAL CONSIDERATIONS

Figures 1 and 2 show basic circuit diagrams for K-Series modem integrated circuits. K-Series products are designed to be used in conjunction with a control processor, a UART or RS-232 serial data interface, and a DAA phone line interface to function as a typical intelligent modem. The K-Series ICs interface directly with Intel 8048 and 80C51 microprocessors for control and status monitoring purposes. Two typical DAA arrangements are shown: one for a split ±5 or ±12 volt design and one for a single 5 volt design. These diagrams are for reference only and do not represent production-ready modem designs.

K-Series devices are available with two control interface versions: one for a parallel multiplexed address/data interface, and one for a serial interface. The parallel version is intended for use with 8039/48 or 8031/51 microcontrollers from Intel or many other manufacturers. The serial interface 22-pin version can be used with other microcontrollers or in applications where only a limited number of port lines are available or the application does not lend itself to a multiplexed address/data interface. The parallel versions may also be used in the serial mode, as explained in the data sheet pin description.

In most applications the controller will monitor the serial data for commands from the DTE and the received data for break signals from the far end modem. In this way, commands to the modem are sent over the same line as the transmitted data. In other applications the RS-232 interface handshake lines are used for modem control.

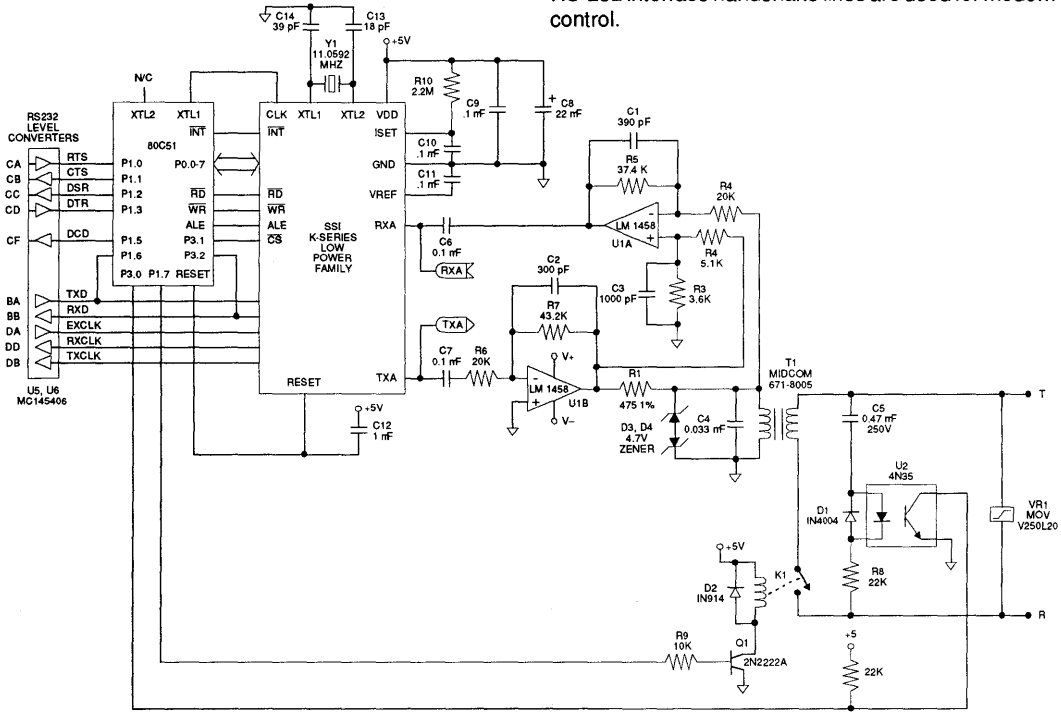


FIGURE 1: Basic Box Modem with Dual-Supply Hybrid

DIRECT ACCESS ARRANGEMENT (DAA)

The telephone line interfaces show two examples of how the "hybrid" may be implemented. The split supply design (Figure 1) is a typical two op-amp hybrid. The receive op-amp serves two purposes. It supplies gain to amplify the receive signal to the proper level for the modem's detectors and demodulator, and it removes the transmitted signal from the receive signal present at the transformer. This is done by supplying a portion of the transmitted signal to the non-inverting input of the receive op-amp at the same amplitude as the signal appearing at the transformer, making the transmit signal common mode.

The single-supply hybrid is more complex than the dual-supply version described above, but its use eliminates the need for a second power supply. This circuit (Figure 2) uses a bridged drive to allow undistorted signals to be sent with a single 5V supply. Because DTMF tones utilize a higher amplitude than data, these signals will clip if a single-ended drive approach is used. The bridged driver uses an extra op-amp (U1A) to invert the signal coming from the gain setting op-amp (U1B) before sending it to the other leg of the transformer. Each op-amp then supplies half the drive signal to the transformer. The receive amplifier (U1C) picks off its signal at the junction of the impedance matching resistor and the transformer. Because the bottom leg of the transformer is being driven in one direction by U1A and the resistor is driven in the opposite direction at the same time by U1B, the junction of the transformer and resistor remains relatively constant and the receive signal is unaffected.

DESIGN CONSIDERATIONS

Silicon Systems' 1-chip modem products include all basic modem functions. This makes these devices adaptable for use in a variety of applications, and as easy to control as conventional digital bus peripherals.

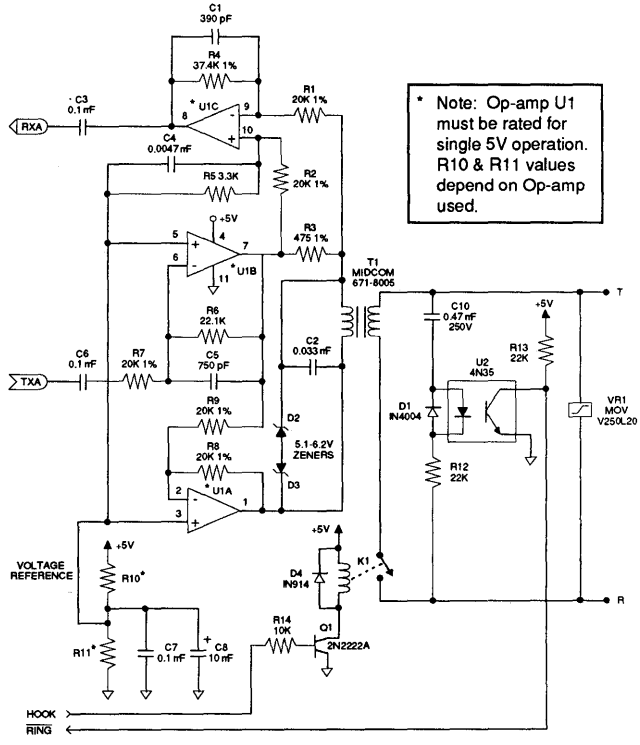


FIGURE 2: Single 5V Hybrid Version

Unlike digital logic circuitry, modem designs must properly contend with precise frequency tolerances and very low level analog signals, to ensure acceptable performance. Using good analog circuit design practices will generally result in a sound design. Following are additional recommendations which should be taken into consideration when starting new designs.

CRYSTAL OSCILLATOR

The K-Series crystal oscillator requires a parallel mode (antiresonant) crystal which operates at 11.0592 MHz. It is important that this frequency be maintained to within ±0.01% accuracy.

In order for a parallel mode crystal to operate correctly and to specification, it must have a load capacitor connected to the junction of each of the crystal and internal inverter connections, terminated to ground. The values of these capacitors depend primarily on the crystal's characteristics, and to a lesser degree on the internal inverter circuit. The values used affect the accuracy and start up characteristics of the oscillator.

LAYOUT CONSIDERATIONS

Good analog/digital design rules must be used to control system noise in order to obtain highest performance in modem designs. The more digital circuitry present on the PC board, the more this attention to noise control is needed. The modem should be treated as a high impedance analog device. A 22 mF electrolytic capacitor in parallel with a 0.1 mF ceramic capacitor between VDD and GND is recommended. Liberal use of ground planes and larger traces on power and ground are also highly favored. High speed digital circuits tend to generate a significant amount of EMI (Electro-Magnetic Interference) which must be minimized in order to meet regulatory agency limitations. To accomplish this, high speed digital devices should be locally bypassed, and the telephone line interface and K-Series device should be located close to each other near the area of the board where the phone line connection is accessed. To avoid problems, power supply and ground traces should be routed separately to the analog and digital functions on the board, and digital signals should not be routed near low level or high impedance analog traces. The analog and digital grounds should only connect at one point near the K-Series device ground pin to avoid ground loops. The K–Series modem IC's should have both high frequency and low frequency bypassing as close to the package as possible.

MODEM PERFORMANCE CHARACTERISTICS

The curves presented here define modem IC performance under a variety of line conditions while inducing disturbances that are typical of those encountered during data transmission on public service telephone lines. Test data was taken using an AEA Electronics' "Autotest I" modem test set and line simulator, operating under computer control. All tests were run full-duplex, using a Concord Data Systems 224 as the reference modem. A 511 pseudo-random-bit pattern was used for each data point. Noise was C-message weighted and all signal-to-noise (S/N) ratios reflect total power measurements similar to the CCITT V.56 measurement specification. The individual tests are defined as follows.

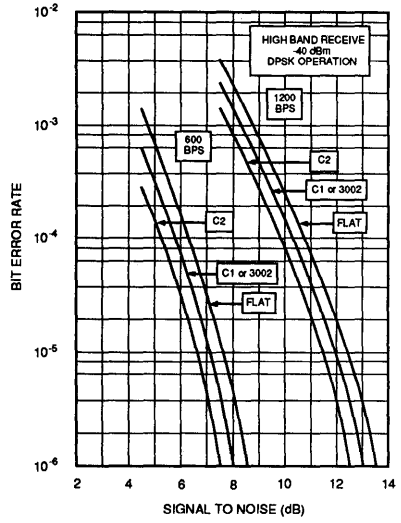
BER vs. S/N

This test measures the ability of the modem to operate over noisy lines with a minimum of data-transfer errors. Since some noise is generated in the best of dial-up lines, the modem must operate with the lowest S/N ratio possible. Better modem performance is indicated by test curves that are closest to the BER axis. A narrow spread between curves representing the four line parameters indicates minimal variation in performance while operating over a range of aberrant operating conditions. Typically, a DPSK modem will exhibit better BER-performance test curves receiving in the low band than in the high band.

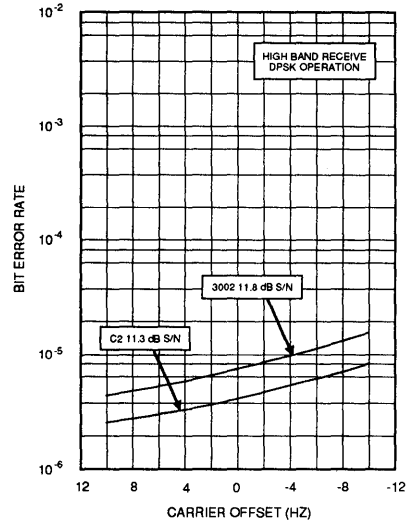
BER vs. Receive Level

This test measures the dynamic range of the modem. Because signal levels vary widely over dial-up lines, the widest possible dynamic range is desirable. The minimum Bell specification calls for 36 dB of dynamic range. S/N ratios are held constant at the indicated values while the receive level is lowered from a very high to very low signal levels. The width of the "bowl" of these curves, taken at the BER point, is the measure of dynamic range.

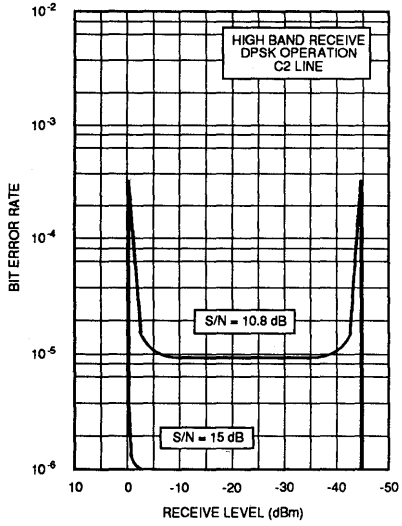
*SSI 73K222L
BER vs SIGNALTO NOISE



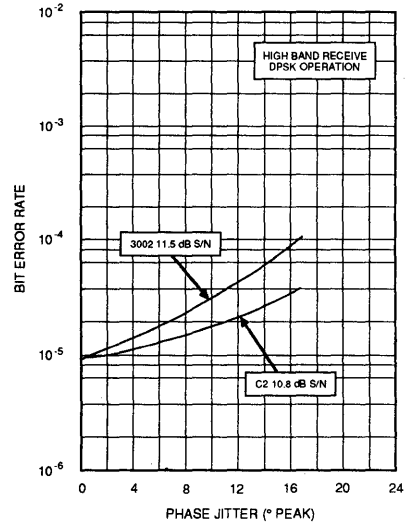
*SSI 73K222L
BER vs CARRIER OFFSET



*SSI 73K222L
BER vs RECEIVE LEVEL



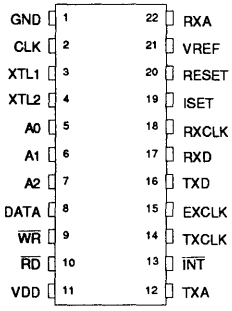
*SSI 73K222L
BER vs PHASE JITTER



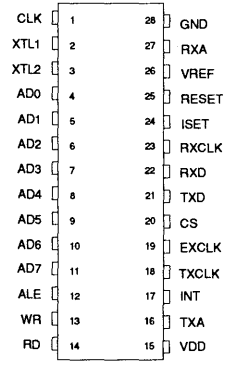
* = "EQ On" Indicates bit CR1 D4 is set for additional phase equalization.

PACKAGE PIN DESIGNATIONS
(Top View)

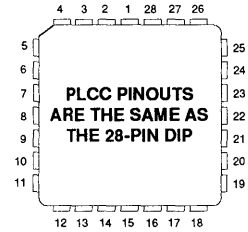
CAUTION: Use handling procedures necessary for a static sensitive component.



400-Mil 22-Pin DIP



600-Mil 28-Pin DIP



28-Pin PLCC

3

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 73K222L with Parallel Bus Interface		
28-Pin Dip	73K222L-IP	73K222L-IP
28-Pin PLCC	73K222L-IH	73K222L-IH
SSI 73K222L with Serial Interface	73K222SL-IP	73K222SL-IP
22-Pin Sip	73K222SL-IC	73K222SL-IC

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Notes:

SSI 73K222U
Single-Chip Modem with UART

December 1993

DESCRIPTION

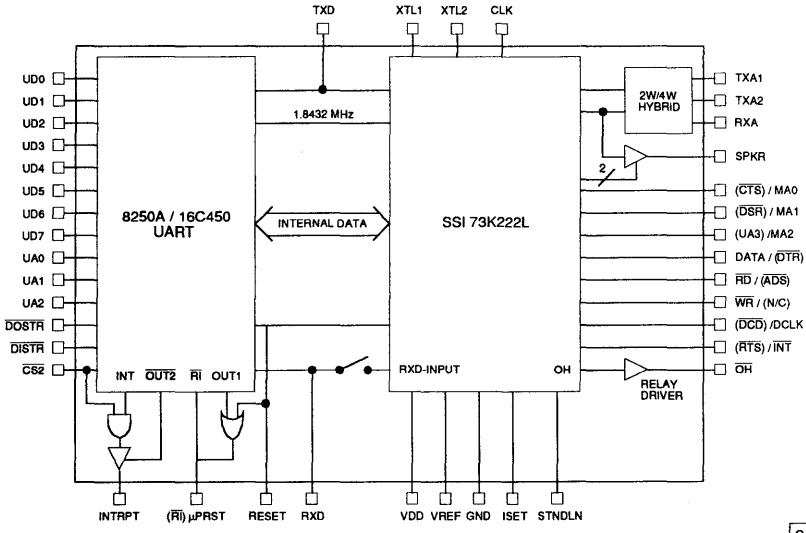
The SSI 73K222U is a compact, high-performance modem which includes a 8250A/16C450 compatible UART with the 1200 bit/s modem function on a single chip. Based on the SSI 73K222L 5V low power CMOS modem IC, the SSI 73K222U is the perfect modem/UART component for integral modem applications. It is ideal for applications such as portable terminals and laptop computers. The SSI 73K222U is the first fully featured modem IC which can function as an intelligent modem in integral applications without requiring a separate dedicated microcontroller. It provides for data communication at 1200, 600, and 300 bit/s in a multi-mode manner that allows operation compatible with both Bell 212A/103 and CCITT V.22/V.21 standards. The digital interface section contains a high speed version of the industry standard 8250A/16C450 UART, commonly used in personal computer products. A unique feature of the SSI 73K222U is that the UART section can be used without the modem function, providing an additional asynchronous port at no added cost. The SSI 73K222U is designed in CMOS technology and operates from a single +5V supply. Available packaging includes 40-pin DIP or 44-pin PLCC for surface mount applications.

FEATURES

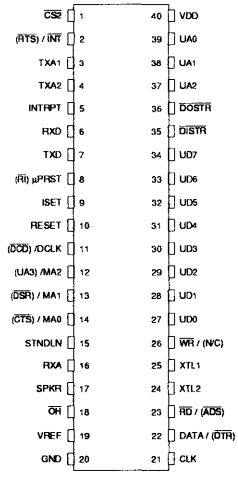
- **Modem/UART combination optimized for integral bus applications**
- **Includes features of SSI 73K222L single-chip modem**
- **Fully compatible 16C450/8250 UART with 8250B or 8250A selectable interrupt emulation**
- **High speed UART will interface directly with high clock rate bus with no wait states**
- **Single-port mode allows full modem and UART control from CPU bus, with no dedicated microprocessor required**
- **Dual-port mode suits conventional designs using local microprocessor for transparent modem operation**
- **Complete modem functions for 1200 bit/s (Bell 212A, V.22) and 0-300 bit/s (Bell 103, V.21)**
- **Includes DTMF generator, carrier, call-progress and precise answer-tone detectors for intelligent dialing capability**
- **On chip 2-wire/4-wire hybrid driver and off-hook relay buffer**
- **Speaker output with four-level software driven volume control**
- **Low power CMOS (40 mW) with power down mode (15 mW)**
- **Operates from single +5V supply**

3

BLOCK DIAGRAM



PIN DIAGRAM



Parentheses indicate single-port mode.

CAUTION: Use handling procedures necessary for a static sensitive component.

SSI 73K222U
Single-Chip Modem with UART

FUNCTIONAL DESCRIPTION

The SSI 73K222U integrates an industry standard 8250/16C450 UART function with the modem capability provided by the SSI 73K222L single chip modem IC. The SSI 73K222U is designed specifically for integral microprocessor bus intelligent modem products. These designs typically require the standard 8250 or higher speed 16450 UART to perform parallel-to-serial and serial-to-parallel conversion process necessary to interface a parallel bus with the inherently serial modem function. The SSI 73K222U provides a highly integrated design which can eliminate multiple components in any integral bus modem application, and is ideal for internal PC modem applications.

The SSI 73K222U includes two possible operating modes. In the dual-port mode, the device is suitable for conventional plug-in modem card designs which use a separate local microprocessor for command interpretation and control of the modem function. In this mode, a dedicated microcontroller communicates with the SSI 73K222U using a separate serial command port. In the single-port mode the main CPU can control both the UART and modem function using the parallel data bus. This allows very efficient modem design with no local microprocessor required for dedicated applications such as laptop PC's or specialized terminals.

To make designs more space efficient, the SSI 73K222U includes the 2-wire to 4-wire hybrid drivers, off-hook relay driver, and an audio monitor output with software volume control for audible call progress monitoring. As an added feature the UART function can be used independent of the modem function, providing an added asynchronous port in a typical PC application with no additional circuitry required.

UART FUNCTION (16C450)

The UART section of the SSI 73K222U is completely compatible with the industry standard 16C450 and the 8250 UART devices. The bus interface is identical to the 16450, except that only a single polarity for the control signals is supported. The register contents and addresses are also the same as the 16C450. To insure compatibility with all existing releases of the 8250 UART design, external circuitry normally used in PC applications to emulate 8250B or 8250A interrupt operation has been included on the SSI 73K222U. A select line is then provided to enable the desired interrupt operation. The UART used in the SSI 73K222U can be used with faster bus read and write cycles than a conventional 16C450 UART. This allows it to interface directly with higher clock rate microprocessors with no need for external circuitry to generate wait states.

The primary function of the UART is to perform parallel-to-serial conversion on data received from the CPU and serial-to-parallel conversion on data received from the internal modem or an external device. The UART can program the number of bits per character, parity bit generation and checking, and the number of stop bits. The UART also provides break generation and detection, detection of error conditions, and reporting of status at any time. A prioritized maskable interrupt is also provided.

The UART block has a progammable baud rate generator which divides an internal 1.8432 MHz clock to generate a clock at 16 x the data rate. The data rate for the transmit and receive sections must be the same. For DPSK modulation, the data rate must be 1200 Hz or 600 Hz. For FSK modulation, the data rate must be 300 Hz or less. The baud generator can create a clock that supports digital transfer at up to 115.2 kHz. The output of the baud generator can be made available at the CLK pin under program control.

MODEM FUNCTION (SSI 73K222L)

The modem section of the SSI 73K222U provides all necessary analog functions required to create a single chip Bell 212A/103 and CCITT V.22/V.21 modem, controlled by the system CPU or a local dedicated microprocessor. Asynchronous 1200 bit/s DPSK (Bell 212A and V.22) and 300 baud FSK (Bell 103 and V.21) modes are supported.

The modem portion acts as a peripheral to the microprocessor. In both modes of operation, control information is stored in register memory at specific address locations. In the single-port mode, the modem section can be controlled through the 16C450 interface, with no external microcontroller required. The primary analog blocks are the DPSK modulator/demodulator, the FSK modulator/demodulator, the high and low band filters, the AGC, the special detect circuitry, and the DTMF tone generator. The analog functions are performed with switched capacitor technology.

PSK MODULATOR / DEMODULATOR

The SSI 73K222U modulates a serial bit stream into dibit pairs that are represented by four possible phase shifts as prescribed by the Bell 212A or V.22 standard. The baseband signal is then filtered to reduce intersymbol interference on the band limited 2-wire PSTN line. Transmission occurs using either a 1200 Hz (originate mode) or 2400 Hz carrier (answer mode). Demodulation is the reverse of the modulation process, with the incoming analog signal eventually decoded into dibits and converted back to a serial bit stream. The demodulator also recovers the clock which was encoded into the analog signal during modulation. The demodulator decodes either a 1200 Hz carrier (originate carrier) or a 2400 Hz carrier (answer carrier). The SSI 73K222U uses a phase-locked-loop coherent demodulation technique that offers inherently better performance than typical DPSK demodulators used by other manufacturers.

FSK MODULATOR/DEMODULATOR

The FSK modulator frequency modulates the analog output signal using two discrete frequencies to represent the binary data. In Bell 103, the standard frequencies of 1270 Hz and 1070 Hz (originate mark and space) and 2225Hz and 2025 Hz (answer mark and space) are used. V.21 mode uses 980 Hz and 1180 Hz (originate, mark and space) or 1650 Hz and 1850 Hz (answer, mark and space). Demodulation involves detecting the received frequencies and decoding them into the appropriate binary value.

PASSBAND FILTERS AND EQUALIZERS

A high and low band filter is included to shape the amplitude and phase response of the transmit signal and provide compromise delay equalization and rejection of out-of-band signals in the receive channel. Amplitude and phase equalization is necessary to compensate for distortion of the transmission line and to reduce intersymbol interference in the band limited receive signal. The transmit signal filtering approximates a 75% square root of raised Cosine frequency response characteristic.

AGC

The automatic gain control maintains a signal level at the input to the demodulators which is constant to within 1 dB. It corrects quickly for increases in signal which would cause clipping, and provides a total dynamic range of >45 dB.

SPECIAL DETECT CIRCUITRY

The special detect circuitry monitors the received analog signal to determine status or presence of carrier, call-progress tones, answer tone, and weak received signal (long loop condition). An unscrambled mark signal is also detected when the received data out of the DPSK demodulator before the descrambler has been high for 165.5 mS ±13.5 mS. The appropriate status bit is set when one of these conditions changes and an interrupt is generated for all monitored conditions except long loop. The interrupts are disabled (masked) when the enable interrupt bit is set to a 0.

DTMF GENERATOR

The DTMF generator will output one of 16 standard dual-tones determined by a 4-bit binary value and TX DTMF mode bit previously loaded into the tone register. Tone generation is initiated when the DTMF mode is selected and the transmit enable (CR0 bit D1) is changed from a 0 to a 1.

TEST FEATURES

Test features such as analog loopback (ALB), remote digital loopback, local digital loopback, and internal pattern generators are also included.

LINE INTERFACE

The line interface of the SSI 73K222U consists of a two-to-four wire hybrid, and an off-hook relay driver.

The two-to-four wire converter has a differential transmit output and requires only a line transformer and an external impedance matching resistor. Four-wire operation is also available by simply using either of the transmit output signals.

The relay driver output of the SSI 73K222U is an open drain signal capable of sinking 20 mA, which can control a line closure relay used to take the line off hook and to perform pulse dialing.

AUDIO MONITOR

An audio monitor output is provided which has a software programmable volume control. Its output is the received signal. The audio monitor output can directly drive a high impedance load, but an external power amplifier is necessary to drive a low-impedance

PIN DESCRIPTION

GENERAL

NAME	DIP	PLCC	TYPE	DESCRIPTION
VDD	40	44	I	+5V Supply ±10%, bypass with a .1 and a 22µF capacitor to GND
GND	20	22	I	System Ground
VREF	19	21	O	VREF is an internally generated reference voltage which is externally bypassed by a 0.1µF capacitor to the system ground.
ISET	9	11	I	The analog current is set by connecting this pin to VDD through a 2 MΩ resistor. ISET should be bypassed to GND. Alternatively, an internal bias can be selected by connecting ISET to GND, which will result in a larger worst-case supply current due to the tolerance of on-chip resistors. Bypass with .1µF capacitor if resistor is used.
XTL1 XTL2	25 24	27 26	I I	These pins are connections for the internal crystal oscillator requiring an 11.0592 MHz crystal (9216Hz x 1200). XTL2 can also be TTL driven from an external clock.
CLK	21	23	O	Output Clock. This pin is selectable under processor control to be either the crystal frequency (which might be used as a processor clock) or the output of the baud generator.
RESET	10	12	I	Reset. An active signal (high) on this pin will put the chip into an inactive state. The control register bits (except the Receiver Buffer, Transmitter Holding, and Divisor latches) will be reset. The output of the CLK pin will be set to the crystal frequency. An internal pull-down resistor permits power-on reset using a 0.1µF capacitor connected to the 5V supply.
STNDLN	15	17	I	Single-port mode select (active high). In a single-port system there is no local microprocessor and all the modem control is done through the 16C450 parallel bus interface. The local microprocessor interface is replaced with UART control signals which allow the device to function as a digital UART as well as modem.

PIN DESCRIPTION (continued)

UART INTERFACE

NAME	DIP	PLCC	TYPE	DESCRIPTION
UA0-UA2 UA3	37-39 12	41-43 14	I I	UART Address. These pins determine which of the UART registers is being selected during a read or write on the UART data bus. The contents of the DLAB bit in the UART's Line Control Register also control which register is referenced. In single-port mode, UA0-UA3 are latched when $\overline{ADS}$ goes high. In dual-port, only UA0-UA2 are used.
UD0-UD7	27-34	30-37	I/O	(3 state) UART Data. Data or control information to the UART registers is carried over these lines.
$\overline{DISTR}$	35	38	I	Data Input Strobe. A low on this pin requests a read of the internal UART registers. Data is output on the D0-D7 lines if $\overline{DISTR}$ and $\overline{CS2}$ are active.
$\overline{DOSTR}$	36	39	I	Data Output Strobe. A low on this pin requests a write of the internal UART registers. Data on the D0-D7 lines are latched on the rising edge of $\overline{DOSTR}$. Data is only written if both $\overline{DOSTR}$ and $\overline{CS2}$ are active.
$\overline{CS2}$	1	2	I	Chip Select. A low on this pin allows a read or write to the UART registers to occur. In single port mode, $\overline{CS2}$ is latched on $\overline{ADS}$.
INTRPT	5	7	O	(3 state) UART Interrupt. This signal indicates that an interrupt condition on the UART side has occurred. If the Enable 8250A interrupt bit in the interrupt Enable Register is 0 the interrupt is gated by the $\overline{DISTR}$ signal to provide compatibility with the 8250B. The output can be put in a high impedance state with the OUT2 register bit in the Modem Control Register. In single-port mode, INTRPT also becomes valid when a modem interrupt signal is generated by the modem section's Detect Register.
RXD	6	8	I/O	Function is determined by STNDLN pin and bit 7, Tone Control Register:

STNDLN	D7	
0	0	RXD outputs data received by modem.
1	0	RXD is electrically an input but signal is ignored.
X	1	RXD is a serial input to UART.

3

PIN DESCRIPTION (continued)

UART INTERFACE (continued)

<table>
<tr><td>TXD</td><td>7</td><td>9</td><td>O</td><td colspan="3">Function is determined by STNDLN pin and bit 7, Tone Control Register:</td></tr>
<tr><td></td><td></td><td></td><td></td><td>STNDLN</td><td>D7</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>0</td><td>0</td><td>TXD is a serial output of UART.</td></tr>
<tr><td></td><td></td><td></td><td></td><td>1</td><td>0</td><td>TXD is forced to a mark.</td></tr>
<tr><td></td><td></td><td></td><td></td><td>X</td><td>1</td><td>TXD is a serial output of UART.</td></tr>
</table>

ANALOG / LINE INTERFACE

NAME	DIP	PLCC	TYPE	DESCRIPTION
TXA1 TXA2	3 4	4 5	O O	(differential) Transmitted Analog. These pins provide the analog output signals to be transmitted to the phone line. The drivers will differentially drive the impedance of the line transformer and the line matching resistor. An external hybrid can also be built using TXA1 as a single ended transmit signal.
RXA	16	18	I	Received Analog. This pin inputs analog information that is being received by the two-to-four wire hybrid. This input can also be taken directly from an external hybrid.
SPKR	17	19	O	Speaker Output. This pin outputs the received signal through a programmable attenuator stage, which can be used for volume control and disabling the speaker.
$\overline{OH}$	18	20	O	Off-hook relay driver. This signal is an open drain output capable of sinking 20mA and is used for controlling a relay. The output is the complement of the $\overline{OH}$ register bit in CR3.

PIN DESCRIPTION (continued)

UART CONTROL INTERFACE (STNDLN = 1)

(See Figure 1: Single-port mode)

NAME	DIP	PLCC	TYPE	DESCRIPTION
$\overline{ADS}$	23	25	I	Address Strobe. $\overline{ADS}$ is used to latch address and chip select to simplify interfacing to a multiplexed Address/Data Bus. UA0-UA3 and $\overline{CS2}$ are latched when the $\overline{ADS}$ signal goes high.
UA3	12	14	I	UART Address Bit 3. UA3 is used in single-port mode to address the modem registers from the 16C450 interface. If UA3 is 0, the normal 16C450 registers are addressed by UA0-UA2 and if UA3 is 1, the modem registers are addressed. UA3 is latched when $\overline{ADS}$ goes high.
$\overline{CTS}$	14	16	I	Clear to Send. This pin is the complement of CTS bit in the Modem Status Register. The signal is used in modem handshake control to signify that communications have been established and that data can be transmitted.
$\overline{DSR}$	13	15	I	Data Set Ready.This pin is the complement of DSR bit in the Modem Status Register.The signal is used in modem handshake to signify that the modem is ready to establish communications.
$\overline{DCD}$	11	13	I	Data Carrier Detect. This pin is the complement of DCD bit in the Modem Status Register. The signal is used in modem control handshake to signify that the modem is receiving a carrier.
$\overline{DTR}$	22	24	O	Data Terminal Ready.The $\overline{DTR}$ output is programmed through a bit in the Modem Control Register. The signal is used in modem handshake to signify that the 16C450 is available to communicate.
$\overline{RTS}$	2	3	O	Request to Send. The $\overline{RTS}$ output is programmed through a bit in the Modem Control Register. The signal is used in modem handshake to signify that the 16C450 has data to transmit.
$\overline{RI}$	8	10	I	Ring Indicator. This Indicates that a telephone ringing signal is being received. This pin is the complement of the RI bit in the Modem Status Register.

PIN DESCRIPTION (continued)

MICROPROCESSOR INTERFACE (STNDLN = 0)

(See Figure 2: Dual-port mode)

NAME	DIP	PLCC	TYPE	DESCRIPTION
MA0-MA2	12-14	14-16	I	Modem Address Control. These lines carry register addresses for the modem registers and should be valid throughout any read or write operation.
DATA	22	24	I/O	Serial Control Data. Serial control data to be read/written is clocked in/out on the falling edge of the DCLK pin. The direction of data transfer is controlled by the state of the $\overline{RD}$ pin. If the $\overline{RD}$ pin is active (low) the DATA line is an output. Conversely, if the $\overline{RD}$ pin is inactive (high) the DATA line is an input.
$\overline{RD}$	23	25	I	Read. A low on this input informs the SSI 73K222U that control data or status information is being read by the processor from a modem register.
$\overline{WR}$	26	28	I	Write. A low on this input informs the SSI 73K222U that control data or status information is available for writing into a modem register. The procedure for writing is to shift in data LSB first on the DATA pin for eight consecutive cycles of DCLK and then to pulse $\overline{WR}$ low. Data is written on the rising edge of $\overline{WR}$.
DCLK	11	13	I	Data Clock. The falling edge of this clock is used to strobe control data for the modem registers in or out on the DATA pin. The normal procedure for a write is to shift in data LSB first on the DATA pin for eight consecutive cycles of DCLK and then to pulse $\overline{WR}$ low. Data is written on the rising edge of $\overline{WR}$. The falling edge of the $\overline{RD}$ signal must continue for eight cycles of DCLK in order to read all eight bits of the reference register. Read data is provided LSB first. Data will not be output unless the $\overline{RD}$ signal is active.
$\overline{INT}$	2	3	O	(with weak pull-up) Modem Interrupt. This output signal is used to inform the modem processor that a change in a modem detect flag has occurred. The processor must then read the Modem Detect Register to determine which detect triggered the interrupt. $\overline{INT}$ will stay active until the processor reads the Modem Detect Register or does a full reset.
mPRST*	8	10	O	Microprocessor Reset. This output signal is used to provide a hardware reset to the microprocessor. This signal is high if the RESET pin is high or the MCR bit D3 (OUT1) bit is set.
* NOTE: The mPRST pin is an upgraded function which was not included in the initial definition of the SSI 73K222U.				

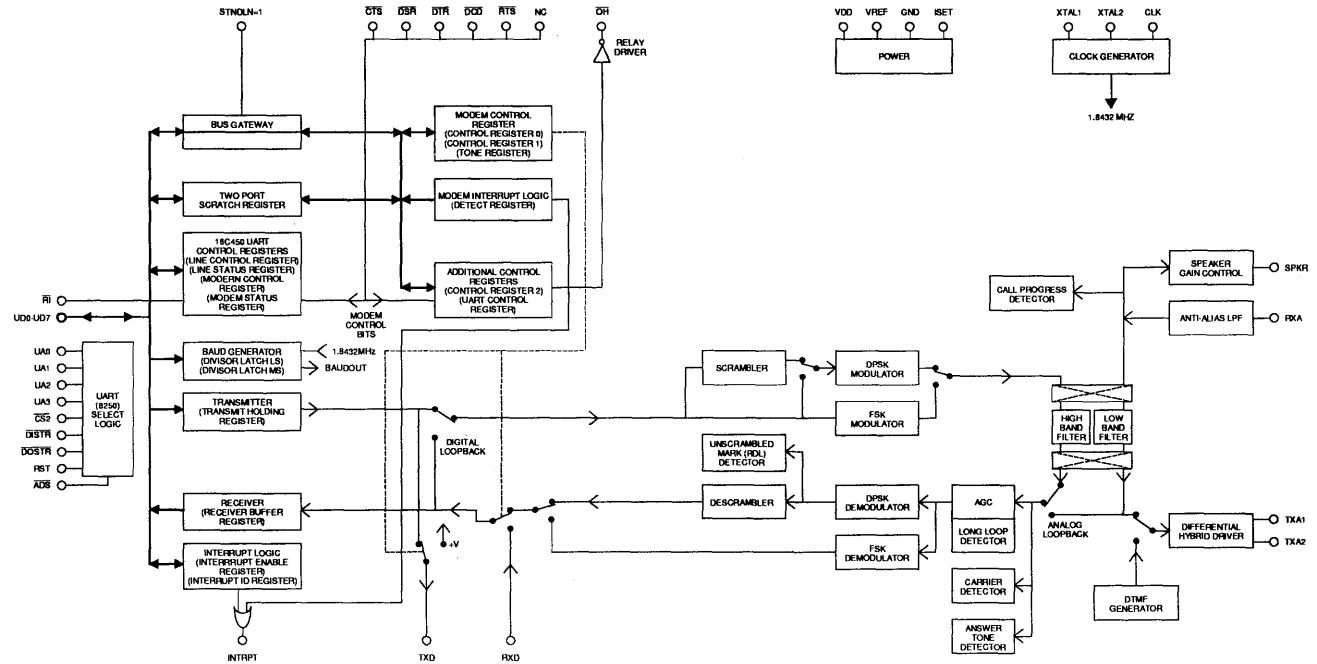


FIGURE 1:
Single-Port Mode

In the single-port mode, the SSI 73K222U is designed to be accessed only by the main CPU using the same parallel bus utilized for data transfer. This mode is enabled when the STNDLN pin is at a logic "1". In the single port mode, internal registers are accessed by the main CPU to configure both the UART section and the modem function, eliminating the need for a separate microcontroller. In this mode, multiplexed pins provide the $\overline{CTS}$, $\overline{DSR}$, $\overline{DTR}$, $\overline{DED}$ and $\overline{RI}$ signals normally associated with the UART function. A separate pin, $\overline{ADS}$, is used for bus control.

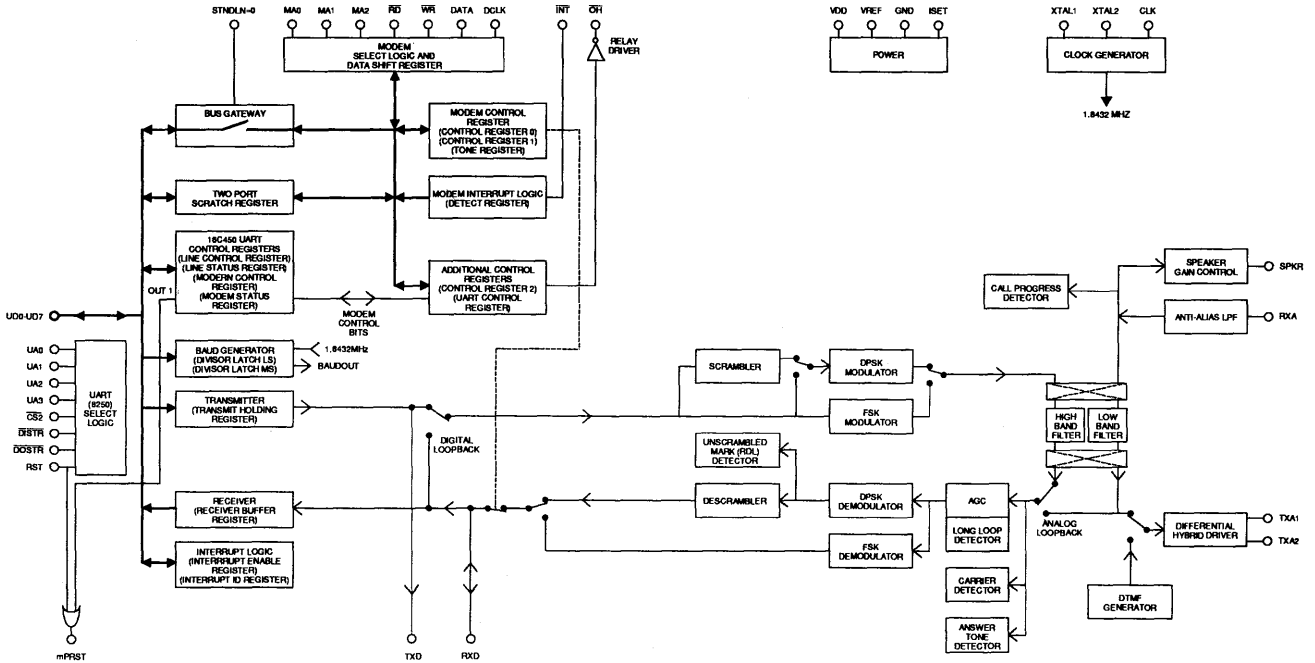


FIGURE 2:
Dual-Port Mode

The dual-port mode allows use of a dedicated microprocessor for control of the modem function, and is enabled when the STNDLN pin = "0". This mode is useful for conventional plug-in card modem designs where it is necessary to make the modem function transparent to the main CPU. In this mode, the SSI 73K222U's multiplexed pins form the serial command bus used to communicate with the external microprocessor. The $\overline{RI}$, $\overline{CTS}$, $\overline{DSR}$, $\overline{DTR}$, and $\overline{DCD}$ logic functions must then be implemented using ports from the dedicated microprocessor.

The serial control interface allows access to the control and status registers via a serial command port. In this mode the MA0, MA1, and MA2 lines provide register addresses for data passed through the DATA pin under control of the $\overline{RD}$ and $\overline{WR}$ lines. A read operation is initiated when the $\overline{RD}$ line is taken low. The next eight cycles of DCLK will then transfer out eight bits of the selected address location LSB first. A write takes place by shifting in eight bits of data LSB first for eight consecutive cycles of DCLK. $\overline{WR}$ is then pulsed low and data transfer into the selected register occurs on the rising edge of $\overline{WR}$.

UART CONTROL REGISTER OVERVIEW

REGISTER		UART ADDRESS UA3-UA0*	DATA BIT NUMBER D7	D6	D5	D4	D3	D2	D1	D0
RECEIVER BUFFER REGISTER (READ ONLY)	RBR	0000 DLAB = 0	BIT 7 (MSB)	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0 (LSB)
TRANSMIT HOLDING REGISTER (WRITE ONLY)	THR	0000 DLAB = 0	BIT 7 (MSB)	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0 (LSB)
INTERRUPT ENABLE REGISTER	IER	0001 DLAB = 0	0	0	0	ENABLE 8250A/ 16C450 INTERRUPT	ENABLE MODEM STATUS INTERRUPT	ENABLE REC. LINE STATUS INTERRUPT	ENABLE THR EMPTY INTERRUPT	ENABLE REC. DATA AVAILABLE INTERRUPT
INTERRUPT ID REGISTER (READ ONLY)	IIR	0010	0	0	0	0	0	INTERRUPT ID BIT 1	INTERRUPT ID BIT 0	"0" IF INTERRUPT PENDING
LINE CONTROL REGISTER	LCR	0011	DIVISOR LATCH ACCESS (DLAB)	SET BREAK	STICK PARITY	EVEN PARITY SELECT (EPS)	PARITY ENABLE (PEN)	NUMBER OF STOP BITS (STB)	WORD LENGTH SELECT 1 (WLS1)	WORD LENGTH SELECT 0 (WLS0)
MODEM CONTROL REGISTER	MCR	0100	0	0	0	LOOP	ENABLE INTERRUPT (OUT2 IN 16C450)	mPRST (OUT1 IN 16C450)	REQUEST TO SEND (RTS)	DATA TERMINAL READY (DTR)
LINE STATUS REGISTER	LSR	0101	0	TRANSMIT SHIFT REG. EMPTY (TSRE)	TRANSMIT HOLDING REGISTER EMPTY(THRE)	BREAK INTERRUPT (BI)	FRAMING ERROR (FE)	PARITY ERROR (PE)	OVERRUN ERROR (OE)	DATA READY (DR)
MODEM STATUS REGISTER (READ ONLY)	MSR	0110	DATA CARRIER DETECT (DCD)	RING INDICATOR (RI)	DATA SET READY (DSR)	CLEAR TO SEND (CTS)	DELTA DATA CARR. DETECT (DDCD)	TRAILING EDGE RING INDICATOR (TERI)	DELTA DATA SET READY (DDSR)	DELTA CLEAR TO SEND (DCTS)
SCRATCH REGISTER	SCR	0111	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
DIVISOR LATCH (LS)	DLL	0000 DLAB = 1	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
DIVISOR LATCH (MS)	DLM	0001 DLAB = 1	BIT 15	BIT 14	BIT 13	BIT 12	BIT 11	BIT 10	BIT 9	BIT 8

* In single-port mode (STNDLN pin = 1), all four address lines UA3-UA0 are used to address the UART Control Registers.

* In dual-port mode (STNDLN pin = 0), only three address lines UA2-UA0 are used to address the UART Control Registers; the UA3 pin becomes the MA2 pin in this mode.

MODEM CONTROL REGISTER OVERVIEW

REGISTER		ADDRESS STNDLN 0 MA2-MA0	ADDRESS STNDLN 1 UA3-UA0	DATA BIT NUMBER D7	D6	D5	D4	D3	D2	D1	D0
CONTROL REGISTER 0	CR0	000	1000	MODULATION OPTION	0	MODULATION MODE	POWER ON	CHARACTER SIZE 1 (READ ONLY)	CHARACTER SIZE 0 (READ ONLY)	TRANSMIT ENABLE	ORIGINATE/ ANSWER
CONTROL REGISTER 1	CR1	001	1001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTERRUPT	BYPASS SCRAMBLER	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0
DETECT REGISTER	DR	010	1010	DEVICE SIGNATURE 1	DEVICE SIGNATURE 0	RECEIVE DATA	UNSCR. MARK DETECT	CARRIER DETECT	ANSWER TONE DETECT	CALL PROGRESS DETECT	LONG LOOP DETECT
TONE CONTROL REGISTER	TONE	011	1011	RXD/TXD CONTROL	TRANSMIT GUARD TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2	DTMF 1	DTMF 0 GUARD/ANS. TONE
CONTROL REGISTER 2	CR2	100	1100	RESERVED FOR FUTURE USE							
CONTROL REGISTER 3	CR3	101	1101	SPEAKER VOLUME 1	SPEAKER VOLUME 0	OFF-HOOK	X	X	X	X	X
SCRATCH REGISTER	SCR	110	1110	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
UART CONTROL REGISTER	UCR	111	1111	TXCLK (READ ONLY)	X	REQUEST TO SEND (RTS) (READ ONLY)	DATA TERM. READY (DTR) (READ ONLY)	RING INDICATOR (RI)	DATA CARRIER DETECT (DCD)	DATA SET READY (DSR)	CLEAR TO SEND (CTS)

UART REGISTER BIT DESCRIPTIONS

RECEIVER BUFFER REGISTER (RBR) (READ ONLY)

STNDLN:	**0**	**1**
ADDRESS:	**UA2 - UA0 = 000, DLAB = 0**	**UA3 - UA0 = 0000, DLAB = 0**

This read only register contains the parallel received data with start, stop, and parity bits (if any) removed. The high order bits for less than 8 data bits/character will be set to 0.

TRANSMIT HOLDING REGISTER (THR) (WRITE ONLY)

STNDLN:	**0**	**1**
ADDRESS:	**UA2 - UA0 = 000, DLAB = 0**	**UA3 - UA0 = 0000, DLAB = 0**

This write only register contains the parallel data to be transmitted. The data is sent LSB first with start, stop, and parity bits (if any) added to the serial bit stream as the data is transferred.

INTERRUPT ENABLE REGISTER (IER)

STNDLN:	**0**	**1**
ADDRESS:	**UA2 - UA0 = 001, DLAB = 0**	**UA3 - UA0 = 0001, DLAB = 0**

This 8-bit register enables the four types of interrupts of the UART to separately activate the chip Interrupt (INTRPT) output signal. It is possible to totally disable the interrupt system by resetting bits 0 through 3 of the Interrupt Enable Register. Similarly, by setting the appropriate bits of this register to a logic 1, selected interrupts can be enabled. Disabling the interrupt system inhibits the Interrupt Identification Register and the active (high) INTRPT output from the chip. All other system functions operate in their normal manner, including the setting of the Line Status and Modem Status Registers.

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	Received Data	1	This bit enables the Received Data Available Interrupt when set to logic 1.
D1	Transmitter Holding Register Empty	1	This bit enables the Transmitter Holding Register Empty Interrupt, when set to logic 1.
D2	Receiver Line Status Interrupt	1	This bit enables the Receiver Line Status Interrupt, when set to logic 1.
D3	Modem Status	1	This bit enables the Modem Status Register Interrupt when set to interrupt logic 1.
D4	8250A/16450	1/0	Set for compatibility with 8250A/16C450 UARTS. Reset this bit to disable the gating of the INTRPT interrupt line with the $\overline{\text{DISTR}}$ signal which is needed for 8250B compatibility.
D5 - D7	Not Used	0	These three bits are always logic 0.

INTERRUPT ID REGISTER (IIR) (READ ONLY) UART SECTION

STNDLN: 0 1

ADDRESS: UA2 - UA0 = 010 UA3 - UA0 = 0010

The IIR register gives prioritized information as to the status of interrupt conditions. When accessed, the IIR freezes the highest priority interrupt pending and no other interrupts are acknowledged until the particular interrupt is serviced by the CPU.

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	Interrupt Pending	0	This bit can be used in either a hardwired priortized or polled environment to indicate whether an interrupt is pending. When bit 0 is a logic 0, an interrupt is pending and the IIR contents may be used as a pointer to the appropriate interrupt service routine.
		1	When bit 0 is a logic 1, no interrupt is pending.
D1, D2	Interrupt ID bits 0, 1	Table below	These two bits of the IIR are used to identify the highest priority interrupt pending as indicated in the following table.
D3 - D7	Not Used	0	These five bits of the IIR are always logic 0.

INTERRUPT PRIORITY TABLE

D2	D1	D0	PRIORITY	TYPE	SOURCE	RESET
0	0	1	-	None	None	-
1	1	0	Highest	Receiver Line Status	Overrun Error, Parity Error, Framing Error or Break Interrupt	Reading the Line Status Register
1	0	0	Second	Receive Data Available	Receive Data Available	Reading the Rcvr. Buffer Register
0	1	0	Third	Transmit Holding Register Empty	Transmit Holding Register Empty	Reading IIR Register (if source of interrupt) or Writing to Transmit Holding Register
0	0	0	Fourth	Modem Status	Clear to Send or Data Set Ready or Ring Indicator or Data Carrier Det.	Reading the Modem Status Register

LINE CONTROL REGISTER (LCR)
STNDLN: 0 1
ADDRESS: UA2 - UA0 = 011 UA3 - UA0 = 0011

UART SECTION

The user specifies the format of the asynchronous data communications exchange via the Line Control Register. In addition to controlling the format, the user may retrieve the contents of the Line Control Register for inspection. This feature simplifies system programming and eliminates the need for separate storage in system memory of the line characteristics.

BIT NO.	NAME	CONDITION		DESCRIPTION
D0	Word Length Select 0			Bits D0 and D1 select the number of data bits per character as shown:
D1	Word Length Select 1	D1	D0	Word Length
		0	0	5 bits
		0	1	6 bits
		1	0	7 bits
		1	1	8 bits
D2	Number of Stop Bits	0 or 1		This bit specifies the number of stop bits in each transmitted character. If bit 2 is a logic 0, one stop bit is generated in the transmitted data. If bit 2 is a logic 1 when a 5-bit word length is selected via bits 0 and 1, one-and-a-half stop bits are generated. If bit 2 is a logic 1 when either a 6, 7, or 8-bit word length is selected, two stop bits are generated. The receiver checks the first stop bit only, regardless of the number of stop bits selected.
D3	Parity Enable	1		This bit is the Parity Enable bit. When bit 3 is a logic 1, a parity bit is generated (transmit data) or checked (receive data) between the last data word bit and stop bit of the serial data. (The parity bit is used to produce an even or odd number of 1's when the data word bits and the parity bit are summed).
D4	Even Parity Select	1 or 0		This bit is the Even Parity Select bit. When bit 3 is a logic 1 and bit 4 is a logic 0, an odd number of logic 1's are transmitted or checked in the data word bits and parity bit. When bit 3 is a logic 1 and bit 4 is a logic 1, an even number of logic 1's are transmitted or checked.

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LINE CONTROL REGISTER (LCR) (Continued)

UART SECTION

BIT NO.	NAME	CONDITION		DESCRIPTION
D5	Stick Parity	1 or 0		This bit is the Stick Parity bit. When bit 3 is a logic 1 and bit 5 is a logic 1, the parity bit is transmitted and checked by the receiver as a logic 0 if bit 4 is a logic 1 or as a logic 1 if bit 4 is a logic 0.
		D5	D4	Parity
		0	0	ODD Parity
		0	1	EVEN Parity
		1	0	MARK Parity
		1	1	SPACE Parity
D6	Set Break	1		Output of modem is set to a spacing state. When the modem is transmitting DPSK data if the Set Break bit is held for one full character (start, data, parity, stop) the break will be extended to 2 N + 3 space bits (where N = # data bits + parity bit + 1 start + 1 stop). Any data bits generated during this time will be ignored. See note below.
D7	Divisor Latch Access Bit (DLAB)	1		This bit is the Divisor Latch Access Bit (DLAB). It must be set high (logic 1) to access the Divisor Latches of the baud generator during a Read or Write operation. It must be set low (logic 0) to access the Receiver Buffer, the Transmitter Holding Register, or the Interrupt Enable Register.

NOTE: This feature enables the CPU to alert a terminal in a computer communications system. If the following sequence is followed, no erroneous or extraneous characters will be transmitted because of the break.

1. Load an all 0's pad character in response to THRE.
2. Set break in response to the next THRE.
3. Wait for the Transmitter to be idle. (TSRE = 1), and clear break when normal transmission has to be restored.

During the break, the Transmitter can be used as a character timer to accurately establish the break duration.

MODEM CONTROL REGISTER (MCR)
STNDLN: 0 1
ADDRESS: UA2 - UA0 = 100 UA3 - UA0 = 0100

UART SECTION

The MCR register controls the interface with the modem. Bits D1 and D0 are also available as read only bits in the UART Control Register in the Modem Registers. In single-port mode, bits D1 and D0 are available inverted at the $\overline{RTS}$ and $\overline{DTR}$ pins.

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	DTR	1	This bit controls the Data Terminal Ready ($\overline{DTR}$) output. When bit 0 is set to a logic 1, the $\overline{DTR}$ output is forced to a logic 0. When bit 0 is reset to a logic 0, the $\overline{DTR}$ output is forced to a logic 1.
D1	RTS	1	This bit controls the Request to Send ($\overline{RTS}$) output. When bit 1 is set to a logic 1, the $\overline{RTS}$ output is forced to a logic 0. When bit 1 is reset to a logic 0, the $\overline{RTS}$ output is forced to a logic 1.
D2	mPRST* (OUT1 in 16C450)	1	In single-port mode inactive unless loop = 1, then functions as below (D4). In dual-port mode the mPRST pin is the logical OR of this bit and the RESET pin.
D3	Enable Interrupt (OUT2 in 16C450)	0	Sets INTRPT pin to high impedance if STNDLN = 1.
		1	INTRPT output enabled.
D4	LOOP	1	This bit provides a local loopback feature for diagnostic testing of the UART portion of the SSI 73K222U. When bit D4 is set to logic 1, the following occurs: 1. TXD is forced to mark, RXD is ignored. 2. The output of the Transmitter is looped to the Receiver. 3. The four modem control inputs to the UART ($\overline{CTS}$, $\overline{DSR}$, $\overline{DCD}$, and $\overline{RI}$) are ignored and the UART signals $\overline{RTS}$, $\overline{DTR}$, Enable Interrupt, and mPRST are forced inactive. 4. The UART signals RTS, DTR, Enable Interrupt, and mPRST are internally connected to the four control signals CTS, DSR, DCD and RI respectively. Note that the Modem Status Register Interrupts are now controlled by the lower four bits of the Modem Control Register. The interrupts are still controlled by the Interrupt Enable Register.
D5 - D7		0	These bits are permanently set to logic 0.

* Note: The mPRST bit has an upgraded function which was not included in the initial definition of the SSI 73K222U.

LINE STATUS REGISTER (LSR) UART SECTION

STNDLN:	**0**	**1**
ADDRESS:	**UA2 - UA0 = 101**	**UA3 - UA0 = 0101**

This register provides status information to the CPU concerning the data transfer.

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	DR	1	The Data Ready (DR) bit is set to a 1 whenever a complete incoming character has been received and transferred into the Receiver Buffer Register. Data Ready is reset to 0 by reading the data in the Receiver Buffer Register or by writing a 0 into it from the processor.
D1	OE	1	The Overrun Error (OE) bit indicates that the data in the Receiver Buffer Register was not read by the CPU before the next character was transferred into the Receiver Buffer Register, thereby destroying the previous character. The OE indicator is reset whenever the CPU reads the contents of the Line Status Register.
D2	PE	1	The Parity Error (PE) bit indicates that the received character did not have the correct parity. The bit is reset to 0 whenever the CPU reads the Line Status Register.
D3	FE	1	The Framing Error (FE) bit indicates that the received character did not have a valid stop bit. The FE indicator is reset whenever the CPU reads the contents of the Line Status Register. A framing error will not occur in DPSK receive from the modem due to the fact that missing stop bits are reinserted.
D4	BI	1	The Break Interrupt (BI) bit indicates that a break has been received. A break occurs whenever the received data is held to 0 for a full data word (start + data + stop) or for two full data words when receiving in DPSK mode from the modem. The BI bit is reset to 0 whenever the CPU reads the Line Status Register.
D5	THRE	1	The Transmit Holding Register Empty (THRE) indicates that the Transmitter is ready to accept a new character for transmission. The THRE bit is reset when the CPU loads a character into the Transmit Holding Register.
D6	TSRE	1	The Transmit Shift Empty (TSRE) indicates that both the Transmit Holding Register and the Transmit Shift Registers are empty.
D7	-	0	Always zero.

MODEM STATUS REGISTER (MSR) (READ ONLY) **UART SECTION**

STNDLN: 0 1

ADDRESS: UA2 - UA0 = 110 UA3 - UA0 = 0110

This register provides the current state of the control signals from the modem. In addition, four bits provide change information. The CTS, DSR, DCD, and RI signals come from the UART Control Register if STNDLN = 0 and from the $\overline{CTS}$, $\overline{DSR}$, $\overline{DCD}$ and $\overline{RI}$ pins (inverted) if STNDLN = 1. This register is READ ONLY. The delta bits indicate whether the inputs have changed since the last time the Modem Status Register has been read. In Loop Mode CTS, DSR, RI and DCD are taken from RTS, DTR, mPRST, and Enable Interrupt in the Modem Control Register respectively.

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	DCTS	1	This bit is the Delta Clear to Send (DCTS) indicator. Bit 0 indicates that the $\overline{CTS}$ input to the chip has changed state since the last time it was read by the CPU.
D1	DDSR	1	This bit is the Delta Data Set Ready (DDSR) indicator. Bit 1 indicates that the $\overline{DSR}$ input to the chip has changed state since the last time it was read by the CPU.
D2	TERI	1	This bit is the Trailing Edge of the Ring Indicator (TERI) detector. Bit 2 indicates that the $\overline{RI}$ input to the chip has changed state.
D3	DDCD	1	This bit is the Delta Data Carrier Detect (DDCD) indicator. Bit 3 indicates that the $\overline{DCD}$ input to the chip has changed state.
D4	CTS	1	This bit is the complement of the Clear To Send ($\overline{CTS}$) input. If STNDLN = 0, this reflects the status of the UART Control Register bit. If bit 4 (loop) of the MCR is set to a 1, this bit is equivalent to RTS in the MCR.
D5	DSR	1	This bit is the complement of the Data Set Ready ($\overline{DSR}$) input. If STNDLN = 0, this reflects the status of the UART Control Register bit. If bit 4 of the MCR is set to a 1, this bit is the equivalent of DTR in the MCR.
D6	RI	1	This bit is the complement of the Ring Indicator ($\overline{RI}$) input. If STNDLN = 0, this reflects the status of the UART Control Register bit. If bit 4 of the MCR is set to a 1, this bit is equivalent to mPRST in the MCR.
D7	DCD	1	This bit is the complement of the Data Carrier Detect ($\overline{DCD}$) If STNDLN = 0, this reflects the status of the UART Control Register bit. If bit 4 of the MCR is set to a 1, this bit is equivalent to Enable Interrupt in the MCR.

SCRATCH REGISTER (SCR)

STNDLN:	**0**	**1**
ADDRESS:	**UA2 - UA0 = 111**	**UA3 - UA0 = 0111**

The Scratch Register is a dual port register which can be simultaneously accessed through both the UART bus and the modem bus.This provides the possibility for the modem controller to communicate directly with the central CPU. Note that if both processors write the Scratch Register, the data stored will be from whichever processor last wrote the register.

DIVISOR LATCH (Least significant byte) (DLL)

STNDLN:	**0**	**1**
ADDRESS:	**UA2 - UA0 = 000, DLAB = 1**	**UA3 - UA0 = 0000, DLAB = 1**

DIVISOR LATCH (Most significant byte) (DLM)

STNDLN:	**0**	**1**
ADDRESS:	**UA2 - UA0 = 001, DLAB = 1**	**UA3 - UA0 = 0001, DLAB = 1**

DIVISOR LATCH VALUE VS. DATA RATE

The Divisor Latch is two 8-bit write only registers which control the rate of the programmable baud generator. The programmable baud generator generates an output clock by dividing an internal 1.8432 MHz clock by the value stored in the divisor latch. This output clock has a value of 16X the data rate at which the modem will operate. This output clock is available at pin 21 under the control of bit 3 (D3) of the Modem Control Register 1. Upon loading either of the Divisor Latches the 16-bit device counter is immediately loaded, preventing long counts on initial load. The following table shows divisor values for common data rates.

DESIRED DATA RATE	DIVISOR USED FOR 16 x DATA RATE CLOCK	% ERROR GENERATED	DESIRED DATA RATE	DIVISOR USED FOR 16 x DATA RATE CLOCK	% ERROR GENERATED
50 [1]	2304		4800	24	
75 [1]	1536		7200	16	
110 [1]	1047		9600	12	
134.5 [1]	857	0.058	19200	6	
159 [1]	768		38400	3	
300 [1]	384		56000	2	2.86
600 [2]	192				
1200 [3]	96				
1800	64				
2000	58	0.69			
2400	48				
3600	32				

1. Data Rate valid for FSK transmission.
2. Data Rate valid for halfspeed DPSK transmission.
3. Data Rate valid for normal 1200 BIT/S DPSK transmission.

MODEM REGISTER BIT DESCRIPTIONS

MODEM SECTION

CONTROL REGISTER (CR0)
STNDLN: 0 1
ADDRESS: MA2 - MA0 = 000 UA3 - UA0 = 1000

BIT NO.	NAME	CONDITION		DESCRIPTION
D0	Answer/Originate	0		Selects Answer Mode (transmit in high band, receive in low band).
		1		Selects Originate Mode (transmit in low band, receive in high band).
D1	Transmit Enable	0		Disables transmit output at TXA.
		1		Enables transmit output at TXA. NOTE: Answer tone and DTMF TX control require Transmit Enable. If Transmit Enable is on, call progress and answer tone detector interrupts are masked.
D2, D3	Character Size 0, 1			These bits are read only. These bits represent the character size. The character size is determined by the UART Line Control Register and includes data, parity (if used), one start bit, and one stop bit.
		D3	D2	Character length
		0	0	8-bit character
		0	1	9-bit character
		1	0	10-bit character
		1	1	11-bit character
D4	Power ON			This bit controls the power down mode of the SSI 73K222U, the analog, and most digital portions of the chip. The digital interface is active during power down.
		0		Power down mode.
		1		Normal operation.
D5	Modulation Mode	0		DPSK
		1		FSK
D6	Reserved	0		Must be written as zero.
D7	Modulation Option	0		DPSK: 1200 bit/s
		1		600 bit/s
		0		FSK: 103 mode
		1		V.21 mode

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CONTROL REGISTER (CR1) MODEM SECTION
STNDLN: 0 1
ADDRESS: MA2 - MA0 = 001 UA3 - UA0 = 1001

BIT NO.	NAME	CONDITION		DESCRIPTION
D0, D1	Test Mode	D1	D0	
		0	0	Selects normal operating mode.
		0	1	Analog Loopback Mode. Loops the transmitted analog signal back to the receiver, and causes the receiver to use the same center frequency as the Transmitter. To squelch the TXA pin, transmit enable bit must be forced low.
		1	0	Selects remote digital loopback. Received data is looped back to transmit data internally, and RXD is forced to a mark. Data in TXD is ignored.
		1	1	Selects half-duplex. Internally performs a logical AND of TXD and RXD to send to the UART receiver. Both transmit and receive characters will occur at the Receiver Buffer Register.
D2	Reset	0		Selects normal operation.
		1		Resets modem to power down state. All Control Register bits (CR0, CR1, TONE) are reset to zero. The output of the clock pin will be set to the crystal frequency.
D3	CLK Control (Clock Control)	0		CLK pin output is selected to be an 11.0592 MHz crystal echo output.
		1		CLK pin output is selected to be 16 x the Data Rate set by the UART divisor latch.
D4	Bypass Scrambler	0		Selects normal operation. DPSK data is passed through scrambler.
		1		Selects Scrambler Bypass. DPSK data is routed around scrambler in the transmit path.

CONTROL REGISTER (CR1) (Continued)

BIT NO.	NAME	CONDITION		DESCRIPTION
D5	Enable Detect Interrupt	0		Disables interrupts generated by Detect Register bits D1 - D4 at INT pin in dual-port mode, or at INTRPT pin in single-port mode. All interrupts normally disabled in power down modes.
		1		Enables interrupts generated by Detect Register bits D1 - D4 at $\overline{INT}$ pin in dual-port mode, or at INTRPT pin in single-port mode. An interrupt will be generated with a change in status of DR bits D1 - D4. The answer tone and call progress detect interrupts are masked when the TX enable bit is set. Carrier detect is masked when TX DTMF is activated. All interrupts will be disabled if the device is in power down mode. The interrupt is reset when the DR register is read.
D6, D7	Transmit Pattern	D7	D6	
		0	0	Selects normal data transmission as controlled by the state of the TXD pin.
		0	1	Selects an alternating mark/space transmit pattern for modem testing.
		1	0	Selects a constant mark transmit pattern.
		1	1	Selects a constant space transmit pattern.

DETECT REGISTER (DR) MODEM SECTION
STNDLN: 0 1
ADDRESS: MA2 - MA0 = 010 UA3 - UA0 = 1010

BIT NO.	NAME	CONDITION		DESCRIPTION
D0	Long Loop	0		Indicates normal received signal.
		1		Indicates low received signal level (< -38 dBm).
D1	Call Progress Detect	0		No call progress tone detected.
		1		Indicates presence of call progress tones. The call progress detection circuitry is activated by energy in the normal 350 to 620 Hz call progress bandwidth.
D2	Answer Tone Received	0		No answer tone detected.
		1		Indicates detection of 2225 Hz answer tone in Bell mode or 2100 Hz in CCITT mode. The device must be in Originate Mode for detection of answer tone for normal operation. For CCITT answer tone detection, bit D0 of the Tone Register must be set.
D3	Carrier Detect	0		No carrier detected in the receive channel.
		1		Carrier has been detected in the receive channel.
D4	Unscrambled Marks	0		No unscrambled mark detected.
		1		Indicates detection of unscrambled marks in the received data. A valid indication requires that unscrambled marks be received for > 165.5 ± 13.5 ms.
D5	Receive Data			Continuously outputs the received data stream. This data is the same as that output on the RXD pin, but it is not disabled when RXD is tri-stated.
D6, D7	Device Signature 0, 1	D7	D6	Product Identified
		0	0	SSI 73K212U (special order only)
		0	1	SSI 73K221U (special order only)
		1	0	SSI 73K222U

TONE CONTROL REGISTER (TONE)
STNDLN: 0 1
ADDRESS: MA2 - MA0 = 011 UA3 - UA0 = 1011

The Tone Control Register contains information on the tones that are transmitted. Tones are transmitted only if the Transmit Enable bit is set. The priority of the transmit tones are: 1) DTMF, 2) Answer, 3) FSK, 4) Guard.

BIT NO.	NAME	CONDITION				DESCRIPTION
D0	DTMF 0 / Answer/ Guard Tone	D6	D5	D4	D0	D0 interacts with bits D6, D5, and D4 as shown:
		X	X	1	X	Transmit DTMF tones.
		X	1	0	0	Select 2225 Hz answer tone (Bell).
		X	1	0	1	Select 2100 Hz answer tone (CCITT).
		1	0	0	0	Select 1800 Hz guard tone.
		1	0	0	1	Select 550 Hz guard tone.
D0, D1, D2, D3	DTMF	Table below				Programs 1 of 16 DTMF tone pairs that will be transmitted when TX DTMF and TX enable bit (CR0, bit D1) is set. Tone encoding is shown below.

KEYBOARD EQUIVALENT	DTMF CODE D3	D2	D1	D0	TONES LOW	HIGH
1	0	0	0	1	697	1209
2	0	0	1	0	697	1336
3	0	0	1	1	697	1477
4	0	1	0	0	770	1209
5	0	1	0	1	770	1336
6	0	1	1	0	770	1477
7	0	1	1	1	852	1209
8	1	0	0	0	852	1336
9	1	0	0	1	852	1477
0	1	0	1	0	941	1336
*	1	0	1	1	941	1209
#	1	1	0	0	941	1477
A	1	1	0	1	697	1633
B	1	1	1	0	770	1633
C	1	1	1	1	852	1633
D	0	0	0	0	941	1633

TONE CONTROL REGISTER (TONE) (Continued)

D4	TX DTMF (Transmit DTMF)	0		Disable DTMF.
		1		Activates DTMF. The selected DTMF tones are transmitted continuously when this bit is high. TX DTMF overrides all other transmit functions.
D5	TX ANS (Transmit Answer Tone)	D5	D0	D5 interacts with bit D0 as shown.
		0	X	Disables answer tone generator.
		1	0	Enables answer tone generator. A 2225 Hz answer tone will be transmitted continuously when the transmit enable bit is set. The device must be in answer mode.
		1	1	Enables a 2100Hz answer tone generator, with operation same as above.
D6	TX Guard (Transmit Guard Tone)	0		Disables guard tone generator.
		1		Enables guard tone generator. (See D0 for selection of guard tones).
D7	RXD/TXD Control	STNDLN	D7	Function is dependant on status of STNDLN pin.
		0	0	RXD is output data received by modem, TXD is serial output of UART.
		1	0	RXD is electrically an input, but the signal is ignored, TXD is forced to a mark.
		X	1	RXD is serial input to UART, TXD is serial output of UART.

CONTROL REGISTER (CR3)
STNDLN: 0 1
ADDRESS: MA2 - MA0 = 101 UA3 - UA0 = 1101

BIT NO.	NAME	CONDITION		DESCRIPTION
D0 - D4	Not Used			Not presently used.
D5	Off Hook	0		Relay driver open.
		1		Open drain driver pulling low.
D6, D7	Speaker Volume 0, 1	D7	D6	Speaker volume control status.
		0	0	Speaker off
		0	1	-24 dB
		1	0	-12 dB
		1	1	0 dB

SCRATCH REGISTER (SCR)
STNDLN: 0 1
ADDRESS: MA2 - MA0 = 110 UA3 - UA0 = 1110

The Scratch Register is a dual-port register which can be accessed either through the UART bus or the modem bus. It can be used for a communication path outside the data stream.

UART CONTROL REGISTER (UCR)
STNDLN: 0 1
ADDRESS: MA2 - MA0 = 111 UA3 - UA0 = 1111

The UART Control Register contains the handshaking signals necessary for the microprocessor to communicate with the central CPU through the UART.

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	CTS	1	In dual-port mode, CTS, DSR, DCD and RI are writeable locations which can be read through the 16C450 port in the Modem Status Register.
D1	DSR	1	
D2	DCD	1	In the single-port mode, D0 - D3 are ignored and the information for the Modem Status Register comes directly from the external pins.
D3	RI	1	
D4	DTR	1	
D5	RTS	1	DTR and RTS are read only versions of the same register bits in the Modem Contol Register.
D6	Not Used		
D7	TXCLK	Clock	TXCLK is the clock that the UART puts out with TXD. The falling edge of TXCLK is coincident with the transitions of data on TXD. TXCLK can also be used for the microprocessor to send synchronous data independent of the UART by forcing data patterns using CR1 bits 6 and 7 before the rising edge of TXCLK.
NOTE: Control Register 2 (CR2) is reserved for future products and is disabled.			

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

TA = -40°C to 85°C, VDD = 5V ± 10%, unless otherwise noted.

PARAMETER	RATING	UNIT
VDD Supply Voltage	7	V
Storage Temperature	-65 to 150	°C
Soldering Temperature (10 sec.)	260	°C
Applied Voltage	-0.3 to VDD +0.3	V
NOTE: All inputs and outputs are protected from static charge using built-in, industry standard protection devices and all outputs are short-circuit protected.		

RECOMMENDED OPERATING CONDITIONS

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNIT
VDD, Supply Voltage		4.5	5	5.5	V
TA, Operating Free-Air Temperature		-40		85	°C
External Component (Refer to application drawing for placement.)					
VREF Bypass Capacitor [2]	(VREF to GND)	0.1			µF
Bias Setting Resistor [1]	(Placed between VDD and ISET pins)	1.8	2	2.2	MΩ
ISET Bypass Capacitor [2]	ISET pin to GND	0.1			µF
VDD Bypass Capacitor [2]	(VDD to GND)	0.1			µF
XTL1 Load Capacitor	From pin to GND			40	pF
XTL2 Load Capacitor	From pin to GND			20	pF
Input Clock Variation	(11.0592 MHz)	-0.01		+0.01	%
Hybrid Loading					
R1	See Figure 3		600		Ω
R2			600		Ω
C	TXA Hybrid Loading		0.033		µF

1. Optional for minimum worst case current consumption.
2. Minimum for optimized system layout; may require higher values for noisy environments.

DC ELECTRICAL CHARACTERISTICS

TA = -40°C to +85 °C, VDD = 5V ± 10%, unless otherwise noted.

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNIT
IDD, Supply Current					
IDDA, Active	ISET Resistor = 2MΩ		8	12	mA
IDDA, Active	ISET = GND		8	15	mA
IDD1, Power-Down	CLK = 11.0592MHz		3	4	mA
IDD2, Power-Down	CLK = 19.200KHz		2	3	mA
Digital Inputs					
Input High Current IIH	VI = VDD			100	µA
Input Low Current IIL	VI = 0	-200			µA
Input Low Voltage VIL				0.8	V
Input High Voltage VIH	Except RESET & XTL1	2.0			V
Input High Voltage VIH	RESET & XTL1	3.0			V
Pull Down Current RESET PIN		5		30	µA
Input Capacitance				10	pF
Digital Outputs					
Output High Voltage VOH	IOUT = - 1 mA	2.4		VDD	V
VOL UD0-UD7 and INTRPT	IOUT = 3.2 mA			0.4	V
VOL other outputs	IOUT = 1.6 mA			0.4	V
CLK Output VOL	IOUT = 3.2 mA			0.6	V
OH Output VOL	IOUT = 20 mA			1.0	V
OH Output VOL	IOUT = 10 mA			0.5	V
Offstate Current INTRPT pin	VO = 0V	-20		20	µA
Capacitance					
Inputs	Input Capacitance			10	pF
CLK	Maximum capacitive load to pin			15	pF
Analog Pins					
RXA Input Resistance			200		kΩ
RXA Input Capacitance				25	pF

DYNAMIC CHARACTERISTICS AND TIMING
TA = -40°C to +85°C, VDD = 5V ± 10%, unless otherwise noted.

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNIT
DPSK Modulator					
Carrier Suppression	Measured at TXA	55			dB
Output Amplitude	ANS TONE 2225 or 2100 Hz	-11	-10.0	-9	dBm0
	DPSK TX Scrambled Marks	-11	-10.0	-9	dBm0
	FSK Dotting Pattern	-11	-10.0	-9	dBm0
FSK Tone Error	Bell 103 or V.21			±5	Hz
DTMF Generator					
Freq. Accuracy		-.25		.25	%
Output Amplitude	Low Band, not in V.21 mode	-10	-9	-8	dBm0
Output Amplitude	High Band, not in V.21 mode	-8	-7	-6	dBm0
Long Loop Detect	DPSK or FSK	-40		-32	dBm0
Demodulator Dynamic Range	DPSK or FSK		45		dB
Call Progress Detector					
Detect Level	2-Tones in 350-600 Hz Band	-39		0	dBm0
Reject Level	2-Tones in 350-600 Hz Band			-46	dBm0
Delay Time	-70dBm0 to -30 dBm0 Step	27		80	ms
Hold Time	-30dBm0 to -70 dBm0 Step	27		80	ms
Hysteresis		2			dB
Carrier Detect	DPSK or FSK Receive				
Threshold	Data	-49		-42	dBm0
Delay Time	-70 dBm0 to -30 dBm0 Step	15		45	ms
Hysteresis		2	3.0		dB
Hold Time	-30 dBm0 to -70 dBm0 Step	10		24	ms
Answer Tone Detector					
Detect Level Threshold	In FSK mode	-49.5		-42	dBm0
Delay Time	-70 dBm0 to -30 dBm0 STEP	20		45	ms
Hold Time	-30 dBm0 to -70 dBm0 STEP	10		30	ms
Detect Frequency Range		-2.5		+2.5	%

1. All units in dBm0 are measured at the line input to the transformer. The interface circuit inserts an 8 dB loss in the transmit path (TXA1 - TXA2 to line), and a 3dB loss in the receive path (line to RXA).

DYNAMIC CHARACTERISTICS AND TIMING (Continued)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNIT
Speaker Output					
Gain Error		-1		+1	dB
Output Swing SPKR	10K||50 pF LOAD 5% THD	2.75			VP
Carrier VCO					
Capture Range	Originate or Answer	-10		10	Hz
Capture Time	-10 Hz to +10 Hz Carrier Frequency change assumed		40	100	ms
Recovered Clock					
Capture Range	% of Center Frequency	-625		+625	ppm
Data Delay Time	Analog data in at RXA pin to receive data valid at RXD pin.		30	50	ms
Guard Tone Generator					
Tone Accuracy	550 or 1800 Hz	-20		+20	Hz
Tone Level	550 HZ	-4.0	-3.0	-2.0	dB
(Below DPSK Output)	1800 HZ	-7.0	-6.0	-5.0	dB
Harmonic Distortion	700 to 2900 HZ			-60	dB

SERIAL BUS INTERFACE (See Figure 4)
The following times are for CL = 100 pF.

PARAMETER		MIN	NOM	MAX	UNIT
TRD	Data out from Read	0		140	ns
TCKD	Data out after Clock			200	ns
TRDF	Data Float after Read	0		200	ns
TRCK	Clock High after Read	200			ns
TWW	Write Width	140		10000	ns
TDCK	Data Setup Before Clock	150			ns
TCKH	Data Hold after Clock	20			ns
TCKW	Write after Clock	150			ns
TACR	Address setup before Control [1]	50			ns
TCAR	Address Hold after Control [1]	50			ns
TACW	Address setup before Write	50			ns
TCAW	Address Hold after Write	50			ns

1. Control is later of falling edge of RD or DCLK.

PARALLEL BUS INTERFACE (See Figure 5) The following times are for Cl = 100 pF.

PARAMETER		MIN	MAX	MIN	MAX	UNIT
		Dual-Port Mode		Single-Port Mode		
RC	Read Cycle = TAD + TRC	240		340		ns
TDIW	DISTR Width	80		80		ns
TDDD	Delay DISTR to Data (read time)		80		80	ns
THZ**	DISTR to Floating Data Delay	0	50	0	50	ns
TRA	Address Hold after DISTR	20		20		ns
TRCS	Chip select hold after DISTR	20		20		ns
TAR*	DISTR Delay after Address	20		20		ns
TCSR	DISTR Delay after Chip Select	20		20		ns
WC	Write Cycle = TAW + TDOW + TWC	140		140		ns
TDOW	DOSTR Width	80		80		ns
TDS	Data Setup	30		50		ns
TDH**	Data Hold	20		20		ns
TWA	Address Hold after DOSTR	20		20		ns
TWCS	Chip select hold after DOSTR	20		20		ns
TAW*	DOSTR delay after Address	20		20		ns
TCSW	DOSTR delay after Chip Select	20		20		ns
TADS	Address Strobe Width			40		ns
TAS	Address Setup Time			30		ns
TAH	Address Hold Time			0		ns
TCS	Chip Select Setup Time			30		ns
TCH	Chip Select Hold Time			0		ns
TRC	Read Cycle Delay	40		40		ns
TWC	Write Cycle Delay	40		40		ns
TAD	Address to Read Data	200		300		ns

* TAR and TAW are referenced from the falling edge of either $\overline{CS2}$ or $\overline{DISTR}$ or $\overline{DOSTR}$, which ever is later.

** THZ and TDH are referenced from the rising edge of $\overline{CS2}$ or $\overline{DISTR}$ or $\overline{DOSTR}$, which ever is earlier.

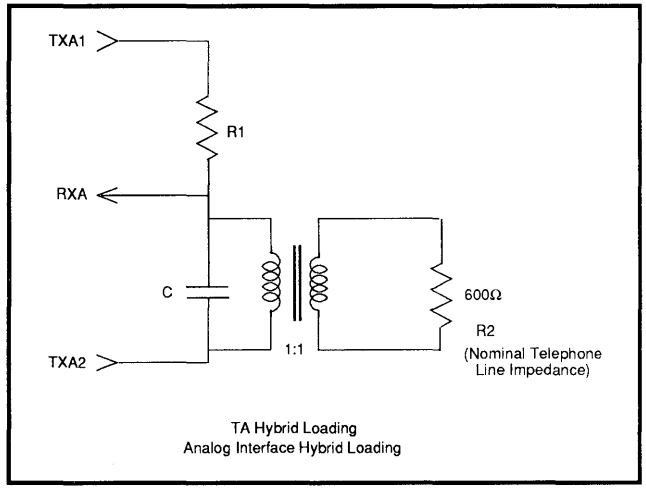


FIGURE 3: TXA Hybrid Loading Analog Interface Hybrid Loading

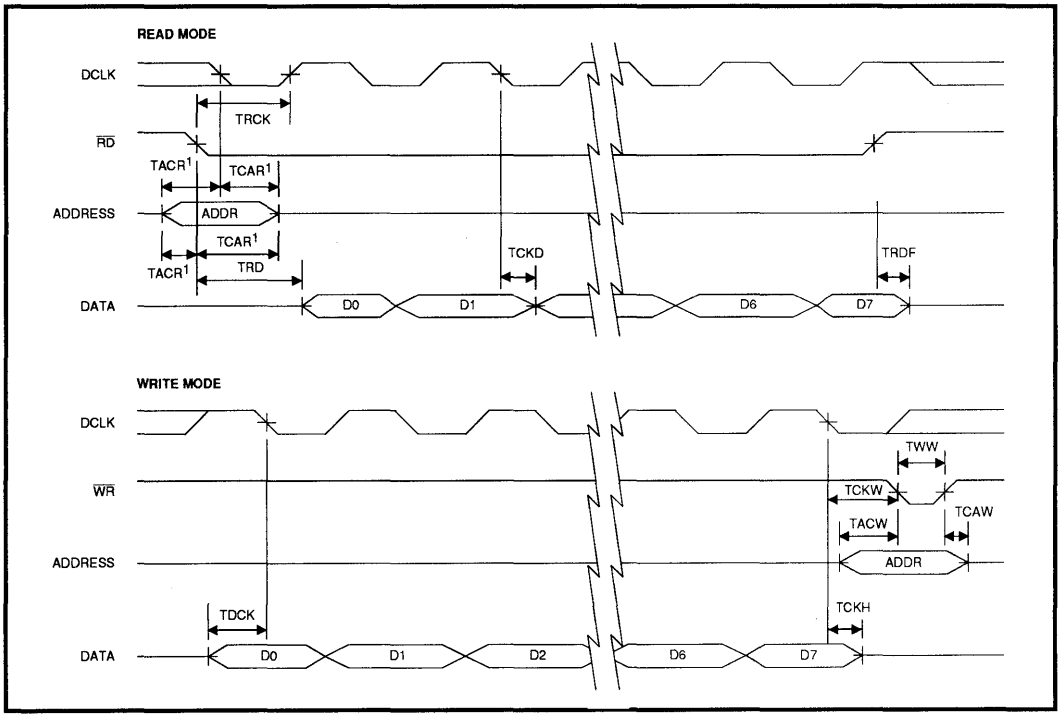


FIGURE 4: Modem Serial Bus Timing

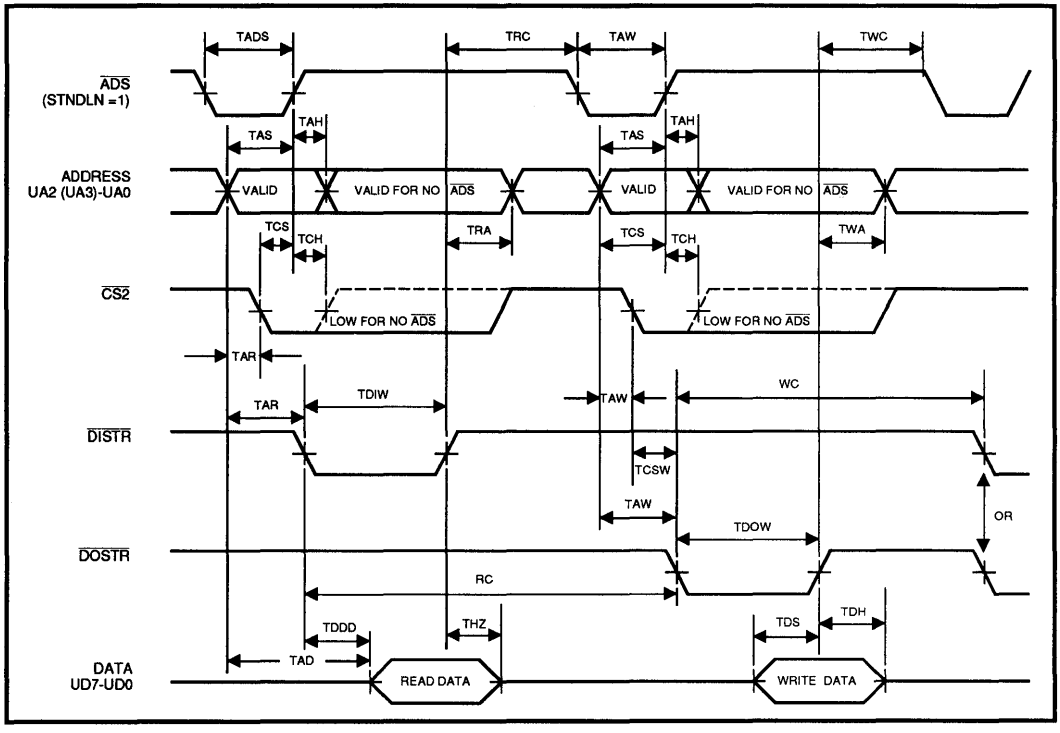


FIGURE 5: UART Bus Timing

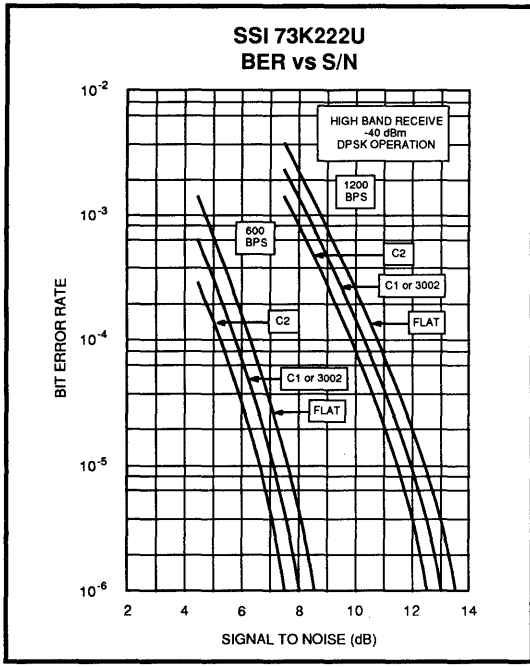
TYPICAL PERFORMANCE CHARACTERISTICS

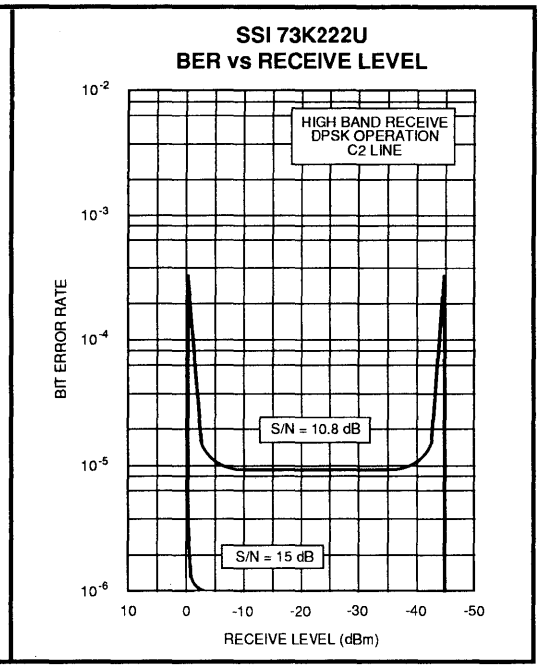
The SSI 73K222U was designed using an integrated analog/digital architecture that offers optimum performance over a wide range of line conditions. The SSI 73K222U utilizes the circuit design proven in SSI's 73K222L one-chip modem, with added enhancements which extend low signal level performance and increase immunity to spurious noise typically encountered in integral bus applications. The SSI 73K222U provides excellent immunity to the types of disturbances present with usage of the dial-up telephone network. The following curves show representative Bit Error Rate performance under various line conditions.

BER vs. S/N

This test measures the ability of the modem to function with minimum errors when operating over noisy lines. Since some noise is generated by even the best dial-up lines, the modem must operate with as low a S/N ratio as possible. Optimum performance is shown by curves that are closest to the zero axis. A narrow spread between curves for the four line conditions indicates minimal variation in performance when operating over a range of line qualities and is typical of high performance adaptive equalization receivers. High band receive data is typically better than low band due to the inherent design of PSK modems.

3



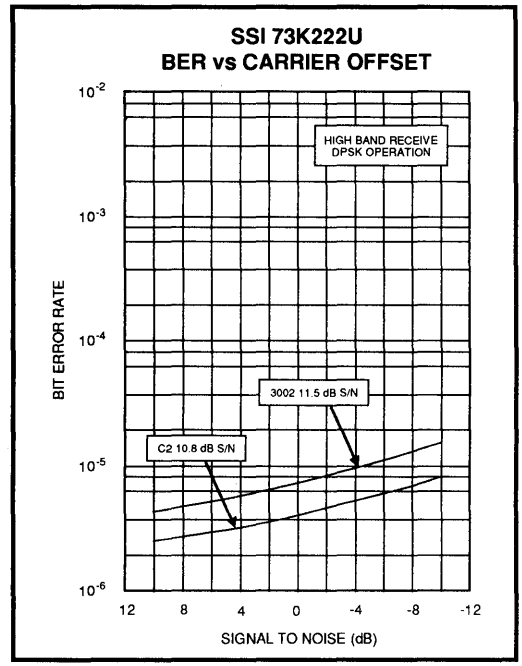


BER vs. Receive Level

This measures the dynamic range of the modem. As signal levels vary widely over dial-up lines, the widest dynamic range possible is desirable. The minimum Bell specification calls for 36dB of dynamic range. S/N ratios were held constant at the indicated values while receive level was lowered from very high to very low signal levels. The "width of the bowl" of these curves taken at the 10- BER point is a measure of the dynamic range.

BER vs. Carrier Offset

This parameter indicates how the modem performance is impacted by frequency shifts encountered in normal PSTN operation. Flat curves show no performance degradation from frequency offsets. The SSI K-Series devices use a 2nd order carrier tracking phase-locked-loop, which is insensitive to carrier offsets in excess of 10Hz. The Bell network specifications allow as much as 7Hz offset, and the CCITT specifications require modems to operate with 7Hz of offset.



APPLICATION

The SSI 73K222U includes additional circuitry to greatly simplify integral modem designs in either of two different configurations. The single-port mode represents the most efficient implementation for an integral modem. Figure 9 shows a typical schematic using this mode. In this configuration, the SSI 73K222U transfers data and commands through the single parallel port. All modem control is provided by the main CPU, eliminating the need for an external microcontroller and supporting components. The SSI 73K222U is unique in that access to both the UART and modem sections is possible through the UART port. Also shown is a separate serial port, which can be used independent of the modem function when the modem section is inactive. Figure 10 shows a more conventional integral modem design, in which a local microprocessor handles modem supervision, allowing the modem function to be transparent to the main processor. Inclusion of the hybrid drivers, audio volume control, and off hook relay driver reduces component count for a highly efficient design. In either mode of operation, the SSI 73K222U's ability to operate from a single +5 volt power supply eliminates the need for additional supply voltages and keeps power usage to a minimum.

(See Figure 9 & 10: Typical Integral Applications Single and Dual-Port Modes.)

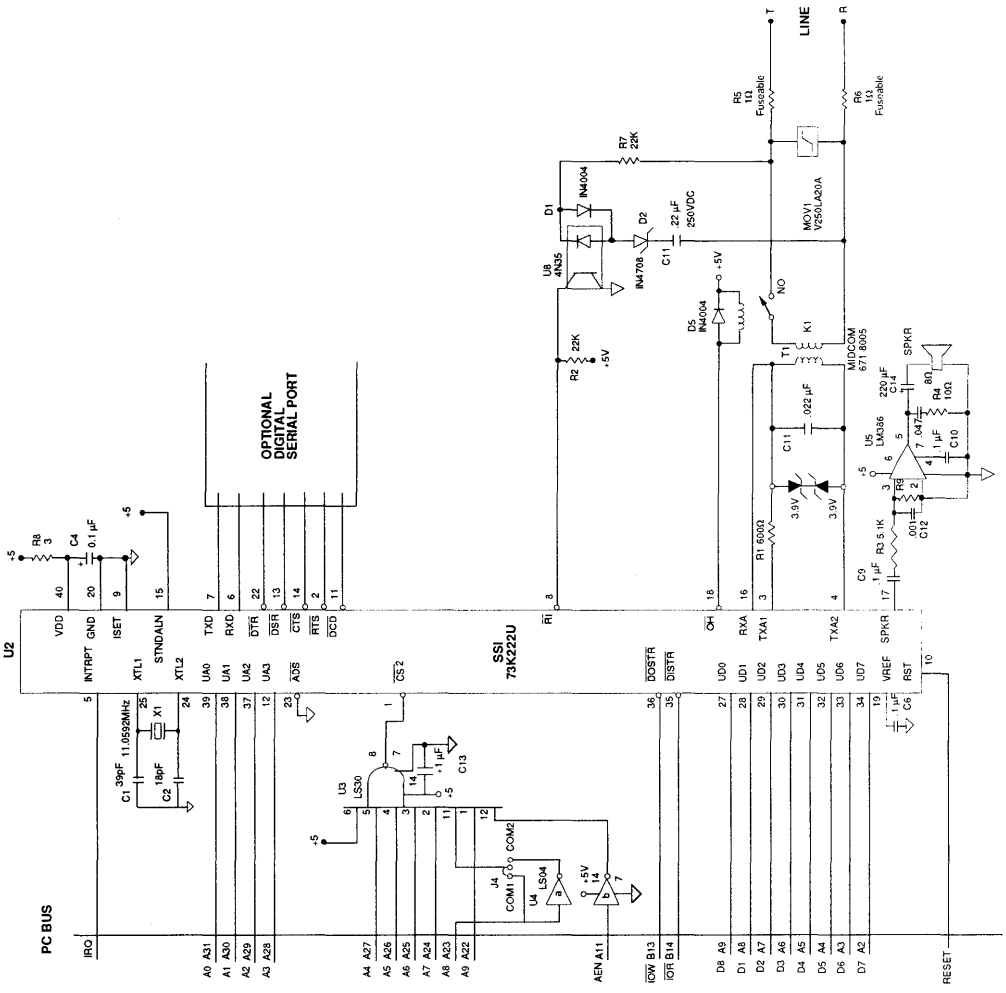


FIGURE 9: 73K222U Typical Integral Application Single-Port Mode

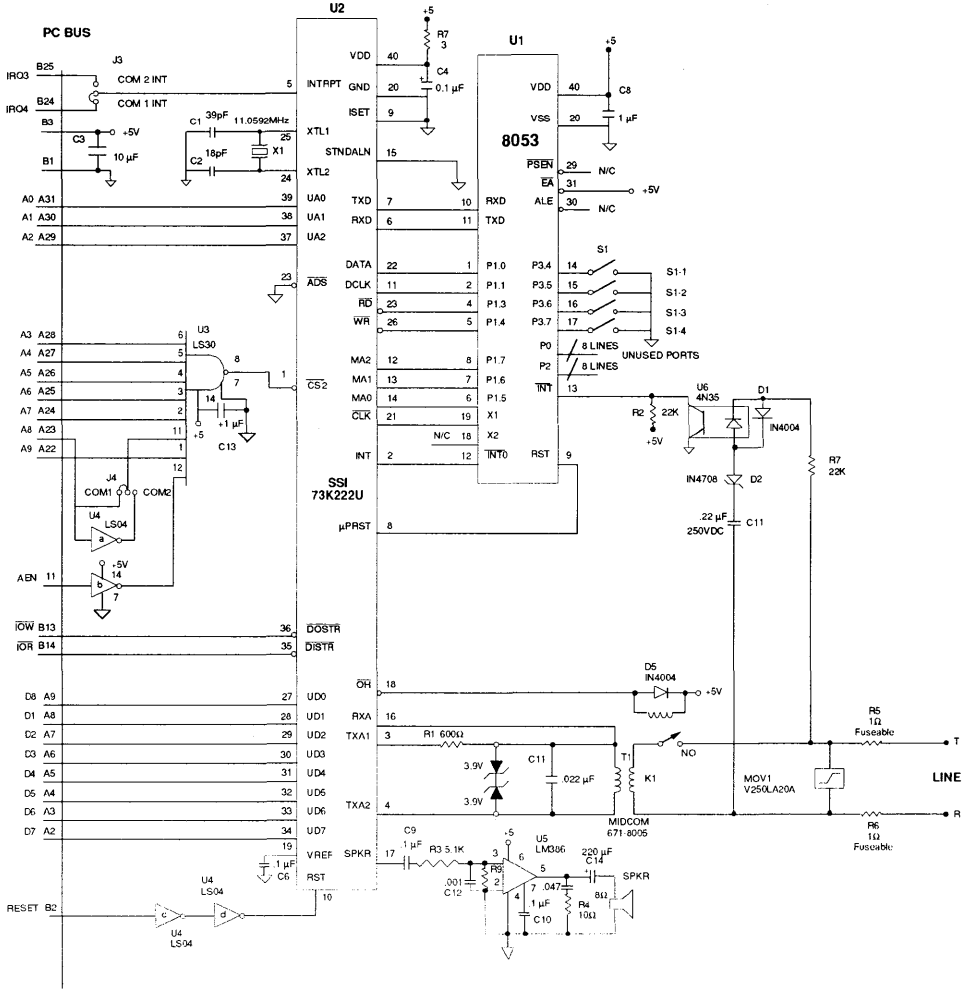
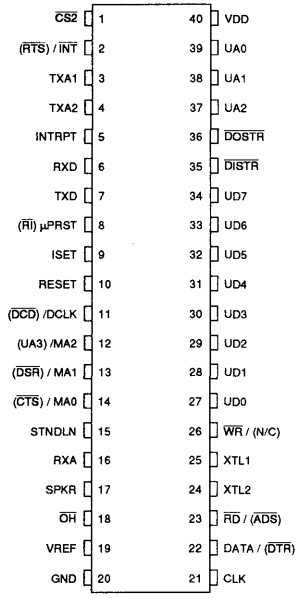


FIGURE 10: 73K222U Typical Integral Application Dual-Port Mode

PACKAGE PIN DESIGNATIONS

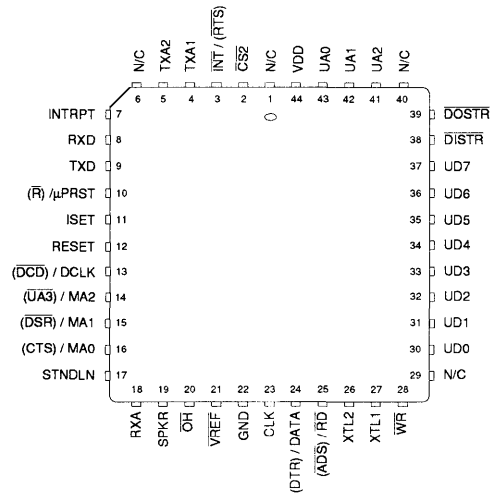
(Top View)



600-Mil
40-Pin DIP

CAUTION: Use handling procedures necessary for a static sensitive component.

Parentheses indicate single-port mode.



44-Pin
PLCC

3

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 73K222U		
40-Pin Plastic Dual-In-Line	73K222U-IP	73K222U-IP
44-Pin Plastic Leaded Chip Carrier	73K222U-IH	73K222U-IH

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SSI 73K224L
V.22bis/V.22/V.21, Bell 212A/103 Single-Chip Modem

January 1994

DESCRIPTION

The SSI 73K224L is a highly integrated single-chip modem IC which provides the functions needed to construct a V.22bis compatible modem, capable of 2400 bit/s full-duplex operation over dial-up lines. The SSI 73K224L offers excellent performance and a high level of functional integration in a single 28-pin DIP. This device supports V.22bis, V.22, V.21, Bell 212A and Bell 103 modes of operation, allowing both synchronous and asynchronous communication.The SSI 73K224L is designed to appear to the systems designer as a microprocessor peripheral, and will easily interface with popular single-chip microprocessors (80C51 typical) for control of modem functions through its 8-bit multiplexed address/data bus or via an optional serial control bus. An ALE control line simplifies address demultiplexing. Data communications normally occur through a separate serial port. The SSI 73K224L is pin and software compatible with the SSI 73K212L and SSI 73K222L single-chip modem ICs, allowing system upgrades with a single component change.

The SSI 73K224L operates from a single +5 V supply for low power consumption.

The SSI 73K224L is ideal for use in either free-standing or integral system modem products where full-duplex

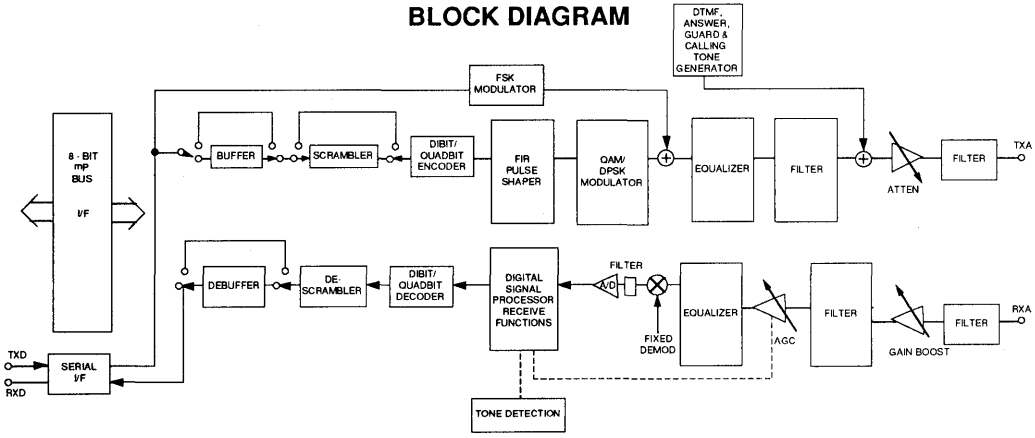
(Continued)

FEATURES

- **One-chip multi-mode V.22bis/V.22/V.21 and Bell 212A/103 compatible modem data pump**
- **FSK (300 bit/s), DPSK (600, 1200 bit/s), or QAM (2400 bit/s) encoding**
- **Pin and software compatible with other SSI K-Series 1-chip modems**
- **Interfaces directly with standard microprocessors (8048, 80C51 typical)**
- **Parallel microprocessor bus for control with a wide range of package options**
- **Selectable asynch/synch with internal buffer/ debuffer and scrambler/descrambler functions**
- **All synchronous and asynchronous operating modes (internal, external, slave)**
- **Adaptive equalization for optimum performance over all lines**
- **Programmable transmit attenuation (16 dB, 1 dB steps), selectable receive boost (+18 dB)**
- **Call progress, carrier, answer tone, unscrambled mark, S1, and signal quality monitors**
- **DTMF, answer and guard tone generators**
- **Test modes available: ALB, DL, RDL, Mark, Space, Alternating bit, S1 pattern**
- **CMOS technology for low power consumption (typically 100 mW @ 5V) with power-down mode (15 mW @ 5V)**
- **TTL and CMOS compatible inputs and outputs**

3

BLOCK DIAGRAM



DESCRIPTION (Continued)

2400 bit/s data communications over the 2–wire switched telephone network is desired. Its high functionality, low power consumption, and efficient packaging simplify design requirements and increase system reliability.

The SSI 73K224L is designed to be a complete V.22bis compatible modem on a chip. The complete modem requires only the addition of the phone line interface, a control microprocessor, and RS-232 level converter for a typical system. Many functions were included to simplify implementation of typical modem designs. In addition to the basic 2400 bit/s QAM, 600/1200 bit/s DPSK and 300 bit/s FSK modulator/demodulator sections, the device also includes SYNCH/ASYNCH converters, scrambler/descrambler, call progress tone detect, DTMF tone generator capabilities and handshake pattern detectors. V.22bis, V.22, V.21 and Bell 212A/103 modes are supported (synchronous and asynchronous) and test modes are provided for diagnostics. Most functions are selectable as options and logical defaults are provided.

OPERATION

QAM MODULATOR/DEMODULATOR

The SSI 73K224L encodes incoming data into quad-bits represented by 16 possible signal points with specific phase and amplitude levels. The baseband signal is then filtered to reduce intersymbol interference on the bandlimited telephone network. The modulator transmits this encoded data using either a 1200 Hz (originate mode) or 2400 Hz (answer mode) carrier. The demodulator, although more complex, essentially reverses this procedure while also recovering the data clock from the incoming signal. Adaptive equalization corrects for varying line conditions by automatically changing filter parameters to compensate for line characteristics.

DPSK MODULATOR/DEMODULATOR

The SSI 73K224L modulates a serial bit stream into di-bit pairs that are represented by four possible phase shifts as prescribed by the Bell 212A/V.22 standards. The base-band signal is then filtered to reduce intersymbol interference on the bandlimited 2-wire PSTN line. Transmission occurs on either a 1200 Hz (originate mode) or 2400 Hz carrier (answer mode). Demodulation is the reverse of the modulation process, with the incoming analog signal eventually decoded into di-bits and converted back to a serial bit stream. The demodulator also recovers the clock which was encoded into the analog signal during modulation.Demodulation occurs using either a 1200 Hz carrier (answer mode or ALB originate mode) or a 2400 Hz carrier (originate mode or ALB answer mode). Adaptive equalization is also used in DPSK modes for optimum operation with varying line conditions.

FSK MODULATOR/DEMODULATOR

The FSK modulator produces a frequency modulated analog output signal using two discrete frequencies to represent the binary data. The Bell 103 standard frequencies of 1270 and 1070 Hz (originate mark and space) and 2225 and 2025 Hz (answer mark and space) are used when this mode is selected. V.21 mode uses 980 and 1180 Hz (originate, mark and space) or 1650 and 1850 Hz (answer, mark and space). Demodulation involves detecting the received frequencies and decoding them into the appropriate binary value. The rate converter and scrambler/descrambler are automatically bypassed in the FSK modes.

PASSBAND FILTERS AND EQUALIZERS

High and low band filters are included to shape the amplitude and phase response of the transmit and receive signals and provide compromise delay equalization and rejection of out-of-band signals. Amplitude and phase equalization are necessary to compensate for distortion of the transmission line and to reduce intersymbol interference in the bandlimited receive signal. The transmit signal filtering corresponds to a 75% square root of raised Cosine frequency response characteristic.

ASYNCHRONOUS MODE

The Asynchronous mode is used for communication with asynchronous terminals which may communicate at 600,1200, or 2400 bit/s +1%, -2.5% even though the modem's output is limited to the nominal bit rate ±.01% in DPSK and QAM modes. When transmitting in this mode the serial data on the TXD input is passed through a rate converter which inserts or deletes stop bits in the serial bit stream in order to output a signal that is the nominal bit rate ±.01%. This signal is then routed to a data scrambler and into the analog modulator where quad-bit/di-bit encoding results in the out-

put signal. Both the rate converter and scrambler can be bypassed for handshaking, and synchronous operation as selected. Received data is processed in a similar fashion except that the rate converter now acts to reinsert any deleted stop bits and output data to the terminal at no greater than the bit rate plus 1%. An incoming break signal (low through two characters) will be passed through without incorrectly inserting a stop bit.

The SYNC/ASYNC converter also has an extended Overspeed mode which allows selection of an output overspeed range of either +1% or +2.3%. In the extended Overspeed mode, stop bits are output at 7/8 the normal width.

Both the SYNC/ASYNC rate converter and the data descrambler are automatically bypassed in the FSK modes.

SYNCHRONOUS MODE

Synchronous operation is possible only in the QAM or DPSK modes. Operation is similar to that of the Asynchronous mode except that data must be synchronized to a provided clock and no variation in data transfer rate is allowable. Serial input data appearing at TXD must be valid on the rising edge of TXCLK.

TXCLK is an internally derived 1200 or 2400 Hz signal in Internal mode and is connected internally to the RXCLK pin in Slave mode. Receive data at the RXD pin is clocked out on the falling edge of RXCLK. The asynch/synch converter is bypassed when Synchronous mode is selected and data is transmitted at the same rate as it is input.

PARALLEL BUS INTERFACE

Eight 8-bit registers are provided for control, option select, and status monitoring. These registers are addressed with the AD0, AD1, and AD2 multiplexed address lines (latched by ALE) and appear to a control microprocessor as seven consecutive memory locations. Six control registers are read/write memory. The detect and ID registers are read only and cannot be modified except by modem response to monitored parameters.

SERIAL CONTROL INTERFACE

The serial Command mode allows access to the SSI 73K324 control and status registers via a serial control port. In this mode the A0, A1, and A2 lines provide register addresses for data passed through the DATA pin under control of the $\overline{RD}$ and $\overline{WR}$ lines. A read operation is initiated when the $\overline{RD}$ line is taken low. The next eight cycles of EXCLK will then transfer out eight bits of the selected addresss location LSB first. A write takes place by shifting in eight bits of data LSB first for eight consectuive cycles of EXCLK. $\overline{WR}$ is then pulsed low and data transfer into the selected register occurs on the rising edge of $\overline{WR}$.

DTMF GENERATOR

The DTMF generator controls the sending of the sixteen standard DTMF tone pairs. The tone pair sent is determined by selecting TRANSMIT DTMF (bit D4) and the 4 DTMF bits (D0-D3) of the TONE register. Transmission of DTMF tones from TXA is gated by the TRANSMIT ENABLE bit of CR0 (bit D1) as with all other analog signals.

PIN DESCRIPTION

POWER

NAME	TYPE	DESCRIPTION
GND	I	System Ground.
VDD	I	Power supply input, 5V -5% +10%. Bypass with .22 µF and 22 µF capacitors to GND.
VREF	O	An internally generated reference voltage. Bypass with .22 µF capacitor to GND.
ISET	I	Chip current reference. Sets bias current for op-amps. The chip current is set by connecting this pin to VDD through a 2 MΩ resistor. Iset should be bypassed to GND with a .22 µF capacitor.

PARALLEL MICROPROCESSOR INTERFACE

ALE	I	Address latch enable. The falling edge of ALE latches the address on AD0-AD2 and the chip select on $\overline{CS}$.
AD0-AD7	I/O / Tristate	Address/data bus.These bidirectional tri-state multi-plexed lines carry information to and from the internal registers.
$\overline{CS}$	I	Chip select. A low on this pin allows a read cycle or a write cycle to occur. AD0-AD7 will not be driven and no registers will be written if $\overline{CS}$ (latched) is not active. $\overline{CS}$ is latched on the falling edge of ALE.
CLK	O	Output clock. This pin is selectable under processor control to be either the crystal frequency (for use as a processor clock) or 16 x the data rate for use as a baud rate clock in QAM/DPSK modes only. The pin defaults to the crystal frequency on reset.
$\overline{INT}$	O	Interrupt. This open drain weak pullup, output signal is used to inform the processor that a detect flag has occurred. The processor must then read the detect register to determine which detect triggered the interrupt. $\overline{INT}$ will stay active until the processor reads the detect register or does a full reset.
$\overline{RD}$	I	Read. A low requests a read of the SSI 73K224L internal registers. Data cannot be output unless both $\overline{RD}$ and the latched $\overline{CS}$ are active or low.
RESET	I	Reset. An active high signal on this pin will put the chip into an inactive state. All control register bits (CR0, CR1, CR2, CR3, Tone) will be reset. The output of the CLK pin will be set to the crystal frequency. An internal pull down resistor permits power on reset using a capacitor to VDD.
$\overline{WR}$	I	Write. A low on this informs the SSI 73K224L that data is available on AD0-AD7 for writing into an internal register. Data is latched on the rising edge of $\overline{WR}$. No data is written unless both $\overline{WR}$ and the latched $\overline{CS}$ are active (low).

Note: The serial control mode is provided in the parallel versions by tying ALE high and $\overline{CS}$ low. In this configuration AD7 becomes DATA and AD0, AD1 and AD2 become A0, A1 and A2, respectively.

DTE USER INTERFACE

NAME	TYPE	DESCRIPTION
EXCLK	I	External Clock. This signal is used in synchronous transmission when the external timing option has been selected. In the external timing mode the rising edge of EXCLK is used to strobe synchronous transmit data available on the TXD pin. Also used for serial control interface.
RXCLK	O/Tristate	Receive Clock. Tri-stateable. The falling edge of this clock output is coincident with the transitions in the serial received data output. The rising edge of RXCLK can be used to latch QAM or DPSK valid output data. RXCLK will be active as long as a carrier is present.
RXD	O	Received Digital Data Output. Serial receive data is available on this pin. The data is always valid on the rising edge of RXCLK when in synchronous mode. RXD will output constant marks if no carrier is detected.
TXCLK	O/Tristate	Transmit Clock. Tri-stateable. This signal is used in synchronous transmission to latch serial input data on the TXD pin. Data must be provided so that valid data is available on the rising edge of the TXCLK. The transmit clock is derived from different sources depending upon the synchronization mode selection. In Internal Mode the clock is generated internally. In External Mode TXCLK is phase locked to the EXCLK pin. In Slave Mode TXCLK is phase locked to the RXCLK pin. TXCLK is always active.
TXD	I	Transmit Digital Data Input. Serial data for transmission is input on this pin. In synchronous modes, the data must be valid on the rising edge of the TXCLK clock. In asynchronous modes (2400/1200/600 bit/s or 300 baud) no clocking is necessary. DPSK data must be +1%, -2.5% or +2.3%, -2.5 % in extended overspeed mode.

ANALOG INTERFACE AND OSCILLATOR

RXA	I	Received modulated analog signal input from the phone line.
TXA	O	Transmit analog output to the phone line.
XTL1	I	These pins are for the internal crystal oscillator requiring a 11.0592 MHz parallel mode crystal. Two capacitors from these pins to ground are also required for proper crystal operation. Consult crystal manufacturer for proper values. XTL2 can also be driven from an external clock.
XTL2	I/O	

PIN DESCRIPTION (continued)

SERIAL MICROPROCESSOR INTERFACE

NAME	TYPE	DESCRIPTION
A0-A2	I	Register Address Selection. These lines carry register addresses and should be valid during any read or write operation.
DATA	I/O	Serial Control Data. Data for a read/write operation is clocked in or out on the falling edge of the EXCLK pin. The direction of data flow is controlled by the $\overline{RD}$ pin. $\overline{RD}$ low outputs data. $\overline{RD}$ high inputs data.
$\overline{RD}$	I	Read. A low on this input informs the SSI 73K322L that data or status information is being read by the processor. The falling edge of the $\overline{RD}$ signal will initiate a read from the addresses register. The $\overline{RD}$ signal must continue for eight falling edges of EXCLK in order to read all eight bits of the referenced register. Read data is provided LSB first. Data will not be output unless the $\overline{RD}$ signal is active.
$\overline{WR}$	I	Write. A low on this input informs the SSI 73K322L that data or status information has been shifted in through the DATA pin and is available for writing to an internal register. The normal procedure for a write is to shift in data LSB first on the DATA pin for eight consecutive falling edges of EXCLK and then to pulse $\overline{WR}$ low. Data is written on the rising edge of $\overline{WR}$.

Note: In the serial, 22-pin version, the pins AD0-AD7, ALE and $\overline{CS}$ are removed and replaced with the pins; A0, A1, A2, DATA, and an unconnected pin. Also, the $\overline{RD}$ and $\overline{WR}$ controls are used differently.

REGISTER DESCRIPTIONS

Eight 8-bit internal registers are accessible for control and status monitoring. The registers are accessed in read or write operations by addressing the A0, A1 and A2 address lines in serial mode, or the AD0, AD1 and AD2 lines in parallel mode. The address lines are latched by ALE. Register CR0 controls the method by which data is transferred over the phone line. CR1 controls the interface between the microprocessor and the SSI 73K224L internal state. DR is a detect register which provides an indication of monitored modem status conditions. TR, the tone control register, controls the DTMF generator, answer and guard tones and RXD output gate used in the modem initial connect sequence. CR2 is the primary DSP control interface and CR3 controls transmit attenuation and receive gain adjustments. All registers are read/write except for DR and ID which are read only. Register control and status bits are identified below:

REGISTER BIT SUMMARY

	ADDRESS	DATA BIT NUMBER							
REGISTER	AD - A0	D7	D6	D5	D4	D3	D2	D1	D0
CONTROL REGISTER 0 CR0	000	MODULATION OPTION	MODULATION TYPE 1	MODULATION TYPE 0	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE
CONTROL REGISTER 1 CR1	001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTERRUPT	BYPASS SCRAMBLER	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0
DETECT REGISTER DR	010	RECEIVE LEVEL	PATTERN S1 DET	RECEIVE DATA	UNSCR. MARK DETECT	CARRIER DETECT	SPECIAL TONE DETECT	CALL PROGRESS DETECT	SIGNAL QUALITY
TONE CONTROL REGISTER TR	011	RXD OUTPUT CONTROL	TRANSMIT GUARD TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF3	DTMF2	DTMF1/ EXTENDED OVERSPEED	DTMF0/GUARD/ ANSWER
CONTROL REGISTER 2 CR2	100		SPECIAL REGISTER ACCESS	CALL INITIALIZE	TRANSMIT S1	16 WAY	RESET DSP	TRAIN INHIBIT	EQUALIZER ENABLE
CONTROL REGISTER 3 CR3	101	TXDALT	TRISTATE TX/RXCLK		RECEIVE GAIN BOOST	TRANSMIT ATTEN. 3	TRANSMIT ATTEN. 2	TRANSMIT ATTEN. 1	TRANSMIT ATTEN. 0
SPECIAL REGISTER SR	101		TX BAUD CLOCK	RX UNSCR. DATA		TXD SOURCE	SQ SELECT 1	SQ SELECT 0	
ID REGISTER ID	110	ID	ID	ID	ID	USER DEFINABLE PERSONALITY			

NOTE: When a register containing reserved control bits is written into, the reserved bits must be programmed as 0's.

REGISTER ADDRESS TABLE

REGISTER	ADDRESS AD2 - AD0	DATA BIT NUMBER D7	D6	D5	D4	D3	D2	D1	D0
CONTROL REGISTER 0 CR0	000	MODULATION OPTION	MODULATION TYPE 1	MODULATION TYPE 0	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE
		QAM: 0=2400 BIT/S DPSK: 0=1200 BIT/S 1=600 BIT/S FSK: 0=103 MODE 1=V.21	10=QAM 00=DPSK 01=FSK	0000=PWR DOWN 0001=INT SYNCH 0010=EXT SYNCH 0011=SLAVE SYNCH 0100=ASYCH 8 BITS/CHAR 0101=ASYCH 9 BITS/CHAR 0110=ASYCH 10 BITS/CHAR 0111=ASYCH 11 BITS/CHAR 1X00=FSK				0=DISABLE TXA OUTPUT 1=ENABLE TXA OUTPUT	0=ANSWER 1=ORIGINATE
CONTROL REGISTER 1 CR1	001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTERRUPT	BYPASS SCRAMBLER	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0
		00=TX DATA 01=TX ALTERNATE 10=TX MARK 11=TX SPACE		0=DISABLE 1=ENABLE	0=NORMAL 1=BYPASS SCRAMBLER	0=XTAL 1=16 X DATA RATE OUTPUT AT CLK PIN IN QAM/DPSK MODE ONLY	0=NORMAL 1=RESET	00=NORMAL 01=ANALOG LOOPBACK 10=REMOTE DIGITAL LOOPBACK 11=LOCAL DIGITAL LOOPBACK	
DETECT REGISTER DR	010	RECEIVE LEVEL INDICATOR	S1 PATTERN DETECT	RECEIVE DATA	UNSCR. MARKS DETECT	CARRIER DETECT	ANSWER TONE DETECT	CP TONE DETECT	SIGNAL QUALITY INDICATOR
		0=SIGNAL BELOW THRESHOLD 1=ABOVE THRESHOLD	0=NOT PRESENT 1=PATTERN FOUND	OUTPUTS RECEIVED DATA STREAM		0=CONDITION NOT DETECTED 1=CONDITION DETECTED			0=GOOD 1=BAD
TONE CONTROL REGISTER TR	011	RXD OUTPUT CONTROL	TRANSMIT GUARD/ CALLING TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF3	DTMF2	DTMF1/ EXTENDED OVERSPEED	DTMF0/ GUARD/ ANSWER
		RXD PIN 0=NORMAL 1=OPEN	0=OFF 1=ON	0=OFF 1=ON	0=DATA 1=TX DTMF	4 BIT CODE FOR 1 OF 16 DUAL TONE COMBINATIONS			0=1800 Hz G.T. 2225 Hz ANS TONE GENERATED. 1=550 Hz G.T. 2100 Hz ANS TONE GENERATED & DETECTED (V.21, V.22)
CONTROL REGISTER 2 CR2	100	0	SPECIAL REGISTER ACCESS	CALL INITIALIZE	TRANSMIT S1	16 WAY	$\overline{\text{RESET}}$ DSP	TRAIN INHIBIT	EQUALIZER ENABLE
			0=ACCESS CR3 1=ACCESS SPECIAL REGISTER	0=DSP IN DEMOD MODE 1=DSP IN CALL PROGRESS MODE	0=NORMAL DOTTING 1=S1	0=RX=TX 1=RX=16 WAY	0=DSP INACTIVE 1=DSP ACTIVE	0=ADAPT EQ ACTIVE 1=ADAPT EQ FROZEN	0=ADAPT EQ IN INIT 1=ADAPT EQ OK TO ADAPT
CONTROL REGISTER 3 CR3	101	TXDALT	TRISTATE TX/RXCLK	0	RECEIVE GAIN BOOST	TRANSMIT ATTEN. 3	TRANSMIT ATTEN. 2	TRANSMIT ATTEN. 1	TRANSMIT ATTEN. 0
		ALTERNATE TRANSMIT DATA SOURCE	0=NORMAL 1=TRISTATE		0=NO BOOST 1=18 dB BOOST	0000-1111, SETS TRANSMIT ATTENUATOR 16 dB RANGE DEFAULT=0100 = -10 dBm0			
SPECIAL REGISTER SR	101		TX BAUD CLOCK	RX UNSCR. DATA		TXD SOURCE	SQ SELECT1	SQ SELECT0	
			OUTPUTS TXBAUD CLOCK	OUTPUTS UNSCR. DATA		0=TXD PIN 1=TXALT BIT	00=10^{-5} BER 01=10^{-6} BER 10=10^{-4} BER 11=10^{-3} BER		
ID REGISTER 10	110	ID	ID	ID	ID				

00XX=73K212L, 322L, 321L
01XX=73K221L, 302L
10XX=73K222L
1100=73K224L
1110=73K324L
1101=73K312L

CONTROL REGISTER 0

	D7	D6	D5	D4	D3	D2	D1	D0
CR0 000	MODUL. OPTION	MODUL. TYPE 1	MODUL. TYPE 0	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	Answer/ Originate	0	Selects answer mode (transmit in high band, receive in low band).
		1	Selects originate mode (transmit in low band,receive in high band).
D1	Transmit Enable	0	Disables transmit output at TXA.
		1	Enables transmit output at TXA.
			Note: Transmit Enable must be set to 1 to allow activation of Answer Tone or DTMF.
D5, D4, D3, D2	Transmit Mode	D5 D4 D3 D2	
		0 0 0 0	Selects power down mode. All functions disabled except digital interface.
		0 0 0 1	Internal synchronous mode. In this mode TXCLK is an internally derived 600,1200 or 2400 Hz signal. Serial input data appearing at TXD must be valid on the rising edge of TXCLK. Receive data is clocked out of RXD on the falling edge of RXCLK.
		0 0 1 0	External synchronous mode. Operation is identical to internal synchronous, but TXCLK is connected internally to EXCLK pin, and a 600, 1200 or 2400 Hz clock must be supplied externally.
		0 0 1 1	Slave synchronous mode. Same operation as other synchronous modes. TXCLK is connected internally to the RXCLK pin in this mode.
		0 1 0 0	Selects asynchronous mode - 8 bits/character (1 start bit, 6 data bits, 1 stop bit).
		0 1 0 1	Selects asynchronous mode - 9 bits/character (1 start bit, 7 data bits, 1 stop bit).
		0 1 1 0	Selects asynchronous mode - 10 bits/character (1 start bit, 8 data bits, 1 stop bit).
		0 1 1 1	Selects asynchronous mode - 11 bits/character (1 start bit, 8 data bits, Parity and/or 1 or 2 stop bits).
		1 X 0 0	Selects FSK operation.
D6,D5	Modulation Type	D6 D5	
		1 0	QAM
		0 0	DPSK
		0 1	FSK

CONTROL REGISTER 0 (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
CR0 000	MODUL. OPTION	MODUL. TYPE 1	MODUL. TYPE 0	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE

BIT NO.	NAME	CONDITION	DESCRIPTION
D7	Modulation Option	0	QAM selects 2400 bit/s. DPSK selects 1200 bit/s. FSK selects 103 mode.
		1	DPSK selects 600 bit/s. FSK selects V.21 mode.

CONTROL REGISTER 1

	D7	D6	D5	D4	D3	D2	D1	D0
CR1 001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INT.	BYPASS SCRAMB	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D1, D0	Test Mode	D1 D0	
		0 0	Selects normal operating mode.
		0 1	Analog loopback mode. Loops the transmitted analog signal back to the receiver, and causes the receiver to use the same carrier frequency as the transmitter. To squelch the TXA pin, TRANSMIT ENABLE bit as well as Tone Reg bit D2 must be low.
		1 0	Selects remote digital loopback. Received data is looped back to transmit data internally, and RXD is forced to a mark. Data on TXD is ignored.
		1 1	Selects local digital loopback. Internally loops TXD back to RXD and continues to transmit data carrrier at TXA pin.
D2	Reset	0	Selects normal operation.
		1	Resets modem to power down state. All control register bits (CR0, CR1, CR2, CR3 and Tone) are reset to zero except CR3 bit D2. The output of the clock pin will be set to the crystal frequency.
D3	Clock Control	0	Selects 11.0592 MHz crystal echo output at CLK pin.
		1	Selects 16 X the data rate, output at CLK pin in DPSK/ QAM modes only.

CONTROL REGISTER 1 (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
CR1 001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INT.	BYPASS SCRAMB	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D4	Bypass Scrambler	0	Selects normal operation. DPSK and QAM data is passed through scrambler.
		1	Selects Scrambler Bypass. Bypass DPSK and QAM data is routed around scrambler in the transmit path.
D5	Enable Detect Interrupt	0	Disables interrupt at $\overline{INT}$ pin. All interrupts are normally disabled in power down mode.
		1	Enables $\overline{INT}$ output. An interrupt will be generated with a change in status of DR bits D1-D4 and D6. The answer tone and call progress detect interrupts are masked when the TX enable bit is set. Carrier detect is masked when TX DTMF is activated. All interrupts will be disabled if the device is in power down mode.
D7, D6	Transmit Pattern	D7 D6	
		0 0	Selects normal data transmission as controlled by the state of the TXD pin.
		0 1	Selects an alternating mark/space transmit pattern for modem testing and handshaking. Also used for S1 pattern generation. See CR2 bit D4.
		1 0	Selects a constant mark transmit pattern.
		1 1	Selects a constant space transmit pattern.

DETECT REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
DR 010	RECEIVE LEVEL INDICATOR	S1 PATTERN DETECT	RECEIVE DATA	UNSCR. MARK DETECT	CARR. DETECT	ANSWER TONE DETECT	CALL PROG. DETECT	SIGNAL QUALITY INDICATOR

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	Signal Quality Indicator	0	Indicates normal received signal.
		1	Indicates low received signal quality (above average error rate). Interacts with special register bits D2, D1.
D1	Call Progress Detect	0	No call progress tone detected.
		1	Indicates presence of call progress tones. The call progress detection circuitry is activated by energy in the normal 350 to 620 Hz call progress bandwidth.

DETECT REGISTER (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
DR 010	RECEIVE LEVEL INDICATOR	S1 PATTERN DETECT	RECEIVE DATA	UNSCR. MARK DETECT	CARR. DETECT	ANSWER TONE DETECT	CALL PROG.	SIGNAL QUALITY INDICATOR

BIT NO.	NAME	CONDITION	DESCRIPTION
D2	Answer Tone Received	0	No answer tone detected.
		1	In Call Init mode, indicates detection of 2225 Hz answer tone in Bell mode (TR bit D0=0) or 2100 Hz if in CCITT mode (TR bit D0=1). The device must be in originate mode for detection of answer tone. Both answer tones are detected in demod mode.
D3	Carrier Detect	0	No carrier detected in the receive channel.
		1	Indicated carrier has been detected in the received channel.
D4	Unscrambled Mark Detect	0	No unscrambled mark.
		1	Indicates detection of unscrambled marks in the received data. Should be time qualified by software.
D5	Receive Data		Continuously outputs the received data stream. This data is the same as that output on the RXD pin, but it is not disabled when RXD is tri-stated.
D6	S1 Pattern Detect	0	No S1 pattern being received.
		1	S1 pattern detected. Should be time qualified by software. S1 pattern is defined as a double di-bit (001100..) unscrambled 1200 bit/s DPSK signal. Pattern must be aligned with baud clock to be detected.
D7	Receive Level Indicator	0	Received signal level below threshold, (typical ≈ -25 dBm0); can use receive gain boost (+18 dB).
		1	Received signal above threshold.

TONE REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.	TRANSMIT GUARD TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2	DTMF 1/ EXTENDED OVER-SPEED	DTMF 0/ ANSWER/ GUARD

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	DTMF 0/ Answer/ Guard Tone	D6 D5 D4 D0	D0 interacts with bits D6, D5, and D4 as shown.
		X X 1 X	Transmit DTMF tones.
		X 1 0 0	Select Bell mode answer tone. Interacts with DR bit D2 and TR bit D5.
		X 1 0 1	Select CCITT mode answer tone. Interacts with DR bit D2 and TR bit D5.

(Continued)

TONE REGISTER (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.	TRANSMIT GUARD TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2/ 4 WIRE FDX	DTMF 1/ EXTENDED OVER-SPEED	DTMF 0/ ANSWER/ GUARD

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	DTMF 0/ Answer/ Guard Tone	D6 D5 D4 D0	D0 interacts with bits D6, D5, and D4 as shown.
		1 0 0 0	Select 1800 Hz guard tone.
		1 0 0 1	Select 550 Hz guard tone.
D1	DTMF 1/ Extended Overspeed	D4 D1	D1 interacts with D4 as shown.
		0 0	Asynchronous QAM or DPSK +1.0% -2.5%. (normal)
		0 1	Asynchronous QAM or DPSK +2.3% -2.5%. (extended overspeed)
D2	DTMF 2/ 4 WIRE FDX	D4 D2	
		0 0	Selects 2 wire duplex or half duplex
		0 1	D2 selects 4 wire full duplex in the modulation mode selected. The receive path corresponds to the ANS/ ORIG bit CR0 D0 in terms of high or low band selection. The transmitter is in the same band as the receiver, but does not have magnitude filtering or equalization on its signal as in the receive path.

3

TONE REGISTER (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.	TRANSMIT GUARD TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2/ 4 WIRE FDX	DTMF 1/ EXTENDED OVER-SPEED	DTMF 0/ ANSWER/ GUARD

BIT NO.	NAME	CONDITION	DESCRIPTION
D3, D2, D1, D0	DTMF 3, 2, 1, 0	D3 D2 D1 D0 0 0 0 0 - 1 1 1 1	Programs 1 of 16 DTMF tone pairs that will be transmitted when TX DTMF and TX enable bit (CR0, bit D1) is set. Tone encoding is shown below:

KEYBOARD EQUIVALENT	DTMF CODE D3 D2 D1 D0	TONES LOW HIGH
1	0 0 0 1	697 1209
2	0 0 1 0	697 1336
3	0 0 1 1	697 1477
4	0 1 0 0	770 1209
5	0 1 0 1	770 1336
6	0 1 1 0	770 1477
7	0 1 1 1	852 1209
8	1 0 0 0	852 1336
9	1 0 0 1	852 1477
0	1 0 1 0	941 1336
*	1 0 1 1	941 1209
#	1 1 0 0	941 1477
A	1 1 0 1	697 1633
B	1 1 1 0	770 1633
C	1 1 1 1	852 1633
D	0 0 0 0	941 1633

D4	TX DTMF (Transmit DTMF)	0	Disable DTMF.
		1	Activate DTMF. The selected DTMF tones are transmitted continuously when this bit is high. TX DTMF overrides all other transmit functions.

Note: DTMF0 - DTMF2 should be set to an appropriate state after DTMF dialing to avoid unintended operation.

TONE REGISTER (Continued)

D7	D6	D5	D4	D3	D2	D1	D0	
TR 011	RXD OUTPUT CONTR.	TRANSMIT GUARD TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2/ 4 WIRE FDX	DTMF 1/ EXTENDED OVER-SPEED	DTMF 0/ ANSWER/ GUARD

BIT NO.	NAME	CONDITION	DESCRIPTION
D5	Transmit Answer Tone	D5 D4 D0	D5 interacts with bits D4 and D0 as shown. Also interacts with DR bit D2 in originate mode. See Detect Register description.
		0 0 X	Disables answer tone generator.
		1 0 0	In answer mode, a Bell 2225 Hz tone is transmitted continuously when the Transmit Enable bit is set.
		1 0 1	Likewise, a CCITT 2100 Hz answer tone is transmitted.
D6	Transmit Guard Tone	0	Disables guard tone generator.
		1	Enables guard tone generator. (See D0 for selection of guard tones.) Bit D4 must be zero.
D7	RXD Output Control	0	Enables RXD pin. Receive data will be output on RXD.
		1	Disables RXD pin. The RXD pin reverts to a high impedance with internal weak pull-up resistor.

CONTROL REGISTER 2

	D7	D6	D5	D4	D3	D2	D1	D0
CR2 100	0	SPEC REG ACCESS	CALL INIT	TRANSMIT S1	16 WAY	$\overline{\text{RESET}}$ DSP	TRAIN INHIBIT	EQUALIZER ENABLE

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	Equalizer Enable	0	The adaptive equalizer is in its initialized state.
		1	The adaptive equalizer is enabled. This bit is used in handshakes to control when the equalizer should calculate its coefficients.
D1	Train Inhibit	0	The adaptive equalizer is active.
		1	The adaptive equalizer coefficients are frozen.
D2	$\overline{\text{RESET}}$ DSP	0	The DSP is inactive and all variables are initialized.
		1	The DSP is running based on the mode set by other control bits
D3	16 Way	0	The receiver and transmitter are using the same decision plane (based on the Modulator Control Mode).
		1	The receiver, independent of the transmitter, is forced into a 16 point decision plane. Used for QAM handshaking.

CONTROL REGISTER 2 (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
CR2 100	0	SPEC REG ACCESS	CALL INIT	TRANSMIT S1	16WAY	$\overline{\text{RESET}}$ DSP	TRAIN INHIBIT	EQUALIZER ENABLE

BIT NO.	NAME	CONDITION	DESCRIPTION
D4	Transmit S1	0	The transmitter when placed in alternating mark/space mode transmits 0101..... scrambled or not dependent on the bypass scrambler bit.
		1	When this bit is 1 and only when the transmitter is placed in alternating mark/space mode by CR1 bits D7, D6, and in DPSK or QAM, an unscrambled repetitive double dibit pattern of 00 and 11 at 1200 bit/s (S1) is sent.
D5	Call Init	0	The DSP is setup to do demodulation and pattern detection based on the various mode bits. Both answer tones are detected in demod mode concurrently; TR-D0 is ignored.
		1	The DSP decodes unscrambled mark, answer tone and call progress tones.
D6	Special Register Access	0	Normal CR3 access.
		1	Setting this bit and addressing CR3 allows access to the SPECIAL REGISTER. See the SPECIAL REGISTER for details.
D7	Not used at this time	0	Only write zero to this bit.

CONTROL REGISTER 3

	D7	D6	D5	D4	D3	D2	D1	D0
CR3 101	TXDALT	TRISTATE TX/RXCLK		RECEIVE BOOST ENABLE	TRANSMIT ATTEN. 3	TRANSMIT ATTEN. 2	TRANSMIT ATTEN. 1	TRANSMIT ATTEN. 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D3, D2, D1,D0	Transmit Attenuator	D3 D2 D1 D0 0 0 0 0 - 1 1 1 1	Sets the attenuation level of the transmitted signal in 1dB steps. The default (D3-D0=0100) is for a transmit level of -10 dBm0 on the line with the recommended hybrid transmit gain. The total range is 16 dB.
D4	Receive Gain Boost	0	18 dB receive front end boost is not used.
		1	Boost is in the path. This boost does not change reference levels. It is used to extend dynamic range by compensating for internally generated noise when receiving weak signals. The receive level detect signal and knowledge of the hybrid and transmit attenuator setting will determine when boost should be enabled.
D5	Not used at this time	0	Only write zero to this bit.
D6	TRISTATE TXCLK/RXCLK	0	TXCLK and RXCLK are driven.
		1	TXCLK and RXCLK are tristated.
D7	TXDALT	Spec. Reg. Bit D3=1	Alternate TX data source. See Special Register.

SPECIAL REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
SR 101		TXBAUD CLOCK	RXUN-DSCR DATA		TXD SOURCE	SIGNAL QUALITY LEVEL SELECT1	SIGNAL QUALITY LEVEL SELECT0	

BIT NO.	NAME	DESCRIPTION
D7, D4, D0		NOT USED AT THIS TIME. Only write ZEROs to these bits.
D6	TXBAUD CLK	TXBAUD clock is the transmit baud-synchronous clock that can be used to synchronize the input of arbitrary quad/di-bit patterns. The rising edge of TXBAUD signals the latching of a baud-worth of data internally. Synchronous data to be entered via the TXDALT bit, CR3 bit D7, should have data transitions that start 1/2 bit period delayed from the TXBAUD clock edges.
D5	RXUNDSCR DATA	This bit outputs the data received before going to the descrambler. This is useful for sending special unscrambled patterns that can be used for signaling.
D3	TXD SOURCE	This bit selects the transmit data source; either the TXD pin if ZERO or the TXDALT if this bit is a ONE. The TRANSMIT PATTERN bits D7 and D6 in CR1 override either of these sources.
D2, D1	SIGNAL QUALITY LEVEL SELECT	The signal quality indicator is a logical ZERO when the signal received is acceptable for low error rate reception. It is determined by the value of the Mean Squared Error (MSE) calculated in the decisioning process when compared to a given threshold. This threshold can be set to four levels of error rate. The SQI bit will be low for good or average connections. As the error rate crosses the threshold setting, the SQI bit will toggle at a 1.66 ms rate. Toggling will continue until the error rate indicates that the data pump has lost convergence and a retrain is required. At that point the SQI bit will be a ONE constantly. The SQI bit and threshold selection are valid for QAM and DPSK only and indicates typical error rate.

D2	D1	THRESHOLD VALUE	UNITS
0	0	10^{-5}	BER (default)
0	1	10^{-6}	BER
1	0	10^{-4}	BER
1	1	10^{-3}	BER

NOTE: This register is "mapped" and is accessed by setting CR2 bit D6 to a ONE and addressing CR3. This register provides functions to the 73K224L user that are not necessary in normal communications. Bits D7-D4 are read only, while D3-D0 are read/write. To return to normal CR3 access, CR2 bit D6 must be returned to a ZERO.

ID REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
ID 110	ID 3	ID 2	ID 1	ID 0	USER DEFINABLE PERSONALITY			

BIT NO.	NAME	CONDITION				DESCRIPTION
		D7	D6	D5	D4	Indicates Device:
D7, D6, D5, D4	Device Identification Signature	0	0	X	X	SSI 73K212L, 73K321L or 73K322L
		0	1	X	X	SSI 73K221L or 73K302L
		1	0	X	X	SSI 73K222L
		1	1	0	1	SSI 73K312L
		1	1	0	0	SSI 73K224L
		1	1	1	0	SSI 73K324L

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

PARAMETER	RATING
VDD Supply Voltage	7V
Storage Temperature	-65 to 150°C
Soldering Temperature (10 sec.)	260°C
Applied Voltage	-0.3 to VDD+0.3V
Note: All inputs and outputs are protected from static charge using built-in, industry standard protection devices and all outputs are short-circuit protected.	

RECOMMENDED OPERATING CONDITIONS

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
VDD Supply voltage		4.5	5	5.5	V
External Components (Refer to Application section for placement.)					
VREF Bypass capacitor	(VREF to GND)	0.22			µF
Bias setting resistor	(Placed between VDD and ISET pins)	1.8	2	2.2	MΩ
ISET Bypass capacitor	(ISET pin to GND)	0.22			µF
VDD Bypass capacitor 1	(VDD to GND)	0.22			µF
VDD Bypass capacitor 2	(VDD to GND)	22			µF
XTL1 Load Capacitance	Depends on crystal requirements		18	39	pF
XTL2 Load Capacitance	Depends on crystal requirements		18	27	pF
Clock Variation	(11.0592 MHz) Crystal or external clock	-0.01		+0.01	%
TA, Operating Free-Air Temperature		-40		85	°C

DC ELECTRICAL CHARACTERISTICS
(TA = -40°C to 85°C, VDD = recommended range unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
IDD, Supply Current	CLK = 11.0592 MHz				
	ISET Resistor = 2 MΩ				
IDD1, Active	Operating with crystal oscillator,		18	25	mA
IDD2, Idle	< 5 pF capacitive load on CLK pin		3	5	mA
Digital Inputs					
VIL, Input Low Voltage				0.8	V
VIH, Input High Voltage					
All Inputs except Reset XTL1, XTL2		2.0		VDD	V
Reset, XTL1, XTL2		3.0		VDD	V
IIH, Input High Current	VI = VDD			100	µA
IIL, Input Low Current	VI = 0V	-200			µA
Reset Pull-down Current	Reset = VDD	2		50	µA
Digital Outputs					
VOH, Output High Voltage	IO = IOH Min IOUT = -0.4 mA	2.4		VDD	V
VOL, Output Low Voltage	IO = IOUT = 1.6 mA			0.4	V
RXD Tri-State Pull-up Curr.	RXD = GND	-2		-50	µA
Capacitance					
Maximum Capacitive Load					
CLK	Maximum permitted load			25	pF
Input Capacitance	All Digital Inputs			10	pF

3

DYNAMIC CHARACTERISTICS AND TIMING
(TA = -40°C to +85°C, VDD = recommended range unless otherwise noted.)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
QAM/DPSK Modulator					
Carrier Suppression	Measured at TXA	35			dB
Output Amplitude	TX scrambled marks ATT=0100 (default)	-11.5	-10.0	-9	dBm0
FSK Modulator/Demodulator					
Output Freq. Error	CLK = 11.0592 MHz	-.31		+.20	%
Transmit Level	ATT = 0100 (Default) Transmit Dotting Pattern	-11.5	-10.0	-9	dBm0
TXA Output Distortion	All products through BPF			-45	dB
Output Bias Distortion at RXD	Dotting Pattern measured at RXD Receive Level -20 dBm, SNR 20 dB	-10		+10	%
Output Jitter at RXD	Integrated for 5 seconds	-15		+15	%
Sum of Bias Distortion and Output Jitter	Integrated for 5 seconds	-17		+17	%
Answer Tone Generator (2100 or 2225 Hz)					
Output Amplitude	ATT = 0100 (Default Level) Not in V.21	-11.5	-10	-9	dBm0
Output Distortion	Distortion products in receive band			-40	dB
DTMF Generator	Not in V.21				
Freq. Accuracy		-0.03		+0.25	%
Output Amplitude	Low Band, ATT = 0100, DPSK Mode	-10		-8	dBm0
Output Amplitude	High Band, ATT = 0100, DPSK Mode	-8		-6	dBm0
Twist	High-Band to Low-Band, DPSK Mode	1.0	2.0	3.0	dB
Receiver Dynamic Range	Refer to Performance Curves	-43		-3.0	dBm0
Call Progress Detector	In Call Init mode				
Detect Level	460 Hz test signal	-34		0	dBm0
Reject Level				-40	dBm0
Delay Time	-70 dBm0 to -30 dBm0 STEP			25	ms
Hold Time	-30 dBm0 to -70 dBm0 STEP			25	ms

NOTE: Parameters expressed in dBm0 refer to the following definition:

0 dB loss in the Transmit path to the line.

2 dB gain in the Receive path from the line.

Refer to the Basic Box Modem diagram in the Applications section for the DAA design.

DYNAMIC CHARACTERISTICS AND TIMING (Continued)

PARAMETERS		CONDITIONS	MIN	NOM	MAX	UNITS
Carrier Detect		**Receive Gain = On for lower input level measurements**				
Threshold		All Modes	-48		-43	dBm0
Hysteresis		All Modes		2		
Delay Time	FSK	70 dBm0 to -6 dBm0	25		37	ms
		70 dBm0 to -40 dBm0	25		37	ms
	DPSK	-70 dBm0 to -6 dBm0	7		17	ms
		-70 dBm0 to -40 dBm0	7		17	ms
	QAM	-70 dBm0 to -6 dBm0	25		37	ms
		-70 dBm0 to -40 dBm0	25		37	ms
Hold Time	FSK	-6 dBm0 to -70 dBm0	25		37	ms
		-40 dBm0 to -70 dBm0	15		30	ms
	DPSK	-6 dBm0 to -70 dBm0	20		29	ms
		-40 dBm0 to -70 dBm0	14		21	ms
	QAM	-6 dBm0 to -70 dBm0	25		32	ms
		-40 dBm0 to -70 dBm0	18		28	ms
Answer Tone Detectors		**DPSK Mode**				
Detect Level			-48		-43	dBm0
Detect Time		Call Init Mode, 2100 or 2225 Hz	6		50	ms
Hold Time			6		50	ms
Pattern Detectors		**DPSK Mode**				
S1 Pattern						
Delay Time		For signals from -6 to -40 dBm0,	10		55	ms
Hold Time		-6 to -40 dBm0, Demod Mode	10		45	ms
Unscrambled Mark						
Delay Time		For signals from -6 to -40	10		45	ms
Hold Time		call Init Mode	10		45	ms
Receive Level Indicator						
Detect On			-22		-28	dBm0
Valid after Carrier Detect		DPSK Mode	1	4	7	ms
Output Smoothing Filter						
Output Impedance		TXA pin		200	300	Ω
Output load		TXA pin; FSK Single	10			KΩ
		Tone out for THD = -50 dB in .3 to 3.4 kHz range			50	pF
Maximum Transmitted Energy		4 kHz, Guard Tones off			-35	dBm0
		10 kHz, Guard Tones off			-55	dBm0
		12 kHz, Guard Tones off			-65	dBm0

3

DYNAMIC CHARACTERISTICS AND TIMING (Continued)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Anti Alias Low Pass Filter					
Out of Band Signal Energy (Defines Hybrid Trans-Hybrid loss requirements)	Level at RXA pin with receive Boost Enabled				
	Scrambled data at 2400 bit/s in opposite band		-14		dBm
	Sinusoids out of band		-9		dBm
Transmit Attenuator					
Range of Transmit Level	Default ATT=0100 (-10 dBm0) 1111-0000	-21		-6	dBm0
Step Accuracy		-0.15		+0.15	dB
Output Impedance			200	300	z
Clock Noise					
	TXA pin; 153.6 kHz			1.5	mVrms
Carrier Offset					
Capture Range	Originate or Answer		±5	±7	Hz
Recovered Clock					
Capture Range	% of frequency (originate or answer)	-0.02		+0.02	%
Guard Tone Generator					
Tone Accuracy	550 Hz		+1.2		%
	1800 Hz		-0.8		
Tone Level	550 Hz	-4.5	-3.0	-1.5	dB
(Below QAM/DPSK Output)	1800 Hz	-7.5	-6.1	-4.5	dB
Harmonic Distortion	550 Hz			-50	dB
(700 to 2900 Hz)	1800 Hz			-50	dB
Timing (Refer to Timing Diagrams)					
Parallel Mode					
TAL	$\overline{CS}$/Addr. setup before ALE Low	30			ns
TLA	$\overline{CS}$/Addr. hold after ALE Low	6			ns
TLC	ALE Low to $\overline{RD}/\overline{WR}$ Low	40			ns
TCL	$\overline{RD}/\overline{WR}$ Control to ALE High	10			ns
TRD	Data out from $\overline{RD}$ Low			90	ns
TLL	ALE width	25			ns
TRDF	Data float after $\overline{RD}$ High			40	ns
TRW	$\overline{RD}$ width	70			ns

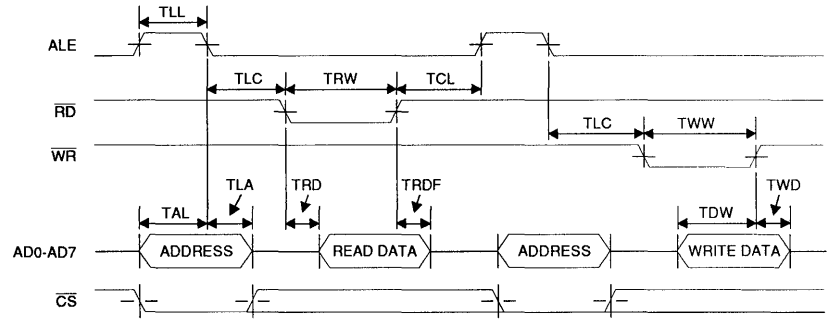
DYNAMIC CHARACTERISTICS AND TIMING (Continued)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Parallel Mode (Continued)					
TWW	$\overline{WR}$ width	70			ns
TDW	Data setup before $\overline{WR}$ High	70			ns
TWD	Data hold after $\overline{WR}$ High	20			ns
Serial Mode					
TRCK	Clock High after $\overline{RD}$ Low	250		T1	ns
TAR	Address setup before $\overline{RD}$ Low	0			ns
TRA	Address hold after $\overline{RD}$ Low	350			ns
TRD	$\overline{RD}$ to Data valid			300	ns
TRDF	Data float after $\overline{RD}$ High			40	ns
TCKDR	Read Data out after Falling Edge of EXCLK			300	ns
TWW	$\overline{WR}$ width	350			ns
TAW	Address setup before $\overline{WR}$ Low	50			ns
TWA	Address hold after Rising Edge of $\overline{WR}$	50			ns
TCKDW	Write Data hold after Falling Edge of EXCLK	200			ns
TCKW	$\overline{WR}$ High after Falling Edge of EXCLK	330		T1 + T2	ns
TDCK	Data setup before Falling Edge of EXCLK	50			ns
T1, T2	Minimum Period	500			ns

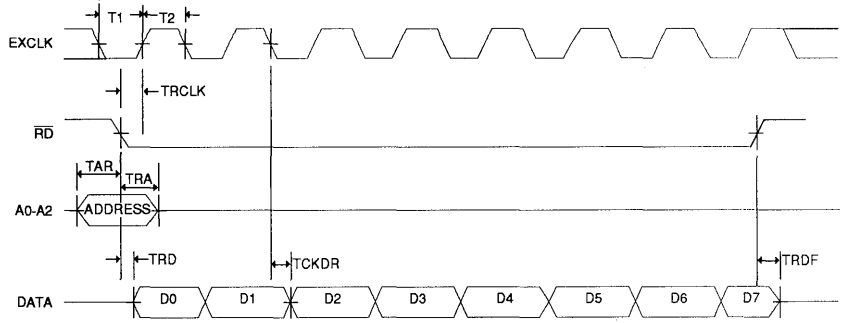
NOTE: T1 and T2 are the low/high periods, respectively, of EXCLK in serial mode.

TIMING DIAGRAMS

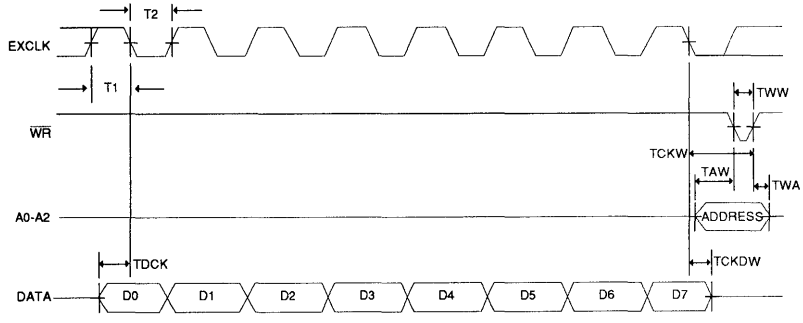
BUS TIMING DIAGRAM (PARALLEL VERSION)



READ TIMING DIAGRAM (SERIAL VERSION)



WRITE TIMING DIAGRAM (SERIAL VERSION)



APPLICATIONS INFORMATION

GENERAL CONSIDERATIONS

Figures 1 and 2 show basic circuit diagrams for K-Series modem integrated circuits. K-Series products are designed to be used in conjunction with a control processor, a UART or RS-232 serial data interface, and a DAA phone line interface to function as a typical intelligent modem. The K-Series ICs interface directly with Intel 8048 and 80C51 microprocessors for control and status monitoring purposes. Two typical DAA arrangements are shown: one for a split ±5 or ±12 V design and one for a single 5 V design. These diagrams are for reference only and do not represent production-ready modem designs.

K-Series devices are available with two control interface versions: one for a parallel multiplexed address/data interface, and one for a serial interface. The parallel version is intended for use with 8039/48 or 8031/51 microcontrollers from Intel or many other manufacturers. The serial interface 22-pin version can be used with other microcontrollers or in applications where only a limited number of port lines are available or the application does not lend itself to a multiplexed address/data interface. The parallel versions may also be used in the serial mode, as explained in the data sheet pin description.

In most applications the controller will monitor the serial data for commands from the DTE and the received data for break signals from the far end modem. In this way, commands to the modem are sent over the same line as the transmitted data. In other applications the RS-232 interface handshake lines are used for modem control.

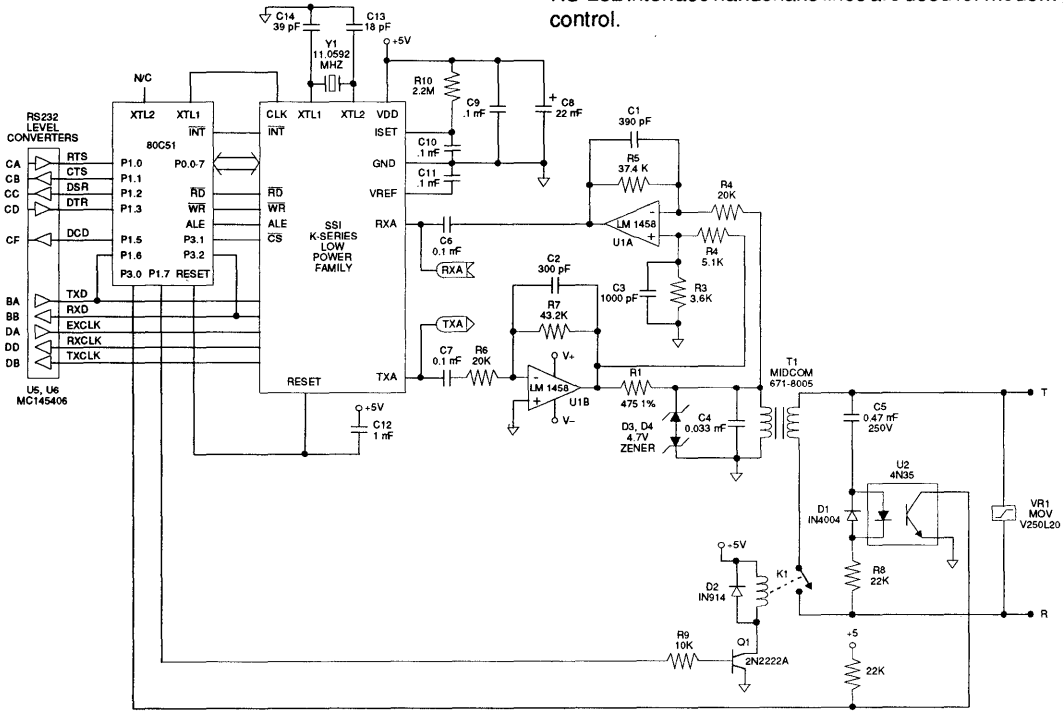


FIGURE 1: Basic Box Modem with Dual-Supply Hybrid

DIRECT ACCESS ARRANGEMENT (DAA)

The telephone line interfaces show two examples of how the "hybrid" may be implemented. The split supply design (Figure 1) is a typical two op-amp hybrid. The receive op-amp serves two purposes. It supplies gain to amplify the receive signal to the proper level for the modem's detectors and demodulator, and it removes the transmitted signal from the receive signal present at the transformer. This is done by supplying a portion of the transmitted signal to the non-inverting input of the receive op-amp at the same amplitude as the signal appearing at the transformer, making the transmit signal common mode.

The single-supply hybrid is more complex than the dual-supply version described above, but its use eliminates the need for a second power supply. This circuit (Figure 2) uses a bridged drive to allow undistorted signals to be sent with a single 5 volt supply. Because DTMF tones utilize a higher amplitude than data, these signals will clip if a single-ended drive approach is used. The bridged driver uses an extra op-amp (U1A) to invert the signal coming from the gain setting op-amp (U1B) before sending it to the other leg of the transformer. Each op-amp then supplies half the drive signal to the transformer. The receive amplifier (U1C) picks off its signal at the junction of the impedance matching resistor and the transformer. Because the bottom leg of the transformer is being driven in one direction by U1A and the resistor is driven in the opposite direction at the same time by U1B, the junction of the transformer and resistor remains relatively constant and the receive signal is unaffected.

DESIGN CONSIDERATIONS

Silicon Systems' 1-chip modem products include all basic modem functions. This makes these devices adaptable for use in a variety of applications, and as easy to control as conventional digital bus peripherals.

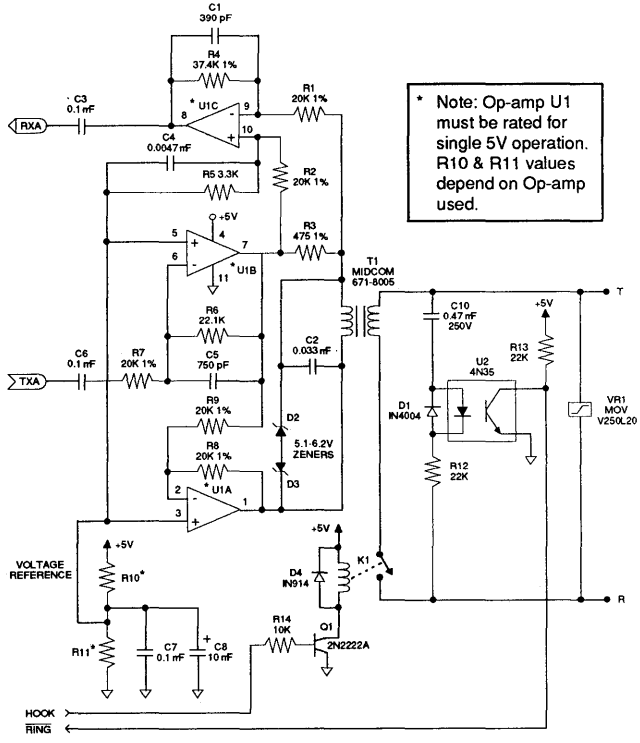


FIGURE 2: Single 5V Hybrid Version

Unlike digital logic circuitry, modem designs must properly contend with precise frequency tolerances and very low level analog signals, to ensure acceptable performance. Using good analog circuit design practices will generally result in a sound design. Following are additional recommendations which should be taken into consideration when starting new designs.

CRYSTAL OSCILLATOR

The K-Series crystal oscillator requires a parallel mode (antiresonant) crystal which operates at 11.0592 MHz. It is important that this frequency be maintained to within ±0.01% accuracy.

In order for a parallel mode crystal to operate correctly and to specification, it must have a load capacitor connected to the junction of each of the crystal and internal inverter connections, terminated to ground. The values of these capacitors depend primarily on the crystal's characteristics, and to a lesser degree on the internal inverter circuit. The values used affect the accuracy and start up characteristics of the oscillator.

LAYOUT CONSIDERATIONS

Good analog/digital design rules must be used to control system noise in order to obtain highest performance in modem designs. The more digital circuitry present on the PC board, the more this attention to noise control is needed. The modem should be treated as a high impedance analog device. A 22 mF electrolytic capacitor in parallel with a 0.22 mF ceramic capacitor between VDD and GND is recommended. Liberal use of ground planes and larger traces on power and ground are also highly favored. The ISET resistor and capacitor should be mounted near the ISET pin, away from digital signals. High speed digital circuits tend to generate a significant amount of EMI (Electro-Magnetic Interference) which must be minimized in order to meet regulatory agency limitations. To accomplish this, high speed digital devices should be locally bypassed, and the telephone line interface and K-Series device should be located close to each other near the area of the board where the phone line connection is accessed. To avoid problems, power supply and ground traces should be routed separately to the analog and digital functions on the board, and digital signals should not be routed near low level or high impedance analog traces. The analog and digital grounds should only connect at one point near the K-Series device ground pin to avoid ground loops. The K–Series modem IC's should have both high frequency and low frequency bypassing as close to the package as possible.

MODEM PERFORMANCE CHARACTERISTICS

The curves presented here define modem IC performance under a variety of line conditions while inducing disturbances that are typical of those encountered during data transmission on public service telephone lines. Test data was taken using an AEA Electronics' "Autotest I" modem test set and line simulator, operating under computer control. All tests were run full-duplex, using a Hayes SmartModem™ 2400 as the reference modem. A 511 pseudo-random-bit pattern was used for each data point. Noise was C-message weighted and all signal-to-noise (S/N) ratios reflect total power measurements similar to the CCITT V.56 measurement specification. The individual tests are defined as follows.

3

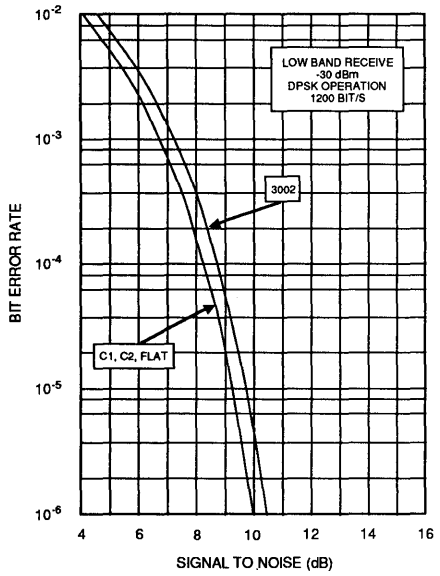
BER vs. S/N

This test measures the ability of the modem to operate over noisy lines with a minimum of data-transfer errors. Since some noise is generated in the best of dial-up lines, the modem must operate with the lowest S/N ratio possible. Better modem performance is indicated by test curves that are closest to the BER axis. A narrow spread between curves representing the four line parameters indicates minimal variation in performance while operating over a range of aberrant operating conditions. Typically, a modem will exhibit better BER-performance test curves receiving in the low band than in the high band.

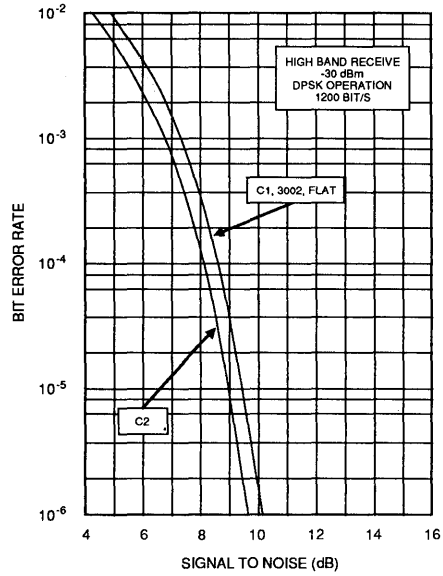
BER vs. Receive Level

This test measures the dynamic range of the modem. Because signal levels vary widely over dial-up lines, the widest possible dynamic range is desirable. The minimum Bell specification calls for 36 dB of dynamic range. S/N ratios are held constant at the indicated values while the receive level is lowered from a very high to very low signal levels. The width of the "bowl" of these curves, taken at the BER point, is the measure of dynamic range.

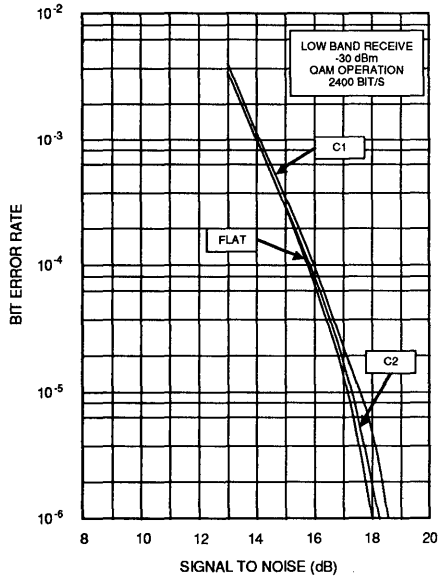
SSI 73K224L BER vs S/N-DPSK LOW BAND



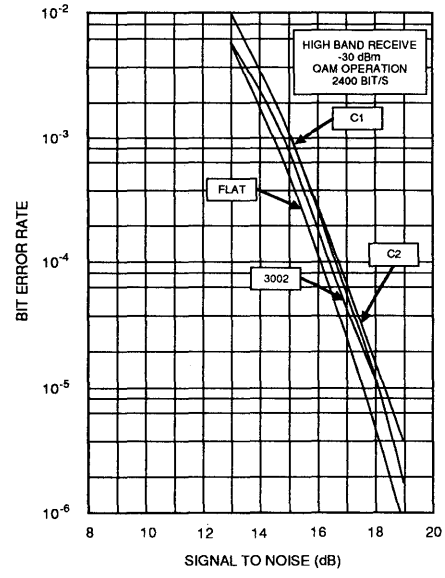
SSI 73K224L BER vs S/N-DPSK HIGH BAND



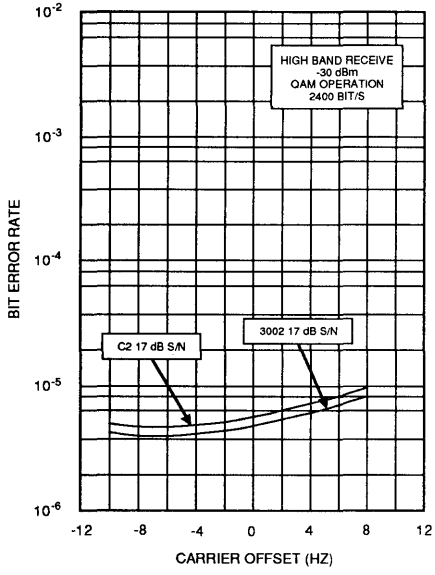
SSI 73K224L BER vs S/N-QAM-LOW BAND



SSI 73K224L BER vs S/N-QAM-HIGH BAND

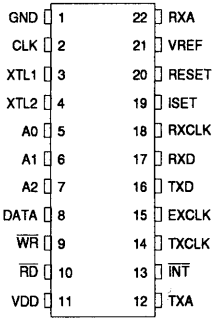


SSI 73K224L BER vs CARRIER OFFSET

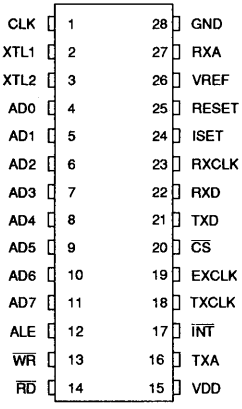


SSI 73K224L
V.22bis/V.22/V.21, Bell 212A/103
Single-Chip Modem

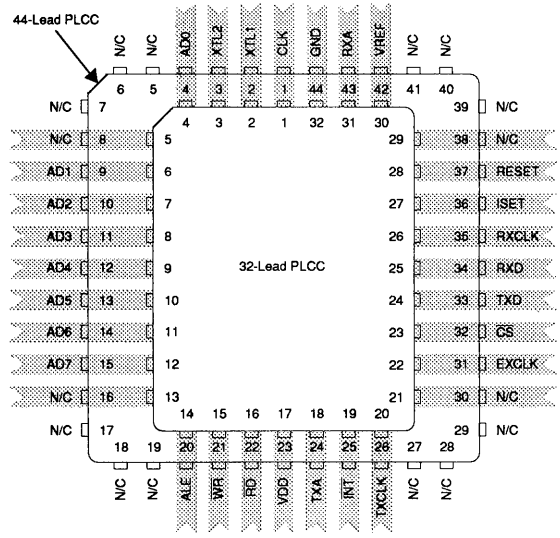
PACKAGE PIN DESIGNATIONS
(Top View)



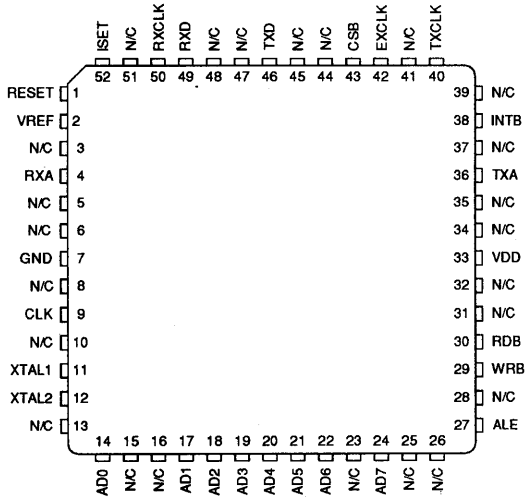
400-Mil 22-Pin DIP



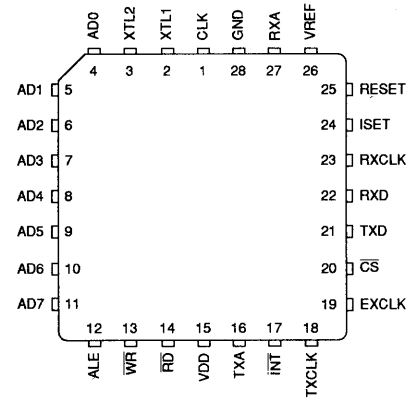
600-Mil 28-Pin DIP



32, 44-Pin PLCC



52-Lead QFP

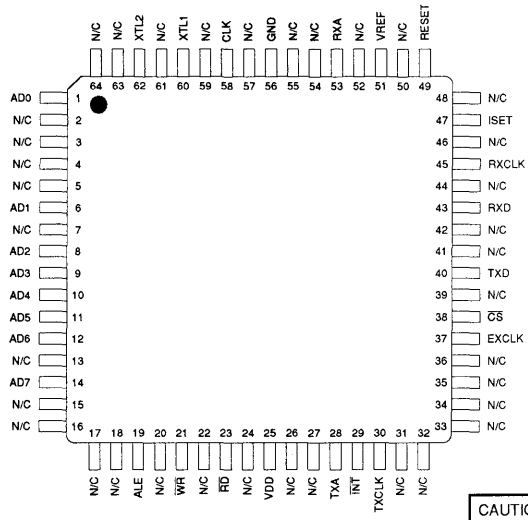


28-Pin PLCC

CAUTION: Use handling procedures necessary for a static sensitive component.

PACKAGE PIN DESIGNATIONS

(Top View)



64-Lead TQFP

CAUTION: Use handling procedures necessary for a static sensitive component.

3

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 73K224L with Serial Bus Interface		
22-Pin Plastic Dual-In-Line	73K224LS-IP	73K224LS-IP
SSI 73K224L with Parallel Bus Interface		
28-Pin Plastic Dual-In-Line	73K224L-IP	73K224L-IP
28-Pin Plastic Leaded Chip Carrier	73K224L-28IH	73K224L-28IH
32-Pin Plastic Leaded Chip Carrier	73K224L-32IH	73K224L-32IH
44-Pin Plastic Leaded Chip Carrier	73K224L-IH	73K224L-IH
52-Lead Quad Flat Pack Package	73K224L-IG	73K224L-IG
64-Lead Thin Quad Flat Pack Package	73K224L-IGT	73K224L-IGT

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SSI 73K302L
Bell 212A, 103, 202 Single-Chip Modem
Preliminary Data

January 1994

DESCRIPTION

The SSI 73K302L is a highly integrated single-chip modem IC which provides the functions needed to construct a Bell 202, 212A and 103 compatible modem. The SSI 73K302L is an enhancement of the SSI 73K212L single-chip modem with Bell 202 mode features added. The 73K302L is capable of 1200 or 0-300 bit/s full-duplex operation over dial-up lines. 4-wire full-duplex capability and a low speed back channel are also provided in Bell 202 mode. The SSI 73K302L recognizes and generates a 900 Hz soft carrier turn-off tone, and allows 103 for 300 bit/s FSK operation. The SSI 73K302L integrates analog, digital, and switched-capacitor array functions on a single substrate, offering excellent performance and a high level of functional integration in a single 28 or 22-pin DIP configuration. The SSI 73K302L operates from a single +5V supply with very low power consumption.

The SSI 73K302L includes the DPSK and FSK modulator/demodulator functions, call progress and handshake tone monitors, test modes, and a tone generator capable of producing DTMF, answer, and 900 Hz soft carrier turn-off tone. This device supports Bell 202, 212A and 103 modes of operation, allowing both

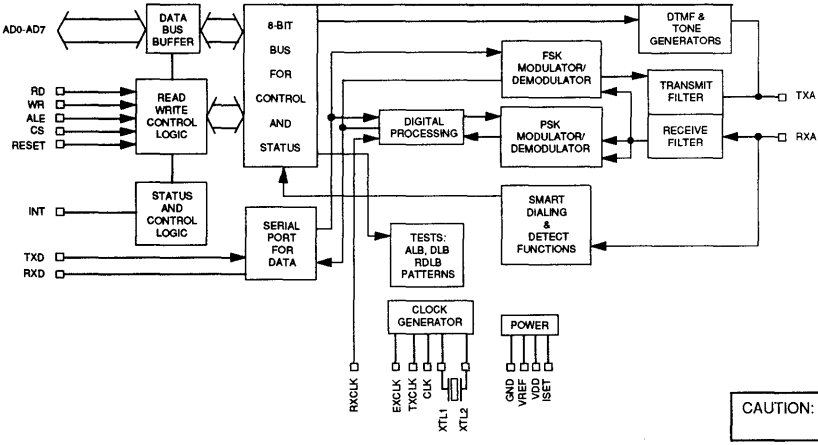
(Continued)

FEATURES

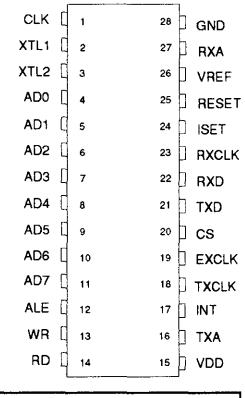
- **One-chip Bell 212A, 103 and 202S/T standard compatible modem data pump**
- **Full-duplex operation at 0-300 bit/s (FSK), 1200 bit/s (DPSK) or 0-1200 bit/s (FSK) forward channel with or without 0-150 bit/s back channel**
- **Full-duplex 4-wire operation in Bell 202 mode**
- **Pin and software compatible with other SSI K-Series 1-chip modems**
- **Interfaces directly with standard microprocessors (8048, 80C51 typical)**
- **Serial (22-pin DIP) or parallel microprocessor bus for control**
- **Serial port for data transfer**
- **Both synchronous and asynchronous modes of operation**
- **Call progress, carrier, precise answer tone (2225 Hz), soft carrier turn-off (SCT), and FSK mark detectors**
- **DTMF, answer, and SCT tone generators**
- **Test modes available: ALB, DL, RDL, Mark, Space, Alternating bit patterns**
- **CMOS technology for low power consumption using 35 mW @ 5V from a single power supply**

3

BLOCK DIAGRAM



PIN DIAGRAM



CAUTION: Use handling procedures necessary for a static sensitive component.

DESCRIPTION (Continued)

synchronous and asynchronous communications. The SSI 73K302L is designed to appear to the systems designer as a microprocessor peripheral, and will easily interface with popular one-chip microprocessors (80C51 typical) for control of modem functions through its 8-bit multiplexed address/data bus or via an optional serial command bus. An ALE control line simplifies address demultiplexing. Data communications occurs through a separate serial port only.

The SSI 73K302L is ideal for use in either free standing or integral system modem products where multi-standard data communications is desired. Its high functionality, low power consumption and efficient packaging simplify design requirements and increase system reliability. A complete modem requires only the addition of the phone line interface, a modem controller, and RS232 level converter for a typical system.

Tri-mode capability in one-chip allows full-duplex Bell 212 and 103 operation or assymetrical Bell 202S operation over the 2-wire switched telephone network. 202T mode full-duplex operation at 1200 bit/s is also possible when operating on 4-wire leased lines.

A soft carrier turn-off feature facilitates fast line turn around when using the 202S mode for half-duplex applications.

The SSI 73K302L is part of Silicon Systems K-Series family of pin and function compatible single-chip modem products. These devices allow systems to be configured for higher speeds and Bell or CCITT operation with only a single component change.

OPERATION

ASYNCHRONOUS MODE

Data transmission for the DPSK mode requires that data ultimately be transmitted in a synchronous fashion. The SSI 73K302L includes ASYNC/SYNC and SYNC/ASYNC converters which delete or insert stop bits in order to transmit data at a regular rate. In asynchronous mode the serial data comes from the TXD pin into the ASYNC/SYNC converter. The ASYNC/SYNC converter accepts the data provided on the TXD pin which normally must be 1200 bit/s +1.0%, 2.5%. The rate converter will then insert or delete stop bits in order to output a signal which is 1200 bit/s ± .01% (±.01% is the required synchronous data rate accuracy).

The SYNC/ASYNC converter also has an extended overspeed mode which allows selection of an output overspeed range of either +1% or +2.3%. In the extended overspeed mode, stop bits are output at 7/8 the normal width.

The serial data stream from the transmit buffer or the rate converter is passed through the data scrambler and onto the analog modulator. The data scrambler can be bypassed under processor control when unscrambled data must be transmitted. If serial input data contains a break signal through one character (including start and stop bits) the break will be extended to at least 2 • N + 3 bits long (where N is the number of transmitted bits/character).

Serial data from the demodulator is passed first through the data descrambler and then through the SYNC/ASYNC converter. The ASYNC/ASYNC converter will reinsert any deleted stop bits and output data at an intra-character rate (bit-to-bit timing) of no greater than 1219 bit/s. An incoming break signal (low through two characters) will be passed through without incorrectly inserting a stop bit.

SYNCHRONOUS MODE

The Bell 212A standard defines synchronous operation at 1200 bit/s. Operation is similar to that of the asynchronous mode except that data must be synchronized to a provided clock and no variation in data transfer rate is allowable. Serial input data appearing at TXD must be valid on the rising edge of TXCLK.

TXCLK is an internally derived signal in internal mode and is connected internally to the RXCLK pin in slave mode. Receive data at the RXD pin is clocked out on the falling edge of RXCLK. The ASYNCH/SYNCH converter is bypassed when synchronous mode is selected and data is transmitted out at the same rate as it is input.

DPSK MODULATOR/DEMODULATOR

In DPSK mode the SSI 73K302L modulates a serial bit stream into di-bit pairs that are represented by four possible phase shifts as prescribed by the Bell 212A standards. The base-band signal is then filtered to reduce intersymbol interference on the bandlimited 2-wire telephone line. Transmission occurs using ei-

ther a 1200 Hz (originate mode) or 2400 Hz (answer mode) carrier. Demodulation is the reverse of the modulation process, with the incoming analog signal eventually decoded into di-bits and converted back to a serial bit stream. The demodulator also recovers the clock which was encoded into the analog signal during modulation. Demodulation occurs using either a 1200 Hz carrier (answer mode or ALB originate mode) or a 2400 Hz carrier (originate mode or ALB answer mode). The SSI 73K302L uses a phase locked loop coherent demodulation technique for optimum receiver performance.

FSK MODULATOR/DEMODULATOR

The FSK modulator produces a frequency modulated analog output signal using two discrete frequencies to represent the binary data. Bell 103 mode uses 1270 and 1070 Hz (originate, mark and space) or 2225 and 2025 Hz (answer, mark and space). Bell 202 mode uses 1200 and 2200 Hz for the main channel and 387 and 487 Hz for the back channel. The modulation rate of the back channel is up to 150 baud. Demodulation involves detecting the received frequencies and decoding them into the appropriate binary value. The rate converter and scrambler/descrambler are automatically bypassed in the 103 or 202 modes.

PASSBAND FILTERS AND EQUALIZERS

High and low band filters are included to shape the amplitude and phase response of the transmit and receive signals and provide compromise delay equalization and rejection of out-of-band signals in the receive channel. Amplitude and phase equalization are necessary to compensate for distortion of the transmission line and to reduce intersymbol interference in the bandlimited receive signal. The transmit signal filtering approximates a 75% square root of raised Cosine frequency response characteristic.

AGC

The automatic gain control maintains a signal level at the input to the demodulators which is constant to within 1 dB. It corrects quickly for increases in signal which would cause clipping and provides a total receiver dynamic range of >45 dB.

PARALLEL BUS INTERFACE

Four 8-bit registers are provided for control, option select and status monitoring. These registers are addressed with the AD0, AD1, and AD2 multiplexed address lines (latched by ALE) and appear to a control microprocessor as four consecutive memory locations. Two control registers and the tone register are read/write memory. The detect register is read only and cannot be modified except by modem response to monitored parameters. The parallel bus interface is not available in the 22-pin package.

SERIAL COMMAND INTERFACE

The serial command interface allows access to the SSI 73K302L control and status registers via a serial command port. In this mode the A0 , A1 and A2 lines provide register addresses for data passed through the data pin under control of the $\overline{RD}$ and $\overline{WR}$ lines. A read operation is initiated when the $\overline{RD}$ line is taken low. The first bit is available after $\overline{RD}$ is brough low and the next seven cycles of EXCLK will then transfer out seven bits of the selected address location LSB first. A write takes place by shifting in eight bits of data LSB first for eight consecutive cycles of EXCLK. $\overline{WR}$ is then pulsed low and data transfer into the selected register occurs on the rising edge of $\overline{WR}$.

SPECIAL DETECT CIRCUITRY

The special detect circuitry monitors the received analog signal to determine status or presence of carrier, answer tone and weak received signal (long loop condition), special tones such as FSK marking and the 900 Hz soft carrier turn-off tone are also detected. A highly frequency selective call progress detector provides adequate discrimination to accurately detect lower quality call progress signals.

DTMF GENERATOR

The DTMF generator will output one of 16 standard tone pairs determined by a 4-bit binary value and TX DTMF mode bit previously loaded into the tone register. Tone generation is initiated when the DTMF mode is selected using the tone register and the transmit enable (CR0 bit D1) is changed from 0 to 1.

SOFT CARRIER TURN-OFF TONE GENERATOR

The soft carrier turn-off tone generator will output a 900 Hz tone. When activated in Bell 202 main channel transmit mode, the output signal will shift to 900 Hz, maintaining phase continuity during the transition.

PIN DESCRIPTION

POWER

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
GND	28	1	I	System Ground.
VDD	15	11	I	Power supply input, 5V ±10%. Bypass with .1 and 22 µF capacitors to GND.
VREF	26	21	O	An internally generated reference voltage. Bypass with .1 µF capacitor to GND.
ISET	24	19	I	Chip current reference. Sets bias current for op-amps. The chip current is set by connecting this pin to VDD through a 2 MΩ resistor. ISET should be bypassed to GND with a .1 µF capacitor.

PARALLEL MICROPROCESSOR INTERFACE

ALE	12	-	I	Address latch enable. The falling edge of ALE latches the address on AD0-AD2 and the chip select on $\overline{CS}$.
AD0-AD7	4-11	-	I/O	Address/data bus. These bidirectional tri-state multiplexed lines carry information to and from the internal registers.
$\overline{CS}$	20	-	I	Chip select. A low on this pin during the falling edge of ALE allows a read cycle or a write cycle to occur. AD0-AD7 will not be driven and no registers will be written if $\overline{CS}$ (latched) is not active. The state of $\overline{CS}$ is latched on the falling edge of ALE.
CLK	1	2	O	Output clock. This pin is selectable under processor control to be either the crystal frequency (for use as a processor clock) or 16 x the data rate for use as a baud rate clock in DPSK mode only. The pin defaults to the crystal frequency on reset.
$\overline{INT}$	17	13	O	Interrupt. This open drain output signal is used to inform the processor that a detect flag has occurred. The processor must then read the detect register to determine which detect triggered the interrupt. $\overline{INT}$ will stay low until the processor reads the detect register or does a full reset.
$\overline{RD}$	14	-	I	Read. A low requests a read of the SSI 73K302L internal registers. Data cannot be output unless both $\overline{RD}$ and the latched $\overline{CS}$ are active or low.
RESET	25	20	I	Reset. An active high signal on this pin will put the chip into an inactive state. All control register bits (CR0, CR1, Tone) will be reset. The output of the CLK pin will be set to the crystal frequency. An internal pull down resistor permits power on reset using a capacitor to VDD.

PIN DESCRIPTION (Continued)

PARALLEL MICROPROCESSOR INTERFACE (Continued)

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
$\overline{WR}$	13	-	I	Write. A low on this informs the SSI 73K302L that data is available on AD0-AD7 for writing into an internal register. Data is latched on the rising edge of $\overline{WR}$. No data is written unless both $\overline{WR}$ and the latched $\overline{CS}$ are active low.

SERIAL MICROPROCESSOR INTERFACE

A0-A2	-	5-7	I	Register Address Selection. These lines carry register addresses and should be valid during any read or write operation.
DATA	-	8	I/O	Serial Control Data. Data for a read/write operation is clocked in or out on the falling edge of the EXCLK pin. The direction of data flow is controlled by the $\overline{RD}$ pin. $\overline{RD}$ low outputs data. $\overline{RD}$ high inputs data.
$\overline{RD}$	-	10	I	Read. A low on this input informs the SSI 73K302L that data or status information is being read by the processor. The falling edge of the $\overline{RD}$ signal will initiate a read from the addressed register. The $\overline{RD}$ signal must continue for eight falling edges of EXCLK in order to read all eight bits of the referenced register. Read data is provided LSB first. Data will not be output unless the $\overline{RD}$ signal is active.
$\overline{WR}$	-	9	I	Write. A low on this input informs the SSI 73K302L that data or status information has been shifted in through the DATA pin and is available for writing to an internal register. The normal procedure for a write is to shift in data LSB first on the DATA pin for eight consecutive falling edges of EXCLK and then to pulse $\overline{WR}$ low. Data is written on the rising edge of $\overline{WR}$.

Note: In the serial, 22-pin version, the pins AD0-AD7, ALE and $\overline{CS}$ are removed and replaced with the pins; A0, A1, A2, DATA, and an unconnected pin. Also, the $\overline{RD}$ and $\overline{WR}$ controls are used differently.

The serial control mode is provided in the parallel control versions by tying ALE high and $\overline{CS}$ low. In this configuration AD7 becomes DATA and AD0, AD1 and AD2 become A0, A1 and A2, respectively.

PIN DESCRIPTION (Continued)

DTE USER INTERFACE

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
EXCLK	19	15	I	External Clock. This signal is used only in synchronous DPSK transmission when the external timing option has been selected. In the external timing mode the rising edge of EXCLK is used to strobe synchronous DPSK transmit data available on the TXD pin. Also used for serial control interface.
RXCLK	23	18	O	Receive Clock. The falling edge of this clock output is coincident with the transitions in the serial received DPSK data output. The rising edge of RXCLK can be used to latch the valid output data. RXCLK will be valid as long as a carrier is present. In Bell 202 mode a clock which is 16 x 1200 or 16 x 150 baud data rate is output.
RXD	22	17	O	Received Data Output. Serial receive data is available on this pin. The data is always valid on the rising edge of RXCLK when in synchronous mode. RXD will output constant marks if no carrier is detected.
TXCLK	18	14	O	Transmit Clock.This signal is used only in synchronous DPSK transmission to latch serial input data on the TXD pin. Data must be provided so that valid data is available on the rising edge of the TXCLK. The transmit clock is derived from different sources depending upon the synchronization mode selection. In Internal Mode the clock is 1200 Hz generated internally. In External Mode TXCLK is phase locked to the EXCLK pin. In Slave Mode TXCLK is phase locked to the RXCLK pin. TXCLK is always active. In Bell 202 mode the output is a 16 x 1200 baud clock or 16 x 150 baud to drive a UART.
TXD	21	16	I	Transmit Data Input. Serial data for transmission is applied on this pin. In synchronous modes, the data must be valid on the rising edge of the TXCLK clock. In asynchronous modes (1200 or 300 baud) no clocking is necessary. DPSK must be 1200 bit/s +1%, -2.5% or +2.3%, -2.5 % in extended overspeed mode.

ANALOG INTERFACE AND OSCILLATOR

RXA	27	22	I	Received modulated analog signal input from the telephone line interface.
TXA	16	12	O	Transmit analog output to the telephone line interface.
XTL1 XTL2	2 3	3 4	I I	These pins are for the internal crystal oscillator requiring a 11.0592 MHz parallel mode crystal and two load capacitors to Ground. XTL2 can also be driven from an external clock.

REGISTER DESCRIPTIONS

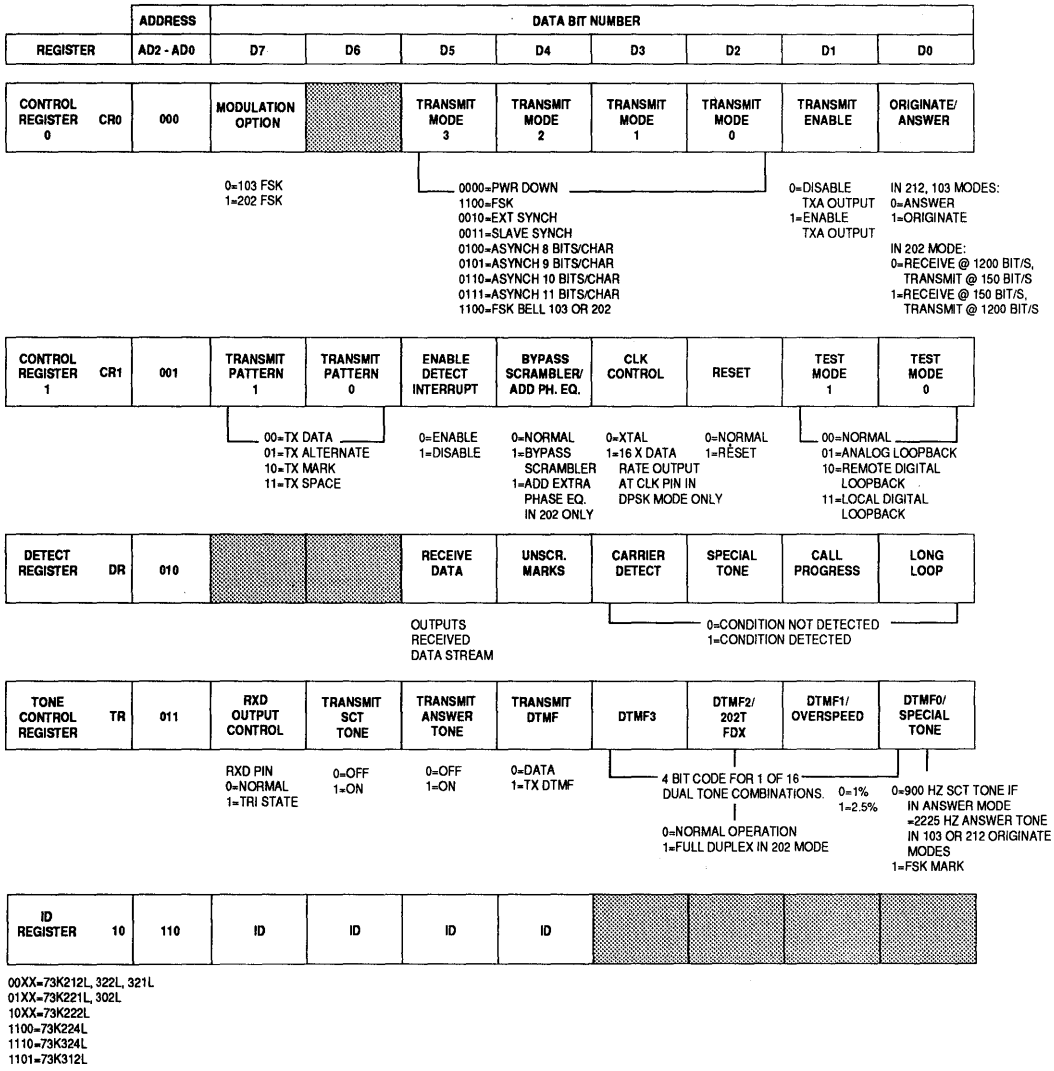
Four 8-bit internal registers are accessible for control and status monitoring. The registers are accessed in read or write operations by addressing the A0 and A1 address lines in serial mode, or the AD0 and AD1 lines in parallel mode. The AD0 and AD1 lines are latched by ALE. Register CR0 controls the method by which data is transferred over the phone line. CR1 controls the interface between the microprocessor and the SSI 73K302L internal state. DR is a detect register which provides an indication of monitored modem status conditions. TR, the tone control register, controls the DTMF generator, answer and guard tones and RXD output gate used in the modem initial connect sequence. All registers are read/write except for DR which is read only. Register control and status bits are identified below:

REGISTER BIT SUMMARY

REGISTER		ADDRESS AD2 - AD0	DATA BIT NUMBER D7	D6	D5	D4	D3	D2	D1	D0
CONTROL REGISTER 0	CR0	000	MODULATION OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE
CONTROL REGISTER 1	CR1	001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTERRUPT	BYPASS SCRAMBLER/ ADD PH. EQ. 202	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0
DETECT REGISTER	DR	010			RECEIVE DATA	UNSCR. MARKS	CARRIER DETECT	SPECIAL TONE	CALL PROGRESS	LONG LOOP
TONE CONTROL REGISTER	TR	011	RXD OUTPUT CONTROL	TRANSMIT SCT TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF3	DTMF/ 202T FDX	DTMF1/ OVERSPEED	DTMF0/ SPEC. TONE/ ANSWER TONE/ SELECT
CONTROL REGISTER 2	CR2	100				THESE REGISTER LOCATIONS ARE RESERVED FOR				
CONTROL REGISTER 3	CR3	101				USE WITH OTHER K-SERIES FAMILY MEMBERS				
ID REGISTER	ID	110	ID	ID	ID	ID				

NOTE: When a register containing reserved control bits is written into, the reserved bits must be programmed as 0's.

REGISTER ADDRESS TABLE



00XX=73K212L, 322L, 321L
01XX=73K221L, 302L
10XX=73K222L
1100=73K224L
1110=73K324L
1101=73K312L

CONTROL REGISTER 0

	D7	D6	D5	D4	D3	D2	D1	D0
CR0 000	MODUL. OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	Answer/ Originate	0	Selects answer mode in 103 and 212A modes (transmit in high band, receive in low band) or in Bell 202 mode, receive at 1200 bit/s and transmit at 150 bit/s.
		1	Selects originate mode in 103 and 212A modes (transmit in low band, receive in high band) or in Bell 202 mode, receive at 150 bit/s and transmit at 1200 bit/s.
			Note: This bit works with TR bit D0 to program special tones detected in Tone Register. See detect and tone registers.
D1	Transmit Enable	0	Disables transmit output at TXA.
		1	Enables transmit output at TXA.
			Note: Answer tone and DTMF TX control require TX enable.
D5, D4,D3, D2	Transmit Mode	D5 D4 D3 D2	
		0 0 0 0	Selects power down mode. All functions disabled except digital interface.
		0 0 0 1	Internal synchronous mode. In this mode TXCLK is an internally derived 1200 Hz signal. Serial input data appearing at TXD must be valid on the rising edge of TXCLK. Receive data is clocked out of RXD on the falling edge of RXCLK.
		0 0 1 0	External synchronous mode. Operation is identical to internal synchronous, but TXCLK is connected internally to EXCLK pin, and a 1200 Hz ± 0.01% clock must be supplied externally.
		0 0 1 1	Slave synchronous mode. Same operation as other synchronous modes. TXCLK is connected internally to the RXCLK pin in this mode.
		0 1 0 0	Selects DPSK asynchronous mode - 8 bits/character (1 start bit, 6 data bits, 1 stop bit).
		0 1 0 1	Selects DPSK asynchronous mode - 9 bits/character (1 start bit, 7 data bits, 1 stop bit).
		0 1 1 0	Selects DPSK asynchronous mode - 10 bits/character (1 start bit, 8 data bits, 1 stop bit).
		0 1 1 1	Selects DPSK asynchronous mode - 11 bits/character (1 start bit, 8 data bits, Parity and 1 or 2 stop bits).
		1 1 0 0	Selects 103 or 202 FSK operation.

CONTROL REGISTER 0 (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
CR0 000	MODUL. OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE

BIT NO.	NAME	CONDITION	DESCRIPTION
D6		0	Not used; must be written as a "0."
D7	Modulation Option	D7 D5 D4	Selects:
		X 0 X	DPSK asynchronous mode at 1200 bit/s.
		0 1 1	FSK Bell 103 mode.
		1 1 1	FSK Bell 202 mode.

CONTROL REGISTER 1

	D7	D6	D5	D4	D3	D2	D1	D0
CR1 001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTER.	BYPASS SCRAMB/ ADD PH. EQ.	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D1, D0	Test Mode	D1 D0	
		0 0	Selects normal operating mode.
		0 1	Analog loopback mode. Loops the transmitted analog signal back to the receiver, and causes the receiver to use the same center frequency as the transmitter. To squelch the TXA pin, transmit enable must be forced low. Not supported in FDX202 mode.
		1 0	Selects remote digital loopback. Received data is looped back to transmit data internally, and RXD is forced to a mark. Data on TXD is ignored.
		1 1	Selects local digital loopback. Internally loops TXD back to RXD and continues to transmit carrier from TXA pin.
D2	Reset	0	Selects normal operation.
		1	Resets modem to power down state. All control register bits (CR0, CR1, Tone) are reset to zero. The output of the CLK pin will be set to the crystal frequency.

CONTROL REGISTER 1 (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
CR1 001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTER.	BYPASS SCRAMB/ ADD PH. EQ.	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D3	CLK Control	0	Selects 11.0592 MHz crystal echo output at CLK pin.
		1	Selects 16 X the data rate, output at CLK pin in DPSK modes only.
D4*	Bypass Scrambler/ Add Phase Equalization	0	Selects normal operation. DPSK data is passed through scrambler.
		1	Selects Scrambler Bypass. DPSK data is routed around scrambler in the transmit path. In Bell 202 mode, additional phase equalization is added to the main channel filters when D4 is set to 1.
D5	Enable Detect Interrupt	0	Disables interrupt at $\overline{INT}$ pin.
		1	Enables $\overline{INT}$ output. An interrupt will be generated with a change in status of DR bits D1-D4. The special tone and call progress detect interrupts are masked when the TX enable bit is set. Carrier detect is masked when TX DTMF is activated. All interrupts will be disabled if the device is in power down mode.
D7, D6	Transmit Pattern	D7 D6	
		0 0	Selects normal data transmission as controlled by the state of the TXD pin.
		0 1	Selects an alternating mark/space transmit pattern for modem testing.
		1 0	Selects a constant mark transmit pattern.
		1 1	Selects a constant space transmit pattern.

* D4 should always be set to 1 when receiving 1200 bit/s data and to 0 when transmitting 1200 bit/s data in 202 mode.

3

DETECT REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
DR 010			RECEIVE DATA	UNSCR. MARK	CARR. DETECT	SPECIAL TONE	CALL PROG.	LONG LOOP

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	Long Loop	0	Indicates normal received signal.
		1	Indicates low received signal level.
D1	Call Progress Detect	0	No call progress tone detected.
		1	Indicates presence of call progress tones. The call progress detection circuitry is activated by energy in the normal 350 to 620 Hz call progress band.
D2	Special Tone Detect	0	No special tone detected as programmed by CR0 bit D0 and Tone Register bit D0.
		1	Special tone detected. The detected tone is:
			(1) 2225 Hz answer tone if D0 of TR=0 and the device is in Bell 103 or 212A originate mode.
			(2) Soft carrier turn-off tone if D0 of TR=0 and the device is in Bell 202 answer mode.
			(3) an FSK mark in the mode the device is set to receive if D0 of TR is set to 1.
			Tolerance on special tones is ±3%.
D3	Carrier Detect	0	No carrier detected in the receive channel.
		1	Indicated carrier has been detected in the received channel.
D4	Unscrambled Mark Detect	0	No unscrambled mark.
		1	(DPSK only) Indicates detection of unscrambled marks in the received data. A valid indication requires that unscrambled marks be received for > 165.5 ± 6.5 ms.
D5	Receive Data		Continuously outputs the received data stream. This data is the same as that output on the RXD pin, but it is not disabled when RXD is tri-stated.
D6, D7			Not used.

TONE REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.	TRANSMIT SOFT CARRIER TURN-OFF TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2/ 202 FDX	DTMF 1/ OVER-SPEED	DTMF 0/ SPECIAL TONE SEL

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	DTMF 0/ Special Tone Detect/Select	D5 D4 D0	D0 interacts with bits D6, D4, and CR0 as shown.
		0 1 X	Transmit DTMF tones.
		0 0 0	2225 Hz answer tone will be detected in D2 of DR if originate mode is selected in CR0.
			900 Hz SCT tone will be detected in D2 of DR if Bell 202 answer mode is selected in CR0.
		X 0 1	Mark of an FSK mode selected in CR0 is to be detected in D2 of DR.
		1 0 0	2225 Hz answer tone will be generated when in answer mode and transmit enable is selected in CR0.
		1 0 1	2100 Hz answer tone will be generated when in answer mode and transmit enable is selected in CR0.
D1	DTMF 1/ Overspeed	D4 D1	D1 interacts with D4 as shown.
		0 0	Asynchronous DPSK 1200 bit/s +1.0% -2.5%.
		0 1	Asynchronous DPSK 1200 bit/s +2.3% -2.5%.
D2	DTMF2/202T FDX	0	Enables 202 half-duplex operation if D4=0
		1	Enables 202 full-duplex operation if D4=0
D3, D2, D1, D0	DTMF 3, 2, 1, 0	D3 D2 D1 D0	
		0 0 0 0 - 1 1 1 1	Programs 1 of 16 DTMF tone pairs that will be transmitted when TX DTMF and TX enable bit (CR0, bit D1) are set. Tone encoding is shown below:

KEYBOARD EQUIVALENT	DTMF CODE D3 D2 D1 D0	TONES LOW HIGH
1	0 0 0 1	697 1209
2	0 0 1 0	697 1336
3	0 0 1 1	697 1477
4	0 1 0 0	770 1209
5	0 1 0 1	770 1336
6	0 1 1 0	770 1477
7	0 1 1 1	852 1209
8	1 0 0 0	852 1336
9	1 0 0 1	852 1477
0	1 0 1 0	941 1336

TONE REGISTER (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.	TRANSMIT SOFT CARRIER TURN-OFF TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2/ 202T FDX	DTMF 1/ OVER-SPEED	DTMF 0/ SPECIAL TONE SEL

BIT NO.	NAME	CONDITION	DESCRIPTION
D3, D2, D1, D0 (cont.)			KEYBOARD EQUIVALENT / DTMF CODE D3 D2 D1 D0 / TONES LOW HIGH
			* 1 0 1 1 941 1209
			# 1 1 0 0 941 1477
			A 1 1 0 1 697 1633
			B 1 1 1 0 770 1633
			C 1 1 1 1 852 1633
			D 0 0 0 0 941 1633
D4	Transmit DTMF	0	Disable DTMF.
		1	Activate DTMF. The selected DTMF tones are transmitted continuously when this bit is high. TX DTMF overrides all other transmit functions.
D5	Transmit Answer Tone	0	Disables answer tone generator.
		1	Enables answer tone generator. A 2225 Hz answer tone will be transmitted continuously when the transmit enable bit is set. To transmit answer tone, the device must be in answer mode.
D6	Transmit SCT Tone	0	Disables SCT tone generator.
		1	Transmit SCT tone in Bell 202 mode.
D7	RXD Output Control	0	Enables RXD pin. Receive data will be output on RXD.
		1	Disables RXD pin. The RXD pin reverts to a high impedance with internal weak pull-up resistor.

Notes for Tone Register use:

1. To detect SCT tone, 202 answer mode must be selected. To transmit SCT tone, 202 originate mode must be selected.
2. For answer tone detection, 103 or 212 originate mode must be active. To transmit answer tone, the 73K302 must be in 103 or 212 answer mode.
3. After completion of DTMF dialing, bit D2 should be reset unless 202 full-duplex mode is selected.

ID REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
ID 110	ID	ID	ID	ID				

BIT NO.	NAME	CONDITION	DESCRIPTION
D7, D6	Device Identification Signature	D7 D6 D5 D4	Indicates Device:
		0 0 X X	SSI 73K212L, 73K321L or 73K322L or 73K321L
		0 1 X X	SSI 73K221L or 73K302L
		1 0 X X	SSI 73K222L
		1 1 0 0	SSI 73K224L
		1 1 1 0	SSI 73K324L
		1 1 0 1	SSI 73K312L

3

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

PARAMETER	RATING
VDD Supply Voltage	14V
Storage Temperature	-65 to 150°C
Soldering Temperature (10 sec.)	260°C
Applied Voltage	-0.3 to VDD+0.3V
Note: All inputs and outputs are protected from static charge using built-in, industry standard protection devices and all outputs are short-circuit protected.	

RECOMMENDED OPERATING CONDITIONS

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
VDD Supply voltage		4.5	5	5.5	V
TA, Operating Free-Air Temp.		-40		+85	°C
Clock Variation	(11.0592 MHz) Crystal or external clock	-0.01		+0.01	%
External Components (Refer to Application section for placement.)					
VREF Bypass Capacitor	(External to GND)	0.1			µF
Bias setting resistor	(Placed between VDD and ISET pins)	1.8	2	2.2	MΩ
ISET Bypass Capacitor	(ISET pin to GND)	0.1			µF
VDD Bypass Capacitor 1	(External to GND)	0.1			µF
VDD Bypass Capacitor 2	(External to GND)	22			µF
XTL1 Load Capacitor	Depends on crystal characteristics;			40	pF
XTL2 Load Capacitor	from pin to GND			20	

DC ELECTRICAL CHARACTERISTICS
(TA = -40°C to 85°C, VDD = recommended range unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
IDD, Supply Current	ISET Resistor = 2 MΩ				
IDDA, Active	CLK = 11.0592 MHz		8	12	mA
IDD1, Power-down	CLK = 11.0592 MHz			4	mA
IDD2, Power-down	CLK = 19.200 kHz			3	mA
Digital Inputs					
VIH, Input High Voltage					
Reset, XTL1, XTL2		3.0		VDD	V
All other inputs		2.0		VDD	V
VIL, Input Low Voltage		0		0.8	V
IIH, Input High Current	VI = VIH Max			100	µA
IIL, Input Low Current	VI = VIL Min	-200			µA
Reset Pull-down Current	Reset = VDD	1		50	µA
Input Capacitance	All Digital Input Pins			10	pF
Digital Outputs					
VOH, Output High Voltage	IOH MIN = -0.4 mA	2.4		VDD	V
VOL, Output Low Voltage	IO MAX = 1.6 mA			0.4	V
VOL, CLK Output	IO = 3.6 mA			0.6	V
RXD Tri-State Pull-up Curr.	RXD = GND	-1		-50	µA
CMAX, CLK Output	Maximum Capacitive Load			15	pF
Capacitance					
Inputs	Capacitance, all Digital Input pins			10	pF
XTL1, 2 Load Capacitors	Depends on crystal	15		60	pF
CLK	Maximum Capacitive Load			15	pF

DYNAMIC CHARACTERISTICS AND TIMING
(TA = -40°C to +85°C, VDD = Recommended range unless otherwise noted.)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
DPSK Modulator					
Carrier Suppression	Measured at TXA	45			dB
Output Amplitude	TX scrambled marks	-11	-10	-9	dBm0
FSK Modulator					
Output Freq. Error	CLK = 11.0592 MHz	-0.35		+0.35	%
Transmit Level	Transmit Dotting Pattern	-11	-10	-9	dBm0
Soft Carrier Turnoff Tone		-11.9	-10.9	-9.9	dBm0
Harmonic Distortion in 700-2900 Hz band	THD in the alternate band DPSK or FSK		-60	-50	dB
Output Bias Distortion	Transmit Dotting Pattern In ALB @ RXD		±3		%
Total Output Jitter	Random Input in ALB @ RXD	-10		+10	%
DTMF Generator	Must not be in 202 mode				
Freq. Accuracy		-0.25		+0.25	%
Output Amplitude, Low group	DPSK mode	-10	-9	-8	dBm0
Output Amplitude, High group	DPSK mode	-8	-7	-6	dBm0
Twist	High-Band to Low-Band	1.0	2.0	3.0	dB
Long Loop Detect	With Sinusoid	-38		-28	dBm0
Dynamic Range	Refer to Performance Curves		45		dB

Note: Parameters expressed in dBm0 refer to the following definition:

5V Version:
0 dB loss in the Transmit path to the line.
2 dB gain in the Receive path from the line.

Refer to the Basic Box Modem diagram in the Applications section for the DAA design.

3

DYNAMIC CHARACTERISTICS AND TIMING (Continued)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Call Progress Detector					
Detect Level	-3 dB points in 285 and 675 Hz	-38			dBm0
Reject Level	Test signal is a 460 Hz sinusoid			-45	dBm0
Delay Time	-70 dBm0 to -30 dBm0 STEP	20		40	ms
Hold Time	-30 dBm0 to -70 dBm0 STEP	20		40	ms
Hysteresis		2			dB
Carrier Detect					
Threshold	DPSK or FSK receive data	-49		-42	dBm0
Delay Time					
Bell 103		8		20	ms
Bell 212A		15		32	ms
Bell 202 Forward Channel		6		12	ms
Bell 202 Back Channel		25		40	ms
Hold Time					
Bell 103		6		20	ms
Bell 212A		10		24	ms
Bell 202 Forward Channel		3		8	ms
Bell 202 Back Channel		10		25	ms
Hysteresis		2			dB
Special Tone Detectors					
Detect Level	See definitions for TR bit D0 mode	-49		-42	dBm0
Delay Time					
Answer tone		10		25	ms
900 Hz SCT tone	Preceded by valid carrier*	4		10	ms
202 Main Channel Mark		10		25	ms
202 Back Channel Mark		20		65	ms
1270 or 2225 Hz marks		10		25	ms

* If SCT duration >4ms, it is guaranteed to detect.

DYNAMIC CHARACTERISTICS AND TIMING (Continued)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Special Tone Detectors (Continued)					
Hold Time					
Answer tone		4		15	ms
900 Hz SCT tone		1		10	ms
202 Main Channel Mark		3		10	ms
202 Back Channel Mark		10		25	ms
1270 or 2225 Hz marks		5		15	ms
Hysteresis		2			dB
Detect Freq. Range	Any Special Tone	-3		+3	%
Output Smoothing Filter					
Output load	TXA pin; FSK Single Tone out for THD = -50 dB in 0.3 to 3.4 kHz	10			kΩ
				50	pF
Out of Band Energy	Frequency >12 kHz in all modes See Transmit Energy Spectrum			-60	dBm0
Output Impedance	TXA pin		20	50	Ω
Clock Noise	TXA pin; 76.8 kHz or 122.88 kHz in 202 main channel		0.1	0.4	mVrms
Carrier VCO					
Capture Range	Originate or Answer	-10		+10	Hz
Capture Time	-10 Hz to +10 Hz Carrier Frequency Change		40	100	ms
DPSK Recovered Clock					
Capture Range	% of data rate (center at 1200 Hz)	-625		+625	ppm
Data Delay Time	Analog data in at RXA pin to receive data valid at RXD pin		30	50	ms
Tone Generator					
Tone Accuracy	DTMF or FSK tones	-5		+5	Hz
Tone Level	For DTMF, must not be in 202 mode	-1		+1	dB

3

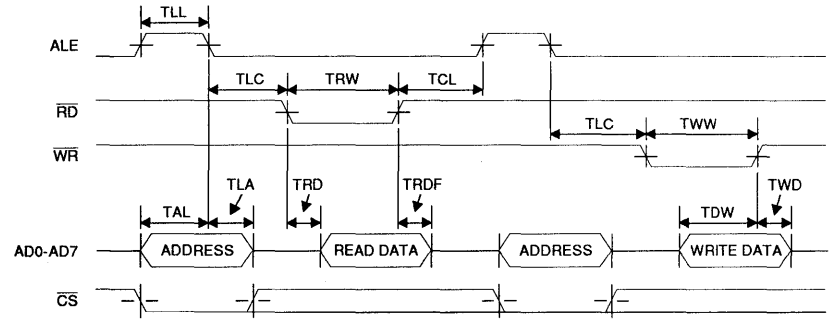
DYNAMIC CHARACTERISTICS AND TIMING (Continued)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Timing (Refer to Timing Diagrams)					
TAL	$\overline{CS}$/Addr. setup before ALE Low	25			ns
TLA	$\overline{CS}$/Addr. hold after ALE Low	20			ns
TLC	ALE Low to $\overline{RD}/\overline{WR}$ Low	30			ns
TCL	$\overline{RD}/\overline{WR}$ Control to ALE High	-5			ns
TRD	Data out from $\overline{RD}$ Low	0		140	ns
TLL	ALE width	30			ns
TRDF	Data float after $\overline{RD}$ High	0		5	ns
TRW	$\overline{RD}$ width	200		25000	ns
TWW	$\overline{WR}$ width	140		25000	ns
TDW	Data setup before $\overline{WR}$ High	40			ns
TWD	Data hold after $\overline{WR}$ High	10			ns
TCKD	Data out after EXCLK Low			200	ns
TCKW	$\overline{WR}$ after EXCLK Low	150			ns
TDCK	Data setup before EXCLK Low	150			ns
TAC	Address setup before control*	50			ns
TCA	Address hold after control*	50			ns
TWH	Data Hold after EXCLK	20			

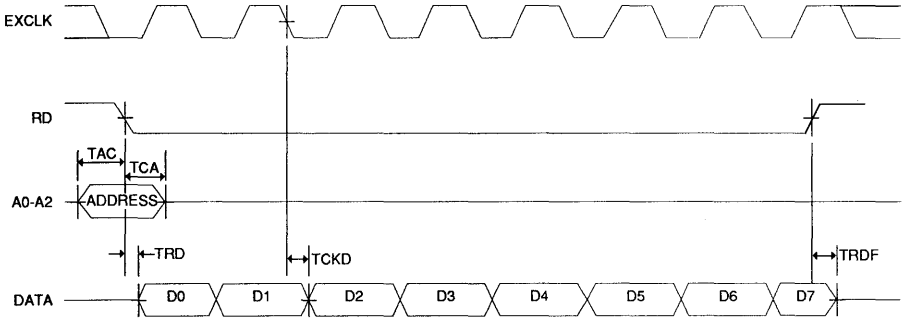
* Control for setup is the falling edge of $\overline{RD}$ or $\overline{WR}$.
Control for hold is the falling edge of $\overline{RD}$ or the rising edge of $\overline{WR}$.

TIMING DIAGRAMS

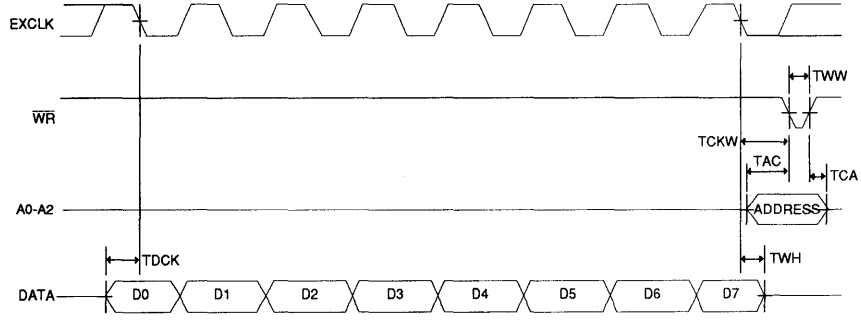
BUS TIMING DIAGRAM (PARALLEL VERSION)



READ TIMING DIAGRAM (SERIAL VERSION)



WRITE TIMING DIAGRAM (SERIAL VERSION)



3

APPLICATIONS INFORMATION

GENERAL CONSIDERATIONS

Figures 1 and 2 show basic circuit diagrams for K-Series modem integrated circuits. K-Series products are designed to be used in conjunction with a control processor, a UART or RS-232 serial data interface, and a DAA phone line interface to function as a typical intelligent modem. The K-Series ICs interface directly with Intel 8048 and 80C51 microprocessors for control and status monitoring purposes. Two typical DAA arrangements are shown: one for a split ±5 or ±12 volt design and one for a single 5V design. These diagrams are for reference only and do not represent production-ready modem designs.

K-Series devices are available with two control interface versions: one for a parallel multiplexed address/data interface, and one for a serial interface. The parallel version is intended for use with 8039/48 or 8031/51 microcontrollers from Intel or many other manufacturers. The serial interface 22-pin version can be used with other microcontrollers or in applications where only a limited number of port lines are available or the application does not lend itself to a multiplexed address/data interface. The parallel versions may also be used in the serial mode, as explained in the data sheet pin description.

In most applications the controller will monitor the serial data for commands from the DTE and the received data for break signals from the far end modem. In this way, commands to the modem are sent over the same line as the transmitted data. In other applications the RS-232 interface handshake lines are used for modem control.

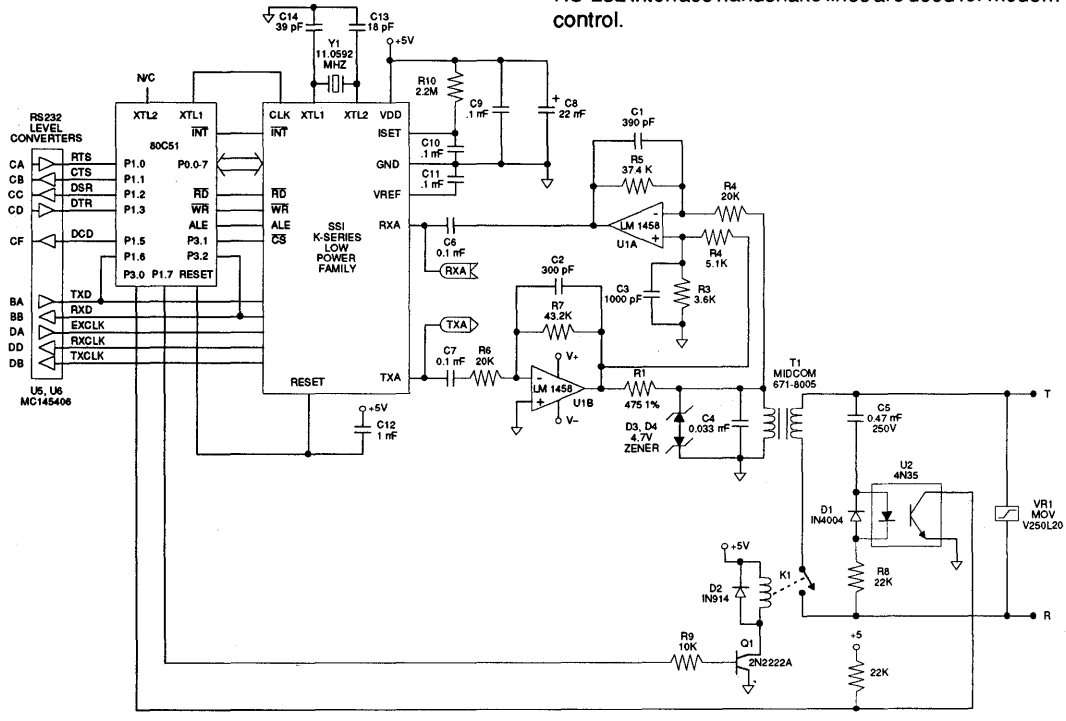


FIGURE 1: Basic Box Modem with Dual-Supply Hybrid

DIRECT ACCESS ARRANGEMENT (DAA)

The telephone line interfaces show two examples of how the "hybrid" may be implemented. The split supply design (Figure 1) is a typical two op-amp hybrid. The receive op-amp serves two purposes. It supplies gain to amplify the receive signal to the proper level for the modem's detectors and demodulator, and it removes the transmitted signal from the receive signal present at the transformer. This is done by supplying a portion of the transmitted signal to the non-inverting input of the receive op-amp at the same amplitude as the signal appearing at the transformer, making the transmit signal common mode.

The single-supply hybrid is more complex than the dual-supply version described above, but its use eliminates the need for a second power supply. This circuit (Figure 2) uses a bridged drive to allow undistorted signals to be sent with a single 5V supply. Because DTMF tones utilize a higher amplitude than data, these signals will clip if a single-ended drive approach is used. The bridged driver uses an extra op-amp (U1A) to invert the signal coming from the gain setting op-amp (U1B) before sending it to the other leg of the transformer. Each op-amp then supplies half the drive signal to the transformer. The receive amplifier (U1C) picks off its signal at the junction of the impedance matching resistor and the transformer. Because the bottom leg of the transformer is being driven in one direction by U1A and the resistor is driven in the opposite direction at the same time by U1B, the junction of the transformer and resistor remains relatively constant and the receive signal is unaffected.

DESIGN CONSIDERATIONS

Silicon Systems' 1-chip modem products include all basic modem functions. This makes these devices adaptable for use in a variety of applications, and as easy to control as conventional digital bus peripherals.

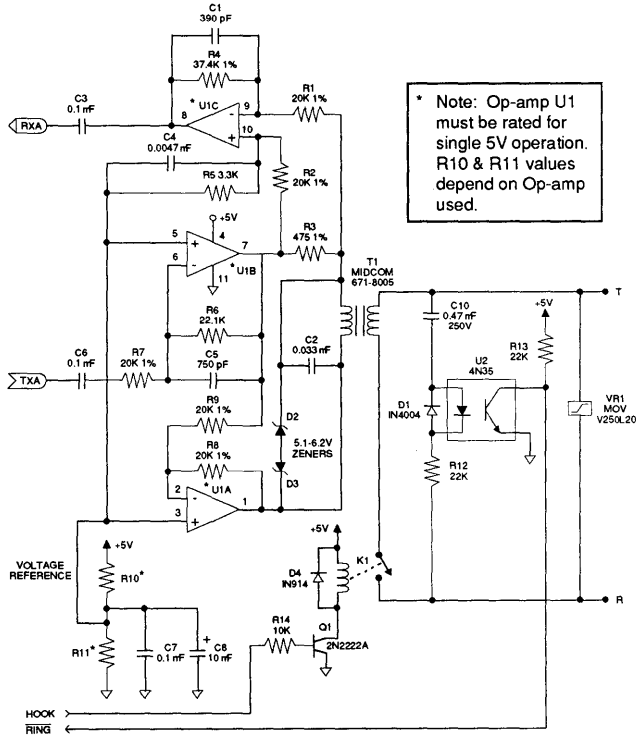


FIGURE 2: Single 5V Hybrid Version

Unlike digital logic circuitry, modem designs must properly contend with precise frequency tolerances and very low level analog signals, to ensure acceptable performance. Using good analog circuit design practices will generally result in a sound design. Following are additional recommendations which should be taken into consideration when starting new designs.

CRYSTAL OSCILLATOR

The K-Series crystal oscillator requires a parallel mode (antiresonant) crystal which operates at 11.0592 MHz. It is important that this frequency be maintained to within ±0.01% accuracy.

In order for a parallel mode crystal to operate correctly and to specification, it must have a load capacitor connected to the junction of each of the crystal and internal inverter connections, terminated to ground. The values of these capacitors depend primarily on the crystal's characteristics, and to a lesser degree on the internal inverter circuit. The values used affect the accuracy and start up characteristics of the oscillator.

LAYOUT CONSIDERATIONS

Good analog/digital design rules must be used to control system noise in order to obtain highest performance in modem designs. The more digital circuitry present on the PC board, the more this attention to noise control is needed. The modem should be treated as a high impedance analog device. A 22 mF electrolytic capacitor in parallel with a 0.1 mF ceramic capacitor between VDD and GND is recommended. Liberal use of ground planes and larger traces on power and ground are also highly favored. High speed digital circuits tend to generate a significant amount of EMI (Electro-Magnetic Interference) which must be minimized in order to meet regulatory agency limitations. To accomplish this, high speed digital devices should be locally bypassed, and the telephone line interface and K-Series device should be located close to each other near the area of the board where the phone line connection is accessed. To avoid problems, power supply and ground traces should be routed separately to the analog and digital functions on the board, and digital signals should not be routed near low level or high impedance analog traces. The analog and digital grounds should only connect at one point near the K-Series device ground pin to avoid ground loops. The K–Series modem IC's should have both high frequency and low frequency bypassing as close to the package as possible.

MODEM PERFORMANCE CHARACTERISTICS

The curves presented here define modem IC performance under a variety of line conditions while inducing disturbances that are typical of those encountered during data transmission on public service telephone lines. Test data was taken using an AEA Electronics' "Autotest I" modem test set and line simulator, operating under computer control. All tests were run full-duplex, using a Concord Data Systems 224 as the reference modem. A 511 pseudo-random-bit pattern was used for each data point. Noise was C-message weighted and all signal-to-noise (S/N) ratios reflect total power measurements similar to the CCITT V.56 measurement specification. The individual tests are defined as follows.

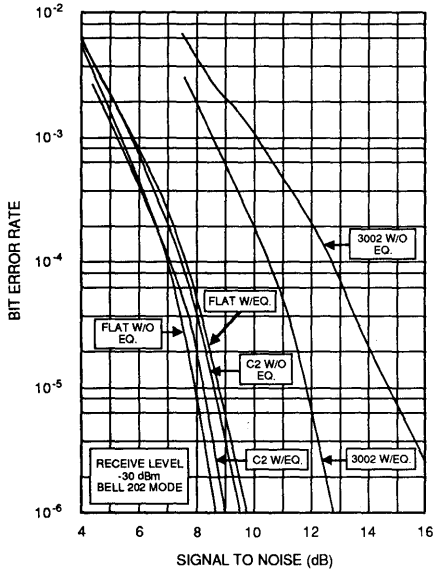
BER vs. S/N

This test measures the ability of the modem to operate over noisy lines with a minimum of data-transfer errors. Since some noise is generated in the best of dial-up lines, the modem must operate with the lowest S/N ratio possible. Better modem performance is indicated by test curves that are closest to the BER axis. A narrow spread between curves representing the four line parameters indicates minimal variation in performance while operating over a range of aberrant operating conditions. Typically, a DPSK modem will exhibit better BER-performance test curves receiving in the low band than in the high band.

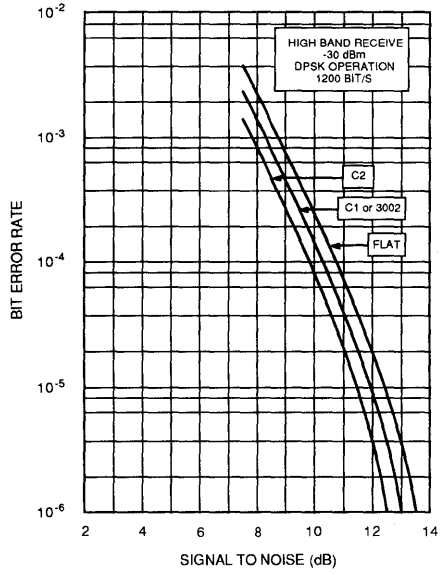
BER vs. Receive Level

This test measures the dynamic range of the modem. Because signal levels vary widely over dial-up lines, the widest possible dynamic range is desirable. The minimum Bell specification calls for 36 dB of dynamic range. S/N ratios are held constant at the indicated values while the receive level is lowered from a very high to very low signal levels. The width of the "bowl" of these curves, taken at the BER point, is the measure of dynamic range.

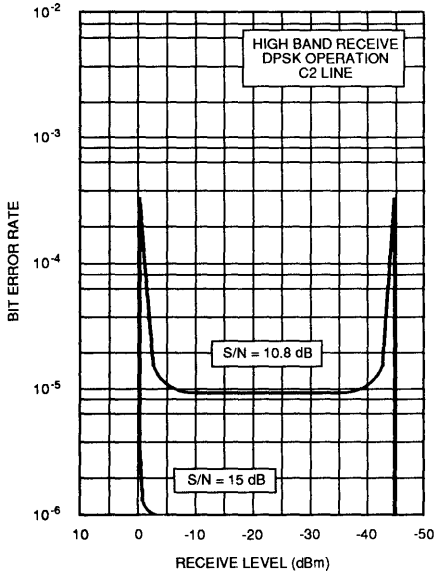
SSI 73K302L
BER vs S/N



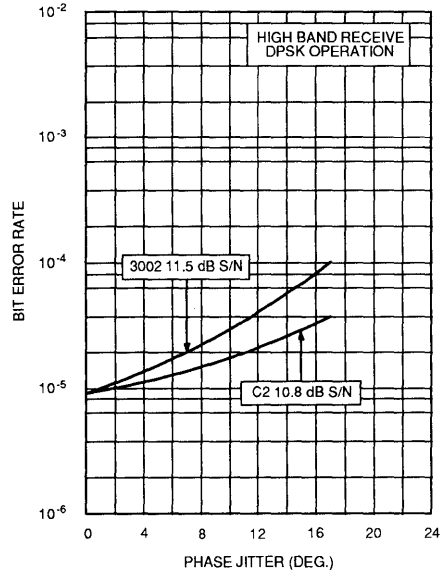
SSI 73K302L
BER vs S/N

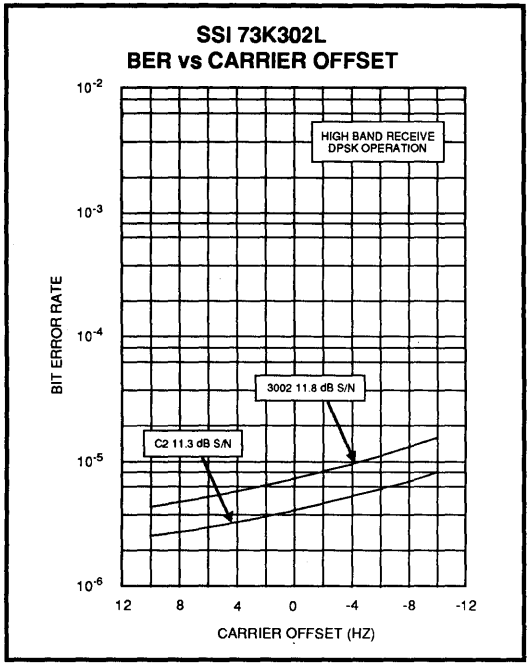


SSI 73K302L
BER vs RECEIVE LEVEL



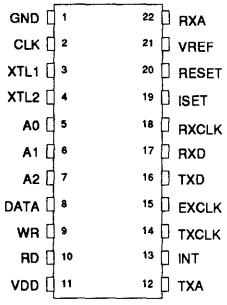
SSI 73K302L
BER vs PHASE JITTER



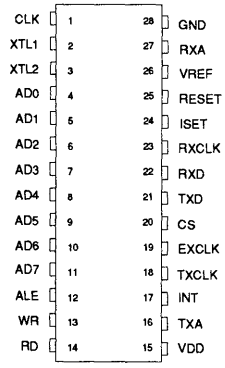

SSI 73K302L
BER vs CARRIER OFFSET
HIGH BAND RECEIVE
DPSK OPERATION
3002 11.8 dB S/N
C2 11.3 dB S/N
BIT ERROR RATE
10-2
10-3
10-4
10-5
10-6
12
8
4
0
-4
-8
-12
CARRIER OFFSET (HZ)

PACKAGE PIN DESIGNATIONS
(Top View)

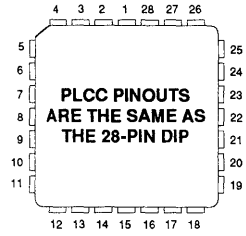
CAUTION: Use handling procedures necessary for a static sensitive component.



400-Mil 22-Pin DIP



600-Mil 28-Pin DIP



28-Pin PLCC

3

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 73K302L with Parallel Bus Interface		
28-Pin Dip	73K302L-IP	73K302L-IP
28-Lead PLCC	73K302L-IH	73K302L-IH
SSI 73K302L with Serial Interface		
22-pin Dip	73K302SL-IP	73K302SL-IP

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Notes:

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SSI 73K321L
CCITT V.23, V.21
Single-Chip Modem

January 1994

3

DESCRIPTION

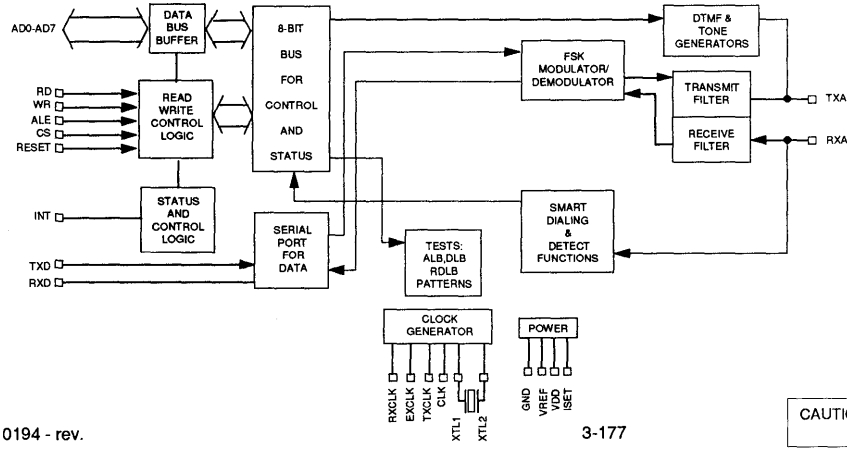
The SSI 73K321L is a highly integrated single-chip modem IC which provides the functions needed to construct a CCITT V.23 and V.21 compatible modem, capable of 0-300 bit/s full-duplex or 0-1200 bit/s half-duplex operation over dial-up telephone lines. The 73K321L provides 1200 bit/s operation in V.23 mode and 300 bit/s in V.21 mode. The SSI 73K321L also can both detect and generate the 2100 Hz answer tone needed for call initiation. The SSI 73K321L integrates analog, digital, and switched-capacitor array functions on a single substrate,offering excellent performance and a high level of functional integration in a single 28- or 22-pin DIP configuration. The SSI 73K321L operates from a single +5V supply with very low power consumption.

The SSI 73K321L includes the FSK modulator/demodulator functions, call progress and handshake tone monitor test modes, and a tone generator capable of producing DTMF, answer, calling tones. The SSI 73K321L is designed to appear to the systems designer as a microprocessor peripheral, and will easily interface with popular one-chip microprocessors (80C51 typical) for control of modem functions through its 8-bit multiplexed address/data bus or via an optional serial control bus. An ALE control line simplifies address demultiplexing. Data communications occurs through a separate serial port only. (Continued)

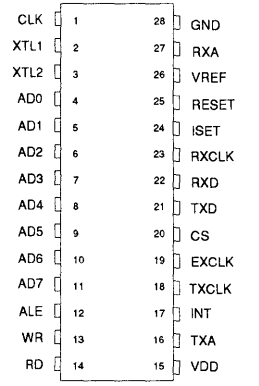
FEATURES

- **One-chip CCITT V.23 and V.21 standard compatible modem data pump**
- **Full-duplex operation at 0-300 bit/s (V.21) or 0-1200 bit/s (V.23) forward channel with or without 0–75 bits/s back channel**
- **Full Duplex 0-1200 bit/s (V.23) in 4-wire mode**
- **Pin and software compatible with other SSI K-Series 1-chip modems**
- **Interfaces directly with standard microprocessors (8048, 80C51 typical)**
- **Serial or parallel microprocessor bus for control**
- **Serial port for data transfer**
- **Call progress, carrier, precise answer tone (2100 Hz), calling tone (1300 Hz) and FSK mark detectors**
- **DTMF generator**
- **Test modes available: ALB, DL, RDL, Mark, Space, Alternating bit patterns**
- **Precise automatic gain control allows 45 dB dynamic range**
- **Space efficient 28-pin PLCC package available**
- **CMOS technology for low power consumption using 30 mW @ 5V from a single power supply**

BLOCK DIAGRAM



PIN DIAGRAM



CAUTION: Use handling procedures necessary for a static sensitive component.

SSI 73K321L
CCITT V.23, V.21
Single-Chip Modem

DESCRIPTION (Continued)

The SSI 73K321L is ideal for either free standing or integral system modem applications where multi-standard data communications over the 2-wire switched telephone network is desired. Typical uses include videotex terminals, low-cost integral modems and built-in diagnostics for office automation or industrial control systems. The 73K321L's high functionality, low power consumption and efficient packaging simplify design requirements and increase system reliability in these applications. A complete modem requires only the addition of the phone line interface, a control microprocessor, and RS-232 level converter for a typical system. The SSI 73K321L is part of Silicon Systems K-Series family of pin and function compatible single-chip modem products. These devices allow systems to be configured for higher speeds and Bell or CCITT operation with only a single component change.

OPERATION

FSK MODULATOR/DEMODULATOR

The FSK modulator produces a frequency modulated analog output signal using two discrete frequencies to represent the binary data. V.21 mode uses 980 and 1180 Hz (originate, mark and space) or 1650 and 1850 Hz (answer, mark and space). V.23 mode uses 1300 and 2100 Hz for the main channel and 390 and 450 Hz for the back channel. The modulation rate of the back channel is up to 75 baud. Demodulation involves detecting the received frequencies and decoding them into the appropriate binary value.

PASSBAND FILTERS AND EQUALIZERS

High and low band filters are included to shape the amplitude and phase response of the transmit and receive signals and provide compromise delay equalization and rejection of out-of-band signals in the receive channel. Amplitude and phase equalization are necessary to compensate for distortion of the transmission line and to reduce intersymbol interference in the bandlimited receive signal.

AGC

The automatic gain control maintains a signal level at the input to the demodulators which is constant to within 1 dB. It corrects quickly for increases in signal which would cause clipping and provides a total receiver dynamic range of >45 dB.

PARALLEL BUS INTERFACE

Four 8-bit registers are provided for control, option select and status monitoring. These registers are addressed with the AD0, AD1, and AD2 multiplexed address lines (latched by ALE) and appear to a control microprocessor as four consecutive memory locations. Two control registers and the tone register are read/write memory. The detect register is read only and cannot be modified except by modem response to monitored parameters. The parallel bus interface is not available with the 22-pin package.

SERIAL COMMAND INTERFACE

The Serial Command mode allows access to the SSI 73K321L control and status registers via a serial command port. In this mode the A0 , A1 and A2 lines provide register addresses for data passed through the data pin under control of the $\overline{RD}$ and $\overline{WR}$ lines. A read operation is initiated when the $\overline{RD}$ line is taken low. The first bit is available after RD is brought low and the next seven cycles of EXCLK will then transfer out seven bits of the selected address location LSB first. A write takes place by shifting in eight bits of data LSB first for eight consecutive cycles of EXCLK. $\overline{WR}$ is then pulsed low and data transferred into the selected register occurs on the rising edge of $\overline{WR}$.

SPECIAL DETECT CIRCUITRY

The special detect circuitry monitors the received analog signal to determine status or presence of carrier, answer tone and weak received signal (long loop condition), special tones such as FSK marking and the 1300 Hz calling tone are also detected. A highly frequency selective call progress detector provides adequate discrimination to accurately detect European call progress signals.

DTMF GENERATOR

The DTMF generator will output one of 16 standard tone-pairs determined by a 4-bit binary value and TX DTMF mode bit previously loaded into the tone register. Dialing is initiated when the DTMF mode is selected using the tone register and the transmit enable (CR0 bit D1) is changed from 0 to 1.

PIN DESCRIPTION

POWER

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
GND	28	1	I	System Ground.
VDD	15	11	I	Power supply input, 5V ±10%. Bypass with 0.1 and 22 µF capacitors to GND.
VREF	26	21	O	An internally generated reference voltage. Bypass with 0.1 µF capacitor to GND.
ISET	24	19	I	Chip current reference. Sets bias current for op-amps. The chip current is set by connecting this pin to VDD through a 2 MΩ resistor. ISET should be bypassed to GND with a 0.1 µF capacitor.

PARALLEL MICROPROCESSOR INTERFACE

ALE	12	-	I	Address latch enable. The falling edge of ALE latches the address on AD0-AD2 and the chip select on $\overline{CS}$.
AD0-AD7	4-11	-	I/O	Address/data bus. These bidirectional tri-state multiplexed lines carry information to and from the internal registers.
$\overline{CS}$	20	-	I	Chip select. A low during the falling edge of ALE on this pin allows a read cycle or a write cycle to occur. AD0-AD7 will not be driven and no registers will be written if $\overline{CS}$ (latched) is not active. The state of $\overline{CS}$ is latched on the falling edge of ALE.
CLK	1	2	O	Output clock. This pin is the output of the crystal oscillator frequency only in the SSI 73K321.
$\overline{INT}$	17	13	O	Interrupt. This open drain output signal is used to inform the processor that a detect flag has occurred. The processor must then read the detect register to determine which detect triggered the interrupt. $\overline{INT}$ will stay low until the processor reads the detect register or does a full reset.
$\overline{RD}$	14	-	I	Read. A low requests a read of the SSI 73K321L internal registers. Data cannot be output unless both $\overline{RD}$ and the latched $\overline{CS}$ are active or low.
RESET	25	20	I	Reset. An active high signal high on this pin will put the chip into an inactive state. All control register bits (CR0, CR1, Tone) will be reset. The output of the CLK pin will be set to the crystal frequency. An internal pull down resistor permits power on reset using a capacitor to VDD.

PIN DESCRIPTION (Continued)

PARALLEL MICROPROCESSOR INTERFACE (Continued)

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
$\overline{WR}$	13	-	I	Write. A low on this informs the SSI 73K321L that data is available on AD0-AD7 for writing into an internal register. Data is latched on the rising edge of $\overline{WR}$. No data is written unless both $\overline{WR}$ and the latched $\overline{CS}$ are low.

SERIAL MICROPROCESSOR INTERFACE

A0-A2	-	5-7	I	Register Address Selection. These lines carry register addresses and should be valid during any read or write operation.
DATA	-	8	I/O	Serial Control Data. Data for a read/write operation is clocked in or out on the falling edge of the EXCLK pin. The direction of data flow is controlled by the $\overline{RD}$ pin. $\overline{RD}$ low outputs data. $\overline{RD}$ high inputs data.
$\overline{RD}$	-	10	I	Read. A low on this input informs the SSI 73K321L that data or status information is being read by the processor. The falling edge of the $\overline{RD}$ signal will initiate a read from the addressed register. The $\overline{RD}$ signal must continue for eight falling edges of EXCLK in order to read all eight bits of the referenced register. Read data is provided LSB first. Data will not be output unless the $\overline{RD}$ signal is active.
$\overline{WR}$	-	9	I	Write. A low on this input informs the SSI 73K321L that data or status information has been shifted in through the DATA pin and is available for writing to an internal register. The normal procedure for a write is to shift in data LSB first on the DATA pin for eight consecutive falling edges of EXCLK and then to pulse $\overline{WR}$ low. Data is written on the rising edge of $\overline{WR}$.

Note: In the serial, 22-pin version, the pins AD0-AD7, ALE and $\overline{CS}$ are removed and replaced with the pins; A0, A1, A2, DATA, and an unconnected pin. Also, the $\overline{RD}$ and $\overline{WR}$ controls are used differently.

The Serial Control mode is provided in the 28-pin version by tying ALE high and $\overline{CS}$ low. In this configuration AD7 becomes DATA and AD0, AD1 and AD2 become A0, A1 and A2, respectively.

DTE USER INTERFACE

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
EXCLK	19	15	I	External Clock. Used for serial control interface to clock control data in or out of the 73K321L.
RXCLK	23	18	O	Receive Clock. A clock which is 16 x 1200, or 16 x 75 in V.23 mode, or 16 x 300 baud data rate is output in V.21.
RXD	22	17	O	Received Digital Data Output. Serial receive data is available on this pin. The data is always valid on the rising edge of RXCLK when in Synchronous mode. RXD will output constant marks if no carrier is detected.
TXCLK	18	14	O	Transmit Clock. TXCLK is always active. In V.23 mode the output is either a 16 x 1200 baud clock or 16 x 75 baud, in V.21 mode the clock is 16 x 300 baud.
TXD	21	16	I	Transmit Digital Data Input. Serial data for transmission is input on this pin. In Asynchronous modes (1200 or 300 baud) no clocking is necessary.

ANALOG INTERFACE AND OSCILLATOR

RXA	27	22	I	Received modulated analog signal input from the phone line.
TXA	16	12	O	Transmit analog output to the phone line.
XTL1 XTL2	2 3	3 4	I I	These pins are for the internal crystal oscillator requiring a 11.0592 MHz Parallel mode crystal and two load capacitors to Ground. XTL2 can also be driven from an external clock.

REGISTER DESCRIPTIONS

Four 8-bit internal registers are accessible for control and status monitoring. The registers are accessed in read or write operations by addressing the A0 and A1 address lines in Serial mode, or the AD0 and AD1 lines in Parallel mode. The AD0 and AD1 lines are latched by ALE. Register CR0 controls the method by which data is transferred over the phone line. CR1 controls the interface between the microprocessor and the SSI 73K321L internal state. DR is a detect register which provides an indication of Monitored modem status conditions. TR, the tone control register, controls the DTMF generator, answer and guard tones and RXD output gate used in the modem initial connect sequence. All registers are read/write except for DR which is read only. Register control and status bits are identified below:

REGISTER BIT SUMMARY

	ADDRESS	DATA BIT NUMBER							
REGISTER	AD2 - AD0	D7	D6	D5	D4	D3	D2	D1	D0
CONTROL REGISTER 0 CR0	000	MODULATION OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE
CONTROL REGISTER 1 CR1	001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTERRUPT	ADD PH. EQ. (V.23)	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0
DETECT REGISTER DR	010			RECEIVE DATA		CARRIER DETECT	SPECIAL TONE	CALL PROGRESS	LONG LOOP
TONE CONTROL REGISTER TR	011	RXD OUTPUT CONTROL	TRANSMIT CALLING TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF3	DTMF2/ V.23 FDX	DTMF1	DTMF0/ ANSWER/SPEC. TONE SELECT
CONTROL REGISTER 2 CR2	100				THESE REGISTER LOCATIONS ARE RESERVED FOR				
CONTROL REGISTER 3 CR3	101				USE WITH OTHER K-SERIES FAMILY MEMBERS				
ID REGISTER ID	110	ID	ID	ID	ID				

NOTE: When a register containing reserved control bits is written into, the reserved bits must be programmed as 0's.

REGISTER ADDRESS TABLE

REGISTER	ADDRESS AD2 - AD0	DATA BIT NUMBER D7	D6	D5	D4	D3	D2	D1	D0
CONTROL REGISTER 0 CR0	000	MODULATION OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ORIGINATE/ ANSWER
		0=V.23 FSK 1=V.21 FSK		0000=PWR DOWN 1100=FSK 0001=TRANSMIT DTMF, CALL PROGRESS DETECTION				0=DISABLE TXA OUTPUT 1=ENABLE TXA OUTPUT	IN V.21 MODE: 0=ANSWER 1=ORIGINATE IN V.23 MODE : 0=RECEIVE @ 1200 BIT/S, TRANSMIT @ 75 BIT/S 1=RECEIVE @ 75 BIT/S, TRANSMIT @ 1200 BIT/S
CONTROL REGISTER 1 CR1	001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTERRUPT	ADD PH. EQ.	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0
		00=TX DATA 01=TX ALTERNATE 10=TX MARK 11=TX SPACE		0=DISABLED 1=ENABLED	0=NORMAL EQ. 1=ADD EXTRA PHASE EQ. IN V.23	0=XTAL 1= NOT SUPPORTED IN THIS DEVICE	0=NORMAL 1=RESET	00=NORMAL 01=ANALOG LOOPBACK 10=REMOTE DIGITAL LOOPBACK 11=LOCAL DIGITAL LOOPBACK	
DETECT REGISTER DR	010			RECEIVE DATA		CARRIER DETECT	SPECIAL TONE	CALL PROGRESS	LONG LOOP
				OUTPUTS RECEIVED DATA STREAM		0=CONDITION NOT DETECTED 1=CONDITION DETECTED			
TONE CONTROL REGISTER TR	011	RXD OUTPUT CONTROL	TRANSMIT GUARD/ CALLING TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF3	DTMF2/ V.23 FDX	DTMF1	DTMF0/ SPECIAL TONE
		RXD PIN 0=NORMAL 1=TRI STATE	0=OFF 1=ON	0=OFF 1=ON	0=DATA 1=TX DTMF	4 BIT CODE FOR 1 OF 16 DUAL TONE COMBINATIONS. OVERIDES OTHER TRANSMIT MODES	0=HALF DUPLEX V.23 1=ALLOWS V.23 FULL DUPLEX OPERATION		0=ANSWER TONE FREQ.=2225 Hz FSK MARK WILL BE INDICATED BY SPECIAL TONE BIT IN DR 1=ANSWER TONE FREQ.=2100 Hz EITHER 2100 Hz (IN ORIG.) OR 1300 Hz (IN ANS.) WILL BE INDICATED BY SPECIAL TONE BIT IN DR
ID REGISTER 10	110	ID	ID	ID	ID				

00XX=73K212L, 322L, 321L
01XX=73K221L, 302L
10XX=73K222L
1100=73K224L
1110=73K324L
1101=73K312L

3

CONTROL REGISTER 0

	D7	D6	D5	D4	D3	D2	D1	D0
CR0 000	MODUL. OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2		TX DTMF	TRANSMIT ENABLE	ANSWER/ ORIGINATE

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	Answer/ Originate	0	Selects Answer mode in V.21 (transmit in high band, receive in low band) or in V.23 mode, receive at 1200 bit/s and transmit at 75 bit/s.
		1	Selects Originate mode in V.21 (transmit in low band, receive in high band) or in V.23 mode, receive at 75 bit/s and transmit at 1200 bit/s. If in V.23 and D2 of TR=1, selects V.23 full duplex operation in 4-wire configuration.
			Note: This bit works with TR bit D0 to program special tones detected in Tone Register. See detect and tone registers.
D1	Transmit Enable	0	Disables transmit output at TXA.
		1	Enables transmit output at TXA.
			Note: Answer tone and DTMF TX control require TX enable.
D5, D4,D3, D2	Transmit Mode	D5 D4 D3 D2	
		0 0 0 1	Transmit DTMF
D2		0 0 0 0	Selects Power Down mode. All functions disabled except digital interface.
		1 1 0 0	Selects FSK operation.
D6	Unused	0	Not used; must be written as a "0."
D7	Modulation Option	D7 D5 D4	Selects:
		0 1 1	FSK CCITT V.23 mode.
		1 1 1	FSK CCITT V.21 mode.

CONTROL REGISTER 1

	D7	D6	D5	D4	D3	D2	D1	D0
CR1 001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTER.	ADD PH. EQ.	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D1, D0	Test Mode	D1 D0	
		0 0	Selects Normal Operating mode.
		0 1	Analog Loopback mode. Loops the transmitted analog signal back to the receiver, and causes the receiver to use the same center frequency as the transmitter. To squelch the TXA pin, transmit enable must be forced low.
		1 0	Selects remote digital loopback. Received data is looped back to transmit data internally, and RXD is forced to a mark. Data on TXD is ignored.
		1 1	Selects local digital loopback. Internally loops TXD back to RXD and continues to transmit data from TXA pin.
D2	Reset	0	Selects normal operation.
		1	Resets modem to power down state. All control register bits (CR0, CR1, Tone) are reset to zero. The output of the clock pin will be set to the crystal frequency.
D3	CLK Control (Clock Control)	Program as 0	Not supported in the SSI 73K321.See the TXCLK and RXCLK pin descriptions for 16x the data rate clocks.
D4	Add Ph. Eq.	0	Selects normal equalization.
		1	In V.23 mode, additional phase equalization is added to the main channel filters when D4 is set to 1.
D5	Enable Detect Interrupt	0	Disables interrupt at $\overline{INT}$ pin. All interrupts are normally disabled in Power Down modes.
		1	Enables $\overline{INT}$ output. An interrupt will be generated with a change in status of DR bits D1-D3. The special tone and call progress detect interrupts are masked when the TX enable bit is set. Carrier detect is masked when TX DTMF is activated. All interrupts will be disabled if the device is in Power Down mode.
D7, D6	Transmit Pattern	D7 D6	
		0 0	Selects normal data transmission as controlled by the state of the TXD pin.
		0 1	Selects an alternating mark/space transmit pattern for modem testing.
		1 0	Selects a constant mark transmit pattern.
		1 1	Selects a constant space transmit pattern.

3

DETECT REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
DR 010			RECEIVE DATA		CARR. DETECT	SPECIAL TONE	CALL PROG.	LONG LOOP

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	Long Loop	0	Indicates normal received signal.
		1	Indicates low received signal level.
D1	Call Progress Detect	0	No call progress tone detected.
		1	Indicates presence of call progress tones. The call progress detection circuitry is activated by energy in the normal 350 to 620 Hz call progress band when CR0 D2 = 1.
D2	Special Tone Detect	0	No special tone detected as programmed by CR0 bit D0 and Tone Register bit D0.
		1	Special tone detected. The detected tone is:
			(1) 2100 Hz answer tone if D0 of TR=1 and the device is in V.21 Originate mode.
			(2) 1300 Hz calling tone if D0 of TR=1 and the device is in V.21 or V.23 Answer mode.
			(3) an FSK mark for the mode the device is set to receive in if D0 of TR = 0.
			NOTE: Tolerance on special tones is ±3%.
D3	Carrier Detect	0	No carrier detected in the receive channel.
		1	Indicated carrier has been detected in the received channel.
D4	Unused		Not used in the 73K321L.
D5	Receive Data		Continuously outputs the received data stream. This data is the same as that output on the RXD pin, but it is not disabled when RXD is tri-stated.
D6, D7			Not used.

TONE REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.	TRANSMIT CALLING TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2	DTMF 1	DTMF 0/ ANS. TONE/ SPECIAL TONE/ SEL

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	DTMF 0/ Answer Tone/ Special Tone/ Detect/Select	D6 D5 D4 D0	D0 interacts with bits D6, D5, D4, and CR0 as shown.
		X X 1 X	Transmit DTMF tones.
		X X 0 0	Mark of an FSK mode selected in CR0 is to be detected in D2 of DR.
		X X 0 1	2100 Hz answer tone will be detected in D2 of DR if V.21 Originate mode is selected in CR0.
			1300 Hz calling tone will be detected in D2 of DR if V.21 or V.23 Answer mode is selected in CR0.
		X 1 0 0	Transmit 2225 Hz answer tone in Answer mode.
		X 1 0 1	Transmit 2100 Hz answer tone in Answer mode.
D3, D2, D1, D0	DTMF 3, 2, 1, 0	D3 D2 D1 D0	
		0 0 0 0 - 1 1 1 1	Programs 1 of 16 DTMF tone pairs that will be transmitted when TX DTMF and TX enable bit (CR0, bit D1) is set. Tone encoding is shown below:

KEYBOARD EQUIVALENT	DTMF CODE D3 D2 D1 D0	TONES LOW	HIGH
1	0 0 0 1	697	1209
2	0 0 1 0	697	1336
3	0 0 1 1	697	1477
4	0 1 0 0	770	1209
5	0 1 0 1	770	1336
6	0 1 1 0	770	1477
7	0 1 1 1	852	1209
8	1 0 0 0	852	1336
9	1 0 0 1	852	1477
0	1 0 1 0	941	1336

TONE REGISTER (Continued)

BIT NO.	NAME	CONDITION	DESCRIPTION
D3, D2, D1, D0 (Cont.)			KEYBOARD EQUIVALENT / DTMF CODE D3 D2 D1 D0 / TONES LOW HIGH
			* 1 0 1 1 941 1209
			# 1 1 0 0 941 1477
			A 1 1 0 1 697 1633
			B 1 1 1 0 770 1633
			C 1 1 1 1 852 1633
			D 0 0 0 0 941 1633
D4	Transmit DTMF	0	Disabled DTMF.
		1	Activates DTMF. The selected DTMF tones are transmitted continuously when this bit is high. TX DTMF overrides all other transmit functions.
D5	Transmit Answer Tone	0	Disables answer tone generator.
		1	Enables answer tone generator. A 2100 Hz answer tone will be transmitted continuously when the transmit enable bit is set. The device must be in Answer mode.
D6	Transmit Calling Tone	0	Disables calling tone generator.
		1	Transmit calling tone in either mode.
D7	RXD Output Control	0	Enables RXD pin. Receive data will be output on RXD.
		1	Disables RXD pin. The RXD pin reverts to a high impedance with internal weak pull-up resistor.

ID REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
ID 110	ID	ID	ID	ID				

BIT NO.	NAME	CONDITION	DESCRIPTION
D7, D6, D5 D4	Device Identification Signature	D7 D6 D5 D4	Indicates Device:
		0 0 X X	SSI 73K212L, 73K321L or 73K322L
		0 1 X X	SSI 73K221L or 73K302L
		1 0 X X	SSI 73K222L
		1 1 0 0	SSI 73K224L
		1 1 1 0	SSI 73K324L
		1 1 0 1	SSI 73K312L

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

PARAMETER	RATING
VDD Supply Voltage	14V
Storage Temperature	-65 to 150°C
Soldering Temperature (10 sec.)	260°C
Applied Voltage	-0.3 to VDD+0.3V
Note: All inputs and outputs are protected from static charge using built-in, industry standard protection devices and all outputs are short-circuit protected.	

RECOMMENDED OPERATING CONDITIONS

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
VDD Supply voltage		4.5	5	5.5	V
TA, Operating Free-Air Temperature		-40		+85	°C
Clock Variation	(11.0592 MHz) Crystal or external clock	-0.01		+0.01	%
External Components (Refer to Application section for placement.)					
VREF Bypass Capacitor	(External to GND)	0.1			µF
Bias setting resistor	(Placed between VDD and ISET pins)	1.8	2	2.2	MΩ
ISET Bypass Capacitor	(ISET pin to GND)	0.1			µF
VDD Bypass Capacitor 1	(External to GND)	0.1			µF
VDD Bypass Capacitor 2	(External to GND)	22			µF
XTL1 Load Capacitor	Depends on crystal characteristics;			40	pF
XTL2 Load Capacitor	from pin to GND			20	

DC ELECTRICAL CHARACTERISTICS
(TA = -40°C to 85°C, VDD = recommended range unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
IDD, Supply Current	ISET Resistor = 2 MΩ				
IDDA, Active	CLK = 11.0592 MHz		8	12	mA
IDD1, Power-down	CLK = 11.0592 MHz			4	mA
IDD2, Power-down	CLK = 19.200 kHz			3	mA
Digital Inputs					
VIH, Input High Voltage					
Reset, XTL1, XTL2		3.0		VDD	V
All other inputs		2.0		VDD	V
VIL, Input Low Voltage		0		0.8	V
IIH, Input High Current	VI = VIH Max			100	µA
IIL, Input Low Current	VI = VIL Min	-200			µA
Reset Pull-down Current	Reset = VDD	1		50	µA
Input Capacitance	All Digital Input Pins			10	pF
Digital Outputs					
VOH, Output High Voltage	IOH MIN = -0.4 mA	2.4		VDD	V
VOL, Output Low Voltage	IO MAX = 1.6 mA			0.4	V
VOL, CLK Output	IO = 3.6 mA			0.6	V
RXD Tri-State Pull-up Curr.	RXD = GND	-1		-50	µA
CMAX, CLK Output	Maximum Capacitive Load			15	pF

DYNAMIC CHARACTERISTICS AND TIMING
(TA = -40°C to +85°C, VDD = Recommended range unless otherwise noted.)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
FSK Modulator					
Output Freq. Error	CLK = 11.0592 MHz	-0.35		+0.35	%
Transmit Level	Transmit Dotting Pattern	-11	-10	-9	dBm0
Harmonic Distortion in 700-2900 Hz band	THD in the alternate band FSK		-60	-50	dB
Output Bias Distortion	Transmit Dotting Pattern in ALB @ RXD		±3		%
Total Output Jitter	Random Input in ALB @ RXD	-10		+10	%
NOTE: Parameters expressed in dBm0 refer to the following definition: 0 dB loss in the Transmit path to the line. 2 dB gain in the Receive path from the line. Refer to the Basic Box Modem diagram in the Applications section for the DAA design.					
DTMF Generator					
Freq. Accuracy		-0.25		+0.25	%
Output Amplitude	Low Band, CR0 bit D2=1	-10	-9	-8	dBm0
Output Amplitude	High Band, CR0 bit D2=1	-8	-7	-6	dBm0
Twist	High-Band to Low-Band, as above	1.0	2.0	3.0	dB
Long Loop Detect	Not valid for V.23 back channel	-38		-28	dBm0
Dynamic Range	Refer to Performance Curves		43		dB
Call Progress Detector					
Detect Level	-3 dB points in 285 and 675 Hz	-38			dBm0
Reject Level	Test signal is a 460 Hz sinusoid			-45	dBm0
Delay Time	-70 dBm0 to -30 dBm0 STEP			40	ms
Hold Time	-30 dBm0 to -70 dBm0 STEP			40	ms
Hysteresis		2			dB
Carrier Detect					
Threshold	Single Tone	-48		-43	dBm0
Delay Time					
V.21		10		20	ms
V.23 Forward Channel		6		12	ms
V.23 Back Channel		25		40	ms
Hold Time					
V.21		6		20	ms
V.23 Forward Channel		3		8	ms
V.23 Back Channel		10		25	ms
Hysteresis		2			dB

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DYNAMIC CHARACTERISTICS AND TIMING (Continued)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Special Tone Detectors					
Detect Level	See definitions for TR bit D0 mode	-48		-43	dBm0
Delay Time	-70 dBm0 to -30 dBm0 Step				
2100 Hz answer tone		10		25	ms
1300 Hz calling tone		10		25	ms
390 Hz V.23 back channel mark		20		65	ms
980 or 1650 Hz V.21 marks		10		25	ms
Hold Time	-30 dBm0 to -70 dBm0 Step				
2100 Hz answer tone		4		15	ms
1300 Hz calling tone		3		10	ms
390 Hz V.23 back channel mark		10		25	ms
980 or 1650 Hz V.21 marks		5		15	ms
Hysteresis		2			dB
Detect Freq. Range	Any Special Tone	-3		+3	%
Output Smoothing Filter					
Output load	TXA pin; FSK Single Tone out for THD = -50 dB in .3 to 3.4 kHz	10		 50	kΩ pF
Out of Band Energy	Frequency >12 kHz in all modes			-60	dBm0
Output Impedance	TXA pin, TXA Enabled		20	50	Ω
Clock Noise	TXA pin; 76.8 kHz or 122.88 kHz in V.23 main channel		0.1	0.4	mVrms

DYNAMIC CHARACTERISTICS AND TIMING (Continued)

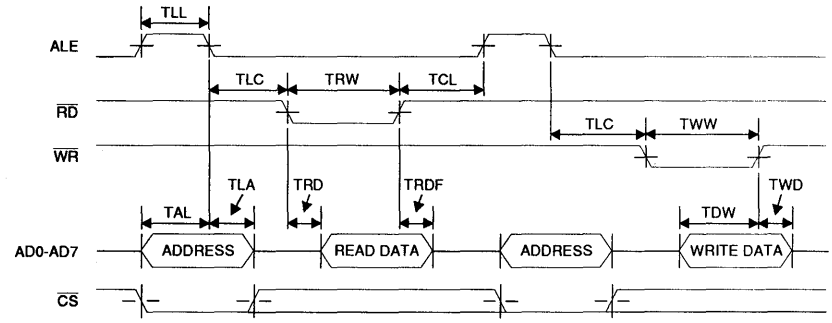
PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Timing (Refer to Timing Diagrams)					
TAL	$\overline{CS}$/Addr. setup before ALE Low	25			ns
TLA	$\overline{CS}$/Addr. hold after ALE Low	20			ns
TLC	ALE Low to $\overline{RD}/\overline{WR}$ Low	30			ns
TCL	$\overline{RD}/\overline{WR}$ Control to ALE High	-5			ns
TRD	Data out from $\overline{RD}$ Low	0		140	ns
TLL	ALE width	30			ns
TRDF	Data float after $\overline{RD}$ High	0		5	ns
TRW	$\overline{RD}$ width	200		25000	ns
TWW	$\overline{WR}$ width	140		25000	ns
TDW	Data setup before $\overline{WR}$ High	40			ns
TWD	Data hold after $\overline{WR}$ High	10			ns
TCKD	Data out after EXCLK Low			200	ns
TCKW	$\overline{WR}$ after EXCLK Low	150			ns
TDCK	Data setup before EXCLK Low	150			ns
TAC	Address setup before control*	50			ns
TCA	Address hold after control*	50			ns
TWH	Data Hold after EXCLK	20			

* Control for setup is the falling edge of $\overline{RD}$ or $\overline{WR}$.
Control for hold is the falling edge of $\overline{RD}$ or the rising edge of $\overline{WR}$.

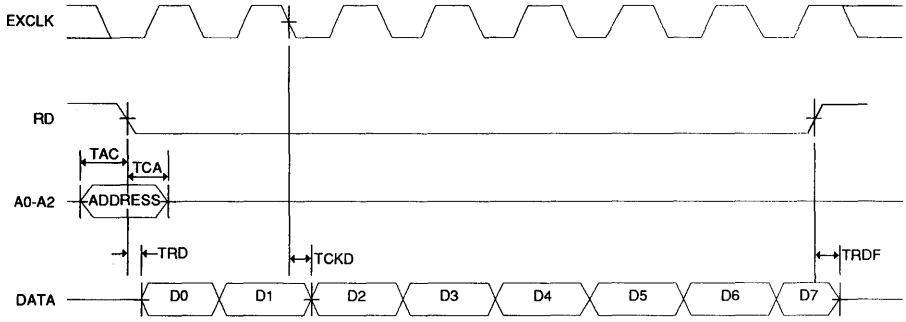
3

TIMING DIAGRAMS

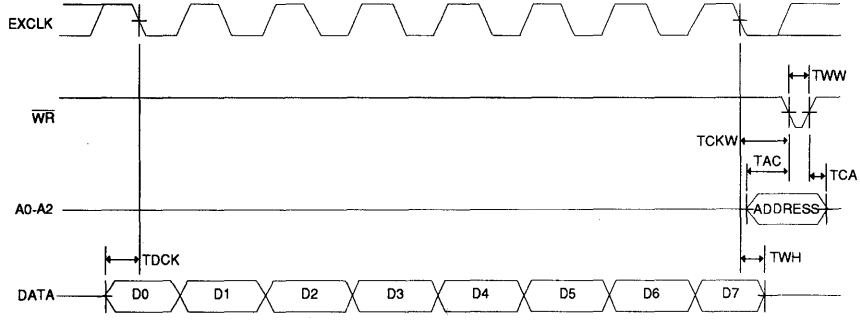
BUS TIMING DIAGRAM (PARALLEL VERSION)



READ TIMING DIAGRAM (SERIAL VERSION)



WRITE TIMING DIAGRAM (SERIAL VERSION)



APPLICATIONS INFORMATION

GENERAL CONSIDERATIONS

Figures 1 and 2 show basic circuit diagrams for K-Series modem integrated circuits. K-Series products are designed to be used in conjunction with a control processor, a UART or RS-232 serial data interface, and a DAA phone line interface to function as a typical intelligent modem. The K-Series ICs interface directly with Intel 8048 and 80C51 microprocessors for control and status monitoring purposes.Two typical DAA arrangements are shown: one for a split ±5 or ±12 volt design and one for a single 5 volt design. These diagrams are for reference only and do not represent production-ready modem designs.

K-Series devices are available with two control interface versions: one for a parallel multiplexed address/data interface, and one for a serial interface. The parallel version is intended for use with 8039/48 or 8031/51 microcontrollers from Intel or many other manufacturers. The serial interface 22-pin version can be used with other microcontrollers or in applications where only a limited number of port lines are available or the application does not lend itself to a multiplexed address/data interface. The parallel versions may also be used in the Serial mode, as explained in the data sheet pin description.

In most applications the controller will monitor the serial data for commands from the DTE and the received data for break signals from the far end modem. In this way, commands to the modem are sent over the same line as the transmitted data. In other applications the RS-232 interface handshake lines are used for modem control.

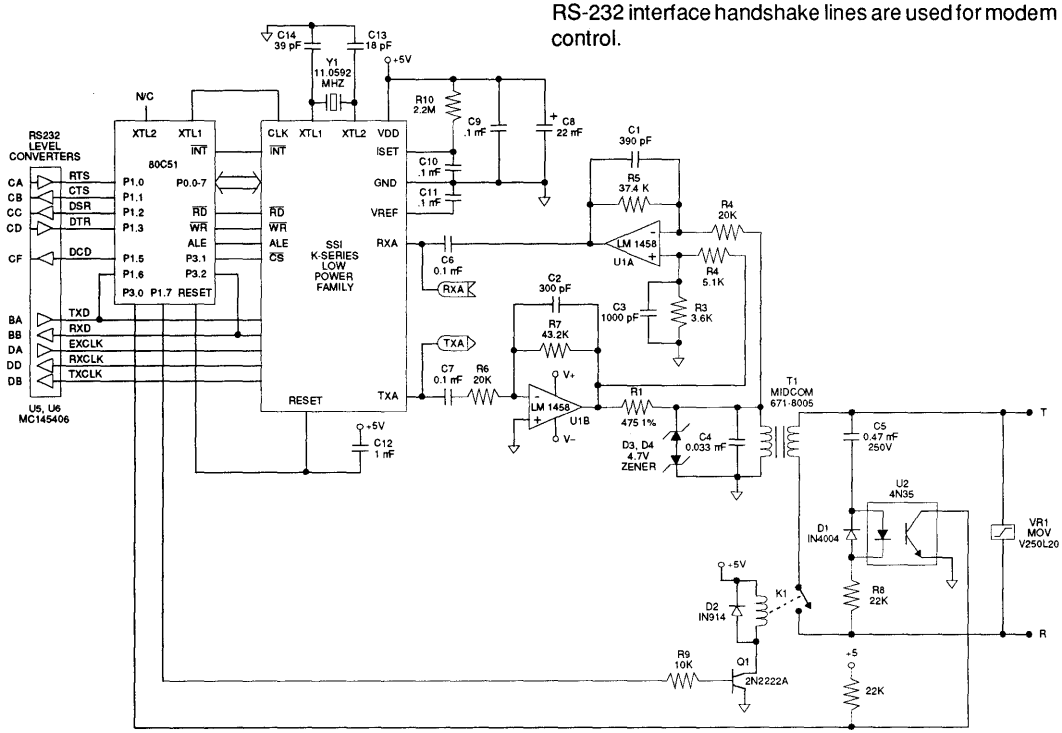


FIGURE 1: Basic Box Modem with Dual-Supply Hybrid

DIRECT ACCESS ARRANGEMENT (DAA)

The telephone line interfaces show two examples of how the "hybrid" may be implemented. The split supply design (Figure 1) is a typical two op-amp hybrid. The receive op-amp serves two purposes. It supplies gain to amplify the receive signal to the proper level for the modem's detectors and demodulator, and it removes the transmitted signal from the receive signal present at the transformer. This is done by supplying a portion of the transmitted signal to the non-inverting input of the receive op-amp at the same amplitude as the signal appearing at the transformer, making the transmit signal Common mode.

The single-supply hybrid is more complex than the dual-supply version described above, but its use eliminates the need for a second power supply. This circuit (Figure 2) uses a bridged drive to allow undistorted signals to be sent with a single 5V supply. Because DTMF tones utilize a higher amplitude than data, these signals will clip if a single-ended drive approach is used. The bridged driver uses an extra op-amp (U1A) to invert the signal coming from the gain setting op-amp (U1B) before sending it to the other leg of the transformer. Each op-amp then supplies half the drive signal to the transformer. The receive amplifier (U1C) picks off its signal at the junction of the impedance matching resistor and the transformer. Because the bottom leg of the transformer is being driven in one direction by U1A and the resistor is driven in the opposite direction at the same time by U1B, the junction of the transformer and resistor remains relatively constant and the receive signal is unaffected.

DESIGN CONSIDERATIONS

Silicon Systems' 1-chip modem products include all basic modem functions. This makes these devices adaptable for use in a variety of applications, and as easy to control as conventional digital bus peripherals.

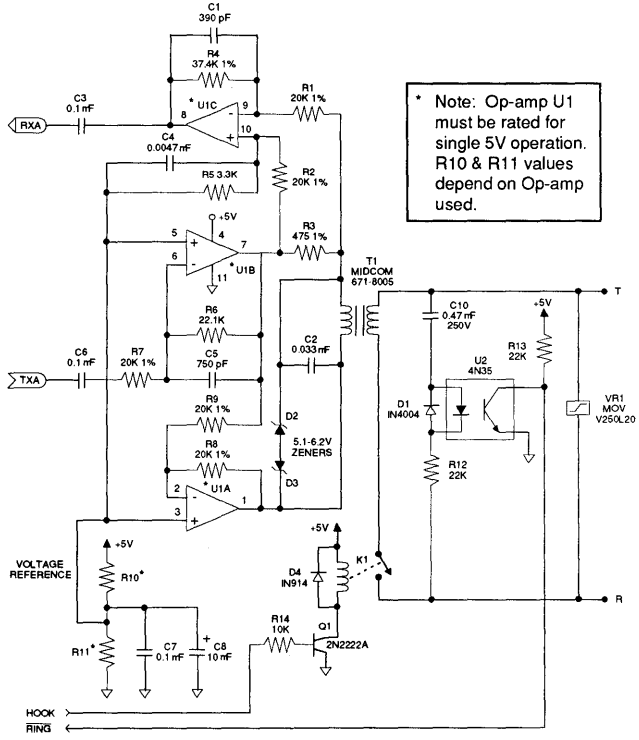


FIGURE 2: Single 5V Hybrid Version

Unlike digital logic circuitry, modem designs must properly contend with precise frequency tolerances and very low level analog signals, to ensure acceptable performance. Using good analog circuit design practices will generally result in a sound design. Following are additional recommendations which should be taken into consideration when starting new designs.

CRYSTAL OSCILLATOR

The K-Series crystal oscillator requires a Parallel mode (antiresonant) crystal which operates at 11.0592 MHz. It is important that this frequency be maintained to within ±0.01% accuracy.

In order for a Parallel mode crystal to operate correctly and to specification, it must have a load capacitor connected to the junction of each of the crystal and internal inverter connections, terminated to ground. The values of these capacitors depend primarily on the crystal's characteristics, and to a lesser degree on the internal inverter circuit. The values used affect the accuracy and start up characteristics of the oscillator.

LAYOUT CONSIDERATIONS

Good analog/digital design rules must be used to control system noise in order to obtain highest performance in modem designs. The more digital circuitry present on the PC board, the more this attention to noise control is needed. The modem should be treated as a high impedance analog device. A 22 mF electrolytic capacitor in parallel with a 0.1 mF ceramic capacitor between VDD and GND is recommended. Liberal use of ground planes and larger traces on power and ground are also highly favored. High speed digital circuits tend to generate a significant amount of EMI (Electro-Magnetic Interference) which must be minimized in order to meet regulatory agency limitations. To accomplish this, high speed digital devices should be locally bypassed, and the telephone line interface and K-Series device should be located close to each other near the area of the board where the phone line connection is accessed. To avoid problems, power supply and ground traces should be routed separately to the analog and digital functions on the board, and digital signals should not be routed near low level or high impedance analog traces. The analog and digital grounds should only connect at one point near the K-Series device ground pin to avoid ground loops. The K–Series modem IC's should have both high frequency and low frequency bypassing as close to the package as possible.

MODEM PERFORMANCE CHARACTERISTICS

The curves presented here define modem IC performance under a variety of line conditions while inducing disturbances that are typical of those encountered during data transmission on public service telephone lines. Test data was taken using an AEA Electronics' "Autotest I" modem test set and line simulator, operating under computer control. All tests were run full-duplex, using a Concord Data Systems 224 as the reference modem. A 511 pseudo-random-bit pattern was used for each data point. Noise was C-message weighted and all signal-to-noise (S/N) ratios reflect total power measurements similar to the CCITT V.56 measurement specification. The individual tests are defined as follows.

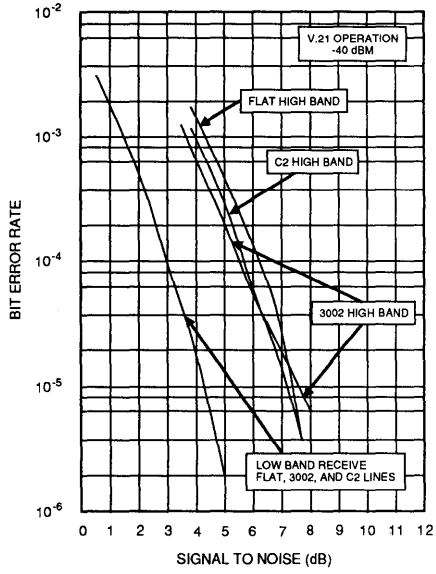
BER vs. S/N

This test measures the ability of the modem to operate over noisy lines with a minimum of data-transfer errors. Since some noise is generated in the best of dial-up lines, the modem must operate with the lowest S/N ratio possible. Better modem performance is indicated by test curves that are closest to the BER axis. A narrow spread between curves representing the four line parameters indicates minimal variation in performance while operating over a range of aberrant operating conditions. Typically, a DPSK modem will exhibit better BER-performance test curves receiving in the low band than in the high band.

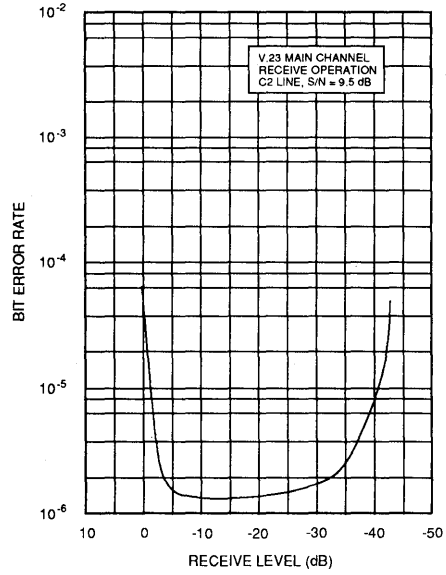
BER vs. Receive Level

This test measures the dynamic range of the modem. Because signal levels vary widely over dial-up lines, the widest possible dynamic range is desirable. The minimum Bell specification calls for 36 dB of dynamic range. S/N ratios are held constant at the indicated values while the receive level is lowered from a very high to very low signal levels. The width of the "bowl" of these curves, taken at the BER point, is the measure of dynamic range.

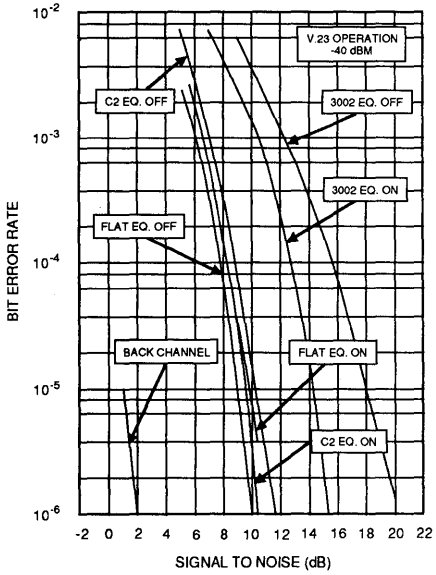
SSI 73K321L
BER vs SIGNAL TO NOISE



***SSI 73K321L**
BER vs RECEIVE LEVEL (V.23)



***SSI 73K321L**
BER vs S/N (V.23 ONLY)**

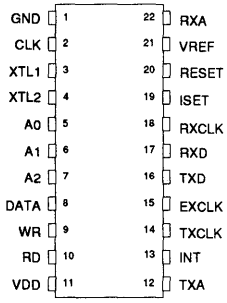


* = "EQ On" Indicates bit CR1 D4 is set for additional phase equalization.

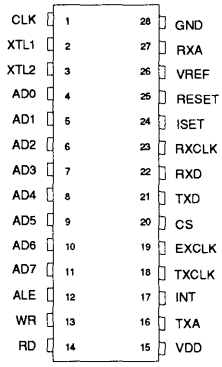
** = 73K302L performance is similar to that of the 73K322L. V.23 operation corresponds to Bell 202.

PACKAGE PIN DESIGNATIONS
(TOP VIEW)

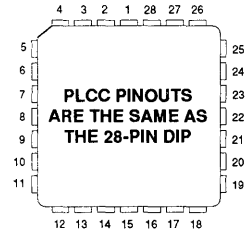
CAUTION: Use handling procedures necessary for a static sensitive component.



400-Mil 22-Pin DIP



600-Mil 28-Pin DIP



28-Pin PLCC

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ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 73K321L with Parallel Bus Interface		
28-Pin 5V Supply		
Plastic Dual-In-Line	73K321L-IP	73K321L-IP
Plastic Leaded Chip Carrier	73K321L-IH	73K321L-IH
SSI 73K321L with Serial Interface		
22-Pin 5V Supply		
Plastic Dual-In-Line	73K321SL-IP	73K321SL-IP

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Notes:

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SSI 73K322L
CCITT V.23, V.22, V.21
Single-Chip Modem

January 1994

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DESCRIPTION

The SSI 73K322L is a highly integrated single-chip modem IC which provides the functions needed to construct a CCITT V.23, V.22 and V.21 compatible modem, capable of 1200 or 0-300 bit/s full-duplex operation or 0-1200 bit/s half-duplex operation with or without the back channel over dial-up lines. The SSI 73K322L is an enhancement of the SSI 73K221L single-chip modem with performance characteristics suitable for European and Asian telephone systems. The SSI 73K322L produces either 550 or 1800 Hz guard tone, recognizes and generates a 2100 Hz answer tone, and supports V.21 for 300 Hz FSK operation. It also operates in V.23, 1200 bit/s FSK mode. The SSI 73K322L integrates analog, digital, and switched-capacitor array functions on a single substrate,offering excellent performance and a high level of functional integration in a single 28- or 22-pin DIP configuration. The SSI 73K322L operates from a single +5V supply with very low power consumption.

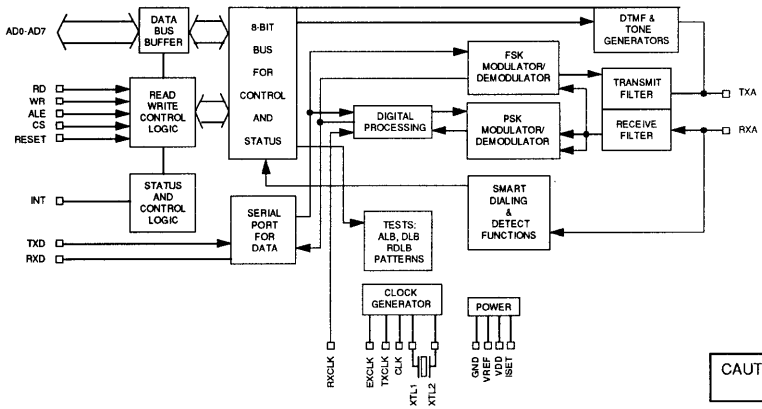
The SSI 73K322L includes the DPSK and FSK modulator/demodulator functions, call progress and handshake tone monitor test modes, and a tone generator capable of producing DTMF, answer, calling and 550 or 1800 Hz guard tone. This device supports V.23, V.22 (except mode v) and V. 21 modes of operation, allowing both synchronous and

(Continued)

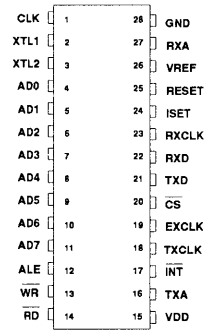
FEATURES

- **One-chip CCITT V.23, V.22 and V.21 standard compatible modem data pump**
- **Full-duplex operation at 0-300 bit/s (FSK) or 600 and 1200 bit/s (DPSK) or 0-1200 bit/s (FSK) forward channel with or without 0-75 bit/s back channel**
- **Interfaces directly with standard microprocessors (8048, 80C51 typical)**
- **Serial or parallel microprocessor bus for control**
- **Serial port for data transfer**
- **Both synchronous and asynchronous modes of operation**
- **Call progress, carrier, precise answer tone (2100 Hz), calling tone (1300 Hz) and FSK mark detectors**
- **DTMF and 550 or 1800 Hz guard tone generators**
- **Test modes available: ALB, DL, RDL, Mark, Space, Alternating bit patterns**
- **Precise automatic gain control allows 45 dB dynamic range**
- **CMOS technology for low power consumption using 30 mW @ 5V from a single power supply**
- **Surface mount PLCC package available**

BLOCK DIAGRAM



PIN DIAGRAM



CAUTION: Use handling procedures necessary for a static sensitive component.

DESCRIPTION (continued)

asynchronous communications. The SSI 73K322L is designed to appear to the systems designer as a microprocessor peripheral, and will easily interface with popular one-chip microprocessors (80C51 typical) for control of modem functions through its 8-bit multiplexed address/data bus or via an optional serial control bus. An ALE control line simplifies address demultiplexing. Data communications occurs through a separate serial port only.

The SSI 73K322L is ideal for use in either free standing or integral system modem products where multi-standard data communications over the 2-wire switched telephone network is desired. Its high functionality, low power consumption and efficient packaging simplify design requirements and increase system reliability. A complete modem requires only the addition of the phone line interface, a control microprocessor, and RS-232 level converter for a typical system. The SSI 73K322L is part of Silicon Systems K-Series family of pin and function compatible single-chip modem products. These devices allow systems to be configured for higher speeds and Bell or CCITT operation with only a single component change.

OPERATION

ASYNCHRONOUS MODE

Data transmission for the DPSK mode requires that data ultimately be transmitted in a synchronous fashion. The SSI 73K322L includes ASYNC/SYNC and SYNC/ASYNC converters which delete or insert stop bits in order to transmit data at a regular rate. In Asynchronous mode the serial data comes from the TXD pin into the ASYNC/SYNC converter. The ASYNC/SYNC converter accepts the data provided on the TXD pin which normally must be 1200 or 600 bit/s +1.0%, -2.5%. The rate converter will then insert or delete stop bits in order to output a signal which is 1200 or 600 bit/s ± 0.01% (± 0.01% is the crystal tolerance).

The SYNC/ASYNC converter also has an extended overspeed mode which allows selection of an output overspeed range of either +1% or +2.3%. In the extended overspeed mode, stop bits are output at 7/8 the normal width.

The serial data stream from the transmit buffer or the rate converter is passed through the data scrambler and onto the analog modulator. The data scrambler can be bypassed under processor control when unscrambled data must be transmitted. If serial input data contains a break signal through one character (including start and stop bits) the break will be extended to at least 2 • N + 3 bits long (where N is the number of transmitted bits/character).

Serial data from the demodulator is passed first through the data descrambler and then through the SYNC/ASYNC converter. The ASYNC/ASYNC converter will reinsert any deleted stop bits and output data at an intra-character rate (bit-to-bit timing) of no greater than 1219 bit/s. An incoming break signal (low through two characters) will be passed through without incorrectly inserting a stop bit.

SYNCHRONOUS MODE

The CCITT V.22 standard defines synchronous operation at 600 and 1200 bit/s. Operation is similar to that of the Asynchronous mode except that data must be synchronized to a provided clock and no variation in data transfer rate is allowable. Serial input data appearing at TXD must be valid on the rising edge of TXCLK.

TXCLK is an internally derived signal in Internal mode and is connected internally to the RXCLK pin in Slave mode. Receive data at the RXD pin is clocked out on the falling edge of RXCLK. The ASYNCH/SYNCH converter is bypassed when Synchronous mode is selected and data is transmitted out at the same rate as it is input.

DPSK MODULATOR/DEMODULATOR

In DPSK mode the SSI 73K322L modulates a serial bit stream into di-bit pairs that are represented by four possible phase shifts as prescribed by the V.22 standards. The base-band signal is then filtered to reduce intersymbol interference on the bandlimited 2-wire telephone line. Transmission occurs using either a 1200 Hz (Originate mode) or 2400 Hz carrier (Answer mode). Demodulation is the reverse of the modulation process, with the incoming analog signal eventually decoded into di-bits and converted back to a serial bit stream. The demodulator also recovers the clock which was encoded into the analog signal during modulation. Demodulation occurs using either a 1200 Hz carrier (Answer mode or ALB Originate mode) or a 2400 Hz carrier (Originate mode or ALB Answer mode). The SSI 73K322L uses a phase locked loop coherent demodulation technique for optimum receiver performance.

FSK MODULATOR/DEMODULATOR

The FSK modulator produces a frequency modulated analog output signal using two discrete frequencies to represent the binary data. V.21 mode uses 980 and 1180 Hz (originate, mark and space) or 1650 and 1850 Hz (answer, mark and space). V.23 mode uses 1300 and 2100 Hz for the main channel and 390 and 450 Hz for the back channel. The modulation rate of the back channel is up to 75 baud. Demodulation involves detecting the received frequencies and decoding them into the appropriate binary value. The rate converter and scrambler/descrambler are automatically bypassed in the V.21 or V.23 modes.

PASSBAND FILTERS AND EQUALIZERS

High and low band filters are included to shape the amplitude and phase response of the transmit and receive signals and provide compromise delay equalization and rejection of out-of-band signals in the receive channel. Amplitude and phase equalization are necessary to compensate for distortion of the transmission line and to reduce intersymbol interference in the bandlimited receive signal. The transmit signal filtering approximates a 75% square root of raised Cosine frequency response characteristic.

AGC

The automatic gain control maintains a signal level at the input to the demodulators which is constant to within 1 dB. It corrects quickly for increases in signal which would cause clipping and provides a total receiver dynamic range of >45 dB.

PARALLEL BUS INTERFACE

Four 8-bit registers are provided for control, option select and status monitoring. These registers are addressed with the AD0, AD1, and AD2 multiplexed address lines (latched by ALE) and appear to a control microprocessor as four consecutive memory locations. Two control registers and the tone register are read/write memory. The detect register is read only and cannot be modified except by modem response to monitored parameters.

SERIAL COMMAND INTERFACE

The serial command interface allows access to the SSI 73K322L control and status registers via a serial command port (22-pin version only). In this mode the A0, A1 and A2 lines provide register addresses for data passed through the data pin under control of the $\overline{RD}$ and $\overline{WR}$ lines. A read operation is initiated when the $\overline{RD}$ line is taken low. The first bit is available after $\overline{RD}$ is brought low and the next seven cycles of EXCLK will then transfer out seven bits of the selected address location LSB first. A write takes place by shifting in eight bits of data LSB first for eight consecutive cycles of EXCLK. $\overline{WR}$ is then pulsed low and data transferred into the selected register occurs on the rising edge of $\overline{WR}$.

SPECIAL DETECT CIRCUITRY

The special detect circuitry monitors the received analog signal to determine status or presence of carrier, answer tone and weak received signal (long loop condition), special tones such as FSK marking and the 1300 Hz calling tone are also detected. A highly frequency selective call progress detector provides adequate discrimination to accurately detect European call progress signals.

DTMF GENERATOR

The DTMF generator will output one of 16 standard tone pairs determined by a 4-bit binary value and TX DTMF mode bit previously loaded into the tone register. Tone generation is initiated when the DTMF mode is selected using the tone register and the transmit enable (CR0 bit D1) is changed from 0 to 1.

PIN DESCRIPTION

POWER

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
GND	28	1	I	System Ground.
VDD	15	11	I	Power supply input, 5V ±10%. Bypass with 0.1 and 22 µF capacitors to GND.
VREF	26	21	O	An internally generated reference voltage. Bypass with 0.1 µF capacitor to GND.
ISET	24	19	I	Chip current reference. Sets bias current for op-amps. The chip current is set by connecting this pin to VDD through a 2 MΩ resistor. ISET should be bypassed to GND with a 0.1 µF capacitor.

PARALLEL MICROPROCESSOR INTERFACE

ALE	12	-	I	Address latch enable. The falling edge of ALE latches the address on AD0-AD2 and the chip select on $\overline{CS}$.
AD0-AD7	4-11	-	I/O	Address/data bus. These bidirectional tri-state multiplexed lines carry information to and from the internal registers.
$\overline{CS}$	20	-	I	Chip select. A low on this pin during the falling edge of ALE allows a read cycle or a write cycle to occur. AD0-AD7 will not be driven and no registers will be written if $\overline{CS}$ (latched) is not active. The state of $\overline{CS}$ is latched on the falling edge of ALE.
CLK	1	2	O	Output clock. This pin is selectable under processor control to be either the crystal frequency (for use as a processor clock) or 16 x the data rate for use as a baud rate clock in DPSK modes only. The pin defaults to the crystal frequency on reset.
$\overline{INT}$	17	13	O	Interrupt. This open drain output signal is used to inform the processor that a detect flag has occurred. The processor must then read the detect register to determine which detect triggered the interrupt. $\overline{INT}$ will stay low until the processor reads the detect register or does a full reset.
$\overline{RD}$	14	-	I	Read. A low requests a read of the SSI 73K322L internal registers. Data cannot be output unless both $\overline{RD}$ and the latched $\overline{CS}$ are active or low.
RESET	25	20	I	Reset. An active high signal on this pin will put the chip into an inactive state. All control register bits (CR0, CR1, Tone) will be reset. The output of the CLK pin will be set to the crystal frequency. An internal pull down resistor permits power on reset using a capacitor to VDD.

PARALLEL MICROPROCESSOR INTERFACE (Continued)

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
$\overline{WR}$	13	-	I	Write. A low on this informs the SSI 73K322L that data is available on AD0-AD7 for writing into an internal register. Data is latched on the rising edge of $\overline{WR}$. No data is written unless both $\overline{WR}$ and the latched $\overline{CS}$ are low.

SERIAL MICROPROCESSOR INTERFACE

A0-A2	-	5-7	I	Register Address Selection. These lines carry register addresses and should be valid during any read or write operation.
DATA	-	8	I/O	Serial Control Data. Data for a read/write operation is clocked in or out on the falling edge of the EXCLK pin. The direction of data flow is controlled by the $\overline{RD}$ pin. $\overline{RD}$ low outputs data. $\overline{RD}$ high inputs data.
$\overline{RD}$	-	10	I	Read. A low on this input informs the SSI 73K322L that data or status information is being read by the processor. The falling edge of the $\overline{RD}$ signal will initiate a read from the addressed register. The $\overline{RD}$ signal must continue for eight falling edges of EXCLK in order to read all eight bits of the referenced register. Read data is provided LSB first. Data will not be output unless the $\overline{RD}$ signal is active.
$\overline{WR}$	-	9	I	Write. A low on this input informs the SSI 73K322L that data or status information has been shifted in through the DATA pin and is available for writing to an internal register. The normal procedure for a write is to shift in data LSB first on the DATA pin for eight consecutive falling edges of EXCLK and then to pulse $\overline{WR}$ low. Data is written on the rising edge of $\overline{WR}$.

Note: In the serial, 22-pin version, the pins AD0-AD7, ALE and $\overline{CS}$ are removed and replaced with the pins; A0, A1, A2, DATA, and an unconnected pin. Also, the $\overline{RD}$ and $\overline{WR}$ controls are used differently.

The Serial Control mode is provided in the parallel control versions by tying ALE high and $\overline{CS}$ low. In this configuration AD7 becomes DATA and AD0, AD1 and AD2 become A0, A1 and A2, respectively.

DTE USER INTERFACE

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
EXCLK	19	15	I	External Clock. This signal is used only in synchronous DPSK transmission when the external timing option has been selected. In the External Timing mode the rising edge of EXCLK is used to strobe synchronous DPSK transmit data available on the TXD pin. Also used for serial control interface.

RS-232 INTERFACE (Continued)

NAME	28-PIN	22-PIN	TYPE	DESCRIPTION
RXCLK	23	18	O	Receive Clock. The falling edge of this clock output is coincident with the transitions in the serial received DPSK data output. The rising edge of RXCLK can be used to latch the valid output data. RXCLK will be valid as long as a carrier is present. In V.23 or V.21 mode a clock which is 16 x1200 (or 16 x 75) or 16 x 300 Hz baud data rate is output, respectively, for driving a UART.
RXD	22	17	O	Received Data Output. Serial receive data is available on this pin. The data is always valid on the rising edge of RXCLK when in Synchronous mode. RXD will output constant marks if no carrier is detected.
TXCLK	18	14	O	Transmit Clock.This signal is used only in synchronous DPSK transmission to latch serial input data on the TXD pin. Data must be provided so that valid data is available on the rising edge of the TXCLK. The transmit clock is derived from different sources depending upon the Synchronization mode selection. In Internal Mode the clock is 1200 Hz generated internally. In External Mode TXCLK is phase locked to the EXCLK pin. In Slave Mode TXCLK is phase locked to the RXCLK pin. TXCLK is always active. In V.23 or V.21 mode the output is a 16 x 1200 (or 16 x 75) or 16 x 300 Hz baud clock, respectively for driving a UART.
TXD	21	16	I	Transmit Data Input. Serial data for transmission is applied on this pin. In Synchronous modes, the data must be valid on the rising edge of the TXCLK clock. In Asynchronous modes (1200 or 300 baud) no clocking is necessary. DPSK must be 1200/600 bit/s +1%, -2.5% or +2.3%, -2.5 % in Extended Overspeed mode.

ANALOG INTERFACE AND OSCILLATOR

RXA	27	22	I	Received modulated analog signal input from the telephone line interface.
TXA	16	12	O	Transmit analog output to the telephone line interface.
XTL1 XTL2	2 3	3 4	I I	These pins are for the internal crystal oscillator requiring a 11.0592 MHz Parallel mode crystal and two load capacitors to Ground. XTL2 can also be driven from an external clock.

REGISTER DESCRIPTIONS

Four 8-bit internal registers are accessible for control and status monitoring. The registers are accessed in read or write operations by addressing the A0 and A1 address lines in Serial mode, or the AD0 and AD1 lines in Parallel mode. The AD0 and AD1 lines are latched by ALE. Register CR0 controls the method by which data is transferred over the phone line. CR1 controls the interface between the microprocessor and the SSI 73K322L internal state. DR is a detect register which provides an indication of monitored modem status conditions. TR, the tone control register, controls the DTMF generator, answer and guard tones and RXD output gate used in the modem initial connect sequence. All registers are read/write except for DR which is read only. Register control and status bits are identified below:

REGISTER BIT SUMMARY

	ADDRESS	DATA BIT NUMBER							
REGISTER	AD2 - AD0	D7	D6	D5	D4	D3	D2	D1	D0
CONTROL REGISTER 0 CR0	000	MODULATION OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE
CONTROL REGISTER 1 CR1	001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTERRUPT	BYPASS SCRAMBLER/ ADD PH. EQ. (V.23)	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0
DETECT REGISTER DR	010			RECEIVE DATA	UNSCR. MARKS	CARRIER DETECT	SPECIAL TONE	CALL PROGRESS	LONG LOOP
TONE CONTROL REGISTER TR	011	RXD OUTPUT CONTROL	TRANSMIT GUARD/ CALLING TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF3	DTMF2/ V.23 FDX	DTMF1/ OVERSPEED	DTMF0/GUARD/ ANSWER/SPEC. TONE SELECT
CONTROL REGISTER 2 CR2	100	THESE REGISTER LOCATIONS ARE RESERVED FOR							
CONTROL REGISTER 3 CR3	101	USE WITH OTHER K-SERIES FAMILY MEMBERS							
ID REGISTER ID	110	ID	ID	ID	ID				

NOTE: When a register containing reserved control bits is written into, the reserved bits must be programmed as 0's.

SSI 73K322L
CCITT V.23, V.22, V.21
Single-Chip Modem

REGISTER ADDRESS TABLE

REGISTER	ADDRESS AD2 - AD0	DATA BIT NUMBER D7	D6	D5	D4	D3	D2	D1	D0
CONTROL REGISTER 0 CR0	000	MODULATION OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ORIGINATE/ ANSWER
		0=1200 BIT/S DPSK 1=600 BIT/S DPSK 0=V.23 FSK 1=V.21 FSK		0000=PWR DOWN 0001=INT SYNCH 0010=EXT SYNCH 0011=SLAVE SYNCH 0100=ASYNCH 8 BITS/CHAR 0101=ASYNCH 9 BITS/CHAR 0110=ASYNCH 10 BITS/CHAR 0111=ASYNCH 11 BITS/CHAR 1100=FSK				0=DISABLE TXA OUTPUT 1=ENABLE TXA OUTPUT	IN V.21 OR V.22 MODE: 0=ANSWER 1=ORIGINATE IN V.23 MODE : 0=RECEIVE @ 1200 BIT/S, TRANSMIT @ 75 BIT/S 1=RECEIVE @ 75 BIT/S, TRANSMIT @ 1200 BIT/S
CONTROL REGISTER 1 CR1	001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTERRUPT	BYPASS SCRAMBLER/ ADD PH. EQ.	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0
		00=TX DATA 01=TX ALTERNATE 10=TX MARK 11=TX SPACE		0=DISABLE 1=ENABLE	0=NORMAL 1=BYPASS SCRAMBLER 1=ADD EXTRA PHASE EQ. IN V.23 ONLY	0=XTAL 1=16 X DATA RATE OUTPUT AT CLK PIN IN DPSK MODE ONLY	0=NORMAL 1=RESET	00=NORMAL 01=ANALOG LOOPBACK 10=REMOTE DIGITAL LOOPBACK 11=LOCAL DIGITAL LOOPBACK	
DETECT REGISTER DR	010			RECEIVE DATA	UNSCR. MARK DETECT	CARRIER DETECT	SPECIAL TONE	CALL PROGRESS	LONG LOOP
				OUTPUTS RECEIVED DATA STREAM		0=CONDITION NOT DETECTED 1=CONDITION DETECTED			
TONE CONTROL REGISTER TR	011	RXD OUTPUT CONTROL	TRANSMIT GUARD/ CALLING TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF3	DTMF2 V.23 FDX	DTMF1/ OVERSPEED	DTMF0/GUARD/ ANSWER/ SPECIAL TONE
		RXD PIN 0=NORMAL 1=TRI STATE	0=OFF 1=ON	0=OFF 1=ON	0=DATA 1=TX DTMF	4 BIT CODE FOR 1 OF 16 DUAL TONE COMBINATIONS.	0=NORMAL 1=ALLOWS V.23 FULL DUPLEX OPERATION		0=1800 Hz G.T. (V.22). 2225 Hz ANS TONE GENERATED, FSK MARK DETECT SELECTED 1=550 Hz G.T. (V.22) 2100 Hz ANS TONE GENERATED & DETECTED (V.21, V.22) 1300 Hz DETECTED (V.23)
ID REGISTER ID	110	ID	ID	ID	ID				

00XX=73K212L, 322L, 321L
01XX=73K221L, 302L
10XX=73K222L
1100=73K224L
1110=73K324L
1101=73K312L

CONTROL REGISTER 0

	D7	D6	D5	D4	D3	D2	D1	D0
CR0 000	MODUL. OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE

BIT NO.	NAME	CONDITION	DESCRIPTION
D0 high	Answer/	0 Originate	Selects Answer mode in V.21 and V.22 (transmit in band), receive in low band or in V.23 HDX mode, receive at 1200 bit/s and transmit at 75 bit/s.
		1	Selects Originate mode in V.21 and V.22 (transmit in low band),receive in high band or in V.23 HDX mode, receive at 75 bit/s and transmit at 1200 bit/s.
			Note: This bit works with TR bit D0 to program special tones detected in Tone Register. See detect and tone registers.
D1	Transmit Enable	0	Disables transmit output at TXA.
		1	Enables transmit output at TXA.
			Note: Answer tone and DTMF TX control require TX enable.
D5, D4,D3, D2	Transmit Mode	D5 D4 D3 D2	
		0 0 0 0	Selects Power Down mode. All functions disabled except digital interface.
		0 0 0 1	Internal Synchronous mode. In this mode TXCLK is an internally derived 1200 Hz signal. Serial input data appearing at TXD must be valid on the rising edge of TXCLK. Receive data is clocked out of RXD on the falling edge of RXCLK.
		0 0 1 0	External Synchronous mode. Operation is identical to internal synchronous, but TXCLK is connected internally to EXCLK pin, and a 1200 Hz ± 0.01% clock must be supplied externally.
		0 0 1 1	Slave Synchronous mode. Same operation as other Synchronous modes. TXCLK is connected internally to the RXCLK pin in this mode.
		0 1 0 0	Selects DPSK Asynchronous mode - 8 bits/character (1 start bit, 6 data bits, 1 stop bit).
		0 1 0 1	Selects DPSK Asynchronous mode - 9 bits/character (1 start bit, 7 data bits, 1 stop bit).
		0 1 1 0	Selects DPSK Asynchronous mode - 10 bits/character (1 start bit, 8 data bits, 1 stop bit).
		0 1 1 1	Selects DPSK Asynchronous mode - 11 bits/character (1 start bit, 8 data bits, Parity and 1 or 2 stop bits).
		1 1 0 0	Selects FSK operation.

CONTROL REGISTER 0 (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
CR0 000	MODUL. OPTION		TRANSMIT MODE 3	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE

BIT NO.	NAME	CONDITION	DESCRIPTION
D6		0	Not used; must be written as a "0."
D7	Modulation Option	D7 D5 D4	Selects:
		0 0 X	PSK Asynchronous mode at 1200 bit/s.
		1 0 X	PSK Asynchronous mode at 600 bit/s.
		0 1 1	FSK CCITT V.23 mode.
		1 1 1	FSK CCITT V.21 mode.

CONTROL REGISTER 1

	D7	D6	D5	D4	D3	D2	D1	D0
CR1 001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTER.	BYPASS SCRAMB/ ADD PH. EQ.	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D1, D0	Test Mode	D1 D0	
		0 0	Selects normal operating mode.
		0 1	Analog Loopback mode. Loops the transmitted analog signal back to the receiver, and causes the receiver to use the same center frequency as the transmitter. To squelch the TXA pin, transmit enable must be forced low.
		1 0	Selects remote digital loopback. Received data is looped back to transmit data internally, and RXD is forced to a mark. Data on TXD is ignored.
		1 1	Selects local digital loopback. Internally loops TXD back to RXD and continues to transmit carrier from TXA pin.
D2	Reset	0	Selects normal operation.
		1	Resets modem to power down state. All control register bits (CR0, CR1, Tone) are reset to zero. The output of the CLK pin will be set to the crystal frequency.

CONTROL REGISTER 1 (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
CR1 001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTER.	BYPASS SCRAMB/ ADD PH. EQ.	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D3	CLK Control	0	Selects 11.0592 MHz crystal echo output at CLK pin.
		1	Selects 16 X the data rate, output at CLK pin in DPSK modes only.
D4	Bypass Scrambler/ Add Phase Equalization	0	Selects normal operation. DPSK data is passed through scrambler.
		1	Selects Scrambler Bypass. DPSK data is routed around scrambler in the transmit path. In V.23 mode, additional phase equalization is added to the main channel filters when D4 is set to 1.
D5	Enable Detect	0	Disables interrupt at $\overline{INT}$ pin.
		1	Enables $\overline{INT}$ output. An interrupts will be generated with a change in status of DR bits D1-D4. The special tone and call progress detect interrupts are masked when the TX enable bit is set. Carrier detect is masked when TX DTMF is activated. All interrupts will be disabled if the device is in power down mode.
D7, D6	Transmit Pattern	D7 D6	
		0 0	Selects normal data transmission as controlled by the state of the TXD pin.
		0 1	Selects an alternating mark/space transmit pattern for modem testing.
		1 0	Selects a constant mark transmit pattern.
		1 1	Selects a constant space transmit pattern.

3

DETECT REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
DR 010			RECEIVE DATA	UNSCR. MARK	CARR. DETECT	SPECIAL TONE	CALL PROG.	LONG LOOP

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	Long Loop	0	Indicates normal received signal.
		1	Indicates low received signal level.
D1	Call Progress Detect	0	No call progress tone detected.
		1	Indicates presence of call progress tones. The call progress detection circuitry is activated by energy in the normal 350 to 620 Hz call progress band.
D2	Special Tone Detect	0	No special tone detected as programmed by CR0 bit D0 and Tone Register bit D0.
		1	Special tone detected. The detected tone is:
			(1) 2100 Hz answer tone if D0 of TR=1 and the device is in V.21 or V.22 originate mode.
			(2) 1300 Hz calling tone if D0 of TR=1 and the device is in V.21, or V.22 answer mode.
			(3) an FSK mark in the mode the device is set to receive.
			Tolerance on special tones is ±3%.
D3	Carrier Detect	0	No carrier detected in the receive channel.
		1	Indicated carrier has been detected in the received channel.
D4	Unscrambled Mark	0	No unscrambled mark.
		1	Indicates detection of unscrambled marks in the received data. A valid indication requires that unscrambled marks be received for > 165.5 ± 6.5 ms.
D5	Receive Data		Continuously outputs the received data stream. This data is the same as that output on the RXD pin, but it is not disabled when RXD is tri-stated.
D6, D7			Not used.

TONE REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.	TRANSMIT GUARD/ CALLING TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2/ V.23 FDX	DTMF 1/ OVER-SPEED	DTMF 0/ G.T./ANSW./ SP. TONE/ SELECT

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	DTMF 0	D6 D5 D4 D0	D0 interacts with bits D6, D4, and CR0 as shown.
		X X 1 X	Transmit DTMF tones.
	Guard Tone/ Answer Tone	1 X 0 0	Select 1800 Hz guard tone if in V.22 and Answer mode in CR0.
	Special Tone/ Detect/Select	1 X 0 1	Select 550 Hz guard tone if in V.22 and Answer mode in CR0.
		X X 0 0	Mark of an FSK mode selected in CR0 is to be detected in D2 of DR.
		X X 0 1	2100 Hz answer tone will be detected in D2 of DR if V.21 or V.22 Originate mode is selected in CR0.
			1300 Hz calling tone will be detected in D2 of DR if V.21, or V.22 Answer mode is selected in CR0.
		X 1 0 0	Transmit 2225 Hz Answer Tone
		X 1 0 1	Transmit 2100 Hz Answer Tone
D1	DTMF 1/ Overspeed	D4 D1	D1 interacts with D4 as shown.
		0 0	Asynchronous DPSK 1200 or 600 bit/s +1.0% -2.5%.
		0 1	Asynchronous DPSK 1200 or 600 bit/s +2.3% -2.5%.
D2	DTMF 2/ V.23 FDX	0	Half-duplex asymetric operation in V.23 mode.
		1	Full-duplex (4-wire) operation in V.23 mode.
D3, D2, D1, D0	DTMF 3, 2, 1, 0	D3 D2 D1 D0	
		0 0 0 0 - 1 1 1 1	Programs 1 of 16 DTMF tone pairs that will be transmitted when TX DTMF and TX enable bit (CR0, bit D1) are set. Tone encoding is shown below:

KEYBOARD EQUIVALENT	DTMF CODE D3 D2 D1 D0	TONES LOW HIGH
1	0 0 0 1	697 1209
2	0 0 1 0	697 1336
3	0 0 1 1	697 1477
4	0 1 0 0	770 1209
5	0 1 0 1	770 1336
6	0 1 1 0	770 1477
7	0 1 1 1	852 1209

TONE REGISTER (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.	TRANSMIT GUARD/ CALLING TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2/ V.23 FDX	DTMF 1/ OVER-SPEED	DTMF 0/ GUARD/ SPECIAL TONE SEL

BIT NO.	NAME	CONDITION	DESCRIPTION
D3, D2, D1, D0 (Cont.)			KEYBOARD EQUIVALENT / DTMF CODE D3 D2 D1 D0 / TONES LOW HIGH
			8 — 1 0 0 0 — 852 1336
			9 — 1 0 0 1 — 852 1477
			0 — 1 0 1 0 — 941 1336
			* — 1 0 1 1 — 941 1209
			# — 1 1 0 0 — 941 1477
			A — 1 1 0 1 — 697 1633
			B — 1 1 1 0 — 770 1633
			C — 1 1 1 1 — 852 1633
			D — 0 0 0 0 — 941 1633
D4	Transmit DTMF	0	Disable DTMF.
		1	Activate DTMF.The selected DTMF tones are transmitted continuously when this bit is high. TX DTMF overrides all other transmit functions.
D5	Transmit Answer Tone	0	Disables answer tone generator.
		1	Enables answer tone generator. A 2100 Hz answer tone will be transmitted continuously when the transmit enable bit is set. The device must be in Answer mode. To transmit answer tone, the device must be in DPSK Answer mode.
D6	TX Guard or Calling Tone	0	Disables guard/calling tone generator.
		1	Transmit guard tone if in V.22 and answering; otherwise transmit calling tone, in any other mode including V.23 mode.
D7	RXD Output Control	0	Enables RXD pin. Receive data will be output on RXD.
		1	Disables RXD pin. The RXD pin reverts to a high impedance with internal weak pull-up resistor.

ID REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
ID 110	ID	ID	ID	ID				

BIT NO.	NAME	CONDITION	DESCRIPTION
		D7 D6 D5 D4	Indicates Device:
D7, D6, D5 D4	Device Identification Signature	0 0 X X	SSI 73K212L, 73K321L or 73K322L or 73K321L
		0 1 X X	SSI 73K221L or 73K302L
		1 0 X X	SSI 73K222L
		1 1 0 0	SSI 73K224L
		1 1 1 0	SSI 73K324L
		1 1 0 1	SSI 73K312L

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

PARAMETER	RATING	UNIT
VDD Supply Voltage	14	V
Storage Temperature	-65 to 150	°C
Soldering Temperature (10 sec.)	260	°C
Applied Voltage	-0.3 to VDD+0.3	V
Note: All inputs and outputs are protected from static charge using built-in, industry standard protection devices and all outputs are short-circuit protected.		

RECOMMENDED OPERATING CONDITIONS

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
VDD Supply voltage		4.5	5	5.5	V
TA, Operating Free-Air Temp.		-40		+85	°C
Clock Variation	(11.0592 MHz) Crystal or external clock	-0.01		+0.01	%
External Components (Refer to Application section for placement.)					
VREF Bypass Capacitor	(External to GND)	0.1			µF
Bias setting resistor	(Placed between VDD and ISET pins)	1.8	2	2.2	MΩ
ISET Bypass Capacitor	(ISET pin to GND)	0.1			µF
VDD Bypass Capacitor 1	(External to GND)	0.1			µF
VDD Bypass Capacitor 2	(External to GND)	22			µF
XTL1 Load Capacitor	Depends on crystal characteristics;			40	pF
XTL2 Load Capacitor	from pin to GND			20	

DC ELECTRICAL CHARACTERISTICS
(TA = -40°C to 85°C, VDD = recommended range unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
IDD, Supply Current	ISET Resistor = 2 MΩ				
IDDA, Active	CLK = 11.0592 MHz		8	12	mA
IDD1, Power-down	CLK = 11.0592 MHz			4	mA
IDD2, Power-down	CLK = 19.200 KHz			3	mA
Digital Inputs					
VIH, Input High Voltage					
Reset, XTL1, XTL2		3.0		VDD	V
All other inputs		2.0		VDD	V
VIL, Input Low Voltage		0		0.8	V
IIH, Input High Current	VI = VIH Max			100	µA
IIL, Input Low Current	VI = VIL Min	-200			µA
Reset Pull-down Current	Reset = VDD	1		50	µA
Input Capacitance	All Digital Input Pins			10	pF
Digital Outputs					
VOH, Output High Voltage	IOH MIN = -0.4 mA	2.4		VDD	V
VOL, Output Low Voltage	IO MAX = 1.6 mA			0.4	V
VOL, CLK Output	IO = 3.6 mA			0.6	V
RXD Tri-State Pull-up Curr.	RXD = GND	-1		-50	µA
CMAX, CLK Output	Maximum Capacitive Load			15	pF
Capacitance					
Inputs	Capacitance, all Digital Input pins			10	pF
XTAL1, 2 Load Capacitors	Depends on crystal characteristics	15		60	pF
CLK	Maximum Capacitive Load			15	pF

DYNAMIC CHARACTERISTICS AND TIMING
(TA = -40°C to +85°C, VDD = Recommended range unless otherwise noted.)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
DPSK Modulator					
Carrier Suppression	Measured at TXA	45			dB
Output Amplitude	TX scrambled marks	-11	-10	-9	dBm0
FSK Modulator					
Output Freq. Error	CLK = 11.0592 MHz	-0.35		+0.35	%
Transmit Level	Transmit Dotting Pattern	-11	-10	-9	dBm0
Harmonic Distortion in 700-2900 Hz band	THD in the alternate band DPSK or FSK		-60	-50	dB
Output Bias Distortion	Transmit Dotting Pattern In ALB @ RXD		±3		%
Total Output Jitter	Random Input in ALB @ RXD	-10		+10	%
DTMF Generator					
Freq. Accuracy	Must be in V.22 mode	-.25		+.25	%
Output Amplitude	Low Band, V.22 mode	-10	-9	-8	dBm0
Output Amplitude	High Band, V.22 mode	-8	-7	-6	dBm0
Twist	High-Band to Low-Band, V.22 mode	1.0	2.0	3.0	dB
Long Loop Detect	With Sinusoid	-38		-28	dBm0
Dynamic Range	Refer to Performance Curves		45		dB

Note: Parameters expressed in dBm0 refer to the following definition:

0 dB loss in the Transmit path to the line.

2 dB gain in the Receive path from the line.

Refer to the Basic Box Modem diagram in the Applications section for the DAA design.

3

DYNAMIC CHARACTERISTICS AND TIMING (Continued)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Call Progress Detector					
Detect Level	-3 dB points in 285 and 675 Hz	-38			dBm0
Reject Level	Test signal is a 460 Hz sinusoid			-45	dBm0
Delay Time	-70 dBm0 to -30 dBm0 STEP			40	ms
Hold Time	-30 dBm0 to -70 dBm0 STEP			40	ms
Hysteresis		2			dB
Carrier Detect					
Threshold	DPSK or FSK receive data	-48		-43	dBm0
Delay Time					
V.21		10		20	ms
V.22		15		32	ms
V.23 Forward Channel		6		12	ms
V.23 Back Channel		25		40	ms
Hold Time					
V.21		6		20	ms
V.22		10		24	ms
V.23 Forward Channel		3		8	ms
V.23 Back Channel		10		25	ms
Hysteresis		2			dB
Special Tone Detectors					
Detect Level	See definitions for TR bit D0 mode	-48		-43	dBm0
Delay Time					
2100 Hz answer tone		10		25	ms
1300 Hz calling tone		10		25	ms
390 Hz V.23 back channel mark		20		65	ms

DYNAMIC CHARACTERISTICS AND TIMING (Continued)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Special Tone Detectors (Continued)					
980 or 1650 Hz V.21 marks		10		25	ms
Hold Time					
2100 Hz answer tone		4		15	ms
1300 Hz calling tone		3		10	ms
390 Hz V.23 back channel mark		10		25	ms
980 or 1650 Hz V.21 marks		5		15	ms
Hysteresis		2			dB
Detect Freq. Range	Any Special Tone	-3		+3	%
Output Smoothing Filter					
Output load	TXA pin; FSK Single Tone out for THD = -50 dB in 0.3 to 3.4 kHz	10		 50	kΩ pF
Out of Band Energy	Frequency >12 kHz in all modes			-60	dBm0
Output Impedance	TXA pin, TXA enabled		20	50	Ω
Clock Noise	TXA pin; 76.8 kHz or 122.88 kHz in V.23 main channel		0.1	0.4	mVrms
Carrier VCO					
Capture Range	Originate or Answer	-10		+10	Hz
Capture Time	-10 Hz to +10 Hz Carrier Freq. Change Assum.		40	100	ms
Recovered Clock					
Capture Range	% of frequency center frequency (center at 1200 Hz)	-625		+625	ppm
Data Delay Time	Analog data in at RXA pin to receive data valid at RXD pin		30	50	ms

3

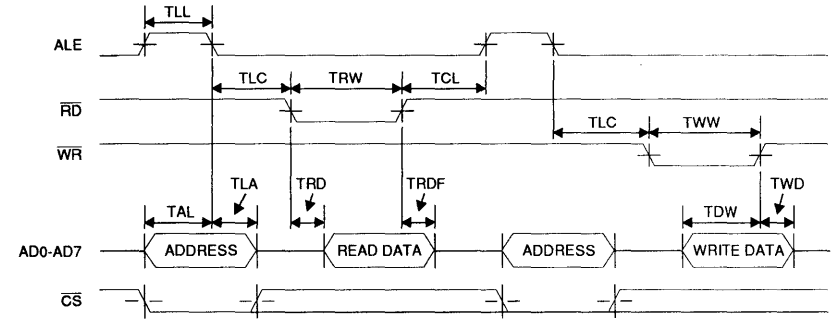
DYNAMIC CHARACTERISTICS AND TIMING (Continued)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Guard Tone Generator					
Tone Accuracy	550 or 1800 Hz	-20		+20	Hz
Tone Level	550 Hz	-4.0	-3.0	-2.0	dB
(Below DPSK Output)	1800 Hz	-7.0	-6.0	-5.0	dB
Harmonic Distortion 700 to 2900 Hz	550 Hz			-50	dB
Timing (Refer to Timing Diagrams)					
TAL	$\overline{CS}$/Addr. setup before ALE Low	25			ns
TLA	$\overline{CS}$/Addr. hold after ALE Low	20			ns
TLC	ALE Low to $\overline{RD}$/$\overline{WR}$ Low	30			ns
TCL	$\overline{RD}$/$\overline{WR}$ Control to ALE High	-5			ns
TRD	Data out from $\overline{RD}$ Low	0		140	ns
TLL	ALE width	30			ns
TRDF	Data float after $\overline{RD}$ High	0		5	ns
TRW	$\overline{RD}$ width	200		25000	ns
TWW	$\overline{WR}$ width	140		25000	ns
TDW	Data setup before $\overline{WR}$ High	40			ns
TWD	Data hold after $\overline{WR}$ High	10			ns
TCKD	Data out after EXCLK Low			200	ns
TCKW	$\overline{WR}$ after EXCLK Low	150			ns
TDCK	Data setup before EXCLK Low	150			ns
TAC	Address setup before control*	50			ns
TCA	Address hold after control*	50			ns
TWH	Data Hold after EXCLK	20			

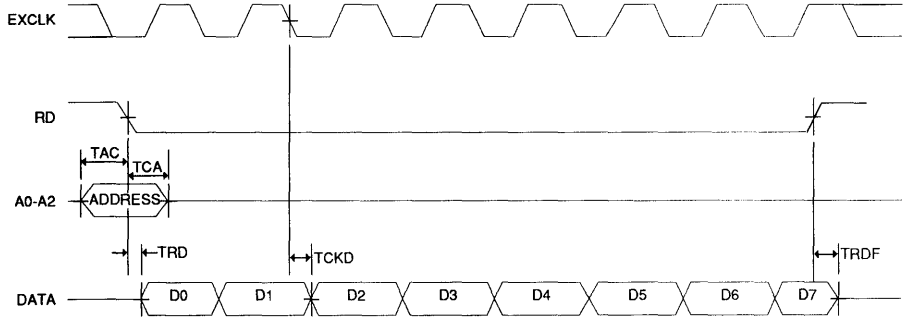
* Control for setup is the falling edge of $\overline{RD}$ or $\overline{WR}$.
Control for hold is the falling edge of $\overline{RD}$ or the rising edge of $\overline{WR}$.

TIMING DIAGRAMS

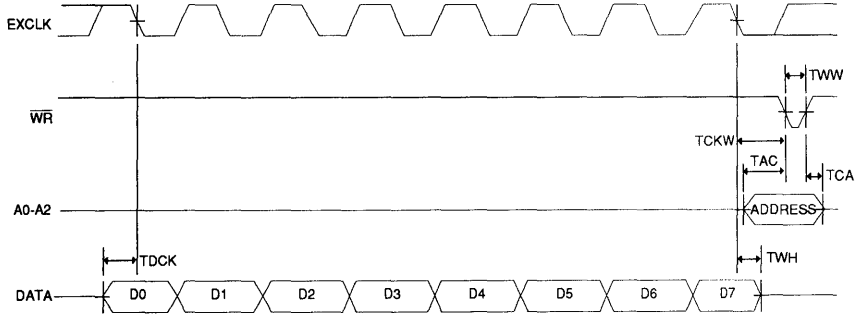
BUS TIMING DIAGRAM (PARALLEL VERSION)



READ TIMING DIAGRAM (SERIAL VERSION)



WRITE TIMING DIAGRAM (SERIAL VERSION)



3

APPLICATIONS INFORMATION

GENERAL CONSIDERATIONS

Figures 1 and 2 show basic circuit diagrams for K-Series modem integrated circuits. K-Series products are designed to be used in conjunction with a control processor, a UART or RS-232 serial data interface, and a DAA phone line interface to function as a typical intelligent modem. The K-Series ICs interface directly with Intel 8048 and 80C51 microprocessors for control and status monitoring purposes. Two typical DAA arrangements are shown: one for a split ±5 or ±12 volt design and one for a single 5 volt design. These diagrams are for reference only and do not represent production-ready modem designs.

K-Series devices are available with two control interface versions: one for a parallel multiplexed address/data interface, and one for a serial interface. The parallel version is intended for use with 8039/48 or 8031/51 microcontrollers from Intel or many other manufacturers. The serial interface 22-pin version can be used with other microcontrollers or in applications where only a limited number of port lines are available or the application does not lend itself to a multiplexed address/data interface. The parallel versions may also be used in the Serial mode, as explained in the data sheet pin description.

In most applications the controller will monitor the serial data for commands from the DTE and the received data for break signals from the far end modem. In this way, commands to the modem are sent over the same line as the transmitted data. In other applications the RS-232 interface handshake lines are used for modem control.

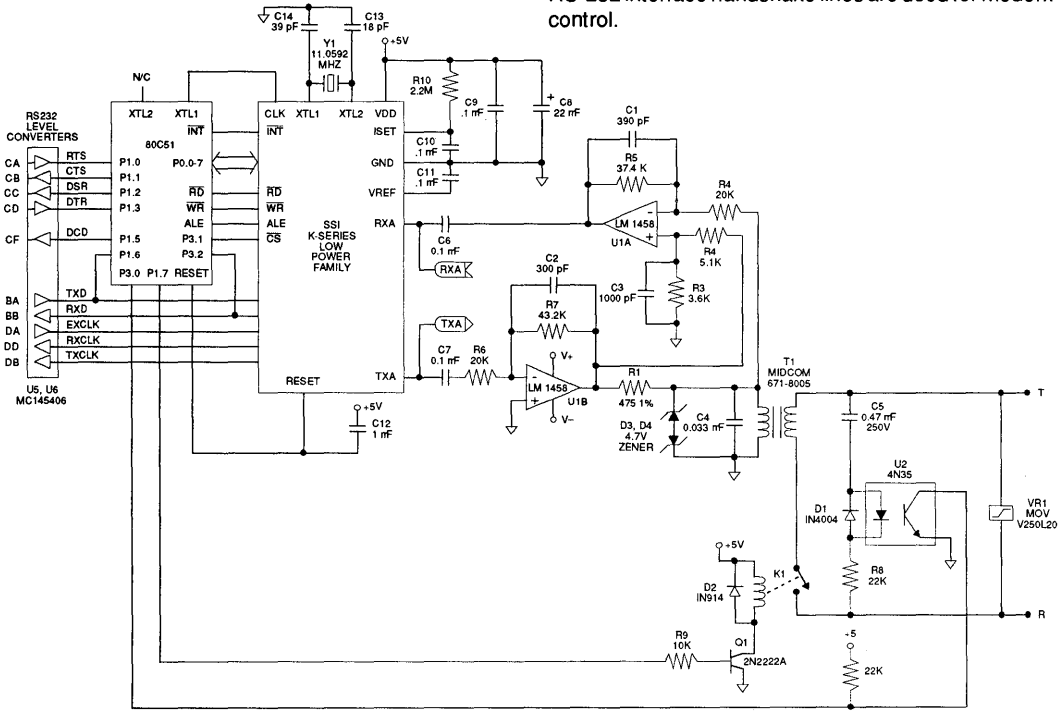


FIGURE 1: Basic Box Modem with Dual-Supply Hybrid

DIRECT ACCESS ARRANGEMENT (DAA)

The telephone line interfaces show two examples of how the "hybrid" may be implemented. The split supply design (Figure 1) is a typical two op-amp hybrid. The receive op-amp serves two purposes. It supplies gain to amplify the receive signal to the proper level for the modem's detectors and demodulator, and it removes the transmitted signal from the receive signal present at the transformer. This is done by supplying a portion of the transmitted signal to the non-inverting input of the receive op-amp at the same amplitude as the signal appearing at the transformer, making the transmit signal Common mode.

The single-supply hybrid is more complex than the dual-supply version described above, but its use eliminates the need for a second power supply. This circuit (Figure 2) uses a bridged drive to allow undistorted signals to be sent with a single 5 volt supply. Because DTMF tones utilize a higher amplitude than data, these signals will clip if a single-ended drive approach is used. The bridged driver uses an extra op-amp (U1A) to invert the signal coming from the gain setting op-amp (U1B) before sending it to the other leg of the transformer. Each op-amp then supplies half the drive signal to the transformer. The receive amplifier (U1C) picks off its signal at the junction of the impedance matching resistor and the transformer. Because the bottom leg of the transformer is being driven in one direction by U1A and the resistor is driven in the opposite direction at the same time by U1B, the junction of the transformer and resistor remains relatively constant and the receive signal is unaffected.

DESIGN CONSIDERATIONS

Silicon Systems' 1-chip modem products include all basic modem functions. This makes these devices adaptable for use in a variety of applications, and as easy to control as conventional digital bus peripherals.

3

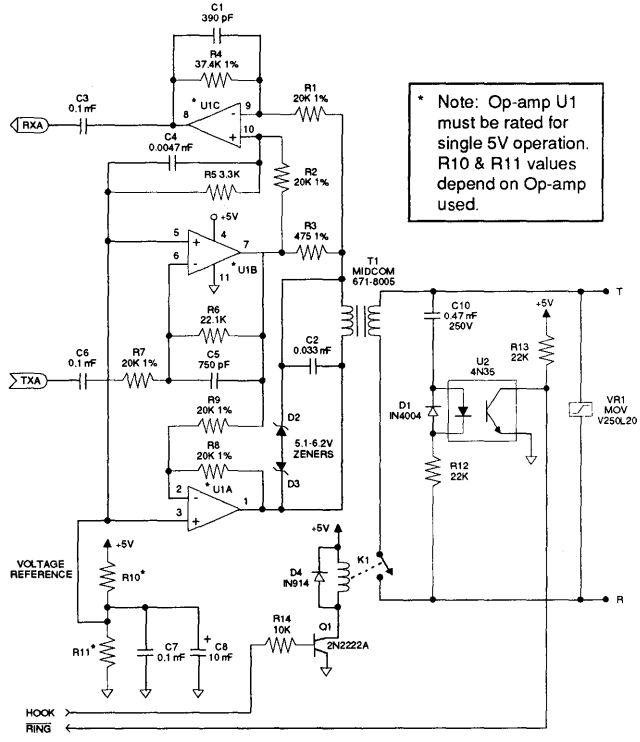


FIGURE 2: Single 5V Hybrid Version

Unlike digital logic circuitry, modem designs must properly contend with precise frequency tolerances and very low level analog signals, to ensure acceptable performance. Using good analog circuit design practices will generally result in a sound design. Following are additional recommendations which should be taken into consideration when starting new designs.

CRYSTAL OSCILLATOR

The K-Series crystal oscillator requires a Parallel mode (antiresonant) crystal which operates at 11.0592 MHz. It is important that this frequency be maintained to within ±0.01% accuracy.

In order for a Parallel mode crystal to operate correctly and to specification, it must have a load capacitor connected to the junction of each of the crystal and internal inverter connections, terminated to ground. The values of these capacitors depend primarily on the crystal's characteristics, and to a lesser degree on the internal inverter circuit. The values used affect the accuracy and start up characteristics of the oscillator.

LAYOUT CONSIDERATIONS

Good analog/digital design rules must be used to control system noise in order to obtain highest performance in modem designs. The more digital circuitry present on the PC board, the more this attention to noise control is needed. The modem should be treated as a high impedance analog device. A 22 mF electrolytic capacitor in parallel with a 0.1 mF ceramic capacitor between VDD and GND is recommended. Liberal use of ground planes and larger traces on power and ground are also highly favored. High speed digital circuits tend to generate a significant amount of EMI (Electro-Magnetic Interference) which must be minimized in order to meet regulatory agency limitations. To accomplish this, high speed digital devices should be locally bypassed, and the telephone line interface and K-Series device should be located close to each other near the area of the board where the phone line connection is accessed. To avoid problems, power supply and ground traces should be routed separately to the analog and digital functions on the board, and digital signals should not be routed near low level or high impedance analog traces. The analog and digital grounds should only connect at one point near the K-Series device ground pin to avoid ground loops. The K–Series modem IC's should have both high frequency and low frequency bypassing as close to the package as possible.

MODEM PERFORMANCE CHARACTERISTICS

The curves presented here define modem IC performance under a variety of line conditions while inducing disturbances that are typical of those encountered during data transmission on public service telephone lines. Test data was taken using an AEA Electronics' "Autotest I" modem test set and line simulator, operating under computer control. All tests were run full-duplex, using a Concord Data Systems 224 as the reference modem. A 511 pseudo-random-bit pattern was used for each data point. Noise was C-message weighted and all signal-to-noise (S/N) ratios reflect total power measurements similar to the CCITT V.56 measurement specification. The individual tests are defined as follows.

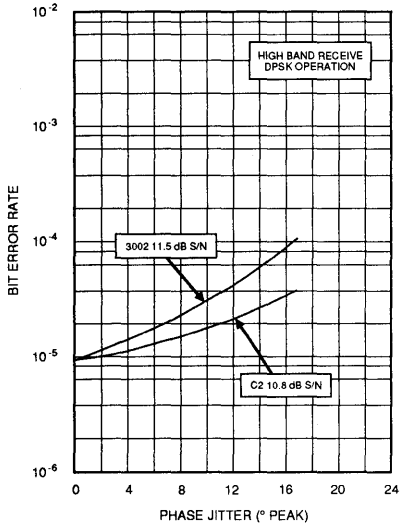
BER vs. S/N

This test measures the ability of the modem to operate over noisy lines with a minimum of data-transfer errors. Since some noise is generated in the best of dial-up lines, the modem must operate with the lowest S/N ratio possible. Better modem performance is indicated by test curves that are closest to the BER axis. A narrow spread between curves representing the four line parameters indicates minimal variation in performance while operating over a range of aberrant operating conditions. Typically, a DPSK modem will exhibit better BER-performance test curves receiving in the low band than in the high band.

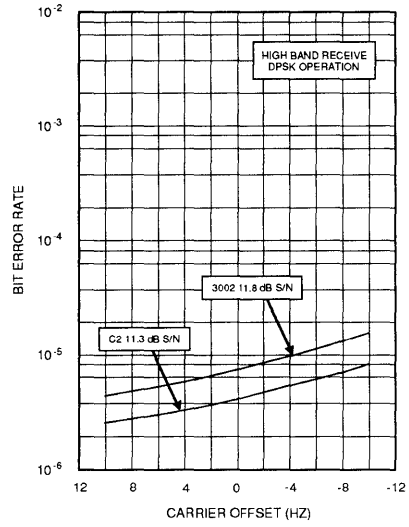
BER vs. Receive Level

This test measures the dynamic range of the modem. Because signal levels vary widely over dial-up lines, the widest possible dynamic range is desirable. The minimum Bell specification calls for 36 dB of dynamic range. S/N ratios are held constant at the indicated values while the receive level is lowered from a very high to very low signal levels. The width of the "bowl" of these curves, taken at the BER point, is the measure of dynamic range.

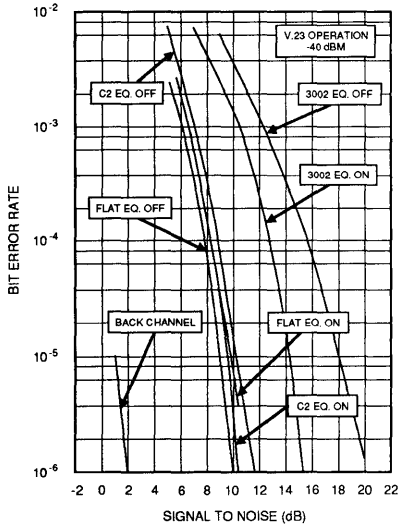
*SSI 73K322L
BER vs PHASE JITTER



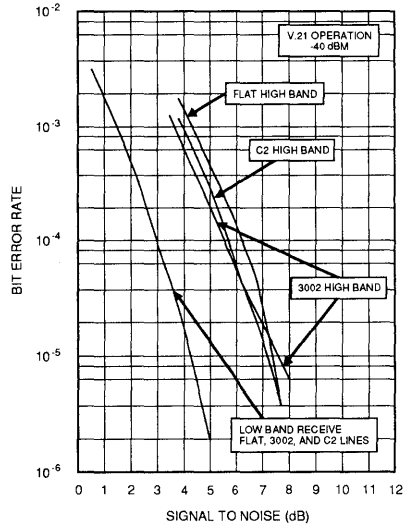
SSI 73K322L
BER vs CARRIER OFFSET



*SSI 73K322L
BER vs S/N (V.23 ONLY)

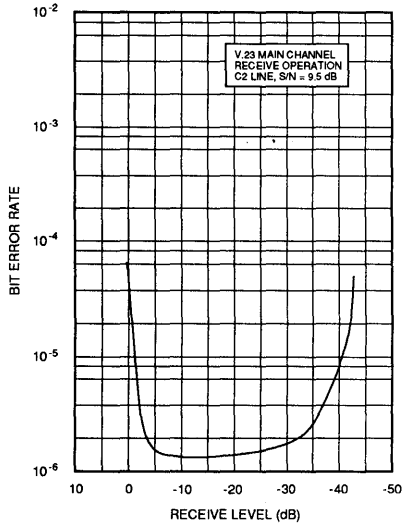


SSI 73K322L
BER vs SIGNAL TO NOISE

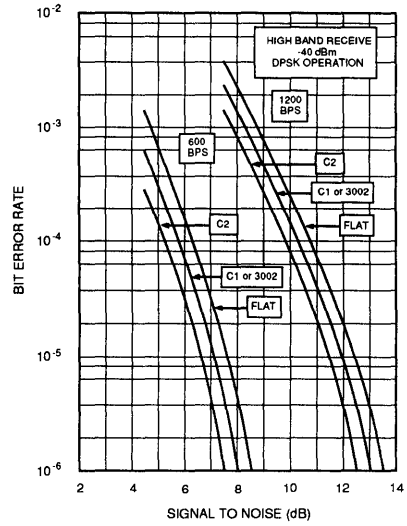


* = "EQ On" Indicates bit CR1 D4 is set for additional phase equalization.

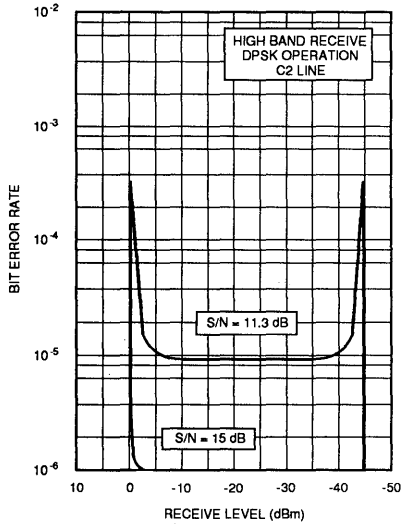
***SSI 73K322**
BER vs RECEVE LEVEL (V.23)



***SSI 73K322L**
BER vs SIGNAL TO NOISE



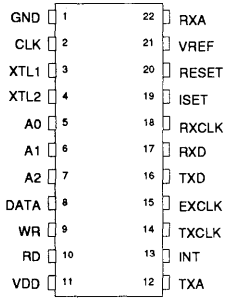
***SSI 73K322**
BER vs RECEVE LEVEL



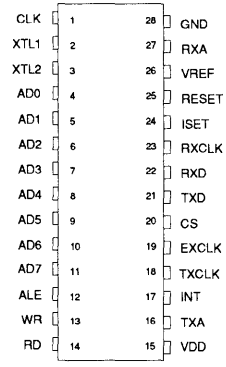
* = "EQ On" Indicates bit CR1 D4 is set for additional phase equalization.

PACKAGE PIN DESIGNATIONS

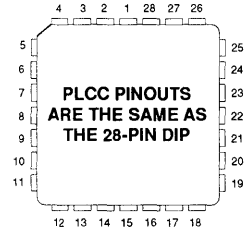
(Top View)



400-Mil 22-Pin DIP



600-Mil 28-Pin DIP



28-Pin PLCC

CAUTION: Use handling procedures necessary for a static sensitive component.

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 73K322L with Parallel Bus Interface		
28-Pin 5V Supply		
Plastic Dual-In-Line	73K322L-IP	73K322L-IP
Plastic Leaded Chip Carrier	73K322L-IH	73K322L-IH
SSI 73K322L with Serial Interface		
22-Pin 5V Supply		
Plastic Dual-In-Line	73K322SL-IP	73K322SL-IP

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Notes:

SSI 73K324L

CCITT V.22bis, V.22, V.21, V.23, Bell 212A Single-Chip Modem

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DESCRIPTION

The SSI 73K324L is a highly integrated single-chip modem IC which provides the functions needed to design a Quad-mode CCITT and Bell 212A compatible modem capable of operation over dial-up lines. The SSI 73K324L adds V.23 capability to the CCITT modes of Silicon Systems' 73K224 one-chip modem, allowing a one-chip implementation in designs intended for European markets which require this added Modulation mode. The SSI 73K324L offers excellent performance and a high level of functional integration in a single IC. The device supports V.22bis, V.22, Bell 212A, V.21, and V.23 operating modes, allowing both synchronous and asynchronous operation as defined by the appropriate standard.

The SSI 73K324L is designed to appear to the Systems Engineer as a microprocessor peripheral, and will easily interface with popular one-chip microcontrollers (80C51 typical) for control of modem functions through its 8-bit multiplexed address/data bus. A serial control bus is available for applications not requiring a parallel interface. An optional package with only the serial control bus is also available. Data communications occurs through a separate serial port.

(Continued)

FEATURES

- **One chip Multi-mode CCITT V.22bis, V.22, V.21, V.23 and Bell 212A compatible modem data pump**
- **FSK (75, 300, 1200 bit/s), DPSK (600, 1200 bit/s), or QAM (2400 bit/s) encoding**
- **Pin and software compatible with other SSI K-Series family one-chip modems**
- **Interfaces directly with standard microprocessors (8048, 80C51 typical)**
- **Serial and parallel microprocessor bus for control**
- **Selectable asynch/synch with internal buffer/ debuffer and scrambler/descrambler functions**
- **All synchronous (internal, external, slave) and Asynchronous Operating modes**
- **Adaptive equalization for optimum performance over all lines**
- **Programmable transmit attenuation (16 dB, 1 dB steps), and selectable receive boost (+18 dB)**
- **Call progress, carrier, answer tone, unscrambled mark, S1, and signal quality monitors**
- **DTMF, answer, calling, SCT and guard tone generators**
- **Test modes available: ALB, DL, RDL; Mark, Space and Alternating bit pattern generators**
- **CMOS technology for low power consumption**
- **4-wire full duplex operation in all modes**

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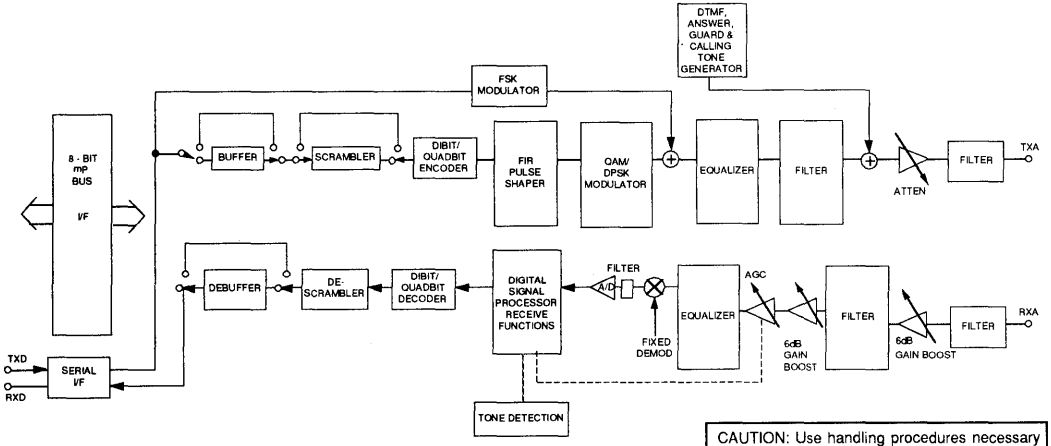
BLOCK DIAGRAM



CAUTION: Use handling procedures necessary for a static sensitive component.

DESCRIPTION (Continued)

The SSI 73K324L offers full hardware and software compatibility with other products in Silicon Systems' K-Series family of single-chip modems, allowing system upgrades with a single component change. The SSI 73K324L is ideal for use in free-standing or integral system modem products where full-duplex 2400 bit/s operation with Alternate mode capability is required. Its high functionality, low power consumption, and efficient packaging simplify design requirements and increase system reliability. A complete modem requires only the addition of the phone line interface, a control microprocessor, and RS-232 level converters for a typical system.

The SSI 73K324L is designed to provide a complete V.22bis, V.22, Bell 212A, V.21, and V.23 compatible modem on a chip. Many functions were included to simplify implementation in typical modem designs. In addition to the basic 2400 bit/s QAM, 1200/600 bit/s DPSK and 1200/300/75 bit/s FSK modulator/demodulator sections, the device also includes synch/asynch buffering, DTMF, answer, soft carrier, guard, and calling tone generator capabilities. Handshake pattern detectors simplify control of connect sequences, and precise tone detectors allow accurate detection of call progress, answer, calling, and soft carrier turn off tones. All Operating modes defined by the incorporated standards are included, and Test modes are provided. Most functions are selectable as options, and logical defaults are provided. The device can be directly interfaced to a microprocessor via its 8-bit multiplexed address/data bus for control and status monitoring. Data communications takes place through a separate serial port. Data may also be sent and received through the control registers. This simplifies designs requiring speed buffering, error control and compression.

FUNCTIONAL DESCRIPTION

QAM MODULATOR/DEMODULATOR

The SSI 73K324L encodes incoming data into quadbits represented by 16 possible signal points with specific phase and amplitude levels. The baseband signal is then filtered to reduce intersymbol interference on the bandlimited telephone network. The modulator transmits this encoded data using either a 1200 Hz (Originate mode) or 2400 Hz (Answer mode) carrier. The demodulator, although more complex, essentially reverses this procedure while also recovering the data clock from the incoming signal. Adaptive equalization corrects for varying line conditions by automatically changing filter parameters to compensate for line characteristics.

DPSK MODULATOR/DEMODULATOR

The SSI 73K324L modulates a serial bit stream into di-bit pairs that are represented by four possible phase shifts as prescribed by the Bell 212A/V.22 standards. The baseband signal is then filtered to reduce intersymbol interference on the bandlimited 2-wire PSTN line. Transmission occurs on either a 1200 Hz (Originate mode) or 2400 Hz carrier (Answer mode). Demodulation is the reverse of the modulation process, with the incoming analog signal eventually decoded into di-bits and converted back to a serial bit stream. The demodulator also recovers the clock which was encoded into the analog signal during modulation. Demodulation occurs using either a 1200 Hz carrier (Answer mode or ALB Originate mode) or a 2400 Hz carrier (Originate mode or ALB Answer mode). The SSI 73K324L use a phase locked loop coherent demodulation technique that offers excellent performance. Adaptive equalization is also used in DPSK modes for optimium operation with varying lines.

FSK MODULATOR/DEMODULATOR

The FSK modulator/demodulator produces a frequency modulated analog output signal using two discrete frequencies to represent the binary data. V.21 frequencies of 980 and 1180 Hz (originate mark and space), or 1650 and 1850 Hz (answer mark and space) are used in V.21 mode. V. 23 mode uses 1300 and 2100 Hz for the main channel or 390 and 450 Hz for the back channel. Demodulation involves detecting the received frequencies and decoding them into the appropriate binary value. The rate converter and scrambler/descrambler are automatically bypassed in the FSK modes.

PASSBAND FILTERS AND EQUALIZERS

High and low band filters are included to shape the amplitude and phase response of the transmit and receive signals and to provide compromise delay equalization as well as rejection of out-of-band signals. The transmit signal filtering corresponds to a $\sqrt{75\%}$ raised cosine frequency response characteristic.

ASYNCHRONOUS MODE

The Asynchronous mode is used for communication with asynchronous terminals which may transfer data at 600, 1200, or 2400 bit/s +1%, -2.5% even though the modem's output is limited to the nominal bit rate ±.01% in DPSK and QAM modes. When transmitting in this mode the serial data on the TxD input is passed through a rate converter which inserts or deletes stop bits in the serial bit stream in order to output a signal that is the nominal bit rate ±.01%. This signal is then routed to a data scrambler and into the analog modulator where di-bit or quad-bit encoding results in the output signal. Both the rate converter and scrambler can be bypassed for handshaking and synchronous operation as selected. Received data is processed in a similar fashion except that the rate converter now acts to reinsert any deleted stop bits and output data to the terminal at no greater than the bit rate plus 1%. An incoming break signal (low through two characters) will be recognized and passed through without incorrectly inserting a stop bit.

The SYNC/ASYNC converter has an extended Overspeed mode which allows selection of an output speed range of either +1% or +2.3%. In the extended Overspeed mode, some stop bits are output at 7/8 the normal width.

Both the SYNC/ASYNC rate converter and the data descrambler are automatically bypassed in the FSK modes.

SYNCHRONOUS MODE

Synchronous operation is possible only in the QAM or DPSK modes. Operation is similar to that of the Asynchronous mode except that data must be synchronized to a clock and no variation in data transfer rate is allowable. Serial input data appearing at TXD must be valid on the rising edge of TXCLK.

TXCLK is an internally derived 1200 or 2400 Hz signal in Internal mode and is connected internally to the RXCLK pin in Slave mode. Receive data at the RXD pin is clocked out on the falling edge of RXCLK. The asynch/synch converter is bypassed when Synchronous mode is selected and data is transmitted out at essentially the same rate as it is input.

PARALLEL CONTROL INTERFACE

Eight 8-bit registers are provided for control, option select, and status monitoring. These registers are addressed with the AD0, AD1, and AD2 multiplexed address lines (latched by ALE) and appear to a control microprocessor as seven consecutive memory locations. Six contol registers are read/write. The detect and ID registers are read only and cannot be modified except by modem response to monitored parameters.

SERIAL CONTROL INTERFACE

The Serial Command mode allows access to the SSI 73K324L control and status registers via a serial control port. In this mode the A0, A1, and A2 lines provide register addresses for data passed through the DATA pin under control of the $\overline{RD}$ and $\overline{WR}$ lines. A read operation is initiated when the $\overline{RD}$ line is taken low. The next eight cycles of EXCLK will then transfer out eight bits of the selected addresss location LSB first. A write takes place by shifting in eight bits of data LSB first for eight consectuive cycles of EXCLK. $\overline{WR}$ is then pulsed low and data transfer into the selected register occurs on the rising edge of $\overline{WR}$.

TONE GENERATOR

The DTMF generator controls the sending of the sixteen standard DTMF tone pairs. The tone pair sent is determined by selecting TRANSMIT DTMF (bit D4) and the 4 DTMF bits (D0-D3) of the TONE register. Transmission of DTMF tones from TXA is gated by the TRANSMIT ENABLE bit of CR0 (bit D1) as with all other analog signals.

FULL DUPLEX OPERATION

Four-wire full duplex operation is allowed in all modes. This feature allows transmission and reception in the same band for four wire applications only.

PIN DESCRIPTION

POWER

NAME	TYPE	DESCRIPTION
GND	I	System Ground.
VDD	I	Power supply input, 5V -5% +10%. Bypass with 0.22 µF and 22 µF capacitors to GND.
VREF	O	An internally generated reference voltage. Bypass with 0.22 µF capacitor to GND.
ISET	I	Chip current reference. Sets bias current for op-amps. The chip current is set by connecting this pin to VDD through a 2 MΩ resistor. Iset should be bypassed to GND with a 0.22 µF capacitor.

PARALLEL MICROPROCESSOR INTERFACE

ALE	I	Address latch enable. The falling edge of ALE latches the address on AD0-AD2 and the chip select on $\overline{CS}$.
AD0-AD7	I/O / Tristate	Address/data bus. These bidirectional tri-state multi-plexed lines carry information to and from the internal registers.
$\overline{CS}$	I	Chip select. A low on this pin allows a read cycle or a write cycle to occur. AD0-AD7 will not be driven and no registers will be written if $\overline{CS}$ (latched) is not active. $\overline{CS}$ is latched on the falling edge of ALE.
CLK	O	Output clock. This pin is selectable under processor control to be either the crystal frequency (for use as a processor clock) or 16 x the data rate for use as a baud rate clock in QAM/DPSK modes only. The pin defaults to the crystal frequency on reset.
$\overline{INT}$	O	Interrupt. This open drain weak pullup, output signal is used to inform the processor that a detect flag has occurred. The processor must then read the detect register to determine which detect triggered the interrupt. $\overline{INT}$ will stay active until the processor reads the detect register or does a full reset.
$\overline{RD}$	I	Read. A low requests a read of the SSI 73K324L internal registers. Data cannot be output unless both $\overline{RD}$ and the latched $\overline{CS}$ are active or low.
RESET	I	Reset. An active high signal on this pin will put the chip into an inactive state. All control register bits (CR0, CR1, CR2, CR3, Tone) will be reset. The output of the CLK pin will be set to the crystal frequency. An internal pull down resistor permits power on reset using a capacitor to VDD.
$\overline{WR}$	I	Write. A low on this informs the SSI 73K324L that data is available on AD0-AD7 for writing into an internal register. Data is latched on the rising edge of $\overline{WR}$. No data is written unless both $\overline{WR}$ and the latched $\overline{CS}$ are low.

Note: The Serial Control mode is provided in the parallel versions by tying ALE high and $\overline{CS}$ low. In this configuration AD7 becomes DATA and AD0, AD1 and AD2 become A0, A1 and A2, respectively.

RS-232 INTERFACE

NAME	TYPE	DESCRIPTION
EXCLK	I	External Clock. This signal is used in synchronous transmission when the external timing option has been selected. In the External Timing mode the rising edge of EXCLK is used to strobe synchronous transmit data available on the TXD pin. Also used for serial control interface.
RXCLK	O/Tristate	Receive Clock Tri-statable. The falling edge of this clock output is coincident with the transitions in the serial received DPSK/QAM data output. The rising edge of RXCLK can be used to latch the valid output data. RXCLK will be valid as long as a carrier is present. In V.23 or V.21 mode a clock which is 16 x 1200/75 or 16 x 300 Hz data rate is output, respectively.
RXD	O	Received Data Output. Serial receive data is available on this pin. The data is always valid on the rising edge of RXCLK when in Synchronous mode. RXD will output constant marks if no carrier is detected.
TXCLK	O/Tristate	Transmit Clock Tri-statable. This signal is used in synchronous DPSK/QAM transmission to latch serial input data on the TXD pin. Data must be provided so that valid data is available on the rising edge of the TXCLK. The transmit clock is derived from different sources depending upon the Synchronization mode selection. In Internal Mode the clock is generated internally (2400 Hz for QAM, 1200 Hz for DPSK or 600 Hz for half-speed DPSK). In External Mode TXCLK is phase locked to the EXCLK pin. In Slave Mode TXCLK is phase locked to the RXCLK pin. TXCLK is always active. In V.23 or V.21 mode the output is a 16 x 1200/75 or 16 x 300 Hz clock, respectively.
TXD	I	Transmit Data Input. Serial data for transmission is input on this pin. In Synchronous modes, the data must be valid on the rising edge of the TXCLK clock. In Asynchronous modes (2400/1200/600 bit/s, or 75/300 baud) no clocking is necessary. DPSK/QAM data must be +1%, -2.5% or +2.3%, -2.5 % in Extended Overspeed mode.

ANALOG INTERFACE

RXA	I	Received modulated analog signal input from the phone line.
TXA	O	Transmit analog output to the phone line.
XTL1	I	These pins are for the internal crystal oscillator requiring a 11.0592 MHz Parallel mode crystal. Two capacitors from these pins to ground are also required for proper crystal operation. Consult crystal manufacturer for proper values. XTL2 can also be driven from an external clock.
XTL2	I/O	

PIN DESCRIPTION (continued)

SERIAL MICROPROCESSOR INTERFACE

NAME	TYPE	DESCRIPTION
A0-A2	I	Register Address Selection. These lines carry register addresses and should be valid during any read or write operation.
DATA	I/O	Serial Control Data. Data for a read/write operation is clocked in or out on the falling edge of the EXCLK pin. The direction of data flow is controlled by the $\overline{RD}$ pin. $\overline{RD}$ low outputs data. $\overline{RD}$ high inputs data.
$\overline{RD}$	I	Read. A low on this input informs the SSI 73K324L that data or status information is being read by the processor. The falling edge of the $\overline{RD}$ signal will initiate a read from the addressed register. The $\overline{RD}$ signal must continue for eight falling edges of EXCLK in order to read all eight bits of the referenced register. Read data is provided LSB first. Data will not be output unless the $\overline{RD}$ signal is active.
$\overline{WR}$	I	Write. A low on this input informs the SSI 73K324L that data or status information has been shifted in through the DATA pin and is available for writing to an internal register. The normal procedure for a write is to shift in data LSB first on the DATA pin for eight consecutive falling edges of EXCLK and then to pulse $\overline{WR}$ low. Data is written on the rising edge of $\overline{WR}$.

Note: In the serial, 22-pin version, the pins AD0-AD7, ALE and $\overline{CS}$ are removed and replaced with the pins; A0, A1, A2, DATA, and EXCLK. Also, the $\overline{RD}$ and $\overline{WR}$ controls are used differently.

REGISTER DESCRIPTIONS

Eight 8-bit internal registers are accessible for control and status monitoring. The registers are accessed in read or write operations by addressing the A0, A1 and A2 address lines in Serial mode, or the AD0, AD1 and AD2 lines in Parallel mode. The address lines are latched by ALE. Register CR0 controls the method by which data is transferred over the phone line. CR1 controls the interface between the microprocessor and the SSI 73K324L internal state. DR is a detect register which provides an indication of monitored modem status conditions. TR, the tone control register, controls the DTMF generator, answer, guard tones, SCT, calling tone, and RXD output gate used in the modem initial connect sequence. CR2 is the primary DSP control interface and CR3 controls transmit attenuation and receive gain adjustments. All registers are read/write except for DR and ID which are read only. Register control and status bits are identified below:

REGISTER BIT SUMMARY

	ADDRESS	DATA BIT NUMBER							
REGISTER	AD - A0	D7	D6	D5	D4	D3	D2	D1	D0
CONTROL REGISTER 0 CR0	000	MODULATION OPTION	MODULATION TYPE 1	MODULATION TYPE 0	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE
CONTROL REGISTER 1 CR1	001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTERRUPT	BYPASS SCRAMBLER/ ADD PH. EQ. (V.23)	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0
DETECT REGISTER DR	010	RECEIVE LEVEL	PATTERN S1 DET	RECEIVE DATA	UNSCR. MARK DETECT	CARRIER DETECT	SPECIAL TONE DETECT	CALL PROGRESS DETECT	SIGNAL QUALITY
TONE CONTROL REGISTER TR	011	RXD OUTPUT CONTROL	TRANSMIT GUARD TONE/ SCT/CALLING TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF3	DTMF2/ 4 WIRE FDX	DTMF1/ OVERSPEED	DTMF0/GUARD/ ANSWER/ CALLING/SCT
CONTROL REGISTER 2 CR2	100	0	SPECIAL REGISTER ACCESS	CALL INITIALIZE	TRANSMIT S1	16 WAY	RESET DSP	TRAIN INHIBIT	EQUALIZER ENABLE
CONTROL REGISTER 3 CR3	101	TXDALT	TRISTATE TX/RXCLK	0	RECEIVE GAIN BOOST	TRANSMIT ATTEN. 3	TRANSMIT ATTEN. 2	TRANSMIT ATTEN. 1	TRANSMIT ATTEN. 0
SPECIAL REGISTER SR	101		TX BAUD CLOCK	RX UNSCR. DATA		TXD SOURCE	SQ SELECT 1	SQ SELECT 0	
ID REGISTER ID	110	ID	ID	ID	ID	USER DEFINABLE PERSONALITY			

NOTE: When a register containing reserved control bits is written into, the reserved bits must be programmed as 0's.

REGISTER ADDRESS TABLE

REGISTER	ADDRESS AD2 - AD0	DATA BIT NUMBER D7	D6	D5	D4	D3	D2	D1	D0
CONTROL REGISTER 0 CR0	000	MODULATION OPTION	MODULATION TYPE 1	MODULATION TYPE 0	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE
		QAM: 0=2400 BIT/S DPSK: 0=1200 BIT/S 1=600 BIT/S FSK: 0=V.23 1=V.21	10=QAM 00=DPSK 01=FSK	0000=PWR DOWN 0001=INT SYNCH 0010=EXT SYNCH 0011=SLAVE SYNCH 0100=ASYCH 8 BITS/CHAR 0101=ASYCH 9 BITS/CHAR 0110=ASYCH 10 BITS/CHAR 0111=ASYCH 11 BITS/CHAR 1X00=FSK				0=DISABLE TXA OUTPUT 1=ENABLE TXA OUTPUT	0=ANSWER 1=ORIGINATE in V.23 0=BC xmit 1=MC xmit
CONTROL REGISTER 1 CR1	001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INTERRUPT	BYPASS SCRAMBLER/ ADD PH. EQ. (V.23)	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0
		00=TX DATA 01=TX ALTERNATE 10=TX MARK 11=TX SPACE		0=OFF 1=ON	0=NORMAL 1=BYPASS SCRAMBLER	0=XTAL 1=16 X DATA RATE OUTPUT AT CLK PIN IN OAM/DPSK MODE ONLY	0=NORMAL 1=RESET	00=NORMAL 01=ANALOG LOOPBACK 10=REMOTE DIGITAL LOOPBACK 11=LOCAL DIGITAL LOOPBACK	
DETECT REGISTER DR	010	RECEIVE LEVEL INDICATOR	S1 PATTERN DETECT	RECEIVE DATA	UNSCR. MARKS DETECT	CARRIER DETECT	SPECIAL TONE DETECT	CP TONE DETECT	SIGNAL QUALITY INDICATOR
		0=SIGNAL BELOW THRESHOLD 1=ABOVE THRESHOLD	0=NOT PRESENT 1=PATTERN FOUND	OUTPUTS RECEIVED DATA STREAM		0=CONDITION NOT DETECTED 1=CONDITION DETECTED			0=GOOD 1=BAD
TONE CONTROL REGISTER TR	011	RXD OUTPUT CONTROL	TRANSMIT GUARD/ CALLING/ SCT TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF3	DTMF2/ V.23 FDX	DTMF1/ OVERSPEED	DTMF0/ GUARD/ ANSWER/ CALLING/SCT
		RXD PIN 0=NORMAL 1=TRI-STATE	0=OFF 1=ON	0=OFF 1=ON	1=TX DTMF	4 BIT CODE FOR 1 OF 16 DUAL TONE COMBINATIONS 0=NORMAL OPERATION 1=ALLOWS V.23 FULL DUPLEX OPERATION			GUARD: 0 - 1800 HZ 1 - 550 HZ ANSWER: 0 - 2225 HZ 1 - 2100 HZ CALLING: 0 - 1300 HZ SCT: 1 - 900 HZ
CONTROL REGISTER 2 CR2	100	MUST BE 0	SPECIAL REGISTER ACCESS	CALL INITIALIZE	TRANSMIT S1	16 WAY	$\overline{\text{RESET}}$ DSP	TRAIN INHIBIT	EQUALIZER ENABLE
			0=ACCESS CR3 1=ACCESS SPECIAL REGISTER	0=DSP IN DEMOD MODE 1=DSP IN CALL PROGRESS MODE	0=NORMAL DOTTING 1=S1	0=RX=TX 1=RX=16 WAY	0=DSP INACTIVE 1=DSP ACTIVE	0=ADAPT EQ ACTIVE 1=ADAPT EQ FROZEN	0=ADAPT EQ IN INIT 1=ADAPT EQ OK TO ADAPT
CONTROL REGISTER 3 CR3	101	TXDALT	TRISTATE TX/RXCLK	0	RECEIVE GAIN BOOST	TRANSMIT ATTEN. 3	TRANSMIT ATTEN. 2	TRANSMIT ATTEN. 1	TRANSMIT ATTEN. 0
		ALTERNATE TRANSMIT DATA SOURCE	0=CLOCK DRIVEN 1=CLOCK TRISTATE		0=NO BOOST 1=18 dB BOOST	0000-1111, SETS TRANSMIT ATTENUATOR 16 dB RANGE DEFAULT=0100 = -10 dbM0			
SPECIAL REGISTER SR	101		TX BAUD CLOCK	RX UNSCR. DATA		TXD SOURCE	SQ SELECT1	SQ SELECT0	
			OUTPUTS TXBAUD CLOCK	OUTPUTS UNSCR. DATA		0=TXD PIN 1=TX DATA CR3-D7	00=10^{-5} BER 01=10^{-6} BER 10=10^{-4} BER 11=10^{-3} BER		
ID REGISTER 10	110	ID	ID	ID	ID	USER DEFINABLE PERSONALITY			

00XX=73K212L, 322L, 321L
01XX=73K221L, 302L
10XX=73K222L
1100=73K224L
1110=73K324L
1101=73K312L

CONTROL REGISTER 0

	D7	D6	D5	D4	D3	D2	D1	D0
CR0 000	MODUL. OPTION	MODUL. TYPE 1	MODUL. TYPE 0	TRANSMIT MODE 2	TRANSMIT MODE 1	TRANSMIT MODE 0	TRANSMIT ENABLE	ANSWER/ ORIGINATE

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	Answer/ Originate	0	Selects Answer mode (transmit in high band, receive in low band) or in V.23 HDX mode, receive at 1200 bit/s and transmit at 75 bit/s.
		1	Selects Originate mode (transmit in low band,receive in high band) or in V.23 HDX mode, receive at 75 bit/s and transmit at 1200 bit/s.
			Note: This bit works with Tone Register bits D0 and D6 to program special tones detected in the Detect Register. See Detect and Tone Registers.
D1	Transmit Enable	0	Disables transmit output at TXA.
		1	Enables transmit output at TXA.
			Note: Transmit Enable must be set to 1 to allow activation of Answer Tone, DTMF, or Carrier.
D5, D4, D3, D2	Transmit Mode	D5 D4 D3 D2	
		0 0 0 0	Selects Power Down mode. All functions disabled except digital interface.
		0 0 0 1	Internal Synchronous mode. In this mode TXCLK is an internally derived 600, 1200 or 2400 Hz signal. Serial input data appearing at TXD must be valid on the rising edge of TXCLK. Receive data is clocked out of RXD on the falling edge of RXCLK.
		0 0 1 0	External Synchronous mode. Operation is identical to internal synchronous, but TXCLK is connected internally to EXCLK pin, and a 600, 1200 or 2400 Hz clock must be supplied externally.
		0 0 1 1	Slave Synchronous mode. Same operation as other Synchronous modes. TXCLK is connected internally to the RXCLK pin in this mode.
		0 1 0 0	Selects Asynchronous mode - 8 bits/character (1 start bit, 6 data bits, 1 stop bit).
		0 1 0 1	Selects Asynchronous mode - 9 bits/character (1 start bit, 7 data bits, 1 stop bit).
		0 1 1 0	Selects Asynchronous mode - 10 bits/character (1 start bit, 8 data bits, 1 stop bit).
		0 1 1 1	Selects Asynchronous mode - 11 bits/character (1 start bit, 8 data bits, Parity and/or 1 or 2 stop bits).
		1 X 0 0	Selects FSK operation.

CONTROL REGISTER 0 (Continued)

BIT NO.	NAME	CONDITION	DESCRIPTION
D6,D5	Modulation Type	D6 D5	
		1 0	QAM
		0 0	DPSK
		0 1	FSK
D7	Modulation Option	0	QAM selects 2400 bit/s. DPSK selects 1200 bit/s. FSK selects V.23 mode.
		1	DPSK selects 600 bit/s. FSK selects V.21 mode.

CONTROL REGISTER 1

	D7	D6	D5	D4	D3	D2	D1	D0
CR1 001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INT.	BYPASS SCRAMB/ ADD PH.EQ	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D1, D0	Test Mode	D1 D0	
		0 0	Selects Normal Operating mode.
		0 1	Analog Loopback mode. Loops the transmitted analog signal back to the receiver, and causes the receiver to use the same carrier frequency as the transmitter. To squelch the TXA pin, transmit enable bit must be low. Tone Register bit D2 must be zero.
		1 0	Selects remote digital loopback. Received data is looped back to transmit data internally, and RXD is forced to a mark. Data on TXD is ignored.
		1 1	Selects local digital loopback. Internally loops TXD back to RXD and continues to transmit data carrrier at TXA pin.
D2	Reset	0	Selects normal operation.
		1	Resets modem to power down state. All control register bits (CR0, CR1, CR2, CR3 and Tone) are reset to zero except CR3 bit D2. The output of the clock pin will be set to the crystal frequency.
D3	CLK Control (Clock Control)	0	Selects 11.0592 MHz crystal echo output at CLK pin.
		1	Selects 16 X the data rate output at CLK pin in QAM and DPSK only.

CONTROL REGISTER 1 (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
CR1 001	TRANSMIT PATTERN 1	TRANSMIT PATTERN 0	ENABLE DETECT INT.	BYPASS SCRAMB/ ADD PH.EQ.	CLK CONTROL	RESET	TEST MODE 1	TEST MODE 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D4	Bypass Scrambler/ Add Ph. Eq.	0	Selects normal operation. DPSK and QAM data is passed through scrambler.
		1	Selects Scrambler Bypass. DPSK and QAM data is routed around scrambler in the transmit path. In the V.23 mode, additional phase equalization is added to the main channel filters when D4 is set to 1.
D5	Enable Detect Interrupt	0	Disables interrupt at $\overline{INT}$ pin. All interrupts are normally disabled in Power Down mode.
		1	Enables $\overline{INT}$ output. An interrupt will be generated with a change in status of DR bits D1-D4 and D6. The answer tone and call progress detect interrupts are masked when the TX enable bit is set. Carrier detect is masked when TX DTMF is activated. All interrupts will be disabled if the device is in Power Down mode.
D7, D6	Transmit Pattern	D7 D6	
		0 0	Selects normal data transmission as controlled by the state of the TXD pin.
		0 1	Selects an alternating mark/space transmit pattern for modem testing and handshaking. Also used for S1 pattern generation. See CR2 bit D4.
		1 0	Selects a constant mark transmit pattern.
		1 1	Selects a constant space transmit pattern.

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DETECT REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
DR 010	RECEIVE LEVEL INDICATOR	S1 PATTERN DETECT	RECEIVE DATA	UNSCR. MARK DETECT	CARRIER DETECT	SPECIAL TONE DETECT	CALL PROG. DETECT	SIGNAL QUALITY INDICATOR

BIT NO.	NAME	CONDITION			DESCRIPTION
D0	Signal Quality Indicator	0			Indicates normal received signal.
		1			Indicates low received signal quality (above average error rate). Interacts with Special Register SQ bits D2, D1.
D1	Call Progress Detect	0			No call progress tone detected.
		1			Indicates presence of call progress tones. The call progress detection circuitry is activated by energy in the normal 350 to 620 Hz call progress band.
D2	Special Tone Detect	0			Condition not detected
		1			Condition detected
		CR0 D0	TR D0	CR2 D5	
		1	0	1	2225 Hz ±10 Hz answer tone detected in V.22bis, V.22, V.21 modes.
		1	1	1	2100 Hz ±21 Hz answer tone detected in V.22bis, V.22, V.21 modes.
		0	X	0	900 Hz SCT tone detected in V.23 mode.
		I	X	0	2100 Hz or 2225 Hz answer tone detected in QAM, DPSK, or V.21 Mode.
D3	Carrier Detect	0			No carrier detected in the receive channel.
		1			Indicated carrier has been detected in the received channel. Should be time qualified by software.
D4	Unscr. Mark Detect	0			No unscrambled mark being received.
		1			Indicates detection of unscrambled marks in the received data. Should be time qualified by software.
D5	Receive Data				Continuously outputs the received data stream. This data is the same as that output on the RXD pin, but it is not disabled when RXD is tri-stated.
D6	S1 Pattern Detect	0			No S1 pattern being received.
		1			S1 pattern detected. Should be time qualified by software. S1 is an unscrambled double dibit (11001100...) sent in DPSK 1200 bit/s mode. Generated pattern must be properly aligned to transmitter baud clock to be detected.
D7	Receive Level Indicator	0			Received signal level below threshold, (≈ -25 dBm0);can use receive gain boost (+18 dB.)
		1			Received signal above threshold.

TONE REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.	TRANSMIT GUARD/ CALLING/SCT TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2/ WIRE FDX	DTMF 1/ OVER-SPEED	DTMF 0/ G.T./ANSW./ CALLING/SCT TONE/SEL

BIT NO.	NAME	CONDITION	DESCRIPTION
D0, D4, D5, D6	DTMF 0/ Guard Tone/ Answer Tone/ Calling/SCT Tone/ Transmit Select	D6 D5 D4 D0	D0 interacts with bits D6, D5, D4, and CR0 as shown.
		X X 1 X	Transmit DTMF tones (overides all other functions).
		1 0 0 0	Select 1800 Hz guard tone if in V.22bis or V.22 and Answer mode in CR0.
		1 0 0 1	Select 550 Hz guard tone if in V.22bis or V.22 and Answer mode in CR0.
		Note: Bit D0 also selects the answer tone detected in Originate mode, see Detect Register Special Tone Detect (bit D2) for details.	
		1 0 0 0	1300 Hz calling tone will be transmittted if V.21, V.22, V.22bis or V.23 Originate mode is selected in CR0.
		X 1 0 0	Transmit 2225 Hz Answer Tone. Must be in DPSK Answer mode.
		X 1 0 1	Transmit 2100 Hz Answer Tone. Must be in DPSK Answer mode.
		1 0 0 1	900 Hz SCT (soft carrier turnoff) tone transmitted in V.23 75 bit/s Receive mode. (CR0 bit D0 = 1).
D1	DTMF 1/ Overspeed	D4 D1	D1 interacts with D4 as shown.
		0 0	Asynchronous QAM/DPSK +1% -2.5%. (Normal).
		0 1	Asynchronous QAM/DPSK, 2400, 1200 or 600 bit/s +2.3% -2.5%. (Extended overspeed).
D2	DTMF 2/ 4 WIRE FDX	D4 D2	
		0 0	Selects 2-wire full-duplex or half-duplex.
		0 1	D2 selects 4 wire full duplex in the Modulation mode selected. The receive path corresponds to the ANS/ ORIG bit CR0 D0 in terms of high or low band selection. The transmitter is in the same band as the receiver, but does not have magnitude filtering or equalization on its signal as in the receive path.

Note: DTMF0 - DTMF2 should be set to an appropriate state after DTMF dialing to avoid unintended operation.

TONE REGISTER (Continued)

	D7	D6	D5	D4	D3	D2	D1	D0
TR 011	RXD OUTPUT CONTR.	TRANSMIT GUARD/ CALLING/SCT TONE	TRANSMIT ANSWER TONE	TRANSMIT DTMF	DTMF 3	DTMF 2/ WIRE FDX	DTMF 1/ OVER-SPEED	DTMF 0/ GUARD/ CALLING/SCT TONE SEL

BIT NO.	NAME	CONDITION	DESCRIPTION
D3, D2, D1, D0	DTMF 3, 2, 1, 0	D4 = 1	Programs 1 of 16 DTMF tone pairs that will be transmitted when TX DTMF and TX enable bit (CR0, bit D1) is set. Tone encoding is shown below:

KEYBOARD EQUIVALENT	DTMF CODE D3	D2	D1	D0	TONES LOW	HIGH
1	0	0	0	1	697	1209
2	0	0	1	0	697	1336
3	0	0	1	1	697	1477
4	0	1	0	0	770	1209
5	0	1	0	1	770	1336
6	0	1	1	0	770	1477
7	0	1	1	1	852	1209
8	1	0	0	0	852	1336
9	1	0	0	1	852	1477
0	1	0	1	0	941	1336
*	1	0	1	1	941	1209
#	1	1	0	0	941	1477
A	1	1	0	1	697	1633
B	1	1	1	0	770	1633
C	1	1	1	1	852	1633
D	0	0	0	0	941	1633

D7	RXD Output Control	0	Enables RXD pin. Receive data will be output on RXD.
		1	Disables RXD pin.The RXD pin reverts to a high impedance with internal weak pull-up resistor.

CONTROL REGISTER 2

	D7	D6	D5	D4	D3	D2	D1	D0
CR2 100	0	SPEC REG ACCESS	CALL INIT	TRANSMIT S1	16 WAY	$\overline{\text{RESET}}$ DSP	TRAIN INHIBIT	EQUALIZER ENABLE

BIT NO.	NAME	CONDITION	DESCRIPTION
D0	Equalizer Enable	0	The adaptive equalizer is in its initialized state.
		1	The adaptive equalizer is enabled. This bit is used in handshakes to control when the equalizer should calculate its coefficients.
D1	Train Inhibit	0	The adaptive equalizer is active.
		1	The adaptive equalizer coefficients are frozen.
D2	$\overline{\text{RESET}}$ DSP	0	The DSP is inactive and all variables are initialized.
		1	The DSP is running based on the mode set by other control bits
D3	16 Way	0	The receiver and transmitter are using the same decision plane (based on the Modulator Control Mode).
		1	The receiver, independent of the transmitter, is forced into a 16 point decision plane. Used for QAM handshaking.
D4	Transmit S1	0	The transmitter when placed in alternating Mark/Space mode transmits 0101 .... scrambled or not dependent on the bypass scrambler bit and Modulation mode.
		1	When this bit is 1 and only when the transmitter is placed in alternating Mark/Space mode by CR1 bits D7, D6, an unscrambled repetitive double dibit pattern of 00 and 11 at 1200 bit/s (S1) is sent.
D5	Call Init	0	The DSP is setup to do demodulation and pattern detection based on the Various mode bits. Both answer tones are detected in Demod Mode concurrently; TR D0 is ignored.
		1	The DSP decodes call progress, calling tones, unscrambled mark, and 2100 Hz and 2225 Hz answer tones.
D6	Special Register Access	0	Normal CR3 access.
		1	Setting this bit and addressing CR3 allows access to the SPECIAL REGISTER. See the SPECIAL REGISTER for details.
D7	N/A	0	Must be 0 for normal operation.

3

CONTROL REGISTER 3

	D7	D6	D5	D4	D3	D2	D1	D0
CR3 101	TXDALT	TRISTATE TX/RXCLK	0	RECEIVE ENABLE BOOST	TRANSMIT ATTEN. 3	TRANSMIT ATTEN. 2	TRANSMIT ATTEN. 1	TRANSMIT ATTEN. 0

BIT NO.	NAME	CONDITION	DESCRIPTION
D3, D2, D1,D0	Transmit Attenuator	D3 D2 D1 D0 0 0 0 0 - 1 1 1 1	Sets the attenuation level of the transmitted signal in 1dB steps. The default (D3-D0=0100) is for a transmit level of -10 dBm0. The total range is 16 dB.
D4	Receive Gain Boost (18 dB)	0	18 dB receive front end boost is not used.
		1	Boost is in the path. This boost does not change reference levels. It is used to extend dynamic range by compensating for internally generated noise when receiving weak signals. The receive level detect signal and knowledge of the hybrid and transmit attenuator setting will determine when boost should be enabled.
D5	Not Used	0	Not used. Only write zeros this location.
D6	Tristate TXCLK/RXCLK	0	TXCLK, RXCLK outputs driven
		1	TXCLK, RXCLK outputs in Tristate mode
D7	TXDALT	Spec. Reg. bit D3=1	Alternate TX data source. See Special Register.

ID REGISTER

SPECIAL REGISTER

	D7	D6	D5	D4	D3	D2	D1	D0
SR 101		TXBAUD CLOCK	RXUN- DSCR DATA		TXD SOURCE	SIGNAL QUALITY LEVEL SELECT1	SIGNAL QUALITY LEVEL SELECT0	

BIT NO.	NAME	DESCRIPTION
D7, D4, D0		NOT USED AT THIS TIME. Only write ZEROs to these bits.
D6	TXBAUD CLK	TXBAUD clock is the transmit baud-synchronous clock that can be used to synchronize the input of arbitrary quad/di-bit patterns. The rising edge of TXBAUD signals the latching of a baud-worth of data internally. Synchronous data to be entered via the TXDALT bit, CR3 bit D7, should have data transitions that start 1/2 bit period delayed from the TXBAUD clock edges.
D5	RXUNDSCR DATA	This bit outputs the data received before going to the descrambler. This is useful for sending special unscrambled patterns that can be used for signaling.

SPECIAL REGISTER (Continued)

BIT NO.	NAME	DESCRIPTION
D3	TXD SOURCE	This bit selects the transmit data source; either the TXD pin if ZERO or the TXDALT if this bit is a ONE. The TRANSMIT PATTERN bits D7 and D6 in CR1 override either of these sources.
D2, D1	SIGNAL QUALITY LEVEL SELECT	The signal quality indicator is a logical zero when the signal received is acceptable for low error rate reception. It is determined by the value of the Mean Squared Error (MSE) calculated in the decisioning process when compared to a given threshold. This threshold can be set to four levels of error rate. The SQI bit will be low for good or average connections. As the error rate crosses the threshold setting, the SQI bit will toggle at a 1.66 ms rate. Toggling will continue until the error rate indicates that the data pump has lost convergence and a retrain is required. At that point the SQI bit will be a ONE constantly. The SQI bit and threshold selection are valid for QAM and DPSK only.

D2	D1	TYPICAL THRESHOLD VALUE	UNITS
0	0	10^{-5}	BER (default)
0	1	10^{-6}	BER
1	0	10^{-4}	BER
1	1	10^{-3}	BER

NOTE: This register is "mapped" and is accessed by setting CR2 bit D6 to a ONE and addressing CR3. This register provides functions to the 73K324L user that are not necessary in normal communications. Bits D7-D4 are read only, while D3-D0 are read/write. To return to normal CR3 access, CR2 bit D6 must be returned to a ZERO.

	D7	D6	D5	D4	D3	D2	D1	D0
ID 110	ID 3	ID 2	ID 1	ID 0	USER DEFINABLE PERSONALITY			

BIT NO.	NAME	CONDITION	DESCRIPTION
D7, D6, D5, D4	Device Identification Signature	D7 D6 D5 D4	Indicates Device:
		0 0 X X	SSI 73K212L or 73K322L or 73K321L
		0 1 X X	SSI 73K221L or 73K302L
		1 0 X X	SSI 73K222L
		1 1 0 0	SSI 73K224L
		1 1 1 0	SSI 73K324L
		1 1 0 1	SSI 73K312L

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

PARAMETER	RATING
VDD Supply Voltage	7V
Storage Temperature	-65 to 150°C
Soldering Temperature (10 sec.)	260°C
Applied Voltage	-0.3 to VDD+0.3V
Note: All inputs and outputs are protected from static charge using built-in, industry standard protection devices and all outputs are short-circuit protected.	

RECOMMENDED OPERATING CONDITIONS

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
VDD Supply voltage		4.5	5	5.5	V
External Components (Refer to Application section for placement.)					
VREF Bypass capacitor	(VREF to GND)	0.22			µF
Bias setting resistor	(Placed between VDD and ISET pins)	1.8	2	2.2	MΩ
ISET Bypass capacitor	(ISET pin to GND)	0.22			µF
VDD Bypass capacitor 1	(VDD to GND)	0.22			µF
VDD Bypass capacitor 2	(VDD to GND)	22			µF
XTL1 Load Capacitance	Depends on crystal requirements		18	39	pF
XTL2 Load Capacitance	Depends on crystal requirements		18	27	pF
Clock Variation	(11.0592 MHz) Crystal or external clock	-0.01		+0.01	%
TA, Operating Free-Air Temperature		-40		85	°C

DC ELECTRICAL CHARACTERISTICS
(TA = -40°C to 85°C, VDD =recommended range unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
IDD, Supply Current	CLK = 11.0592 MHz				
	ISET Resistor = 2 MΩ				
IDD1, Active	Operating with crystal oscillator.		18	25	mA
IDD2, Idle	< 5 pF capacitive load on CLK pin.			5	mA
Digital Inputs					
VIL, Input Low Voltage				0.8	V
VIH, Input High Voltage					
All Inputs except Reset XTL1, XTL2		2.0		VDD	V
Reset, XTL1, XTL2		3.0		VDD	V
IIH, Input High Current	VI = VDD			100	µA
IIL, Input Low Current	VI = 0V	-200			µA
Reset Pull-down Current	Reset = VDD	-2	-30	-70	µA
Digital Outputs					
VOH, Output High Voltage	IO = IOH Min IOUT = -0.4 mA	2.4		VDD	V
VOL, Output Low Voltage	IO = IOUT = 1.6 mA			0.4	V
RXD Tri-State Pull-up Curr.	RXD = GND	-2		-50	µA
Capacitance					
Maximum Capacitive Load					
CLK				25	pF
Input Capacitance	All Digital Inputs			10	pF

3

DYNAMIC CHARACTERISTICS AND TIMING
(TA = -40°C to +85°C, VDD = recommended range unless otherwise noted.)

PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
QAM/DPSK Modulator					
Carrier Suppression	Measured at TXA	35			dB
Output Amplitude	TX scrambled marks ATT=0100 (default)	-11.5	-10.0	-9	dBm0
FSK Modulator/Demodulator					
Output Freq. Error	CLK = 11.0592 MHz	-.31		+0.20	%
Transmit Level	ATT = 0100 (Default) Transmit Dotting Pattern	-11.5	-10.0	-9	dBm0
TXA Output Distortion	All products through BPF			-45	dB
Output Bias Distortion at RXD	Dotting Pattern measured at RXD Receive Level -20 dBm, SNR 20 dB	-10		+10	%
Output Jitter at RXD	Integrated for 5 seconds	-15		+15	%
Sum of Bias Distortion and Output Jitter at RXD	Integrated for 5 seconds	-15		+15	%
2100 Hz Answer Tone Generator					
Output Amplitude	ATT = 0100 (Default Level) Not in V.21 or V.23 Mode	-11.5	-10	-9	dBm0
Output Distortion	Distortion products in receive band			-40	dB
DTMF Generator	Not in V.21 or V.23 mode				
Freq. Accuracy		-0.03		+0.25	%
Output Amplitude	Low Band, ATT = 0100	-10		-8	dBm0
Output Amplitude	High Band, ATT = 0100	-8		-6	dBm0
Twist	High-Band to Low-Band	1.0	2.0	3.0	dB
Receiver Dynamic Range	Refer to Performance Curves	-43		-3.0	dBm0
Call Progress Detector	In Call Init mode				
Detect Level	460 Hz input signal	-34		0	dBm0
Reject Level				-40	dBm0
Delay Time	-70 dBm0 to -30 dBm0 STEP			25	ms
Hold Time	-30 dBm0 to -70 dBm0 STEP			25	ms
Hysteresis	@ 460 Hz input signal	2			dB

NOTE: Parameters expressed in dBm0 refer to the following definition:

0 dB loss in the Transmit path to the line.

2 dB gain in the Receive path from the line.

Refer to the Basic Box Modem diagram in the Applications section for the DAA design.

DYNAMIC CHARACTERISTICS AND TIMING (Continued)

PARAMETERS		CONDITIONS	MIN	NOM	MAX	UNITS
Carrier Detect Receive Gain Boost "On" for Lower Input Level Measurements						
Threshold		QAM/DPSK or FSK receive data	-48		-43	dBm0
Hysteresis		All Modes	2			dB
Delay Time	FSK	70 dBm0 to -6 dBm0	25		37	ms
		70 dBm0 to -40 dBm0	25		37	ms
	DPSK	-70 dBm0 to -6 dBm0	7		17	ms
		-70 dBm0 to -40 dBm0	7		17	ms
	QAM	-70 dBm0 to -6 dBm0	25		37	ms
		-70 dBm0 to -40 dBm0	25		37	ms
Hold Time	FSK	-6 dBm0 to -70 dBm0	25		37	ms
		-40 dBm0 to -70 dBm0	15		30	ms
	DPSK	-6 dBm0 to -70 dBm0	20		29	ms
		-40 dBm0 to -70 dBm0	14		21	ms
	QAM	-6 dBm0 to -70 dBm0	25		32	ms
		-40 dBm0 to -70 dBm0	8		28	ms
Special Tone Detectors						
Detect Level		See definitions for D0 of Tone Register	-48		-43	dBm0
Delay and Hold Time						
2225 or 2100 Hz answer tone		Call INIT mode 2225 ± 10 Hz 2100 ± 21 Hz	6		50	ms
900 Hz SCT Receive V.23 main channel		Tone Accuracy ±9 Hz	10		45	ms
Hysteresis			2			dB
Pattern Detectors		DPSK Mode				
S1 Pattern						
Delay Time		For signals from -6 to -40 dBm0,	10		55	ms
Hold Time		Demod Mode	10		45	ms
Unscrambled Mark						
Delay Time		For signals from -6 to -40	10		45	ms
Hold Time		Demod or call Init Mode	10		45	ms
Receive Level Indicator						
Detect On			-22		-28	dBm0
Valid after Carrier Detect		DPSK Mode	1	4	7	ms

3

DYNAMIC CHARACTERISTICS AND TIMING (Continued)

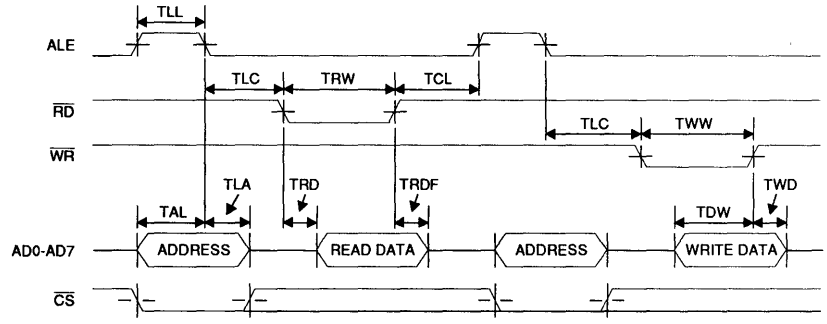
PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Output Smoothing Filter					
Output Impedance	TXA pin		200	300	Ω
Output Load	TXA pin; FSK Single	10			kΩ
	Tone out for THD = -50 dB in 0.3 to 3.4 kHz range			50	pF
Maximum Transmitted Energy	4 kHz, Guard Tones off			-35	dBm0
	10 kHz, Guard Tones off			-55	dBm0
	12 kHz, Guard Tones off			-65	dBm0
Anti Alias Low Pass Filter					
Maximum allowed Out-of-Band Signal Energy (Defines Hybrid Trans-Hybrid loss requirements)	Scrambled data at 2400 bit/s in opposite band		-14		dBm
	Sinusoids out of band		-9		dBm
Transmit Attenuator					
Range of Transmit Level	Default ATT = 0100 (-10 dBm0) 1111-0000	-21		-6	dBm0
Step Accuracy		-0.15		+0.15	dB
Clock Noise	TXA pin; 153.6 kHz		1.5		mV rms
Carrier Offset					
Capture Range	Originate or Answer	-7	±5	+7	Hz
Recovered Clock					
Capture Range	% of data rate originate or answer	-.02		+.02	%
Guard Tone Generator					
Tone Accuracy	550 Hz		+1.2		%
	1800 Hz		-0.8		%
Tone Level	550 Hz	-4.5	-3.0	-1.5	dB
(Below QAM/DPSK Output)	1800 Hz	-7.5	-6.1	-4.5	dB
Harmonic Distortion (700 to 2900 Hz)	550 or 1800 Hz			-50	dB

DYNAMIC CHARACTERISTICS AND TIMING (Continued)

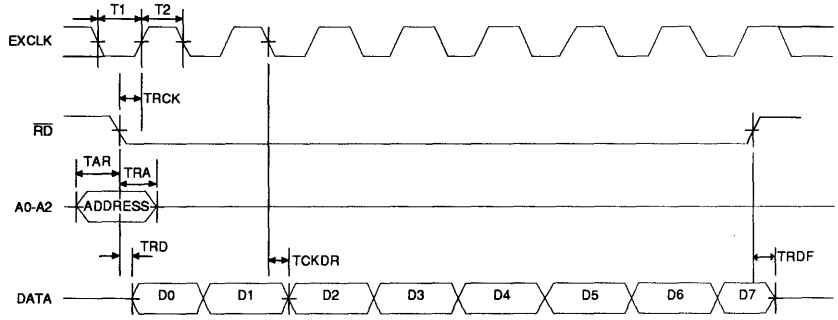
PARAMETERS	CONDITIONS	MIN	NOM	MAX	UNITS
Timing (Refer to Timing Diagrams)					
Parallel Mode:					
TAL	$\overline{CS}$/Addr. setup before ALE Low	30			ns
TLA	$\overline{CS}$/Addr. hold after ALE Low	6			ns
TLC	ALE Low to $\overline{RD}$/$\overline{WR}$ Low	40			ns
TCL	$\overline{RD}$/$\overline{WR}$ Control to ALE High	10			ns
TRD	Data out from $\overline{RD}$ Low			90	ns
TLL	ALE width	25			ns
TRDF	Data float after $\overline{RD}$ High			40	ns
TRW	$\overline{RD}$ width	70			ns
TWW	$\overline{WR}$ width	70			ns
TDW	Data setup before $\overline{WR}$ High	70			ns
TWD	Data hold after $\overline{WR}$ High	20			ns
Serial Mode:					
TRCK	Clock high after $\overline{RD}$	250		T1	ns
TAR	Address setup before $\overline{RD}$ low	0			ns
TRA	Address hold after $\overline{RD}$ low	350			ns
TRD	$\overline{RD}$ to data valid			110	ns
TRDF	Data float after $\overline{RD}$ high			50	ns
TCKDR	Read data out after falling edge of EXCLK			300	ns
TWW	$\overline{WR}$ width	350			ns
TAW	Address setup before $\overline{WR}$	50			ns
TWA	Address hold after rising edge of $\overline{WR}$	50			ns
TCKDW	Write data hold after falling edge of EXCLK	200			ns
TCKW	$\overline{WR}$ high after falling edge of EXCLK	330		T1& T2	ns
TDCK	Data setup before falling edge of EXCLK	50			ns
T1, T2	Minimum period	500			ns
Note: T1 and T2 are the low/high periods, respectively, of EXCLK in Serial mode.					

TIMING DIAGRAMS

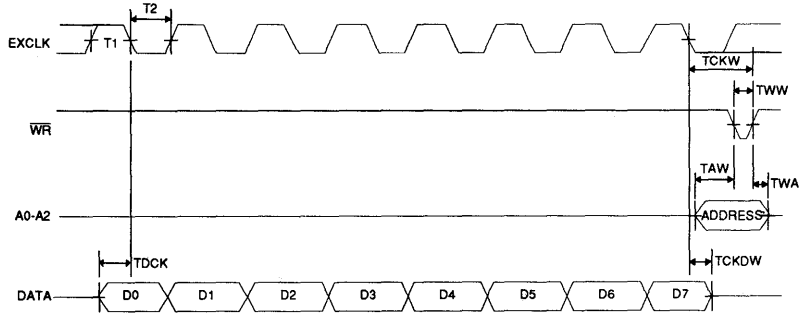
BUS TIMING DIAGRAM (PARALLEL VERSION)



READ TIMING DIAGRAM (SERIAL VERSION)



WRITE TIMING DIAGRAM (SERIAL VERSION)



APPLICATIONS INFORMATION

GENERAL CONSIDERATIONS

Figures 1 and 2 show basic circuit diagrams for K-Series modem integrated circuits. K-Series products are designed to be used in conjunction with a control processor, a UART or RS-232 serial data interface, and a DAA phone line interface to function as a typical intelligent modem. The K-Series ICs interface directly with Intel 8048 and 80C51 microprocessors for control and status monitoring purposes.Two typical DAA arrangements are shown: one for a split ±5 or ±12 volt design and one for a single 5 volt design. These diagrams are for reference only and do not represent production-ready modem designs.

K-Series devices are available with two control interface versions: one for a parallel multiplexed address/data interface, and one for a serial interface. The parallel version is intended for use with 8039/48 or 8031/51 microcontrollers from Intel or many other manufacturers. The serial interface 22-pin version can be used with other microcontrollers or in applications where only a limited number of port lines are available or the application does not lend itself to a multiplexed address/data interface. The parallel versions may also be used in the Serial mode, as explained in the data sheet pin description.

In most applications the controller will monitor the serial data for commands from the DTE and the received data for break signals from the far end modem. In this way, commands to the modem are sent over the same line as the transmitted data. In other applications the RS-232 interface handshake lines are used for modem control.

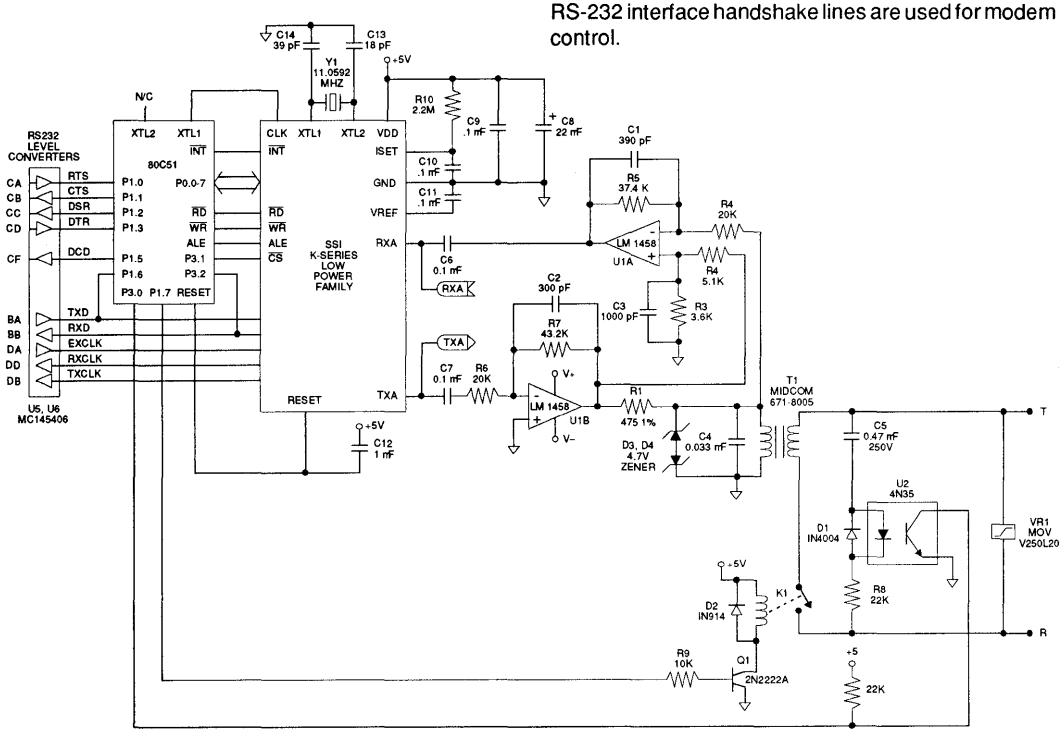


FIGURE 1: Basic Box Modem with Dual-Supply Hybrid

DIRECT ACCESS ARRANGEMENT (DAA)

The telephone line interfaces show two examples of how the "hybrid" may be implemented. The split supply design (Figure 1) is a typical two op-amp hybrid. The receive op-amp serves two purposes. It supplies gain to amplify the receive signal to the proper level for the modem's detectors and demodulator, and it removes the transmitted signal from the receive signal present at the transformer. This is done by supplying a portion of the transmitted signal to the non-inverting input of the receive op-amp at the same amplitude as the signal appearing at the transformer, making the transmit signal Common mode.

The single-supply hybrid is more complex than the dual-supply version described above, but its use eliminates the need for a second power supply. This circuit (Figure 2) uses a bridged drive to allow undistorted signals to be sent with a single 5 volt supply. Because DTMF tones utilize a higher amplitude than data, these signals will clip if a single-ended drive approach is used. The bridged driver uses an extra op-amp (U1A) to invert the signal coming from the gain setting op-amp (U1B) before sending it to the other leg of the transformer. Each op-amp then supplies half the drive signal to the transformer. The receive amplifier (U1C) picks off its signal at the junction of the impedance matching resistor and the transformer. Because the bottom leg of the transformer is being driven in one direction by U1A and the resistor is driven in the opposite direction at the same time by U1B, the junction of the transformer and resistor remains relatively constant and the receive signal is unaffected.

DESIGN CONSIDERATIONS

Silicon Systems' 1-chip modem products include all basic modem functions. This makes these devices adaptable for use in a variety of applications, and as easy to control as conventional digital bus peripherals.

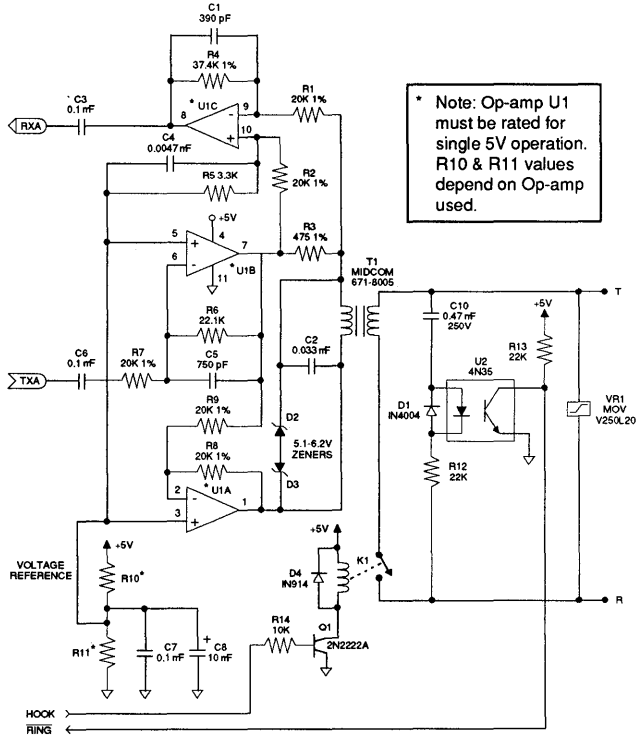


FIGURE 2: Single 5V Hybrid Version

Unlike digital logic circuitry, modem designs must properly contend with precise frequency tolerances and very low level analog signals, to ensure acceptable performance. Using good analog circuit design practices will generally result in a sound design. Following are additional recommendations which should be taken into consideration when starting new designs.

CRYSTAL OSCILLATOR

The K-Series crystal oscillator requires a Parallel mode (antiresonant) crystal which operates at 11.0592 MHz. It is important that this frequency be maintained to within ±0.01% accuracy.

In order for a Parallel mode crystal to operate correctly and to specification, it must have a load capacitor connected to the junction of each of the crystal and internal inverter connections, terminated to ground. The values of these capacitors depend primarily on the crystal's characteristics, and to a lesser degree on the internal inverter circuit. The values used affect the accuracy and start up characteristics of the oscillator.

LAYOUT CONSIDERATIONS

Good analog/digital design rules must be used to control system noise in order to obtain highest performance in modem designs. The more digital circuitry present on the PC board, the more this attention to noise control is needed. The modem should be treated as a high impedance analog device. A 22 mF electrolytic capacitor in parallel with a 0.22 mF ceramic capacitor between VDD and GND is recommended. Liberal use of ground planes and larger traces on power and ground are also highly favored. High speed digital circuits tend to generate a significant amount of EMI (Electro-Magnetic Interference) which must be minimized in order to meet regulatory agency limitations. To accomplish this, high speed digital devices should be locally bypassed, and the telephone line interface and K-Series device should be located close to each other near the area of the board where the phone line connection is accessed. To avoid problems, power supply and ground traces should be routed separately to the analog and digital functions on the board, and digital signals should not be routed near low level or high impedance analog traces. The analog and digital grounds should only connect at one point near the K-Series device ground pin to avoid ground loops. The K–Series modem IC's should have both high frequency and low frequency bypassing as close to the package as possible. The ISET resistor and bypass capacitor need to be as close to device as possible.

MODEM PERFORMANCE CHARACTERISTICS

The curves presented here define modem IC performance under a variety of line conditions while inducing disturbances that are typical of those encountered during data transmission on public service telephone lines. Test data was taken using an AEA Electronics' "Autotest I" modem test set and line simulator, operating under computer control. All tests were run full-duplex, using a Hayes 2400 Smartmodem™ as the reference modem. A 511 pseudo-random-bit pattern was used for each data point. Noise was C-message weighted and all signal-to-noise (S/N) ratios reflect total power measurements similar to the CCITT V.56 measurement specification. The individual tests are defined as follows.

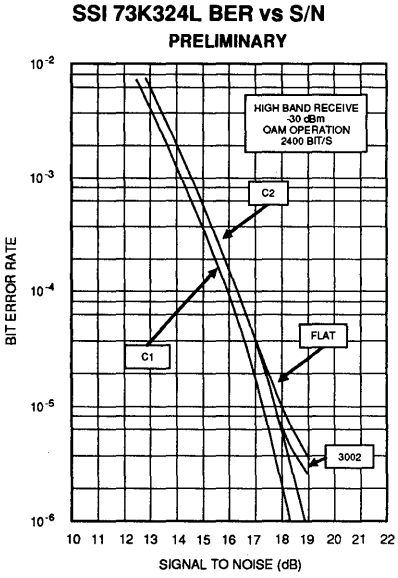
3

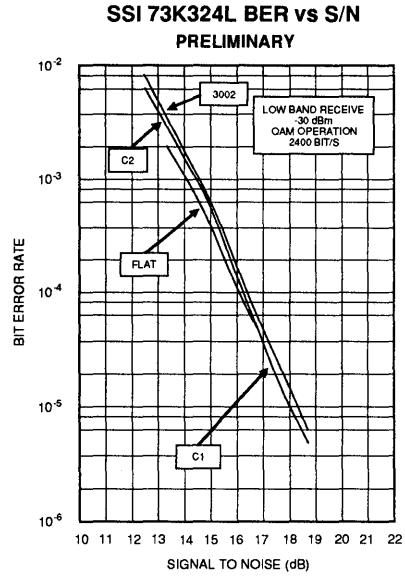
BER vs. S/N

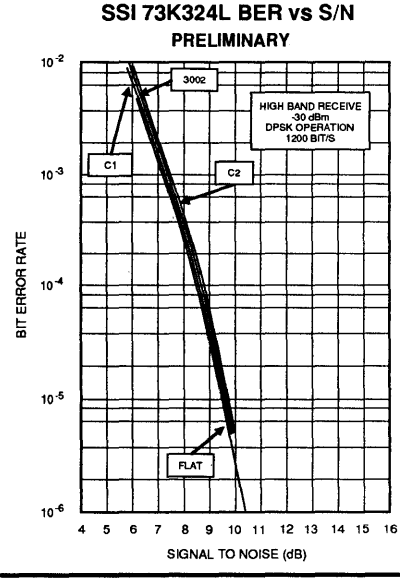
This test measures the ability of the modem to operate over noisy lines with a minimum of data-transfer errors. Since some noise is generated in the best of dial-up lines, the modem must operate with the lowest S/N ratio possible. Better modem performance is indicated by test curves that are closest to the BER axis. A narrow spread between curves representing the four line parameters indicates minimal variation in performance while operating over a range of aberrant operating conditions. Typically, a modem will exhibit better BER-performance test curves receiving in the low band than in the high band.

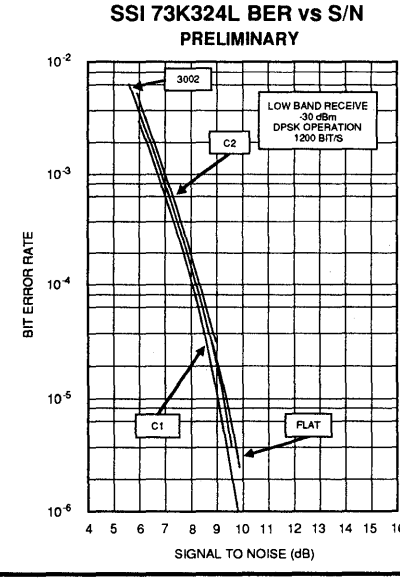
BER vs. Receive Level

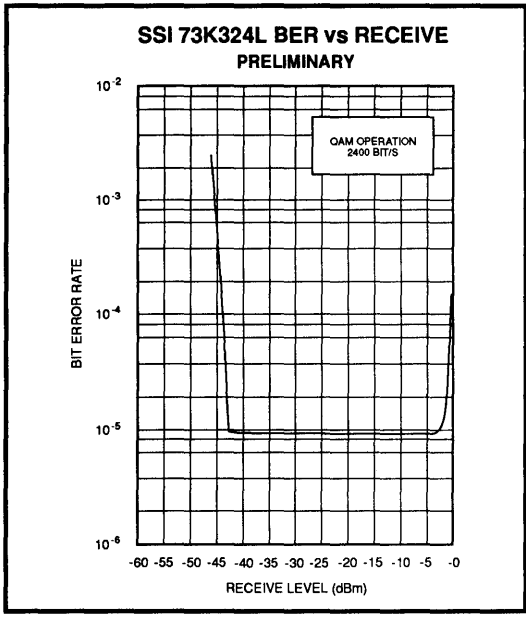
This test measures the dynamic range of the modem. Because signal levels vary widely over dial-up lines, the widest possible dynamic range is desirable. The minimum Bell specification calls for 36 dB of dynamic range. S/N ratios are held constant at the indicated values while the receive level is lowered from a very high to very low signal levels. The width of the "bowl" of these curves, taken at the BER point, is the measure of dynamic range.

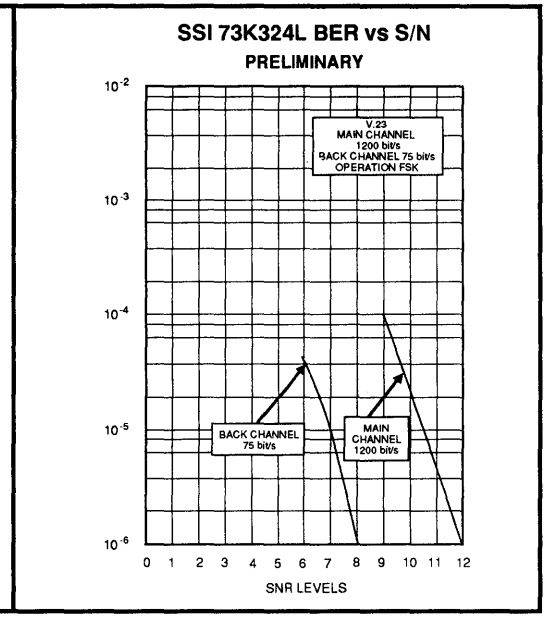

SSI 73K324L BER vs S/N
PRELIMINARY
HIGH BAND RECEIVE
-30 dBm
OAM OPERATION
2400 BIT/S
C2
C1
FLAT
3002
BIT ERROR RATE
SIGNAL TO NOISE (dB)


SSI 73K324L BER vs S/N
PRELIMINARY
3002
LOW BAND RECEIVE
-30 dBm
OAM OPERATION
2400 BIT/S
C2
FLAT
C1
BIT ERROR RATE
SIGNAL TO NOISE (dB)


SSI 73K324L BER vs S/N
PRELIMINARY
3002
HIGH BAND RECEIVE
-30 dBm
DPSK OPERATION
1200 BIT/S
C1
C2
FLAT
BIT ERROR RATE
SIGNAL TO NOISE (dB)


SSI 73K324L BER vs S/N
PRELIMINARY
3002
LOW BAND RECEIVE
-30 dBm
DPSK OPERATION
1200 BIT/S
C2
C1
FLAT
BIT ERROR RATE
SIGNAL TO NOISE (dB)

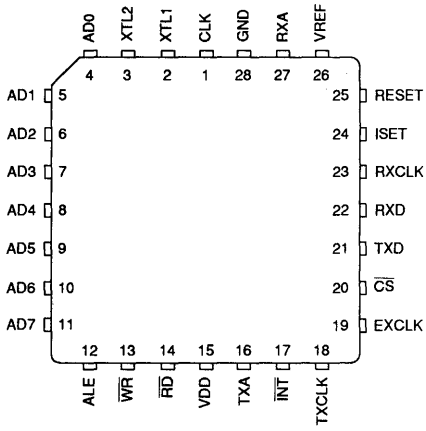

SSI 73K324L BER vs RECEIVE
PRELIMINARY
QAM OPERATION
2400 BIT/S
BIT ERROR RATE
10-2
10-3
10-4
10-5
10-6
-60 -55 -50 -45 -40 -35 -30 -25 -20 -15 -10 -5 -0
RECEIVE LEVEL (dBm)


SSI 73K324L BER vs S/N
PRELIMINARY
V.23
MAIN CHANNEL
1200 bit/s
BACK CHANNEL 75 bit/s
OPERATION FSK
BACK CHANNEL
75 bit/s
MAIN
CHANNEL
1200 bit/s
10-2
10-3
10-4
10-5
10-6
0 1 2 3 4 5 6 7 8 9 10 11 12
SNR LEVELS

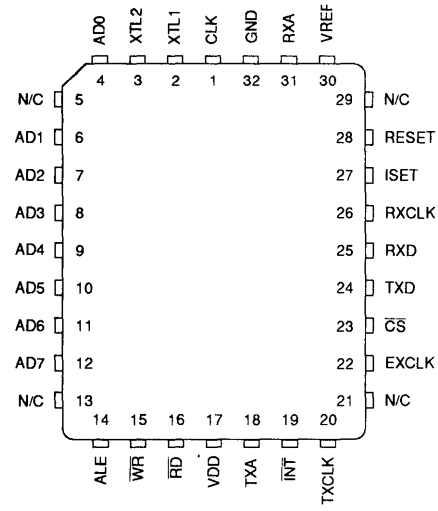
3

PACKAGE PIN DESIGNATIONS

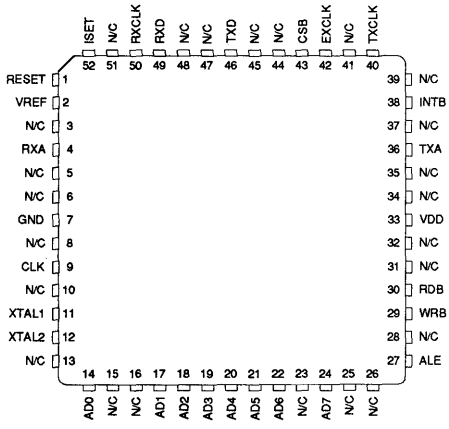
(Top View)



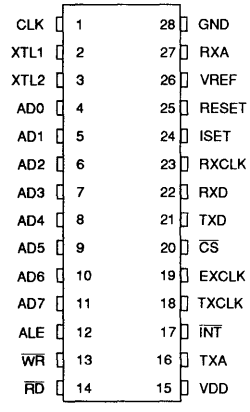
28-Pin PLCC



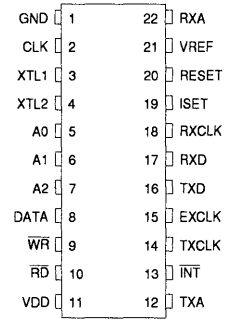
32-Pin PLCC



52-Lead QFP



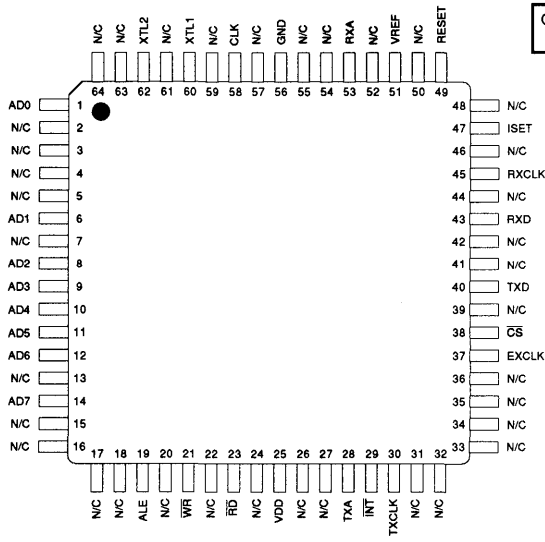
28-Pin DIP



400-Mil 22-Pin DIP

CAUTION: Use handling procedures necessary for a static sensitive component.

CAUTION: Use handling procedures necessary for a static sensitive component.



64-Lead TQFP

3

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 73K324L with Serial Bus Interface		
22-Pin Plastic Dual-In-Line	73K324LS-IP	73K324LS-IP
SSI 73K324L with Parallell Bus Interface		
28-Pin Plastic Dual-In-Line	73K324L-IP	73K324L-IP
28-Pin Plastic Leaded Chip Carrier	73K324L-28IH	73K324L-28IH
32-Pin Plastic Leaded Chip Carrier	73K324L-32IH	73K324L-32IH
44-Pin Plastic Leaded Chip Carrier	73K324L-IH	73K324L-IH
52-Pin Quad Flat Pack Package	73K324L-IG	73K324L-IG
64-Lead Thin Quad Flat Pack Package	73K324L-IGT	73K324L-IGT

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Notes:

Section 4

CONTROLLERS & SPECIAL MODEM PRODUCTS

silicon systems®
A TDK Group Company

SSI 73D2248A/2348A
MNP5, V.42bis Datacom Modem Device Set
Advance Information

September 1994

DESCRIPTION

The SSI 73D2248A/2348A Chip Sets consists of two CMOS integrated circuits which provide the data pump and protocol functions required to implement a high performance 2400 bit/s modem with error control and data compression. The 73D2248A basic modem function is provided by the SSI 73K224L modem chip and is compatible with CCITT V.21, V.22, V.22bis and Bell 103 and 212A protocols. The error control functions are provided by modular software running in the SSI 73D2910 controller. Modules are available for MNP4, and V.42. compression software modules can be can be added to the controller; MNP5 and V.42bis are available. Provisions for customization of the command set are provided, forming the basis for an international modem.

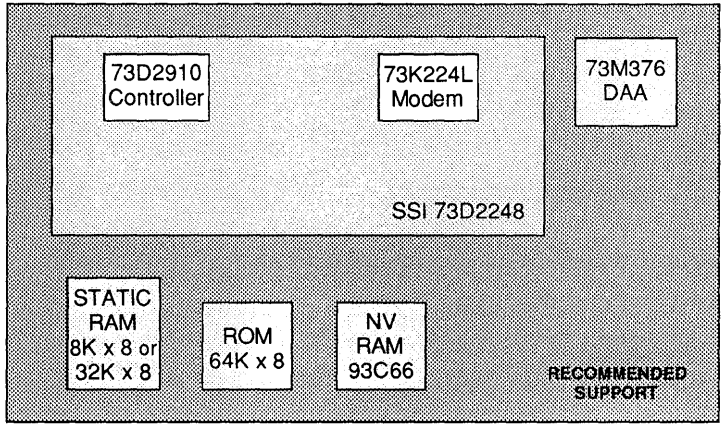
The 73D2348 differs from the 73D2248A in that it uses the 73K324L instead of the 73K224L for the data pump. The 73K324L replaces the Bell 103 300 baud FSK mode of operation with the CCITT V.23 1200 baud FSK mode. The software is also modified to support V.23. The two products are otherwise identical.

FEATURES

- **Combines modem and protocol controller**
- **Supports 0 - 300, 1200 and 2400 bit/s with both sync and async modes**
- **Modular software design allows customization**
- **Modem protocols:**
  - **Bell 103, 212A**
  - **CCITT V.22, V.22bis**
- **Error control/compression protocols Available: MNP4, MNP5, CCITT V.42, V.42bis**
- **Supports non-volatile memory to store user configurations and phone numbers**
- **CMOS design for low power consumption**
- **TQFP packages available for PCMCIA applications**

4

MNP5, V.42bis Datacom Modem Device Set



CAUTION: Use handling procedures necessary for a static sensitive component.

SSI 73D2248A/2348A MNP5, V.42bis Datacom Modem Device Set

FUNCTIONAL DESCRIPTION

The SSI 73D2248A/2348A chip set forms the basis for an international modem design incorporating the most advanced error control and compression algorithms. The set consists of two chips, the SSI 73K224L (73K324L) modem and the 73D2910 controller. Customization of the controller is one of the features of this chip set; software modules allow the modem vendor to provide a range of features from a standard hardware platform.

The 73K224L (73K324L) provides the QAM, PSK and FSK modulator and demodulator functions, call progress and handshake tone monitors, test modes and a tone generator capable of producing DTMF, answer and CCITT guardtones. This single-chip modem supports the V.22bis, V.22, V.21 and Bell 103/CCITT V.23/212A operating protocols in both sync and async modes. Low level functions of the controller provide for automatic detection of DTE speed, auto-dial, auto-answer, handshake with fallback and call progress detection.

The 73D2910 controller handles both the low level modem functions as well as protocol negotiation and protocol operation. Software modules can be chosen to provide the desired protocols for product customization and differentiation. In addition, the "AT" command set source code will be available for those desiring to provide unique or country dependent features.

Basic capabilities of the modem are those found in the 73K224L (73K324L) single-chip modem and are listed in the separate 73K224L (73K324L) data sheet.

AUTOMATIC HANDSHAKE

The 73D2248A/2348A will automatically perform a complete handshake with a called or calling modem and enter the data transfer mode. After the link between the two modems has been established, the modems may remain in the normal data mode or negotiate a link which has error control and data compression. Commands are provided to inform the modem which action is appropriate.

TEST MODES

The 73D2248A/2348A chip set has provisions for three test modes: analog loopback, digital loopback and remote digital loopback. Analog loopback allows data to be sent into the local modem, have it modulated and then demodulated and returned to the local terminal. Digital loopback requires the cooperation of the user at the remote end and allows data to be sent to the remote modem, demodulated, then remodulated and returned to the local end. Remote digital loopback allows the same capability, without the need for a remote operator; signals are sent to the remote modem which perform the switching task that a remote operator would have done.

AT COMMAND INTERPRETER

The SSI 73D2248A/2348A includes an AT Command Interpreter which is a superset of the Hayes 2400 Smartmodem™ command set. Common application software will be able to control the modem though this interpreter. Additional commands have been added to provide for control of the MNP and CCITT V.42 modes.

NON-VOLATILE MEMORY

A serial NVRAM provides 256 bytes of storage for configuration information and telephone numbers. Current hardware provides for a 2K bit memory of which about 400 bytes are used for setup and telephone number storage. The remaining 1600 bytes are avaliable. Memory address space allocated to non-volatile RAM is 8K, so an expansion factor of 4 is available. Alternatively, the address space could be decoded for more hardware functionality.

PROTOCOLS

Microcom Networking Protocol (MNP)

MNP4 is a protocol offering error control while MNP5 offers data compression. Data to be transmitted is broken into blocks of varying sizes, depending on line conditions, and sent to the remote modem along with a 16-bit Cyclic Redundancy Check word. If the algorithm used to derive the CRC word at the transmitter does not produce an identical word when exercised on the received data, a line error is assumed, and the block is repeated. Data compression is obtained by transmitting a short set of characters for a longer redundant set. At the receiver, the short string is replaced with the longer string that it represented, and the data stream is returned to its original state.

CCITT V.42 AND V.42BIS

The CCITT has ratified a set of protocols which operate in a manner similar to MNP. MNP4 corresponds to V.42 while MNP5 corresponds with V.42bis. Greater efficiency is offered, but the tradeoff is a larger memory space requirement. MNP5 requires an 8K buffer, while V.42bis requires 32K. Data files which show compression ratios approaching 2:1 with MNP5 may show ratios of nearly 4:1 with V.42bis.

ADDITIONAL INFORMATION

The Silicon Systems 73D2248/2348 Design Manual defines the AT commands. Please contact your local Silicon Systems sales office or Silicon Systems headquarters in Tustin for a copy of the SSi Protocol Design Manual.

AT COMMAND SUMMARY

Command	Description
AT	command prefix – precedes command line
<CR>	carriage return character – terminates command line
A	go into answer mode; attempt to go to on-line state
A/	re-execute previous command line; not preceded by AT nor followed by <CR>
B0	select CCITT V.22 standard for 1200 bit/s communication
B1	***select Bell 212A standard for 1200 bit/s communication***
D	dial number that follows; attempt to go to on-line state, originate mode
DS=n	dial stored number in location "n" (0-3)
E0	Disable character echo in command state
E1	***Enable character echo in command state***
H0	go on hook (hang up)
H1	go off hook; operate auxiliary relay
I0	request product indentification code
I1	perform checksum on firmware ROM; return checksum
I2	perform checksum on firmware ROM; returns OK or ERROR result codes
L0 or L1	low speaker volume
L2	***medium speaker volume***
L3	high speaker volume
M0	speaker off
M1	***speaker on until carrier detected***
M2	speaker always on
M3	speaker on until carrier detected, except during dialing
O0	go to on-line state
O1	go to on-line state and initiate equalizer retrain at 2400 bit/s
Q0	***modem returns result codes***
Q1	modem does not return result codes
Sr	set pointer to register "r"
Sr=n	set register "r" to value "n"
Sr?	display value stored in register "r"
V0	display result codes in numeric form
V1	***display result codes in verbose form (as words)***
W0	***negotiation progress result codes not returned***
W1	negotiation progress result codes returned
X0	enable features represented by result codes 0-4
X1	enable features represented by result codes 0-5, 10-12
X2	enable features represented by result codes 0-6, 10-12
X3	enable features represented by result codes 0-5, 7, 10-12
X4	***enable features represented by result codes 0-7, 10-12***
Y0	***disable long space disconnect***
Y1	enable long space disconnect
Z0	reset modem
&C0	***assume data carrier always present***
&C1	track presence of data carrier
&D0	***ignore DTR signal***
&D1	assume command state when an on-to-off transition of DTR occurs
&D2	hang up and assume command state when an on-to-off transition of DTR occurs
&D3	reset when an on-to-off transition of DTR occurs
&F	recall factory settings as active configuration
&G0	***no guard tone***
&G1	550 Hz guard tone
&G2	1800 Hz guard tone
&K	flow control method
&M0	***asynchronous mode***
&M1	synchronous mode 1
&M2	synchronous mode 2
&M3	synchronous mode 3
&Q5	error control mode
&Q6	automatic speed buffering (ASB)
&T0	terminate test in progress
&T1	initiate local analog loopback
&T3	initiate local digital loopback
&T4	***grant request from remote modem for RDL***
&T5	deny request from remote modem for RDL
&T6	initiate remote digital loopback
&T7	initiate remote digital loopback with self test
&T8	initiate local analog loopback with self test
&V	view active configuration, user profiles, and stored numbers
&W0	save storable parameters of active configuration
&X0	***modem provides transmit clock signal***
&X1	data terminal provides transmit clock signal
&X2	receive carrier provides transmit clock signal
&Zn=x	store phone number "x" in location "n" (0-3)

Dial string arguments:

, = delay	@ = silent answer	! = flash	
; = return to command	s = dial stored number	W = wait for tone	R=reverse mode

If the NovRAM has not been initialized it may be necessary to power down/power up and type *AT&F&W<cr>* to properly initialize modem state.

TABLE 1: Result Codes

Xn	VERBOSE/TERSE RESULT CODES
X0	OK/0, CONNECT/1, RING/2, NO CARRIER/3, ERROR/4
X1	All functions of X0 + CONNECT (RATE)/1 = 300, 5 = 1200, 10 = 2400
X2	All functions of X1 + NO DIAL TONE/6
X3	All functions of X1 + BUSY/7
X4	All functions of X3 + NO DIAL TONE/6, NO ANSWER/8

TABLE 2: S Registers Supported

Sn	FUNCTION	UNITS	DEFAULT
S0[1]	Answer on ring	No. of rings on which to answer	000[2]
S1	Ring counter	No. of rings accumulated	000
S2	Escape code	ASCII CHR Decimal 0-127	043
S3	Carriage return	ASCII CHR Decimal 0-127	013
S4	Line feed	ASCII CHR Decimal 0-127	010
S5	Back space	ASCII CHR	008
S6	Wait for dial tone	Seconds	002
S7	Wait for carrier	Seconds	030
S8	Pause time	Seconds	002
S9	Carrier valid	100 milliseconds (0.1 sec)	006
S10	Carrier drop out	100 milliseconds (0.1 sec)	014
S11	DTMF tone duration	1 millisecond (0.001 sec)	070
S12	Escape guard time	20 milliseconds (0.05 sec)	050
S13	Unused		N/A
*S14[1]	Bit mapped register	Decimal 0-255	170

[1] Stored in NVRAM with &W command.
[2] Modem will not answer until value is changed to 1 or greater.

TABLE 2: S Registers Supported (Continued)

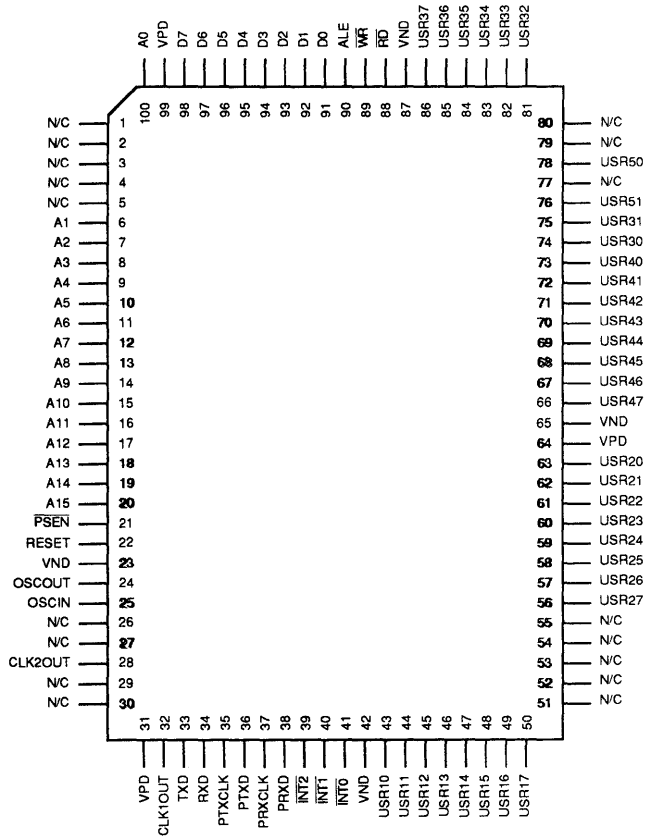
NUMBER	FUNCTION	UNITS	DEFAULT
S15	Unused		N/A
S16	Test register	Decimal #	000
S17	Special test register	Decimal 0-255	096
S18	Test timer	Decimal 0-255	000
S19	Unused		N/A
S20	Unused		N/A
*S21[1]	Bitmapped register	Decimal 0-255	000
*S22[1]	Bitmapped register	Decimal 0-255	118
*S23[1]	Bitmapped register	Decimal 0-255	007
S24	Unused		N/A
S25[1]	DTR delay	10 milliseconds (0.01 sec)	005
S26[1]	CTS delay	10 milliseconds (0.01 sec)	001
*S27[1]	Bitmapped register	Decimal 0-255	064
S36	Negotiation failure treatment		5
S37	Desired modem line speed	Decimal 0-9	000
S38	Hang-up timeout		20
S39	Current flow control setting		3
S43	Current DCE speed		0
S46	Protocol/Compression selection		2
S48	Feature negotiation action		7
S49	ASB Buffer low limit	1-249	8
S50	ASB Buffer high limit	2-250	16
S82	Break select register		128
S95	Extended result code bit map		0

*The bitmapped register functions are equivalent to normal "AT" command modem registers.

[1] Stored in NVRAM with &W command

PACKAGE PIN DESIGNATIONS

(Top View)

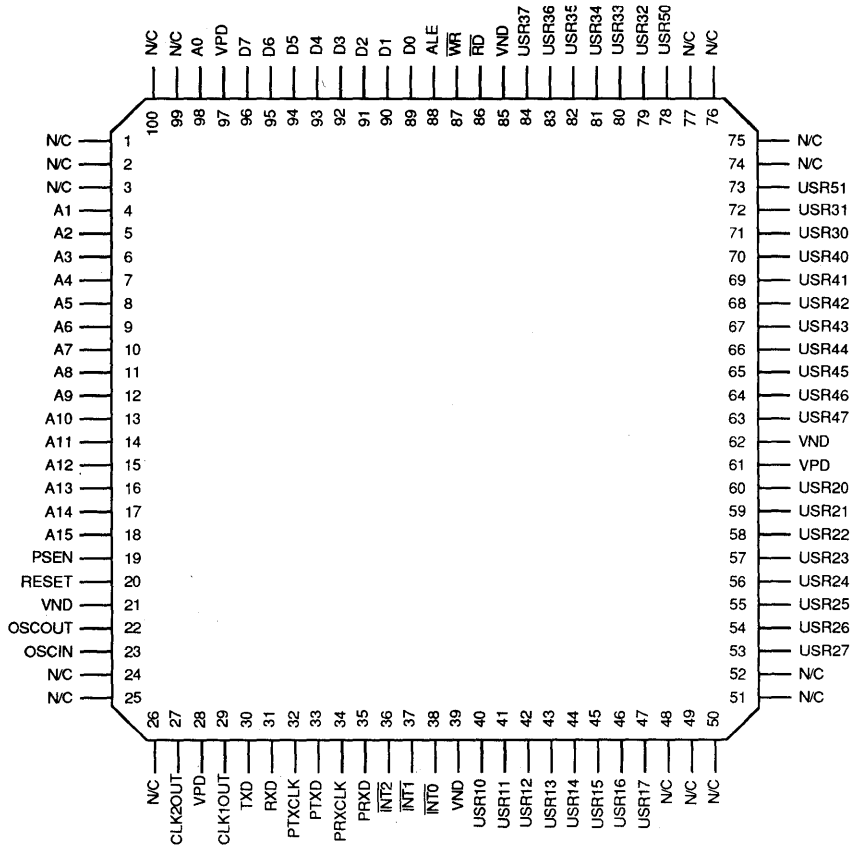


SSI 73D2910
Controller
100-Lead QFP

CAUTION: Use handling procedures necessary for a static sensitive component.

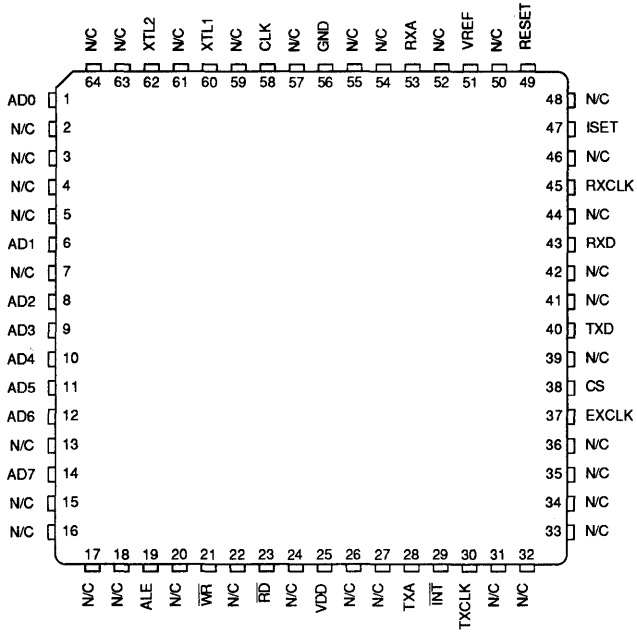
PACKAGE PIN DESIGNATIONS (continued)

(Top View)

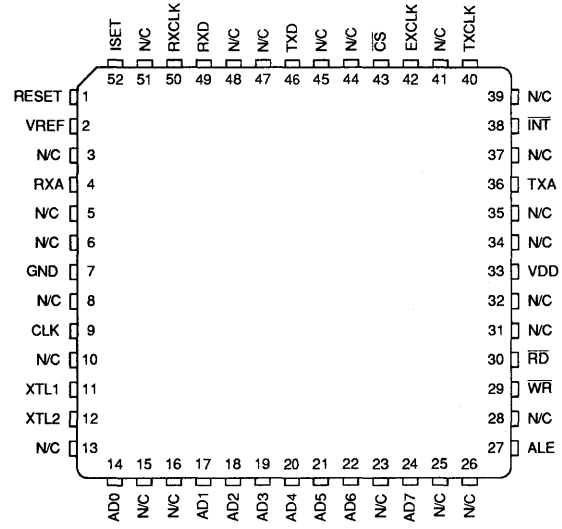


SSI 73D2910
Controller
100-Lead TQFP

CAUTION: Use handling procedures necessary for a static sensitive component.



SSI 73K224L
Single Chip Modem
64-Lead TQFP



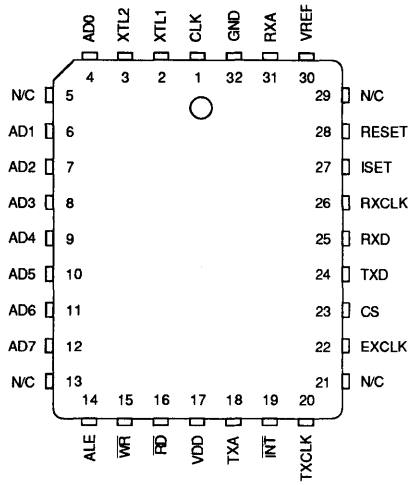
SSI 73K224L
Single Chip Modem
52-Lead QFP

CAUTION: Use handling procedures necessary for a static sensitive component.

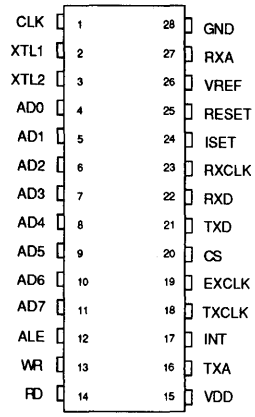
SSI 73D2248A/2348A
MNP5, V.42bis Datacom
Modem Device Set

PACKAGE PIN DESIGNATIONS (continued)

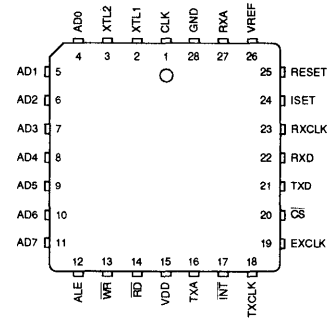
(Top View)



SSI 73K224L
Single Chip Modem
32-Pin PLCC



SSI 73K224L
Single Chip Modem
28-Pin DIP



SSI 73K224L
Single Chip Modem
28-Pin PLCC

CAUTION: Use handling procedures necessary for a static sensitive component.

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SSI 73M2910/2910A
Microcontroller

November 1994

DESCRIPTION

The Silicon Systems 73M2910 high performance microcontroller is based on the industry standard 8-bit 8052 implemented in Silicon Systems' advanced submicron CMOS process. The processor has the same attributes of the 8052 including Instruction cycle time, UART, timers, interrupts, 256 bytes of on-chip RAM and programmable I/O. The architecture has been optimized for low power portable modem or communication applications by integrating unique features with the core CPU.

The main feature is a user friendly HDLC packetizer, accessed through the special function registers. It has a serial I/O, hardware support for 16- and 32-bit CRC, zero insert/delete control, a dedicated interrupt and a clear channel mode for by-passing the packetizer.

Other features include additional user programmable I/O with programmable bank select and chip select logic, designed to eliminate board level glue logic. It also includes two general purpose input ports with programmable wakeup capability.

For devices that require non-multiplexed address and data buses, eight latched outputs for the low byte of the address are available.

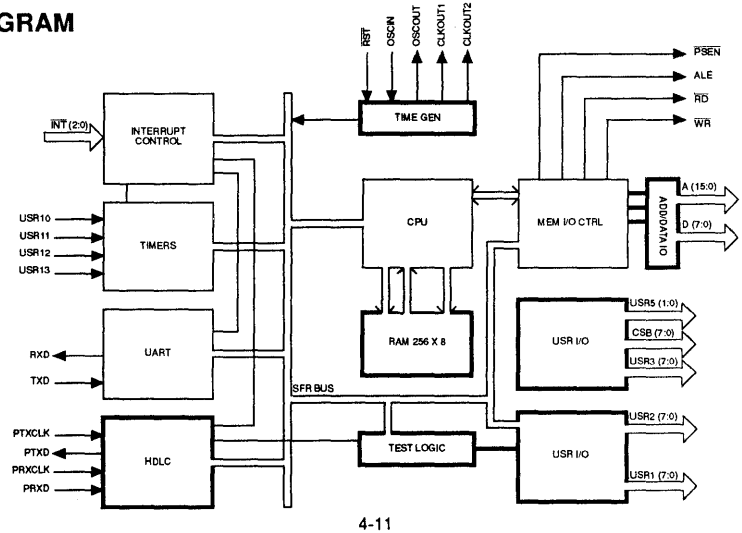
(continued)

FEATURES

- **8052 Compatible Instruction set**
- **34 MHz Operation @ 4.5 – 5.5V**
- **44 MHz Operation @ 4.75 – 5.5V (2910A)**
- **22 MHz Operation @ 3.3 – 5.5V**
- **HDLC Support logic (Packetizer, 16 and 32 CRC, zero ID)**
- **24 pins for user programmable I/O ports**
- **8 pins programmable chip select logic or I/O for memory mapped peripheral eliminating glue logic**
- **3 external interrupt sources (programmable polarity)**
- **16 dedicated latched address pins**
- **Multiplexed data/address bus**
- **Instruction cycle time identical to 8052**
- **Buffered oscillator (or OSC/2) output pin**
- **1.8432 MHz UART clock available**
- **Bank select circuitry to support up to 128K of external program memory**
- **100-Lead TQFP package available for PCMCIA applications**
- **Also available in 100-Lead QFP package**

4

BLOCK DIAGRAM



DESCRIPTION (continued)

The 73M2910 has two extra interrupt sources, an external interrupt and a HDLC interrupt. The HDLC interrupt has two registers associated with it; the HDLC Interrupt Register which is used to determine the source of the interrupt, and the HDLC Interrupt Enable Register that enables the source of the interrupt.

The state of the external interrupts can be read through a register allowing the interrupt pins to be used as inputs. The interrupt pins INT0 and INT1 can be either negative edge, positive edge or level triggered. The INT2 pin is always edge triggered.

Two buffered clock outputs have been added to support peripheral functions such as UARTs, modems and other clocked devices. The main internal processor clock frequency can be divided by 2 for power conservation in functional modes that only require half the clock speed.

Additional internal special function registers are used for firmware control over the HDLC Packetizer, the clocks and the programmable I/O ports.

To accommodate processor peripherals when operating at 22 MHz the processor's timing has been altered somewhat to allow more address setup time for slower peripheral program ROM and memory mapped peripherals. This can offer the system designers an advantage when using higher (22 MHz) oscillator frequencies.

For low power applications the 73M2910 operates from 3 to 5 volts at 22 MHz and supports two power conservation modes: Idle and Power-down. In the Power-down state the total current consumption is less than 10 μA at room temperature.

This device is offered in small form factor 100-lead TQFP packages for PCMCIA applications and 100-lead QFP packages.

DEVELOPER'S NOTE:

The 73M2910 is also available in a 100-pin PGA package for system developers. The PGA package is more convenient and reliable for development emulation systems than the other package styles. Emulation systems for the 73M2910 are available through Signum Systems, 171 E. Thousand Oaks Blvd., #202, Thousand Oaks, CA 91360 (805) 371-4608.

8052 REFERENCE

This Document will describe the features unique to the 73M2910. Please refer to an 8052 Programmer's Guide, Architectural Overview and Hardware Description for details on the instruction set, timers, UART, interrupt control, and memory structure.

REGISTER DESCRIPTION

INTERRUPTS

The core chip provides 8 sources of interrupt; 3 external interrupts, 3 timer interrupts, a serial port interrupt, and an HDLC interrupt. An external interrupt and an HDLC interrupt are unique to the 73M2910. They do not exist in a normal 8052 product. Previously unused bits in the IE and IP registers are now serving functions for these additional interrupt sources. The interrupt vector addresses are as follows:

SOURCE	VECTOR ADDRESS
$\overline{\text{INT0}}$ (IE0)	003H
TF0	00BH
$\overline{\text{INT1}}$ (IE1)	013H
TF1	01BH
RI + TI	023H
TF2 + EXF2	02BH
$\overline{\text{INT2}}$ - ADDED INTERRUPT	033H
HDLC - ADDED INTERRUPT	03BH

The external interrupt sources, $\overline{\text{INT}}$(2:0), come from dedicated input pins. The apparent polarity of these pins is individually controlled by bits in a special interrupt direction register, IDIR (address A9). The interrupt pins $\overline{\text{INT1}}$ and $\overline{\text{INT0}}$ can be either edge or level generated interrupts as indicated by bits 1 and 3 in the TCON register (address 88). Pin $\overline{\text{INT2}}$ is always an edge generated interrupt. A flag is set when a falling transition (rising if IDIR bit 2 is set) on this pin is detected. This flag is automatically cleared when the interrupt is processed.

INTERRUPT ENABLE REGISTER (IE) SFR ADDRESS A8
Bit Addressable
Reset State 00h

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
EA	EX2	ET2	ES	ET1	EX1	ET0	EX0

Note: BIT 6 differs from the 8052. This is a reserved bit in the 8052 and is used as a mask bit for external interrupt 2 in the core implementation. When BIT 6 is set to a 0, external interrupt 2 is disabled.

The mask bit for the HDLC interrupt source is BIT 0 of the HDLC control register.

INTERRUPT PRIORITY REGISTER (IP) SFR ADDRESS B8
Bit Addressable
Reset State 00h

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
PHDLC	PX2	PT2	PS	PT1	PX1	PT0	PX0

Note: BIT 6 and BIT 7 differ from the 8052. These are reserved bits in the 8052 and are used to determine the priority of external interrupt 2 and the HDLC in the core implementation. When BIT 6 is set to a 1, the interrupt is set to the higher priority level.

REGISTER DESCRIPTION (continued)

EXTERNAL INTERRUPT DIRECTION REGISTER (IDIR) SFR ADDRESS 92

Byte Addressable
Reset State 00h

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
0	0	$\overline{INT2}$	$\overline{INT1}$	$\overline{INT0}$	INTD2	INTD1	INTD0

These bits determine the polarity of the corresponding external signals INT(2:0) which will result in an interrupt and will also allow the user to directly read the logic level at the pads INT(2:0).

BITS(5:3) INT(2:0)

BITS(5:3) are read only bits that reflect the logic value at the corresponding pin. The value is not affected by BITS(2:0).

BITS(2:0) Interrupt Polarity Control

If the bit is set to a 0, a falling edge will trigger the interrupt. If the bit is set to a 1, a rising edge will trigger the interrupt. Also, if the bit is set to a 1, level generated interrupts will occur when the corresponding pin is high and the internal pin signal to the timer controls will be inverted.

Bits 6 and 7 will always be read as 0's.

CLOCK CONTROL REGISTER SFR ADDRESS DA

Byte Addressable
Reset State 00h

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
Activity	CLK1 CTRL1	MCLK CTRL	CLK2EN	CLK2 CTRL1	CLK2 CTRL0	CLK1EN	CLK1 CTRL0

These bits determine the behavior at the CLK1OUT and CLK2OUT pins and allow the user to divide the main internal processor clock frequency by two for power conservation.

BIT 7

BIT 7 is an activity bit. It is cleared by a read of this register. If the activity bit is set it will prevent the 73M2910 from entering Sleep mode.

BIT 6

When BIT 6 = 1, CLK1OUT will be OSC/1.5 if bit 1 is a 1 and bit 0 is 0.

BIT 5	CLOCK OUT
0	OSC
1	OSC/2

BIT 5 Master Clock Control

When BIT 5 is set to a 1 the internal processor clock is the oscillator frequency divided by 2. If this bit is a 0, the processor clock is the same frequency as the oscillator's.

BIT 4 Clock 2 Output Enable

BIT 4 enables the clock at the CLOCK 2 output pin if it is set to a 1. The CLOCK 2 pin output is held to a 0, by writing this bit to a 0. This will reduce system power if the clock pin is not used or if a power reduction mode is required.

BIT 3 BIT 2 Clock 2 Output Control

These bits determine the oscillator divisor for the CLOCK 2 output pin. They were designed to provide a 1.8432 MHz clock for an external UART given an oscillator frequency of 11.0592 MHz, 22.1184 MHz, 18.432 MHz, or 13.824 MHz.

BIT 3	BIT 2	CLK 2 OUT	OSC FREQUENCY
0	0	OSC/7.5	13.824 MHz
0	1	OSC/6	11.059 MHz
1	0	OSC/12	22.118 MHz
1	1	OSC/10	18.432 MHz

BIT 1 CLOCK 1 Output Enable

BIT 1 enables the clock at the clock 1 output pin if it is set to a 1. The clock pin output is held to a 0, by writing a 0 to this bit. This will reduce system power if the clock pin is not used or if a power reduction mode is required.

BIT 6 is cleared to a 0 upon a reset.

BIT 0 Clock 1 Output Control

BIT 0 controls the frequency of the clock 1 output pin. The clock output is either the oscillator's output signal divided by two or a buffered oscillator output signal

POWER SAVING MODES

Low Power Modes

The SSI 73M2910 supports two power conservation modes, which are controlled by the PCON.1 and PCON.0 control bits of the PCON register.

If PCON.0 is set, the SSI 73M2910 will go into a power saving mode where the oscillator is running, clocks are supplied to the UART, timers, HDLC, and interrupt blocks, but no clocks are supplied to the CPU. Instruction processing and activity on the address and data ports is halted. Normal operation is resumed when an unmasked interrupt is requested or when a reset occurs.

If PCON.1 is set, the SSI 73M2910 goes into its lowest power mode where the oscillator is halted. The total current consumption in this state should be less than 10 µa. The SSI 73M2910 will start its oscillator and begin to return to normal operation when either a reset occurs, when a falling (rising if corresponding direction bit is set) edge of an unmasked external interrupt from pins $\overline{\text{INT}}$(2:0) is detected, or when the USR5(1:0) pins change to a state according to the USR 5 port register. Edges used in wakeup modes are not filtered in the SSI 73M2910, so the user must be cautious of noise or small glitches inadvertently waking up the chip. From the time the edge that results in the wake up occurs, to the point at which an instruction is executed, depends on the oscillator start-up time. Three good oscillator pulses must be detected before the main internal clocks are generated.

During Power Down mode, both the ALE and $\overline{\text{PSEN}}$ pins are pulled high since these signals often provide the output enable and chip enable for the ROM (active low). This ensures that the external components are in their lowest power state.

REGISTER DESCRIPTION (continued)

USER PROGRAMMABLE I/O

Port Control USR1, USR2, USR3, USR4, USR5

The core chip provides 32 user I/O pins. Each pin is programmed separately as either an input or as an output by a bit in a direction register. If the bit in the direction register is set to a 1, the I/O control will treat the corresponding pin as an input. If it is a 0, the pin will be treated as an output whose value is determined by the port data register. The USR1 and USR2 port registers are accessed through the internal SFR bus. The USR3 and USR4 ports are accessed through the external memory bus by a MOVX instruction. The USR4 port provides the user with an automatic chip select function if selected by the user. If the user does not require some (or any) of the chip select pin options, he may program the USR4 port pins to operate in the same way as USR3 port pins.

The USR DATA register contents determine pin values if chosen as an output. When reading from the DATA register's SFR address, the pin logic values are returned as data except when the port address is the destination address for a read-modify-write instruction. In this case, the latched register values are returned as data. When reading data from a DATA register that is mapped in the external memory space, the pin values are always returned as data.

The USR5 register allows for 2 additional input pins. In normal operation these pins can be used as general purpose inputs. In Power Down mode, the user can program either rising or falling transitions or logical combinations of these pins to wake up the chip.

USER 1 PORT

USR1 DATA SFR Address 90
Bit Addressable
Reset State 00h

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
USR1 7	USR1 6	USR1 5	USR1 4	USR1 3	USR1 2	USR1 1	USR1 0

Bits in this register will be asserted on the USR1(7:0) pins if the corresponding direction register bit is a 0. Reading this SFR's address will return data reflecting the values of pins USR1(7:0) except when address 90h is the destination address for a read-modify-write instruction. In this case, the latched register values are returned as data.

USR1 port signals are also used as timer controls. In applications where the external signals are required for timer count modes, the corresponding port pin should be configured as an input.

USR1 BIT0 = TIMER 0 T0 PIN
USR1 BIT1 = TIMER 1 T1 PIN
USR1 BIT2 = TIMER 2 T2EX PIN
USR1 BIT3 = TIMER 2 T2 PIN

USR1 Port Direction (DIR1) SFR Address 91
Byte Addressable
Reset State FFh

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
DIR1 7	DIR1 6	DIR1 5	DIR1 4	DIR1 3	DIR1 2	DIR1 1	DIR1 0

This register is used to designate the USR1 pins as either inputs or outputs. If the register bit is reset to a 0, the corresponding USR1 pin is programmed as an output that will be driven by the corresponding USR1 DATA register bit. If the register bit is a 1, the corresponding pin will be treated as an input.

After a reset, the USR1 pins will present a high impedance output state and the input values will not be driven from the pin, but will be driven to a 1 internally. The pins will assume normal I/O operation once the processor has written the port direction register. This feature will ensure a low current state at reset (you don't want to drive out against external inputs, and you don't want floating inputs).

USER2 PORT

USR2 Port Data SFR Address D8
Bit Addressable
Reset State 00h

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
USR2 7	USR2 6	USR2 5	USR2 4	USR2 3	USR2 2	USR2 1	USR2 0

Bits in this register will be asserted on the USR2(7:0) pins if the corresponding direction register bit is a 0. Reading this SFR's address will return data reflecting the values of pins USR2(7:0) except when address D8h is the destination address for a read-modify-write instruction. In this case, the latched register values are returned as data.

USR2 Port Direction (DIR2) SFR Address D9
Byte Addressable
Reset State FFh

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
DIR2 7	DIR2 6	DIR2 5	DIR2 4	DIR2 3	DIR2 2	DIR2 1	DIR2 0

This register is used to designate the USR2 pins as either inputs or outputs. If the register bit is reset to a 0, the corresponding USR2 pin is programmed as an output that will be driven by the corresponding USR2 I/O DATA register bit. If the register bit is a 1, the corresponding pin will treated as an input.

After a reset, the USR2 pins will present a high impedance output state and the input values will not be driven from the pin, but will be driven to a 1 internally. The pins will assume normal I/O operation once the processor has written the port direction register. This feature will ensure a low current state at reset (you don't want to drive out against external inputs, and you don't want floating inputs).

USR3 Port Data External address 0000
Byte Addressable
Reset State 00h

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
USR3 7	USR3 6	USR3 5	USR3 4	USR3 3	USR3 2	USR3 1	USR3 0

Bits in this register will be asserted on the USR3(7:0) pins if the corresponding direction register bit is a 0. Reading this SFR's address will return data reflecting the values of pins USR3(7:0).

If the bank select feature is chosen, USR3 PIN7 acts as address bit 17 and USR3 data bit 7 is ignored.

REGISTER DESCRIPTION (continued)

USR3 I/O Port Direction (DIR3) External Address 0001
Byte Addressable
Reset State FFh

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
DIR3 7	DIR3 6	DIR3 5	DIR3 4	DIR3 3	DIR3 2	DIR3 1	DIR3 0

This register is used to designate the USR3 pins as either inputs or outputs. If the register bit is reset to a 0, the corresponding USR3 pin is programmed as an output that will be driven by the corresponding USR3 DATA register bit. If the register bit is a 1, the corresponding pin will be treated as an input.

After a reset, the USR3 pins will present a high impedance output state and the input values will not be driven from the pin, but will be driven to a 1 internally. The pins will assume normal I/O operation once the processor has written the USR3 port direction register. This feature will ensure a low current state at reset (you don't want to drive out against external inputs, and you don't want floating inputs).

If the bank select feature is chosen, USR3 PIN7 is forced to be an output.

Bank Select (BNKSEL) External Address 0002
Byte Addressable
Reset State 00h

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
B7	B6	B5	B4	B3	BSEN	BS1	BS0

This resister is used to accommodate systems where more than 64 Kbytes (up to 128 Kbytes) of program memory are required. USR3 PIN 7 acts as an address pin, A16, if BSEN is set to a 1 and if the processor is fetching an instruction and not data memory. If BSEN is set to a 1, A15 is also modified during instruction fetches as shown. If BSEN is a 0, no alterations to address bit A15 are made, and USR3 PIN 7 is a function of USER3 bit 7 and DIR3 bit 7.

Bits (7-3) are general purpose read/write register bits.

A15 is the value of the 16th address bit as it appears at pin A15.

A15' is the address from port 2 internal logic, the value that will appear as the most significant address bit if no bank select feature is chosen.

A16 is the value of the 17th and MSB of the instruction address seen at the USR3 7 port pin, if the bank select feature is selected. If the bank select feature is not selected, USR3 7 acts as a normal USR3 I/O port pin.

BSEN	BS1	BS0	A15'	A15	A16	ADDRESS
0	*	*	0	0	USR37	0K - 32K
0	*	*	1	1	USR37	32K - 64K
1	0	0	0	0	0	0K - 32K
1	0	0	1	1	0	32K - 64K
1	0	1	0	0	0	0K - 32K
1	0	1	1	0	1	64K - 96K
1	1	0	0	0	0	0K - 32K
1	1	0	1	1	1	96K - 128K
1	1	1	0	0	0	0K - 32K
1	1	1	1	0	1	64K - 96K

* = Don't care.

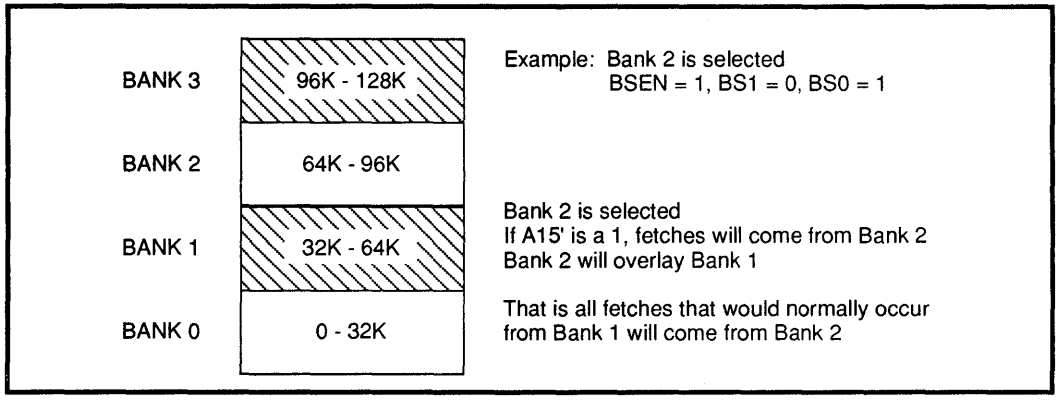


FIGURE 8: Bank Select

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REGISTER DESCRIPTION (continued)

USER4 PORT

USR4 Port Data External Address 0003
Byte Addressable
Reset State 00h

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
USR4 7	USR4 6	USR4 5	USR4 4	USR4 3	USR4 2	USR4 1	USR4 0

Bits in this register will be asserted on the USR4(7:0) pins if the corresponding direction register bit is a 0 and if the corresponding bit in the chip select enable register, 0005, is set to a 0. Reading this register will return data reflecting the values of pins USR4(7:0).

USR4 I/O Port Direction (DIR4) External Address 0004
Byte Addressable
Reset State FFh

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
DIR4 7	DIR4 6	DIR4 5	DIR4 4	DIR4 3	DIR4 2	DIR4	1 DIR4 0

This register is used to designate the USR4 pins as either inputs or outputs. If the register bit is reset to a 0, the corresponding USR4 pin is programmed as an output that will be driven by the corresponding USR4 I/O DATA register bit if the corresponding bit in the chip select enable register, 0005, is set to a 0. If the register bit is a 1, the corresponding pin will treated as an input only if the corresponding bit in register 0005 is set to a 0.

After a reset, the USR4 pins will act as chip select outputs.

USR4 Port Chip Select Enable (CSEN) External Address 0005
Byte Addressable
Reset State FFh

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
CSEN 7	CSEN 6	CSEN 5	CSEN 4	CSEN 3	CSEN 2	CSEN 1	CSEN 0

This register is used to designate the USR4 pins as either user programmable I/Os or as chip select (CS0B - CS7B) functions on a pin by pin basis. This feature is designed to help reduce external glue logic for peripheral memory mapped devices. The chip select function is programmed by setting the appropriate bits in the CSEN register. When a chip select pin is enabled by setting the corresponding CSEN bit to a 1, all data and direction information from registers 0003 and 0004 for this bit are ignored and the selected port becomes an output. If the bit is reset to a 0, the pin will be treated as a normal programmable user I/O pin as defined by registers 0003 and 0004.

The chip select pins have a defined memory map. The intent is that the outputs can be wire ORed together for a flexible selection of peripheral chip selects. All chip selects will be disabled (forced to a logic 1. It is assumed that all chip selects are active low) after the read or write is completed, and the appropriate chip select will be enabled as the next new external addresses is asserted. After a reset, the CSB pull-up devices are all enabled, that is, all chip select outputs are high. Users must account for this if these pins are intended to be general purpose I/Os.

The chip selects partition a 64K memory space as follows:

CHIP SELECT PIN	ADDRESS	# BYTES
RESERVED FOR INTERNAL USE	0000H - 00FFH	256
CS0 (USR4.0)	0100H - 01FFH	256
CS1 (USR4.1)	0200H - 03FFH	512
CS2 (USR 4.2)	0400H - 07FFH	1K
CS3 (USR 4.3)	0800H - 0FFFH	2K
CS4 (USR 4.4)	1000H - 1FFFH	4K
CS5 (USR 4.5)	2000H - 3FFFH	8K
CS6 (USR 4.6)	4000H - 7FFFH	16K
CS7 (USR 4.7)	8000H - FFFFH	32K

Note: You can't read from external addresses 0000H-00FFH. These are reserved for SSI 73M2910 internally defined registers

USER5 PORT

USR5 Port Register External Address 0006
Byte Addressable
Reset State 60h

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
USR5EN	USR50	USR51	POL50	POL51	ACTE0	ACTE1	AND01

This register allows user programmable wakeup capability. If this is not required, this register can be used to read external signals at the USR51 and USR50 pins.

Bit 7 USR5 Input Port Enable

Bit 7 is used to enable the USR51 and USR50 input circuitry. If this bit is a 0, the USR5 pad circuitry is driven to a known level internally and any signal level at the chip pin is ignored. When set to a 1 the pad circuitry is enabled and the values of these pins are reflected in BITS 6 and 7. If these pins are not connected at the board level, this bit should remain at a 0 to keep the pad circuitry from drawing unnecessary current.

The USR5 register can be programmed such that a transition (bit 4 determines rising or falling) of USR50, a transition (bit 3 determines rising or falling) of USR51, or the logical combination of USR50(B) (bit 4 determines high or low level) AND USR51(B) (bit 3 determines high or low level) can wakeup the processor from its Power Down mode.

BIT 6 USR50

BIT 6 reflects the value of chip pin USR50 if the USR5EN bit is set to a 1.

BIT 5 USR50

BIT 5 reflects the value of chip pin USR51 if the USR5EN bit is set to a 1.

REGISTER DESCRIPTION (continued)

BIT 4 USR50 Polarity

BIT 4 determines which edge or level is used in the wakeup detection circuit. A low level selects a rising transition and the true pin value of USR50 to the wakeup combinatorial circuit. When this bit is set to a 1, a falling transition and complemented USR50 value is presented to the wakeup combinatorial circuit.

BIT 3 USR51 Polarity

BIT 3 determines which edge or level is used in the wakeup detection circuit. A low level selects a rising transition and the true pin value of USR51 to the wakeup combinatorial circuit. When this bit is set to a 1, a falling transition and complemented USR51 value is presented to the wakeup combinatorial circuit.

BIT 2 USR50 Edge Activity Enabled

When BIT 2 is set to a 1, a transition of USR50 of the appropriate level as dictated by BIT 4, will wake up the processor. If this bit is reset to a 0, edge activity on this pin is ignored.

BIT 1 USR51 Edge Activity Enabled

When BIT 1 is set to a 1, a transition of USR50 of the appropriate level as dictated by BIT 3, will wake up the processor. If this bit is reset to a 0, edge activity on this pin is ignored.

BIT 0 Combinatorial and of USR50 and USR51 Level Enabled

When BIT 0 is set to a 1, the value USR50 or its complimented value as dictated by BIT 3, ANDed with the value USR51 or its complimented value as dictated by BIT 2, will wake up the processor. If this bit is reset to a 0, the levels of USR50 and USR51 are ignored.

USR50	USR51	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0	WAKEUP
*	*	*	*	0	0	0	NO
0-1	*	0	*	1	*	*	YES
1-0	*	1	*	1	*	*	YES
*	0-1	*	0	*	1	*	YES
*	1-0	*	1	*	1	*	YES
0	0	1	1	*	*	1	YES
1	0	0	1	*	*	1	YES
0	1	1	0	*	*	1	YES
1	1	0	0	*	*	1	YES

* = Don't care.

HDLC CONTROL REGISTER 0

HDLC Control Register 0 (HDLC0) SFR Address C0
Bit Addressable Reset State 00XX 0000 b
Bits 5 and 4 are read only bits

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
WRXD	WPTXD	TXD R	PRXD R	RXD CTRL1	RXD CTRL0	PTX CTRL1	PTX CTRL0

This register controls the basic set-up of the DTE and modem pins RXD, TXD, PRXD, and PTXD.

BIT 7 WRXD

BIT 7 allows the processor to write directly to the SSI 73M2910 RXD output pin. The value of BIT 7 will appear at the PTXD pin only if BIT 1 is a 1 and BIT 0 is a 0.

BIT 6 WPTXD

BIT 6 allows the processor to write directly to the SSI 73M2910 PTXD output pin. The value of BIT 6 will appear at the PTXD pin only if BIT 1 is a 1 and BIT 0 is a 0.

BIT 5 TXD

BIT 5 is a read only bit that reflects the value at the SSI 73M2910 TXD input pin.

BIT 4 PRXD

BIT 4 is a read only bit that reflects the value at the SSI 73M2910 PRXD input pin.

BIT 3 BIT 2 RXD Control

BIT 3 and BIT2 control the source of the SSI 73M2910 RXD output pin. This output goes to the DTE's RS232 interface. The source of this signal can be the core's UART TXD output, the PRXD output from a modem peripheral (clear channel), the DTE's TXD(echo), or the value written into bit 7 of this register.

BIT 3	BIT 2	RXD OUTPUT
0	0	UART TXD OUTPUT
0	1	PRXD BUFFERED (CLEAR CHANNEL)
1	0	TXD BUFFERED (ECHO)
1	1	WRXD (BIT 7)

BIT 1 BIT 0 PTXD Control

BIT 1 and BIT0 control the source of the SSI 73M2910 PTXD output pin. This output goes to the modem's TX data input. The source of this signal can be the core's HDLC TX output, the DTE's TXD output (clear channel), or the value written into bit 6 of this register.

BIT 1	BIT 0	PTXD Output
0	0	HDLC TX Output
0	1	TXD Buffered (Clear Channel)
1	0	WPTXD (BIT 6)
1	1	0

REGISTER DESCRIPTION (continued)

HDLC CONTROL REGISTER 1

HDLC Control Resister 1 (HDLC1) SFR Address C1
Byte Addressable
Reset State 00h

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
HDLC RST	CCITT	CRC PRE	RXCRC 32	RXCRC 16	TXCRC CTRL	ZERO ID	HDLC EN

This register controls the basic set-up of the HDLC block. This register will be written during initialization and not during normal message processing.

BIT 7 HDLC Software Reset

When BIT 7 is a 1, the HDLC circuit is reset and held in a low power state and no interrupts from the HDLC circuitry will be generated. When a 0 is written to this bit, the HDLC circuit will behave according to its control bits. BIT 7 and the power on reset signal are OR'ed together to form a reset signal for the HDLC block.

BIT 7 is cleared to a 0 upon a power up reset.

BIT 6 CRC Type Control

BIT 6 selects the CRC algorithm used in the 16 bit CRC calculation. There are two types of 16-bit CRCs commonly used, CRC16 and the CCITT 16-bit CRC. If this bit is set to a 1, the CCITT type is selected.

BIT 6 is cleared to a 0 upon a reset.

BIT 5 CRC Preset Value

BIT 5 selects the reset value for the CRC generator and receiver. If this bit is set to a 1, the CRC generator and receiver are initialized to ones and if this bit is reset to a 0, they are initialized to 0s. This bit should be set to a 1 for most CCITT polynomials.

BIT 5 is cleared to a 0 upon a reset.

BIT 4 BIT 3 RX CRC Control

BIT 4 and BIT 3 determine the type of CRC remainder that will be checked at the end of a received frame. There is a 16-bit CRC, and a 32-bit CRC that the HDLC block can support. If both BIT 4 and BIT 3 are reset, bits 7 and 6 of the HDLC STATUS register will be held to a 0. If both BIT 4 and BIT 3 are 1s, a special CRC search mode is enabled where both bits 7 and 6 of the HDLC status register are enabled. This mode is used during a connection to determine which CRC is used by the initiating modem. If the 16-bit CRC remainder is not matched at the end of the received frame, then BIT 6 of the HDLC STATUS register is set. If the 32-bit CRC remainder is not matched at the end of the received frame, then BIT 7 of the HDLCSTATUS register is set. Once the correct CRC type is established during a connection, either BIT 4 or BIT 3 should be set to a 1 enabling the appropriate INVALID CRC status bit.

BIT 4	BIT 3	CRC TYPE
0	0	NO CRC Check
0	1	Enable CRC16 Status
1	0	Enable CRC32 Status
1	1	Enable CRC16 Status and CRC32 Status

BIT 2 TXCRC Control

BIT 2 controls the CRC type to be transmitted. If BIT 2 is reset to a 0, a 16-bit CRC will be transmitted with the SEND CRC command. If BIT 2 is set to a 1, a 32 bit CRC will be transmitted.

BIT 1 Zero Insert/Delete Control

When BIT 1 is set to a 1, a 0 will be transmitted if either the SEND DATA or SENDCRC bits of the HDLCTX CONTROL are set after five consecutive 1s have been transmitted. Also, when this bit is set, a 0 will be removed from the received data stream if it immediately follows a pattern of a 0 followed by five consecutive ones. If BIT 1 is reset to a 0, no 0s will be inserted during transmission, and no 0s will be deleted during reception.

BIT 1 is cleared to a 0 upon a reset.

BIT 0 HDLC Interupt Enable

When BIT 0 is reset to a 0, the HDLC will be prevented from generating an interrupt. The status bits that indicate the source of the interrupt can still be set allowing the HDLC block to be serviced in a polled mode.

BIT 0 is cleared to a 0 upon reset.

HDLC TX Control Resister (HTXC) SFR Address C2
Byte Addressable
Reset State 00h

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
0	0	0	DIV16 CLK	SEND ABORT	SEND CRC	SEND DATA	SEND FLAG

This register is used to control the source of data that appears on the PTXD pin. Bits are shifted out on every rising edge of the PTXCLK pin input. If no control bits are set, or more than 1 TX CONTROLbit is set, the PTXD pin will go to a binary 1.

BIT 7 - BIT 5 Always 0

BIT 4 16X Clock Select

Under normal synchronous operation, the PTXCLKand PRXCLK are used to receive and transmit data PRXD and PTXD. The clock rate is equal to the data rate. In asynchronous modes, a clock 16 times the bit rate is provided at PTXCLK and PRXCLK.

When BIT 4 is set to a 1 for asynchronous operation, the clocks at the PTXCLK and PRXCLK pins are divided by 16 to provide transmit and receive shift clocks. An internal clock for sampling incoming PRXD data is synchronized by detecting any falling edge on the PRXD data pin. The rising edge of this internal clock, which used to sample incoming data, is delayed from the falling data edge by 8 PRXCLK periods and will continue at this phase and at a PRXCLK/16 frequency until another falling PRXD edge is detected.

If BIT 4 is reset to a 0, the rising edge of PTXCLK is used to sample the data at PRXD, and the falling edge of PTXCLK is used to shift new data onto PTXD.

BIT 3 is cleared to a 1 upon a reset.

REGISTER DESCRIPTION (continued)

BIT 3 Abort

When BIT 3 is set to a 1, a series of consecutive ones will immediately be transmitted through the PTXD pin on every falling edge of PTXCLK. The message will have been aborted after 2 TX ready interrupts are received. No zeros will be inserted during the abort transmission.

BIT 3 is cleared to a 1 upon a reset.

BIT 2 Send CRC

When BIT 2 is set, the bytes in the TX CRC generator will be inverted and serially transmitted to the PTXD output on the falling edge on PTXCLK as soon as the present data byte transmission is completed. If BIT 1 of the HDLC control register is a 0, a 0 will be inserted into the CRC data stream after five consecutive ones are transmitted. As soon as the last bit of the CRC is sent, a series of Flags will be automatically sent until another TX control bit is set. No TX Ready interrupts will be generated during the transmission of the CRC bytes. A TX Ready interrupt will be generated as the first bit of each Flag byte is transmitted indicating that the CRC transmission has been completed. This should be cleared by a dummy write to the TX DATA register.

BIT 2 will be cleared to a 0 upon a reset.

BIT 1 Send Data

When BIT 1 is set, the data is the TX data register will be serially transmitted through the PTXD pin on every falling edge of PTXCLK, LSB first. If BIT 1 ofthe HDLC control register is a 0, a 0 will be inserted into the data stream after five consecutive 1s are transmitted. After all eight data register bits have been sent, the HDLC will continue to send data by loading the parallel serial transmit register with new transmit register data, unless either a TX underrun is detected or one of the other TX control bits has been set. This bit will be cleared by the HDLC circuitry as soon as a TX underrun is detected. A TXRDY interrupt will be generated at as the first data of each data byte is transmitted. BIT 1 will be cleared to a 0 upon a reset.

BIT 0 Send Flag

When BIT 0 is set, a pattern of 7E will be transmitted to the PTXD output as soon as either the next data byte or CRC has completed transmission. No 0s will be inserted during the flag transmission. When BIT 0 is reset back to a 0, the HDLC circuitry will complete the flag byte in progress and then transmit according to bits in the TX CONTROL register. TX Ready interrupts will be generated as each byte of flag transmission is initiated.

BIT 0 will be cleared to a 0 upon a reset.

HDLC STATUS REGISTER

HDLC Status Register (HSTAT) SFR Address C3
Byte Addressable
Reset state 00h
Read only register

If any of the HDLC status bits are set, BIT 1 of the HDLC INTERRUPT register (NEW STATUS) will be set if the corresponding bit in the HDLC INTERRUPT ENABLE register is set.

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
INVAL CRC32	INVAL CRC16	TX UNDRN	RX OVRN	INVAL FLAG	ABORT DET	IDLE DET	FLAG DET

BIT 7 Invalid CRC32

BIT 7 will be set if the CRC search mode or the 32-bit CRC is enabled by the HDLC control register and an incorrect remainder for the 32-bit CRC is detected at the last received byte prior to receiving a flag.

BIT 7 will by cleared upon a reset and is cleared by a read of the HDLCSTAT register.

BIT 6 Invalid CRC16

BIT 6 will be set if the CRC search mode or the 16-bit CRC is enabled by the HDLC CONTROL register and an incorrect remainder for the 16-bit CRC is detected at the last received byte prior to receiving a flag.

BIT 6 will by cleared upon a reset and is cleared by a read of the HDLC STAT register.

BIT 5 TX Underrun

When BIT 5 is set, a transmit underrun condition has been detected. This is a condition where the HDLC has finished transmitting a message byte, but no new data has been loaded into the TX DATA register, and no other transmit control bit has been set. This bit will be set only if the SEND DATA bit, BIT 1 of the TXCONTROL register is set. The transmit data is double buffered since the TX data register is downloaded into a TX serial register when the HDLC begins to transmit a new data byte. At the time of loading the TX serial register, a TX READY interrupt is generated. This interrupt must be serviced by either loading a new data byte (the next data byte to be transmitted) into the TX data register, or by setting another TX control bit, before the current data byte has completed transmission (at which point another TX READY interrupt would be generated). If a TX UNDERRUN is detected, the HDLC will abort the current transmission by sending continuous ones and will reset the SEND DATA control bit in the TX CONTROL register.

BIT 5 will by cleared upon a reset and is cleared by a read of the HDLCSTAT register.

BIT 4 RX Overrun

When BIT 4 is set, a receive overrun condition has been detected. This is a condition where the HDLC has received a new byte, but the last received data byte has not yet been read from the RX data register. As soon as a new data byte has been received in an eight bit serial register, it is loaded into the RX data register and a NEW RX DATA interrupt is generated. If this interrupt is not serviced by reading the RX data register during the time another new data byte is received, the RX OVERRUN status bit will be set. The new received data will not overwrite the older unread data.

BIT 4 will by cleared upon a reset and is cleared by a read of the HDLCSTAT register.

BIT 3 Invalid Flag

When BIT 3 is set, an invalid flag has been detected. This is a condition where a 7E pattern with no inserted 0s is detected, and this pattern did not originate on a byte boundary. Note, two consecutive flags may share a 0, so that the second (or subsequent) flag may not appear to be on a byte boundary. This condition does not result in an invalid flag indication.

BIT 3 will by cleared upon a reset and is cleared by a read of the HDLC STAT register.

BIT 2 Abort Detect

When BIT 2 is set, an abort condition has been detected. This is a condition where seven consecutive ones, with no inserted zeros, are received after an active state. BIT 2 will be cleared upon a reset and is cleared by a read of the HDLC STAT register.

REGISTER DESCRIPTION (continued)

BIT 1 Idle Detect

When BIT 1 is set, the first indication of an idle state is detected. An idle state is declared when 15 consecutive ones, with no inserted zeros, are received after an active state.

BIT 1 will be cleared upon a reset and is cleared by a read of the HDLC STAT register.

BIT 0 Flag Detect

When BIT 0 is set, the HDLC has received a 7E pattern with no inserted 0's. BIT 0 will by cleared upon a reset and is cleared by a read of the HDLCSTAT register.

HDLC INTERRUPT ENABLE REGISTER

HDLC Interrupt Enable Register (HIE) SFR Address C4
Byte Addressable
Reset state 00h

If the bit is set, the corresponding interrupt source is enabled.

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
TX RDY IE	RX RDY IE	TX RDY EN	RX RDY EN	INVAL FLG IE	ABORT IE	IDLE IE	FLAG IE

BIT 7 Transmitter Ready Interrupt Enable

When BIT 7 is set, an HDLC interrupt will be generated if BIT 0 (TX RDY) of the HDLC INTERRUPT register is also set. If BIT 7 is reset to a 0, no HDLC interrupt indication will be given as TX RDY is set. This interrupt enable allows the TX RDY to be a polled bit. Note that BIT 5 of this register is a pre-mask to the TX RDY bit, that is, it will prevent the TX RDY bit from ever being set.

BIT 7 will be cleared upon a reset.

BIT 6 Receiver Ready Interrupt Enable

When BIT 6 is set, an HDLC interrupt will be generated if BIT 1 (RXRDY) of the HDLC INTERRUPT register is also set. If BIT 6 is reset to a 0, no HDLC interrupt indication will be given as RX RDY is set. This interrupt enable allows the RX RDY to be a polled bit. Note that BIT 4 of this register is a pre-mask to the RX RDY bit, that is, it will prevent the RX RDY bit from ever being set.

BIT 6 will be cleared upon a reset.

BIT 5 Transmit Ready Enable

BIT 5 is used to enable the TX RDY and TX UNDERRUN interrupt sources. When BIT 5 is set, the transmitter ready indication will set BIT 0 of the HDLC interrupt register. The TX RDY indication will go active as the first bit of a message byte is being transmitted, except during CRC transmission. Also, if this bit is set, the TX underrun condition will result in a NEW STATUS interrupt. If IT5 is reset to a 0, BIT 0 of the HDLC INTERRUPT register will not be set, and no corresponding HDLC interrupt will be generated. Also, a Tx underrun condition, as indicated by BIT 5 of the HDLC STATUS register, will not result in an HDLC interrupt or in setting the NEW STATUS interrupt bit.

BIT 5 will be cleared upon a reset.

BIT 4 Receiver Ready Enable

BIT 4 is used to enable the RX RDY and RX OVERRUN interrupt sources. When BIT 4 is set, the receiver ready indication will set BIT 1 of the HDLC INTERRUPT register. The RX RDY indication will go active when a data byte (a byte that is not a flag, idle, or an abort pattern) is loaded into the RX DATA register. Also, if this bit is set, the RX overrun condition will result in a NEW STATUS interrupt. If BIT 4 is reset to a 0, BIT 1 of the HDLC INTERRUPT register will not be set, and no corresponding HDLC interrupt will be generated. Also, a Rx overrun condition, as indicated by BIT 4 of the HDLC STATUS register, will not result in a HDLC interrupt or in setting the NEW STATUS interrupt bit.

BIT 4 will be cleared upon a reset.

BIT 3 Invalid Flag Interrupt Enable

When BIT 3 is set, a HDLC interrupt will be generated if BIT 3 (INVALID FLAG) of the HDLC STATUS register is also set. If BIT 3 is reset to a 0, BIT 2 (NEW STATUS) of the HDLC INTERRUPT register will not be set as a result of an invalid flag boundary detection and no HDLC interrupt will be generated.

BIT 3 will be cleared upon a reset.

BIT 2 Abort Detect Interrupt Enable

When BIT 2 is set, a HDLC interrupt will be generated if BIT 2 (ABORT DETECT) of the HDLC STATUS register is also set. If BIT 2 is reset to a 0, BIT 2 (NEW STATUS) of the HDLC INTERRUPT register will not be set as a result of an abort pattern detection and no HDLC interrupt will be generated.

BIT 2 will be cleared upon a reset.

BIT 1 Idle Detect Interrupt Enable

When BIT 1 is set, an HDLC interrupt will be generated if BIT 1 (IDLE DETECT) of the HDLC STATUS register is also set. If BIT 1 is reset to a 0, BIT 2 (NEW STATUS) of the HDLC INTERRUPT register will not be set as a result of an idle pattern detection and no HDLC interrupt will be generated.

BIT 1 will be cleared upon a reset.

BIT 0 Flag Detect Interrupt Enable

When BIT 0 is set, a HDLC interrupt will be generated if BIT 0 (FLAG DETECT) of the HDLC STATUS register is also set. If BIT 0 is reset to a 0, BIT 2 (NEW STATUS) of the HDLC INTERRUPT register will not be set as a result of a flag pattern detection and no HDLC interrupt will be generated.

BIT 0 will be cleared upon a reset.

HDLC INTERRUPT REGISTER

HDLC Interrupt Register (HINT) SFR Address C5
Byte Addressable
Read Only register
Reset State 00h

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
0	0	0	0	0	NEW STAT	DATA RDY	TX RDY

This register is used to determine the source of HDLC interrupts. If one or more of these register bits are set, the HDLC interrupt will go active if BIT 0 of the HDLC CONTROL register is set to a 1.

REGISTER DESCRIPTION (continued)

BIT 2 New Status

When BIT 2 is set, an unmasked HDLC status bit from the HDLC STATUS register is set.

BIT 2 will by cleared upon a reset and is cleared by a read of the HDLC STATUS register.

BIT 1 Data Ready

When BIT 1 is set, a new received byte has been loaded into the RX DATA register. Note, received bits that are flag, abort, or idle patterns are not considered data, and will not be loaded into the RX DATA register. All inserted 0s have been removed from this byte. The RX DATA register must be read prior to the completed reception of the next data byte.

BIT 1 will by cleared upon a reset and is cleared by a read of the RX DATA register.

BIT 0 TX READY

BIT 0 is set if any TX control bit is set as the first bit of data, flag or an idle byte is being transmitted. While transmitting the current byte, the HDLC state machines are ready for commands pertaining to the next byte to be transmitted. A new data byte must be loaded into the TX DATA register to clear the TX READY status bit.

BIT 0 will by cleared upon a reset and is cleared by writing to the TX DATA register.

RX DATA REGISTER

RX Data Register (RXD) SFR Address C6
Byte Addressable
Reset state XXh
Read Only

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
RX DAT7	RX DAT6	RX DAT5	RX DAT4	RX DAT3	RX DAT2	RX DAT	RX DAT0

BIT 7 - BIT 0 Received Data Byte

BIT 7 through BIT 0 is the received data byte (LSB is received first) with all inserted 0s removed. A DATA READY interrupt will be generated when a new data byte is received. Reading this register will clear the DATA READY interrupt.

TX DATA REGISTER

TX Data Register (TXD) SFR Address C7
Byte Addressable
Reset state XXh
Write Only

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
TX DAT7	TX DAT6	TX DAT5	TX DAT4	TX DAT3	TX DAT2	TX DAT1	TX DAT0

BIT 7 - BIT 0 Transmit Data Byte

BIT 7 through BIT 0 will be transmitted at the next byte boundary (LSB first) if the TX CONTROL SEND DATA bit is set. The HDLC will insert all necessary 0s. A TX READY interrupt will be generated when a new data byte can be loaded into the TX DATA register. Writing this register will clear the TX READY interrupt.

REGISTER	ADDRESS	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
HDLC CONTROL 0	C0	WRXD	WPTXD	TXD	PRXD	RXD CTRL1	RXD CTRL0	PTXD CTRL1	PTX CTRL0
HDLC CONTROL1	C1	RESET	CCITT	CRC PRE	RXCRC32	RXCRC16	TXCRC32	ZERO ID	HDLC EN
TX CONTROL	C2	0	0	0	DIV16 CLK	SEND ABORT	SEND CRC	SEND DATA	SEND FLAG
HDLC STATUS	C3	INVAL CRC32	INVAL CRC16	TX UNDERRUN	RX UNDERRUN	INVAL FLAG	ABORT DETECT	IDLE DETECT	FLAG DETECT
HDLC INT ENABLE	C4	TX RDY IE	RX RDY IE	TX RDY EN	RX RDY EN	INVAL FLAG IE	ABORT IE	IDLE IE	FLAG IE
HDLC INT SOURCE	C5	0	0	0	0	0	NEW STATUS	RX READY	TX READY
RX DATA	C6	RXDAT7	RXDAT6	RXDAT5	RXDAT4	RXDAT3	RXDAT2	RXDAT1	RXDAT0
TX DATA	C7	TXDAT7	TXDAT6	TXDAT5	TXDAT4	TXDAT3	TXDAT2	TXDAT1	TXDAT0

FIGURE 9: HDLC SFR Registers

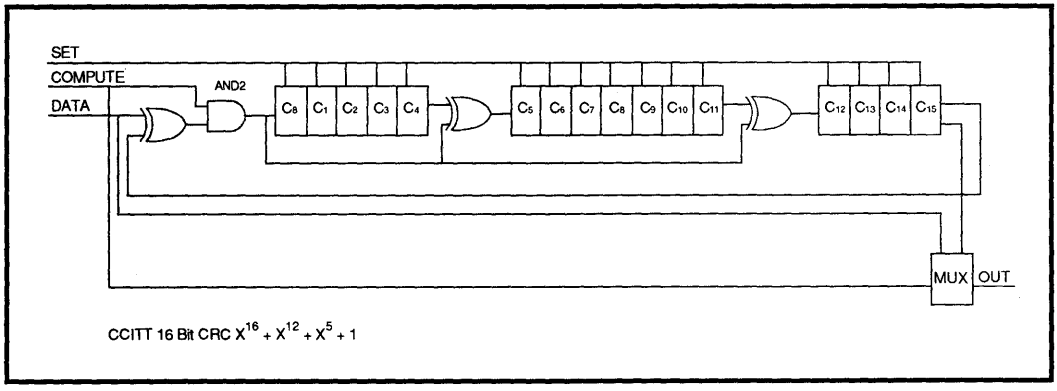


FIGURE 10: CCITT Type

The CRC check field is generated by the transmitter. The computation starts with the first transmitted bit after the opening flag and stops at the last data bit prior to the frame check sequence bytes, and excludes inserted 0s. The CRC generating logic is initialized to all ones. The bits are shifted in and operated on by the generating polynomial, $X^{16} + X^{12} + X^5 + 1$. During CRC transmission, the bytes in the CRC generating logic are inverted and transmitted, high order bit first.

The receiver also initializes its CRC computation logic to all ones after the beginning flag. Its polynomial generator (also $X^{16} + X^{12} + X^5 + 1$) should see the same value as the transmitter's polynomial generator as the last data bit is received. Note the receiver's polynomial generator does not process inserted 0s. After the bytes are received in the frame check sequence, a remainder of 1111 0000 1011 1000 (X^0 through X^{15}, respectively) should be detected in the receiver's polynomial generator. If this is not the case, it is assumed that the preceding frame was in error and an invalid CRC is declared.

REGISTER DESCRIPTION (continued)

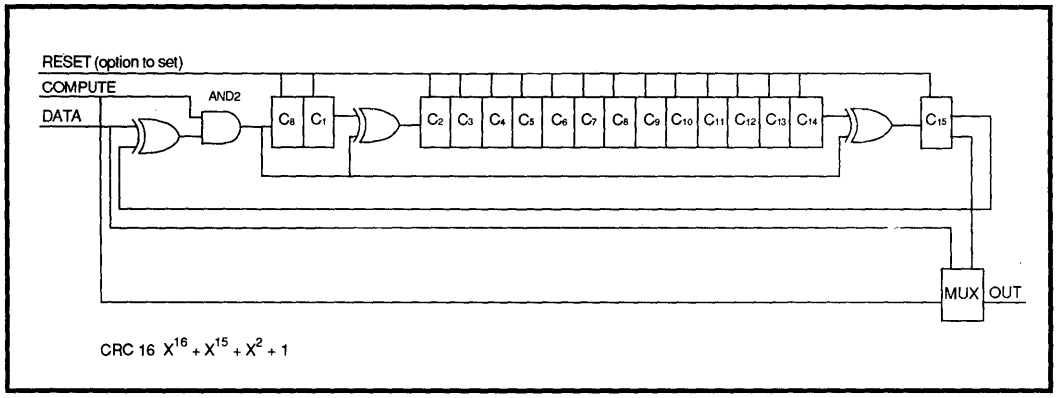


FIGURE 11: CRC 16

The CRC check field is generated by the transmitter. The computation starts with the first transmitted bit after the opening flag and stops at the last data bit prior to the frame check sequence bytes, and excludes inserted 0s. The CRC generating logic is initialized to all 0s. The bits are shifted in and operated on by the generating polynomial, $X^{16} + X^{12} + X^5 + 1$. During CRC transmission, the bytes in the CRC generating logic are transmitted, high order bit first.

The receiver also initializes its CRC computation logic to all ones after the beginning flag. Its polynomial generator (also $X^{16} + X^{12} + X^5 + 1$) should see the same value as the transmitter's polynomial generator as the last data bit is received. Note the receiver's polynomial generator does not process inserted 0s. After the bytes are received in the frame check sequence, a remainder of 1111 0000 1011 1000 should be detected in the receiver's polynomial generator. If this is not the case, it is assumed that the preceding frame was in error and an invalid CRC is declared.

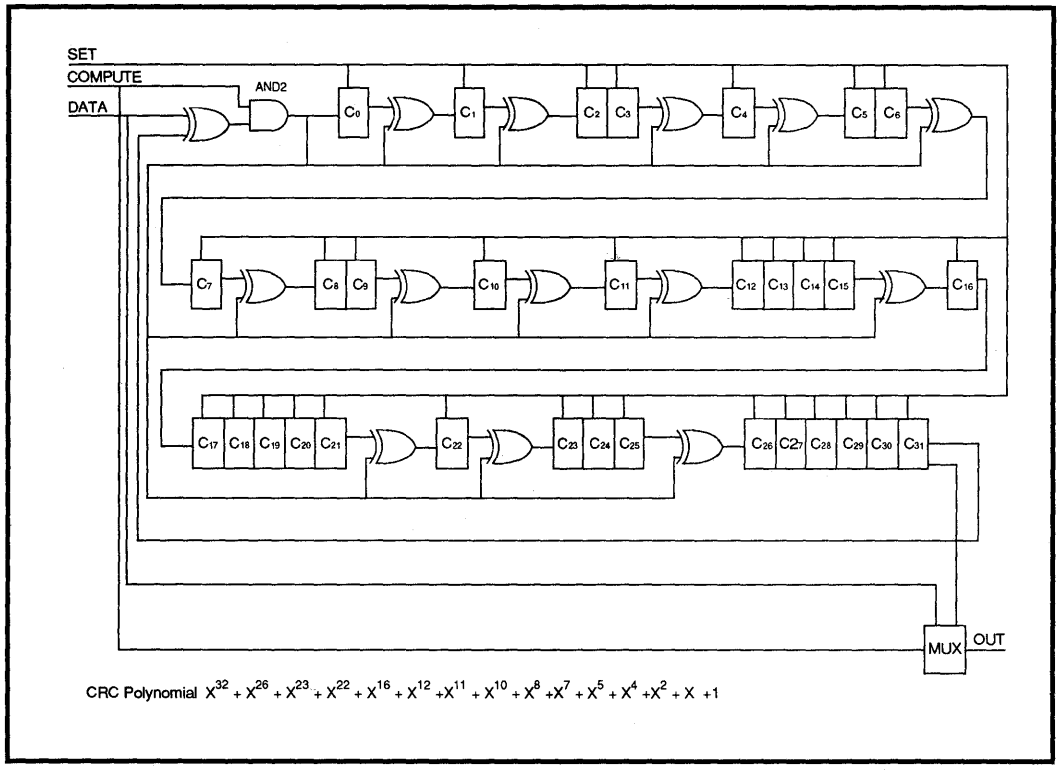


FIGURE 12: 32 Bit CRC

The CRC check field is generated by the transmitter. The computation starts with the first transmitted bit after the opening flag and stops at the last data bit prior to the frame check sequence bytes, and excludes inserted 0s. The CRC generating logic is initialized to all ones. The bits are shifted in and operated on by the generating polynomial, $X^{32} + X^{26} + X^{23} + X^{22} + X^{16} + X^{12} + X^{11} + X^{10} + X^8 + X^7 + X^5 + X^4 + X^2 + X + 1$. During CRC transmission, the bytes in the CRC generating logic are inverted and transmitted, high order bit first. The receiver also initializes its CRC computation logic to all ones after the beginning flag. Its polynomial generator should see the same value as the transmitter's polynomial generator as the last data bit is received. Note the receiver's polynomial generator does not process inserted 0s. After the bytes are received in the frame check sequence, a remainder of 1101 1110 1011 1011 0010 0000 1110 0011 (X^0) through X^{32}, respectively) should be detected in the receiver's polynomial generator. If this is not the case, it is assumed that the preceding frame was in error and an invalid CRC is declared.

PIN DESCRIPTION

NAME	TYPE	DESCRIPTION
$\overline{PSEN}$	O	Program store enable. This output occurs only during a fetch to external program memory.
RESET	I	Input which is used to initialize the processor.
VND	GND	Negative digital voltage ground
OSCIN	I	Crystal input for internal oscillator, also input for external source.
OSCOUT	O	Crystal oscillator output.
VPD	I	Positive digital voltage (+5V Digital Supply)
CLKOUT1	O	Clock output programmable either OSC/2, OSC/1 or logic 0.
CLKOUT2	O	Clock output 1.8432 MHz clock for an external UART given an oscillator frequency of 11.0592 MHz, 22.1184 MHz, 18.432 MHz, or 13.824 MHz.
TXD	I	Serial input port to 73M2910 from DTE same as RXD UART input.
RXD	O	Serial output port of 73M2910 UART to DTE.
PTXCLK	I	Input clock used to transmit data PTXD.
PTXD	O	HDLC Packetizer TX output. This pin can also be programmed to the DTE's TXD output (clear channel) or the value written into bit 6 of the HDLC control register. Connects to modem device TXD.
PRXCLK	I	Input clock used to receive data PRXD.
PRXD	I	Serial input port (from modem device).
$\overline{INT(0)}$-$\overline{INT(2)}$	I	External interrupt 0,1 and 2.
USR1(0) -USR1(7)	I/O	User programmable I/O port.
USR2(0) -USR2(7)	I/O	User programmable I/O port.
USR3(0) -USR3(7)	I/O	User programmable I/O port. If the bank select feature is chosen, USR (7) acts as address bit 17 and USR3 data bit 7 is ignored. Register BNKSEL bit 2 (BSEN) enables bank select, bit 1 (BS1) and bit 0 (BS0) select the appropriate bank.
USR4(0) -USR4(7)	I/O	User programmable I/O port also Chip select enable.
USR5(0) - USR5(1)	I/O	General purpose input port, can also be used for wakeup.
$\overline{RD}$	O	Output strobe activated during a bus read. Can be used to enable data onto the bus from an external device. Used as a read strobe to external data memory.
$\overline{WR}$	O	Output strobe during a bus write. Used as a write strobe to external data memory.
ALE	O	Address Latch Enable output pulse for latching the low byte of the address during accesses to external memory.
AD(0)-AD(7)	I/O	Data bus lines-I/O for devices that require multiplexed address and data bus.
A(0)-A(15)	O	Address bus lines-output latched address for devices that require separate data and address bus.
NO CONNECTS		No connections, leave open.

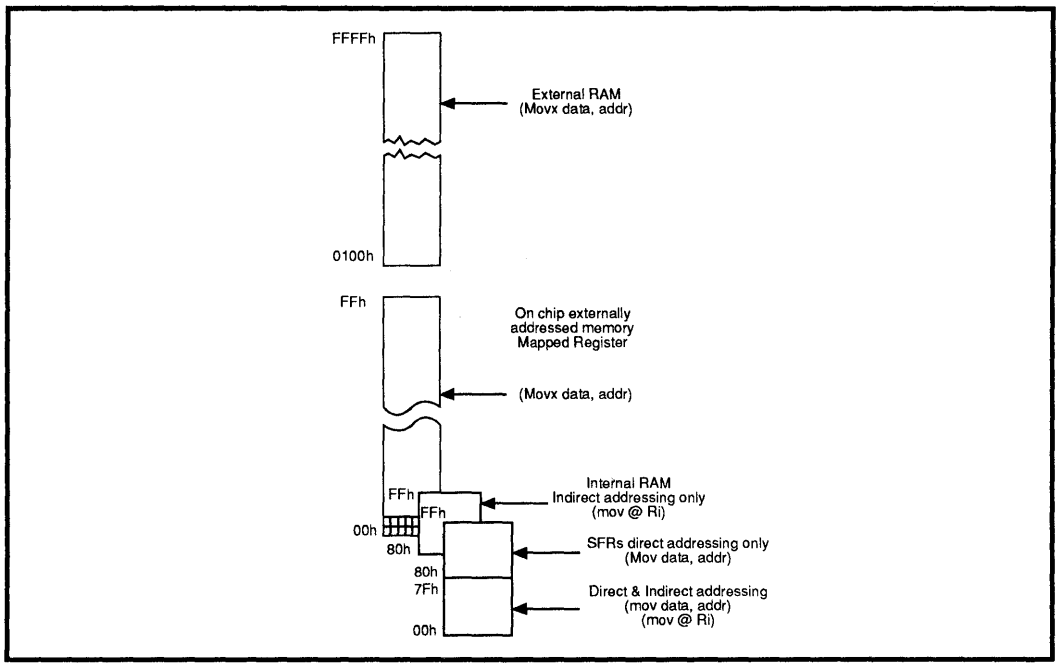


FIGURE 1: Memory Map

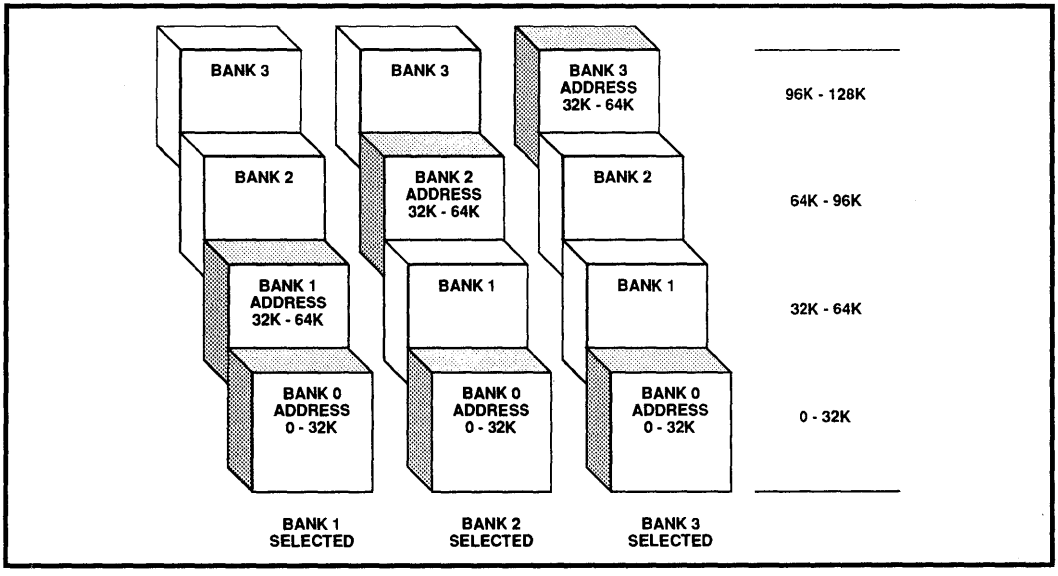


FIGURE 2: 128K of Bank-Selected Program Memory

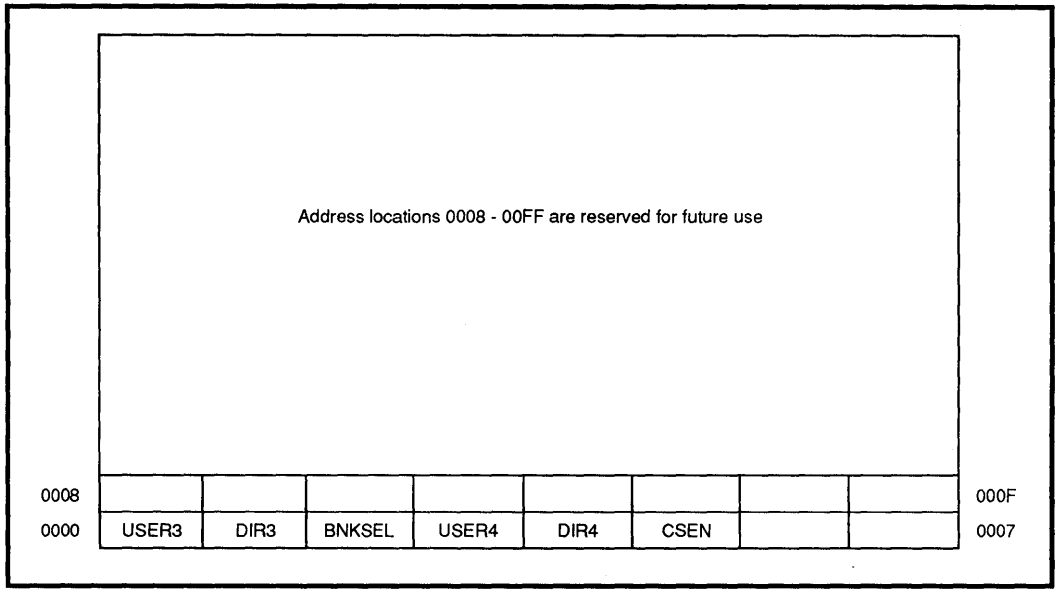


FIGURE 3: Memory Mapped Registers

F8									FF
F0	B								F7
E8									EF
E0	ACC								E7
D8	*USER2	*DIR2	CLK CTRL						DF
D0	PSW								D7
C8	T2CON		RCAP2L	RCAP2H	TL2	TH2			CF
C0	*HDLC0	*HDLC1	*TXC	*HSTAT	*HIE	*HINT	*HRXD	*HTXD	C7
B8	IP								BF
B0									B7
A8	IE								AF
A0	P2								A7
98	SCON	SBUF							9F
90	*USER1	*DIR1	*IDIR						97
88	TCON	TMOD	TL0	TL1	TH0	TH1			8F
80	P0	SP	DPL	DPH				PCON	87

* Unique to the SSI 73M2910. There may not be an equivalent function on an 8052.

BIT ADDRESSABLE

FIGURE 4: 73M2910 SFR Map

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Recommended conditions apply unless otherwise specified.

PARAMETER	RATING
Supply Voltage	-0.5 to +7.0V
Pin Input Voltage	-0.5 to Vcc +0.5V
Storage Temperature	-55 to +150°C

RECOMMENDED OPERATING CONDITIONS

Supply Voltage	4.5 to 5.5V
Oscillator Frequency	DC to 33 MHz
Supply Voltage	4.75 to 5.5V
Oscillator Frequency	DC to 44 MHz
Supply Voltage	3.0 to 5.5V
Oscillator Frequency	DC to 22 MHz
Operating Temperature	-40 to +85°C

DC CHARACTERISTICS

PARAMETER		CONDITION	MIN	NOM	MAX	UNIT
Input Low Voltage (Except OSCIN, RESET, TEST)	VIL		-0.5		0.2 Vcc - 0.1	V
Input Low Voltage OSCIN, RESET, TEST	VIL		-0.5		0.2 Vcc	V
Input High Voltage (Except OSCIN, RESET, TEST)	VIH		0.5 Vcc		Vcc + 0.5	V
Input High Voltage OSCIN, RESET, TEST	VIH		0.7 Vcc		Vcc + 0.5	V
Output Low Voltage (Except OSCOUT)	VOL	Iol = 3.2 mA			0.45	V
Output Low Voltage OSCOUT	VOLOSC	Iol = 1.5 mA			0.7	V
Output High Voltage (Except OSCOUT)	VOH	Ioh = -3.2 mA	Vcc - 0.45			V
Output High Voltage OSCOUT	VOHOSC	Ioh = 1.5 mA	Vcc - 0.7			V
Input Leakage Current	IIL	Vss < Vin < Vcc			±10	µA
Maximum Power Supply Normal Operation	IDD1	22MHz 30 pF/pin			40	mA
Maximum Power Supply Idle Mode	IDD2	22 MHz			10	mA

ELECTRICAL SPECIFICATIONS (continued)

DC CHARACTERISTICS

PARAMETER		CONDITION	MIN	NOM	MAX	UNIT
Maximum Power Supply Power Down Mode	IDD3				10	µA
Pin Capacitance	CIO	@1 MHz			10	pF

AC TIMING

Oscillator Frequency	FOSC		0		22.2	MHz
Oscillator Period	TOSC		45			ns
ALE Pulse Width	TLHLL		2TOSC - 10			ns
Address Valid To ALE low	TAVLL		TOSC			ns
Address Valid ALE low	TLLAX		TOSC - 10			ns
ALE low to $\overline{PSEN}$ low	TLLPL		TOSC - 10			ns
$\overline{PSEN}$ Pulse width low	TPLPH		3TOSC - 20			ns
$\overline{PSEN}$ Low to Valid Inst In	TPLIV				3TOSC - 50	ns
Address to Valid Inst In	TAVIV				5TOSC - 50	ns
Input Instr Hold-$\overline{PSEN}$ Hi	TPXIX		0			ns
PSEN Instr Float-$\overline{PSEN}$ Hi	TPXIZ				20+	ns
$\overline{PSEN}$ Low to Address HIZ	TPLAZ				10	ns
$\overline{RD}$ Pulse Width	TRLRH		6TOSC - 20			ns
$\overline{WR}$ Pulse Width	TWLWH		6TOSC - 20			ns
$\overline{RD}$ Low to Vlaid Data In	TRLDV				5TOSC - 50	ns
Data Hold After $\overline{RD}$	TRHDX		0			ns
Data Float After $\overline{RD}$	TRHDZ				20+	ns
ALE Low to Valid Data In	TLLDV				8TOSC - 50	ns
ALE low to $\overline{RD}$ or $\overline{WR}$ low	TLLWL		3TOSC - 20		3TOSC + 20	ns
Data Valid to $\overline{WR}$ low	TQVWX		TOSC			ns
Data Hold After $\overline{WR}$ Hi	TWHQX		TOSC - 10			ns
$\overline{RD}$ low to Address Float	TRLAZ				10	ns

AC TIMING (continued)

The SSI 73M2910 timing is very similar to the 8051 except in AD(7:0), the multiplexed address data port known as port 0 in the 8051. Its timing has been altered somewhat to allow more address setup time for peripheral program ROM and memory mapped peripherals. This is important at 22 MHz operation. The 8052 has a "dead" cycle of one oscillator period between the time PSEN goes high, indicating that the instruction ROM will release the AD(7:0) bus, to the time the processor will assert address on the AD(7:0) bus. This dead time of one whole oscillator cycle has been shortened to approximately 15 ns after the PSEN (or RD) signal is sensed to be high.

The timing specification for TPXIZ and TRHDZ of a maximum of 20 ns can be violated at the expense of increased operating current. The SSI 73M2910 will begin asserting the AD(7:0) bus approximately 20 ns after PSEN or RD go high. This should be ample time for the control signals in the peripheral device to turn off their pad drivers. If the peripheral device does not release the bus promptly, there will be a short time where there is contention on the AD(7:0) bus between the processor and peripheral. This should not prevent proper operation, but it will increase operating current slightly.

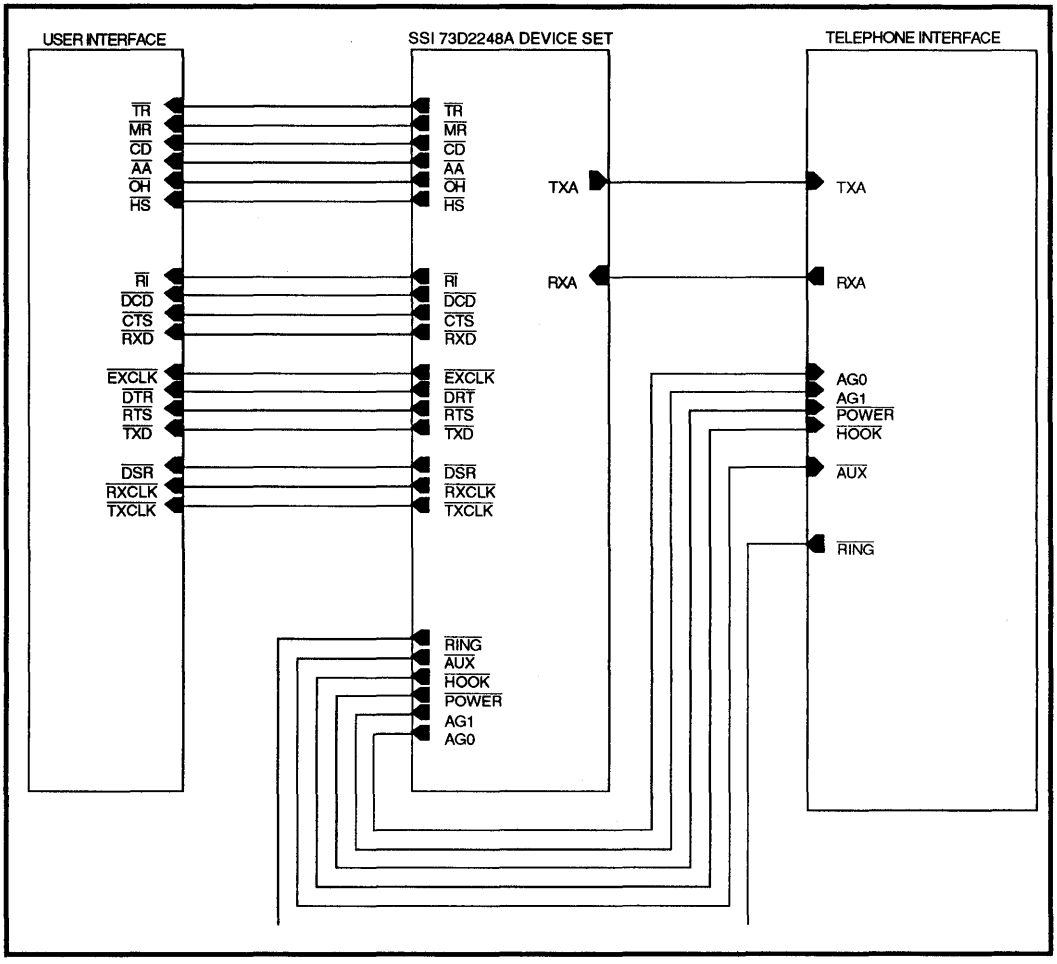


FIGURE 13: Modem Block Diagram

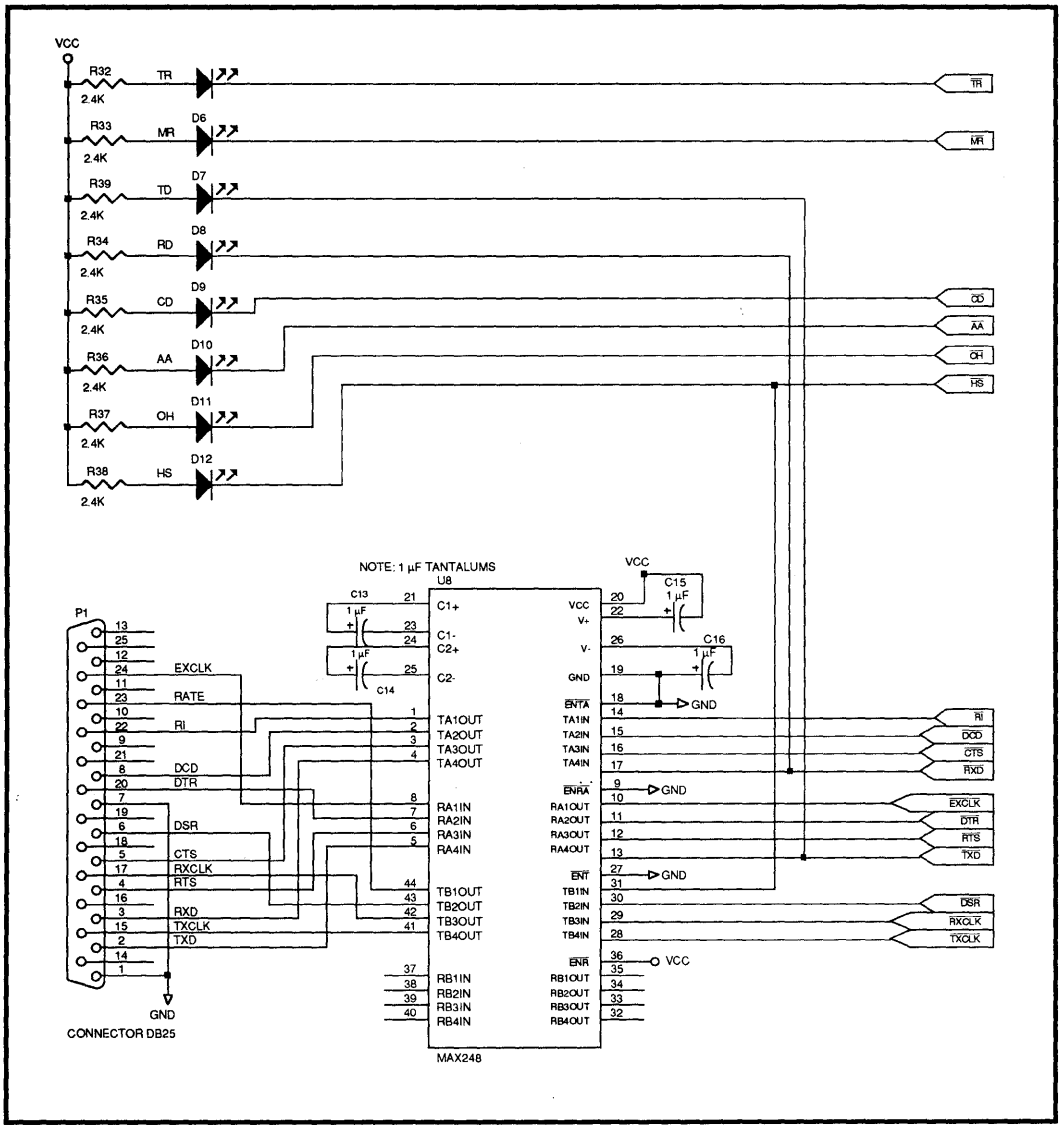
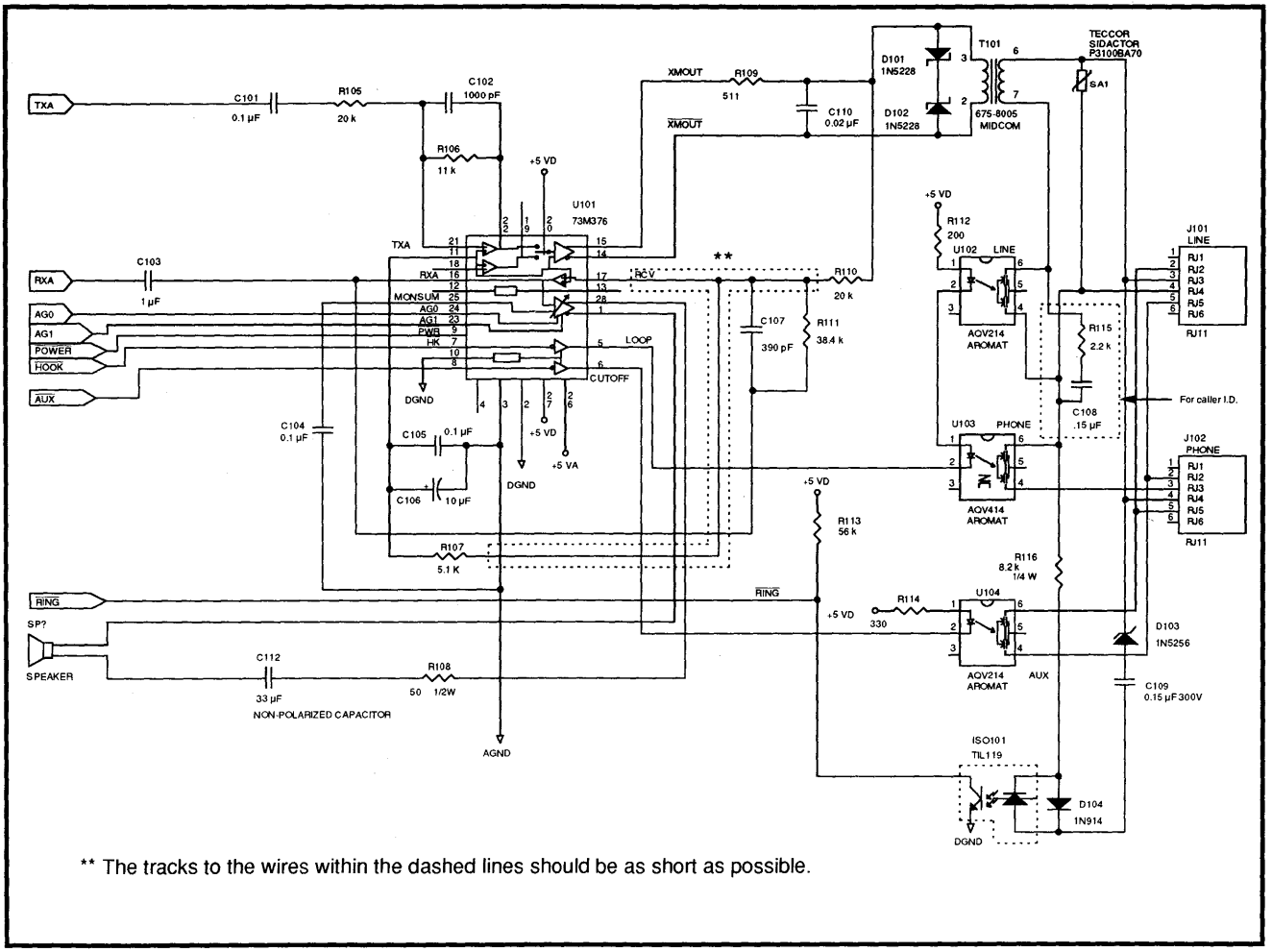


FIGURE 14: Display and User Interface



** The tracks to the wires within the dashed lines should be as short as possible.

FIGURE 15: Telephone Interface

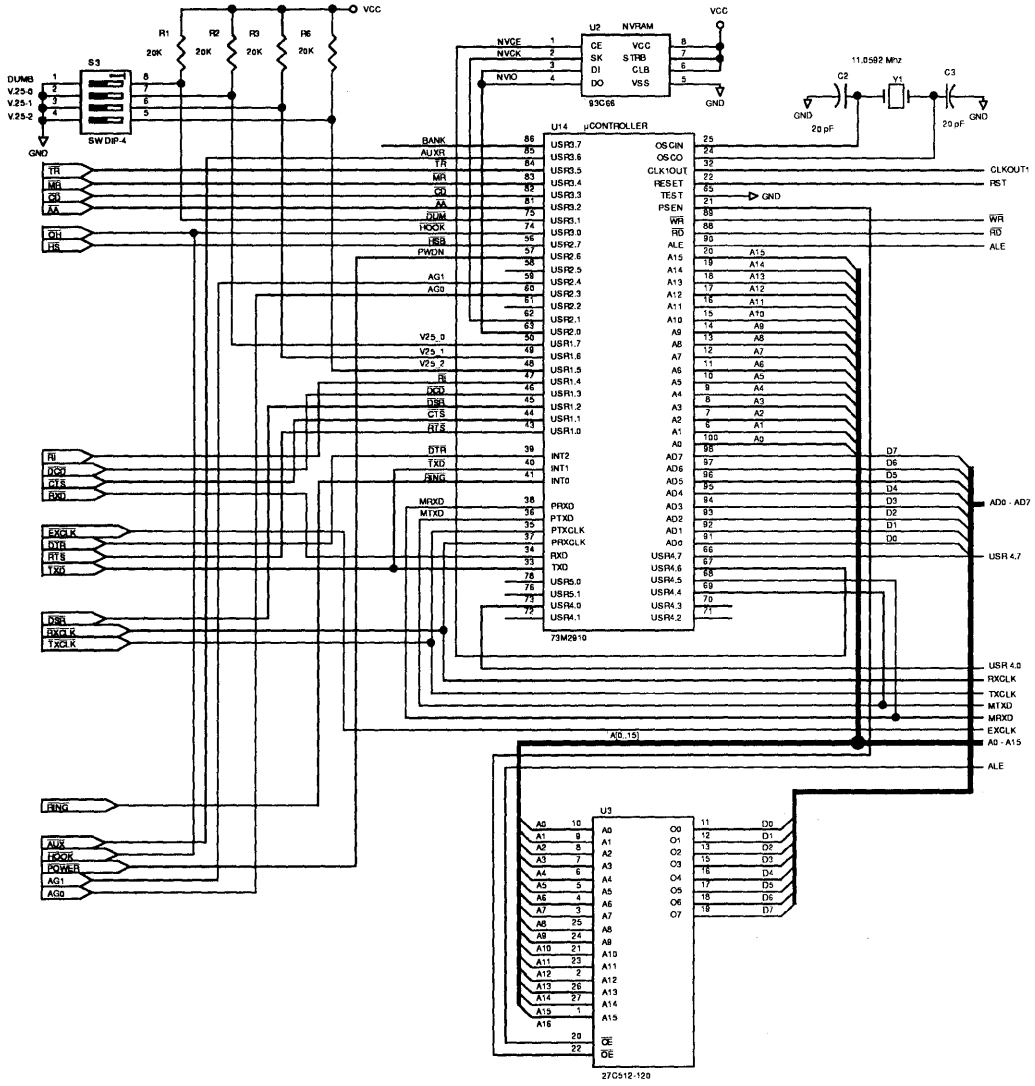


FIGURE 16A: SSI 73D2248A Modem System Interconnect - Front End

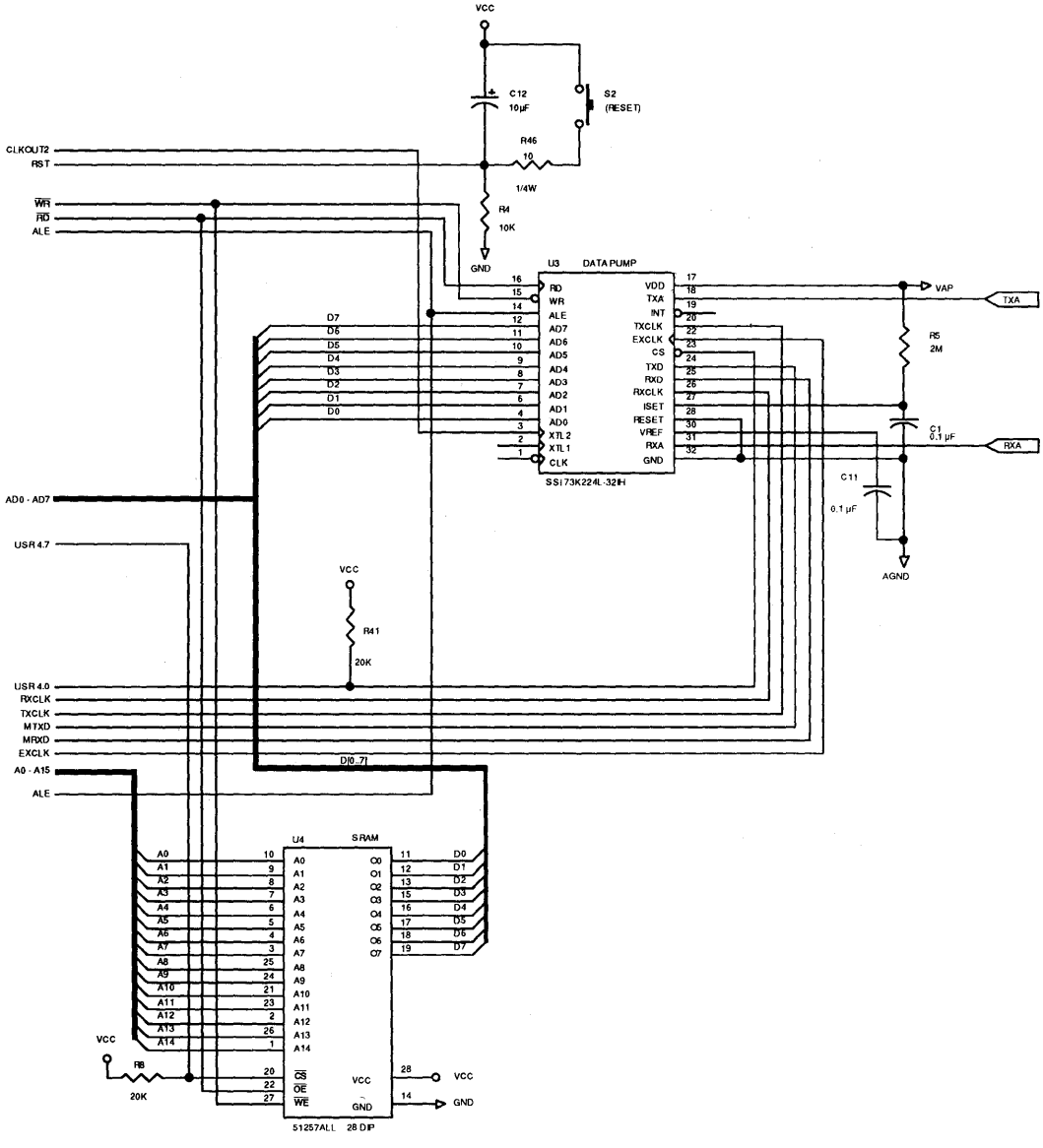


FIGURE 16B: SSI 73D2248A Modem System Interconnect - Back End

100-Pin PGA (For developement purposes only; not a production package.)

BOND PRD	PIN #	SIGNAL NAME
1	B2	NO CONNECT
2	B1	NO CONNECT
3	C1	USR26
4	C2	USR27
5	D2	USR25
6	D1	USR24
7	E2	USR23
8	E1	USR22
9	F3	USR21
10	F2	USR20
11	F1	VPD
12	G2	GND
13	G2	USR47
14	G1	USR46
15	H1	USR45
16	H2	USR44
17	H3	USR43
18	J1	USR42
19	J2	USR41
20	K1	USR40
21	K2	USR30
22	L1	USR31
23	M1	USR51
24	L2	NO CONNECT
25	N1	NO CONNECT
26	M2	NO CONNECT
27	N2	NO CONNECT
28	M3	USR50
29	N3	USR32
30	M4	USR33
31	N4	USR34
32	M5	USR35
33	N5	USR36
34	L6	USR37
35	M6	GND
36	N6	$\overline{RD}$

BOND PRD	PIN #	SIGNAL NAME
37	M7	$\overline{WR}$
38	L7	ALE
39	N7	D0
40	N8	D1
41	M8	D2
42	L8	D3
43	N9	D4
44	M9	D5
45	N10	D6
46	M10	D7
47	N11	VPD
48	N12	A0
49	M11	NO CONNECT
50	N13	NO CONNECT
51	M12	NO CONNECT
52	M13	NO CONNECT
53	L12	NO CONNECT
54	L13	A1
55	K12	A2
56	K13	A3
57	J12	A4
58	J13	A5
59	H11	A6
60	H12	A7
61	H13	A8
62	G12	A9
63	G11	A10
64	G13	A11
65	F13	A12
66	F12	A13
67	F11	A14
68	E13	A15
69	E12	$\overline{PSEN}$
70	D13	RESET
71	D12	GND
72	C13	OSCOUT

100-Pin PGA (continued)

BOND PRD	PIN #	SIGNAL NAME
73	B13	OSCIN
74	C12	NO CONNECT
75	A13	NO CONNECT
76	B12	NO CONNECT
77	A12	CLK2OUT
78	B11	VPD
79	A11	CLK1OUT
80	B10	TXD
81	A10	RXD
82	B9	PTXCLK
83	A9	PTXD
84	C8	PRXCLK
85	B8	PRXD
86	A8	$\overline{INT2}$

BOND PRD	PIN #	SIGNAL NAME
87	B7	$\overline{INT1}$
88	C7	$\overline{INT0}$
89	A7	GND
90	A6	USR10
91	B6	USR11
92	C6	USR12
93	A5	USR13
94	B5	USR14
95	A4	USR15
96	B4	USR16
97	A3	USR17
98	A2	NO CONNECT
99	B3	NO CONNECT
100	A1	NO CONNECT

100-Pin PGA (For developement purposes only; not a production package.)

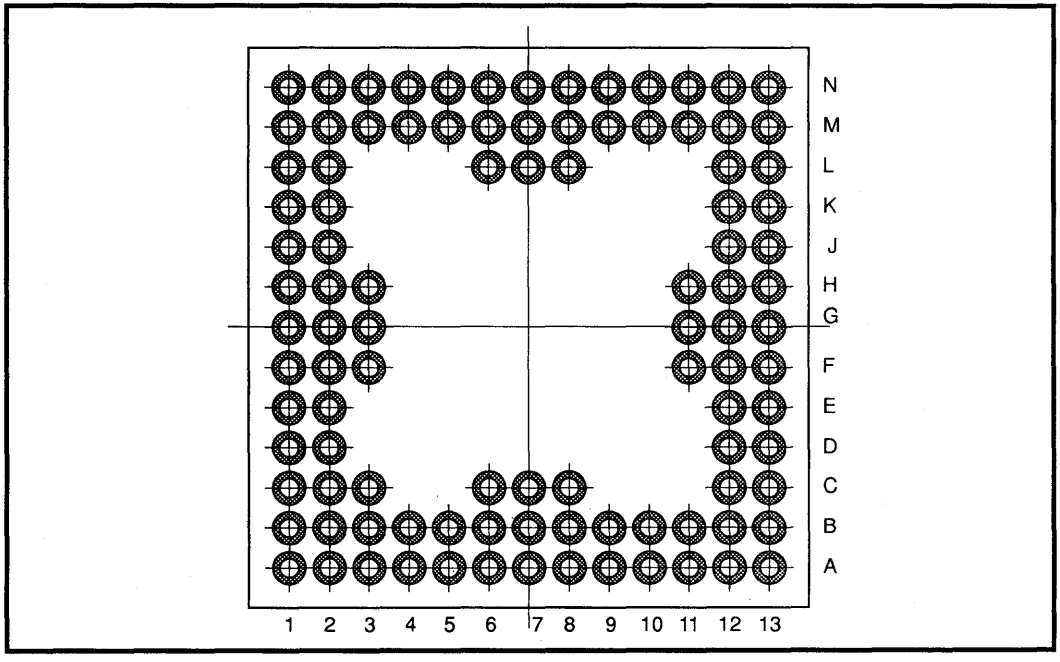
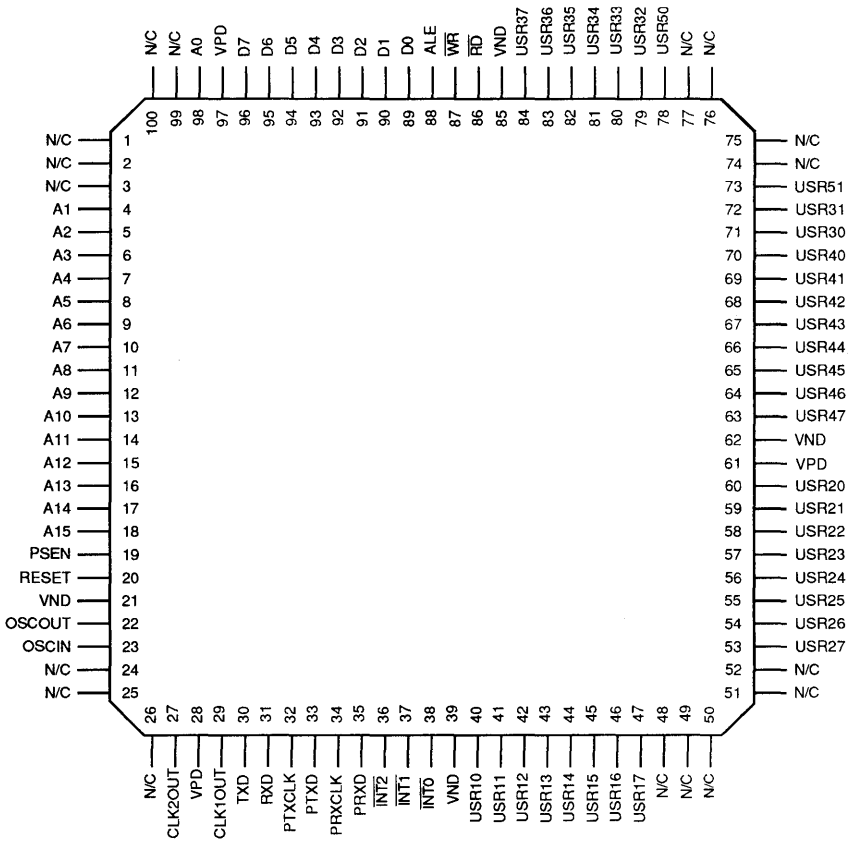


FIGURE 17: 100-Pin Plug-In Package

PACKAGE PIN DESIGNATIONS

(Top View)

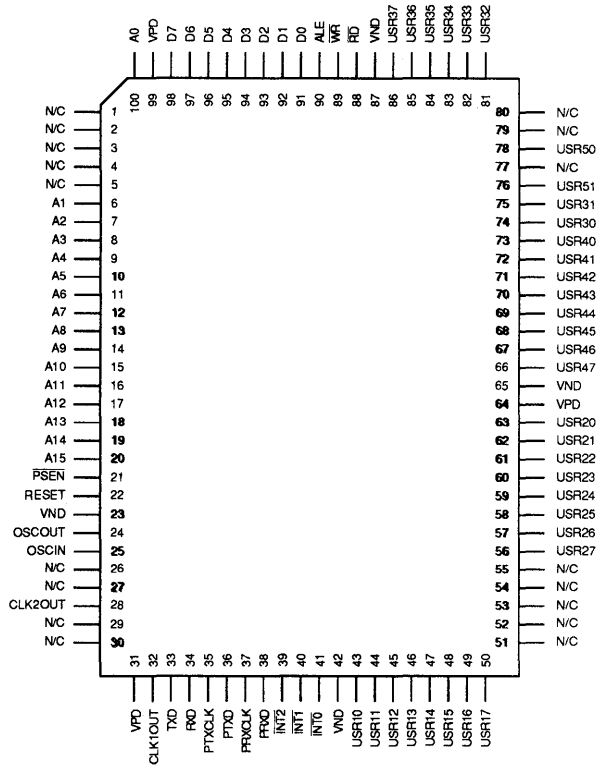


100-Lead TQFP

CAUTION: Use handling procedures necessary for a static sensitive component.

SSI 73M2910/2910A
Microcontroller

PACKAGE PIN DESIGNATIONS
(Top View)



100-Lead QFP

CAUTION: Use handling procedures necessary for a static sensitive component.

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Abridged Version

SSI 73M2918/2918A

Plug and Play Microcontroller and UART

Advance Information

January 1995

DESCRIPTION

The SSI 73M2918 is a combination of the SSI 73M2910 modem microcontroller, a virtual 550 UART, and built-in hardware to support the Plug and Play ISA standard, implemented in Silicon Systems' advanced CMOS process. The 8-bit processor has the same attributes as the 8052 including instruction cycle time, UART, timers, interrupts, 256 bytes of on-chip RAM and programmable I/O. The virtual 550 UART utilizes proprietary technology, which results in a complete emulation of the industry standard 550 UART, and adds significant features. The 550 UART emulator provides familiar 550 functions to the PC and replaces the serial link between the PC and the dedicated processor with a parallel data interface. The architecture results in a high-performance system solution that is optimized for low power applications.

The 73M2918 also includes the user friendly HDLC packetizer that is available in the 73M2910. It has a serial I/O, hardware support for 16- and 32-bit CRC, zero insert/delete control, a dedicated interrupt and a clear channel mode for by-passing the packetizer.

(continued)

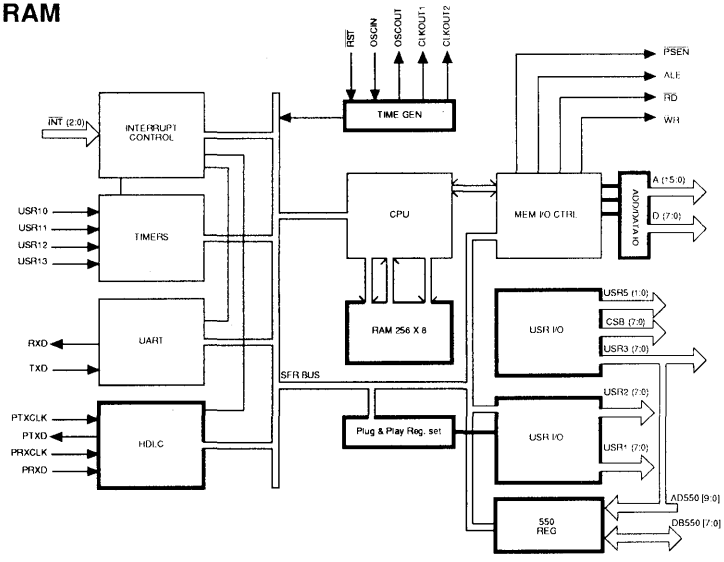
FEATURES

- **8052-compatible instruction set**
- **Virtual 550 UART**
- **Dedicated Plug and Play ISA bus hardware**
- **33 MHz 73M2918, 44 MHz 73M2918A operation**
- **Operates at 3.3V and 5V**
- **HDLC Support logic (Packetizer, 16 and 32 CRC, zero ID)**
- **24 pins for user programmable I/O ports**
- **8 pins programmable chip select logic for memory mapped peripheral eliminating glue logic**
- **3 external interrupt sources (programmable polarity)**
- **16 dedicated latched address pins**
- **Multiplexed data/address bus**
- **Instruction cycle time identical to 8052**
- **Buffered oscillator (or OSC/2, OSC/1.5) output pin**

(continued)

4

BLOCK DIAGRAM



SSI 73M2918/2918A
Plug and Play
Microcontroller and UART

DESCRIPTION (continued)

Other features include additional user programmable I/O with programmable bank select and chip select logic, designed to eliminate board level glue logic. It also includes two general purpose input pins with programmable wakeup capability.

For devices that require non-multiplexed address and data buses, eight latched outputs for the low byte of the address are available.

The 73M2918 has two extra interrupt sources, an external interrupt and an HDLC interrupt. The HDLC interrupt has two registers associated with it: the HDLC interrupt register which is used to determine the source of the interrupt, and the HDLC interrupt enable register that enables the source of the interrupt.

The state of the external interrupts can be read through a register allowing the interrupt pins to be used as inputs. The interrupt pins INT0 and INT1 can be either negative edge, positive edge or level triggered. INT2 pin is always edge triggered.

Two buffered clock outputs have been added to support peripheral functions such as UARTs, modems and other clocked devices. The main internal processor clock frequency can be divided by 2 for power conservation in functional modes that only require half the clock speed.

Additional internal special function registers are used for firmware control over the HDLC Packetizer, the clocks and the programmable I/O ports.

The processor's timing has been altered slightly to allow more address setup time for slower peripheral program ROM and memory mapped peripherals. This can offer the system designers an advantage when using higher oscillator frequencies.

For low power applications the 73M2918 operates from 3 to 5 volts at 22 MHz and supports two power conservation modes: Idle and power-down. In the power-down state the total current consumption is less than 1 µA at room temperature.

This device is offered in a small form factor 100-lead TQFP package and a 100-lead QFP package.

DEVELOPER'S NOTE

The SSI 73M2918/2918A is also available in a 100-pin PGA package for system developers. The PGA package is more convenient and reliable for development emulation systems than the other package styles. Emulation systems for the SSI 73M2918/2918A are available through Signum Systems,171 E. Thousand Oaks Blvd., # 202, Thousand Oaks, CA 91360, (805) 371-4608.

8052 REFERENCE

This document will describe the features unique to the SSI 73M2918/2918A. Please refer to an 8052 Programmer's Guide, Architectural Overview and Hardware Description for details on the SSI 73M2918/2918A core processor instruction set, timers, UART, interrupt control, and memory structure.

FEATURES (continued)

- 1.8432 MHz UART clock available if crystal frequencies 11.0592 MHz, 22.1184 MHz, 18.432 MHz, or 13.824 MHz are used
- Bank select circuitry to support up to 128K of external program memory
- Available in a 100-Lead QFP package

For a complete SSI 73M2918/2918A data sheet contact your local Silicon Systems sales office. See listing of sales offices in Section 11.

Advance Information: Indicates a product still in the design cycle, and any specifications are based on design goals only. Do not use for final design.

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SSI 73M223
1200 Baud FSK Modem

December 1993

DESCRIPTION

The SSI 73M223 modem device receives and transmits serial and binary data over existing telephone networks using Frequency Shift Keying (FSK). It provides the filtering, modulation, and demodulation to implement a serial, asynchronous data communication channel. The SSI 73M223 employs the CCITT V.23 signaling frequencies of 1302 and 2097 Hz, operating at 1200 baud, and is intended for half duplex operation over a two-line system.

The SSI 73M223 provides a cost-effective alternative to existing modem solutions. It is ideally suited for R.F. data links, credit verification systems, point-of-sale terminals, and remote process control.

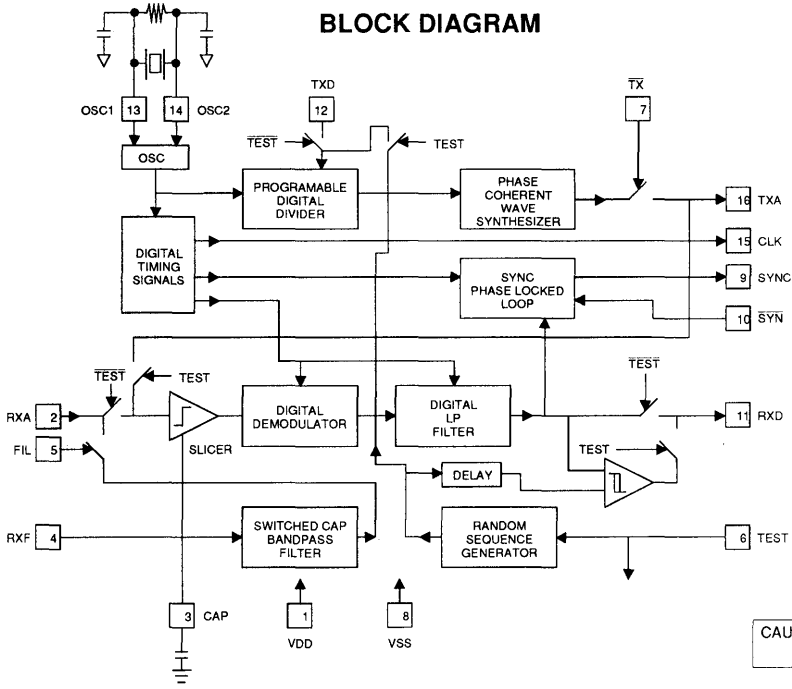
CMOS technology ensures small size, low-power consumption and enhanced reliability.

FEATURES

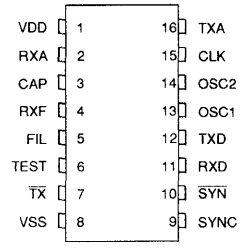
- **Low cost FSK Modem**
- **1200 baud operation**
- **CMOS switched capacitor technology**
- **Built-in self-test feature**
- **On-chip filtering, and Modulation/Demodulation**
- **Uses CCITT V.23 frequencies**
- **On chip crystal oscillator**
- **Low power/High reliability**
- **16-pin plastic packages**

4

BLOCK DIAGRAM



PIN DIAGRAM



CAUTION: Use handling procedures necessary for a static sensitive component.

FUNCTIONAL DESCRIPTION

The SSI 73M223 has four main functional sections: timing, transmit, receive, and test. Each section of the chip will be individually described below.

TIMING

The timing section contains the oscillator (OSC) and random logic which generates digital timing signals used throughout the chip. The time base can be derived from 3.18 MHz crystal or an external digital input. The digital timing logic divides the oscillator frequency to give a 1200 Hz output than can be used for system timing. The signaling frequencies are 1302 Hz for logic "1" and 2097 Hz for logic "0." The modem will operate with clock inputs from 330 kHz to 3.3 MHz. However, the signaling frequencies and the system timing will be directly proportional to the difference in clock frequency.

TRANSMITTER

The SSI 73M223 transmitter consists of a programmable divider that drives a coherent phase frequency synthesizer. The programmable divider is digitally controlled via the Data Input pin (TXD). The output of the divider clocks a 16 segment phase coherent frequency synthesizer. A sine wave is constructed by eight weighted capacitors which are the inputs to a high pass filter. The synthesized signal is output directly to the transmit pin TXA. The transmit signal can be disabled by using the digital control pin $\overline{TX}$.

RECEIVER

The SSI 73M223's receiver is comprised of three sections: the input bandpass filter, the synchronization loop, and the demodulator.

The input bandpass filter is a four pole Butterworth filter, implemented using switched capacitor technology. This filter reduces wideband noise which significantly improves data error rates. The SSI 73M223 can be configured with the bandpass filter in series with the receiver by setting FIL = 1 and inserting the received signal at RXF. The bandpass filter can be deleted from the system by setting FIL = 0 and inputting the received signal through RXA.

The demodulator is used to detect a received mark or space.

The synchronization for sampling the digital output at RXD is derived from a digital phase locked loop. The phase locked loop is clocked at 16 times the bit rate with a maximum lock period of 8 clocks to lock on the data output signal. The output is nominally 1200 Hz, but is resynchronized to the center of the data bit on each data transition.

SELF TEST MODE

The SSI 73M223 features an autotest mode which provides easy field test capability of the chip's functionality. The modem is placed in the test mode by taking the test pin high. In the test mode the Data Input pin is disconnected and the programmable divider is driven by a pseudo random PN sequence generator and the transmitter's output is connected to the receiver's input. The input data to the programmable divider is delayed by the system delay time and compared to the digital output on sync transitions. If the detected data matches the delayed input data from the PN sequence counter, the SSI 73M223 is properly functioning as indicated by RXD low. A high on the RXD pin indicates a functional problem on the SSI 73M223.

PIN DESCRIPTION

PIN NO.	PIN NAME	DESCRIPTION
1	VDD	Positive Supply Voltage. Bypasses to Vss with 0.1 µF capacitor.
2	RXA	Receive Analog Input. Analog input from the telephone network.
3	CAP	Capacitor. Connect a 0.1µF capacitor between Pin 3 and ground (VSS).
4	RXF	Filtered Receive Analog Input
5	FIL	Analog Input Control. A logical 1 selects the filtered input. A logical 0 selects the non-filtered input.
6	TEST	Self-Test Mode Control. Normal operation when a logical 0.A logical 1 places the device into the self-test mode. A low appears at RXD, to indicate a properly functioning device.
7	$\overline{TX}$	Transmitter Control. A logical 0 selects transmit mode. A logical 1 selects a stand-by condition forcing TXA to VDD/2 VDC.
8	VSS	Ground
9	SYNC	Synchronous Clock Output. Digital output synchronized with the 1200 bit/s received data and used to sample the received eye pattern.
10	$\overline{SYN}$	Sync Disable. A logical 1 input disables the phase locked signal from the received data and locks it to the 1200 Hz reference. Logic 0 enables Rec PLL.
11	RXD	Receiver Digital Output
12	TXD	Transmitter Digital Input
13	OSC_1	Crystal Input (3.1872 MHz) or External Clock Input
14	OSC_2	Crystal Return
15	CLK	1200 Hz Squarewave Output. Can drive up to 10 CMOS loads.
16	TXA	Transmitter Analog Output

ELECTRICAL SPECIFICATIONS

Recommended conditions apply unless otherwise specified.

ABSOLUTE MAXIMUM RATINGS

Operation outside these rating limits may cause permanent damage to this device.

PARAMETER	RATING
Power Supply Voltage (VDD-VSS)	14 V
Analog Input Voltage at RXA	- 0.3 to VDD V
Analog Input Voltage at RXF	- 3 to VDD V
Digital Input Voltage	VSS - 0.3 to VDD + 0.3 V
Storage Temperature Range	- 65 to + 150 °C
Operating Temperature Range	- 25 to + 70 °C
Lead Temperature (10 secs soldering)	260 °C

ELECTRICAL CHARACTERSITICS
Unless otherwise specified, 4.5 <VDD <13 VDC, VSS = 0 VDC, -25° C <TA

POWER SUPPLY

PARAMETER	TEST CONDITIONS	MIN	NOM	MAX	UNIT
VDD Voltage Supply Range		4.5		13	V
Supply Current	VDD = 5V 25° C		2.0		mA
	VDD = 12V 25° C		5.0		mA
Digital Inputs					
Input Low Voltage VIL		VSS - 0.3		VSS + 1.5	V
Input High Voltage VIH		VDD - 1.5		VDD + 0.3	V
Input Low Current IIL		-1			µA
Input High Current IIH				1	µA
Digital Outputs					
Output Low Voltage VOL	IOL < 1µA			0.05	V
Output High Voltage VOH	IOL < -1µA VDD = 5V	4.95			V
Output Low Current IOL	VOL = 0.4V VDD = 5V	0.5			mA
Output High Current IOH	VOH = 4.5V VDD = 5V	-0.2			mA
Analog Input Level @ RXA	Centered at VDD/2 + 0.5V	0.2		VDD/4	Vpp
Analog Input Level @ RXF	*DC Level between VDD & VSS	0.2		VDD/2	VDC
Error Rate	S/N = 8dB Input @ RXF			5×10^{-3}	
Analog Output Level @ TXA	RL ≥ 10K $\overline{TX}$ = 0		VDD/4		Vpp
	$\overline{TX}$ = 1		VDD/2		VDC
Output Frequency @ TXA	XTAL = 3.1872MHz TXD=1		1302		Hz
	TXD=0		2097		Hz
Output Harmonics	2nd to 14th Harmonics		-60	-50	dB
	15th Harmonic			-20	dB
Input Filter (RFX)	*Input = 200 m Vpp to VDD/2 Vpp				
Lower 3dB Corner			760		Hz
Upper 3dB Corner			2625		Hz

* Note: The SSI 73M223 RXF input is AC coupled internally but the DC value of the input must be between the two supplies VDD & VSS.

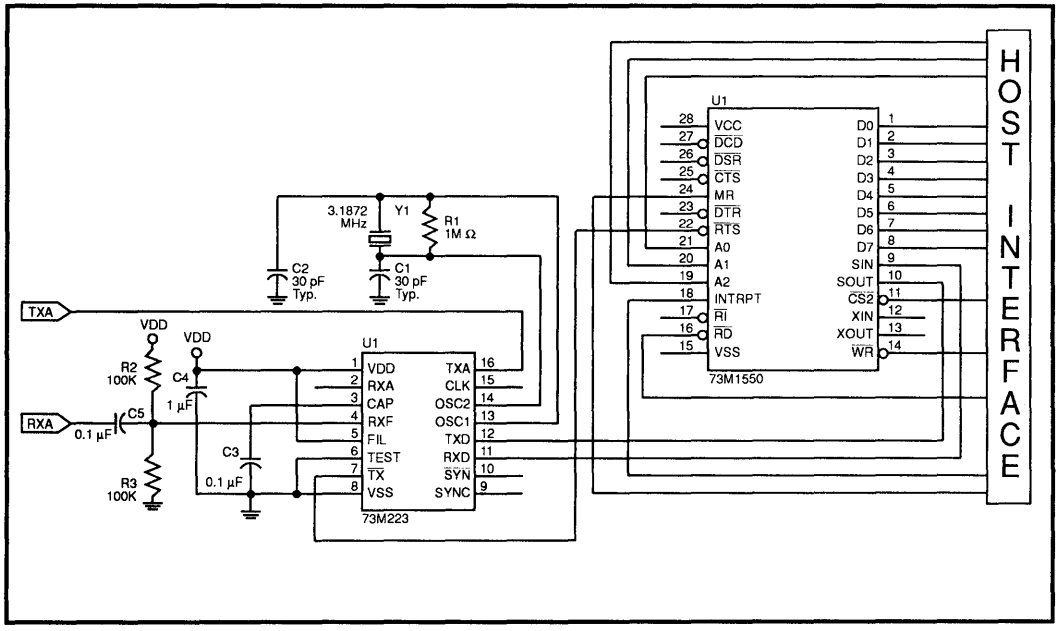
APPLICATION INFORMATION

The SSI 73M223 modem chip allows low cost communications in a private network, utilizing twisted pair telephone wires. This chip is the prime choice of those designers who require an efficient, high performance modem solution for dedicated private networks, HDX dial-up and other specialized applications. Such applications include credit verification systems, point-of-sale terminals, remote process control, private data links and acoustic modem designs. No microprocessors or external adjustments are necessary with this device.

Utilizing a crystal input of 3.1872 MHz, the SSI 73M223 is a 1200 Baud, FSK modem. The signaling frequencies generated are 1302Hz for a logic "1" and 2097Hz for a logic "0." Crystals with frequencies varying between 330 kHz to 3.3 MHz or higher can be used. The baud rate and signaling frequencies vary linearly with variation in crystal frequency.

A typical implementation on the SSI 73M223 is shown in the figure below. An SSI 73M1550 UART receives data to be transmitted from a microprocessor bus. The UART sends the data in a serial format to the SSI 73M223 modem after inserting the necessary start and stop bits. The modem transmits this data to the far end via the TXA pin. Full-duplex operation can be implemented by utilizing separate transmit and receive circuits. A USART can be used instead of a UART if synchronous operation is desired. With synchronous operation, a USART uses the modem's SYNC signal for timing to sample the received data, and the modem's CLK signal to send data clock to be transmitted.

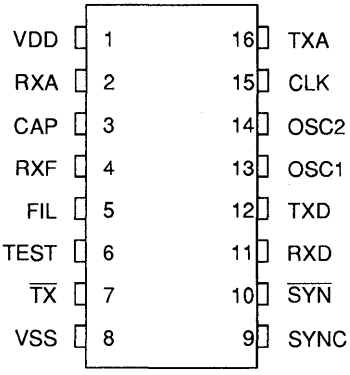
4



SSI 73M223 TYPICAL APPLICATION

SSI 73M223
1200 Baud FSK Modem

PACKAGE PIN DESIGNATIONS
(Top View)



16-Pin DIP and
16-Lead SOL

CAUTION: Use handling procedures necessary for a static sensitive component.

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 73M223 16-Pin Plastic DIP	73M223 - CP	SSI 73M223 - CP
SSI 73M223 16-Lead SOL	73M223 - CL	SSI 73M223 - CL

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Section 5

ANALOG SIGNALLING & SWITCHING

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A TDK Group Company

SSI 75T201
Integrated DTMF Receiver

October 1991

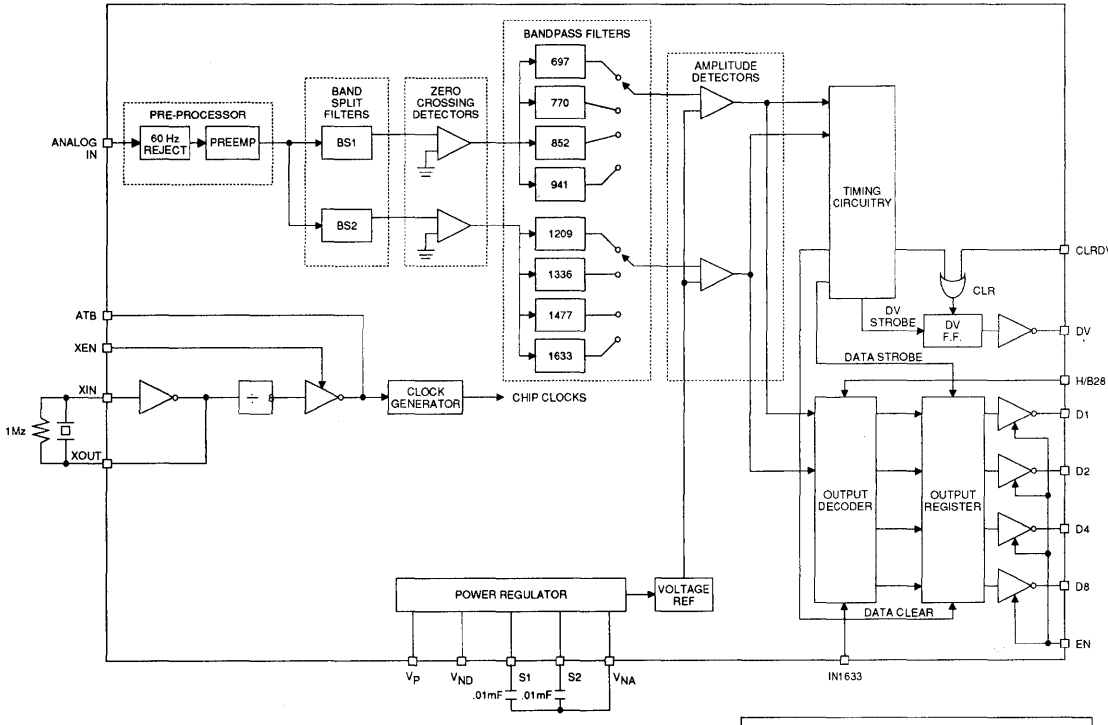
DESCRIPTION

The SSI 75T201 is a complete Dual-Tone Multifrequency (DTMF) receiver detecting a selectable group of 12 or 16 standard digits. No front-end prefiltering is needed. The only external components required are an inexpensive 3.58 MHz television "colorburst" crystal (for frequency reference) and two low-tolerance bypass capacitors. Extremely high system density is made possible by using the clock output of a crystal connected SSI 75T201 receiver to drive the time bases of additional receivers. The SSI 75T201 is a monolithic integrated circuit fabricated with low-power, complementary symmetry MOS (CMOS) processing. It requires only a single low tolerance voltage supply and is packaged in a standard 22-pin DIP. (Continued)

FEATURES

- **Central office quality**
- **NO front-end band-splitting filters required**
- **Single, low-tolerance, 12-volt supply**
- **Detects either 12 or 16 standard DTMF digits**
- **Uses inexpensive 3.579545 MHz crystal for reference**
- **Excellent speech immunity**
- **Output in either 4-bit hexadecimal code or binary coded 2-of-8**
- **22-pin DIP package for high system density**
- **Synchronous or handshake interface**
- **Three-state outputs**

BLOCK DIAGRAM



CAUTION: Use handling procedures necessary for a static sensitive component.

SSI 75T201
Integrated
DTMF Receiver

DESCRIPTION (Continued)

The SSI 75T201 employs state-of-the-art circuit technology to combine digital and analog functions on the same CMOS chip using a standard digital semiconductor process. The analog input is preprocessed by 60 Hz reject and band splitting filters and then hard-limited to provide AGC. Eight bandpass filters detect the individual tones. The digital post-processor times the tone durations and provides the correctly coded digital outputs. Outputs interface directly to standard CMOS circuitry, and are three-state enabled to facilitate bus-oriented architectures.

ANALOG IN

This pin accepts the analog input. It is internally biased so that the input signal may be AC coupled. The input may be DC coupled as long as it does not exceed the positive supply. Proper input coupling is illustrated in Figure 1.

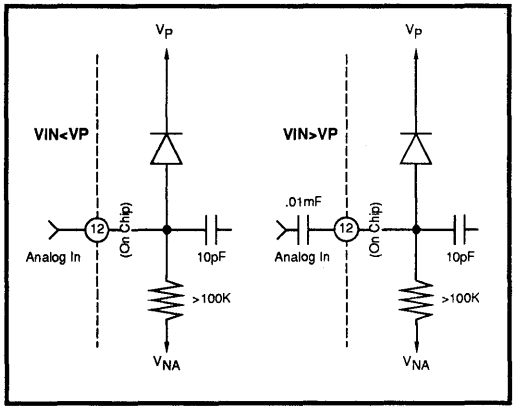


FIGURE 1: Input Coupling

CRYSTAL OSCILLATOR

The SSI 75T201 contains an onboard inverter with sufficient gain to provide oscillation when connected to a low-cost television "colorburst" crystal. The crystal oscillator is enabled by tying XEN high. The crystal is connected between XIN and XOUT. A 1 MΩ 10% resistor is also connected between these pins. In this mode, ATB is a clock frequency output. Other SSI 75T201's may use the same frequency reference by tying their ATB pins to the ATB of a crystal connected device. XIN and XEN of the auxiliary devices must then be tied high and low respectively. Twenty-five devices may run off a single crystal-connected SSI 75T201 as shown in Figure 2.

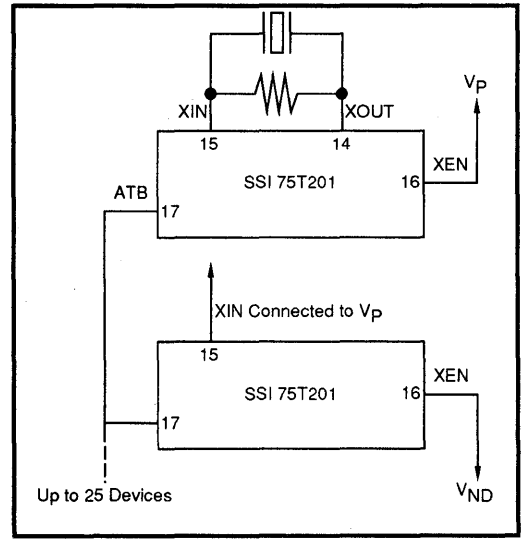


FIGURE 2: Crystal Connections

H/B28

This pin selects the format of the digital output code. When H/B28 is tied high, the output is hexadecimal. When tied low, the output is binary coded 2-of-8. The table below describes the two output codes.

Hexadecimal					Binary Coded 2-of-8				
Digit	D8	D4	D2	D1	Digit	D8	D4	D2	D1
1	0	0	0	1	1	0	0	0	0
2	0	0	1	0	2	0	0	0	1
3	0	0	1	1	3	0	0	1	0
4	0	1	0	0	4	0	1	0	0
5	0	1	0	1	5	0	1	0	1
6	0	1	1	0	6	0	1	1	0
7	0	1	1	1	7	1	0	0	0
8	1	0	0	0	8	1	0	0	1
9	1	0	0	1	9	1	0	1	0
0	1	0	1	0	0	1	1	0	1
*	1	0	1	1	*	1	1	0	0
#	1	1	0	0	#	1	1	1	0
A	1	1	0	1	A	0	0	1	1
B	1	1	1	0	B	0	1	1	1
C	1	1	1	1	C	1	0	1	1
D	0	0	0	0	D	1	1	1	1

TABLE 1: Output Codes

IN1633

When tied high, this pin inhibits detection of tone pairs containing the 1633 Hz component. For detection of all 16 standard digits, IN1633 must be tied low.

OUTPUTS D1, D2, D4, D8 and EN

Outputs D1, D2, D4, and D8 are CMOS push-pull when enabled (EN high) and open circuited (high impedance) when disabled by pulling EN low. These digital outputs provide the code corresponding to the detected digit in the format programmed by the H/B28 pin. The digital outputs become valid after a tone pair has been detected and they are then cleared when a valid pause is timed.

DV and CLRDV

DV signals a detection by going high after a valid tone pair is sensed and decoded at the output pins D1, D2, D4, and D8. DV remains high until a valid pause occurs or the CLRDV is raised high, whichever comes first.

INTERNAL BYPASS PINS, S1, S2

In order for the SSI 75T201 DTMF Receiver to function properly, these pins must be bypassed to V_{NA} with 0.01 µF ±20% capacitors.

SSI 75T201
Integrated
DTMF Receiver

POWER SUPPLY PINS, V_P, V_{NA}, V_{ND}

The analog (V_{NA}) and digital (V_{ND}) supplies are brought out separately to enhance analog noise immunity on the chip. V_{NA} and V_{ND} should be connected externally as shown in Figure 3.

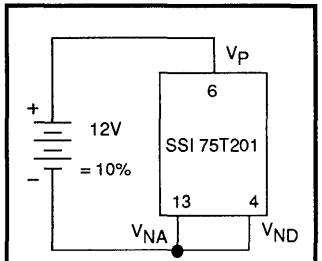


FIGURE 3: 12V System

N/C PINS

These pins have no internal connection and may be left floating.

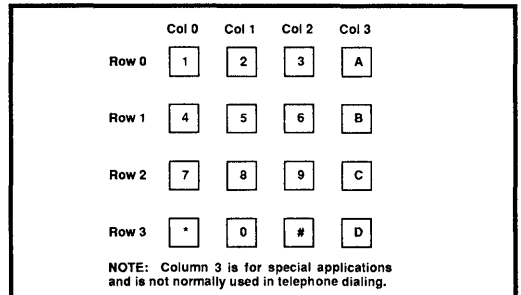


FIGURE 4: DTMF Dialing Matrix

DETECTION FREQUENCY

Low Group f_0	High Group f_0
Row 0 = 697 Hz	Column 0 = 1209 Hz
Row 1 = 770 Hz	Column 1 = 1336 Hz
Row 2 = 852 Hz	Column 2 = 1477 Hz
Row 3 = 941 Hz	Column 3 = 1633 Hz

ELECTRICAL CHARACTERISTICS

ABSOLUTE MAXIMUM RATINGS

Operation above absolute maximum ratings may damage the device. All SSI 75T201 unused inputs must be connected to V_P or V_{ND}, as appropriate.

PARAMETER	RATING
DC Supply Voltage - V_P Referenced to V_{NA}, V_{ND}	+16V
Operating Temperature	-40 to +85°C Ambient
Storage Temperature	-65 to +150°C
Power Dissipation (25°C)	1W
Input Voltage (All inputs except ANALOG IN)	(V_P+ 0.5V) to (V_{ND} -0.5V)
ANALOG IN Voltage	(V_P + 0.5V) to (V_P - 22V)
DC Current into any Input	±1.0 mA
Lead Temperature - Soldering, 10 sec.	300°C

ELECTRICAL CHARACTERISTICS
(-40°C ≤ Ta ≤ +85°C, V_P - V_{ND} = V_P - V_{NA} = 12V ± 10%)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Frequency Detect Bandwidth		± (1.5+2 Hz)	±2.3	±3.0	% of f_O
Amplitude for Detection	each tone	-24		+6	dBm ref. to 600Ω
Twist Tolerance	$\text{Twist} = \frac{\text{High Tone}}{\text{Low Tone}}$	-8		+4	dB
60 Hz Tolerance				2	Vrms
Dial Tone Tolerance	"precise" dial tone			0	dB*
Talk Off	MITEL tape #CM 7290		2		hits
Digital Outputs	"0" level, 750 µA load	V_{ND}		V_{ND}+0.5	V
(except XOUT)	"1" level, 750 µA load	V_P-0.5		V_P	V
Digital Inputs	"0" level	V_{ND}		**	V
(except H/B28, XEN)	"1" level	***		V_P	V
Digital Inputs	"0" level	V_{ND}		V_{ND}+1	V
H/B28, XEN	"1" level	V_P-1		V_P	V
Power Supply Noise	wide band			25	mVp-p
Supply Current	Ta = 25°C V_P - V_{NA} = V_P - V_{ND} = 12V±10%		29	50	mA
Noise Tolerance	MITEL tape #CM 7290			-12	dB*
Input Impedance	$V_P \geq V_{IN} \geq V_P$ - 22	100 kΩ||5 pF			

* dB referenced to lowest amplitude tone
** V_{ND} + 0.3(V_P - V_{ND})
*** V_P - 0.3(V_P - V_{ND})

TIMING CHARACTERISTICS
(-40°C ≤ Ta ≤ +85°C, V_P - V_{ND} = V_P - V_{NA} = 12V ± 10%)

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
t_v	Tone Detection Time		20	25	40	ms
t_{slh}	Data Overlap of DV Rising Edge	CLRDV = V_{ND}, EN = V_P	7			µs
t_p	Pause Detection Time		25	32	40	ms
t_{dv}	Time between end of Tone and Fall of DV		40	45	50	ms

5

TIMING CHARACTERISTICS (Continued)

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
t_{shl}	Data overlap of DV Falling Edge		4	4.56	4.8	ms
t_{phl}	Prop. Delay: Rise of CLRDV to fall of DV	Cl = 300 pF Measured at 50% points			1	µs
	Output Enable Time	Cl = 300 pF, Rl = 10K Measured from 50% point of Rising Edge of EN to the 50% point of the data output with Rl to opposite rail.			1	µs
	Output Disable Time	Cl = 300 pF, Rl = 1K, ΔV = 1V Measured from 50% point of Falling Edge of EN to time at which output has changed 1V with Rl to opposite rail.			1	µs
	Output 10-90% Transition Time	Cl = 300 pF			1	µs

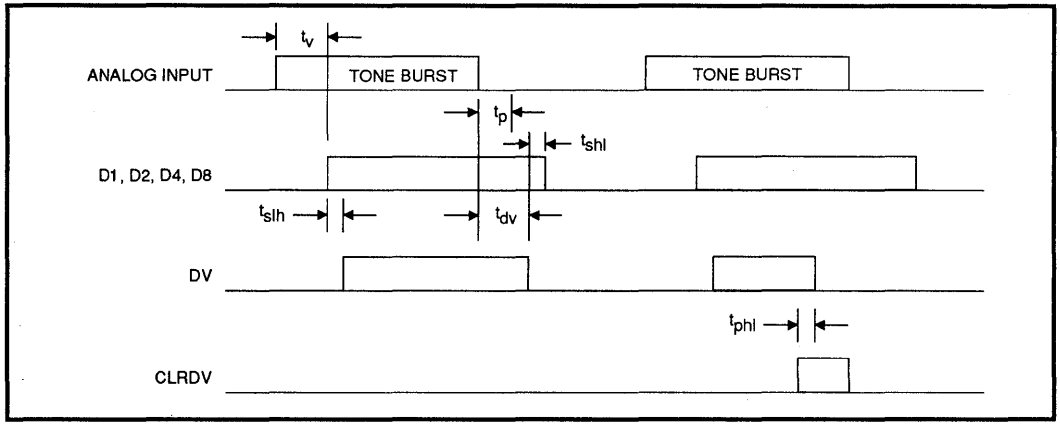


FIGURE 5: Timing Diagram

APPLICATION INFORMATION

TELEPHONE LINE INTERFACE

In applications that use the SSI 75T201 to decode DTMF signals from a phone line, a DAA (Direct Access Arrangement) must be implemented. Equipment intended for connection to the public telephone network must comply with and be registered in accordance with FCC Part 68. For PBX applications refer to EIA Standard RS-464.

Some of the basic guidelines are:

1) Maximum voltage and current ratings of the SSI 75T201 must not be exceeded; this calls for protection from ringing voltage, if applicable, which ranges from 80 to 120 volts RMS over a 20 to 80Hz frequency range.

2) The interface equipment must not breakdown with high-voltage transient tests (including a 2500 volt peak surge) as defined in the applicable document.

3) Phone line termination must be less than 200Ω DC and approximately 600Ω AC (200-3200 Hz).

4) Termination must be capable of sustaining phone line loop current (off-hook condition) which is typically 18 to 120 mA DC.

5) The phone line termination must be electrically balanced with respect to ground.

6) Public phone line termination equipment must be registered in accordance to FCC Part 68 or connected through registered protection circuitry. Registration typically takes about six months.

Figure 6 shows a simplified phone line interface using a 600Ω 1:1 line transformer. Transformers specially designed for phone line coupling are available from many transformer manufacturers.

Figure 7 shows a more featured version of Figure 6. These added options include:

1) A 150-volt surge protector to eliminate high voltage spikes.

2) A Texas Instruments TCM1520A ring detector, optically isolated from the supervisory circuitry.

3) Back-to-back Zener diodes to protect the DTMF (and optional multiplexer Op-Amp) from ringer voltage.

4) Audio multiplexer which allows voice or other audio to be placed on the line (a recorded message, for example) and not interfere with incoming DTMF tone detection.

An integrated voice circuit may also be implemented for line coupling, such as the Texas Instruments TCM1705A, however, this approach is typically more expensive than using a transformer as shown above.

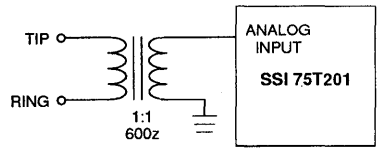


FIGURE 6: Simplified Interface

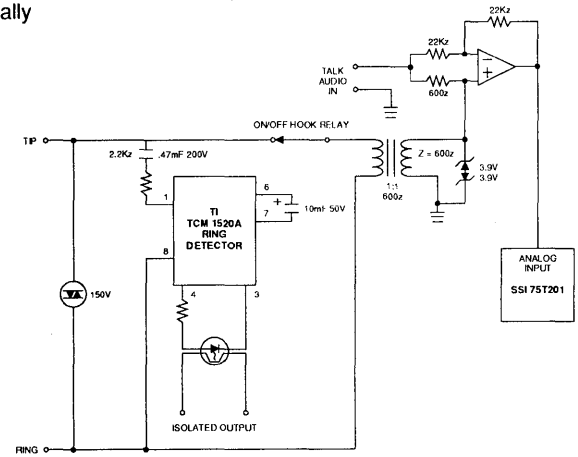
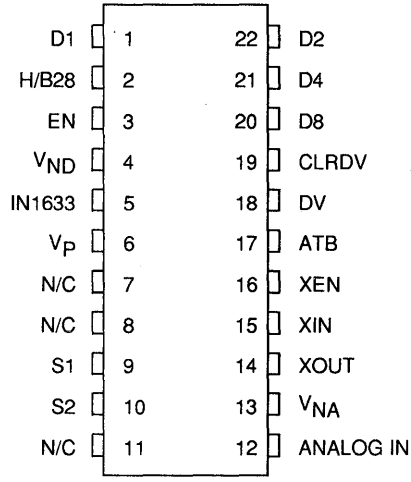


FIGURE 7: Full Featured Interface

SSI 75T201
Integrated
DTMF Receiver

PACKAGE PIN DESIGNATIONS
(TOP VIEW)



22-Pin DIP

CAUTION: Use handling procedures necessary for a static sensitive component.

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 75T201 22-Pin Plastic DIP	75T201 - IP	75T201 - IP

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SSI 75T202/203
5V Low-Power DTMF Receiver

October 1991

DESCRIPTION

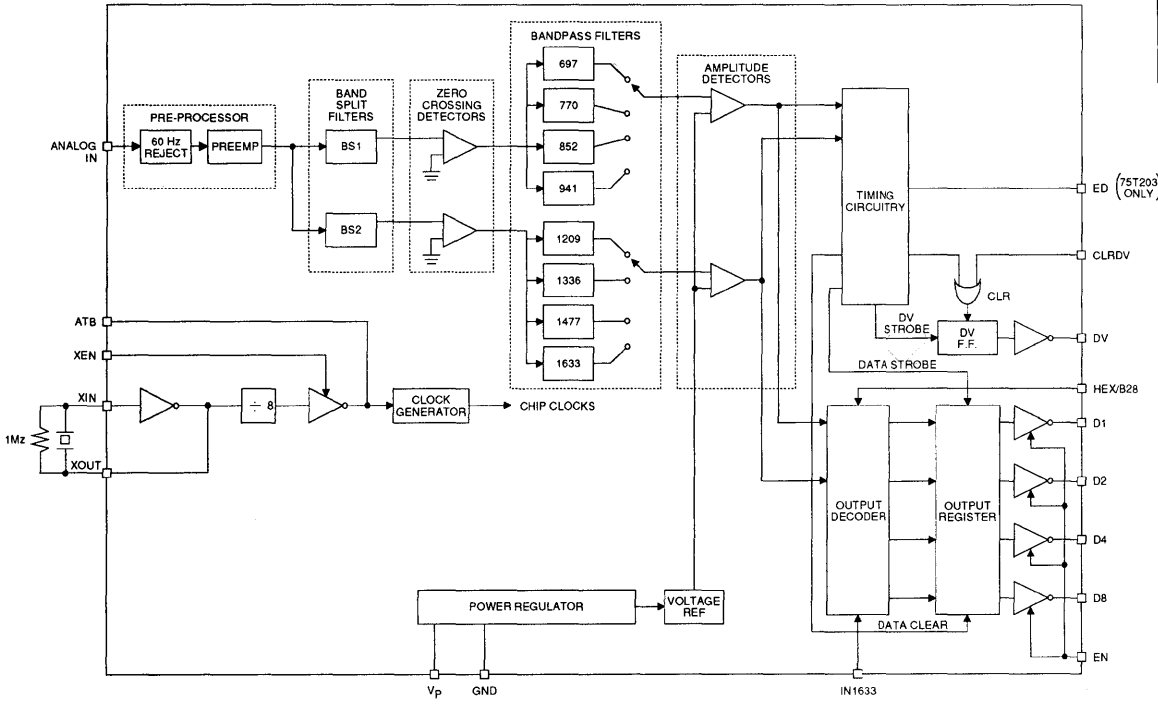
The SSI 75T202 and 75T203 are complete Dual-Tone Multifrequency (DTMF) receivers detecting a selectable group of 12 or 16 standard digits. No front-end pre-filtering is needed. The only externally required components are an inexpensive 3.58-MHz television "colorburst" crystal (for frequency reference) and a bias resistor. Extremely high system density is made possible by using the clock output of a crystal-connected SSI 75T202 or 75T203 receiver to drive the time bases of additional receivers. Both are monolithic integrated circuits fabricated with low-power, complementary symmetry MOS (CMOS) processing. They require only a single low tolerance voltage supply and are packaged in a standard 18-pin plastic DIP.

(Continued)

FEATURES

- **Central office quality**
- **NO front-end band-splitting filters required**
- **Single, low-tolerance, 5-volt supply**
- **Detects either 12 or 16 standard DTMF digits**
- **Uses inexpensive 3.579545-MHz crystal for reference**
- **Excellent speech immunity**
- **Output in either 4-bit hexadecimal code or binary coded 2-of-8**
- **18-pin DIP package for high system density**
- **Synchronous or handshake interface**
- **Three-state outputs**
- **Early detect output (SSI 75T203 only)**

BLOCK DIAGRAM



5

CAUTION: Use handling procedures necessary for a static sensitive component.

SSI 75T202/203
5V Low-Power
DTMF Receiver

DESCRIPTION (Continued)

The SSI 75T202 and 75T203 employ state-of-the-art circuit technology to combine digital and analog functions on the same CMOS chip using a standard digital semicondutor process. The analog input is pre-processed by 60-Hz reject and band splitting filters and then hard-limited to provide AGC. Eight bandpass filters detect the individual tones. The digital post-processor times the tone durations and provides the correctly coded digital outputs. Outputs interface directly to standard CMOS circuitry, and are three-state enabled to facilitate bus-oriented architectures.

ANALOG IN

This pin accepts the analog input. It is internally biased so that the input signal may be AC coupled. The input may be DC coupled as long as it does not exceed the positive supply. Proper input coupling is illustrated in Figure 1.

The SSI 75T202 is designed to accept sinusoidal input wave forms but will operate satisfactorily with any input that has the correct fundamental frequency with harmonics less then -20 dB below the fundamental.

CRYSTAL OSCILLATOR

The SSI 75T202 and 75T203 contain an onboard inverter with sufficient gain to provide oscillation when connected to a low-cost television "colorburst" crystal. The crystal oscillator is enabled by tying XEN high. The crystal is connected between XIN and XOUT. A 1 Mz 10% resistor is also connected between these pins. In this mode, ATB is a clock frequency output. Other SSI 75T202's (or 75T203's) may use the same frequency reference by tying their ATB pins to the ATB of a crystal connected device. XIN and XEN of the auxiliary devices must then be tied high and low respectively. Ten devices may run off a single crystal-connected SSI 75T202 or 75T203 as shown in Figure 2.

HEX/B28

This pin selects the format of the digital output code. When HEX/B28 is tied high, the output is hexadecimal. When tied low, the output is binary coded 2-of-8. The table below describes the two output codes.

Hexadecimal					Binary Coded 2-of-8				
Digit	D8	D4	D2	D1	Digit	D8	D4	D2	D1
1	0	0	0	1	1	0	0	0	0
2	0	0	1	0	2	0	0	0	1
3	0	0	1	1	3	0	0	1	0
4	0	1	0	0	4	0	1	0	0
5	0	1	0	1	5	0	1	0	1
6	0	1	1	0	6	0	1	1	0
7	0	1	1	1	7	1	0	0	0
8	1	0	0	0	8	1	0	0	1
9	1	0	0	1	9	1	0	1	0
0	1	0	1	0	0	1	1	0	1
*	1	0	1	1	*	1	1	0	0
#	1	1	0	0	#	1	1	1	0
A	1	1	0	1	A	0	0	1	1
B	1	1	1	0	B	0	1	1	1
C	1	1	1	1	C	1	0	1	1
D	0	0	0	0	D	1	1	1	1

TABLE 1: Output Codes

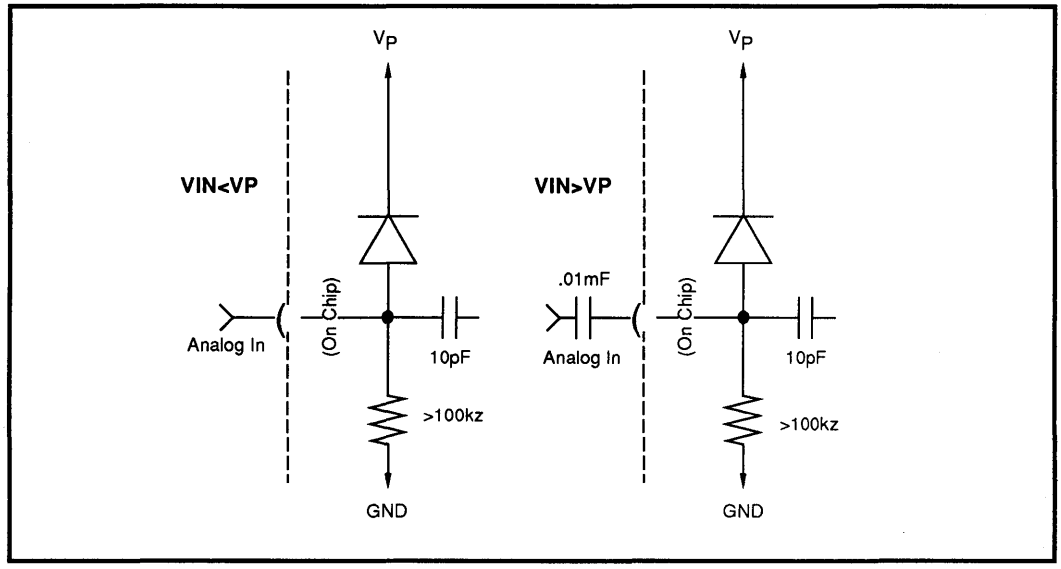


FIGURE 1: Input Coupling

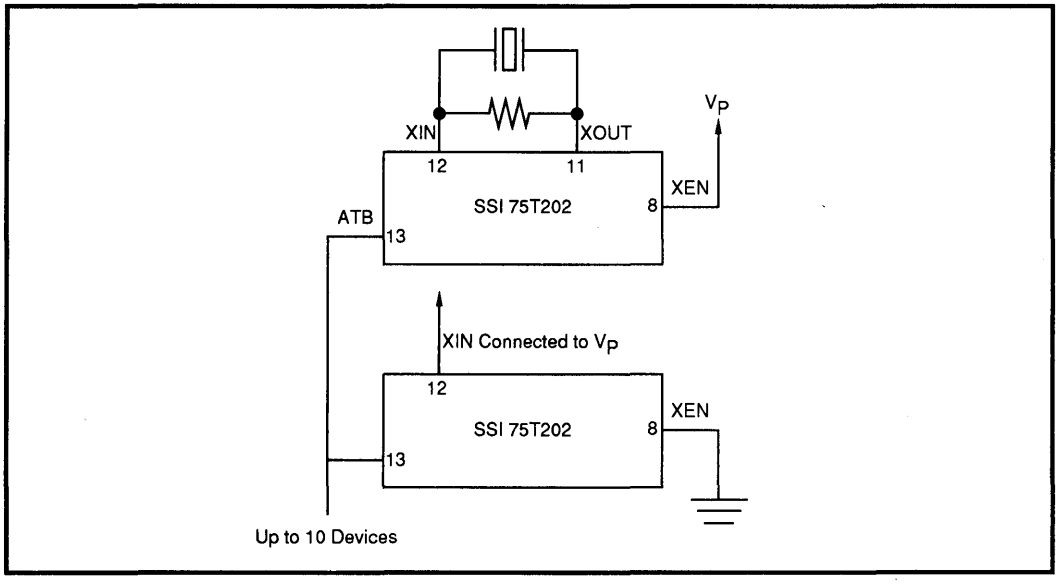


FIGURE 2: Crystal Connections

IN1633

When tied high, this pin inhibits detection of tone pairs containing the 1633 Hz component. For detection of all 16 standard digits, IN1633 must be tied low.

OUTPUTS D1, D2, D4, D8 and EN

Outputs D1, D2, D4, D8 are CMOS push-pull when enabled (EN high) and open circuited (high impedance) when disabled by pulling EN low. These digital outputs provide the code corresponding to the detected digit in the format programmed by the HEX/B28 pin. The digital outputs become valid after a tone pair has been detected and they are then cleared when a valid pause is timed.

DV and CLRDV

DV signals a detection by going high after a valid tone pair is sensed and decoded at the output pins D1, D2, D4, and D8. DV remains high until a valid pause occurs or the CLRDV is raised high, whichever is earlier.

ED (SSI 75T203 only)

The ED output goes high as soon as the SSI 75T203 begins to detect a DTMF tone pair and falls when the 75T203 begins to detect a pause. The D1, D2, D4, and D8 outputs are guaranteed to be valid when DV is high, but are not necessarily valid when ED is high.

N/C PINS

These pins have no internal connection and may be left floating.

DTMF DIALING MATRIX

See Figure 3. Please make note that column 3 is for special applications and is not normally used in telephone dialing.

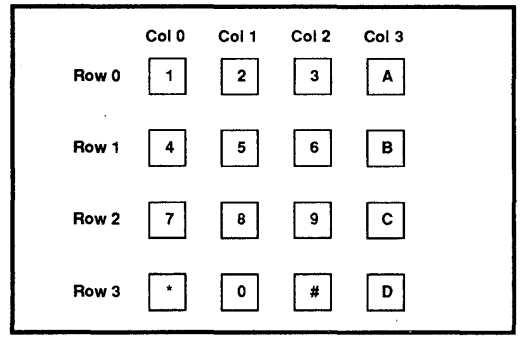


FIGURE 3: DTMF Dialing Matrix

DETECTION FREQUENCY

Low Group f_0	High Group f_0
Row 0 = 697 Hz	Column 0 = 1209 Hz
Row 1 = 770 Hz	Column 1 = 1336 Hz
Row 2 = 852 Hz	Column 2 = 1477 Hz
Row 3 = 941 Hz	Column 3 = 1633 Hz

ABSOLUTE MAXIMUM RATINGS

(Operation above absolute maximum ratings may damage the device. All SSI 75T202/203 unused inputs must be connected to V_P or GND, as appropriate.)

PARAMETER	RATING
DC Supply Voltage - V_P	+7V
Operating Temperature	-40°C to +85°C Ambient
Storage Temperature	-65°C to +150°C
Power Dissipation (25°C)	65mW
Input Voltage (All inputs except ANALOG IN)	(V_P + .5V) to -.5V
ANALOG IN Voltage	(V_P + .5V) to (V_P - 10V)
DC Current into any Input	±1.0mA
Lead Temperature - Soldering, 10 sec.	300°C

ELECTRICAL CHARACTERISTICS

(-40°C ≤ T_A ≤ +85°C, V_P = 5V ± 10%)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Frequency Detect Bandwidth		±(1.5+2Hz)	±2.3	±3.5	% of fo
Amplitude for Detection	each tone	-32		-2	dBm ref. to 600Ω
Twist Tolerance	$\text{Twist} = \frac{\text{High Tone}}{\text{Low Tone}}$	-10		+10	dB
60-Hz Tolerance				0.8	Vrms
Dial Tone Tolerance	"precise" dial tone			0dB	dB*
Talk Off	MITEL tape #CM 7290		2		hits
Digital Outputs	"0" level, 400µA load	0		0.5	V
(except XOUT)	"1" level, 200µA load	V_P-0.5		V_P	V
Digital Inputs	"0" level	0		0.3V_P	V
	"1" level	0.7V_P		V_P	V
Power Supply Noise	wide band			10	mV p-p
Supply Current	T_A = 25°C		10	16	mA
Noise Tolerance	MITEL tape #CM 7290			-12	dB*
Input Impedance	$V_P \geq V_{IN} \geq V_P$-10	100kΩ||15pF			

* dB referenced to lowest amplitude tone

5

SSI 75T202/203 TIMING

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNITS
t_{ON}	Tone Time	for detection	40	-	-	ms
		for rejection	-	-	20	ms
t_{OFF}	Pause Time	for detection	40	-	-	ms
		for rejection	-	-	20	ms
t_D	Detect Time		25	-	46	ms
t_R	Release Time		35	-	50	ms
t_{SU}	Data Setup Time		7	-	-	µs
t_H	Data Hold Time		4.2	-	5.0	ms
t_{CL}	DV Clear Time		-	160	250	ns
t_{PW}	CLRDV Pulse Width		200	-	-	ns
t_{ED}	ED Detect Time		7	-	22	ms
t_{ER}	ED Release Time		2	-	18	ms
	Output Enable Time	C_L = 50pF, R_L = 1kΩ	-	-	200	ns
	Output Disable Time	C_L = 35pF, R_L = 500Ω	-	-	200	ns
	Output Rise Time	C_L = 50pF	-	-	200	ns
	Output Fall Time	C_L = 50pF	-	160	200	ns

SSI 75T202/203 TIMING (Continued)

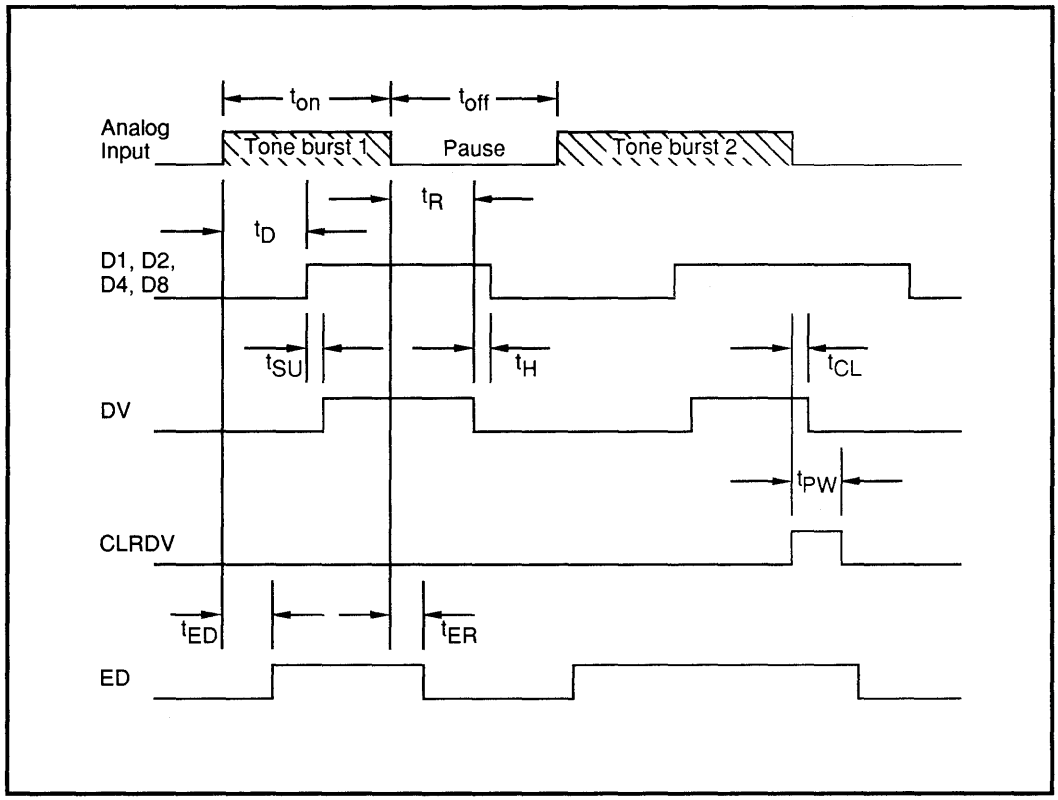
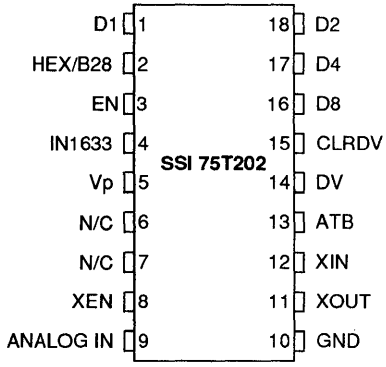


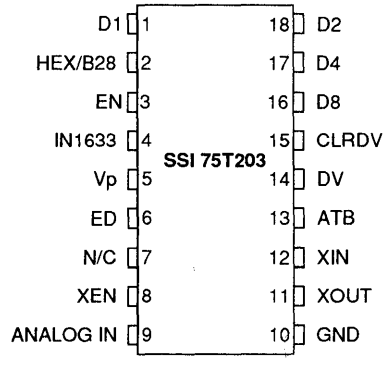
FIGURE 4: Timing Diagram

SSI 75T202/203
5V Low-Power
DTMF Receiver

PACKAGE PIN DESIGNATIONS
(TOP VIEW)



18 - Pin DIP
SSI 75T202



18 - Pin DIP
SSI 75T203

CAUTION: Use handling procedures necessary for a static sensitive component.

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 75T202 18-pin Plastic DIP	75T202-IP	75T202-IP
SSI 75T203 18-pin Plastic DIP	75T203-IP	75T203-IP

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SSI 75T204
5V Low-Power Subscriber DTMF Receiver

October 1991

DESCRIPTION

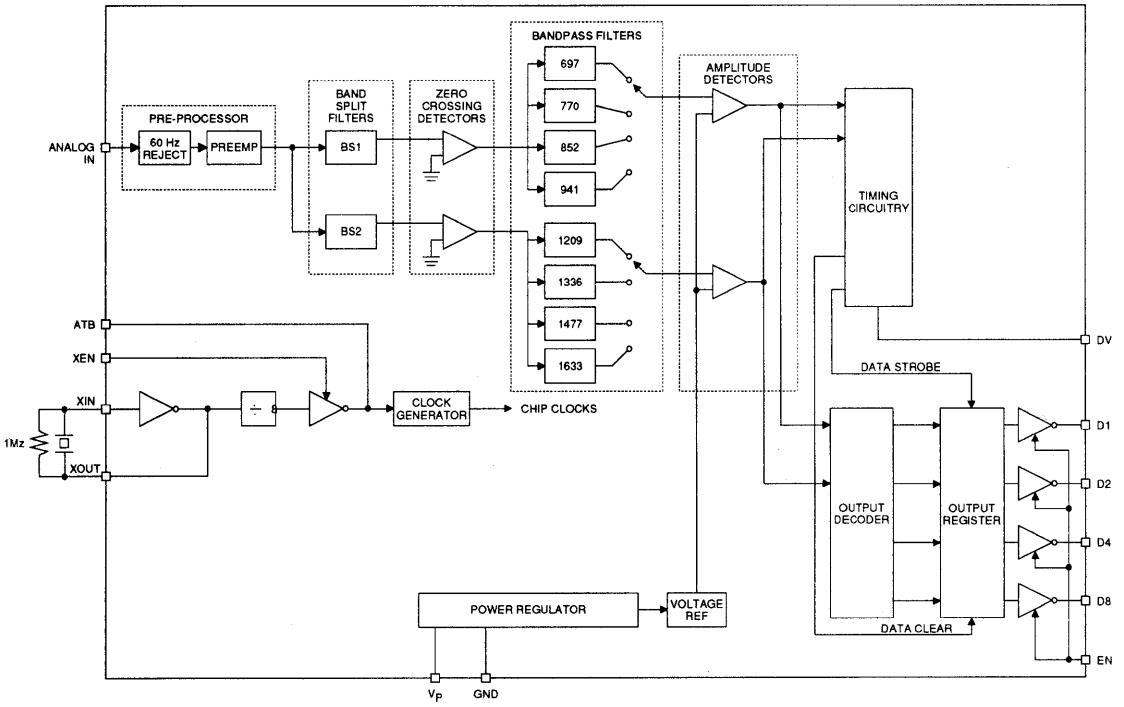
The SSI 75T204 is a complete Dual-Tone Multifrequency (DTMF) receiver that detects 16 standard digits. No front-end pre-filtering is needed. The only external components required are an inexpensive 3.58-MHz television "colorburst" crystal for frequency reference and a bias resistor. An Alternate Time Base (ATB) is provided to permit operation of up to 10 SSI 75T204's from a single crystal. The SSI 75T204 employs state-of-the-art "switched-capacitor" filter technology, resulting in approximately 40 poles of filtering, and digital circuitry on the same CMOS chip. The analog input signal is pre-processed by 60-Hz reject and band split filters and then zero-cross detected to provide AGC. Eight bandpass filters detect the individual tones. Digital processing is used to

(Continued)

FEATURES

- **Intended for applications with less requirements than the SSI 75T202**
- **14-pin plastic DIP or 16-pin SO package for high system density**
- **NO front-end band-splitting filters required**
- **Single low-tolerance 5-volt supply**
- **Detects all 16 standard DTMF digits.**
- **Uses an inexpensive 3.579545-MHz crystal**
- **Excellent speech immunity**
- **Output in 4-bit hexadecimal code**
- **Three-state outputs for microprocessor interface**

BLOCK DIAGRAM



CAUTION: Use handling procedures necessary for a static sensitive component.

1091 rev.

DESCRIPTION (Continued)

measure the tone and pause durations and to provide output timing and decoding. The outputs interface directly to standard CMOS circuitry and are three-state enabled to facilitate bus-oriented architectures.

ANALOG IN

This pin accepts the analog input. It is internally biased so that the input signal may be AC coupled. The input may be DC coupled as long as it does not exceed the positive supply. Proper input coupling is illustrated in Figure 1.

The SSI 75T204 is designed to accept sinusoidal input wave forms but will operate satisfactorily with any input that has the correct fundamental frequency with harmonics less then -20 dB below the fundamental.

CRYSTAL OSCILLATOR

The SSI 75T204 contains an onboard inverter with sufficient gain to provide oscillation when connected to a low-cost television "colorburst" crystal. The crystal oscillator is enabled by tying XEN high. The crystal is connected between XIN and XOUT. A 1 Mz 10% resistor is also connected between these pins. In this mode, ATB is a clock frequency output. Other SSI 75T204's (or 75T202's) may use the same frequency reference by tying their ATB pins to the ATB of a crystal connected device. XIN and XEN of the auxiliary devices must then be tied high and low respectively. Ten devices may run off a single crystal-connected SSI 75T204 (or 75T202) as shown in Figure 2.

OUTPUTS D1, D2, D4, D8 and EN

Outputs D1, D2, D4, D8 are CMOS push-pull when enabled (EN high) and open circuited (high impedance) when disabled by pulling EN low. These digital outputs provide the hexadecimal code corresponding to the detected digit. The digital outputs become valid after a tone pair has been detected (DV is high) and they are then cleared when a valid pause is timed. The hexadecimal codes are described in Table 1.

DV

DV signals a detection by going high after a valid tone pair is sensed and decoded at the output pins D1, D2, D4, and D8. DV remains high until a valid pause occurs.

N/C PINS

These pins have no internal connection and may be left floating.

	Output Code			
Digit	**D8**	**D4**	**D2**	**D1**
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
0	1	0	1	0
*	1	0	1	1
#	1	1	0	0
A	1	1	0	1
B	1	1	1	0
C	1	1	1	1
D	0	0	0	0

TABLE 1: Output Codes

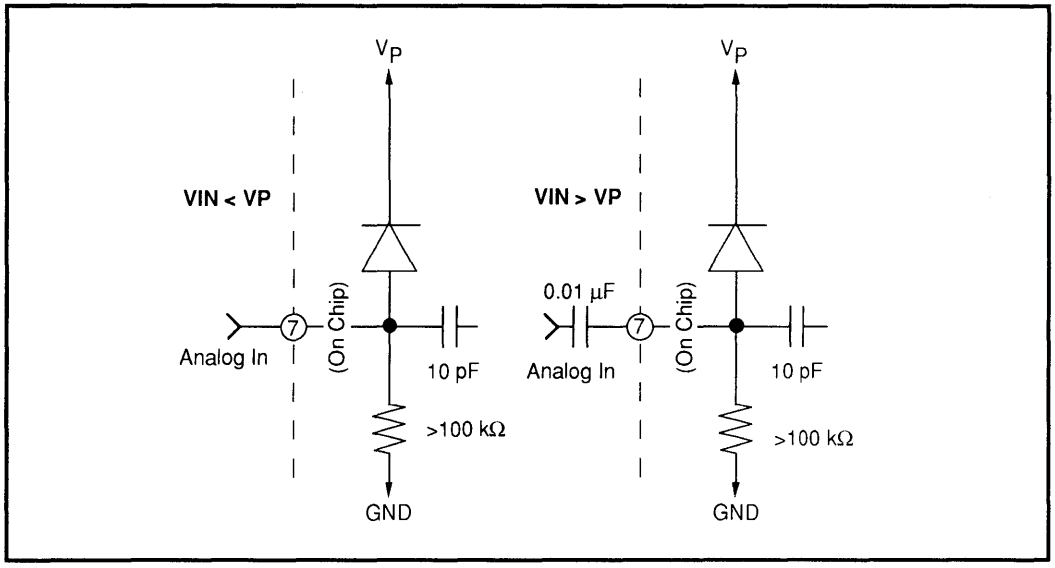


FIGURE 1: Input Coupling

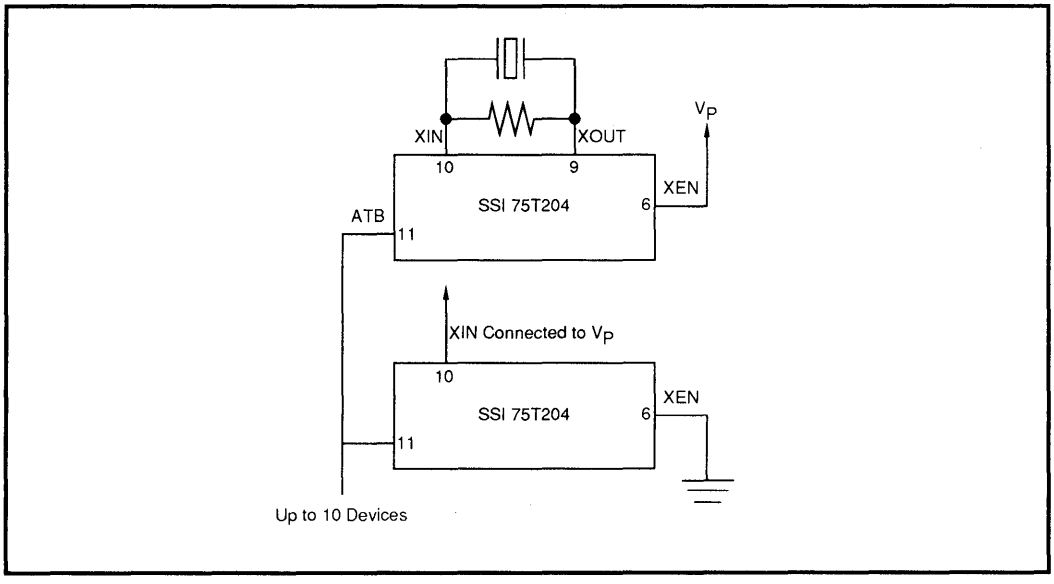


FIGURE 2: Crystal Connections

DTMF DIALING MATRIX

See Figure 3. Please note that column 3 is for special applications and is not normally used in telephone dialing.

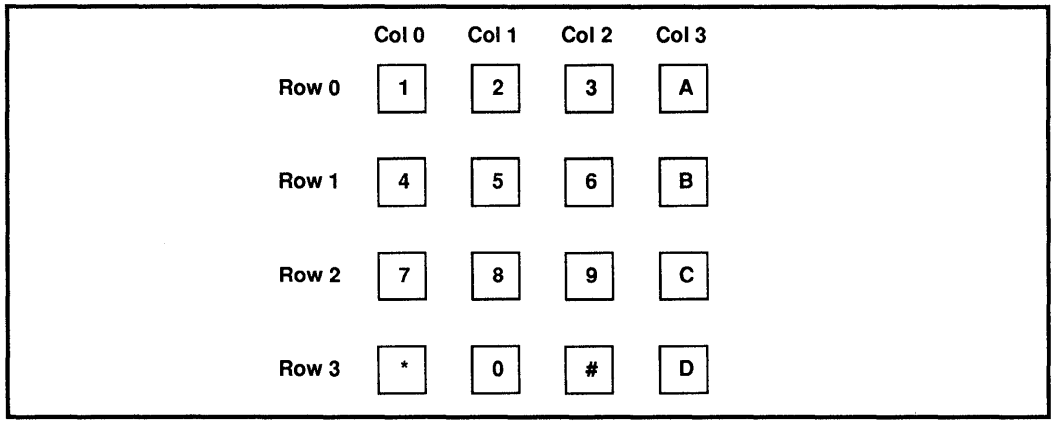


FIGURE 3: DTMF Dialing Matrix

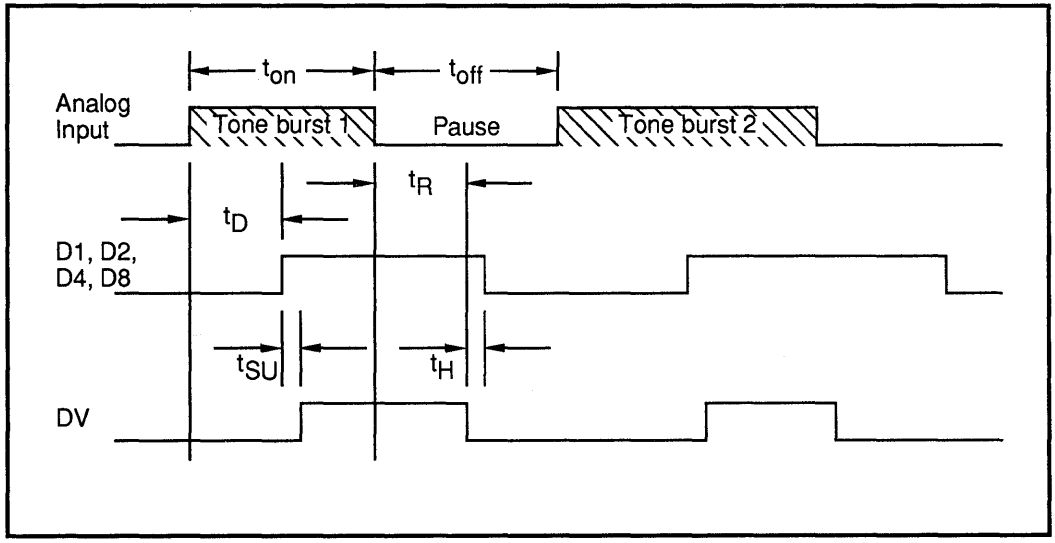


FIGURE 4: Timing Diagram

DETECTION FREQUENCY

Low Group f_0	High Group f_0
Row 0 = 697 Hz	Column 0 = 1209 Hz
Row 1 = 770 Hz	Column 1 = 1336 Hz
Row 2 = 852 Hz	Column 2 = 1477 Hz
Row 3 = 941 Hz	Column 3 = 1633 Hz

SSI 75T204 TIMING (Refer to Figure 4.)

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNITS
t_{ON}	Tone Time	for detection	40	-	-	ms
		for rejection	-	-	20	ms
t_{OFF}	Pause Time	for detection	40	-	-	ms
		for rejection	-	-	20	ms
t_D	Detect Time		25	-	46	ms
t_R	Release Time		35	-	50	ms
t_{SU}	Data Setup Time		7	-	-	µs
t_H	Data Hold Time		4.2	-	5.0	ms
	Output Enable Time	C_L = 50pF, R_L = 1kΩ	-	-	200	ns
	Output Disable Time	C_L = 35pF, R_L = 500Ω	-	-	200	ns
	Output Rise Time	C_L = 50pF	-	-	200	ns
	Output Fall Time	C_L = 50pF	-	-	200	ns

5

APPLICATION INFORMATION

The SSI 75T204 will tolerate total input RMS noise up to 12dB below the lowest amplitude tone. For most telephone applications, the combination of the high frequency attenuation of the telephone line and internal band-limiting make special circuitry at the input to the SSI 75T204 unnecessary. However, noise near the 56kHz internal sampling frequency will be aliased (folded back) into the audio spectrum, so if excessive noise is present above 28kHz, the simple RC filter shown in Figure 5 may be employed to band limit the incoming signal.

Noise will also be reduced by placing a grounded trace around the XIN and XOUT pins on the circuit board layout when using a crystal. It is important to note that XOUT is not intended to drive an additional device. XIN may be driven externally; in this case leave XOUT floating.

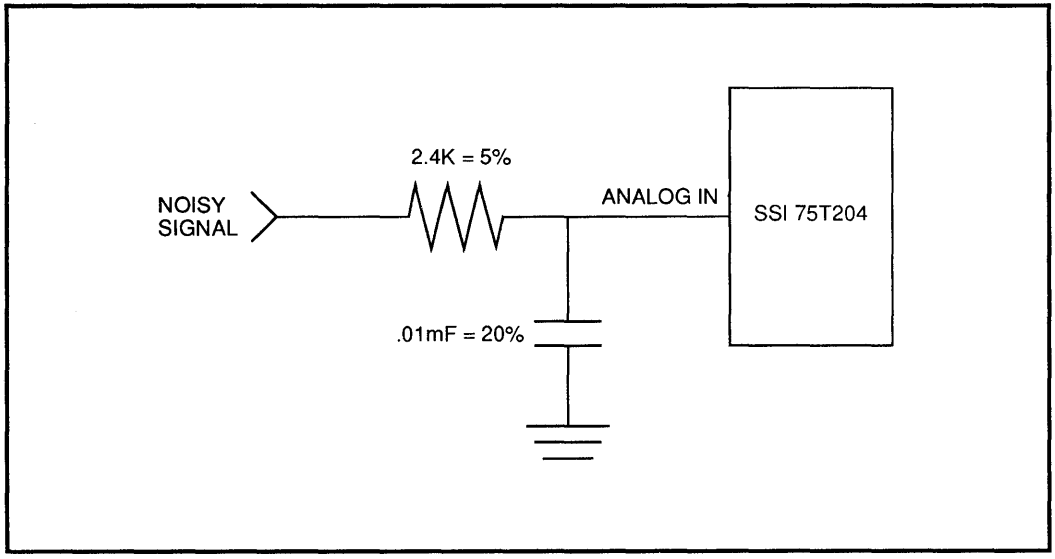


FIGURE 5: RC Filter

ABSOLUTE MAXIMUM RATINGS

(Operation above absolute maximum ratings may damage the device. All SSI 75T204 unused inputs must be connected to V_P or GND, as appropriate.)

PARAMETER	RATING
DC Supply Voltage - V_P	+7V
Operating Temperature	-40°C to +85°C Ambient
Storage Temperature	-65°C to +150°C
Power Dissipation (25°C)	65mW
Input Voltage (All inputs except ANALOG IN)	(V_P + 0.5V) to -0.5V
ANALOG IN Voltage	(V_P + .5V) to (V_P - 10V)
DC Current into any Input	±1.0mA
Lead Temperature - Soldering, 10 sec.	300°C

ELECTRICAL CHARACTERISTICS

(-40°C ≤ T_A ≤ +85°C, V_P = 5V ± 10%)

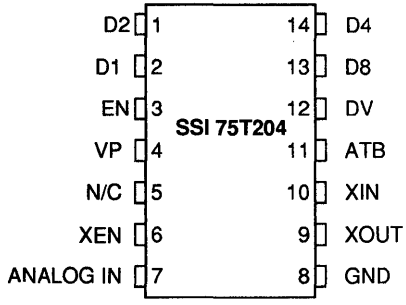
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Frequency Detect Bandwidth		±(1.5+2Hz)	±2.3	±3.5	% of fo
Amplitude for Detection	each tone	-32		-2	dBm ref. to 600Ω
Twist Tolerance	$\text{Twist} = \frac{\text{High Tone}}{\text{Low Tone}}$	-10		+10	dB
60-Hz Tolerance				0.8	Vrms
Dial Tone Tolerance	"precise" dial tone			0dB	dB*
Talk Off	MITEL tape #CM 7290		2		hits
Digital Outputs	"0" level, 400µA load	0		0.5	V
(except XOUT)	"1" level, 200µA load	V_P-0.5		V_P	V
Digital Inputs	"0" level	0		0.3V_P	V
	"1" level	0.7V_P		V_P	V
Power Supply Noise	wide band			10	mV p-p
Supply Current	T_A = 25°C		10	16	mA
Noise Tolerance	MITEL tape #CM 7290			-12	dB*
Input Impedance	$V_P \geq V_{IN} \geq V_P$-10	100KΩ||15pF			

* dB referenced to lowest amplitude tone

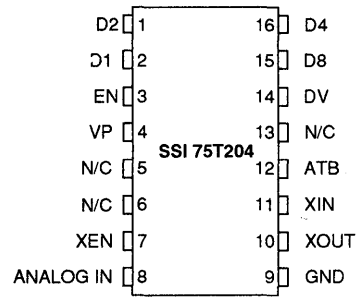
5

SSI 75T204
5V Low-Power
Subscriber DTMF Receiver

PACKAGE PIN DESIGNATIONS
(TOP VIEW)



14 - Pin DIP



16 - Lead SOL

CAUTION: Use handling procedures necessary for a static sensitive component.

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 75T204 14-pin PDIP	75T204-IP	75T204-IP
SSI 75T204 16-lead SOL	75T204-IL	75T204-IL

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SSI 75T2089/2090/2091
DTMF Transceivers

DESCRIPTION

Silicon Systems' SSI 75T2089/2090/2091 are complete Dual-Tone Multifrequency (DTMF) Transceivers that can both generate and detect all 16 DTMF tone-pairs. These ICs integrate the performance-proven SSI 75T202 DTMF receiver with a DTMF generator circuit.

The DTMF receiver electrical characteristics are identical to the standard SSI 75T202 device characteristics. The DTMF generator provides performance similar to the Mostek MK5380, but with an improved (tighter) output amplitude range specification and with the addition of independent latch and reset controls.

An additional feature of the SSI 75T2090/2091 is "imprecise" call progress detector. The detector detects the presence of signals in the 305-640 Hz band.

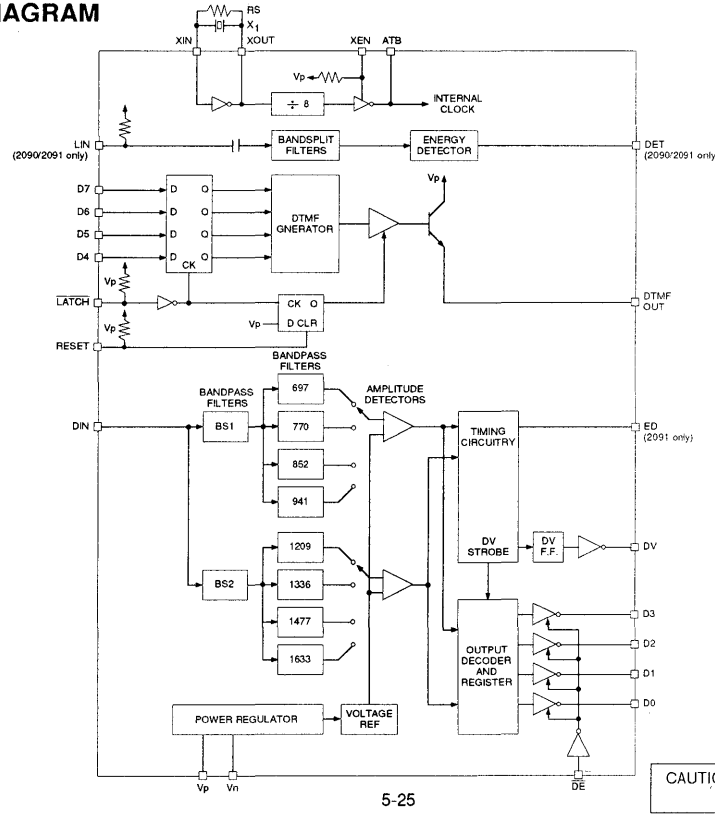
(Continued)

FEATURES

November 1991

- **DTMF Generator and Receiver on one-chip**
- **Call progress detection (2090/2091 only)**
- **Early detect output (2091 only)**
- **DTMF Receiver exhibits excellent speech immunity**
- **Analog input range from –32 to –2 dBm (ref 600Ω)**
- **Three-state outputs (4-bit hexadecimal) from DTMF Receiver**
- **AC coupled, internally biased analog input**
- **Latched DTMF Generator inputs**
- **DTMF output typ. –8 dBm (Low Band) and –5.5 dBm (High Band)**
- **Easy interface for microprocessor dialing**
- **Uses inexpensive 3.579545 MHz crystal for reference**
- **Low-power 5 volt CMOS**

BLOCK DIAGRAM



CAUTION: Use handling procedures necessary for a static sensitive component.

5

DESCRIPTION (Continued)

The SSI 75T2091 also incorporates an early detect function which is useful in multi-channel radio scanning applications. The only external components necessary for the SSI 75T2089/2090/2091 are a 3.58 MHz "colorburst" crystal with a parallel 1 MΩ resistor. This provides the time base for digital functions and switched-capacitor filters in the device. No external filtering is required.

CIRCUIT OPERATION

RECEIVER

The DTMF Receiver in the SSI 75T2089/2090/2091 detects the presence of a valid tone pair (indicating a single dialed digit) on a telephone line or other transmission medium. The analog input is pre-processed by 60 Hz reject and band-splitting filters, then hard-limited to provide Automatic Gain Control. Eight bandpass filters detect the individual tones. The digital post-processor times the tone durations and provides the correctly coded digital outputs. The outputs will drive standard CMOS circuitry, and are three-state enabled to facilitate bus-oriented architectures.

DIN

This pin accepts the analog input. It is internally biased so that the input signal may be AC coupled. The input may be DC coupled as long as it does not exceed the positive supply. Proper input coupling is illustrated in Figure 1.

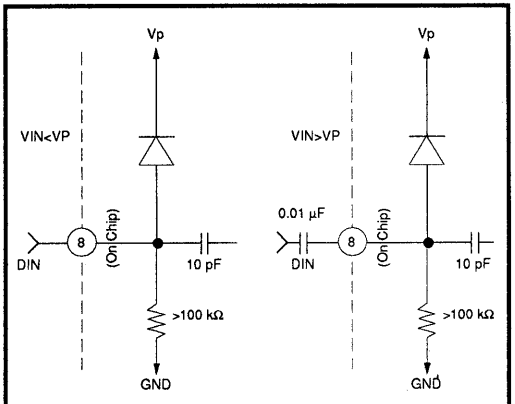


FIGURE 1: Input Coupling

The IC is designed to accept sinusoidal input waveforms but will operate satisfactorily with any input that has the correct fundamental frequency with harmonics greater than -20 dB below the fundamental.

CRYSTAL OSCILLATOR

The IC contains an onboard inverter with sufficient gain to provide oscillation when connected to a low-cost television "color-burst" crystal. The crystal is placed between XIN and XOUT in parallel with a 1Mz resistor, while XEN is tied high. Since the switched-capacitor-filter time base is derived from the crystal oscillator, the frequency accuracy of all portions of the IC depends on the time base tolerance. The SSI DTMF Receiver frequency response and timing is specified for a time base accuracy of at least =0.005%. ATB is a clock output with the frequency of 1/8 of crystal. Other devices may use the same frequency reference by tying their ATB pins to the ATB of a crystal connected device. XIN and XEN of the auxiliary devices must then be tied high and low respectively, XOUT is left floating. XOUT is designed to drive a resonant circuit only and is not intended to drive additional devices. Ten devices may run off a single crystal-connected transceiver as shown in Figure 2.

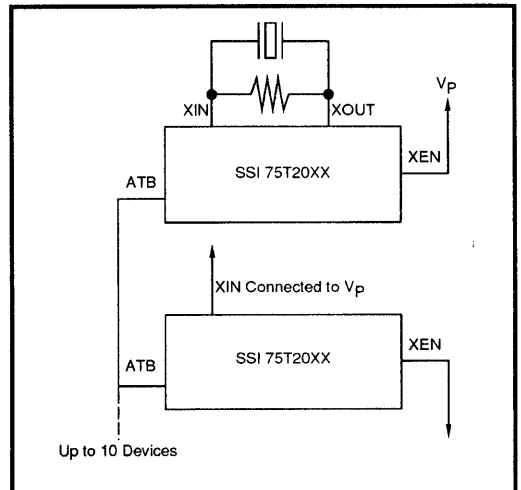


FIGURE 2: Crystal Connections

RECEIVER OUTPUTS AND THE $\overline{DE}$ PIN

Outputs D0, D1, D2, D3 are CMOS push-pull when enabled ($\overline{DE}$ low) and open-circuited (high impedance) when disabled ($\overline{DE}$ high). These digital outputs provide the hexadecimal code corresponding to the detected digit. Figure 3 shows that code.

The digital outputs become valid and DV signals a detection after a valid tone pair has been sensed. The outputs and DV are cleared when a valid pause has been timed.

	Hexadecimal Code			
Digit In Out	D7 D3	D6 D2	D5 D1	D4 D0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
0	1	0	1	0
*	1	0	1	1
#	1	1	0	0
A	1	1	0	1
B	1	1	1	0
C	1	1	1	1
D	0	0	0	0

FIGURE 3

ED OUTPUT (75T2091 only)

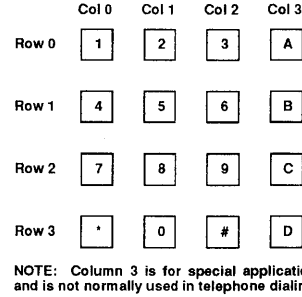
The ED output goes high as soon as the SSI 75T2091 begins to detect a DTMF tone pair and falls when the SSI 75T2091 begins to detect a pause. The D1, D2, D4, and D8 outputs are guaranteed to be valid when DV is high, but are not necessarily valid when ED is high.

GENERATOR

The DTMF generator responds to a hexadecimal code input with a valid tone pair. Pins D4-D7 are the data inputs for the generator. A high to low transition on $\overline{LATCH}$ causes the hexadecimal code to be latched internally and generation of the appropriate DTMF tone pair to begin. The DTMF output is disabled by a high on RESET and will not resume until new data is latched in.

DIGITAL INPUTS

The D4, D5, D6, D7, $\overline{LATCH}$, RESET inputs to the DTMF generator may be interfaced to open-collector TTL with a pull-up resistor or standard CMOS. These inputs follow the same hexadecimal code format as the DTMF receiver output. Figure 4 shows the code for each digit. The dialing matrix and detection frequency table below list the frequencies of the digits.



NOTE: Column 3 is for special applications and is not normally used in telephone dialing.

FIGURE 4: DTMF Dialing Matrix

DETECTION FREQUENCY

Low Group f_0	High Group f_0
Row 0 = 697Hz	Column 0 = 1209Hz
Row 1 = 770Hz	Column 1 = 1336Hz
Row 2 = 852Hz	Column 2 = 1477Hz
Row 3 = 941Hz	Column 3 = 1633Hz

5

DTMF OUT

The output amplitude characteristics listed in the specifications are given for a supply voltage of 5.0V. However, the output level is directly proportional to the supply, so variations in it will affect the DTMF output. A recommended line interface for this output is shown in Figure 5.

CALL PROGRESS DETECTION (75T2090/2091)

The 75T2090/2091 have a Call Progress Detector that consists of a bandpass filter and an energy detector for turning the on/off cadences into a microprocessor compatible signal.

DET OUTPUT (75T2090/2091)

The output is TTL compatible and will be of a frequency corresponding to the various candences of Call Progress signals such as: on 0.5 sec/off 0.5 sec for a busy tone, on 0.25 sec/off 0.25 sec for a reorder tone and on 0.8-1.2 sec/off 2.7-3.3 sec for an audible ring tone.

LIN INPUT (75T2090/2091)

This analog input accepts the call progress signal and should be used in the same manner as the receiver input DIN.

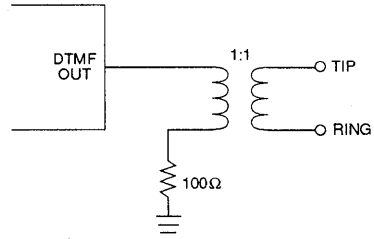


FIGURE 5: DTMF Output

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Operating above absolute maximum ratings may damage the device.

PARAMETER	RATING
DC Supply Voltage (Vp - Vn)	+7V
Voltage at any Pin (Vn = 0)	-0.3 to Vp + 0.3V
DIN Voltage	Vp + 0.5 to Vp - 10V
Current through any Protection Device	=20mA
Operating Temperature Range	-40 to + 85°C
Storage Temperature	-65 to 150°C

RECOMMENDED OPERATING CONDITIONS

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
Supply Voltage		4.5		5.5	V
Power Supply Noise (wide band)				10	mVp-p
Ambient Temperature		-40		+85	°C
Crystal Frequency (F Nominal = 3.579545MHz)		-0.01		+0.01	%
Crystal Shunt Resistor		0.8		1.2	MΩ
DTMF OUT Load Resistance		100			Ω

DIGITAL AND DC REQUIREMENTS

The following electrical specifications apply to the digital input and output signals over the recommended operating range unless otherwise noted. The specifications do not apply to the following pins: LIN, DIN, XIN, XOUT, and DTMF OUT. Positive current is defined as entering the circuit. Vn = 0 unless otherwise stated.

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
Supply Current*			15	30	mA
Power Dissipation				225	mW
Input Voltage High		0.7Vp			V
Input Voltage Low				0.3Vp	V
Input Current High				10	µA
Input Current Low		-10			µA
Output Voltage High	Ioh = -0.2mA	Vp-0.5			V
Output Voltage Low	Iol = +0.4mA			Vn+0.5	V
* with DTMF output disabled					

DTMF RECEIVER: Electrical Characteristics

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
Frequency Detect Bandwidth		=(1.5+2Hz)	=2.3	=3.5	%Fo
Amplitude for Detection	Each Tone	-32		-2	dBm/tone
Twist Tolerance		-10		+10	dB
60Hz Tolerance				0.8	Vrms
Dial Tone Tolerance	Precise Dial Tone			0	dB*
Speech Immunity	MITEL Tape #CM7290		2		hits
Noise Tolerance	MITEL Tape #CM7290			-12	dB*
Input Impedance		100			kΩ
* Referenced to lowest amplitude tone					

DTMF RECEIVER: Timing Characteristics

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
TON	Tone Time for Detect		40			ms
TON	Tone Time for No Detect				20	ms
TOFF	Pause Time for Redetection		40			ms
TOFF	Pause Time for Bridging				20	ms
TD1	Detect Time		25		46	ms
TR1	Release Time		35		50	ms

DTMF RECEIVER: Timing Characteristics (Continued)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
TSU1 Data Set Up Time		7			µs
THD1 Data Hold Time		4.2		5.0	ms
TED ED Detect Time	75T2091 only	7		22	ms
BER ED Release Time	75T2091 only	2		18	ms
Output Enable Time				200	ns
Output Disable Time				200	ns

DTMF GENERATOR: Electrical Characteristics

Frequency Accuracy		-1.0		+1.0	%Fo
Output Amplitude	R1 = 100Ω to Vn, Vp - Vn = 5.0V				
Low Band		-9.2		-7.2	dBm
High Band		-6.6		-4.6	dBm
Output Distortion	DC to 50 kHz			-20	dB

DTMF GENERATOR: Timing Characteristics

TSTART Start-Up Time				2.5	µs
TSU2 Data Set-Up Time		100			ns
THD2 Data Hold Time		50			ns
TRP RESET Pulse Width		100			ns
TPW $\overline{\text{LATCH}}$ Pulse Width		100			ns

CALL PROGRESS DETECTOR: Electrical Characteristics (75T2090/2091 only)

Amplitude for Detection	305 Hz-640 Hz	-40		0	dBm
Amplitude for No Detection	305 Hz-640 Hz			-50	dBm
	f>2200 Hz, <160 Hz			-25	dBm
Detect Output	Logic 0			0.5	V
	Logic 1	4.5			V
"LIN" Input	Max. Voltage	V_{DD}-10		V_{DD}	V
Input Impedance	500 Hz	100			kΩ

CALL PROGRESS DETECTOR: Electrical Characteristics (Continued)

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
TON	Signal Time for Detect		40			ms
TON	Signal Time for No Detect				10	ms
TOFF	Interval Time for Detect		40			ms
TOFF	Interval Time for No Detect				20	ms
TD2	Detect Time				40	ms
TR2	Release Time				40	ms

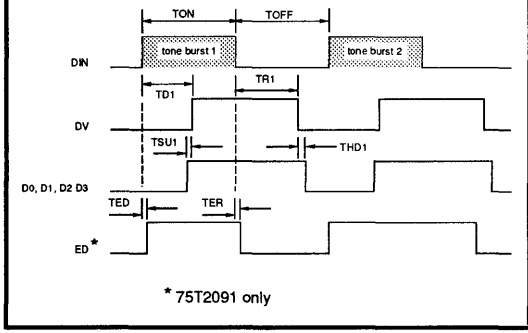


FIGURE 6: DTMF Decoder

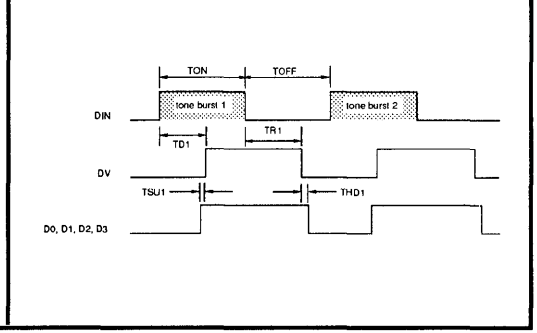


FIGURE 7: Call Progress Detector (75T2090/2091 only)

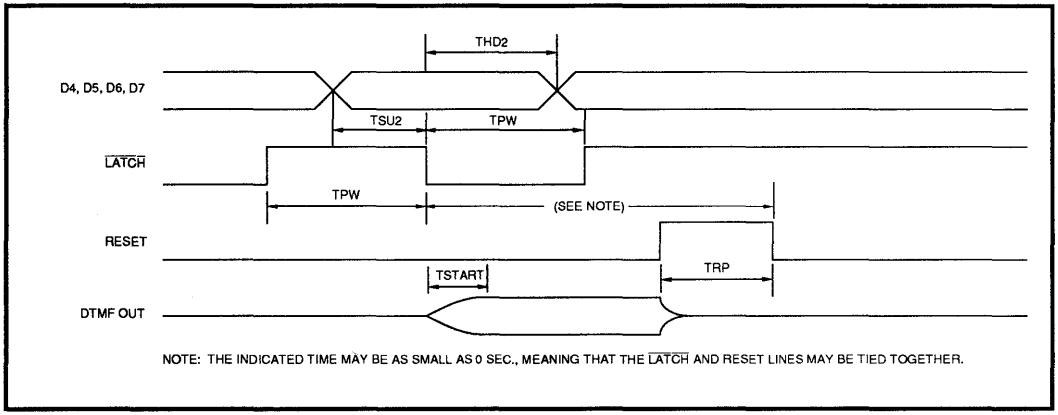
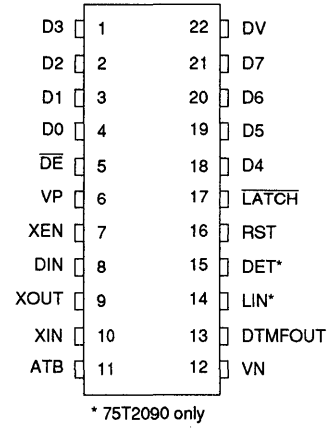


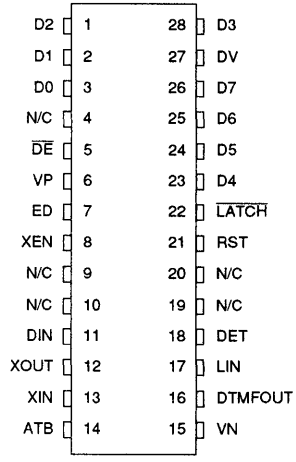
FIGURE 8: DTMF Generator

SSI 75T2089/2090/2091
DTMF Transceivers

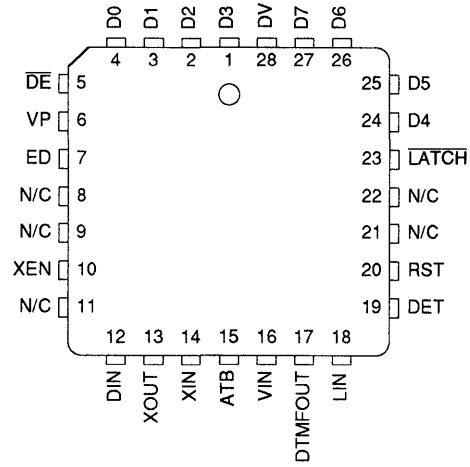
PACKAGE PIN DESIGNATIONS
(Top View)



75T2089/2090
22-Pin DIP



75T2091
28-Pin DIP



75T2091
28-Pin PLCC

CAUTION: Use handling procedures necessary for a static sensitive component.

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 75T2089		
22-Pin Plastic DIP	75T2089 - IP	75T2089 - IP
SSI 75T2090		
22-Pin DIP	75T2090 - IP	75T2090 - IP
SSI 75T2091		
28-Pin Plastic DIP	75T2091 - IP	75T2091 - IP
28-Pin PLCC	75T2091 - IH	75T2091 - IH

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SSI 75T980
Call Progress Tone Detector

June 1994

DESCRIPTION

The SSI 75T980 Call Progress Tone Detector circuit allows automatic equipment to monitor tones in dial telephone systems that relate to the routing of calls. Such tones commonly include dial tones, circuits-busy tones, station-busy tones, audible ringing tones and others. By sensing signals in the range of 315 to 640 Hz, the SSI 75T980 does not require the use of precision tones to function. This means that tones which vary with location or call destination can be detected regardless of their exact frequency.

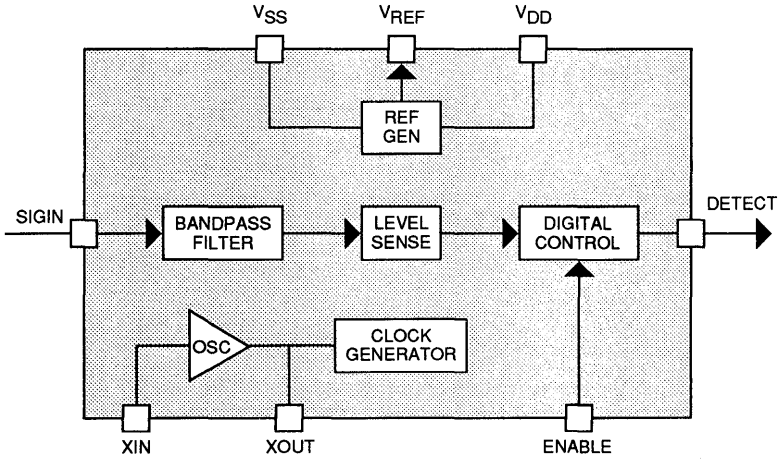
The low power CMOS switched capacitor filters used in the SSI 75T980 derive their accuracy from a 3.58 MHz clock, which in turn may be derived from other devices in the system being designed. The SSI 75T980 is available in a plastic 8-pin DIP and 16-pin SO packages.

FEATURES

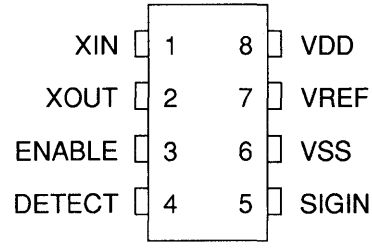
- **Detects tones throughout the telephone progress supervision band (315 to 640 Hz)**
- **Sensitivity to -38 dBm**
- **Dynamic range over 36 dB**
- **40 ms minimum detect (50 ms to output)**
- **Single supply CMOS (low power)**
- **Supply range 4.5 to 5.5 VDC**
- **Uses 3.58 MHz crystal or external clock**
- **8-pin DIP and 16-pin SO packages**
- **Second source of Teltone M-980**

5

BLOCK DIAGRAM



PIN DIAGRAM



8-Pin DIP

CAUTION: Use handling procedures necessary for a static sensitive component.

SSI 75T980
Call Progress
Tone Detector

PIN DESCRIPTION

NAME	TYPE	DESCRIPTION
SIGIN	I	Accepts analog input signal. See "Electrical Characteristics" for voltage levels, and "Timing Characteristics" for timing.
DETECT	O	Call progress detect output. Goes to logic "1" when signal in 315-640 Hz band is sensed. See "Timing Characteristics."
ENABLE	I	Application of logic "1" on this pin enables the output; logic "0" disables output.
V_{REF}	O	Supplies voltage at half V_{DD} for voltage reference of on-chip op amps.
XIN, XOUT	I	Crystal connections to on-chip oscillator circuit.
V_{DD}	-	Positive power supply connection
Vss	-	Negative power supply connection

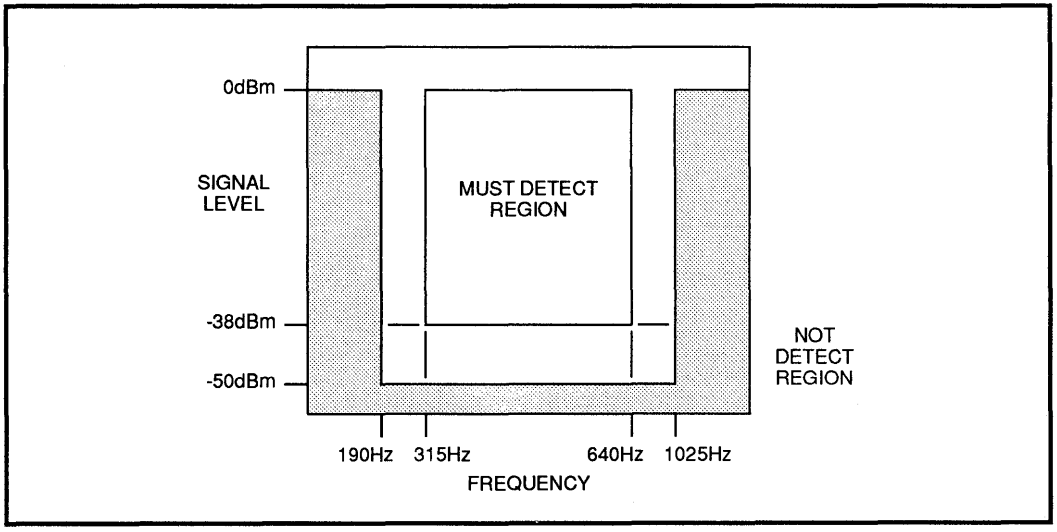


FIGURE 1: Detect and Reject Regions

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

(Operation above absolute maximum ratings may permanently damage the device.)

PARAMETER		RATING
DC Supply Voltage	V_{DD}–V_{SS}	16V
Input Voltage	All inputs except SIGNAL IN	(V_{DD} + 0.5V) to (V_{SS} – 0.5V)
SIGNAL IN Voltage		(V_{DD} + 0.5V) to (V_{SS} – 22V)
Storage Temperature		–65°C to 150°C
Operating Temperature		-30°C to 70°C
Lead Temperature	Soldering, 5 sec.	260°C

ELECTRICAL CHARACTERISTICS

(T_A = 25°C, V_{DD} – V_{SS} = 4.5V to 5.5V, dBm is referenced to 600Ω)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
Supply Current	V_{DD} – V_{SS} = 5V	-	4	10	mA
Signal level for detection	315-640 Hz	–38	-	0	dBm
Signal level for rejection	315-640 Hz	-	-	–50	dBm
	f >1025 Hz, f <190 Hz	-	-	0	dBm
DETECT output (Iout = +1mA)	Logic 0	-	-	0.5	V
	Logic 1	4.5	-	-	V
ENABLE, XIN input (Iin=10μA)	Logic 0	V_{SS}	-	V_{SS}+0.2	V
	Logic 1	V_{DD}–0.2	-	V_{DD}	V
XIN duty cycle		40	-	60	%
XIN, XOUT loading		-	-	10	pF
VREF output	Deviation	–2	(V_{DD}+V_{SS})/2	+2	%
	Resistance	3.25	-	6.75	kΩ
SIGIN input	Maximum voltage	V_{DD}–10	-	V_{DD}	V
	Impedance (500 Hz)	80	-	-	kΩ

5

ELECTRICAL SPECIFICATIONS (continued)

TIMING CHARACTERISTICS
(TA = 25°C, V_{DD} – V_{SS} = 4.5V TO 5.5V)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
t_{MD} Signal duration for detection	315-640 Hz	40		-	ms
Interval duration for detection	Signal dropping from				
	–38 dBm to –50 dBm (t_2)	-		40	ms
	Signal dropping from				
	0 dBm to –50 dBm (t_1)	-		90	ms
t_B Tone dropout bridging		-		20	ms

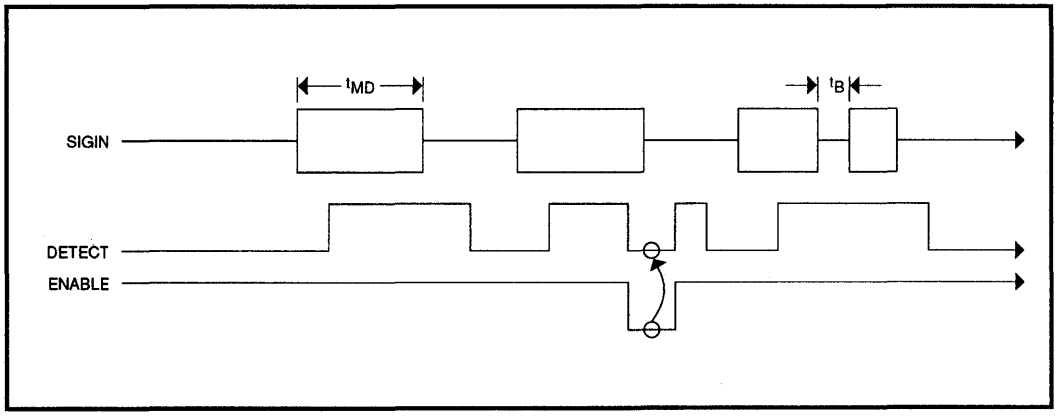


FIGURE 2: Basic Timing

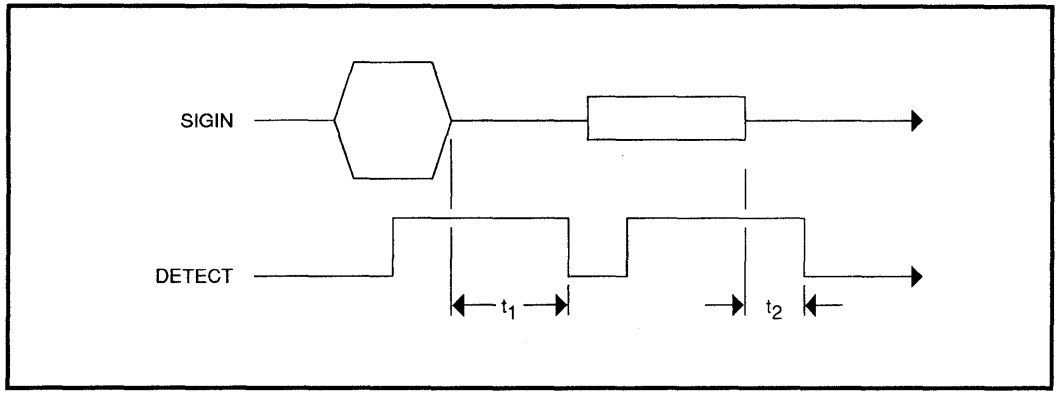


FIGURE 3: Effect of Amplitude on Timing

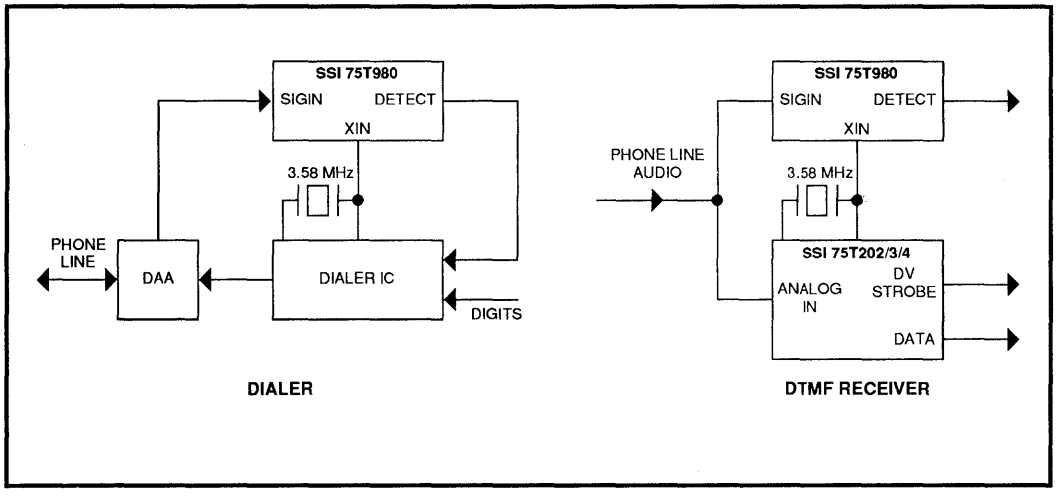
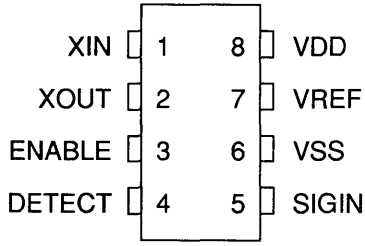


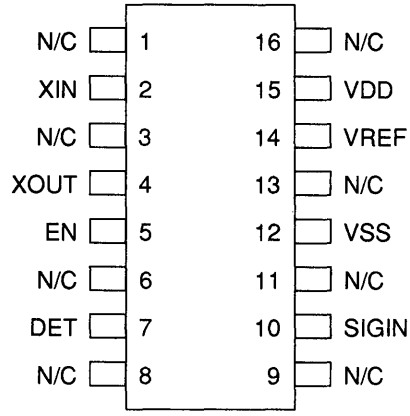
FIGURE 4: Applications Circuits

SSI 75T980
Call Progress
Tone Detector

PACKAGE PIN DESIGNATIONS
(Top View)



8-Pin DIP



16-Lead SO

CAUTION: Use handling procedures necessary for a static sensitive component.

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 75T980 8-pin Plastic DIP	75T980-CP	75T980-CP
SSI 75T980 16-pin SO Package	75T980-CL	75T980C

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SSI 78A207
MFR1 Receiver

July 1990

DESCRIPTION

The SSI 78A207 is a single-chip, Multi-Frequency (MF) receiver that can detect all 15 tone-pairs, including ST and KP framing tones. This receiver is intended for use in equal access applications and thus meets both Bell and CCITT R1 central office register signalling specifications.

The SSI 78A207 employs state-of-the-art switched capacitor filters in CMOS technology. The receiver consists of a bank of channel-separation bandpass filters followed by zero-crossing detectors and frequency-measurement bandpass filters, an amplitude check circuit, a timer and decoder circuit, and a clock generator. The device does not attempt to identify strings of digits by the KP (key pulse) and ST (stop) tone pairs.

No anti-alias filtering is needed if the input signal is band-limited to 26 KHz. The only external component required is an inexpensive television "color burst" 3.58 MHz crystal.

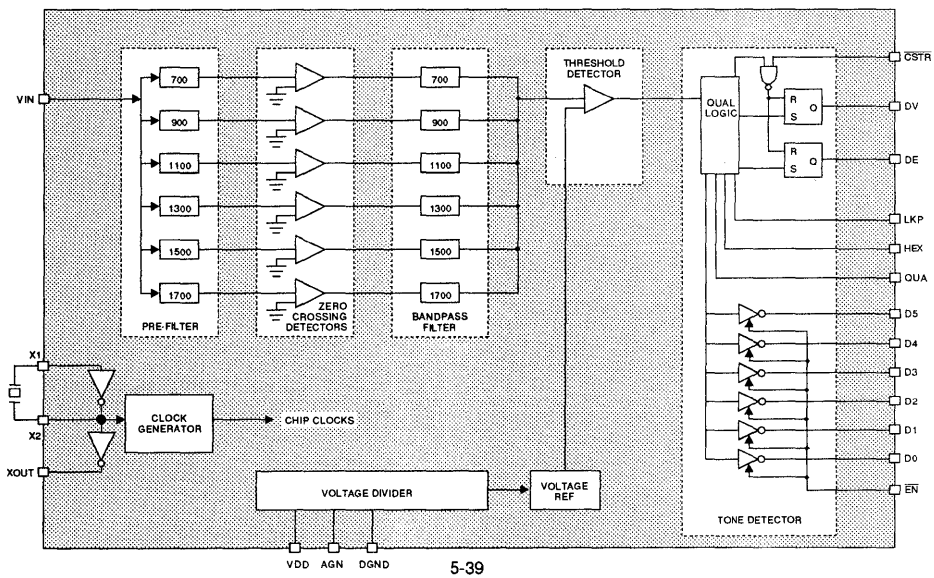
The outputs interface directly with standard CMOS or TTL circuitry and are three-state enabled to facilitate bus-oriented architecture.

FEATURES

- **Meets Bell and CCITT R1 specifications**
- **20-pin plastic DIP**
- **Single low-tolerance 5V supply**
- **Detects all 15 tone-pairs including ST and KP**
- **Long KP capability**
- **Built-in amplitude discrimination**
- **Excellent noise tolerance**
- **Outputs in either "n of 6" or hexadecimal code**
- **Three-state outputs, CMOS-compatible and TTL-compatible**

5

BLOCK DIAGRAM



FUNCTIONAL DESCRIPTION

VIN

This pin accepts the analog input. It is internally biased to half the supply and is capacitively coupled to the channel separation filters. The input may be DC coupled as long as it does not exceed VDD or drop below GND. Equivalent input circuit is shown below in Figure 1.

CRYSTAL OSCILLATOR

The SSI 78A207 contains an on-board inverter with sufficient gain to provide oscillation when connected to a low cost television "color-burst" crystal. The on-chip clock signals are generated from the oscillator. The crystal is connected between X1 and X2.

XOUT is a 3.58 MHz square wave capable of driving other circuits as long as the capacitive load does not exceed 50 pF. Other devices driven by XOUT should use X1 as the input pin, while X2 should be left floating.

LKP

The KP timer control: When high, the KP detect time is increased. When low, the KP detect time is the same as for other tones.

QUAL

Enables tone pair qualification. When low, the threshold detector outputs are passed to the data outputs (D0-D5) without validation in the format selected by the HEX pin. These outputs, plus strobes DV and DE, are updated once per 2.3 ms frame. Note that the strobes will cycle once per frame (even when the inputs are stable.) As always, data changes only when both strobes are low.

$\overline{\text{CSTR}}$

This input clears both the DV and DE strobes, and is active low. After $\overline{\text{CSTR}}$ is released, the strobes will remain low until a new detect (or error) occurs. The output data is latched by $\overline{\text{CSTR}}$ and will not change while $\overline{\text{CSTR}}$ is low, even in the event that a new detect is qualified internally. (Note that improper use of $\overline{\text{CSTR}}$ may result in missed detects.)

$\overline{\text{EN}}$

The three-state enable control: When low, the D0-D5 outputs are in the low impedance state. In an interrupt oriented microprocessor interface, $\overline{\text{EN}}$ and $\overline{\text{CSTR}}$ will often be tied together to provide automatic reset of the strobes when the output data is enabled.

STROBE PINS - DV AND DE

Valid data is indicated on the DV strobe pin, and data errors are indicated on the DE strobe pin. Whenever a valid 2 of 6 code has been detected, the DV strobe rises. It remains high until the code goes away, or the $\overline{\text{CSTR}}$ line is activated. When an invalid code is detected, e.g., 1 of 6, 3 of 6, etc., the DE strobe remains high until all errors stop, a valid tone pair is detected, or the $\overline{\text{CSTR}}$ line is activated. Once cleared by $\overline{\text{CSTR}}$, DE will not reactivate until a new invalid condition is detected. The DE and DV strobes will never be high simultaneously.

DATA OUTPUT MODES

The digital output format may be either "n of 6" or 4-bit hexadecimal.

For "hex" mode, the HEX pin is pulled high. Outputs D0 to D3 provide a 4-bit code identifying one of the 15 valid tone combinations according to Table1.

The outputs will be cleared to zero when no valid tone pair is present.

For the "n of 6" mode, the HEX pin is pulled low, and each output represents one of the six frequencies as shown below:

FREQUENCY	OUTPUT PIN
700	D0
900	D1
1100	D2
1300	D3
1500	D4
1700	D5

The outputs will be cleared to zero when no valid tone is present.

TABLE 1:

Channels	Tone Pair Freq.	Name	D3	D2	D1	D0
0-1	700, 900	1	0	0	0	1
0-2	700, 1100	2	0	0	1	0
1-2	900, 1100	3	0	0	1	1
0-3	700, 1300	4	0	1	0	0
1-3	900, 1300	5	0	1	0	1
2-3	1100, 1300	6	0	1	1	0
0-4	700, 1500	7	0	1	1	1
1-4	900, 1500	8	1	0	0	0
2-4	1100, 1500	9	1	0	0	1
3-4	1300, 1500	0	1	0	1	0
2-5	1100, 1700	KP	1	0	1	1
4-5	1500, 1700	ST	1	1	0	0
1-5	900, 1700	ST1	1	1	0	1
3-5	1300, 1700	ST2	1	1	1	0
0-5	700, 1700	ST3	1	1	1	1
	any other signal		0	0	0	0

NOTE: In the hex mode, D4 = DE and D5 = DV.

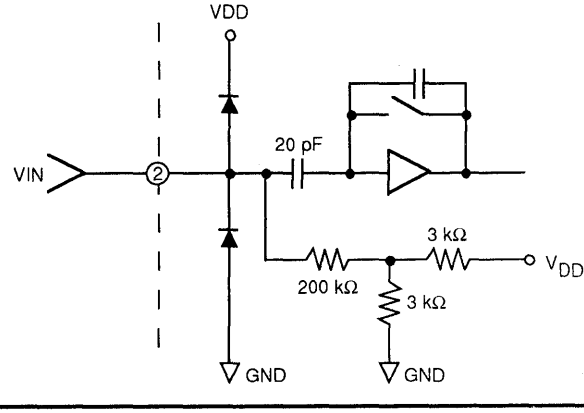


FIGURE 1: VIN Equivalent Input Circuit

TIMING SPECIFICATIONS

	PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
Ton	Tone Time, KP (LKP = VDD)	detect	55			ms
Ton		reject			30	ms
Ton	Tone Time, KP (LKP = DGND)	detect	30			ms
Ton		reject			10	ms
Ton	Tone Time, All Others	detect	30			ms
Ton		reject			10	ms
Tpse	Pause Time	detect	20			ms
Tbr		reject			10	ms
Tsu	Data Setup Time		6			µs
Th	Data Hold Time		7			µs
Tskew	Tone Skew Tolerance				4	ms
Tstr	Minimum Strobe Pulse Width					
	QUAL High		20			ms
	QUAL Low		2			ms
Tsep	Minimum Strobe Separation					
	QUAL High		20			ms
	QUAL Low		2			ms
Tr	Rise Time DV, DE, D0-D5 10-90%	CL = 20 pF			100	ns
Tf	Fall Time DV, DE, D0-D5 10-90%	CL = 20 pF			100	ns
Tw	$\overline{\text{CSTR}}$ Width		50			ns
Ten	Data Enable Time	CL = 20 pF			100	ns
Tdis	Data Disable Time				100	ns
Trst	Strobe Reset Time	CL = 20 pF			100	ns

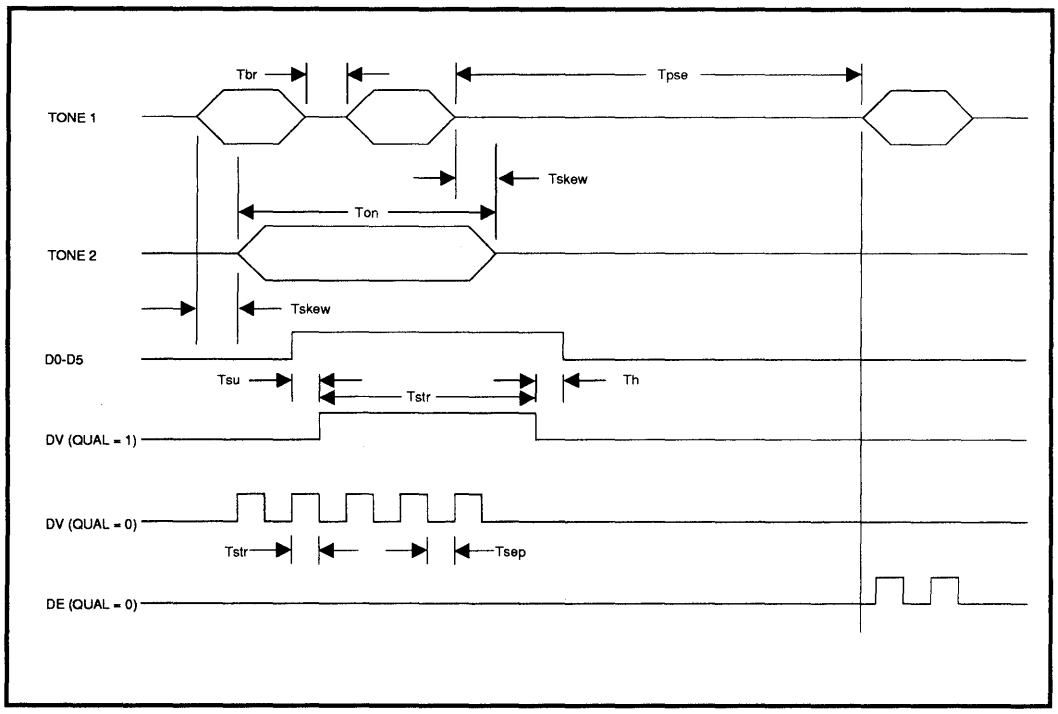


FIGURE 2: SSI 78A207 Timing Diagram

ELECTRICAL CHARACTERISTICS

ABSOLUTE MAXIMUM RATINGS

(Operating above absolute maximum ratings may damage the device.)

PARAMETER	RATING
DC Supply Voltage V_{DD}	+ 7V
Operating Temperature	0 to 70 (Ambient)°C
Storage Temperature	65 to 150°C
Power Dissipation (25°C) (Derate above TA=25°C @ 6.25 mW/°C)	650mW
Input Voltage	(V_{DD} + 0.3V) to -0.3V
DC Current into any input	±10mA
Lead Temperature (Soldering, 10 sec.)	300°C

DC ELECTRICAL CHARACTERISTICS (0°C ≤ TA ≥ 70°C, VDD = 5V ± 10%)

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
Idd	Supply Current				20	mA
Vol	Output Logic 0					
	Iol = 8 mA				0.5	V
	Iol = 1 mA				0.4	V
Voh	Output Logic 1					
	Ioh = -4 mA		VDD-1.0			V
	Ioh = -1 mA		VDD-0.5			V
Vih	Input Logic 1		2.0			V
Voh	Input logic 0				0.8	V
Zin	Analog Input Impedance (Input between VDD and AGND)		$\frac{100K}{30pF}$			Ω
Iin	Digital Input Current (Input between VDD and DGND)		-50		50	µA

AC CHARACTERISTICS (0°C ≤ TA ≥ 70°, VDD = 5V ± 10%)

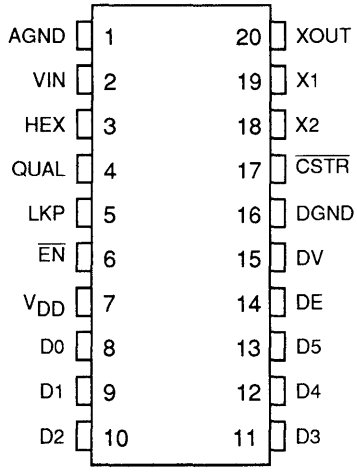
PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
F	Frequency for Detect Tolerance		±(0.015 xFo + 5)			Hz
A	Amplitude for Detect	each tone	-25		0	dBm
			0.123		2.191	Vpp
AN	Amplitude for no Detect				-35	dB
					0.039	Vpp
TW	Twist Tolerance	$TW=\frac{\text{high tone}}{\text{low tone}}$	-6		+6	dB
T3	Third MF Tone Reject Amp	relative to highest amplitude tone	-15			dB
N60	60 HZ Tolerance	not more than one error	81			dBrn
		in 2500 10-digit calls	0.777			Vpp
N180	180 HZ Tolerance	same as above	68			dBrn
			0.174			Vpp
Nn	Noise Tolerance[1]	same as above			-20	dB
NI	Impulse Noise Tolerance[2]	same as above			+12	dB

NOTES: 1. C-message weighted. Measured with respect to highest amplitude tone.

2. With noise tape 201 per PUB 56201. Measured with respect to highest amplitude tone.

PACKAGE PIN DESIGNATIONS

(TOP VIEW)



20 - PIN DIP

CAUTION: Use handling procedures necessary for a static sensitive component.

5

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 78A207 20-Pin Plastic DIP	78A207-CP	78A207-CP

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Notes:

Section 6

PCM PRODUCTS

silicon systems®
A TDK Group Company

SSI 78P300

T1/E1 Integrated Short Haul Transceiver with Receive Jitter Attenuation

December 1993

DESCRIPTION

The SSI 78P300 is a fully integrated transceiver for both North American 1.544 MHz (T1), and European 2.048 MHz (E1/CEPT) applications. Transmit pulse shapes (DSX-1 or E1/CEPT) are selectable for various line lengths and cable types.

The SSI 78P300 provides receive jitter attenuation starting at 3 Hz, and is microprocessor controllable through a serial interface.

The SSI 78P300 offers a variety of diagnostic features including transmit and receive monitoring. Clock inputs may be derived from an on-chip crystal oscillator or digital inputs. The SSI 78P300 uses an advanced double-poly, double-metal CMOS process and requires only a single 5-volt power supply.

APPLICATIONS

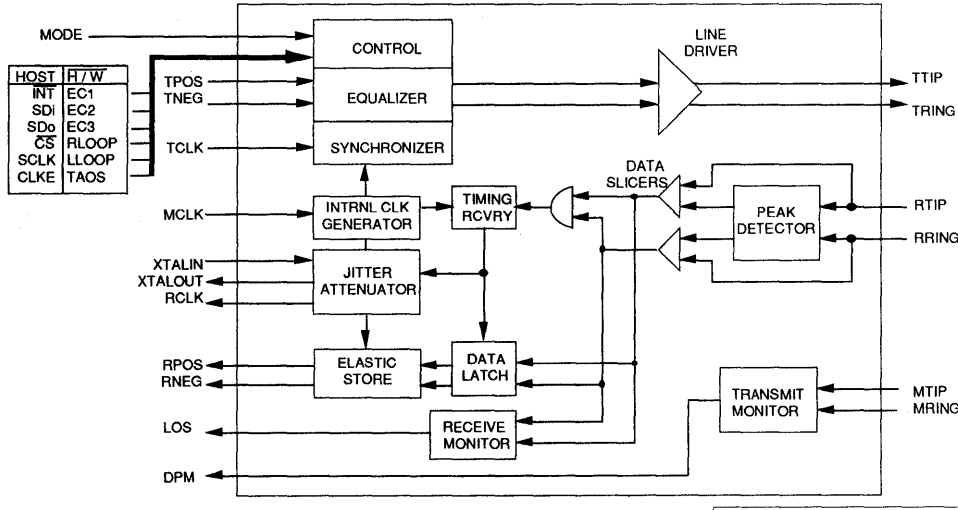
- PCM / Voice Channel Banks
- Data Channel Bank / Concentrator
- T1 / E1 multiplexer
- Digital Access and Cross-connect Systems (DACS)
- Computer to PBX interface (CPI & DMI)
- High speed data transmission lines
- Interfacing Customer Premises Equipment to a CSU
- Digital Loop Carrier (DLC) terminals

FEATURES

- **Compatible with most popular PCM framers including the 2180A and 2181**
- **Line driver, data recovery and clock recovery functions**
- **Pin and functionally compatible with Crystal CS61574**
- **Minimum receive signal of 500 mV**
- **Selectable slicer levels (CEPT/DSX-1) improve SNR**
- **Programmable transmit equalizer shapes pulses to meet DSX-1 pulse template from 0 to 655 ft**
- **Local and remote loopback functions**
- **Transmit Driver Performance Monitor (DPM) output**
- **Receive monitor with Loss of Signal (LOS) output**
- **Receiver jitter tolerance 0.4 UI from 40 kHz to 100 kHz**
- **Microprocessor controllable**
- **Receive jitter attenuation starting at 6 Hz**
- **Available in 28 pin DIP or PLCC**

6

BLOCK DIAGRAM



CAUTION: Use handling procedures necessary for a static sensitive component.

SSI 78P300
T1/E1 Integrated Short Haul Transceiver with Receive Jitter Attenuation

FUNCTIONAL DESCRIPTION

The SSI 78P300 is a fully integrated PCM transceiver for both 1.544 MHz (DSX-1) and 2.048 MHz (CEPT) applications. This transceiver allows transmission of digital data over existing twisted-pair installations.

The SSI 78P300 transceiver interfaces with two twisted-pair lines (one twisted-pair for transmit, one twisted-pair for receive) through standard pulse transformers and appropriate resistors.

TRANSMITTER

Data received for transmission onto the line is clocked serially into the device at TPOS and TNEG. Input synchronization is supplied by the transmit clock (TCLK). The transmitted pulse shape is determined by Equalizer Control signals EC1 through EC3 as shown in Table 1. Refer to Table 2 and Figure 1 for master and transmit clock timing characteristics. Shaped pulses are applied to the AMI line driver for transmission onto the line at TTIP and TRING. Equalizer Control signals may be hardwired in the Hardware mode, or input as part of the serial data stream (SDI) in the Host mode.

Pulses can be shaped for either 1.544 or 2.048 MHz applications. 1.544 MHz pulses for DSX-1 applications can be programmed to match line lengths from 0 to 655 feet of ABAM cable. The SSI 78P300 also matches FCC and ECSA specifications for CSU applications. 2.048 MHz pulses can drive coaxial or shielded twisted-pair lines using appropriate resistors in line with the output transformer.

DRIVER PERFORMANCE MONITOR

The transceiver incorporates a Driver Performance Monitor (DPM) in parallel with the TTIP and TRING at the output transformer. The DPM output level goes high upon detection of 63 consecutive zeros. It is reset when a one is detected on the transmit line, or when a reset command is received.

LINE CODE

The SSI 78P300 transmits data as a 50% AMI line code as shown in Figure 2. Power consumption is reduced by activating the AMI line driver only to transmit a mark. The output driver is disabled during transmission of a space.

RECEIVER

The SSI 78P300 receives AMI signals from one twisted-pair line on each side of a center-grounded transformer. Positive pulses are received at RTIP and negative pulses are received at RRING. Recovered data is output at RPOS and RNEG, and the recovered clock is output at RCLK. Refer to Table 3 and Figure 3 for SSI 78P300 receiver timing.

The signal received at RPOS and RNEG is processed through the peak detector and data slicers. The peak detector samples the inputs and determines the maximum value of the received signal. A percentage of the peak value is provided to the data slicers as a threshold level to ensure optimum signal-to-noise ratio.

For DSX-1 applications (determined by Equalizer Control inputs EC1 - EC3 $\neq$ 000) the threshold is set to 70% of the peak value. This threshold is maintained above 65% for up to 15 successive zeros over the range of specified operating conditions. For CEPT applications (EC inputs = 000) the threshold is set to 50 %.

The receiver is capable of accurately recovering signals with up to -13.6 dB of cable attenuation (from 2.4 V), corresponding to a received signal level of approximately 500 mV (1500 feet of ABAM cable.) Regardless of received signal level, the peak detectors are held above a minimum level of .3 V to provide immunity from impulsive noise.

After processing through the data slicers, the received signal is routed to the data and clock recovery sections, and to the receive monitor. The receive monitor generates a Loss of Signal (LOS) output upon receipt of 175 consecutive zeros (spaces). The receiver monitor loads a digital counter at the RCLK frequency. The count is incremented each time a zero is received, and reset to zero each time a one (mark) is received. Upon receipt of 175 consecutive zeros the LOS pin goes high, and the RCLK output is replaced with the MCLK. If MCLK is not supplied the RCLK output will be replaced with the centered crystal clock.

The LOS pin will reset as soon as a one (mark) is detected.Recovered clock signals are supplied to the jitter attenuator and the data latch. The recovered data is passed to the elastic store where it is buffered and synchronized with the dejittered recovered clock (RCLK).

JITTER ATTENUATION

Jitter attenuation of the SSI 78P300 clock and data outputs is provided by a Jitter Attenuation Loop (JAL) and an Elastic Store (ES). An external crystal oscillating at 4 times the bit rate provides clock stabilization. Refer to Table 4 for crystal specifications. The ES is a 32 x 2-bit register. Recovered data is clocked into the ES with the recovered clock signal, and clocked out of the ES with the dejittered clock from the JAL. When the bit count in the ES is within two bits of overflowing or underflowing, the ES adjusts the output clock by 1/8 of a bit period. The ES produces an average delay of 16 bits in the receive path.

OPERATING MODES

The SSI 78P300 transceiver can be controlled through hard-wired pins (Hardware mode). This transceiver can also be commanded to operate in one of several diagnostic modes.

The SSI 78P300 can be controlled by a microprocessor through a serial interface (Host mode). The mode of operation is set by the MODE pin logic level.

HOST MODE OPERATION

To allow a host microprocessor to access and control the SSI 78P300 through the serial interface, MODE is set to 1. The serial interface (SDI/SDO) uses a 16-bit word consisting of an 8-bit Command/Address byte and an 8-bit Data byte. Figure 4 shows the serial interface data structure and timing.

The Host mode provides a latched Interrupt output ($\overline{INT}$) which is triggered by a change in the Loss of Signal (LOS) and/or Driver Performance Monitor (DPM) bits. The Interrupt is cleared when the interrupt condition no longer exists, and the host processor enables the respective bit in the serial input data byte. Host mode also allows control of the serial data and receive data output timing. The Clock Edge (CLKE) signal determines when these outputs are valid, relative to the Serial Clock (SCLK) or RCLK as follows:

CLKE	OUTPUT	CLOCK	VALID EDGE
LOW	RPOS	RCLK	RISING
	RNEG	RCLK	RISING
	SDO	SCLK	FALLING
HIGH	RPOS	RCLK	FALLING
	RNEG	RCLK	FALLING
	SDO	SCLK	RISING

The SSI 78P300 serial port is addressed by setting bit A4 in the Address/Command byte, corresponding to address 16. The SSI 78P300 contains only a single output data register so no complex chip addressing scheme is required. The register is accessed by causing the Chip Select (CS) input to make a transition from high to low. Bit 1 of the serial Address/Command byte provides Read/Write control when the chip is accessed. A logic 1 indicates a read operation, and a logic 0 indicates a write operation. Table 5 lists serial data output bit combinations for each status. Serial data I/O timing characteristics are shown in Table 6, and Figures 5 and 6.

HARDWARE MODE OPERATION

In Hardware mode the transceiver is accessed and controlled through individual pins. With the exception of the $\overline{INT}$ and CLKE functions, Hardware mode provides all the functions provided in the Host mode. In the Hardware mode RPOS and RNEG outputs are valid on the rising edge of RCLK. To operate in Hardware mode, MODE must be set to 0. Equalizer Control signals (EC1 through EC3) are input on the Interrupt, Serial Data In and Serial Data Out pins. Diagnostic control for Remote Loopback (RLOOP), Local Loopback (LLOOP), and Transmit All Ones (TAOS) modes is provided through the individual pins used to control serial interface timing in the Host mode.

RESET OPERATION

Upon power up, the transceiver is held static until the power supply reaches approximately 3V. Upon crossing this threshold, the device begins a 32 ms reset cycle to calibrate the transmit and receive delay lines and lock the Phase Lock Loop to the receive line. A reference clock is required to calibrate the delay lines. The transmitter reference is provided by TCLK. The crystal oscillator provides the receiver reference in the SSI 78P300. If the SSI 78P300 crystal oscillator is grounded, MCLK is used as the receiver reference clock.

The transceiver can also be reset from the Host or Hardware mode. In Host mode, reset is commanded by simultaneously writing RLOOP and LLOOP to the register. In Hardware mode, reset is commanded by holding RLOOP and LLOOP high simultaneously for 200 ns. Reset is initiated on the falling edge of the reset request. In either mode, reset clears and sets all registers to 0 and centers the oscillator, then begins calibration.

DIAGNOSTIC MODE OPERATION

In Transmit All Ones (TAOS) mode the TPOS and TNEG inputs to the transceiver are ignored. The transceiver transmits a continuous stream of 1's when the TAOS mode is activated. TAOS can be commanded simultaneously with Local Loopback, but is inhibited during Remote loopback.

In Remote Loopback (RLOOP) mode, the transmit data and clock inputs (TPOS, TNEG and TCLK) are ignored. The RPOS and RNEG outputs are looped back through the transmit circuits and output on TTIP and TRING at the RCLK frequency. Receiver circuits are unaffected by the RLOOP command and continue to output the RPOS, RNEG and RCLK signals received from the twisted-pair line.

In Local Loopback (LLOOP) mode, the receiver circuits are inhibited. The transmit data and clock inputs (TPOS, TNEG and TCLK) are looped back onto the receive data and clock outputs (RPOS, RNEG and RCLK.) The transmitter circuits are unaffected by the LLOOP command. The TPOS and TNEG inputs (or a stream of 1's if the TAOS command is active) will be transmitted normally. When used in this mode with a crystal, the transceiver can be used as a stand-alone jitter attenuator.

POWER REQUIREMENTS

The SSI 78P300 is a low-power CMOS device. It operates from a single +5V power supply which can be connected externally to both the transmitter and receiver. However, the two inputs must be within ±.3V of each other, and decoupled to their respective grounds separately, as shown in Figure 7. Isolation between the transmit and receive circuits is provided internally.

PIN DESCRIPTION

NAME	TYPE	DESCRIPTION
MCLK	I	Master Clock: A 1.544 or 2.048 MHz clock input used to generate internal clocks. Upon Loss of Signal (LOS), RCLK is derived from MCLK. If MCLK not applied, this pin should be grounded.
TCLK	I	Transmit Clock: Transmit clock input. TPOS and TNEG are sampled on the falling edge of TCLK.
TPOS	I	Transmit Positive Data: Input for positive pulse to be transmitted on the twisted-pair or coaxial cable.
TNEG	I	Transmit Negative Data: Input for negative pulse to be transmitted on the twisted-pair or coaxial cable.
MODE	I	Mode Select: Setting MODE to logic 1 puts the SSI 78P300 in the Host mode. In the Host mode, the serial interface is used to control the SSI 78P300 and determined its status. Setting MODE to logic 0 puts the SSI 78P300 in the Hardware (H/W) mode. In the Hardware mode the serial interface is disabled and hard-wired pins are used to control configuration and report status.
RNEG/RPOS	O	Receive Negative Data/Receive Positive Data: Received data outputs. A signal on RNEG corresponds receipt of a negative pulse on RTIP and RRING. A signal on RPOS corresponds to receipt of a positive pulse on RTIP and RRING. RNEG and RPOS outputs are Non-Return-to-Zero (NRZ). In the Host Mode, CLKE determines the clock edge (RCLK) at which these outputs are stable and valid. In the Hardware mode both outputs are stable and valid on the rising edge or RCLK.
RCLK	O	Recovered Clock: This is the clock recovered from the signal received at RTIP and RRING.

PIN DESCRIPTION (continued)

NAME	TYPE	DESCRIPTION
XTALIN/ XTALOUT	I/O	Crystal Input/Crystal Output: An external crystal operating at four times the bit rate (6.176 MHz for DSX-1, 8.192 MHz for CEPT applications with an 18.7 pF load) is required to enable the jitter attenuation function of the SSI 78P300. These pins may also be used to disable the jitter attenuator by connecting the XTALIN pin to the positive supply through a resistor, and tying the XTALOUT pin to ground.
DPM	O	Driver Performance Monitor: DPM goes to a logic 1 when the transmit monitor loop (MTIP and MRING) does not detect a signal for 63 ±2 clock periods. DPM remains at logic 1 until a signal is detected.
LOS	O	Loss Of Signal: LOS goes to a logic 1 when 175 consecutive spaces have been detected. LOS returns to a logic 0 when a mark is detected.
TTIP/TRING	O	Transmit Tip/Transmit Ring: Differential Driver Outputs. These outputs are designed to drive a 25 Ω load. The transmitter will drive 100 Ω shielded twisted-pair cable through a 2:1 step-up transformer without additional components. To drive 75 Ω coaxial cable, two 2.2 Ω resistors are required in series with the transformer.
TGND	-	Transmit Ground: Ground return for the transmit drivers power supply TV+.
TV+	I	Transmit Power Supply: +5 VDC power supply input for the transmit drivers. TV+ must not vary from RV+ by more than ±0.3V.
MTIP/MRING	I	Monitor Tip/Monitor Ring: These pins are used to monitor the tip and ring transmit outputs. The transceiver can be connected to monitor its own output or the output of another SSI 78P300. To prevent false interrupts in the Host mode if the monitor is not used, apply a clock signal to one of the monitor pins and tie the other monitor pin to approximately the clock's mod-level voltage. The monitor clock can range from 100 kHz to the TCLK frequency.
RTIP/RRING	I	Receive Tip/Receive Ring: The AMI signal received from the line is applied at these pins. A center-tapped, center-grounded, 2:1 step-up transformer is required on these pins. Data and clock from the signal applied at these pins are recovered and output on the RPOS/RNEG, and RCLK pins.
RV+	I	Receive Power Supply: +5 VDC power supply for all circuits except the transmit drivers. (Transmit drivers are supplied by TV+.)
RGND	-	Receive Ground: Ground return for power supply RV+.
$\overline{INT}$	O	Interrupt (Host Mode): This SSI 78P300 Host mode output goes low to flag the host processor when LOS or DPM go active. $\overline{INT}$ is an open-drain output and should be tied to power supply RV+ through a resistor. $\overline{INT}$ is reset by clearing the respective register bit (LOS and/or DPM.)
EC1	I	Equalizer Control 1 (H/W Mode): The signal applied at this pin in the SSI 78P300 Hardware mode is used in conjunction with EC2 and EC3 inputs to determine shape and amplitude of AMI output transmit pulses.

PIN DESCRIPTION (continued)

NAME	TYPE	DESCRIPTION
SDI	I	Serial Data In (Host Mode): The serial data input stream is applied to this pin when the SSI 78P300 operates in the Host mode. SDI is sampled on the rising edge of SCLK.
EC2	I	Equalizer Control 2 (H/W Mode): The signal applied at this pin in the SSI 78P300 Hardware mode is used in conjunction with EC1 and EC3 inputs to determine shape and amplitude of AMI output transmit pulses.
SDO	O	Serial Data Out (Host Mode): The serial data from the on-chip register is output on this pin in the SSI 78P300 Host mode. If CLKE is high, SDO is valid on the rising edge of SCLK. If CLKE is low SDO is valid on the falling edge of SCLK. This pin goes to a high-impedance state when the serial port is being written to and when $\overline{CS}$ is high.
EC3	I	Equalizer Control 3 (H/W Mode): The signal applied at this pin in the SSI 78P300 Hardware mode is used in conjunction with EC1 and EC2 inputs to determine shape and amplitude of AMI output transmit pulses.
$\overline{CS}$	I	Chip Select (Host Mode): This input is used to access the serial interface in the SSI 78P300 Host mode. For each read or write operation, $\overline{CS}$ must remain low for duration of operation.
RLOOP	I	Remote Loopback (H/W Mode): This input controls loopback functions in the SSI 78P300 Hardware mode. Setting RLOOP to a logic 1 enables the Remote Loopback mode. Setting both RLOOP and LLOOP causes a Reset.
SCLK	I	Serial Clock (Host Mode): This clock is used in the SSI 78P300 Host mode to write data to or read data from the serial interface registers.
LLOOP	I	Local Loopback (H/W Mode): This input controls loopback functions in the SSI 78P300 Hardware mode. Setting LLOOP to a logic 1 enables the Local Loopback Mode.
CLKE	I	Clock Edge (Host Mode): Setting CLKE to logic 1 causes RPOS and RNEG to be valid on the falling edge of RCLK, and SDO to be valid on the rising edge of SCLK. When CLKE is a logic 0, RPOS and RNEG are valid on the rising edge of RCLK, and SDO is valid on the falling edge of SCLK.
TAOS	I	Transmit All Ones (H/W Mode): When set to a logic 1, TAOS causes the SSI 78P300 (Hardware mode) to transmit a continuous stream of marks at the TCLK frequency. Activating TAOS causes TPOS and TNEG inputs to be ignored. TAOS is inhibited during Remote Loopback.

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Operation above maximum ratings may damage the device.

PARAMETER	RATING
DC Supply (referenced to GND), RV+, TV+	0 to 6.0V
Input Voltage, Any Pin, V_{IN} (see note 1)	RGND -0.03 to RV+ +0.03V
Input Current, Any Pin, I_{in} (see note 2)	-10 to 10mA
Ambient Operating Temperature, T_A	-40 to 85°C
Storage Temperature, T_{STG}	-65 to 150°C

[1] Excluding RTIP and RRING which must stay within -6V to RV+ + 0.3V.

[2] Transient currents of up to 100 mA will not cuase SCR latch-up. TTIP, TRING, TV+ and TGND can withstand a continuous current of 100 mA.

RECOMMENDED OPERATING CONDITIONS

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
DC supply, RV+, TV+ (see note 1)		4.75	5.0	5.25	V
Ambient Operating Temp., T_A		-40	25	85	°C
Total Power Dissipation, P_D (see note 2)	100% Ones Density & Maximum Line Length @ 5.25V	-	620	-	mW

[1] TV+ must not exceed RV+ by more than ±0.3V.

[2] Power dissipation while driving 25Ω load over operating temperature range. Includes device and load. Digital input levels are within 10% of the supply rails and digital outputs are driving a 50pF capacitive load.

DIGITAL CHARACTERISTICS

T_A = -40° to 85°C, V+ = 5.0 V± 5%, GND = 0V

V_{IH}	High Level Input Voltage (pins 1-5, 10, 23-28) (see note 1, 2)		2.0	-	-	V
V_{IL}	Low Level Input Voltage (pins 1-5, 10, 23-28) (see note 1, 2)		-	-	0.8	V
V_{OH}	High Level Output Voltage (pins 6-8, 11, 12, 23, 25) (see note 1, 2)	I_{OUT} = -400 µA	2.4	-	-	V
V_{OL}	Low Level Output Voltage (pins 6-8, 11, 12, 23, 25) (see note 1, 2)	I_{OUT} = 1.6 mA	-	-	0.4	V
I_{LL}	Input Leakage Current		0		±10	µA
I_{3L}	Three -State Leakage Current (pin 25) (see note 1)		0	-	±10	µA

[1] Functionality of pins 23 and 25 depends on mode. See Host / Hardware Mode descriptions.

[2] Output drivers will output CMOS logic levels into CMOS loads.

ELECTRICAL SPECIFICATIONS (continued)

ANALOG SPECIFICATIONS

T_A = -40° to 85°C, V+ = 5.0 V± 5%, GND = 0V

PARAMETER		TEST CONDITIONS	MIN	NOM	MAX	UNIT
AMI Output Pulse Amplitudes	DSX-1	Measured at the DSX	2.4	3.0	3.6	V
	CEPT	Measured at Line Side	2.7	3.0	3.3	V
Load Presented to Transmitter Output			-	25	-	Ω
Jitted Added by the Transmitter (see note 1)	10 Hz - 8 kHz		-	-	0.01	UI
	8 kHz - 40 kHz		-	-	0.025	UI
	10 Hz - 40 kHz		-	-	0.025	UI
	Broad Band		-	-	0.05	UI
Sensitivity Below DSX	(0dB = 2.4V)		13.6	-	-	dB
			500	-	-	mV
Loss of Signal Threshold			-	0.3	-	V
Data Decision Threshold	DSX-1		63	70	77	%peak
	CEPT		43	50	57	%peak
Allowable Consecutive Zeros Before LOS			160	175	190	-
Input Jitter Tolerance 10 kHz - 100 kHz			0.4	-	-	UI
Jitter Attenuation Curve Corner Frequency (see note 2)			-	3	-	Hz

[1] Input signal to TCLK is jitter-free.
[2] Circuit attenuates jitter at 20 dB/decade above the corner frequency.

TABLE 1: Equalizer Control Inputs

EC3	EC2	EC1	LINE LENGTH	CABLE LOSS	APPLICATION	FREQUENCY
0	1	1	0 - 133 ft ABAM	0.6 dB		
1	0	0	133 - 266 ft ABAM	1.2 dB		
1	0	1	266 - 399 ft ABAM	1.8 dB	DSX-1	1.544 MHz
1	1	0	399 - 533 ft ABAM	2.4 dB		
1	1	1	533 - 655 ft ABAM	3.0 dB		
0	0	0	CCITT Recommendation G.703		CEPT	2.048 MHz
0	1	0	FCC Part 68, Option A		CSU	1.544 MHz
0	1	1	ECSA T1C1.2			

TABLE 2: 78P300 Master Clock and Transmit Timing Characteristics

PARAMETER			CONDITIONS	MIN	NOM	MAX	UNIT
Master clock frequency	MCLK	DSX-1		-	1.544	-	MHz
	MCLK	CEPT		-	2.048	-	MHz
Master clock tolerance	MCLKt			-	±100	-	ppm
Master clock duty cycle	MCLKd			40	-	60	%
Crystal frequency	fc	DSX-1		-	6.176	-	MHz
	fc	CEPT		-	8.192	-	MHz
Transmit clock frequency	TCLK	DSX-1		-	1.544	-	MHz
	TCLK	CEPT		-	2.048	-	MHz
Transmit clock tolerance	TCLKt			-	-	±50	ppm
Transmit clock duty cycle	TCLKd			10	-	90	%
TPOS/TNEG to TCLK setup time	t_{SUT}			25	-	-	ns
TCLK to TPOS/TNEG Hold time	t_{HT}			25	-	-	ns

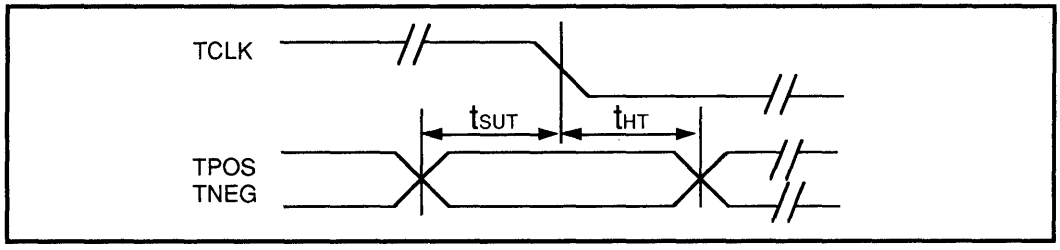


FIGURE 1: 78P300 Transmit Clock Timing Diagram

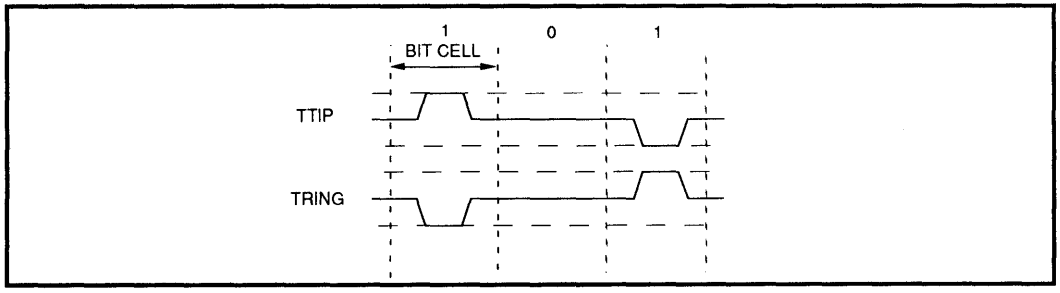


FIGURE 2: 50% AMI Coding Diagram

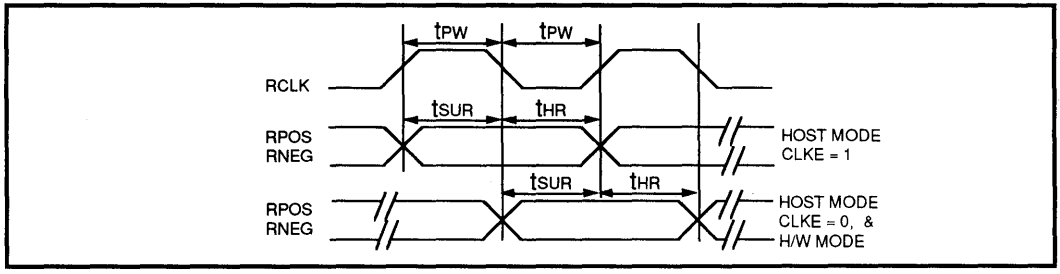


FIGURE 3: 78P300 Receive Clock Timing Diagram

TABLE 3: 78P300 Receive Timing Characteristics

PARAMETER			CONDITIONS	MIN	NOM[1]	MAX	UNIT
Receive clock duty cycle RCLKd				40	-	60	%
Receive clock pulse width	tPW	DSX-1		-	324	-	ns
	tPW	CEPT		-	244	-	ns
RPOS/RNEG to RCLK	tSUR	DSX-1		-	274	-	ns
rising setup time	tSUR	CEPT		-	194	-	ns
RCLK rising to RPOS/	tHR	DSX-1		-	274	-	ns
RNEG hold time	tHR	CEPT		-	194	-	ns

[1] Typical figures are at 25°C and are for design aid only; not guaranteed and not subject to production testing.

TABLE 4: SSI 78P300 Crystal Specifications (External)

PARAMETER	T1	CEPT
Frequency	6.176 MHz	8.192 MHz
Frequency Stability	±20 ppm @ 25°C	±20 ppm @ 25°C
	±25 ppm from -40°C to + 85°C (Ref 25°C reading)	± 25 ppm from -40°C to + 85°C (Ref 25°C reading)
Pullability	CL = 11 pF to 18.7 pF, +ΔF = 175 to 195 ppm	CL = 11 pF to 18.7 pF, +ΔF = 95 to 115 ppm
	CL = 18.7 pF to 34 pF, -ΔF = 175 to 195 ppm	CL = 18.7 pF to 34 pF, -ΔF = 95 to 115 ppm
Effective series resistance	40 Ω Maximum	30 Ω Maximum
Crystal cut	AT	AT
Resonance	Parallel	Parallel
Maximum drive level	2.0 mW	2.0 mW
Mode of operation	Fundamental	Fundamental
Crystal holder	HC49 (R3W), C_O = 7 pF Maximum C_M = 17 pF typical	HC49 (R3W), C_O = 7 pF Maximum C_M = 17 pF typical

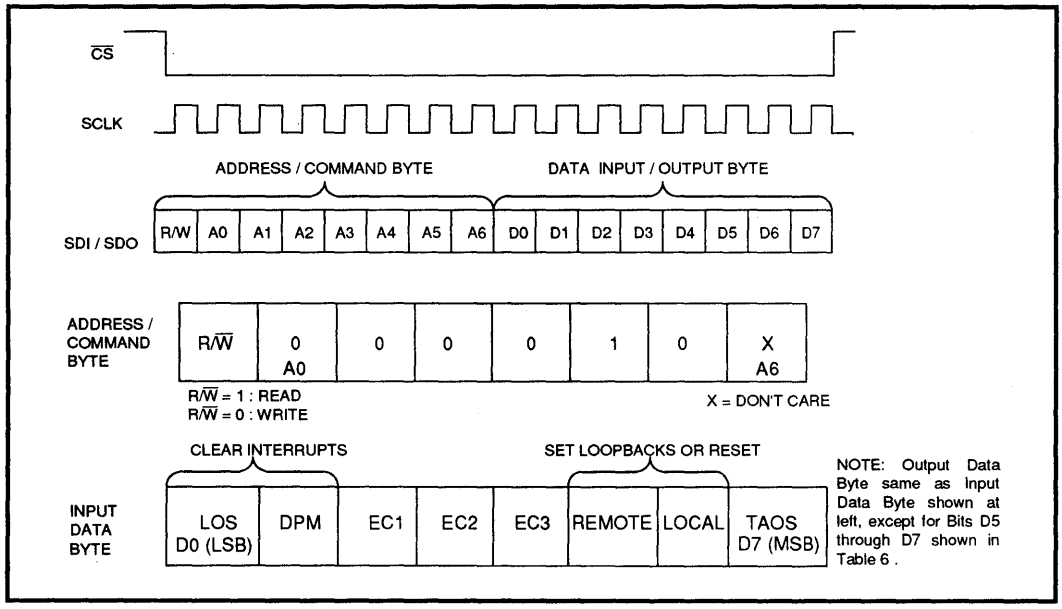


FIGURE 4: SSI 78P300 Serial Interface Data Structure

TABLE 5: SSI 78P300 Serial Data Output Bits (See Figure 4)

BIT D5	BIT D6	BIT D7	STATUS
0	0	0	Reset has occurred, or no program input.
0	0	1	TAOS active
0	1	0	Local Loopback active
0	1	1	TAOS and Local Loopback active
1	0	0	Remote Loopback active
1	0	1	DPM has changed state since last Clear DPM occurred
1	1	0	LOS has changed state since last Clear LOS occurred
1	1	1	LOS and DPM have both changed state since last Clear DPM and Clear LOS occurred

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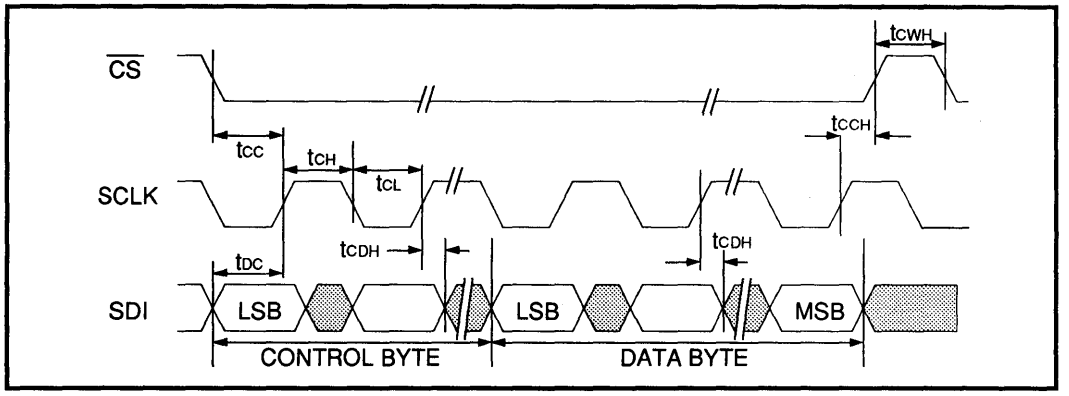


FIGURE 5: SSI 78P300 Serial Data Input Timing Diagram

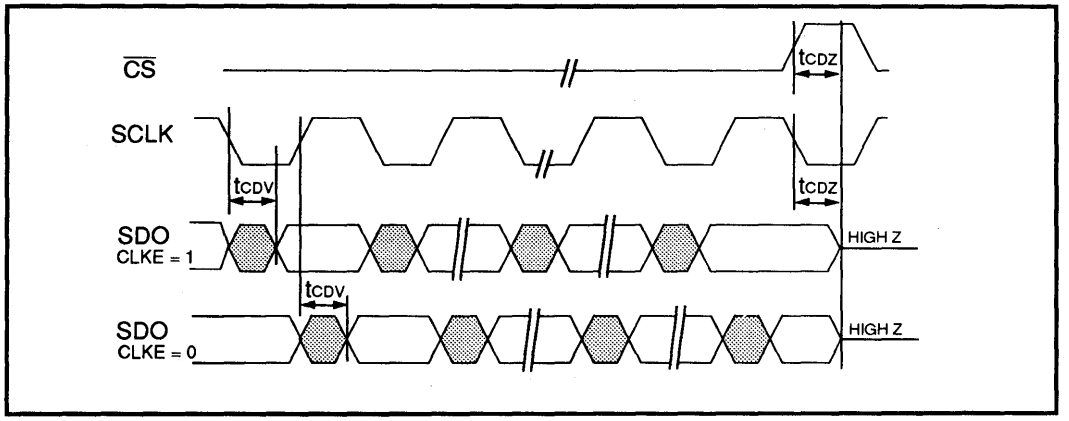


FIGURE 6: SSI 78P300 Serial Data Output Timing Diagram

TABLE 6: SSI 78P300 Serial I/O Timing Characteristics (See Figures 5 and 6)

PARAMETER		CONDITIONS	MIN	NOM[1]	MAX	UNIT
Rise/Fall time - any digital output	t_{RF}	Load 1.6 mA, 50 pF	-	-	100	ns
SDI to SCLK setup time	t_{DC}		50	-	-	ns
SCLK to SDI hold time	t_{CDH}		50	-	-	ns
SCLK low time	t_{CL}		240	-	-	ns
SCLK high time	t_{CH}		240	-	-	ns
SCLK rise and fall time	t_R, t_F		-	-	50	ns
CS to SCLK setup time	t_{CC}		50	-	-	ns
SCLK to CS hold time	t_{CCH}		50	-	-	ns
CS inactive time	t_{CWH}		250	-	-	ns
SCLK to SDO valid	t_{CDV}		-	-	200	ns
SCLK falling edge or CS rising edge to SDO high Z	t_{CDZ}		-	100	-	ns

[1] Typical figures are at 25°C and are for desing aid only; not guaranteed and not subject to production testing.

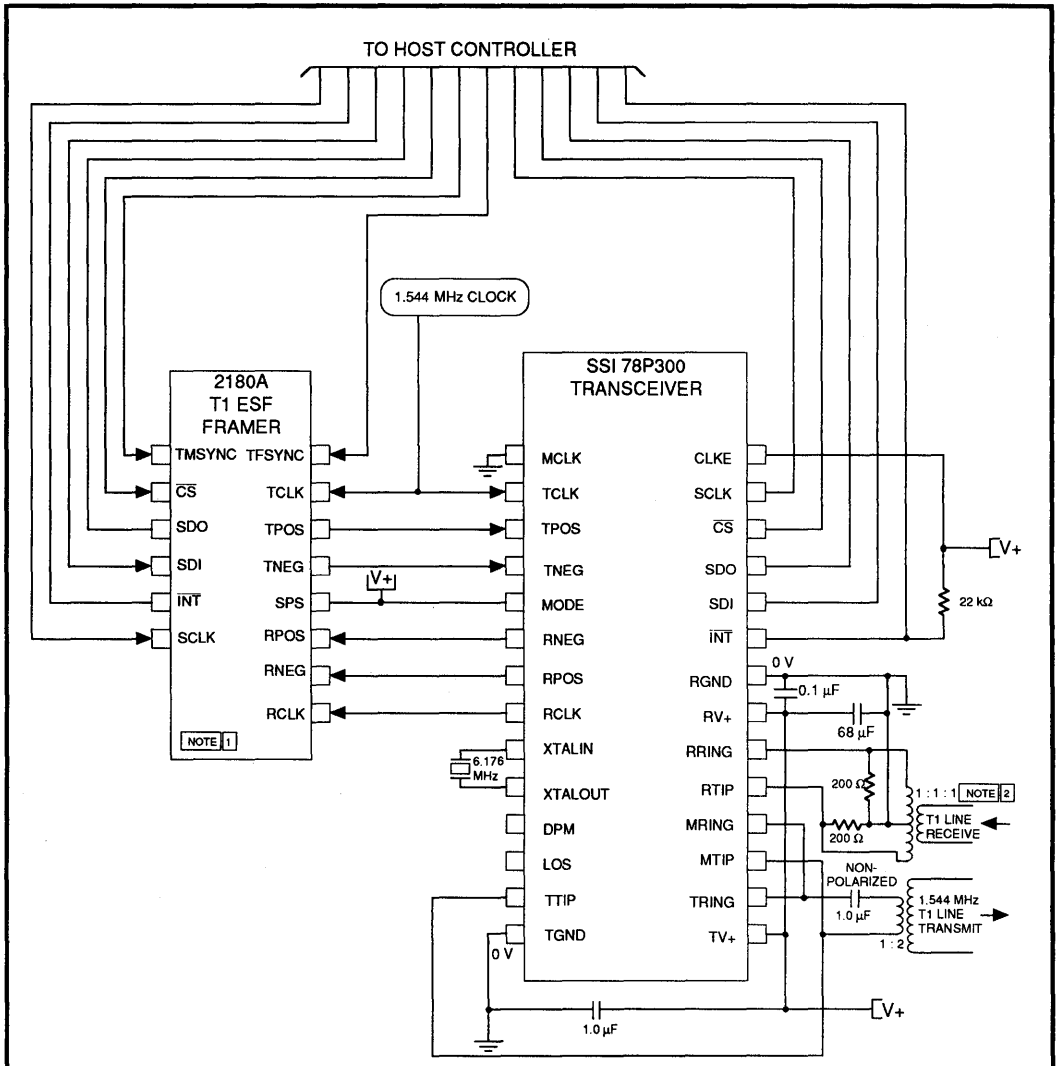
APPLICATION INFORMATION

SSI 78P300 1.544 MHz T1 INTERFACE APPLICATIONS

Figure 7 is a typical 1.544 MHz T1 application. The SSI 78P300 is shown in the Host mode with the 2180A T1/ESF Framer providing the digital interface with the host controller. Both devices are controlled through the serial interface. The power supply inputs are tied to a common bus with appropriate decoupling capacitors installed (1.0 µF on the transmit side, 68 µF and 0.1 µF on the receive side.)

SSI 78P300 2.048 MHz E1/CEPT INTERFACE APPLICATIONS

Figure 8 is a typical 2.048 MHz E1/CEPT application. The SSI 78P300 is shown in Hardware mode with the 2181 E1/CRC4 Framer. Resistors are installed in line with the transmit transformer for loading a 75 Ω coaxial cable. The in-line resistors are not required for transmission on 100 Ω shielded twisted-pair lines. As in the T1 application Figure 7, this configuration is illustrated with a crystal in place to enable the SSI 78P300 Jitter Attenuation Loop, and a single power supply bus. The hard-wired control lines for TAOS, LLOOP and RLOOP are individually controllable, and the LLOOP and RLOOP lines are also tied to a single control for the Reset function.



NOTE 1 THE SSI 78P300 IS COMPATIBLE WITH A WIDE VARIETY OF DIGITAL FRAMING AND SIGNALING DEVICES, INCLUDING THE LXP 2180A, LXP2181, DS2180A, MT8976, AND R8070.

NOTE 2 WHEN THE SSI 78P300 IS CONNECTED TO THE CROSS-CONNECT FRAME THROUGH A LOW LEVEL MONITOR JACK, RECEIVE TRANSFORMER SHOULD BE 1 : 2 : 2 TO BOOST THE INPUT SIGNAL.

FIGURE 7: Typical SSI 78P300 1.544 MHz T1 Application (Host Mode)

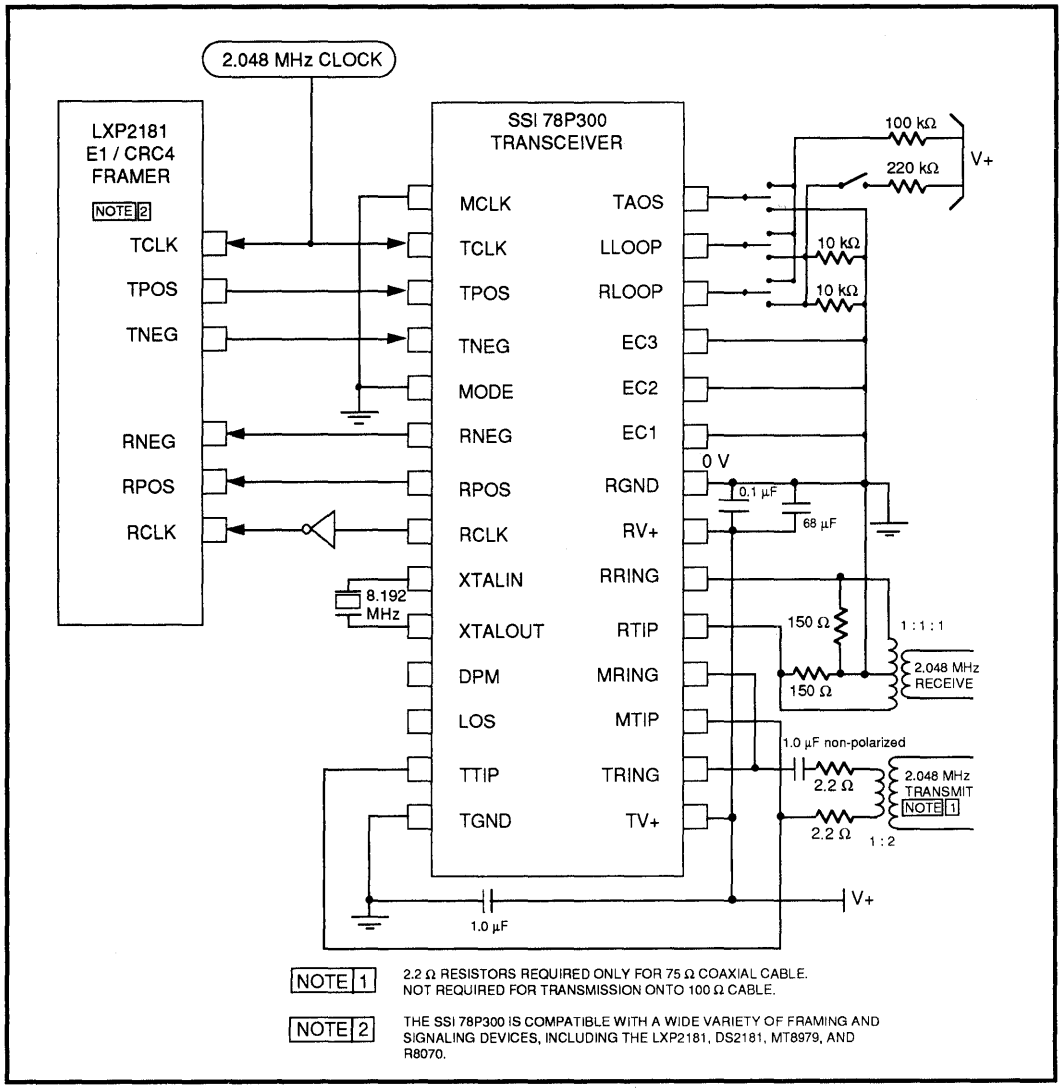


FIGURE 8: Typical SSI 78P300 2.048 MHz E1 Application (Hardware Mode)

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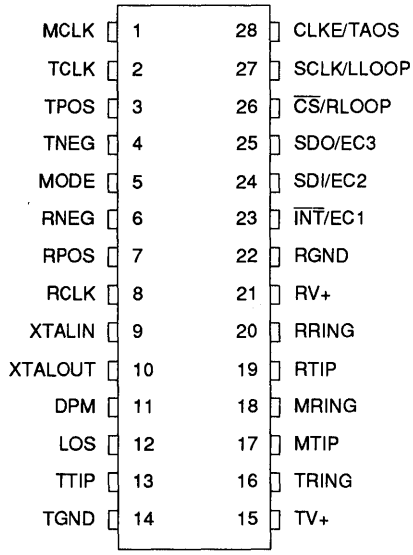
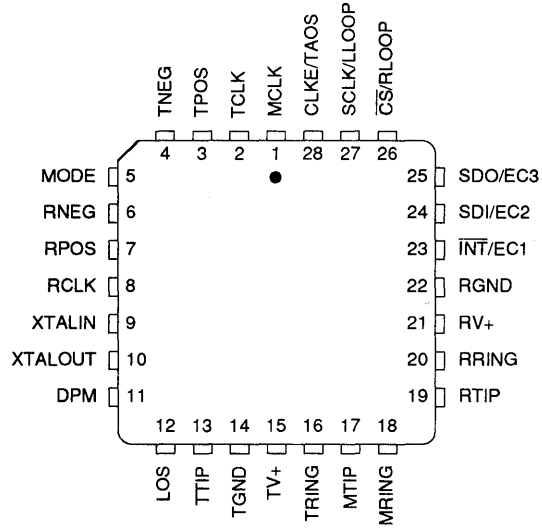
SSI 78P300
T1/E1 Integrated Short Haul Transceiver with Receive Jitter Attenuation

PACKAGE PIN DESIGNATIONS
(Top View)

CAUTION: Use handling procedures necessary for a static sensitive component.



28-Pin DIP



28-Pin PLCC

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 78P300 28-Pin PLCC	78P300-IH	78P300-IH
SSI 78P300 28-Pin DIP	78P300-IP	78P300-IP

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SSI 78P304A

Low-Power T1/E1 Integrated Short Haul Transceiver with Receive Jitter Attenuation

December 1993

DESCRIPTION

The SSI 78P304A is a fully integrated low-power transceiver for both North American 1.544 MHz (T1), and European 2.048 MHz (E1/CEPT) applications. It features a constant low output impedance transmitter allowing for high transmitter return loss in E1 applications. Transmit pulse shapes (DSX-1 or E1/CEPT) are selectable for various line lengths and cable types.

The SSI 78P304A provides receive jitter attenuation starting at 3 Hz, and is microprocessor controllable through a serial interface.

The SSI 78P304A offers a variety of diagnostic features including transmit and receive monitoring. The device incorporates an on-chip crystal oscillator, and also accepts digital clock inputs. It uses an advanced double-poly, double-metal CMOS process and requires only a single 5-volt power supply.

APPLICATIONS

- PCM / Voice Channel Banks
- Data Channel Bank / Concentrator
- T1 / E1 multiplexer
- Digital Access and Cross-connect Systems (DACS)
- Computer to PBX interface (CPI & DMI)
- High speed data transmission lines
- Interfacing Customer Premises Equipment to a CSU
- Digital Loop Carrier (DLC) terminals

FEATURES

- **Low power consumption (400 mW maximum) 40% less than the SSI 78P300**
- **Constant low output impedance transmitter regardless of data pattern**
- **High transmit and receive return loss**
- **Meets or exceeds all industry specifications including CCITT G.703, ANSI T1.403 and ATT Pub 62411**
- **Compatible with most popular PCM framers including the 2180A (T1) and 2181/2181A (E1)**
- **Line driver, data recovery and clock recovery functions**
- **Minimum receive signal of 500 mV**
- **Selectable slicer levels (CEPT/DSX-1) improve SNR**
- **Programmable transmit equalizer shapes pulses to meet DSX-1 pulse template from 0 to 655 ft**
- **Local and remote loopback functions Transmit / Receive performance monitors with DPM and LOS outputs**
- **Receiver jitter tolerance 0.4 UI from 40 kHz to 100 kHz**
- **Receive jitter attenuation starting at 6 Hz**
- **Microprocessor controllable**
- **Available in 28 pin DIP or PLCC**

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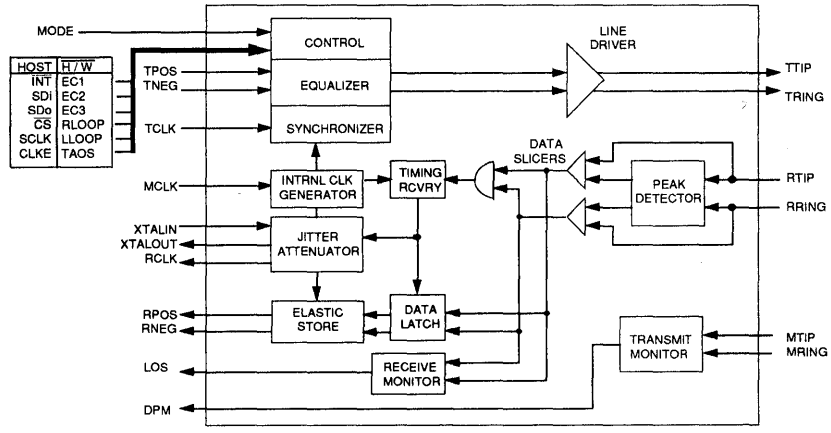
FIGURE 1: BLOCK DIAGRAM



SSI 78P304A
Low-Power T1/E1 Integrated Short Haul Transceiver with Receiver Jitter Attenuation

FUNCTIONAL DESCRIPTION

The SSI 78P304A is a fully integrated PCM transceiver for both 1.544 MHz (DSX-1) and 2.048 MHz (E1) applications. It allows transmission of digital data over existing twisted-pair installations. The SSI 78P304A transceiver interfaces with two twisted-pair lines, one twisted-pair for transmit, one twisted-pair for receive.

TRANSMITTER

Data received for transmission onto the line is clocked serially into the device at TPOS and TNEG. Input synchronization is supplied by the transmit clock (TCLK). The transmitted pulse shape is determined by Equalizer Control signals EC1 through EC3 as shown in Table 1. Refer to Table 2 and Figure 2 for master and transmit clock timing characteristics. Shaped pulses are applied to the AMI line driver for transmission onto the line at TTIP and TRING. Equalizer Control signals may be hardwired in the Hardware mode, or input as part of the serial data stream (SDI) in the Host mode.

Pulses can be shaped for either 1.544 or 2.048 MHz applications. 1.544 MHz pulses for DSX-1 applications can be programmed to match line lengths from 0 to 655 feet of ABAM cable. The SSI 78P304A also matches FCC and ECSA specifications for CSU applications. A 1:1.15 transmit transformer is used for all 1.544 MHz systems.

2.048 MHz pulses can drive coaxial or shielded twisted-pair lines. For E1 systems, a 1:2 transmit transformer and series resistors are recommended. This design meets or exceeds all CCITT and European PTT specifications for transmit and receive return loss. A 1:1 or 1:1.26 transformer may be used without series resistors.

DRIVER PERFORMANCE MONITOR

The transceiver incorporates a Driver Performance Monitor (DPM) in parallel with TTIP and TRING at the output transformer. The DPM output goes high upon detection of 63 consecutive zeros. It is reset when a one is detected on the transmit line, or when a reset command is received.

LINE CODE

The SSI 78P304A transmits data as a 50% AMI line code as shown in Figure 3. The output driver maintains a constant low output impedance regardless of whether it is driving marks or spaces.

RECEIVER

The SSI 78P304A receives the signal input from one twisted-pair line on each side of a center-grounded transformer. Positive pulses are received at RTIP and negative pulses are received at RRING. Recovered data is output at RPOS and RNEG, and the recovered clock is output at RCLK. Refer to Table 3 and Figure 4 for SSI 78P304A receiver timing.

The signal received at RPOS and RNEG is processed through the peak detector and data slicers. The peak detector samples the inputs and determines the maximum value of the received signal. A percentage of the peak value is provided to the data slicers as a threshold level to ensure optimum signal-to-noise ratio. For DSX-1 applications (determined by Equalizer Control inputs EC1 - EC3 $\neq$ 000) the threshold is set to 70% of the peak value. This threshold is maintained above 65% for up to 15 successive zeros over the range of specified operating conditions. For E1 applications (EC inputs = 000 or 001) the threshold is 50%.

The receiver is capable of accurately recovering signals with up to -13.6 dB of attenuation (from 2.4V), corresponding to a received signal level of approximately 500 mV. Maximum line length is 1500 feet of ABAM cable (approximately 6 dB of attenuation). Regardless of received signal level, the peak detectors are held above a minimum level of .3V to provide immunity from impulsive noise.

After processing through the data slicers, the received signal is routed to the data and clock recovery sections, and to the receive monitor. The receive monitor generates a Loss of Signal (LOS) output upon receipt of 175 consecutive zeros (spaces). The receiver monitor loads a digital counter at the RCLK frequency. The count is incremented each time a zero is received, and reset to zero each time a one (mark) is received. Upon receipt of 175 consecutive zeros the LOS pin goes high, and a smooth transition replaces the RCLK output with the MCLK. (If MCLK is not supplied the RCLK output will be replaced with the centered crystal clock.) The LOS pin is reset immediately upon receipt of a one.

Recovered clock signals are supplied to the jitter attenuator and the data latch. The recovered data is passed to the elastic store where it is buffered and synchronized with the dejittered recovered clock (RCLK).

JITTER ATTENUATION

Jitter attenuation of the SSI 78P304A clock and data outputs is provided by a Jitter Attenuation Loop (JAL) and an Elastic Store (ES). An external crystal oscillating at 4 times the bit rate provides clock stabilization. Refer to Table 4 for crystal specifications. The ES is a 32 x 2-bit register. Recovered data is clocked into the ES with the recovered clock signal, and clocked out of the ES with the dejittered clock from the JAL. When the bit count in the ES is within two bits of overflowing or underflowing, the ES adjusts the output clock by 1/8 of a bit period. The ES produces an average delay of 16 bits in the receive path.

OPERATING MODES

The SSI 78P304A transceiver can be controlled through hard-wired pins (Hardware mode) or by a microprocessor through a serial interface (Host mode). The mode of operation is set by the MODE pin logic level. The SSI 78P304A can also be commanded to operate in one of several diagnostic modes.

HOST MODE OPERATION

To allow a host microprocessor to access and control the SSI 78P304A through the serial interface, MODE is set to 1. The serial interface (SDI/SDO) uses a 16-bit word consisting of an 8-bit Command/Address byte and an 8-bit Data byte. Figure 5 shows the serial interface data structure and timing.

The Host mode provides a latched Interrupt output ($\overline{INT}$) which is triggered by a change in the Loss of Signal (LOS) and/or Driver Performance Monitor (DPM) bits. The Interrupt is cleared when the interrupt condition no longer exists, and the host processor enables the respective bit in the serial input data byte. Host mode also allows control of the serial data and receive data output timing. The Clock Edge (CLKE) signal determines when these outputs are valid, relative to the Serial Clock (SCLK) or RCLK as follows:

CLKE	Output	Clock	Valid Edge
LOW	RPOS	RCLK	Rising
	RNEG	RCLK	Rising
	SDO	SCLK	Falling
HIGH	RPOS	RCLK	Falling
	RNEG	RCLK	Falling
	SDO	SCLK	Rising

The SSI 78P304A serial port is addressed by setting bit A4 in the Address/Command byte, corresponding to address 16. The SSI 78P304A contains only a single output data register so no complex chip addressing scheme is required. The register is accessed by causing the Chip Select (CS) input to make a transition from high to low. Bit 1 of the serial Address/Command byte provides Read/Write control when the chip is accessed. A logic 1 indicates a read operation, and a logic 0 indicates a write operation. Table 6 lists serial data output bit combinations for each status. Serial data I/O timing characteristics are shown in Table 6, and Figures 6 and 7.

HARDWARE MODE OPERATION

In Hardware mode the transceiver is accessed and controlled through individual pins. With the exception of the $\overline{INT}$ and CLKE functions, Hardware mode provides all the functions provided in the Host mode. In the Hardware mode RPOS and RNEG outputs are valid on the rising edge of RCLK. To operate in Hardware mode, MODE must be set to 0. Equalizer Control signals (EC1 through EC3) are input on the Interrupt, Serial Data In and Serial Data Out pins. Diagnostic control for Remote Loopback (RLOOP), Local Loopback (LLOOP), and Transmit All Ones (TAOS) modes is provided through the individual pins used to control serial interface timing in the Host mode.

RESET OPERATION

Upon power up, the transceiver is held static until the power supply reaches approximately 3V. Upon crossing this threshold, the device begins a 32 ms reset cycle to calibrate the transmit and receive delay lines and lock the Phase Lock Loop to the receive line. A reference clock is required to calibrate the delay lines. The transmitter reference is provided by TCLK. The crystal oscillator provides the receiver reference. If the 78P304A crystal oscillator is grounded, MCLK is used as the receiver reference clock.

The transceiver can also be reset from the Host or Hardware mode. In Host mode, reset is commanded by simultaneously writing RLOOP and LLOOP to the register. In Hardware mode, reset is commanded by holding RLOOP and LLOOP high simultaneously for 200 ns. Reset is initiated on the falling edge of the reset request. In either mode, reset clears and sets all registers to 0 and centers the oscillator, then calibration begins.

DIAGNOSTIC MODE OPERATION

In Transmit All Ones (TAOS) mode the TPOS and TNEG inputs to the transceiver are ignored. The transceiver transmits a continuous stream of 1's when the TAOS mode is activated. TAOS can be commanded simultaneously with Local Loopback, but is inhibited during Remote Loopback.

In Remote Loopback (RLOOP) mode, the transmit data and clock inputs (TPOS, TNEG and TCLK) are ignored. The RPOS and RNEG outputs are looped back through the transmit circuits and output on TTIP and TRING at the RCLK frequency. Receiver circuits are unaffected by the RLOOP command and continue to output the RPOS, RNEG and RCLK signals received from the twisted-pair line.

In Local Loopback (LLOOP) mode, the receiver circuits are inhibited. The transmit data and clock inputs (TPOS, TNEG and TCLK) are looped back onto the receive data and clock outputs (RPOS, RNEG and RCLK.) The transmitter circuits are unaffected by the LLOOP command. The TPOS and TNEG inputs (or a stream of 1's if the TAOS command is active) will be transmitted normally. When used in this mode with a crystal, the transceiver can be used as a stand-alone jitter attenuator.

POWER REQUIREMENTS

The SSI 78P304A is a low-power CMOS device. It operates from a single +5 V power supply which can be connected externally to both the transmitter and receiver. However, the two inputs must be within ± .3V of each other, and decoupled to their respective grounds separately, as shown in Figure 8. Isolation between the transmit and receive circuits is provided internally.

PIN DESCRIPTION

NAME	TYPE	DESCRIPTION
MCLK	I	Master Clock: A 1.544 or 2.048 MHz clock input used to generate internal clocks. Upon Loss of Signal (LOS), RCLK is derived from MCLK. If MCLK is not applied, this pin should be grounded.
TCLK	I	Transmit Clock: Transmit clock input. TPOS and TNEG are sampled on the falling edge of TCLK.
TPOS	I	Transmit Positive Data: Input for positive pulse to be transmitted on the twisted-pair or coaxial cable.
TNEG	I	Transmit Negative Data: Input for negative pulse to be transmitted on the twisted-pair or coaxial cable.
MODE	I	Mode Select: Setting MODE to logic 1 puts the SSI 78P304A in the Host mode. In the Host mode, the serial interface is used to control the SSI 78Q904A and determine its status. Setting MODE to logic 0 puts the SSI 78P304A in the Hardware (H/W) mode. In the Hardware mode the serial interface is disabled and hard-wired pins are used to control configuration and report status.
RNEG / RPOS	O	Receive Negative/Positive Data: Received data outputs. A signal on RNEG corresponds to receipt of a negative pulse on RTIP and RRING. A signal on RPOS corresponds to receipt of a positive pulse on RTIP and RRING. RNEG and RPOS outputs are Non-Return-to-Zero (NRZ). In the Host mode, CLKE determines the clock edge at which these outputs are stable and valid. In the Hardware mode both outputs are stable and valid on the rising edge of RCLK.
RCLK	O	Recovered Clock: This is the clock recovered from the signal received at RTIP and RRING.

PIN DESCRIPTION (continued)

NAME	TYPE	DESCRIPTION
XTALIN / XTALOUT	I	Crystal Input / Crystal Output: An external crystal operating at four times the bit rate (6.176 MHz for DSX-1, 8.192 MHz for E1 applications with an 18.7 pF load) is required to enable the jitter attenuation function of the SSI 78P304A. These pins may also be used to disable the jitter attenuator by connecting the XTALIN pin to the positive supply through a resistor, and tying the XTALOUT pin to ground.
DPM	O	Driver Performance Monitor: DPM goes to a logic 1 when the transmit monitor loop (MTIP and MRING) does not detect a signal for 63 ±2 clock periods. DPM remains at logic 1 until a signal is detected.
LOS	O	Loss of Signal: LOS goes to a logic 1 when 175 consecutive spaces have been detected. LOS returns to a logic 0 when a mark is received.
TTIP / TTRING	O	Transmit Tip / Transmit Ring: Differential Driver Outputs. These low impedance outputs achieve maximum power savings through a 1:1.15 transformer (T1), or a 1:1 or 1:1.26 transformer (E1) without additional components. To provide higher return loss for E1 systems, resistors may be used in series with a 1:2 transformer (use 15Ω resistors for 120Ω terminations, and 9.3Ω resistors for 75Ω terminations.)
TGND	-	Transmit Ground: Ground return for the transmit drivers power supply TV+.
TV+	I	Transmit Power Supply: +5 VDC power supply input for the transmit drivers. TV+ must not vary from RV+ by more than ±0.3V.
MTIP / MRING	I	Monitor Tip / Monitor RIng: These pins are used to monitor the tip and ring transmit outputs. The transceiver can be connected to monitor its own output or the output of another 78P304A on the board. To prevent false interrupts in the host mode if the monitor is not used, apply a clock signal to one of the monitor pins and tie the other monitor pin to approximately the clock's mid-level voltage. The monitor clock can range from 100kHz to the TCLK frequency.
RTIP / RRING	O	Receive Tip / Receive Ring: The AMI signal received from the line is applied at these pins. A center-tapped, center-grounded, 2:1 step-up transformer is required on these pins. Data and clock from the signal applied at these pins are recovered and output on the RPOS/RNEG, and RCLK pins.
RV+	I	Received Power Supply: +5 VDC power supply for all circuits except the transmit drivers. (Transmit drivers are supplied by TV+.)
RGND	-	Receive Ground: Ground return for power supply RV+.
$\overline{INT}$	O	Interrupt (Host Mode): This SSI 78P304A Host mode output goes low to flag the host processor when LOS or DPM go active. $\overline{INT}$ is an open-drain output and should be tied to power supply RV+ through a resistor. $\overline{INT}$ is reset by clearing the respective register bit (LOS and/or DPM.)
EC1	I	Equalizer Control 1 (H/W Mode): The signal applied at this pin in the SSI 78P304A Hardware mode is used in conjunction with EC2 and EC3 inputs to determine shape and amplitude of AMI output transmit pulses.

PIN DESCRIPTION (continued)

NAME	TYPE	DESCRIPTION
SDI	I	Serial Data In (Host Mode): The serial data input stream is applied to this pin when the SSI 78P304A operates in the Host mode. SDI is sampled on the rising edge of SCLK.
EC2	I	Equalizer Control 2 (H/W Mode): The signal applied at this pin in the SSI 78P304A Hardware mode is used in conjunction with EC1 and EC3 inputs to determine shape and amplitude of AMI output transmit pulses.
SDO	O	Serial Data Out (Host Mode): The serial data from the on-chip register is output on this pin in the SSI 78P304A Host mode. If CLKE is high, SDO is valid on the rising edge of SCLK. If CLKE is low SDO is valid on the falling edge of SCLK. This pin goes to a high-impedance state when the serial port is being written to and when $\overline{CS}$ is high.
EC3	I	Equalizer Control 3 (H/W Mode): The signal applied at this pin in the SSI 78P304A Hardware mode is used in conjunction with EC1 and EC2 inputs to determine shape and amplitude of AMI output transmit pulses.
$\overline{CS}$	I	Chip Select (Host Mode): This input is used to access the serial interface in the SSI 78P304A Host mode. For each read or write operation, $\overline{CS}$ must remain low for the duration of operation.
RLOOP	I	Remote Loopback (H/W Mode): This input controls loopback functions in the SSI 78P304A Hardware mode. Setting RLOOP to a logic 1 enables the Remote Loopback mode. Setting both RLOOP and LLOOP causes a Reset.
SCLK	I	Serial Clock (Host Mode): This clock is used in the SSI 78P304A Host mode to write data to or read data from the serial interface registers.
LLOOP	I	Local Loopback (H/W Mode): This input controls loopback functions in the SSI 78P304A Hardware mode. Setting LLOOP to a logic 1 enables the Local Loopback Mode.
CLKE	I	Clock Edge (Host Mode): Setting CLKE to logic 1 causes RPOS and RNEG to be valid on the falling edge of RCLK, and SDO to be valid on the rising edge of SCLK. When CLKE is a logic 0, RPOS and RNEG are valid on the rising edge of RCLK, and SDO is valid on the falling edge of SCLK.
TAOS	I	Transmit All Ones (H/W Mode): When set to a logic 1, TAOS causes the SSI 78P304A (Hardware mode) to transmit a continuous stream of marks at the TCLK frequency. Activating TAOS causes TPOS and TNEG inputs to be ignored. TAOS is inhibited during Remote Loopback.

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Operation above maximum ratings may damage the device. Normal operation not guaranteed at these extremes.

PARAMETER		RATING	UNIT
DC supply (referenced to GND)	RV+, TV+	-0 to 6.0	V
Input voltage, any pin (see note 1)	V_{IN}	RGND -0.3 to RV+ + 0.3	V
Input current, any pin (see note 2)	I_{IN}	-10 to +10	mA
Ambient operating temperature	T_A	-40 to 85	°C
Storage temperature	T_{STG}	-65 to 150	°C

[1] Excluding RTIP and RRING which must stay within -6V to RV+ + 0.3V.
[2] Transient currents of up to 100 mA will not cause SCR latch-up. TTIP, TRING, TV+ and TGND can withstand a continuous current of 100 mA.

RECOMMENDED OPERATING CONDITIONS

PARAMETER	SYMBOL	MIN	NOM	MAX	UNIT
DC supply (see note 1)	RV+, TV+	4.75	5.0	5.25	V
Ambient Operating Temperature	T_A	-40	25	85	°C
Total power dissipation P_D (see note 2)	100% ones density & max line length @ 5.25V	-	-	400	mW

[1] TV+ must not exceed RV+ by more than ±0.3 V.
[2] Power dissipation while driving 25Ω load over operating temperature range. Includes device and load. Digital input levels are within 10% of the supply rails and digital outputs are driving a 50 pF capacitive load.

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DIGITAL CHARACTERISTICS (T_A = -40° to 85 °C, V+ = 5.0V ±5%, GND = 0V)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
High level input voltage V_{IH} (see notes 1 & 2)		2.0	-	-	V
Low level input voltage V_{IL} (see notes 1 & 2)		-	-	0.8	V
High level output voltage V_{OH} (see notes 1 & 2)	I_{OUT} = -400 µA	2.4	-	-	V
Low level output voltage V_{OL} (see notes 1 & 2)	I_{OUT} = 1.6 mA	-	-	0.4	V
Input leakage current I_{LL} (see note 3)		0	-	±10	µA
Three-state leakage current (see note 2) I_{3L}		0	-	±10	µA

[1] Functionality of pins 23 and 25 depends on mode. See Host / Hardware Mode descriptions.
[2] Output drivers will output CMOS logic levels into CMOS loads.
[3] Except MTIP and MRING I_{LL} = ± 50 µA.

ELECTRICAL SPECIFICATIONS (continued)

ANALOG SPECIFICATIONS (T_A = -40 to 85 °C, V+ = 5.0V ±5%, GND = 0V)

PARAMETER		TEST CONDITIONS	MIN	NOM	MAX	UNIT
AMI Output	DSX-1	measured at the DSX	2.4	3.0	3.6	V
Pulse Amplitudes	CEPT	measured at line side	2.7	3.0	3.3	V
Load presented to transmitter output			-	75	-	Ω
Jitter added by	10 Hz - 8 kHz		-	-	0.01	UI
the transmitter	8 kHz - 40 kHz		-	-	0.025	UI
(see note 1)	10 Hz - 40 kHz		-	-	0.025	UI
	Broad Band		-	-	0.05	UI
Sensitivity below DSX (0 dB = 2.4V)			13.6	-	-	dB
			500	-	-	mV
Loss of Signal threshold			-	0.3	-	V
Data decision	DSX-1		63	70	77	%peak
threshold	CEPT		43	50	57	%peak
Allowable consecutive zeros before LOS			160	175	190	-
Input jitter tolerance	10 kHz - 100 kHz		0.4	-	-	UI
Jitter attenuation curve corner frequency (see note 2)			-	6	-	Hz
Minimum Return Loss (see notes 3 & 4)			Transmit		Receive		
			Min	Typ	Min	Typ	
	51 kHz - 102 kHz		20	28	20	30	dB
	102 kHz - 2.048 MHz		20	28	20	30	dB
	2.048 MHz - 3.072 MHz		20	24	20	25	dB

[1] Input signal to TCLK is jitter-free.
[2] Circuit attenuates jitter at 20 dB/decade above the corner frequency.
[3] In accordance with CCITT G.703/RC6367A return loss specifications (CEPT), when wired as shown in Figure 9.
[4] Guaranteed by design.

TABLE 1: Equalizer Control Inputs for Transmitter

EC3	EC2	EC1	Line Length[1]	Cable Loss[2]	Application	Frequency
0	1	1	0 - 133 ft ABAM	0.6 dB	DSX-1	1.544 MHz
1	0	0	133 - 266 ft ABAM	1.2 dB		
1	0	1	266 - 399 ft ABAM	1.8 dB		
1	1	0	399 - 533 ft ABAM	2.4 dB		
1	1	1	533 - 655 ft ABAM	3.0 dB		
0	0	0	CCITT Recommendation G.703		E1 - Coax (75 Ω) E1 - Twisted-pair (120 Ω)	2.048 MHz
0	0	1				
0	1	0	FCC Part 68, Option A		CSU	1.544 MHz
0	1	1	ECSA T1C1.2			

[1] Line length from transceiver to DSX-1 cross-connect point.
[2] Maximum cable loss at 772 kHz.

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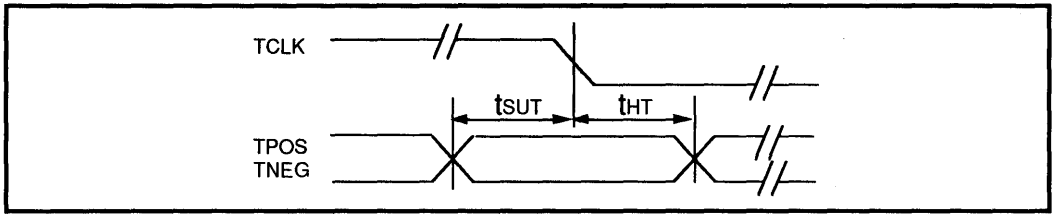

Figure 2: SSI 78P304A Transmit Clock Timing

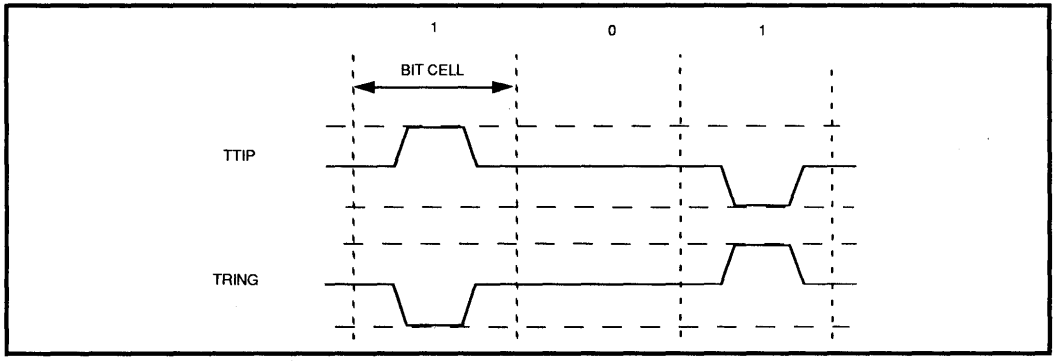

Figure 3: 50% AMI Coding

TABLE 2: SSI 78P304A Master Clock and Transmit Timing Characteristics (See Figure 2)

Parameter		Sym	Min	Typ[1]	Max	Units
Master clock frequency	DSX-1	MCLK	-	1.544	-	MHz
	E1	MCLK	-	2.048	-	MHz
Master clock tolerance		MCLKt	-	±100	-	ppm
Master clock duty cycle		MCLKd	40	-	60	%
Crystal frequency	DSX-1	fc	-	6.176	-	MHz
	E1	fc	-	8.192	-	MHz
Transmit clock frequency	DSX-1	TCLK	-	1.544	-	MHz
	E1	TCLK	-	2.048	-	MHz
Transmit clock tolerance		TCLKt	-	-	±50	ppm
Transmit clock duty cycle		TCLKd	40	-	60	%
TPOS/TNEG to TCLK setup time		t_{SUT}	25	-	-	ns
TCLK to TPOS/TNEG Hold time		t_{HT}	25	-	-	ns

[1] Typical figures are at 25°C and are for design aid only; not guaranteed and not subject to production testing.

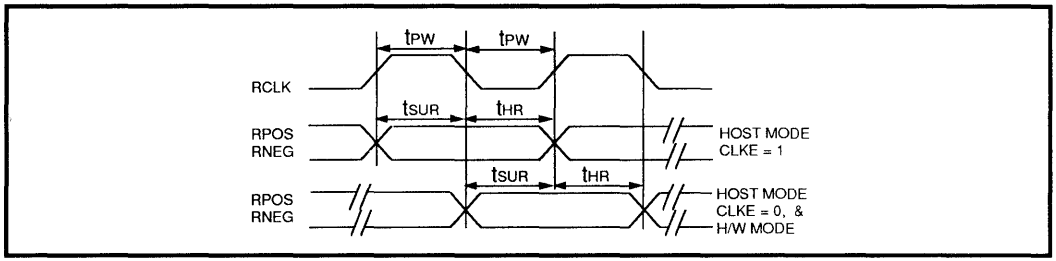

FIGURE 4: SSI 78P304A Receive Clock Timing

TABLE 3: SSI 78P304A Receive Timing Characteristics (See Figure 4)

Parameter		Sym	Min	Typ[1]	Max	Units
Receive clock duty cycle		RCLKd	40	-	60	%
Receive clock pulse width	DSX-1	tPW	-	324	-	ns
	CEPT	tPW	-	244	-	ns
RPOS / RNEG to RCLK	DSX-1	tSUR	-	274	-	ns
rising setup time	CEPT	tSUR	-	194	-	ns
RCLK rising to RPOS /	DSX-1	tHR	-	274	-	ns
RNEG hold time	CEPT	tHR	-	194	-	ns

[1] Typical figures are at 25°C and are for design aid only; not guaranteed and not subject to production testing.

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TABLE 4: SSI 78P304A Crystal Specifications (External)

Parameter	T1	E1
Frequency	6.176 MHz	8.192 MHz
Frequency Stability	±20 ppm @ 25° C ±25 ppm from -40° C to + 85° C (Ref 25° C reading)	±20 ppm @ 25° C ±25 ppm from -40° C to + 85° C (Ref 25° C reading)
Pullability	CL = 11 pF to 18.7 pF, +ΔF = 175 to 195 ppm CL = 18.7 pF to 34 pF, -ΔF = 175 to 195 ppm	CL = 11 pF to 18.7 pF, +ΔF = 95 to 115 ppm CL = 18.7 pF to 34 pF, -ΔF = 95 to 115 ppm
Effective series resistance	40Ω Maximum	30Ω Maximum
Crystal cut	AT	AT
Resonance	Parallel	Parallel
Maximum drive level	2.0 mW	2.0 mW
Mode of operation	Fundamental	Fundamental
Crystal holder	HC49 (R3W), C_O = 7 pF maximum C_M = 17 pF typical	HC49 (R3W), C_O = 7 pF maximum C_M = 17 pF typical

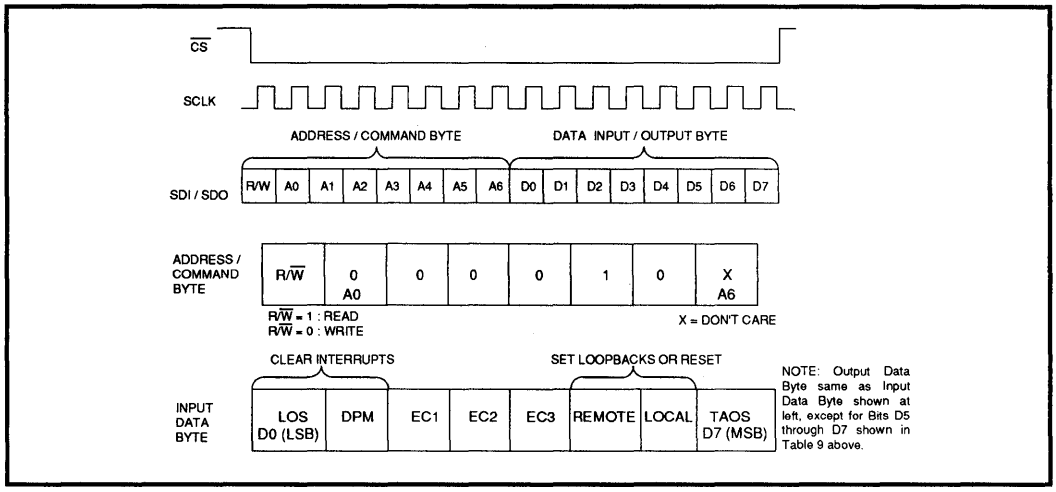

FIGURE 5: SSI 78P304A Serial Interface Data Structure

TABLE 5: SSI 78P304A Serial Data Output Bits (See Figure 5)

Bit D5	Bit D6	Bit D7	Status
0	0	0	Reset has occurred, or no program input.
0	0	1	TAOS active
0	1	0	Local Loopback active
0	1	1	TAOS and Local Loopback active
1	0	0	Remote Loopback active
1	0	1	DPM has changed state since last Clear DPM occurred
1	1	0	LOS has changed state since last Clear LOS occurred
1	1	1	LOS and DPM have both changed state since last Clear DPM and Clear LOS occurred

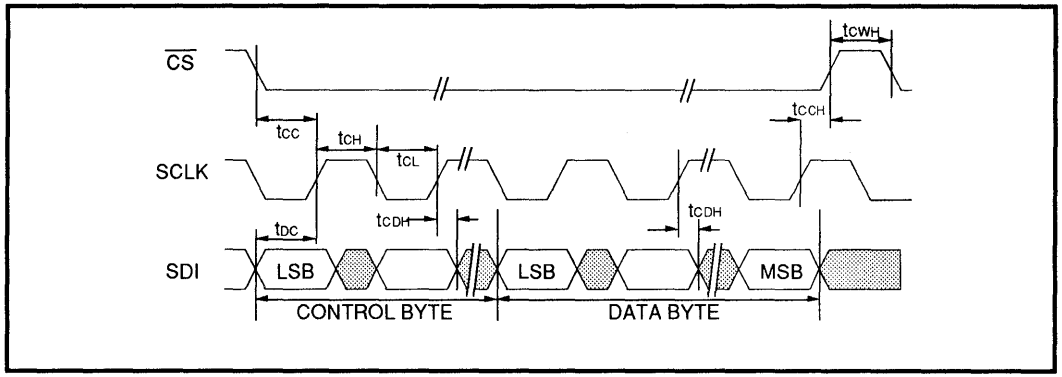

FIGURE 6: SSI 78P304A Serial Data Input Timing Diagram

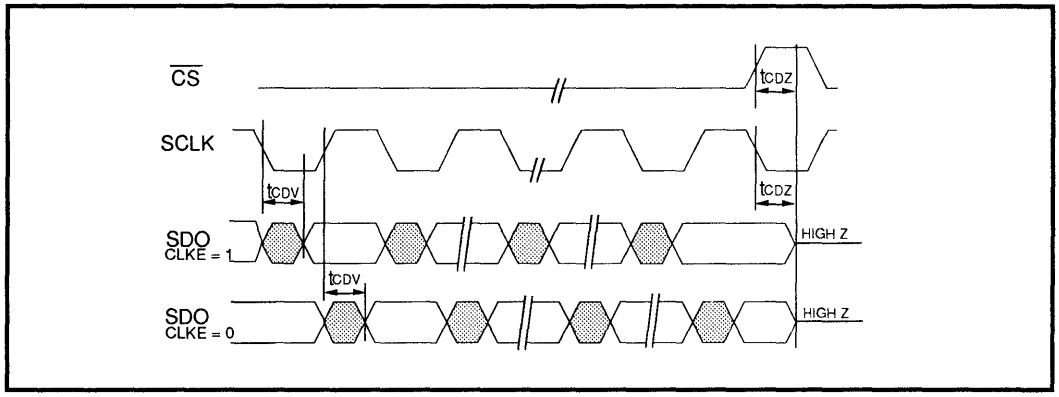

Figure 7: SSI 78P304A Serial Data Output Timing Diagram

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TABLE 6: SSI 78P304A Serial I/O Timing Characteristics (See Figures 6 and 7)

Parameter	Sym	Min	Typ[1]	Max	Units	Test Conditions
Rise/Fall time - any digital output	t_{RF}	-	-	100	ns	Load 1.6 mA, 50pF
SDI to SCLK setup time	t_{DC}	50	-	-	ns	
SCLK to SDI hold time	t_{CDH}	50	-	-	ns	
SCLK low time	t_{CL}	240	-	-	ns	
SCLK high time	t_{CH}	240	-	-	ns	
SCLK rise and fall time	t_R , t_F	-	-	50	ns	
$\overline{CS}$ to SCLK setup time	t_{CC}	50	-	-	ns	
SCLK to $\overline{CS}$ hold time	t_{CCH}	50	-	-	ns	
$\overline{CS}$ inactive time	t_{CWH}	250	-	-	ns	
SCLK to SDO valid	t_{CDV}	-	-	200	ns	
SCLK falling edge or $\overline{CS}$ rising edge to SDO high Z	t_{CDZ}	-	100	-	ns	

[1] Typical figures are at 25°C and are for design aid only; not guaranteed and not subject to production testing.

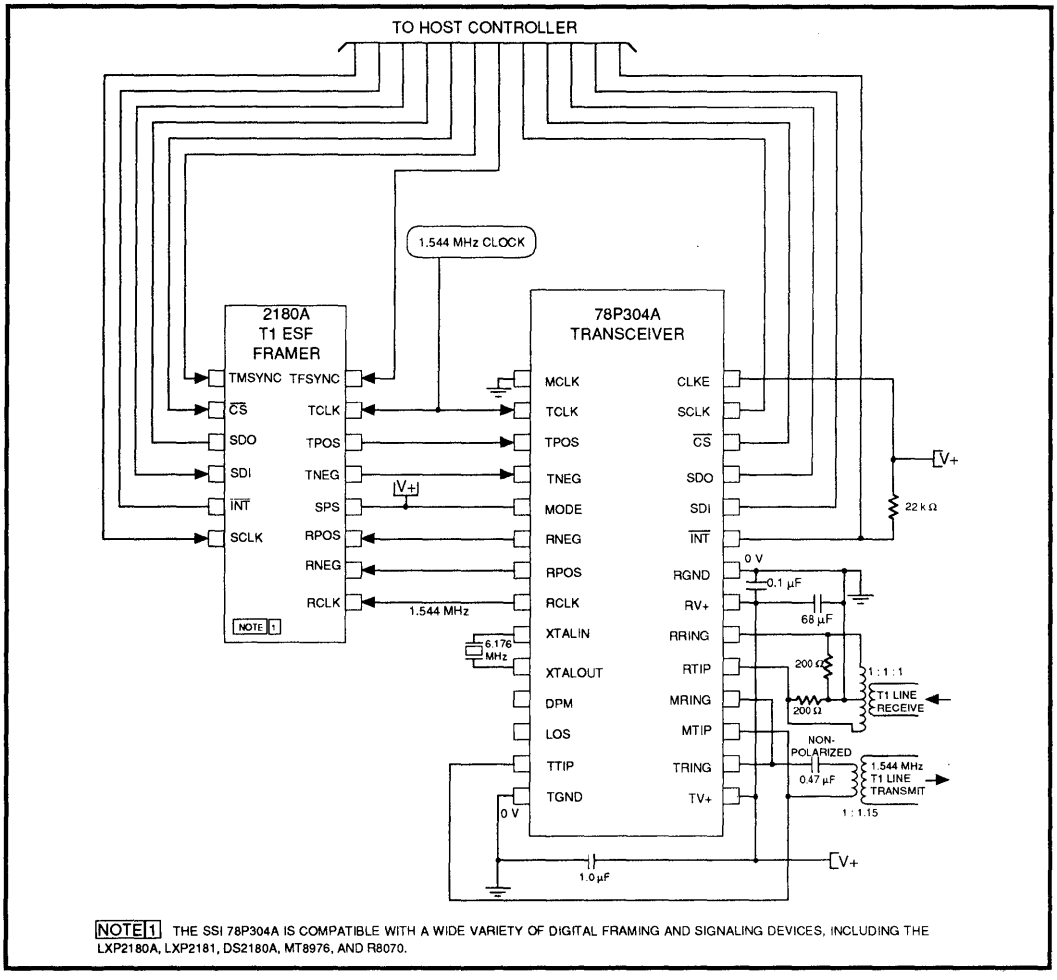
APPLICATION INFORMATION

1.544 MHz T1 INTERFACE APPLICATIONS

Figure 8 is a typical 1.544 MHz T1 application. The SSI 78P304A is shown in the Host mode with the 2180A T1/ESF Framer providing the digital interface with the host controller. Both devices are controlled through the serial interface. The power supply inputs are tied to a common bus with appropriate decoupling capacitors installed (1.0 µF on the transmit side, 68 µF and 0.1 µF on the receive side.)

TABLE 7: E1/CEPT Output Combinations

EC	75Ω Coax	120Ω TWP
0 0 1	1:1, Rt = 10Ω	1:1, Rt = 0Ω
0 0 1	1:2, Rt = 14.3Ω	1:2, Rt = 15Ω
0 0 0	1:1, Rt = 0Ω	1:1.26, Rt = 0Ω
0 0 0	1:2, Rt = 9.37Ω	1:2, Rt = 8.7Ω



NOTE 1 THE SSI 78P304A IS COMPATIBLE WITH A WIDE VARIETY OF DIGITAL FRAMING AND SIGNALING DEVICES, INCLUDING THE LXP2180A, LXP2181, DS2180A, MT8976, AND R8070.

FIGURE 8: Typical SSI 78P304A 1.544 MHz T1 Application (Host Mode)

2.048 MHZ E1/CEPT INTERFACE APPLICATIONS

Figure 9 is a 2.048 MHz E1/CEPT coax application using EC code 000 and 15Ω Rt resistors in line with the transmit transformer to provide high return loss. When high return loss is not a critical factor, a 1:1 or 1:1.26 transformer without in-line resistors provides maximum power savings. Table 7 lists transformer ratios and Rt values with associated 2.048 MHz EC codes for both 75Ω coax and 120Ω TWP. The SSI 78P304A is shown in Hardware mode with the 2181A E1/CRC4 Framer. The hard-wired control lines for TAOS, LLOOP and RLOOP are individually controllable, and the LLOOP and RLOOP lines are also tied to a single control for the Reset function. As in the T1 application Figure 8, this configuration is illustrated with a crystal in place to enable the SSI 78P304A Jitter Attenuation Loop, and a single power supply bus.

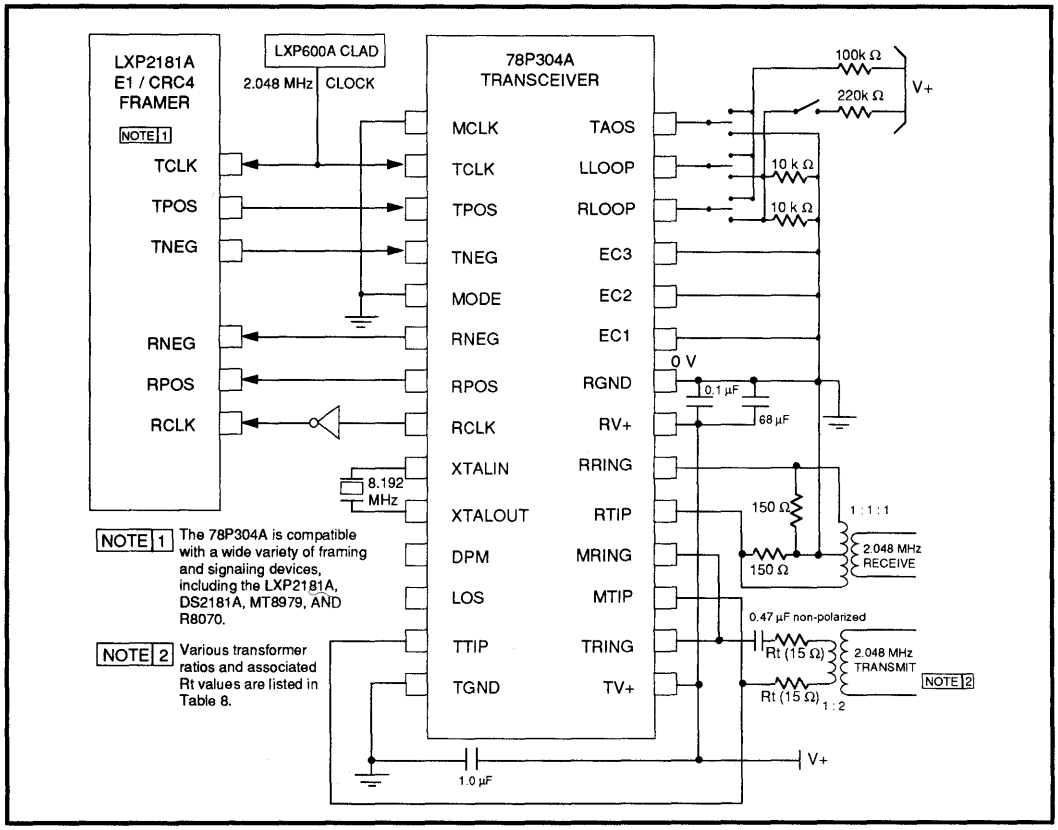
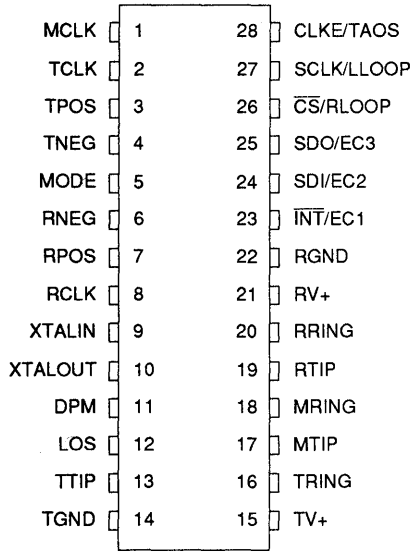


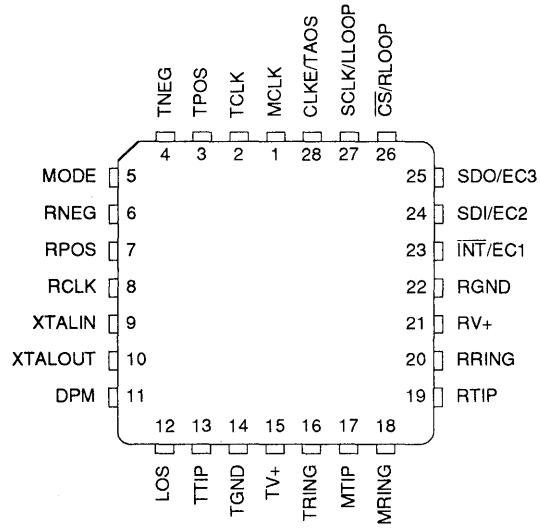
FIGURE 9: SSI 78P304A 2.048 MHz E1 Application (Hardware Mode)

PACKAGE PIN DESIGNATIONS
(Top View)

CAUTION: Use handling procedures necessary for a static sensitive component.



28-Pin DIP



28-Pin PLCC

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ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 78P304A 28-Pin DIP	78P304A-IP	78P304A-IP
SSI 78P304A 28-Pin PLCC	78P304A-IH	78P304A-IH

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Notes:

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SSI 78P7200
E3/DS-3 Line Interface with Receive Equalizer
Preliminary Data

November 1994

DESCRIPTION

The SSI 78P7200 is a line interface transceiver IC intended for DS-3 (44.736 Mbit/s) and E3 (34.368 Mbit/s) applications. The receiver has a very wide dynamic range and is designed to accept HDB3 or B3ZS-encoded Alternate-Mark Inversion (AMI) inputs; it provides clock, positive data, negative data, and low-level signal detector logical outputs. An on-chip equalizer improves the intersymbol interference tolerance on the receive path. The transmitter converts clock and data input signals into AMI pulses of the appropriate shape for transmission. A line buildout (LBO) equalizer may be selected to shape the outgoing pulses for shorter line lengths. The SSI 78P7200 requires a single 5 volt supply and is available in DIP and surface mount packages.

The 78P7200 works in either rate of DS-3 or E3 by simple external components modification.

FEATURES

- **Single chip transmit and receive interface for E3 (34.368 Mbit/s) or DS-3 (44.736 Mbit/s) applications**
- **On-chip Receive Equalizer**
- **Unique clock recovery circuit, requires no crystals, tuned components or external clock**
- **Selectable transmit line buildout (LBO) to accommodate shorter line lengths**
- **Compliant with ANSI T1.102 - 1987, TR-TSY-000499, CCITT G.703 and G.823**
- **Low-level input signal indication**
- **Available in DIP or surface mount packages**
- **-40°C to +85°C operating range**
- **Pin-compatible with SSI 78P236, 78P2361 and 78P2362**

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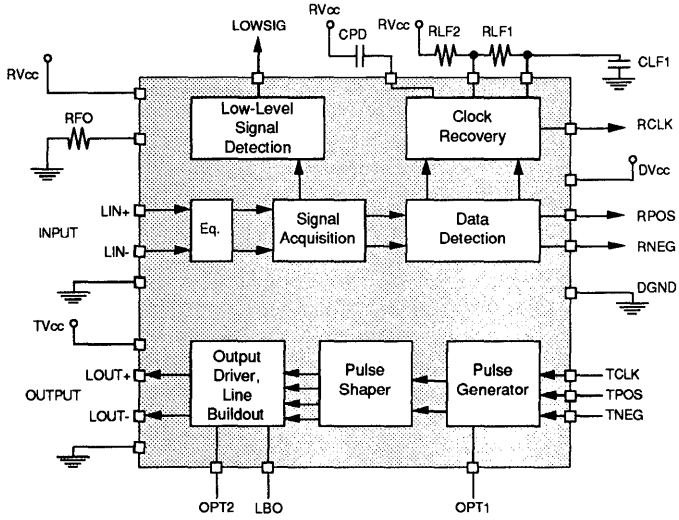
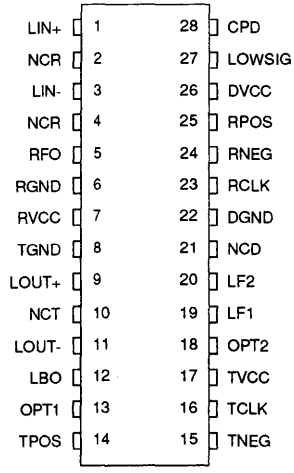
BLOCK DIAGRAM



PIN DIAGRAM



28-Pin DIP

CAUTION: Use handling procedures necessary for a static sensitive component.

SSI 78P7200
E3/DS-3 Line Interface with Receive Equalizer

FUNCTIONAL DESCRIPTION

The SSI 78P7200 is a single chip line interface IC designed to work with a 44.736 Mbit/s DS-3 or 34.368 Mbit/s E3 signal. The receiver recovers clock, positive data and negative data from an Alternate Mark Inversion (AMI) signal. The input signal should be B3ZS or HDB3 coded.

The transmitter accepts CMOS level logical clock, positive data and negative data and converts them to the AMI signal to drive a 75Ω coaxial cable. Programmable internal Line Buildout (LBO) circuitry eliminates the need for external LBO networks for DS-3 applications. When the option pins are properly selected, the shape of the transmitted signal through any cable length of 0 to 450 feet complies with the published templates of ANSI T1.102-1987, CCITT G.703 and TR-TSY-000499. The SSI 78P7200 is designed to work with a B3ZS or HDB3 coded signal. The B3ZS or HDB3 encoding and decoding functions are normally included in the framer ICs or can easily be implemented in a PAL.

RECEIVER

The receiver input is normally transformer-coupled to the AMI signal. The inputs to the IC are internally referenced to RVCC. Since the input impedance of the SSI 78P7200 is high, the AMI line must be terminated in 75Ω. The input signal to the SSI 78P7200 must be limited to a maximum of three consecutive zeros using a coding scheme such as B3ZS or HDB3.

The AMI signal first enters a fixed equalizer which is designed to overcome the intersymbol interference caused by long cable lengths and crosstalk. This fixed equalizer is optimized for DS-3 application and its effect should be compensated by an external filter circuit similar to Fig. 1, for all square shaped signals such as DS3-high or 34 Mbit/s E3. The signal is then input to a variable gain differential amplifier whose output is maintained at a constant voltage level regardless of the input voltage level. The gain of this amplifier is adjusted by detecting the peak of the signal and comparing it to a fixed reference.

The output of the variable gain amplifier is compared to a threshold value which is a fixed percentage of the signal peak. In this way, even though the input signal amplitude may fall below the minimum value that can be regulated by the variable gain circuit, the proper detection threshold is maintained.

Outputs of the data comparators are connected to the clock recovery circuits. The clock recovery system employs a unique phase locked loop which has an auxiliary frequency-sensitive acquisition loop which is active only when cycle-slipping occurs between the received signal rate and the internal oscillator.

This system permits the loop to independently lock to the frequency and phase of the incoming data stream without the need for high precision and/or adjustable oscillator or tuned circuits.

The response characteristic for the phase locked loop is established by external filter components, RLF1, RLF2 and CLF1. The values of these components are specified such that the bandwidth of the phase locked loop is greater than 200 kHz.

The jitter tolerance of the SSI 78P7200 exceeds the requirements of TR-TSY-000499 for Category II equipment for DS-3 rate and exceeds the requirements of CCITT G.823 for E3 rate. The jitter transfer function is maximally flat so the IC doesn't add any significant jitter to the system.

Figure 2 shows the recovered clock (RCLK), positive data (RPOS) and negative data (RNEG) signals timing. The data is valid on the rising edge of the clock. The minimum setup and hold times allow easy interface to framer circuits. These signals are CMOS-level outputs.

Should the input signal fall below a minimum value, the $\overline{\text{LOWSIG}}$ pin goes active low. A time delay is provided before this output is active so that transient interruptions do not cause false indications. This signal should be used as one of many indications to the cable disconnect; the framer device should count the number of zeros to declare the loss of signal. The RPOS and RNEG signals generate random data following a silence period. The framer device should ignore RPOS and RNEG data if the $\overline{\text{LOWSIG}}$ pin is active low.

TRANSMITTER

The transmitter accepts unipolar CMOS level logical clock (RCLK), positive data (RPOS) and negative data (RNEG) signals and generates high current drive pulses on the LOUT+ and LOUT- pins. When properly connected to a center tapped transformer, an AMI pulse is generated which can drive a 75Ω coaxial cable.

Figure 3 shows the timing for the transmitter logic signals. The output pulse width is internally set and is not sensitive to input clock (TCLK) pulse width.

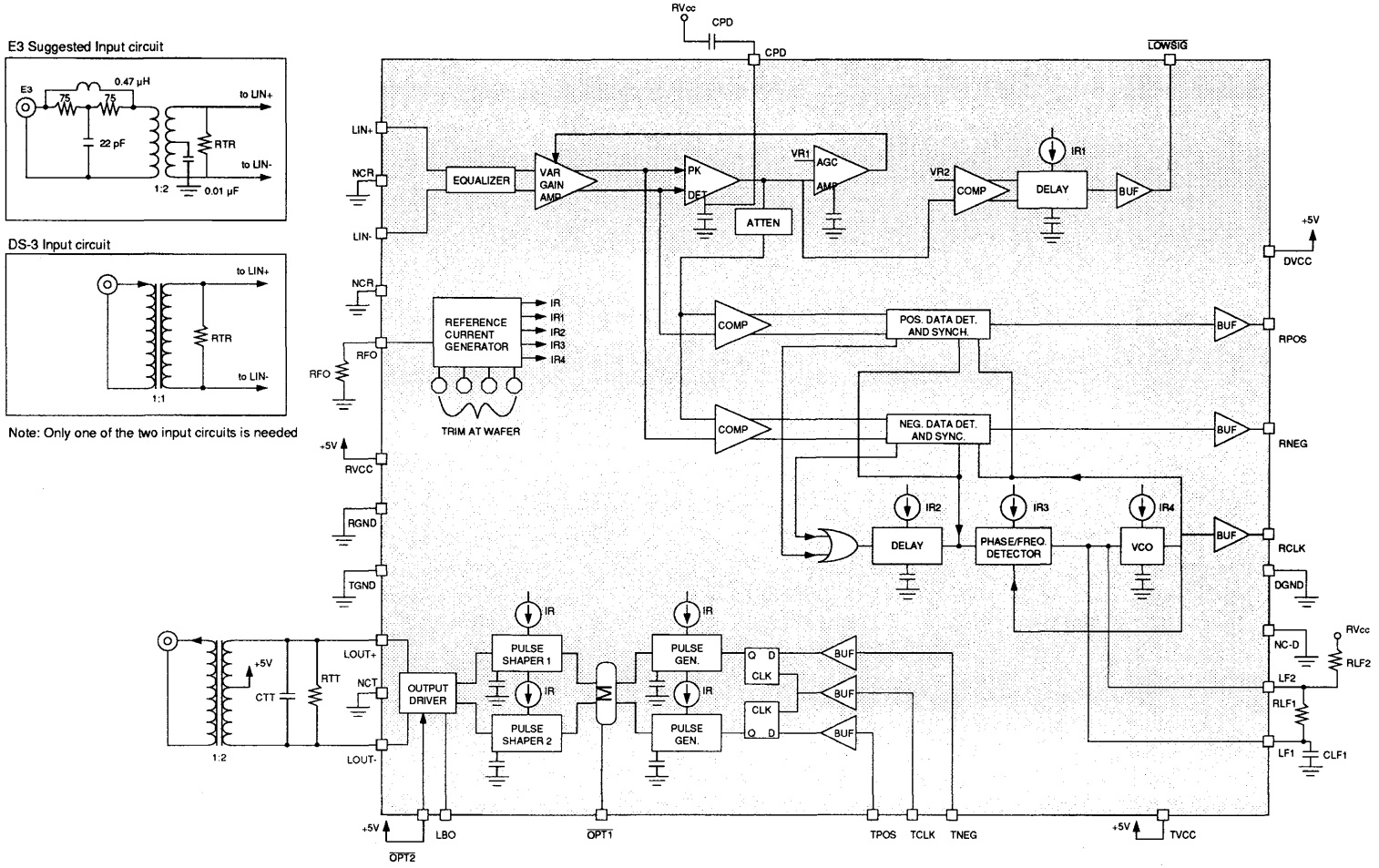
When a recommended transformer is used and option pins are properly set, the transmitted pulse shape at the end of a 75Ω terminated cable of 0 to 450 feet will fit the template for DSX3 pulse published in ANSI T1.102-1987, BELLCORE TR-TSY-000499 and CCITT G.703 documents for RFO = 5.23 kΩ.

For 34 Mbit/s E3 application, when RFO = 6.81 kΩ, the transmitted pulse for a short cable matches the requirements of CCITT G.703 when both LBO and $\overline{\text{OPT1}}$ pins are set LOW.

The SSI 78P7200 incorporates a selectable Line Buildout (LBO) equalizer in the transmitter path. For DS-3 applications, the LBO pin should be set HIGH if the cable is shorter than 225 feet and set LOW for longer cable lengths. For E3 application, LBO pin should be set LOW regardless of cable length.

The $\overline{\text{OPT1}}$ pin is set HIGH for normal DS-3 operation. Setting the $\overline{\text{OPT1}}$ pin to LOW increases the transmitter power. The $\overline{\text{OPT1}}$ pin should be set LOW for E3 applications.

The $\overline{\text{OPT2}}$ pin should be set HIGH for normal operation. Setting the $\overline{\text{OPT2}}$ pin to LOW disables the transmitter drivers and reduces the power consumption of the circuit by approximately 125 mW.



Note: NC pins should be tied to the ground pin indicated by the trailing letter.

FIGURE 1: Functional Diagram

PIN DESCRIPTION

RECEIVER

NAME	TYPE	DESCRIPTION
LIN+, LIN-	I	Differential inputs, transformer-coupled from line.
RPOS	O	Unipolar receiver output, active as result of positive pulse at inputs.
RNEG	O	Unipolar receiver output, active as result of negative pulse at inputs.
RCLK	O	Clock pulses recovered from line data.
$\overline{\text{LOWSIG}}$	O	Low signal logic output indicating that input signal is less than threshold value.

TRANSMITTER

TPOS	I	Unipolar transmitter data input, active high.
TNEG	I	Unipolar transmitter data input, active high.
TCLK	I	Transmitter clock input, active high.
LOUT+	O	Output to transformer for positive data pulses.
LOUT-	O	Output to transformer for negative data pulses.
LBO	I	Transmitter line buildout control. Set low for E3 or DS-3 cable of 225' or longer.
$\overline{\text{OPT1}}$	I	Transmit option 1. Selects faster output pulse transition time and higher amplitude when low. Set high for normal DS-3 and set low for E3.
$\overline{\text{OPT2}}$	I	Transmit option 2. Disables output driver and reduces output bias current when low.Set high for normal transmit operation.

EXTERNAL COMPONENT CONNECTION

RFO	I	Resistor connected to RGND to provide basic center frequency of receiver phase locked loop oscillator.
LF1, LF2	-	Resistor-capacitor loop filter network to establish bandwidth of phase locked loop.
CPD	-	Capacitor to RVcc that is connected to peak detector node to reduce signal-dependent ripple on that node.

POWER

TVcc	-	5V power supply for transmit circuits.
RVcc	-	5V power supply for receive circuits.
DVcc	-	5V power supply for receive logic circuits.
TGND	-	Ground return for transmit circuits.
RGND	-	Ground return for receive circuits.
DGND	-	Ground return for receive logic circuits.
NCR	-	No connect, Tie to Receiver Ground (RGND).
NCT	-	No connect, Tie to Transmitter Ground (TGND).
NCD	-	No connect, Tie to Digital Ground.

ELECTRICAL SPECIFICATIONS

(TA = -40°C to 85°C, Vcc = 5V ±5%, unless otherwise noted.) Currents flowing into the chip are positive. Current maximums are currents with the largest absolute value. Operation above absolute maximum ratings may permanently damage the device.

ABSOLUTE MAXIMUM RATINGS

PARAMETER	RATING
Positive 5V supply: TVcc, RVcc, DVcc	6V
Storage Temperature	-65 to 150°C
Soldering Temperature (10 sec.)	260 °C
Ambient Operating Temperature, TA	-40 to +85°C
Pin Ratings: LOUT+, LOUT-	Vcc -2 to Vcc +2V
LIN+, LIN-, TPOS, TNEG, TCLK, LBO, RFO, LF2, LF1, $\overline{OPT1}$, $\overline{OPT2}$ Pins	-0.3 to Vcc +0.3V
RPOS, RNEG, RCLK, $\overline{LOWSIG}$ Pins	-0.3 to Vcc +0.3V or +12 mA

SUPPLY CURRENTS AND POWER

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
Supply Current	ICC	Outputs Unloaded, normal operation, transmit and receive all 1's pattern		150	182	mA
Power Dissipation	P	Outputs unloaded, TA = 85°C			0.93	W

EXTERNAL COMPONENTS (Common to DS3/E3, Nominal value.)

Loop filter resistor	RLF1	1% tolerance		6.04		kΩ
Loop filter resistor	RLF2	1%		100		kΩ
Loop filter capacitor	CLF1	5%		0.22		µF
Peak detector capacitor	CPD	10%		0.022		µF

EXTERNAL COMPONENTS (Dependent on speed, Nominal Value.)

				DS-3	E3	
Loop center frequency resistor	RFO	1% tolerance		5.23	6.81	kΩ
Transmit termination capacitor	CTT	5%		10	3	pF
Transmit termination resistor	RTT	1%		301	604	Ω
Receive termination resistor	RTR	1%		75	422	Ω
Receive Transformer Turns Ratio	T1	3%		1:1	1:2	

DIGITAL INPUTS AND OUTPUTS

(CMOS-compatible pins: $\overline{\text{LOWSIG}}$, RPOS, RNEG, RCLK, TPOS, TNEG, TCLK, LBO, $\overline{\text{OPT1}}$.) Currents flowing into the chip are positive. Current maximums are currents with the largest absolute value.

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
Input low voltage	VIL		-0.3		1.5	V
Input high voltage	VIH		3.5		Vcc +0.3	V
Input low current	IIL	VIL = 1.5V	-5		5	µA
Input high current	IIH	VIH = 3.5V	-5		5	µA
Output low voltage	VOL	IOL = 0.1 mA			0.4	V
Output high voltage	VOH	IOH = -0.1 mA	4			V

$\overline{\text{OPT2}}$ CHARACTERISTICS

Input low voltage	VIL	IIL = 0.4 mA			0.5	V
Input high voltage	VIH		2			V

RECEIVER

All of the measurements for the receiver are made with the following conditions unless otherwise stated:

1. The input signal is transformer coupled as shown in Figure 1.
2. RFO = 5.23 kΩ for DS-3 and 6.81 kΩ for E3.
3. UI (Unit Interval) defined as 22.35 ns for DS-3 and 29.1 ns for E3.

Input signal voltage	VIN	Input AC-Coupled CPD = 0.022 µF	±0.045		±1.2	V
		CPD not used	±0.090		±1.2	V
Input Resistance	RIN	Input at device's common mode voltage	15	20	30	kΩ
Receive data detection threshold	VDTH	Relative to peak amplitude for 22.37/17.18 MHz sinusoidal input		50		%
Receive data low signal threshold	VLOW	Relative to peak amplitude for 22.37/17.18 MHz sinusoidal input	±20		±80	mV
Receive data low signal delay	TLOW	Relative to peak amplitude for 22.37/17.18 MHz sinusoidal input CPD = 0.022 µF		500		µs
		CPD not used VIN(max) = ±250 mV	0.5		3	µs
Receive clock period	TRCF	DS-3		22.35		ns
		E3		29.1		ns
Receive clock pulse width	TRC	DS-3		12.24		ns
		E3		14.55		ns

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RECEIVER (continued)

PARAMETER		CONDITIONS		MIN	NOM	MAX	UNIT
Receive clock positive transition time	TRCPT	C_L = 15 pF			4.5	6	ns
Receive clock negative transition time	TRCNT	C_L = 15 pF			4.5	6	ns
Positive or negative	TRDP		DS-3		22.35		ns
Receive data pulse width	TRDN		E3		29.1		
Receive data set-up time	TRDPS		DS-3	5	11.18	13.7	ns
	TRDNS		E3	5	14.55		
Receive data hold time	TRDPH		DS-3	5	11.18	13.7	ns
	TRDNH		E3	5	14.55		
Receive input jitter tolerance high frequency (Note 3)		60 - 300 kHz VIN (min) = ±45 mV	DS-3	0.3			UIPP
		10 - 800 kHz VIN (min) = ±45 mV	E3	0.15			UIPP
		10 - 800 kHz VIN (min) = ±90 mV	E3	0.20			UIPP
Receive input jitter tolerance		10 Hz to 2.3 kHz	DS-3	10			UIPP
low frequency (Note 3)		100 Hz to 10 kHz	E3	10			UIPP
Clock Recovery Phase	KD	All 1's data pattern	DS-3	72	80	88	µA/Rad
Detector Gain		KD = 0.418/RFO	E3		62		
Clock Recovery Phase Locked Oscillator Gain	KO			12	14.5	17	Mrad/ sec. -Volt

TRANSMITTER

All of the measurements for the transmitter are made with the following conditions unless otherwise stated:

1. Transmit pulse characteristics are obtained using a line transformer which has the characteristics, similar to pulse engineering PE-65969, Mini circuit T4-1, Valor PT5045.
2. The circuit is connected as in Figure 1.

Transmit clock repetition TTCF	DS-3		22.35		ns
	E3		29.1		
Transmit clock pulse width TTC	DS-3		11.18		ns
	E3		14.55		
Transmit clock negative transition time TTCNT			4.5	6	ns
Transmit clock positive transition time TTCPT			4.5	6	ns
Transmit data set-up time TTPDS	DS-3	3.5	11.18		ns
TTNDS	E3	3.5	14.55		

TRANSMITTER (continued)

PARAMETER		CONDITIONS		MIN	NOM	MAX	UNIT
Transmit data hold time	TTPDH		DS-3	3.5	11.18		ns
	TTNDH		E3	3.5	14.55		
Transmit positive line pulse width	TTPL	Measured at transformer,	DS-3	10.62	11.18	12	ns
		LBO = Low	E3		14.5		
Transmit negative line pulse width	TTNL	Measured at transformer,	DS-3	10.62	11.18	12	ns
		LBO = Low	E3		14.5		ns
Transmit line pulse waveshape		See Note 1 for DS-3 See Note 2 for E3					

Note 1:Characteristics are in accordance with ANSI T1.102 - 1987, Table 5 and Figure 8.
Note 2:Characteristics are in accordance with CCITT G.703 - 1988 Figure 17.

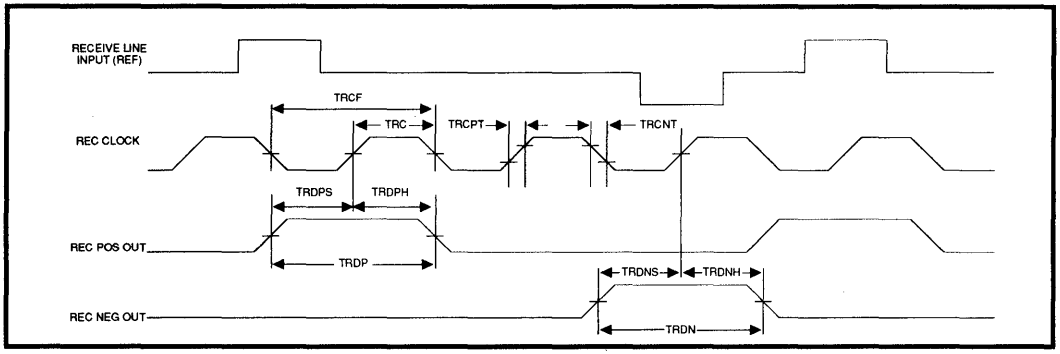


FIGURE 2: Receive Waveforms

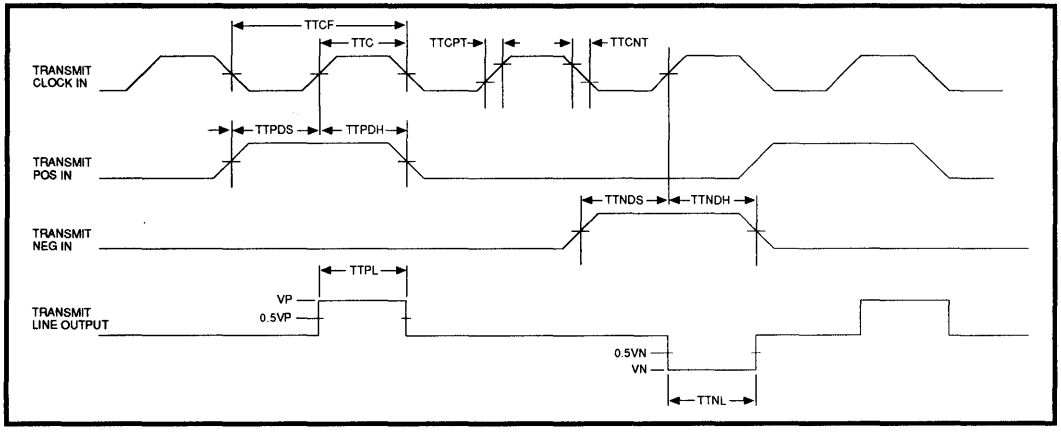
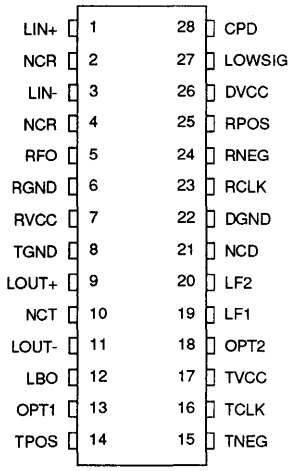


FIGURE 3: Transmit Waveforms

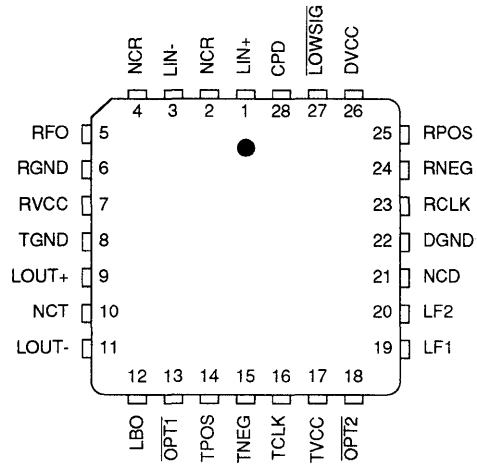
SSI 78P7200
E3/DS-3 Line Interface with Receive Equalizer

PACKAGE PIN DESIGNATIONS
(Top View)

CAUTION: Use handling procedures necessary for a static sensitive component.



28-Pin DIP



28-Pin PLCC

ORDERING INFORMATION

PART DESCRIPTION	ORDER NUMBER	PACKAGE MARK
SSI 78P7200, E3/DS-3 Line Interface – 28-pin		
Standard Width Plastic DIP (600 mil)	78P7200-IP	78P7200-IP
Surface Mount 28-pin PLCC	78P7200-IH	78P7200-IH

Preliminary Data: Indicates a product not completely released to production. The specifications are based on preliminary evaluations and are not guaranteed. Small quantities are available, and Silicon Systems should be consulted for current information.

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Section 7

LAN PRODUCTS

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A TDK Group Company

SSI 78Q902
Ethernet Twisted-Pair Media Attachment Unit

December 1992

DESCRIPTION

The SSI 78Q902 twisted-pair Media Attachment Unit (TP-MAU) is designed to allow Ethernet connections to use the existing twisted-pair wiring plant through an Ethernet Attachment Unit Interface (AUI). The SSI 78Q902 provides the electrical interface between the AUI and the twisted-pair wire.

SSI 78Q902 functions include level-shifted data pass-through from one transmission media to another, collision detection, Signal Quality Error (SQE) testing and automatic correction of polarity reversal on the twisted pair input. It also includes LED drivers for transmit, receive, jabber, collision, reversed polarity detect and link functions.

The SSI 78Q902 is an advanced CMOS device and requires only a single 5-volt power supply.

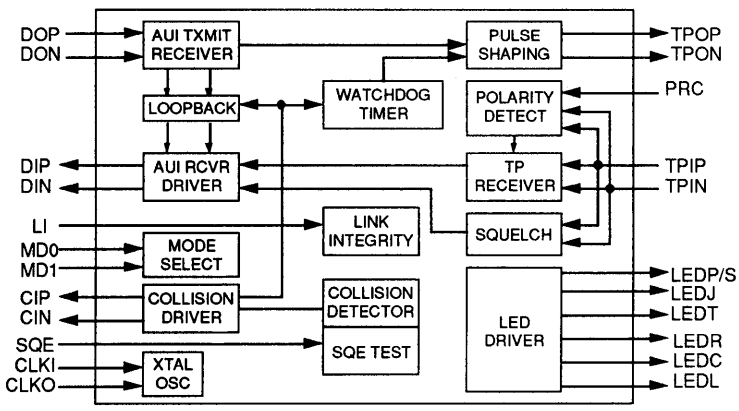
APPLICATIONS

- Computer/workstation interface boards
- LAN repeater
- External 10Base-T converter

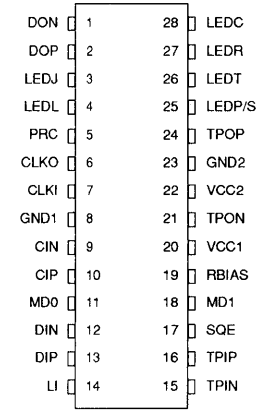
FEATURES

- **Meets or exceeds IEEE 802.3 standards for AUI and 10Base-T interface**
- **Direct interface to AUI and RJ45 connectors**
- **Automatic AUI/RJ45 selection**
- **Internal predistortion generation**
- **Internal common mode voltage generation**
- **Jabber function**
- **Selectable link test, SQE test disable**
- **Twisted-pair receive polarity reverse detection and selectable polarity correction**
- **LED driver for transmit, receive, jabber, collision, link and reversed polarity indicators or for flashing status indicator**
- **Single +5V supply, CMOS technology**
- **Available in 28-pin DIP or PLCC**

BLOCK DIAGRAM



PIN DIAGRAM



28-Pin DIP

CAUTION: Use handling procedures necessary for a static sensitive component.

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SSI 78Q902
Ethernet Twisted-Pair Media Attachment Unit

FUNCTIONAL DESCRIPTION

The SSI 78Q902 Media Attachment Unit (MAU) interfaces the Attachment Unit Interface (AUI) to the unshielded twisted pair cables, transferring data in both directions between the two. The AUI side of the interface comprises three circuits: Data Output (DO), Data Input (DI) and Collision Interface (CI). The twisted pair network side of the interface comprises two circuits: Twisted Pair Input (TPI) and Twisted Pair Output (TPO). In addition to the five basic circuits, the SSI 78Q902 contains an internal crystal oscillator, separate power and ground pins for analog and digital circuits, various logic controls and six LED drivers for status indications.

Functions are defined from the AUI side of the interface. The SSI 78Q902 Transmit function refers to data transmitted by the Data Terminal Equipment (DTE) through the AUI and MAU to the twisted pair network. The SSI 78Q902 Receive function refers to data received by the DTE through the MAU and AUI from the twisted pair network. In addition to basic transmit and receive functions, the SSI 78Q902 performs all required MAU functions defined by the IEEE 802.3 10Base-T specification such as collision detection, link integrity testing, Signal Quality Error (SQE), jabber control and loopback.

TRANSMIT FUNCTION

The SSI 78Q902 transfers Manchester encoded data from the AUI port of the DTE (the DO circuit) to the twisted pair network (the TPO circuit). The output signal on TPON and TPOP is pre-distorted to meet the 10 Base-T jitter template, and filtered to meet FCC requirements. The output waveform (after the transmit filter) is shown in Figure 1. If the differential inputs at the DO circuit fall below 75% of the threshold level for 8 bit times (typical), the SSI 78Q902 transmit function will enter the idle state. During idle periods, the SSI 78Q902 transmits link integrity test pulses on the TPO circuit.

RECEIVE FUNCTION

The SSI 78Q902 receive function transfers serial data from the twisted pair network (the TPI circuit) to the DTE (over the DI circuit of the AUI). An internal squelch function discriminates noise from link test pulses and valid data streams. Only valid data streams activate the receive function. If the differential inputs at the TPI circuit fall below 75% of the threshold level (unsquelched) for 8 bit times (typical), the SSI 78Q902 receive function will enter the idle state. The TPI threshold can be reduced by approximately 3 dB to allow for longer loops in low-noise environments. The reduced threshold is selected when MD1 = 0 and MD0 = 1.

DIFFERENTIAL INPUT MODE

In the differential input mode, the transmit interface consists of TXP and TXN, PE, PDC, and the Transmit Enable input ($\overline{TEN}$). Transmission starts when PE is high and $\overline{TEN}$ is low, and ends when either PE or $\overline{TEN}$ goes inactive. Predistortion control is provided by the PDC input.

POLARITY REVERSE FUNCTION

The SSI 78Q902 polarity reverse function uses both link pulses and end-of-frame data to determine polarity of the received signal. A reversed polarity condition is detected when eight opposite receive link pulses are detected without receipt of a link pulse with the expected polarity. Reversed polarity is also detected if four frames are received with a reversed start-of-idle. Whenever polarity is reversed, these two counters are reset to zero. If the SSI 78Q902 enters the link fail state and no data or link pulses are received within 96 to 128 ms, the polarity is reset to the default non-flipped condition. (If Link Integrity is disabled, polarity detection is based only on received data pulses.)

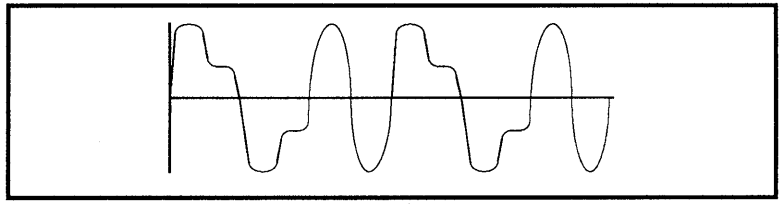


FIGURE 1: 78Q902 TPO Output Waveform

COLLISION DETECTION FUNCTION

The collision detection function operates on the twisted pair side of the interface. A collision is defined as the simultaneous presence of valid signals on both the TPI circuit and the TPO circuit. The SSI 78Q902 reports collisions to the AUI by sending a 10 MHz signal over the CI circuit. The collision report signal is output no more than 9 bit times (BT) after the chip detects a collision. If the TPI circuit becomes active while there is activity on the TPO circuit, the TPI data is passed to the DTE over the DI circuit, disabling the loopback. Figure 2 is a state diagram of the SSI 78Q902 collision detection function (refer to IEEE 802.3 10Base-T specification).

LOOPBACK FUNCTION

The SSI 78Q902 loopback function operates in conjunction with the transmit function. Data transmitted by the DTE is internally looped back within the SSI 78Q902 from the DO pins to the DI pins and returned to the DTE. The loopback function is disabled when a data collision occurs, clearing the DI circuit for the TPI data. Loopback is also disabled during link fail and jabber states.

SQE TEST FUNCTION

Figure 3 is a state diagram of the SQE Test function. The SQE test function is enabled when the SQE pin is tied high. When enabled, the SQE test sequence is transmitted to the controller after every successful transmission on the 10Base-T network. When a successful transmission is completed, the SSI 78Q902 transmits the SQE signal to the AUI over the CI circuit for 10 BT ± 5 BT. The SQE function can be disabled for hub applications by tying the SQE pin to ground.

JABBER CONTROL FUNCTION

Figure 4 is a state diagram of the SSI 78Q902 Jabber control function. The SSI 78Q902 on-chip watchdog timer prevents the DTE from locking into a continous transmit mode. When a transmission exceeds the time limit, the Watchdog timer disables the transmit and loopback functions, and sends the SQE signal to the DTE over the CI circuit. Once the SSI 78Q902 is in the jabber state, the DO circuit must remain idle for a period of 491 to 525 ms before it will exit the jabber state.

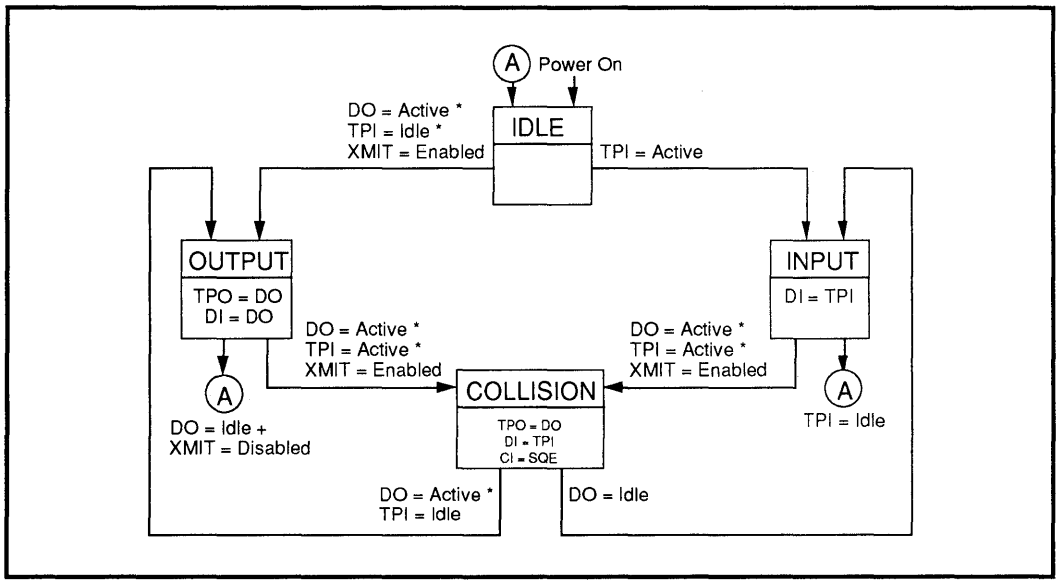


FIGURE 2: Collision Detection Function

LINK INTEGRITY TEST FUNCTION

Figure 5 is a state diagram of the SSI 78Q902 Link Integrity Test Function. The Link Integrity Test is used to determine the status of the receive side twisted pair cable. The link integrity test is enabled when the LI pin is tied high. When enabled, the receiver recognizes link integrity pulses which are transmitted in the absence of receive traffic. If no serial data stream or link integrity pulses are detected within 50 - 150 ms, the chip enters a link fail state and disables the transmit and loopback functions. The SSI 78Q902 ignores any link integrity pulse with intervals less than 2 - 7 ms. The SSI 78Q902 will remain in the link fail state until it detects either a serial data packet or two or more link integrity pulses.

TEST MODE

The SSI 78Q902 Test mode is selected when a 2 to 2.5 MHz clock is input on the MD0 mode select pin. Test mode sets the internal counter chains to run at 1024 times their normal speed. The maximum transmit time, unjab time, Link Integrity timing and LED timing are reduced by a factor of 1024. During test operation, 10 MHz and 20 MHz signals are output on the PRC and SQE pins, respectively. When Test mode is selected, the SQE function cannot be disabled. In Test mode the PRC function can be disabled by the LI pin. Jabber can be disabled by setting MD1 = 0.

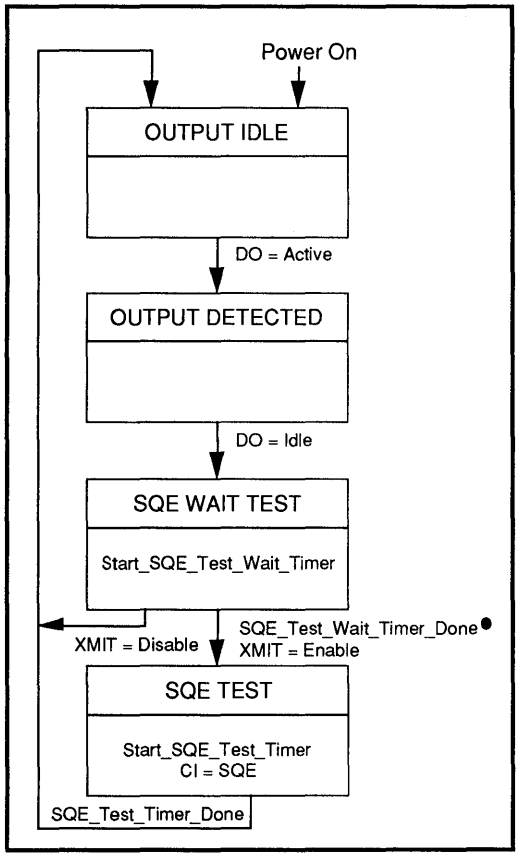


FIGURE 3: SQE Test Function

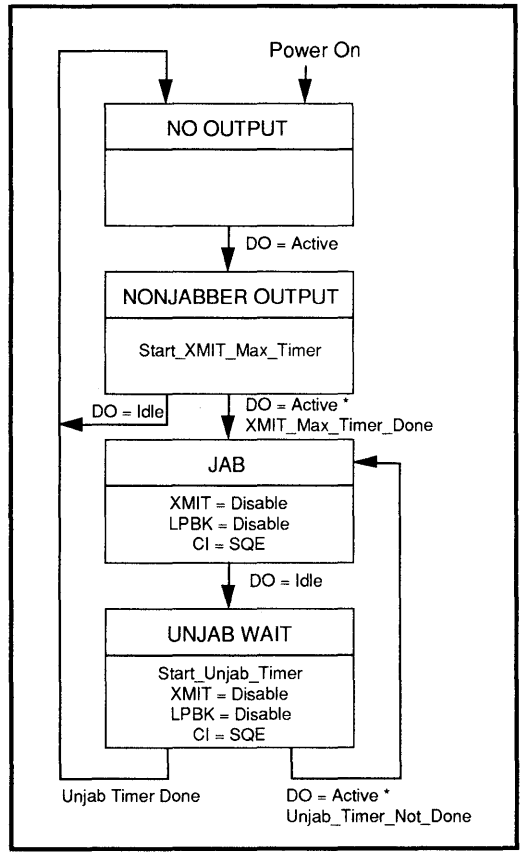


FIGURE 4: Jabber Control Function

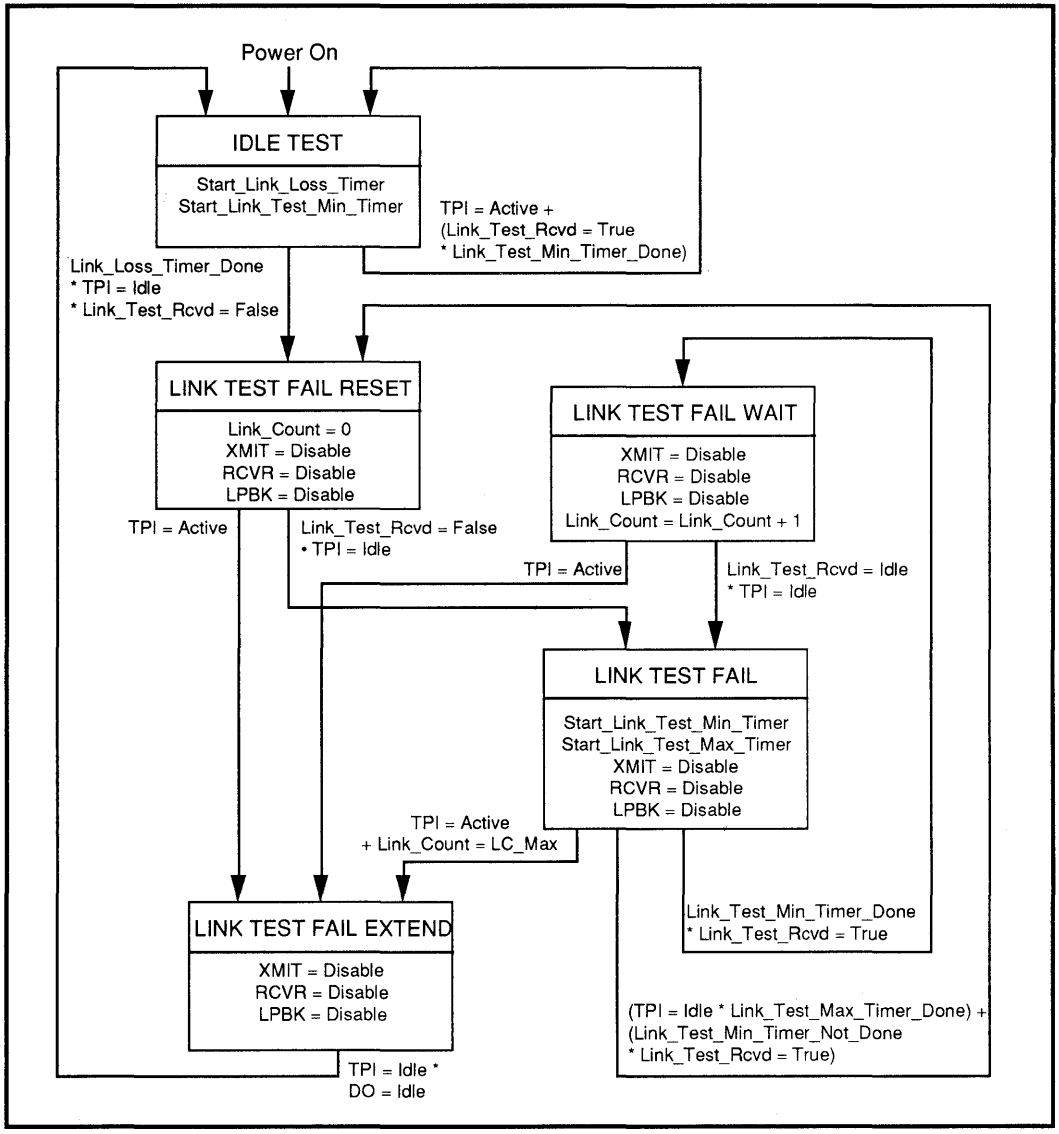


FIGURE 5: Link Integrity Test Function

TABLE 1: Mode Select Options

MD1	MD0	MODE
0	0	Base-T compliant MAU
0	1	Reduced squelch level
1	0	Half current AUI driver
1	1	DO, DI & CI ports disabled
1	Clock	Test mode, jabber on
0	Clock	Test mode, jabber disabled

PIN DESCRIPTION

NAME	TYPE	DESCRIPTION
DON/DOP	I	Data Out Negative/Data Out Positive: Differential input pair connected to the AUI transceiver DO circuit
LEDJ	I/O	Jabber LED Driver: Open drain driver for the Jabber indicator LED. Output goes active[1] when watchdog timer begins jab, and stays active until end of the unjab wait period (491 - 525 ms). When tied to ground, causes LEDP/S to act as a multi-function blinking status indicator.
LEDL	O	Link LED Driver: Open drain driver for the Link indicator LED. Output is active except during Link Fail or when Link Integrity Test is disabled.
PRC	I/O	Polarity Reverse Correction: The SSI 78Q902 automatically corrects reversed polarity at TPI when PRC is tied high. In Test mode, this pin is a 10 MHz output.
CLKO/CLKI	-	Crystal Oscillator: The SSI 78Q902 requires either a 20 MHz crystal (or ceramic resonator) connected across these pins, or a 20 MHz clock applied at CLKI.
GND1	-	Ground #1.
CIN/CIP	O	Collision Negative/Collision Positive: Differential driver output pair tied to the collision presence pair of the Ethernet transceiver AUI cable. The collision presence signal is a 10 MHz square wave. This output is activated when a collision is detected on the network, during self-test by the SQE sequence, or after the watchdog timer has expired to indicate the transmit wire pair has been disabled.
MD0	I	Mode Select 0: Selects operating modes in conjunction with MD1. See Table 1 above for mode select options.
DIN/DIP	O	Data In Negative/Data In Positive: Differential driver pair connected to the AUI transceiver DI circuit.

[1] LED drivers pull low when active.

PIN DESCRIPTION (continued)

NAME	TYPE	DESCRIPTION
LI	I	Link Integrity Test Enable: Link integrity testing is enabled when this pin is tied high. With link test enabled, the SSI 78Q902 sends the link integrity signal in the absence of transmit traffic. It also recognizes received link test pulses, indicating the receive wire pair is present in the absence of transmit traffic.
TPIN/TPIP	I	Twisted Pair Receive Inputs: Differential receive inputs from the twisted pair input filter.
SQE	I/O	Signal Quality Error Test Enable: SQE is enabled when this pin is tie high. When enabled, the SSI 78Q902 sends the signal quality error test sequence to the CI of the AUI cable after every successful transmission to the media. In Test mode, SQE becomes a 20 MHz output.
MD1	I	Mode Select 1: Selects operating modes in conjunction with MD0, (see Table 1). MD1 clock input between 2.0 and 2.5 MHz enables Test mode.
RBIAS	-	Resistor Bias Control: Bias control pin for the operating circuit. Bias set from external resistor to ground. External resistor value = 12.4 kΩ (±1%).
VCC1	I	Power Supply 1: +5V power supply.
TPON/TPOP	O	Twisted Pair Transmit Outputs: Transmit drivers to the twisted-pair output filter. The output is Manchester encoded and pre-distorted to meet the 10Base-T template.
VCC2	I	Power Supply 2: +5V power supply.
GND2	-	Ground #2.
LEDP/S	O	Polarity/Status LED Driver: Open drain LED driver. In normal mode, LEDP/S is active when reversed polarity is detected. If LEDJ is tied to ground, the output LEDP/S indicates multiple status conditions as shown in Figure 6. On solid = Normal, 1 Blink = Link Down, 2 Blinks = Jabber, 5 Blinks = Polarity Reversed
LEDT	O	Transmit LED Driver: Open drain driver for the Transmit indicator LED. Output is active during transmit.
LEDR	O	Receive LED Driver: Open drain driver for the Receive indicator LED. Output is active during receive.
LEDC	O	Collision LED Driver: Open drain driver for the Collision indicator LED. Output is active when a collision occurs.

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Operation above maximum ratings may damage the device.

PARAMETER	RATING	UNIT
Supply Voltage, Vcc	-0.3 to 6	V
Operating Temperature, TOP	0 to +70	°C
Storage Temperature, TST	-65 to +150	°C

RECOMMENDED OPERATING CONDITIONS

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
Supply Voltage[1], Vcc		4.75	5.0	5.25	V
Operating Temperature, TOP		0	-	70	°C

[1]Maximum voltage differential between VCC1 and VCC2 must not exceed 0.3V.

SWITCHING CHARACTERISTICS (Ta = 0 to 70°C, Vcc = 5V ±5%)

PARAMETER	CONDITIONS	MIN	NOM [1]	MAX	UNIT
Jabber Timing					
Maximum transmit time [2]		98.5	-	131	ms
Unjab time [2]		491	-	525	ms
Time from Jabber to CS0 on CIP/CIN[3]		0	-	900	ns
Link Integrity Timing					
Time link loss [2]		65	-	66	ms
Time between Link Integrity Pulses [2]		9	-	11	ms
Interval for valid receive Link Integrity Pulses [2]		4.1	-	65	ms
Collision Timing					
Simultaneous TPI/TPO to CSO state on CIN/CIP		0	-	900	ns
DO loopback to TPI on DI[3]		300	-	900	ns
CS0 state delay after TPI/DO idle[3]		-	-	900	ns
CS0 high pulse width		40	-	60	ns
CS0 low pulse width		40	-	60	ns
CS0 frequency		-	10	-	MHz

1 Typical figures are at 25 °C and are for design aid only; not guaranteed and not subject to production testing.
2 Switching times reduced by a factor of 1024 during Test mode.
3 Parameter is guaranteed by design; not subject to production testing.

SWITCHING CHARACTERISTICS (Ta = 0 to 70°C, Vcc = 5V ±5%) (continued)

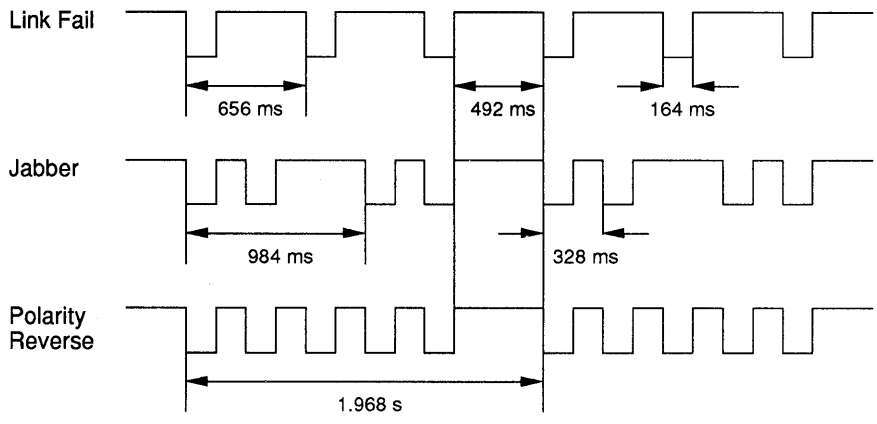
PARAMETER	CONDITIONS	MIN	NOM[1]	MAX	UNIT
SQE Timing					
SQE signal duration		500	-	1500	ns
Delay after last positive transition of DO		0.6	-	1.6	µs
LED Timing					
LEDC, LEDT, LEDR on time[2]		100	-	-	ms
LEDP/S on time[2] (See Figure 6)		-	164	-	ms
LEDP/S period [2] (See Figure 6)		-	328	-	ms
General					
Receive start-up delay		0	-	500	ns
Transmit start-up delay		0	-	200	ns
Loopback start-up delay		0	-	500	ns

[1] Typical figures are at 25 °C and are for design aid only; not guaranteed and not subject to production testing.
[2] Switching times reduced by a factor of 1024 during Test mode.

I/O ELECTRICAL CHARACTERISTICS (Ta = 0 to 70 °C, Vcc = 5V ±5%)

PARAMETER		CONDITIONS	MIN	NOM[1]	MAX	UNIT
Input low voltage[2]	V_{IL}		-	-	0.8	V
Input high voltage[2]	V_{IH}		2.0	-	-	V
Output low voltage (Open drain LED Driver[3])	V_{OL}	R_{LOAD} = 2 kΩ	-	-	0.13	V
Supply current	I_{CC}	Line Idle	-	60	69.3	mA
(Vcc1 = Vcc2 = 5.25V)		Line Active, transmitting all ones	-	125	140	mA
Input leakage current[4]	I_{LL}	Input between VCC and GND	-	±1	±10	µA
Tristate leakage current	I_{TS}	Output between VCC and GND	-	±1	±10	µA

[1] Typical figures are at 25°C and are for desing aid only; not guaranteed and not subject to production testing.
[2] MD0, MD1, SQE, PRC and LI pins. MD1 clock (test mode) must be CMOS level input.
[3] LED Drivers can sink up to 10 mA of drive current.
[4] Not including TPIN, TPIP, DOP or DON.



NOTE: LEDP/S status indications are shown in order of priority, i.e., Link Fail indication supersedes Jabber indication which supersedes Polarity Reverse (when PRC = 1). Reversed polarity conditions supersede Link Fail conditions when PRC = 0 (Polarity Correction Disabled). At the LEDL indicator, reversed polarity condition reported as Link Fail when PRC = 0. This allows the user to distinguish between actual link failure and apparent link failure due to polarity reversal.

FIGURE 6: LEDP/S Status Indication Timing

AUI ELECTRICAL CHARACTERISTICS (Ta = 0 to 70°C, Vcc = 5V ±5%)

PARAMETER		CONDITIONS	MIN	NOM[1]	MAX	UNIT
Input low current	I_{IL}		-	-	-700	µA
Input high current	I_{IH}		-	-	500	µA
Differential output voltage	V_{OD}		±550	-	±1200	mA
Differential squelch threshold	V_{DS}		-	220	-	mV
Receive input impedance	Rz	Between DOP and DON	-	20	-	kΩ

[1] Typical figures are at 25°C and are for design aid only; not guaranteed and not subject to production testing.

TRANSMIT CHARACTERISTICS (Ta = 0 to 70°C, Vcc = 5V ±5%)

PARAMETER	CONDITIONS	MIN	NOM[1]	MAX	UNIT
Transmit output impedance Z_{OUT}		-	5	-	Ω
Peak differential output voltage V_{OD}	Load = 200Ω at TPOP and TPON	±4.5	-	±5.2	V
Transmit timing jitter addition[2]	After Tx filter, 0 line length	-	-	±8	ns
Transmit timing jitter addition[2]	After Tx filter, line model as shown in IEEE 802.3 standard for 10Base-T	-	-	±3.5	ns

RECEIVE CHARACTERISTICS (Ta = 0 to 70°C, Vcc = 5V ±5%)

Receive input impedance Z_{IN}	Between TPIP/TPIN	-	20	-	kΩ
Differential squelch threshold V_{DS}		-	420	-	mV
Reduced squelch threshold V_{DSR}		-	300	-	mV
Receive timing jitter[2]		-	-	1.5	ns

[1] Typical figures are at 25°C and are for design aid only; not guaranteed and not subject to production testing.
[2] Parameter is guaranteed by design; not subject to production testing.

APPLICATION INFORMATION

EXTERNAL MAU

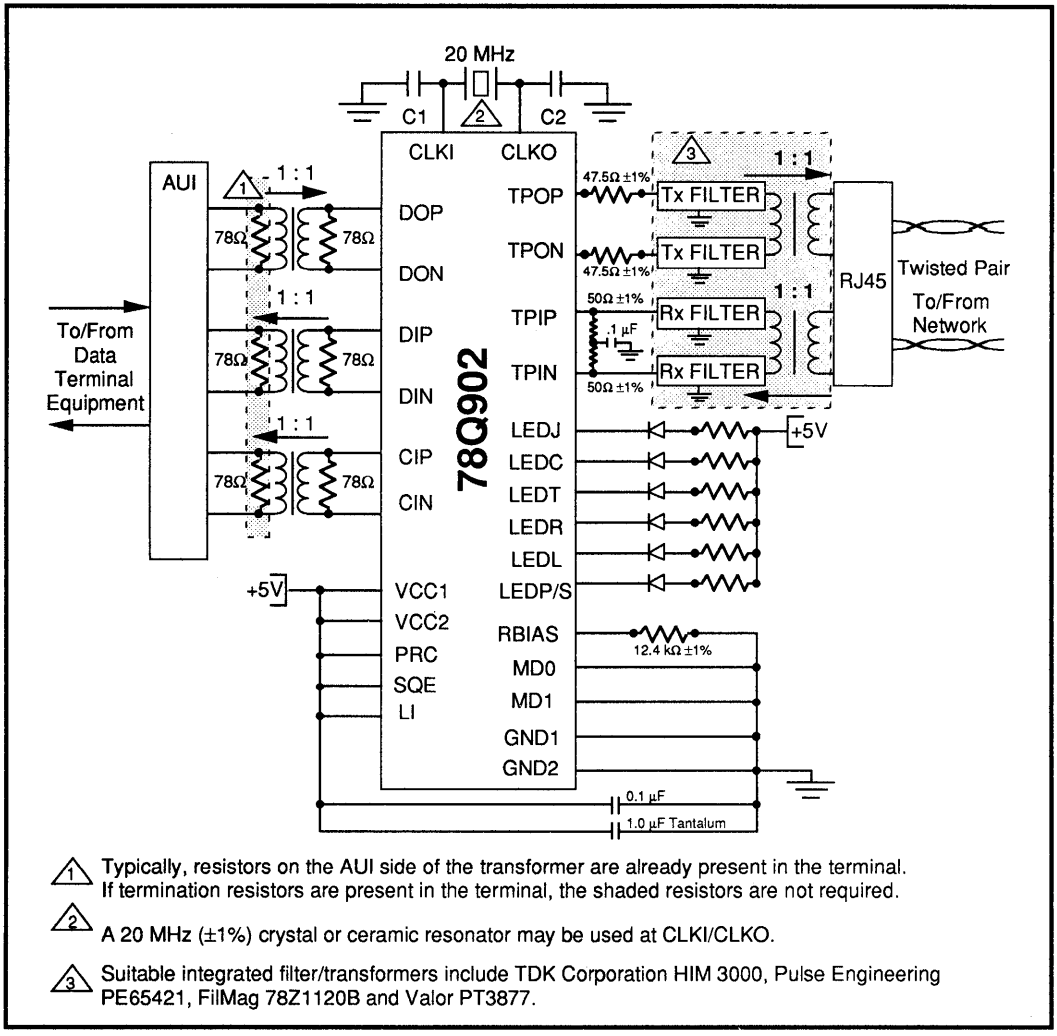
Figure 7 shows the SSI 78Q902 in a typical external MAU application, interfacing between an AUI and the RJ45 connectors of the twisted pair network. A 20 MHz crystal (or ceramic resonator) connected across CLKI and CLKO provides the required clock signal. Transmit and receive filters are required in the TPO and TPI circuits. Details of the transmit and receive filters are shown in Figures 8 and 9, respectively. (Differential filters are also recommended.)

INTERNAL MAU

Figure 10 shows an internal MAU application which takes advantage of the SSI 78Q902's unique AUI/10Base-T switching feature to select either the D-connector (AUI) or the RJ45 connector (10Base-T). No termination resistors are used on the SSI 78Q902 side of the AUI interface to prevent impedance mismatch with the drop cable. The half current drive mode is used to maintain the same voltage levels in the absence of termination resistors. This application uses capacitive coupling instead of transformer coupling. MD1 is tied high so MD0 functions as the mode control switch.

When MD0 is low, the half current drive mode is selected. When MD0 is high, the SSI 78Q902 is effectively removed from the circuit. The 902 AUI ports (DO, DI and CI) are disabled isolating the SSI 78Q902 from the AUI. The SSI 78Q902 DI and CI ports go to a high impedance state and the DO port is ignored.

To implement an auto-select function, LEDL can be tied to MD0. This activates the 902/AUI interface when the TP link is active (data or link integrity pulses) and disables it when the link is inactive.



1. Typically, resistors on the AUI side of the transformer are already present in the terminal. If termination resistors are present in the terminal, the shaded resistors are not required.
2. A 20 MHz (±1%) crystal or ceramic resonator may be used at CLKI/CLKO.
3. Suitable integrated filter/transformers include TDK Corporation HIM 3000, Pulse Engineering PE65421, FilMag 78Z1120B and Valor PT3877.

FIGURE 7: SSI 78Q902 External MAU Application Diagram

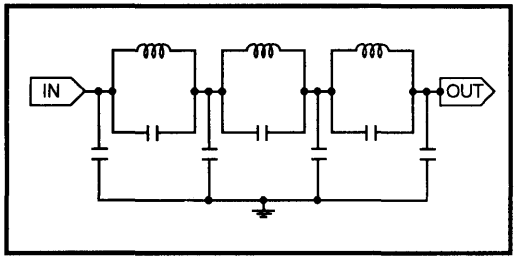


FIGURE 8: Transmit Filter Diagram

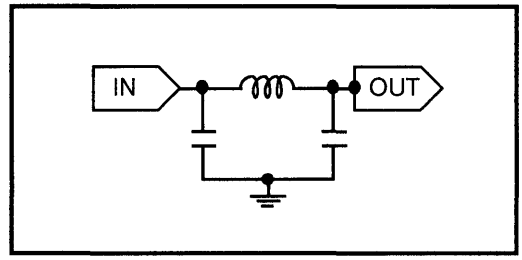


FIGURE 9: Receive Filter Diagram

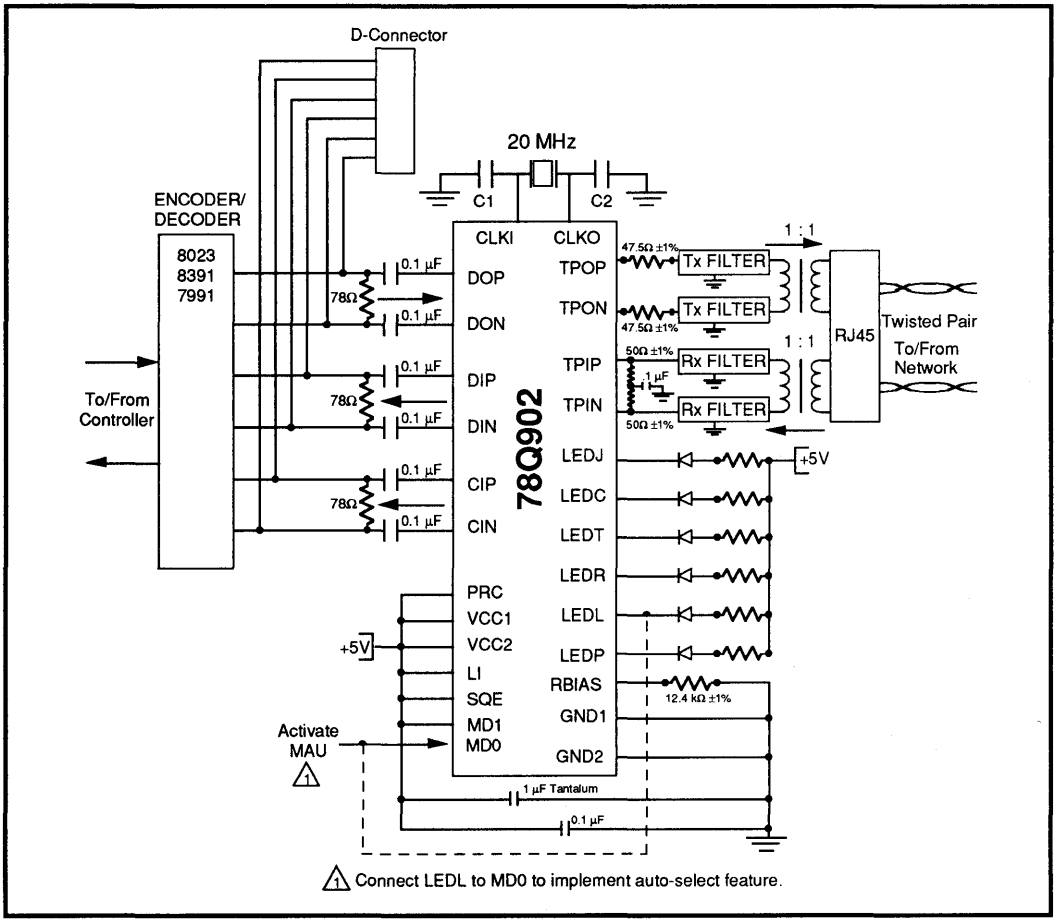


FIGURE 10: SSI 78Q902 Internal MAU Application Diagram

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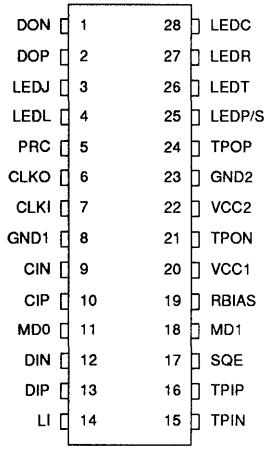
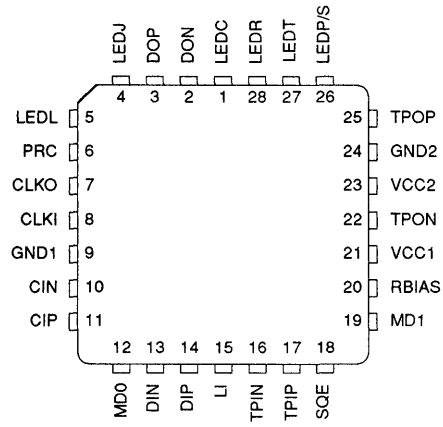
SSI 78Q902
Ethernet Twisted-Pair Media Attachment Unit

PACKAGE PIN DESIGNATIONS
(Top View)

CAUTION: Use handling procedures necessary for a static sensitive component.



28-Pin DIP



28-Pin PLCC

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 78Q902 28-Pin DIP	78Q902-CP	78Q902-CP
SSI 78Q902 28-Pin PLCC	78Q902-CH	78Q902-CH

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SSI 78Q8373
3V, 5V PCMCIA Ethernet Combo
Preliminary Data

January 1995

DESCRIPTION

The SSI 78Q8373 is a highly integrated Ethernet IC for use in PCMCIA (Personal Computer Memory Card International Association) applications and can operate with a power supply of 3.3V or 5V. It contains a Media Access Controller (MAC), a 10 Mbit/s Manchester encoder/decoder (ENDEC), a 10Base-T transceiver, a memory-card bus interface (PCMCIA), and an Attachment Unit Interface (AUI). This level of integration allows the user to implement a PCMCIA card for 10Base-T using only the SSI 78Q8373, external memory, and some passive components. The internal bus interface circuit allows connection to a PCMCIA 2.1 bus without other external components. The PCMCIA bus-decoding logic can be bypassed for connection to other bus types. The SSI 78Q8373 connects to twisted-pair media via line transformers through the on-chip transceiver circuit. Connection to other media such as coaxial cable is made through the AUI port to an external transceiver, such as the SSI 78Q8330 Ethernet Coax Transceiver.

The SSI 78Q8373 has a sophisticated power management capability with three different operating modes allowing the user to maximize power savings, making it ideal for use in PCMCIA applications. During normal operation, the IC monitors its own actions and shuts down the circuits that are not being used, resulting in the lowest possible operating power. It also has a standby mode which leaves only the oscillator running, and a full shutdown mode which also turns off the oscillator.

An intelligent Buffer Manager is controlled by the host read, host write, receive and transmit pointers, and the SSI 78Q8373 manages the pointers internally without any host intervention. The device interleaves access to the buffer memory so that accesses from the host and from the network media seem to operate concurrently. Big and little endian byte orderings make for simple bus interface to all standard microprocessors.

The SSI 78Q8373 is available in both a 100-lead QFP and thin QFP (TQFP) packages, and can operate with a power supply of 3.3 volts or 5 volts.

FEATURES

- **Single-chip solution for 10Base-T/PCMCIA designs**
- **Operation at 3.3V or 5V**
- **Pin-compatible with SSI 78Q8370**
- **Integrated 10Base-T transceiver:**
  - **Programmable/automatic selection of twisted pair (RJ45) or AUI port**
  - **Receive polarity detection/correction on twisted-pair inputs**
- **Manchester Encoder/Decoder circuit**
- **AUI port for connection to 10Base2/5 transceiver or AUI cable**
- **Integrated bus interface compliant with PCMCIA release 2.1 specification**
- **Bus interface can be bypassed for non-PCMCIA applications**
- **Protocol Controller compliant with IEEE 802.3 and Ethernet 2.0**
- **Advanced Buffer Manager architecture:**
  - **Automatic management of all pointers**
  - **Allows "simultaneous" access to data in buffer memory by both the network and host**
  - **High-speed received packet skip**
- **Configurable Buffer Memory for design flexibility:**
  - **Two-bank transmit buffer in 2, 4, 8, or 16 Kbyte sizes**
  - **Ring-structure receive buffer from 4 to 62 Kbytes**
- **Software-configurable system bus structure:**
  - **Compatible with major microprocessors**
  - **8- or 16-bit wide data path communications with hosts**
- **Power management options:**
  - **Intelligent power mode automatically shuts off unused circuitry**
  - **Standby mode reduces power while not in operation**
  - **Full shutdown mode offers maximum power savings**
- **Available in 100-lead QFP and TQFP packages**

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FUNCTIONAL DESCRIPTION

The 78Q8373 consists of six major blocks as shown in Figure 1.

- Buffer Manager (and SRAM Interface)
- Data Link Controller
- Host/PCMCIA Interface
- Manchester ENDEC
- Twisted Pair Transceiver
- Power Management

BUFFER MANAGER

The Buffer Manager manages all accesses to the buffer memory through the SRAM interface. The buffer memory is connected directly to the Data Link Controller (DLC), thus eliminating the need for a local microprocessor. The Buffer Manager also keeps track of all buffer memory pointers automatically, simplifying the software driver task. Together with intelligent arbitration, this makes the 8373 a high performance LAN controller.

The buffer memory is divided into two portions: transmit memory portion and receive memory portion. The transmit memory portion can be partitioned into 2K, 4K, 8K or 16 Kbyte buffer sizes. There is only one transmit bank if a 2 KB transmit buffer size is selected. If the transmit buffer size is greater than 2 KB, then the transmit buffer is configured into two banks of equal size. With the two bank configuration, one transmit bank may be tied up during transmission but the host can still continue to load data packets into the second transmit bank to be transmitted later. The receive buffer has a ring architecture which can be configured from 4K to 62 KB depending on the buffer memory configuration which has a range of 8K to 64 KB.

A central arbitrator inside the Buffer Manager prioritizes and services requests for access to the buffer memory from 4 sources: the Transmitter, the Receiver, Host Read and Host Write. If necessary, the 8373 will assert a 'not ready' handshake to the host while servicing the Transmitter and/or Receiver. The 8373 arbitration mechanism provides packet management by interleaving packet data accesses to the buffer memory such that the operations appear to be simultaneous.

For instance, in the situation where 2 transmit banks are configured, the host can load the first transmit bank and initiate a transmission. While the first transmit bank is being transmitted, the host can continue to load packets in the second transmit bank. At this stage, the 8373 can potentially be receiving data from the medium and loading it into the receive buffer (if the 8373 is in a loop back mode or if self-reception occurs).

DATA LINK CONTROLLER

The Data Link Controller (DLC) implements the ISO/ANSI/IEEE 8802-3 CSMA/CD protocol. It consists of a Transmitter, a Receiver and CRC logic (which is shared by both transmit and receive operations). Automatic generation and stripping of the 64-bit preamble and the 32-bit CRC code are provided on-chip.

HOST/PCMCIA INTERFACE

The Host Interface (HIF) provides connection to the host system. It consists of the various registers, DMA circuits and ready logic. Both word and byte interfaces are supported as well as big endian and little endian data ordering. Host access to the buffer memory is through BMR8 (and BMR9). Reading from BMR8 will read a byte or word from the receive buffer and writing to BMR8 will write a byte or word to the transmit buffer. The ready logic is capable of delaying host access to the buffer memory with a time-out mechanism. Both single and burst DMA transfer modes are supported.

The PCMCIA interface circuitry builds on top of the 8373 generic host interface and is only active if the MODE pin is left unconnected (internally pulled-up). The 8373 can thus connect directly to a PCMCIA release 2.1 compliant bus. It also supports decoding for the external CIS memory (both ROM and Flash types). The 8373 pinout has been defined to minimize criss-crossing connections to the PCMCIA connector. This allows for a cost effective 2-layer PCB design.

MANCHESTER ENDEC

This block implements Manchester encoding and decoding. Serial NRZ data from the DLC is converted to Manchester encoded data and sent to either the twisted-pair transceiver block or to the Attachment Unit Interface (AUI) driver, depending on which block is active. The decoder section performs three functions: clock recovery, carrier detection and Manchester decoding. The recovered receive clock will be low at the end of reception and during idle to save power. Jitter of up to ±18 ns can be tolerated by the decoder. This block also translates a 10 MHz collision signal to a logic-level signal before sending it to the DLC block if the AUI port is selected.

TWISTED PAIR TRANSCEIVER

The on-chip Twisted Pair module consists of a number of functions. It has a smart squelch circuitry to determine valid data present on the differential receive inputs TPIP/TPIN. Its transmit and pre-distortion drivers connect to the twisted pair network via the summing resistors and transformer/filter. The link detector/ generator circuitry checks the integrity of the cable connecting the two twisted pair MAUs. Collision, jabber and SQE are also incorporated.

POWER MANAGEMENT

One very useful and important feature that the 8373 offers is intelligent power management. It supports three different power saving modes: Intelligent, Standby, and Full Shutdown. All modes are configurable through registers. In the Intelligent mode, clocks are active only when they are needed. For example, when not transmitting, the clock supplied to the transmitter circuit in the DLC block is not active while host read from buffer memory may be active. In Standby mode, the oscillator clock is disconnected from the rest of the circuits, so that only the oscillator circuits draw power. Full Shutdown turns off the oscillator, resulting in maximum power savings. Note that this mode is not available when using an external clock source.

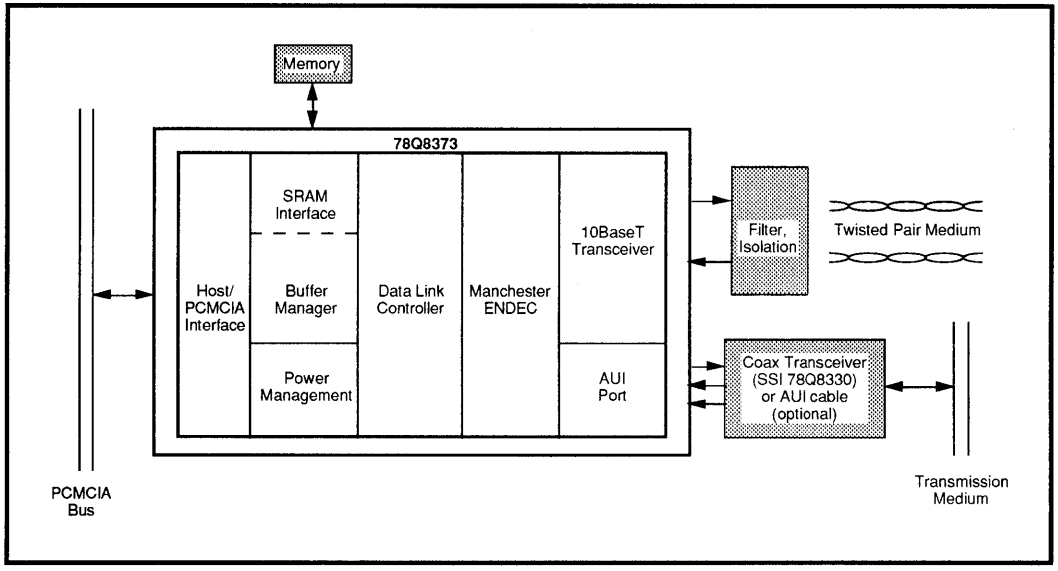

FIGURE 1: System Diagram

7

Pin Assignment Table - PCMCIA Bus Mode - 100-Pin TQFP

PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE
1	D1	IO4	26	$\overline{OE}$	I	51	RA4	O4	76	DON	AO
2	D8	IO4U	27	$\overline{WE}$	I	52	RA5	O4	77	DOP	AO
3	D0	IO4	28	$\overline{INPACK}$	O4	53	RA6	O4	78	AGND	P
4	A0	I	29	$\overline{REG}$	I	54	GND	P	79	REXT	R
5	A1	I	30	$\overline{ROMG}$	O4	55	VDD	P	80	AVDD	P
6	A2	I	31	$\overline{FCE}$	O4	56	RA7	O4	81	TPIN	AI
7	A3	I	32	$\overline{XPD}$	O4	57	RA12	O4	82	TPIP	AI
8	RESET	SI	33	XRST	O4	58	RA14	O4	83	MODE	TI
9	VDD	P	34	GND	P	59	$\overline{RWE}$	O4	84	DIN	AI
10	GND	P	35	RD0	IO4U	60	RA13	O4	85	DIP	AI
11	$\overline{IOWR}$	I	36	RD1	IO4U	61	RA8	O4	86	CIN	AI
12	$\overline{IORD}$	I	37	RD2	IO4U	62	RA9	O4	87	CIP	AI
13	$\overline{CE2}$	I	38	RD3	IO4U	63	RA11	O4	88	GND	P
14	D15	IO4U	39	RD4	IO4U	64	$\overline{ROE}$	O4	89	SPKRIN	SI
15	$\overline{CE1}$	I	40	RD5	IO4U	65	RA15	O4	90	$\overline{SPKR}$	O8
16	D14	IO4U	41	RD6	IO4U	66	OSCI	CI	91	CCRA	I
17	D7	IO4	42	RD7	IO4U	67	OSCO	O	92	RRST	O4
18	GND	P	43	GND	P	68	VDD	P	93	LEDLT	OD16
19	D13	IO4U	44	$\overline{RCS0}$	O4	69	GND	P	94	CB	O4
20	D6	IO4	45	$\overline{RCS1}$	O4	70	GND	P	95	$\overline{IOIS16}$	O4
21	D12	IO4U	46	RA10	O4	71	TPDN	AO	96	$\overline{IREQ}$	O8
22	D5	IO4	47	RA0	O4	72	TPDP	AO	97	$\overline{WAIT}$	O4
23	D11	IO4U	48	RA1	O4	73	TPON	AO	98	D10	IO4U
24	D4	IO4	49	RA2	O4	74	TPOP	AO	99	D2	IO4
25	D3	IO4	50	RA3	O4	75	VDD	P	100	D9	IO4U

Legend:

I:	Input (TTL level)
O4, O8:	Output with IOL = 4 or 8 mA
OD16:	Output Open Drain with IOL = 16 mA
IO4, IO4U:	Input (TTL level) and Output with IOL = 4 mA; IO4U refers to IO4 with an internal pull-up resistor
CI:	CMOS level input
SI:	Schmitt trigger input
TI:	Three-state input. May be connected to low, high, or left open.
AI:	Analog input
AO:	Analog output
P:	Power
R:	Resistor to ground
O:	Output

Pin Assignment Table - PCMCIA Bus Mode - 100-Pin QFP

PIN #	PIN NAME	TYPE	PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE
1	D10	IO4U	26	D11	IO4U	51	RA1	O4	76	TPON	AO
2	D2	IO4	27	D4	IO4	52	RA2	O4	77	TPOP	AO
3	D9	IO4U	28	D3	IO4	53	RA3	O4	78	VDD	P
4	D1	IO4	29	$\overline{OE}$	I	54	RA4	O4	79	DON	AO
5	D8	IO4U	30	$\overline{WE}$	I	55	RA5	O4	80	DOP	AO
6	D0	IO4	31	$\overline{INPACK}$	O4	56	RA6	O4	81	AGND	P
7	A0	I	32	$\overline{REG}$	I	57	GND	P	82	REXT	R
8	A1	I	33	$\overline{ROMG}$	O4	58	VDD	P	83	AVDD	P
9	A2	I	34	$\overline{FCE}$	O4	59	RA7	O4	84	TPIN	AI
10	A3	I	35	$\overline{XPD}$	O4	60	RA12	O4	85	TPIP	AI
11	RESET	SI	36	XRST	O4	61	RA14	O4	86	MODE	TI
12	VDD	P	37	GND	P	62	$\overline{RWE}$	O4	87	DIN	AI
13	GND	P	38	RD0	IO4U	63	RA13	O4	88	DIP	AI
14	$\overline{IOWR}$	I	39	RD1	IO4U	64	RA8	O4	89	CIN	AI
15	$\overline{IORD}$	I	40	RD2	IO4U	65	RA9	O4	90	CIP	AI
16	$\overline{CE2}$	I	41	RD3	IO4U	66	RA11	O4	91	GND	P
17	D15	IO4U	42	RD4	IO4U	67	$\overline{ROE}$	O4	92	SPKRIN	SI
18	$\overline{CE1}$	I	43	RD5	IO4U	68	RA15	O4	93	$\overline{SPKR}$	O8
19	D14	IO4U	44	RD6	IO4U	69	OSCI	CI	94	CCRA	I
20	D7	IO4	45	RD7	IO4U	70	OSCO	O	95	RRST	O4
21	GND	P	46	GND	P	71	VDD	P	96	LEDLT	OD16
22	D13	IO4U	47	$\overline{RCS0}$	O4	72	GND	P	97	CB	O4
23	D6	IO4	48	$\overline{RCS1}$	O4	73	GND	P	98	$\overline{IOIS16}$	O4
24	D12	IO4U	49	RA10	O4	74	TPDN	AO	99	$\overline{IREQ}$	O8
25	D5	IO4	50	RA0	O4	75	TPDP	AO	100	$\overline{WAIT}$	O4

Legend:

I: Input (TTL level)
O4, O8: Output with IOL = 4 or 8 mA
OD16: Output Open Drain with IOL = 16 mA
IO4, IO4U: Input (TTL level) and Output with IOL = 4 mA; IO4U refers to IO4 with an internal pull-up resistor
CI: CMOS level input
SI: Schmitt trigger input
TI: Three-state input. May be connected to low, high, or left open.
AI: Analog input
AO: Analog output
P: Power
R: Resistor to ground
O: Output

Pin Assignment Table - Generic Bus Mode - 100-Pin TQFP

PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE
1	HD1	IO4	26	RD8	IO4U	51	RA4	O4	76	DON	AO
2	HD8	IO4U	27	RD9	IO4U	52	RA5	O4	77	DOP	AO
3	HD0	IO4	28	RD10	IO4U	53	RA6	O4	78	AGND	P
4	HA0	I	29	RD11	IO4U	54	GND	P	79	REXT	R
5	HA1	I	30	RD12	IO4U	55	VDD	P	80	AVDD	P
6	HA2	I	31	RD13	IO4U	56	RA7	O4	81	TPIN	AI
7	HA3	I	32	RD14	IO4U	57	RA12	O4	82	TPIP	AI
8	RESET	SI	33	RD15	IO4U	58	RA14	O4	83	MODE	TI
9	VDD	P	34	GND	P	59	$\overline{RWE}$	O4	84	DIN	AI
10	GND	P	35	RD0	IO4U	60	RA13	O4	85	DIP	AI
11	$\overline{WR}$	I	36	RD1	IO4U	61	RA8	O4	86	CIN	AI
12	$\overline{RD}$	I	37	RD2	IO4U	62	RA9	O4	87	CIP	AI
13	$\overline{BHE}$	I	38	RD3	IO4U	63	RA11	O4	88	GND	P
14	HD15	IO4U	39	RD4	IO4U	64	$\overline{ROE}$	O4	89	$\overline{DMACK}$	SI
15	$\overline{CS}$	I	40	RD5	IO4U	65	RA15	O4	90	DMREQ	O8
16	HD14	IO4U	41	RD6	IO4U	66	OSCI	CI	91	EOP	I
17	HD7	IO4	42	RD7	IO4U	67	OSCO	O	92	RRST	O4
18	GND	P	43	GND	IO4U	68	VDD	P	93	LEDLT	OD16
19	HD13	IO4U	44	$\overline{RCS0}$	P	69	GND	P	94	CB	O4
20	HD6	IO4	45	$\overline{RCS1}$	O4	70	GND	P	95	HWORD	O4
21	HD12	IO4U	46	RA10	O4	71	TPDN	AO	96	$\overline{INT}$	O8
22	HD5	IO4	47	RA0	O4	72	TPDP	AO	97	READY	O4
23	HD11	IO4U	48	RA1	O4	73	TPON	AO	98	HD10	IO4U
24	HD4	IO4	49	RA2	O4	74	TPOP	AO	99	HD2	IO4
25	HD3	IO4	50	RA3	O4	75	VDD	P	100	HD9	IO4U

Legend:

I:	Input (TTL level)
O4, O8:	Output with IOL = 4 or 8 mA
OD16:	Output Open Drain with IOL = 16 mA
IO4, IO4U:	Input (TTL level) and Output with IOL = 4 mA; IO4U refers to IO4 with an internal pull-up resistor
CI:	CMOS level input
SI:	Schmitt trigger input
TI:	Three-state input. May be connected to low, high, or left open.
AI:	Analog input
AO:	Analog output
P:	Power
R:	Resistor to ground
O:	Output

Pin Assignment Table - Generic Bus Mode -100-Pin QFP

PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE
1	HD10	IO4U	26	HD11	IO4U	51	RA1	O4	76	TPON	AO
2	HD2	IO4	27	HD4	IO4	52	RA2	O4	77	TPOP	AO
3	HD9	IO4U	28	HD3	IO4	53	RA3	O4	78	VDD	P
4	HD1	IO4	29	RD8	IO4U	54	RA4	O4	79	DON	AO
5	HD8	IO4U	30	RD9	IO4U	55	RA5	O4	80	DOP	AO
6	HD0	IO4	31	RD10	IO4U	56	RA6	O4	81	AGND	P
7	HA0	I	32	RD11	IO4U	57	GND	P	82	REXT	R
8	HA1	I	33	RD12	IO4U	58	VDD	P	83	AVDD	P
9	HA2	I	34	RD13	IO4U	59	RA7	O4	84	TPIN	AI
10	HA3	I	35	RD14	IO4U	60	RA12	O4	85	TPIP	AI
11	RESET	SI	36	RD15	IO4U	61	RA14	O4	86	MODE	TI
12	VDD	P	37	GND	P	62	$\overline{RWE}$	O4	87	DIN	AI
13	GND	P	38	RD0	IO4U	63	RA13	O4	88	DIP	AI
14	$\overline{WR}$	I	39	RD1	IO4U	64	RA8	O4	89	CIN	AI
15	$\overline{RD}$	I	40	RD2	IO4U	65	RA9	O4	90	CIP	AI
16	$\overline{BHE}$	I	41	RD3	IO4U	66	RA11	O4	91	GND	P
17	HD15	IO4U	42	RD4	IO4U	67	$\overline{ROE}$	O4	92	$\overline{DMACK}$	SI
18	$\overline{CS}$	I	43	RD5	IO4U	68	RA15	O4	93	DMREQ	O8
19	HD14	IO4U	44	RD6	IO4U	69	OSCI	CI	94	EOP	I
20	HD7	IO4	45	RD7	IO4U	70	OSCO	O	95	RRST	O4
21	GND	P	46	GND	P	71	VDD	P	96	LEDLT	OD16
22	HD13	IO4U	47	$\overline{RCS0}$	O4	72	GND	P	97	CB	O4
23	HD6	IO4	48	$\overline{RCS1}$	O4	73	GND	P	98	HWORD	O4
24	HD12	IO4U	49	RA10	O4	74	TPDN	AO	99	$\overline{INT}$	O8
25	HD5	IO4	50	RA0	O4	75	TPDP	AO	100	READY	O4

Legend:

I:	Input (TTL level)
O4, O8:	Output with IOL = 4 or 8 mA
OD16:	Output Open Drain with IOL = 16 mA
IO4, IO4U:	Input (TTL level) and Output with IOL = 4 mA; IO4U refers to IO4 with an internal pull-up resistor
CI:	CMOS level input
SI:	Schmitt trigger input
TI:	Three-state input. May be connected to low, high, or left open.
AI:	Analog input
AO:	Analog output
P:	Power
R:	Resistor to ground
O:	Output

PIN DESCRIPTION

HOST BUS INTERFACE - PCMCIA BUS MODE

<table>
<tr><th>NAME</th><th>TYPE</th><th>DESCRIPTION</th></tr>
<tr><td>RESET</td><td>I</td><td>HARDWARE RESET. Active high. A minimum pulse length of 800 ns is required. This pin resets the 8373's internal pointers and registers to their appropriate states. It also clears the CI (Configuration Index) in the CCR (Card Configuration Register), thus placing the 8373 in an unconfigured (Memory-only Interface) state. The 8373 remains in the unconfigured state until the CI has been written with a non-zero value.</td></tr>
<tr><td>$\overline{IOWR}$</td><td>I</td><td>I/O WRITE. The $\overline{IOWR}$ pin is an active low input that enables a write operation by the host to the 8373 internal registers as selected by the host address inputs A[0:3]. The $\overline{REG}$ and at least one of $\overline{CE1}$ or $\overline{CE2}$ must be also active for the I/O write to take place. The 8373 will not respond to the $\overline{IOWR}$ signal until it has been configured for I/O operation by the host.</td></tr>
<tr><td>$\overline{IORD}$</td><td>I</td><td>I/O READ. The $\overline{IORD}$ pin is an active low input that enables a read operation by the host from the 8373 internal registers as selected by the host address inputs A[0:3]. The $\overline{REG}$ and at least one of $\overline{CE1}$ or $\overline{CE2}$ must be also active for the I/O read to take place. The 8373 will not respond to the $\overline{IORD}$ signal until it has been configured for I/O operation by the host.</td></tr>
<tr><td>$\overline{CE1}$, $\overline{CE2}$</td><td>I</td><td>CHIP ENABLE. Active low input signals acting as chip select for the 8373. $\overline{CE1}$ enables even-numbered address bytes and $\overline{CE2}$ enables odd-numbered address bytes. When the 8373 is programmed to be in byte mode (DLCR6<5> HBYTE bit is a "1"), $\overline{CE2}$ is a don't care and only lower databus D[0:7] is used for data transfer. Combinations of $\overline{CE1}$, $\overline{CE2}$, A0 and HBYTE bit (DLCR6<5>) are used to select the different modes of I/O space word/byte transfer according to the following table (the table assumes $\overline{REG}$ is activated):
<table>
<tr><th>HBYTE</th><th>$\overline{CE2}$</th><th>$\overline{CE1}$</th><th>A0</th><th>D[15:8]</th><th>D[7:0]</th></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td><td>X</td><td>even-byte</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>1</td><td>X</td><td>odd-byte</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>odd-byte</td><td>even-byte</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>X</td><td>odd-byte</td><td>X</td></tr>
<tr><td>1</td><td>X</td><td>0</td><td>0</td><td>X</td><td>even-byte</td></tr>
<tr><td>1</td><td>X</td><td>0</td><td>1</td><td>X</td><td>odd-byte</td></tr>
</table>
For Attribute Memory access, data transfer occurs only on D[7:0] with the following valid combinations only:
<table>
<tr><th>HBYTE</th><th>$\overline{CE2}$</th><th>$\overline{CE1}$</th><th>A0</th><th>D[15:8]</th><th>D[7:0]</th></tr>
<tr><td>X</td><td>X</td><td>0</td><td>0</td><td>X</td><td>even-byte</td></tr>
</table></td></tr>
<tr><td>CCRA</td><td>I</td><td>CARD CONFIGURATION REGISTER ADDRESS. This pin connects to PCMCIA higher address bit. A high (together with $\overline{REG}$ activation) on this bit selects the internal CCR registers and a low selects the external CIS (Card Information Structure) ROM/Flash memory.</td></tr>
<tr><td>$\overline{OE}$</td><td>I</td><td>OUTPUT ENABLE. An active low input signal used to read data from the internal CCR (Card Configuration Registers) and from the external Attribute Memory (through the activation of $\overline{FCE}$ and $\overline{ROMG}$). This $\overline{OE}$ should also connect to the output enable of the external Flash Memory or the ROM.</td></tr>
</table>

HOST BUS INTERFACE - PCMCIA BUS MODE (continued)

NAME	TYPE	DESCRIPTION
$\overline{WE}$	I	WRITE ENABLE. An active low input signal used to write data to the internal CCR (Card Configuration Registers) and to the external Attribute (Flash) Memory (through the activation of $\overline{FCE}$). This $\overline{WE}$ should also connect to the write enable of the external Flash Memory.
$\overline{REG}$	I	ATTRIBUTE MEMORY SELECT. When this signal is active (low), it signifies access from or to the Attribute Memory ($\overline{OE}$ or $\overline{WE}$ active) or the I/O space ($\overline{IORD}$ or $\overline{IOWR}$ active). Attribute Memory is generally used to record card capacity and other configuration and attribute information. This includes the standardized CCRs (Card Configuration Registers) which are located internally in the 8373. When Attribute Memory is accessed, only data signals D[0:7] are valid and signals D[8:15] are ignored.
A[0:3]	I	ADDRESS BUS. Selects the set of 8373 internal registers including the CCR (Card Configuration Registers) for read or write operations.
D[0:15]	I/O	DATA BUS. A bi-directional, tri-state bus. The combinations of $\overline{CE1}$, $\overline{CE2}$ and A0 control the portion of the bus that is being utilized. A[0:3] and RBNK1,0 (DLCR7<3:2>) select the set of internal registers for access.

HOST BUS INTERFACE - PCMCIA BUS MODE

The following output signals are inactive (high) until the 8373 is configured for I/O mode.

$\overline{WAIT}$	O	$\overline{WAIT}$. An active low output that is asserted to delay completion of the current I/O read or write operation. It will also be used if the device is unable to respond to read or write requests within 2.4 µs. In these situations, the 8373 will also assert $\overline{IREQ}$ and the host read error status bit (DLCR1<6>) or host write error status bit (DLCR0<0>).
$\overline{INPACK}$	O	INPUT ACKNOWLEDGE. This active low output signal is asserted when the 8373 is selected and it can respond to an I/O read cycle requested by the host. This signal is used by the host to control the enable of any input data buffer between the card and the CPU. This signal will only be active after the 8373 is configured for I/O mode.
$\overline{IOIS16}$	O	I/O IS 16 BIT PORT. This active low output signal is asserted when the 8373 is configured for word transfer to indicate to the host that it is capable of 16-bit access. Therefore, this pin follows the register bit HBYTE (DLCR6<5>) once the 8373 is configured for I/O mode.
$\overline{IREQ}$	O	INTERRUPT REQUEST. This signal is available only after the 8373 is configured for I/O mode. It is asserted when the 8373 requires the intervention of the Host in situations as depicted in DLCR0,1 and BMR15. The IREQ signal is masked by writing a "0" to the respective interrupt enable register. To comply to with PCMCIA 2.0 spec, the 8373 supports both Pulsed- and Level- Mode interrupts as selected by the LevIREQ (CCR0<6>) register bit.
$\overline{SPKR}$	O	SPEAKER. This signal is held inactive (i.e. high) until the 8373 is configured for I/O mode. It provides a single-amplitude, on-off, binary audio waveform intended to drive the host's loudspeaker. The source for the signal is SPKRIN.

PIN DESCRIPTION (continued)

PCMCIA APPLICATION PINS

NAME	TYPE	DESCRIPTION
$\overline{\text{ROMG}}$	O	ROM ENABLE. Active low. This signal will be activated when an attribute memory read is performed on the external CIS memory.
$\overline{\text{FCE}}$	O	FLASH MEMORY CHIP ENABLE. Active low. The flash memory $\overline{\text{WE}}$ (Write Enable) and $\overline{\text{OE}}$ (Output Enable) come from PCMCIA pins $\overline{\text{WE}}$ and $\overline{\text{OE}}$.
$\overline{\text{XPD}}$	O	EXTERNAL POWER DOWN. Active low. When the 8373 enters power down mode, this pin will be low. It can be used to control power down of external devices residing on the same card.
XRST	O	EXTERNAL RESET. Active high. This pin is a reflection of CCR0<7> register bit. This allows a software controlled hardware reset of the 8373 and the rest of the devices residing on the same card.
SPKRIN	I	SPEAKER IN. This pin is qualified with the AUDIO bit, CCR1<3> to produce the inverted $\overline{\text{SPKR}}$ output.

HOST BUS INTERFACE - GENERIC BUS MODE

NAME	TYPE	DESCRIPTION
RESET	I	HARDWARE RESET. Active high. A minimum pulse length of 800 ns is required. This pin resets the 8373's internal pointers and registers to their appropriate states. Note: the 8373 must be reset after power on before usage.
READY	O	READY. This output is asserted to indicate to the host that the 8373 is ready to complete the requested read or write operation. It will also be used if the device is unable to respond to read or write requests within 2.4 µs. In these situations, the 8373 will also assert $\overline{INT}$ and the host read error status bit (DLCR1 <6>) or host write error status bit (DLCR0 <0>). The polarity of the READY pin is determined by the MODE pin.
$\overline{WR}$	I	WRITE. The $\overline{WR}$ pin is an active low input that enables a write operation from the host to the 8373's internal registers as selected by the host address inputs HA[0:3].
$\overline{RD}$	I	READ. The $\overline{RD}$ pin is an active low input that enables a read operation by the host from the 8373's internal registers as selected by the host address inputs HA[0:3].
$\overline{CS}$	I	CHIP SELECT. An active low input signal as the chip select for the 8373.
$\overline{BHE}$	I	BYTE HIGH ENABLE. This is an active low byte/word control pin used only when the 8373 is configured for word transfer by HBYTE bit (DLCR6 <5>). Combinations of $\overline{BHE}$ and HA0 are used to select word, upper byte only or lower byte only transfers.

HBYTE	$\overline{BHE}$	HA0	FUNCTION
0	0	0	Word transfer
0	0	1	Byte transfer on high bus HD[8:15].
0	1	0	Byte transfer on low bus HD[0:7].
0	1	1	Reserved
1	X	X	Byte transfer (HD[0:7])

$\overline{INT}$	O	INTERRUPT. This active low signal is asserted when the 8373 requires the intervention of the Host in situations as depicted in DLCR0,1 and BMR15. The $\overline{INT}$ signal is masked by writing a '0' to the respective interrupt enable register.
EOP	I	END OF PROCESS. Asserted at the end of a DMA transfer by the Host DMA controller. Further DMA requests (DMREQ) will be discontinued after EOP is asserted. Polarity can be selected via the register bit (DLCR7 <1>).
DMREQ	O	DMA REQUEST. The 8373 issues a DMREQ to the Host DMA controller to initiate a write to its transmit buffer or a read from its receive buffer.

PIN DESCRIPTION (continued)

HOST BUS INTERFACE - GENERIC BUS MODE

NAME	TYPE	DESCRIPTION
$\overline{DMACK}$	I	DMA ACKNOWLEDGE. An active low signal issued by the Host DMA controller when it is ready to perform data transfers between the Host and the 8373's buffer memory via BMR8.
HA[0:3]	I	HOST ADDRESS. Selects the set of internal registers to be accessible by the 8373 for read or write operations.
HD[0:15]	I/O	HOST DATA BUS. A bi-directional, tri-state bus for data, command and status transfers between the Host and the 8373 with the direction being controlled by $\overline{RD}$ and $\overline{WR}$. The combinations of HBYTE, $\overline{BHE}$ and HA0 control the portion of the bus that is being utilized. HA[0:3] and RBNK <0:1> (DLCR7 <2:3>) select the set of internal registers for access.
HWORD	O	HOST WORD CONFIGURATION. This pin is the complement of the register bit HBYTE (DLCR6 <5>). If HBYTE is a '0', the Host interface is configured for word transfers. If HBYTE is a '1', the Host interface is configured for byte transfers on the lower bus, HD[0:7].

BUFFER MEMORY INTERFACE

$\overline{RCS0}$, $\overline{RCS1}$	O	RAM CHIP SELECT. $\overline{RCS0}$ and $\overline{RCS1}$ are active low chip select lines for the SRAM with $\overline{RCS0}$ as the least significant byte.
$\overline{ROE}$	O	RAM OUTPUT ENABLE. Active low. This is the output enable asserted by the 8373 during buffer memory read cycles for the SRAM.
$\overline{RWE}$	O	RAM WRITE ENABLE. Active low. This is the write enable asserted by the 8373 during buffer memory write cycles for the SRAM.
RD[0:15]	I/O	RAM DATA BUS. This is the data bus between the 8373 and the buffer memory. It can be configured for byte or word transfer depending on register bit RBYTE (DLCR6 <4>) RAM BYTE. For word transfers, the ordering of the most and least significant byte is defined by the register bit, INTLMOT (DLCR7 <0>). In PCMCIA bus mode, this data bus is only 8 bits wide (RD[0:7]).
RA[0:15]	O	RAM ADDRESS BUS. Addresses up to 64 KByte of SRAM buffer memory.

NETWORK ATTACHMENT UNIT INTERFACE

DON, DOP	O	TRANSMIT DATA NEGATIVE and POSITIVE. Differential outputs to external transceiver for transmission.
DIN, DIP	I	RECEIVE DATA NEGATIVE and POSITIVE. Manchester differential inputs from external transceiver for reception.
CIN, CIP	I	COLLISION DETECT NEGATIVE and POSITIVE. When an externally connected transceiver detects a collision on the medium, these differential inputs are driven by a 10 MHz signal.
REXT	-	EXTERNAL RESISTOR. External biasing resistor. Connect to 20 kΩ ±1% to AGND.

NETWORK TWISTED-PAIR MEDIUM INTERFACE

NAME	TYPE	DESCRIPTION
TPON, TPOP	O	TWISTED-PAIR OUTPUT NEGATIVE and POSITIVE. Driver outputs to twisted-pair medium. Must be summed together with TPDN and TPDP by external resistors in a pre-equalization network to produce twisted-pair transmit signal.
TPDN, TPDP	O	TWISTED-PAIR DELAYED NEGATIVE and POSITIVE. Delayed (50 ns) driver outputs to twisted-pair medium. Must be summed together with TPON and TPOP by external resistors in a pre-equalization network to produce twisted-pair transmit signal.
TPIN, TPIP	I	TWISTED-PAIR INPUT NEGATIVE and POSITIVE. Inputs from twisted-pair medium.

DEVICE POWER

VDD	P	POWER SUPPLY. A +5V DC (±5%) or +3.3 VDC (±0.3V) supply is required.
GND	P	SYSTEM GROUND.
AVDD	P	ANALOG VDD. The analog VDD pin required by the internal AUI and twisted-pair circuits is to be connected to a different VDD path from the digital VDD. A +5V DC (±5%) or +3.3 VDC (±0.3V) supply is required.
AGND	P	ANALOG GROUND. The analog ground required by the internal encoder/decoder is to be connected to a separate GND path from the digital GND.

CRYSTAL OSCILLATOR

OSCI	I	OSCILLATOR IN. Connection for one side of the 20 MHz crystal or an input for an external 20 MHz clock source.
OSCO	O	OSCILLATOR OUT. Connection for other side of the 20 MHz crystal. Left unconnected if an external clock is used.

MISCELLANEOUS

CB	O	CONTROL BIT. A complement of the internal register bit, DLCR4 <2>, which is used to activate any external hardware.
RRST	O	REMOTE RESET. This pin follows the RMTRST register bit (DLCR1 <4>). The RMTRST bit is '1' only if a packet with the pattern 0900H in the Type Field is detected and ENA_RMTRST (DLCR5 <2>) is activated. This feature can be used by the nodes on the network to remotely-control external hardware.
MODE	I	MODE SELECT. Tied high to select Generic bus mode with active high READY timing. Tied low to select Generic bus mode with active low READY timing. Left open to select PCMCIA bus mode (it will be internally pulled up).
LEDLT	O	LED LINK, TRANSMIT. Connect to LED with current limiting resistor to VDD. LED is on during link up and off during link down. During link up (when LED is on), a transmission will blink off the LED temporarily to indicate activity. This feature is available for both twisted pair and AUI interfaces.

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Operation beyond the maximum ratings may damage the device.

PARAMETER	RATING
Supply voltage, Vdd	-0.5 to 6.0V
Input voltage, Vin	-0.5 to Vdd + 0.5V
Output voltage, Vout	-0.5 to Vdd + 0.5V
Storage temperature, Tstg	-55 to 150°C
Lead temperature (max 10 sec soldering), Tl	250°C max

DC CHARACTERISTICS (Ta = 0 to 70°C, Vdd = 5V ±5%, 5V Values)

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
Low level input voltage	Vil	TTL inputs			0.8	V
		OSCI pin			1.6	V
		Schmitt inputs			1.1	V
High level input voltage	Vih	TTL inputs	2.2			V
		OSCI pin	3.8			V
		Schmitt inputs	3.5			V
Pull down current (RESET pin)	Ipd		13		50	µA
Low level output voltage	Vol	Rated Iol	0		0.4	V
High level output voltage	Voh	Rated Ioh	2.4		Vdd	V
Low level output current	Iol	Pin types O4, IO4, IO4U Vdd = 5V	4			mA
(with Vol = 0.4V)		Pin type O8 Vdd = 5V	8			mA
		Pin type OD16 Vdd = 5V	16			mA
High level output current	Ioh	Pin types O4, IO4, IO4U Vdd = 5V	-4			mA
(with Voh = 2.4V)		Pin type O8 Vdd = 5V	-8			mA
Leakage current (input/output)	Il		-10		10	µA
Supply current	Idd	Fully active(1)			40	mA
		Idle			30	mA
Power down supply current	Ipwrdn	Osc. on			10	mA
		Osc. off			100	µA

Note: (1) Fully active means 3 "simultaneous" operations: transmitting, receiving (through twisted-pair port) and either host write or read.

DC CHARACTERISTICS (Ta = 0 to 70°C, Vdd = 3.3V ±0.3V, 3V Values)

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
Low level input voltage	Vil	TTL inputs			0.8	V
		OSCI pin			0.7	V
		Schmitt inputs			0.4	V
High level input voltage	Vih	TTL inputs	2			V
		OSCI pin	2.1			V
		Schmitt inputs	2.4			V
Pull down current (RESET pin)	Ipd		5		28	µA
Low level output voltage	Vol	Rated Iol	0		0.4	V
High level output voltage	Voh	Rated Ioh	2.4		Vdd	V
Low level output current	Iol	Pin types O4, IO4, IO4U Vdd = 3.3V	2.4			mA
(with Vol = 0.4V)		Pin type O8 Vdd = 3.3V	4.9			mA
		Pin type OD16 Vdd = 3.3V	9.8			mA
High level output current	Ioh	Pin types O4, IO4, IO4U Vdd = 3.3V	-1.5			mA
(with Voh = 2.4V)		Pin type O8 Vdd = 3.3V	-3			mA
Leakage current (input/output)	Il		-10		10	µA
Supply current	Idd	Fully active(1)			28	mA
		Idle			20	mA
Power down supply current	Ipwrdn	Osc. on			6	mA
		Osc. off			100	µA

Note: (1) Fully active means 3 "simultaneous" operations: transmitting, receiving (through twisted-pair port) and either host write or read.

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ELECTRICAL SPECIFICATIONS (continued)

AUI CHARACTERISTICS

(VDD = 5V ± 5%, 3.3 ± 0.3V, Vss = 0V, Ta = 0°C to +70°C)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
Low Output Voltage for DOP, DON Vaol	Rext = 20 kΩ Rl = 78Ω	Vdd-1.5		Vdd-0.75	V
High Output Voltage for DOP, DON Vaoh	Rext = 20 kΩ Rl = 78Ω	Vdd-0.55		Vdd	V
DOP, DON Output Current Iao	Rext = 20 kΩ	8		14	mA
DIP, DIN, CIP, CIN Open Circuit Input Voltage (bias) Valb	Vdd = 5V ± 5% Vdd = 3.3 ± 0.3V	2.45 2.13		3.33 2.88	V
DIP, DIN, CIP, CIN Diff Squelch Threshold Vasq		-300		-120	mV
DOP, DON Diff Idle Output Vadi	Rl = 78Ω	-40		40	mV
DOP, DON Diff Peak Output Vadv	Rext = 20 kΩ Rl = 78Ω	620		1100	mV
DOP, DON Output Resistance Rao				75	Ω

TWISTED PAIR
(VDD = 5V ± 5%, Ta = 0°C to +70°C)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
TPIP, TPIN Diff Input Resistance Rti		3			kΩ
TPIP, TPIN Open Circuit Input Voltage (bias) Vtib		2.45		3.33	V
TPIP, TPIN Diff Input Voltage Range Vtiv	VDD = 5V	-3.1		3.1	V
TPIP, TPIN Positive Squelched Threshold Vtps	Note 1	300		585	mV
TPIP, TPIN Negative Squelched Threshold Vtns	Note 1	-585		-300	mV
TPIP, TPIN Positive Unsquelched Threshold Vtpu	Note 2		180		mV
TPIP, TPIN Negative Unsquelched Threshold Vtnu	Note 2		-180		mV
TPIP, TPIN Positive Squelched Threshold Long Distance Mode Vltps	Note 1	120		300	mV
TPIP, TPIN Negative Squelched Threshold Long Distance Mode Vltns	Note 1	-300		-120	mV
TPIP, TPIN Positive Unsquelched Threshold Long Distance Mode Vltpu	Note 2		100		mV
TPIP, TPIN Negative Unsquelched Threshold Long Distance Mode Vltnu	Note 2		-100		mV
TPOP, TPON High Output Voltage Vtoh	I = 32 mA	Vddtp -0.44		Vddtp	V
TPOP, TPON Low Output Voltage Vtol	I = 32 mA	Vsstp		Vsstp +0.44	V
TPDP, TPDN High Voltage Vtdh	I = 16 mA	Vddtp -0.44		Vddtp	V
TPDP, TPDN Low Voltage Vtdl	I = 16 mA	Vsstp		Vsstp +0.44	V
TPDP, TPDN Output Resistance Rtd				27	Ω
TPOP, TPON Output ResistanceRto				13.5	Ω

Note 1: Sine wave at 2 MHz, 5 MHz and 7 MHz
Note 2: Sine wave : 5 MHz ≤ f ≤ 10 MHz

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ELECTRICAL SPECIFICATIONS (continued)

TWISTED PAIR
(VDD = 3.3 ± 0.3V, Ta = 0°C to +70°C)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
TPIP, TPIN Diff Input Resistance Rti		3			kΩ
TPIP, TPIN Open Circuit Input Voltage (bias) Vtib		2.13		2.88	V
TPIP, TPIN Diff Input Voltage Range Vtiv	VDD = 3.3V	-2.2		2.2	V
TPIP, TPIN Positive Squelched Threshold Vtps	Note 1	210		410	mV
TPIP, TPIN Negative Squelched Threshold Vtns	Note 1	-410		-210	mV
TPIP, TPIN Positive Unsquelched Threshold Vtpu	Note 2		130		mV
TPIP, TPIN Negative Unsquelched Threshold Vtnu	Note 2		-130		mV
TPIP, TPIN Positive Squelched Threshold Long Distance Mode Vltps	Note 1	90		210	mV
TPIP, TPIN Negative Squelched Threshold Long Distance Mode Vltns	Note 1	-210		-90	mV
TPIP, TPIN Positive Unsquelched Threshold Long Distance Mode Vltpu	Note 2		70		mV
TPIP, TPIN Negative Unsquelched Threshold Long Distance Mode Vltnu	Note 2		-70		mV
TPOP, TPON High Output Voltage Vtoh	I = 50 mA	V_{DDTP} -0.3		V_{DDTP}	V
TPOP, TPON Low Output Voltage Vtol	I = 50 mA	V_{SSTP}		V_{SSTP} +0.3	V
TPDP, TPDN High Voltage Vtdh	I = 25 mA	V_{DDTP} -0.3		V_{DDTP}	V
TPDP, TPDN Low Voltage Vtdl	I = 25 mA	V_{SSTP}		V_{SSTP} +0.3	V
TPDP, TPDN Output Resistance Rtd				12	Ω
TPOP, TPON Output Resistance Rto				6	Ω

Note 1: Sine wave at 2 MHz, 5 MHz and 7 MHz
Note 2: Sine wave: 5 MHz ≤ f ≤ 10 MHz

TRANSFORMER RATIO:

5V OPERATION		3.3V OPERATION	
RX	TX	RX	TX
1:1	1:1	1:1.4 (step down)	1:1.4 (step down)

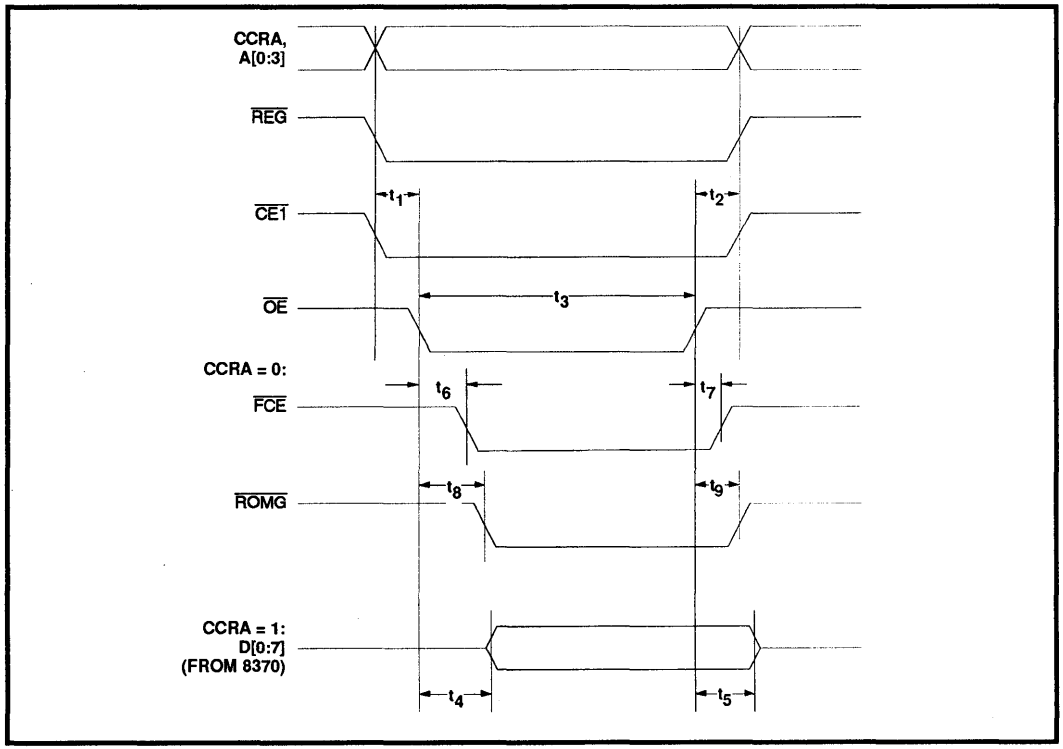

FIGURE 2: Attribute Memory Read Cycle (PCMCIA mode)

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Unless otherwise stated, the following conditions apply to the remaining timing tables:
Ta = 0°C to +70°C, Vdd = 5 ± 5%, Vdd = 3.3V ± 0.3V

TABLE 1: Attribute Memory Read Cycle (PCMCIA mode) (Refer to Figure 2)

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
CCRA, A[0:3] Valid to $\overline{OE}$ low; $\overline{REG}$, $\overline{CE1}$ low to $\overline{OE}$ low	t_1		0			ns
$\overline{OE}$ high to CCRA, A[0:3] invalid; $\overline{OE}$ high to $\overline{REG}$, $\overline{CE1}$ high	t_2		0			ns
$\overline{OE}$ low pulse width	t_3	Vdd = 5V	30			ns
		Vdd = 3.3V	35			ns
$\overline{OE}$ low to D[0:7] valid	t_4				45	ns
$\overline{OE}$ high to D[0:7] invalid (data hold)	t_5		10			ns
$\overline{OE}$ low to $\overline{FCE}$ low	t_6	Vdd = 5V			25	ns
		Vdd = 3.3V			35	ns
$\overline{OE}$ high to $\overline{FCE}$ high	t_7	Vdd = 5V			25	ns
		Vdd = 3.3V			35	ns
$\overline{OE}$ low to $\overline{ROMG}$ low	t_8	Vdd = 5V			25	ns
		Vdd = 3.3V			35	ns
OE high to ROMG high	t_9	Vdd = 5V			25	ns
		Vdd = 3.3V			35	ns

TABLE 2: Attribute Memory Write Cycle (PCMCIA MODE) (Refer to Figure 3)

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
CCRA, A[0:3] Valid to $\overline{WE}$ low; $\overline{REG}$, $\overline{CE1}$ low to $\overline{WE}$ low	t_1		0			ns
$\overline{WE}$ high to CCRA, A[0:3] invalid; $\overline{WE}$ high to $\overline{REG}$, $\overline{CE1}$ high	t_2		0			ns
$\overline{WE}$ low pulse width	t_3	Vdd = 5V	30			ns
		Vdd = 3.3V	35			ns
D[0:7] valid to $\overline{WE}$ high (data setup)	t_4		15			ns
$\overline{WE}$ high to D[0:7] invalid (data hold)	t_5		10			ns
$\overline{WE}$ low to $\overline{FCE}$ low	t_6	Vdd = 5V			25	ns
		Vdd = 3.3V			35	ns
WE high to FCE high	t_7	Vdd = 5V			25	ns
		Vdd = 3.3V			35	ns

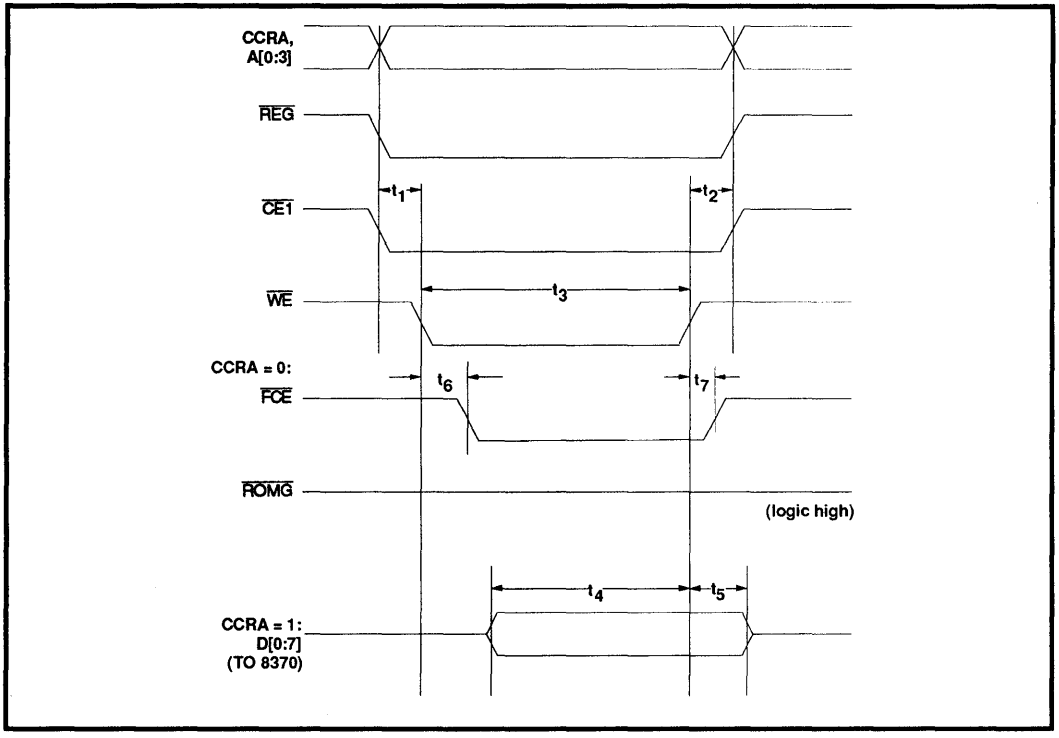

FIGURE 3: Attribute Memory Write Cycle (PCMCIA mode)

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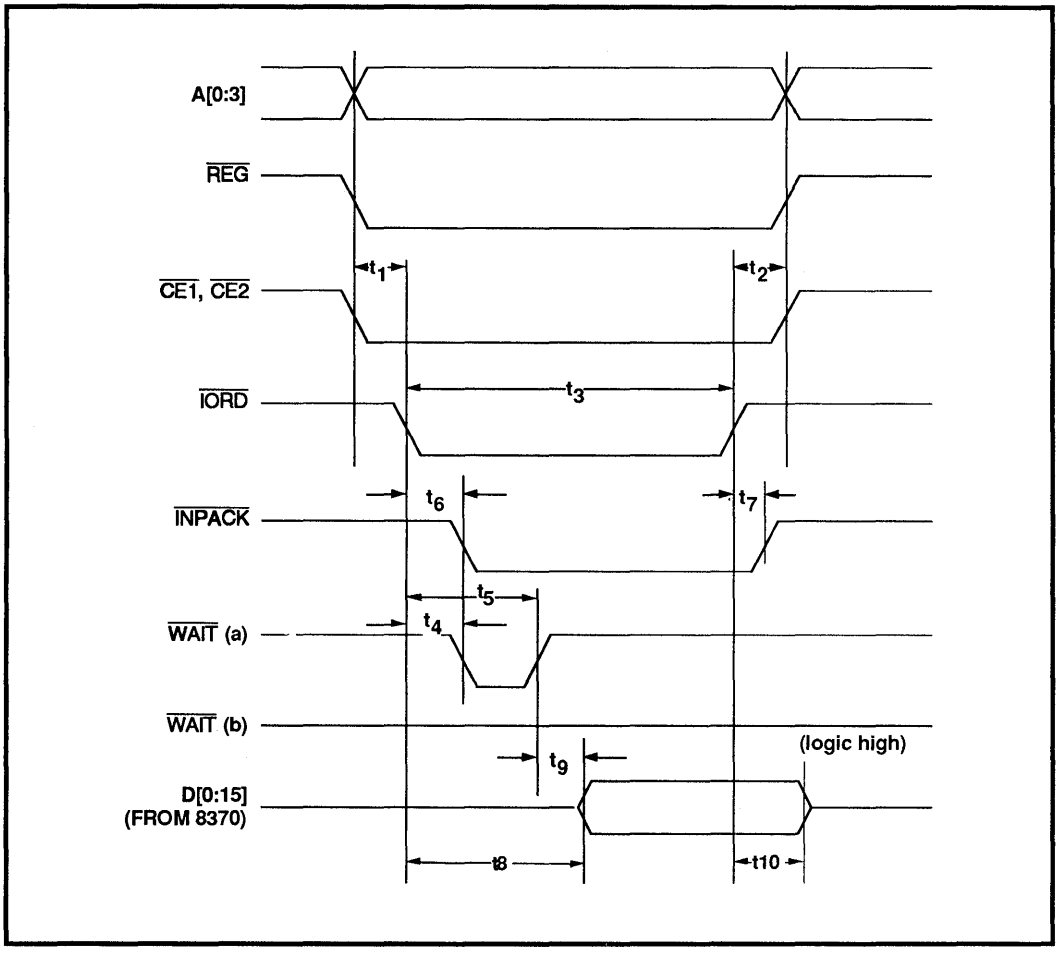

FIGURE 4: I/O Read Cycle (PCMCIA mode)

TABLE 3: I/O Read Cycle (PCMCIA mode) (Refer to Figure 4)

PARAMETER		CONDITIONS		MIN	NOM	MAX	UNIT
A[0:3] valid to $\overline{IORD}$ LOW; $\overline{REG}$, $\overline{CE1}$, $\overline{CE2}$ low to $\overline{IORD}$ low	t_1			0			ns
$\overline{IORD}$ high to A[0:3] invalid; $\overline{IORD}$ high to $\overline{REG}$, $\overline{CE1}$, $\overline{CE2}$ high	t_2			0			ns
$\overline{IORD}$ low pulse width	t_3		Vdd = 5V	30			ns
			Vdd = 3.3V	35			ns
$\overline{IORD}$ low to $\overline{WAIT}$ low	t_4	Port busy (a)	Vdd = 5V	0		35	ns
			Vdd = 3.3V			50	ns
$\overline{IORD}$ low to $\overline{WAIT}$ high(1)	t_5	Port busy (a)				350	ns
$\overline{IORD}$ low to $\overline{INPACK}$ low	t_6		Vdd = 5V			25	ns
			Vdd = 3.3V			35	ns
$\overline{IORD}$ high to $\overline{INPACK}$ high	t_7		Vdd = 5V			25	ns
			Vdd = 3.3V			35	ns
$\overline{IORD}$ low to D[0:15] valid	t_8	Register access (b)	Vdd = 5V			50	ns
			Vdd = 3.3V			70	ns
$\overline{WAIT}$ high to D[0:15] valid	t_9	Port busy (a)				5	ns
$\overline{IORD}$ high to D[0:15] invalid (data hold)	t_{10}			10			ns

TABLE 4: I/O Write Cycle (PCMCIA mode) (Refer to Figure 5)

A[0:3] valid to $\overline{IOWR}$ LOW; $\overline{REG}$, $\overline{CE1}$, $\overline{CE2}$ low to $\overline{IOWR}$ low	t_1			0			ns
$\overline{IOWR}$ high to A[0:3] invalid; $\overline{IOWR}$ high to $\overline{REG}$, $\overline{CE1}$, $\overline{CE2}$ high	t_2			0			ns
$\overline{IOWR}$ low pulse width	t_3		Vdd = 5V	30			ns
			Vdd = 3.3V	35			ns
$\overline{IOWR}$ low to $\overline{WAIT}$ low	t_4	Port busy (a)	Vdd = 5V			35	ns
			Vdd = 3.3V			50	ns
$\overline{IOWR}$ low to $\overline{WAIT}$ high(1)	t_5	Port busy (a)				350	ns
D[0:15] valid to $\overline{IOWR}$ high (data setup)	t_6			15			ns
$\overline{IOWR}$ high to D[0:15] invalid (data hold)	t_7			10			ns

Note: (1) Maximum of 350 ns may occur if system makes contiguous system read cycles at less than 100 ns intervals, and both the transmitter and receiver are active in "loopback" reception (if the transmitter and receiver are idle, the max value becomes 250 ns). 2.4 µs max for host read error.

(a) For Buffer Memory Port when port is busy.

(b) For register or port is not busy.

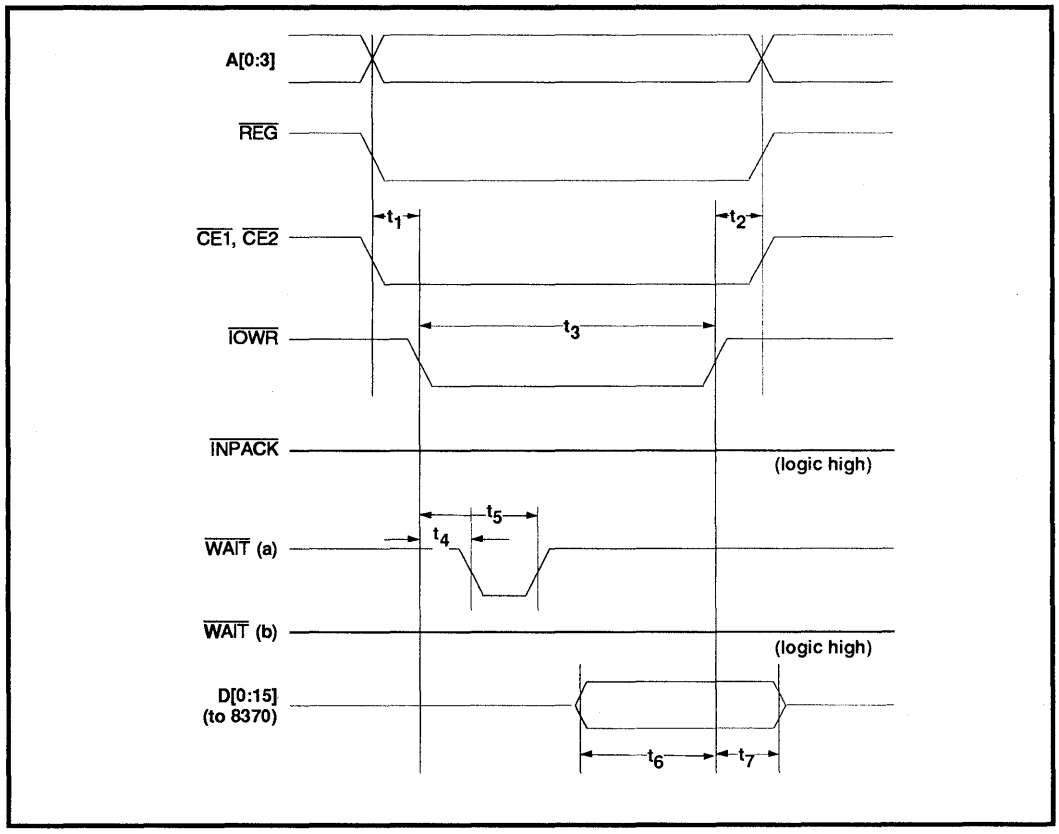

FIGURE 5: I/O Write Cycle (PCMCIA mode)

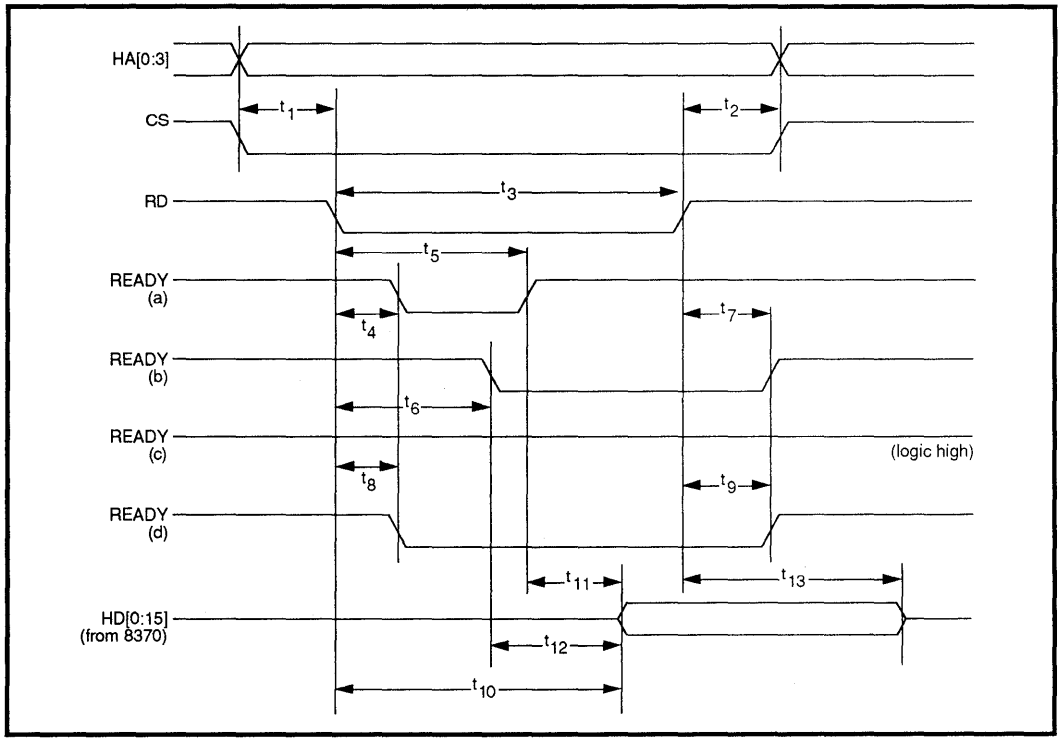

FIGURE 6: Read Cycle, Generic Bus Mode (Refer to Table 9)

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TABLE 5: Read Cycle, Generic Bus Mode (Refer to Figure 6)

PARAMETER		CONDITIONS		MIN	NOM	MAX	UNIT
$\overline{CS}$ low to $\overline{RD}$ low; HA[0:3] valid to $\overline{RD}$ low	t_1			0			ns
$\overline{RD}$ high to $\overline{CS}$ high; $\overline{RD}$ high to HA[0:3] invalid	t_2			0			ns
$\overline{RD}$ low pulse width	t_3		Vdd = 5V	30			ns
			Vdd = 3.3V	35			ns
$\overline{RD}$ low to READY low	t_4	(a)	Vdd = 5V	0		35	ns
			Vdd = 3.3V			45	ns
$\overline{RD}$ low to READY high (1)	t_5	(a)				350	ns
$\overline{RD}$ low to READY low (1)	t_6	(b)		0		350	ns
$\overline{RD}$ high to READY high	t_7	(b)		0		25	ns
$\overline{RD}$ low to READY low	t_8	(d)	Vdd = 5V	0		30	ns
			Vdd = 3.3V			40	ns
$\overline{RD}$ high to READY high	t_9	(d)		0		28	ns
$\overline{RD}$ low to HD[0:15] valid	t_{10}	Register access	Vdd = 5V			45	ns
			Vdd = 3.3V			60	ns
READY high to HD[0:15] valid	t_{11}	Port access				5	ns
READY low to HD[0:15] valid	t_{12}	Port access				5	ns
$\overline{RD}$ high to HD[0:15] invalid (data hold)	t_{13}			10			ns

Note: (1) Maximum of 350 ns may occur if system makes contiguous system read cycles at less than 100 ns intervals, and both the transmitter and receiver are active in "loopback" reception (if the transmitter and receiver are idle, the max value becomes 250 ns). 2.4 µs max for host read error.

(a) For Buffer Memory Port when port is busy and RDYSEL = 1.
(b) For Buffer Memory Port when port is busy and RDYSEL = 0.
(c) For register or port is not busy and RDYSEL = 1.
(d) For register or port is not busy and RDYSEL = 0.

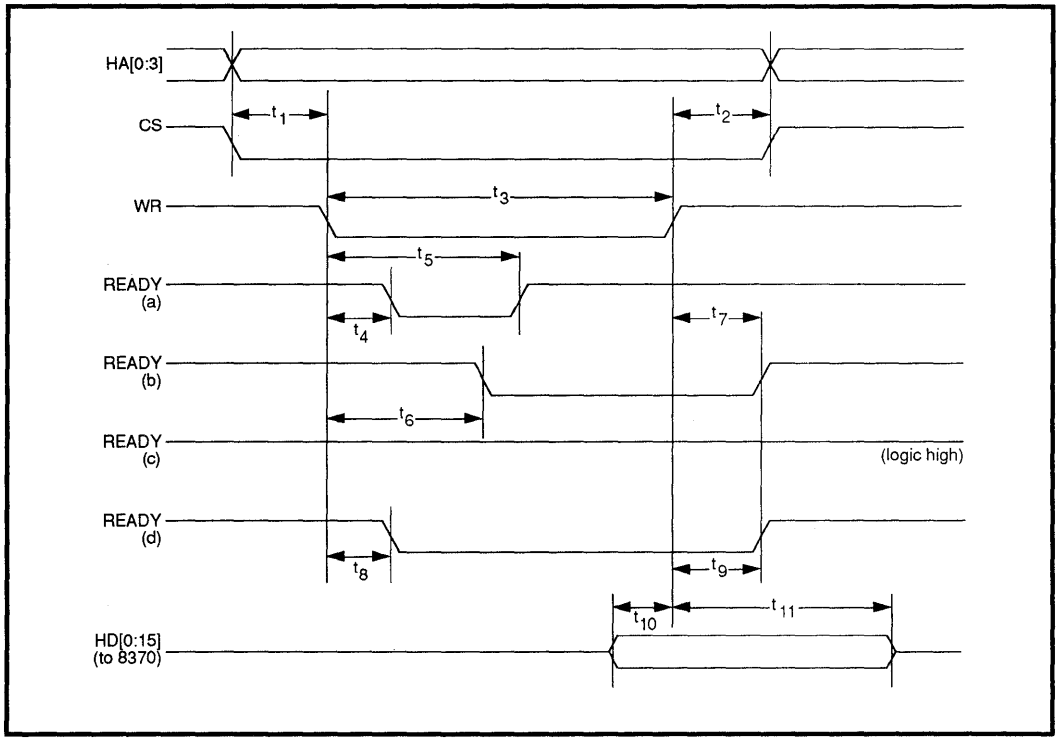

FIGURE 7: Write Cycle, Generic Bus Mode (Refer to Table 10)

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TABLE 6: Write Cycle, Generic Bus Mode (Refer to Figure 7)

PARAMETER		CONDITIONS		MIN	NOM	MAX	UNIT
$\overline{CS}$ low to $\overline{WR}$ low; HA[0:3] valid to WR low	t_1			0			ns
$\overline{WR}$ high to $\overline{CS}$ high; $\overline{WR}$ high to HA[0:3] invalid	t_2			0			ns
$\overline{WR}$ low pulse width	t_3		Vdd = 5V	30			ns
			Vdd = 3.3V	35			ns
$\overline{WR}$ low to READY low	t_4	(a)	Vdd = 5V	0		35	ns
			Vdd = 3.3V			45	ns
$\overline{WR}$ low to READY high (1)	t_5	(a)				350	ns
$\overline{WR}$ low to READY low (1)	t_6	(b)		0		350	ns
$\overline{WR}$ high to READY high	t_7	(b)				28	ns
$\overline{WR}$ low to READY low	t_8	(d)	Vdd = 5V	0		30	ns
			Vdd = 3.3V			40	ns
$\overline{WR}$ high to READY high	t_9	(d)		0		25	ns
HD[0:15] valid to WR high (data setup)	t_{10}			15			ns
$\overline{WR}$ high to HD[0:15] invalid (data hold)	t_{11}			10			ns

Note: (1) Maximum of 350 ns may occur if system makes contiguous system read cycles at less than 100 ns intervals, and both the transmitter and receiver are active on "loopback" reception (if the transmitter and receiver are idle, the max value becomes 250 ns). 2.4 µs max for host write error.
(a) For Buffer Memory Port when port is busy and RDYSEL = 1.
(b) For Buffer Memory Port when port is busy and RDYSEL = 0.
(c) For register or port is not busy and RDYSEL = 1.
(d) For register or port is not busy and RDYSEL = 0.

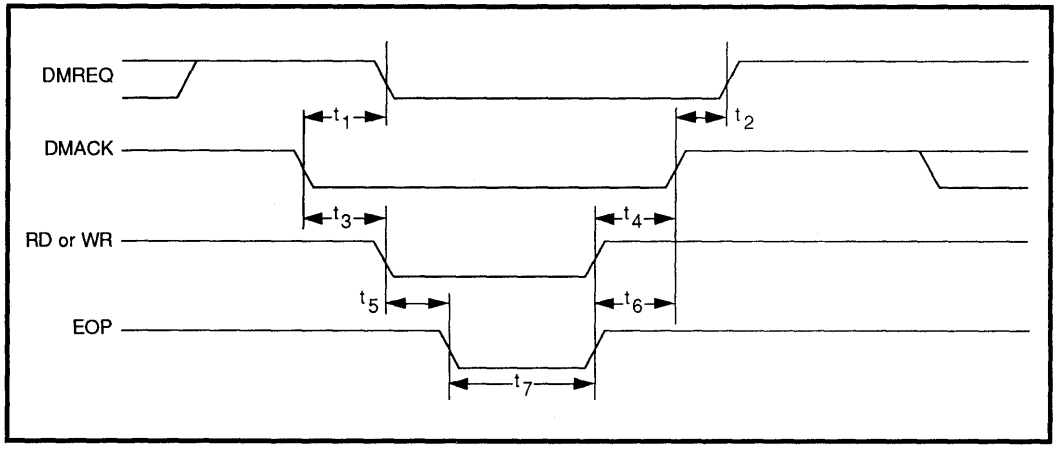

FIGURE 8: Single-Cycle DMA Timing

TABLE 7: Single-Cycle DMA Timing (Refer to Figure 8)

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
$\overline{DMACK}$ low to DMREQ low	t_1	Vdd = 5V	0		25	ns
		Vdd = 3.3V			30	ns
$\overline{DMACK}$ high to DMREQ high	t_2	Vdd = 5V	0		25	ns
		Vdd = 3.3V			30	ns
$\overline{DMACK}$ low to $\overline{RD}$ or $\overline{WR}$ low	t_3		0			ns
$\overline{RD}$ or $\overline{WR}$ high to $\overline{DMACK}$ high	t_4		0			ns
$\overline{RD}$ or $\overline{WR}$ low to EOP low	t_5		0			ns
EOP high to $\overline{DMACK}$ high	t_6		0			ns
EOP low pulse width	t_7		10			ns

Note: (1) An asserted EOP terminates any further DMREQ after $\overline{DMACK}$ returns high.
(2) The DMA cycle uses $\overline{DMACK}$ as the chip select. $\overline{DMACK}$ overrides $\overline{CS}$ and HA[0:3] if they are both asserted at the same time, forcing selection of the Buffer Memory Port as in a DMA cycle.
(3) For READY timing and HD[0:15] timing, see Figure 6, t_4-t_{13}, and Figure 7, t_4-t_{11}.

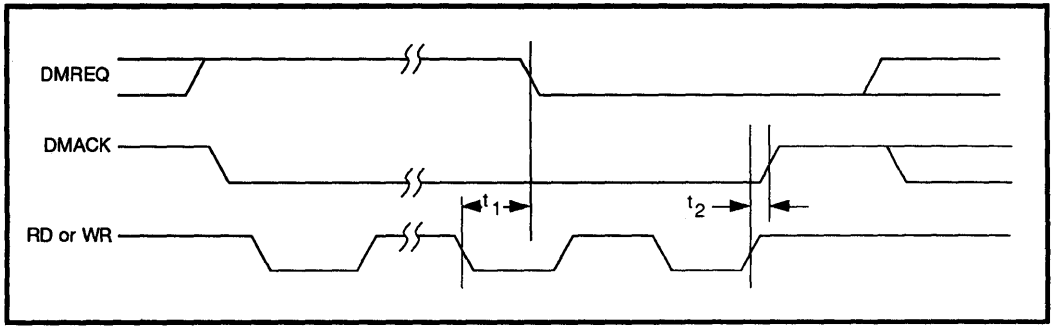

FIGURE 9: Burst DMA Timing

TABLE 8: Burst DMA Timing

PARAMETER	CONDITIONS		MIN	NOM	MAX	UNIT
$\overline{RD}$ or $\overline{WR}$ low to DMREQ low	5V	t_1			30	ns
	3.3V	t_1			40	ns
$\overline{RD}$ or $\overline{WR}$ high to DMACK high		t_2	0			ns

Note: (1) DMREQ goes low during the next-to-last transfer of the burst. $\overline{DMACK}$ should not go high until after the $\overline{RD}$ or $\overline{WR}$ pulse of the last transfer cycle goes high

(2) The DMA cycle uses $\overline{DMACK}$ as the chip select. $\overline{DMACK}$ overrides $\overline{CS}$ and HA[0:3] if they are both asserted at the same time, forcing selection of the Buffer Memory Port as in a DMA cycle.

(3) For READY timing and HD[0:15] timing, see Figure 6, t_4-t_{13}, and Figure 7, t_4-t_{11}.

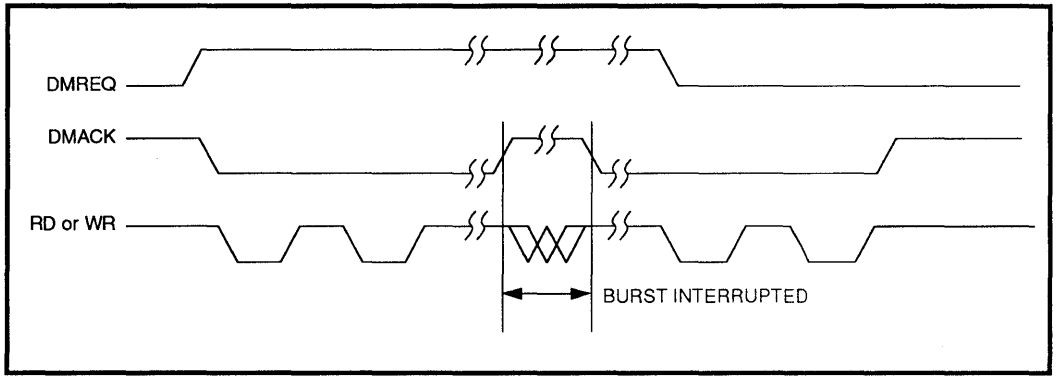

FIGURE 10: Burst DMA Interrupted by $\overline{\text{DMACK}}$

Note: Burst can be interrupted by $\overline{\text{DMACK}}$ high-going pulse during the burst. Burst will resume when $\overline{\text{DMACK}}$ returns low.

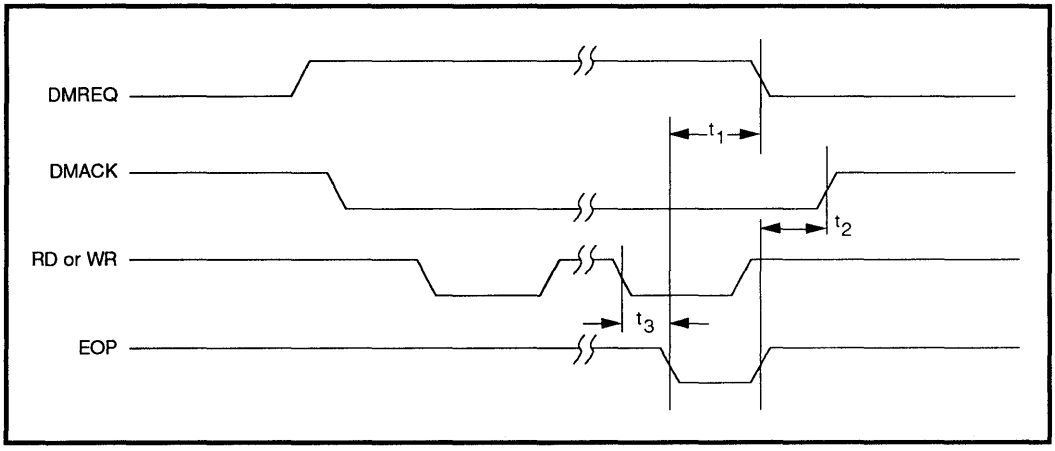

FIGURE 11: Burst DMA Terminated by EOP

TABLE 9: Burst DMA Terminated by EOP

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
EOP low to DMREQ low	t_1	Vdd = 5V	4		28	ns
		Vdd = 3.3V			35	ns
EOP high to DMACK high	t_2		3			ns
RD or WR low to EOP low	t_3		0			ns

Note: EOP can be asserted during any transfer of the burst to terminate the process following that transfer.

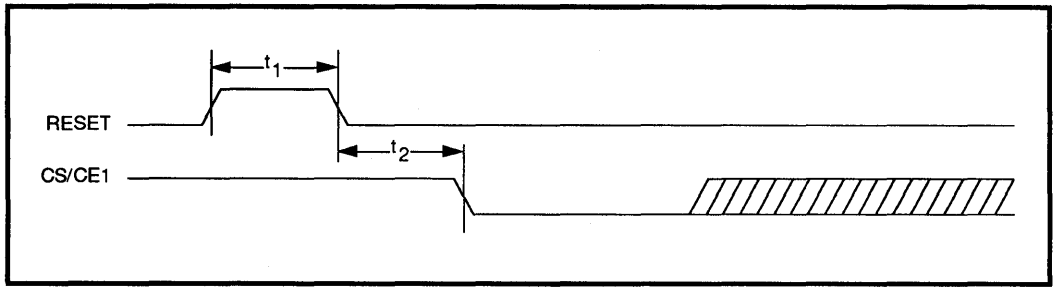

FIGURE 12: RESET Timing

TABLE 10: RESET Timing

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
RESET pulse width t_1		500			ns
RESET low to first $\overline{CS}/\overline{CE1}$ low t_2		800			ns

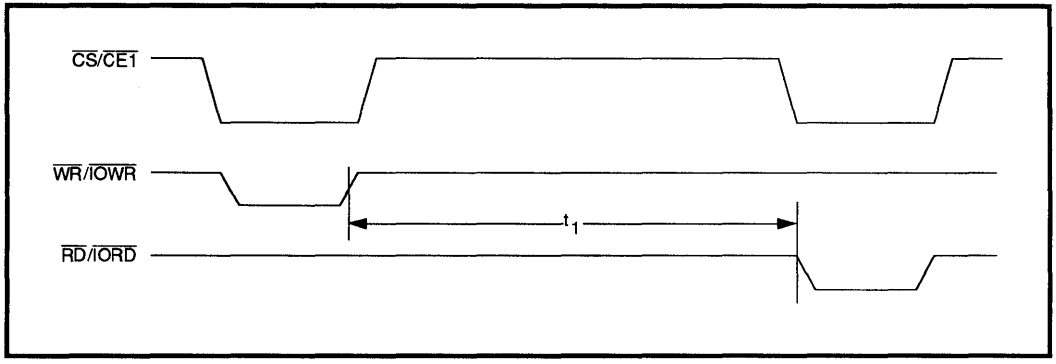

FIGURE 13: Skip Packet Timing

TABLE 11: Skip Packet Timing

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
Writing Skip Packet high to next Buffer Memory Port read t_1		200			ns

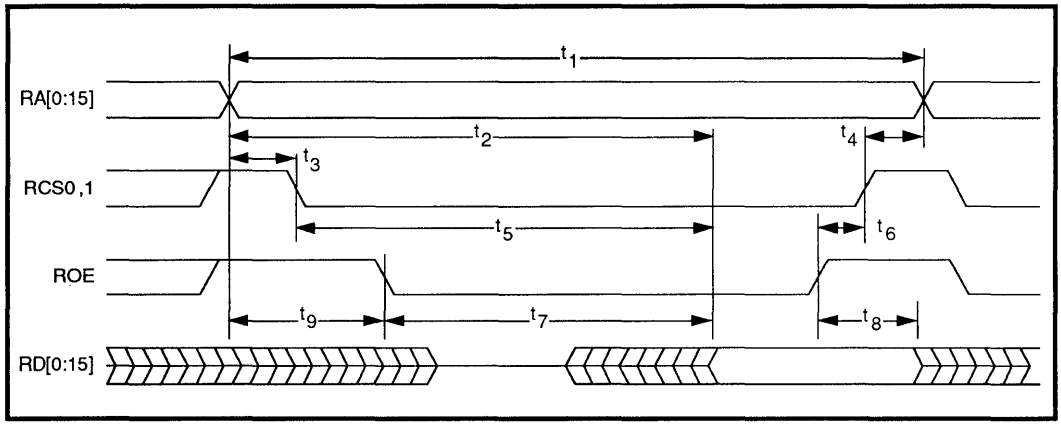

FIGURE 14: SRAM Read Timing

TABLE 12: SRAM Read Timing

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
Read cycle	t_1	RAMSP = 1	95			ns
		RAMSP = 0	145			ns
Address access time	t_2	RAMSP = 1			75	ns
		RAMSP = 0			125	ns
Address valid to $\overline{RCS0,1}$ low	t_3				8	ns
$\overline{RCS0,1}$ high to address invalid	t_4		0			ns
Chip select access time	t_5	RAMSP = 1			75	ns
		RAMSP = 0			125	ns
$\overline{ROE}$ high to $\overline{RCS0,1}$ high	t_6		0		8	ns
Output enable access time	t_7	RAMSP = 1			50	ns
		RAMSP = 0			100	ns
Data hold time	t_8		0			ns
Address valid to $\overline{ROE}$ low	t_9				30	ns

Note: Use SRAM with address access time of 75 ns or less for RAMSP = 1 and 125 ns or less for RAMSP = 0. RAMSP is DLCR6 <6>.

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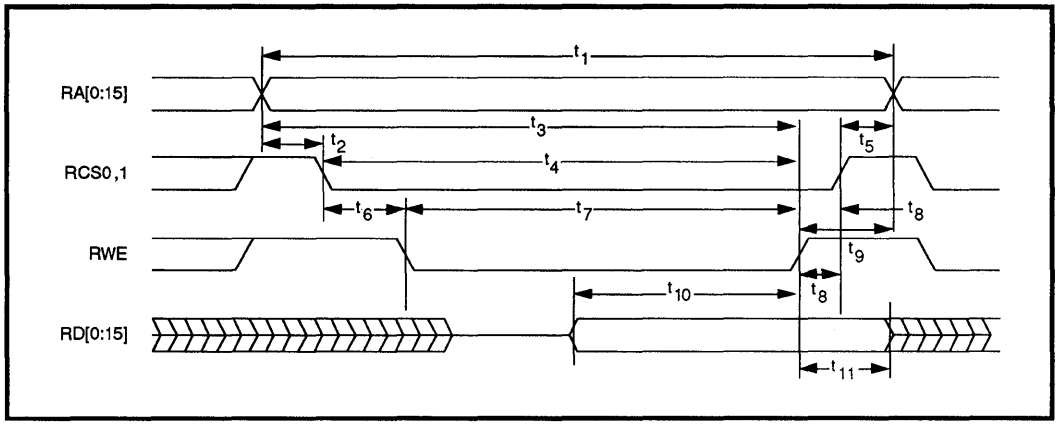


FIGURE 15: SRAM Write Timing

TABLE 13: SRAM Write Timing

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
Write Cycle	t_1	RAMSP = 1	95			ns
		RAMSP= 0	145			ns
Address Valid to $\overline{RCS0,1}$ low	t_2				8	ns
Address Valid to $\overline{RWE}$ high	t_3	RAMSP = 1	70			ns
		RAMSP = 0	120			ns
$\overline{RCS0,1}$ low to $\overline{RWE}$ high	t_4	RAMSP = 1	70			ns
		RAMSP = 0	120			ns
$\overline{RCS0,1}$ high to Address Invalid	t_5		0			ns
$\overline{RCS0,1}$ low to $\overline{RWE}$ low	t_6		0			ns
$\overline{RWE}$ Pulse Width	t_7	RAMSP = 1	70			ns
		RAMSP = 0	120			ns
$\overline{RWE}$ high to $\overline{RCS0,1}$ high	t_8		0			ns
$\overline{RWE}$ high to Address Invalid	t_9		10			ns
Data Setup Time	t_{10}	RAMSP = 1	40			ns
		RAMSP = 0	90			ns
Data Hold Time	t_{11}		20			ns

Note: Use SRAM with address access time of 75 ns or less for RAMSP = 1 and 125 ns or less for RAMSP = 0. RAMSP is DLCR6 <6>.

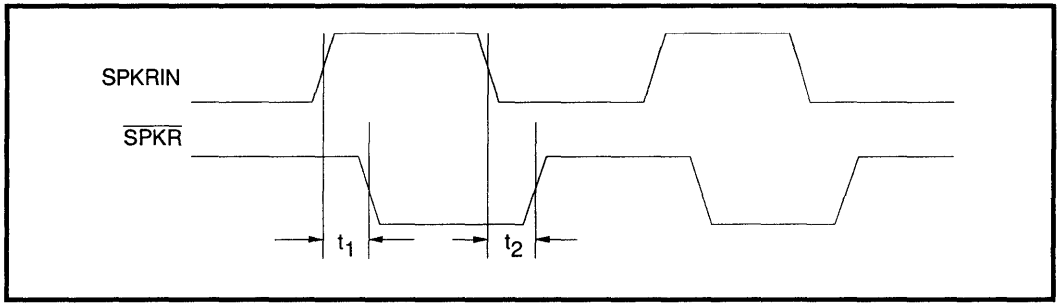


FIGURE 16: Speaker Timing

TABLE 14: Speaker Timing (Refer to Figure 16)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
SPKR high to low propagation delay t_1	Vdd = 5V			25	ns
	Vdd = 3.3V			30	ns
SPKR low to high propagation delay t_2	Vdd = 5V			25	ns
	Vdd = 3.3V			30	ns

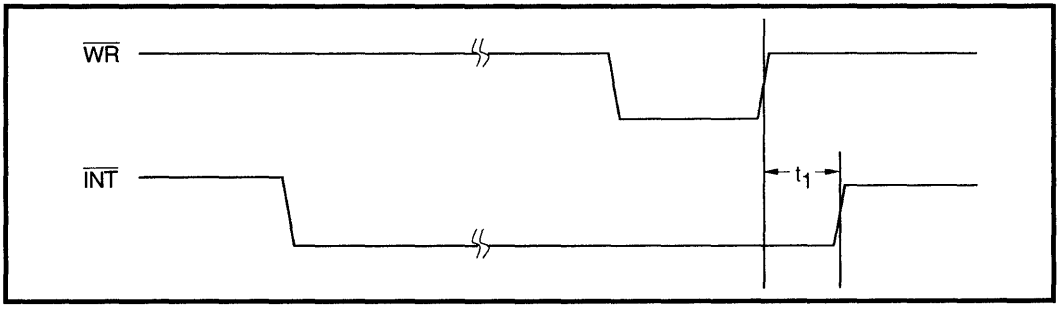


FIGURE 17: Interrupt Timing (Generic Bus Mode)

TABLE 15: Interrupt Timing (Generic Bus Mode)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
INT signal cleaning delay t_1	Vdd = 5V	7		40	ns
	Vdd = 3.3V			50	ns

7

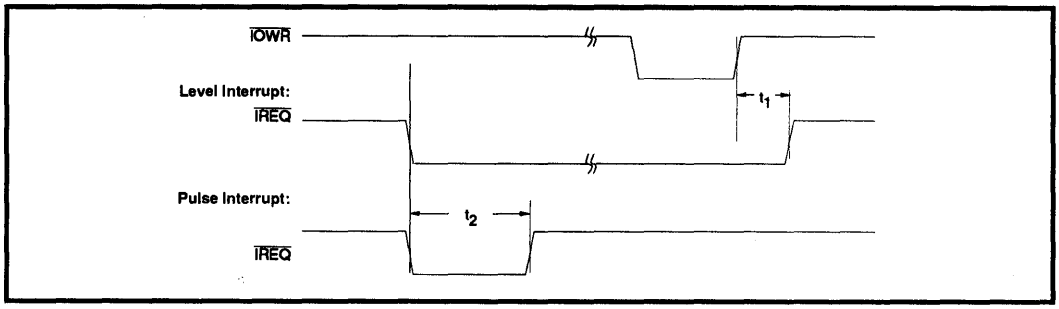


FIGURE 18: Interrupt Timing (PCMCIA Mode)

TABLE 16: Interrupt Timing (PCMCIA Mode)

PARAMETER		CONDITIONS		MIN	NOM	MAX	UNIT
IREQ		level interrupt	Vdd = 5V	7		40	ns
signal clearing delay	t_1		Vdd = 3.3V			50	ns
IREQ low pulse width	t_2	pulse interrupt		750		800	ns

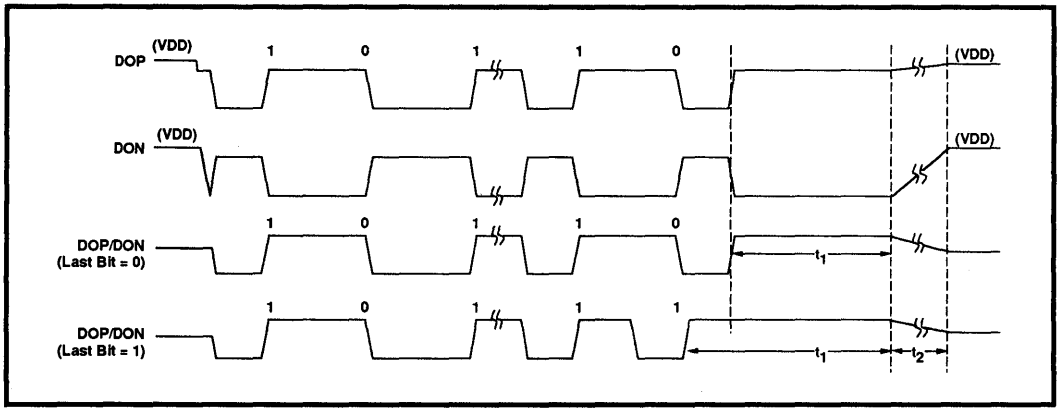


FIGURE 19: Transmit Timing (AUI)

TABLE 17: Transmit Timing (AUI)

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
DOP/DON end-of-packet delimiter	t_1		200			ns
DOP/DON line voltage transition	t_2				8	µs

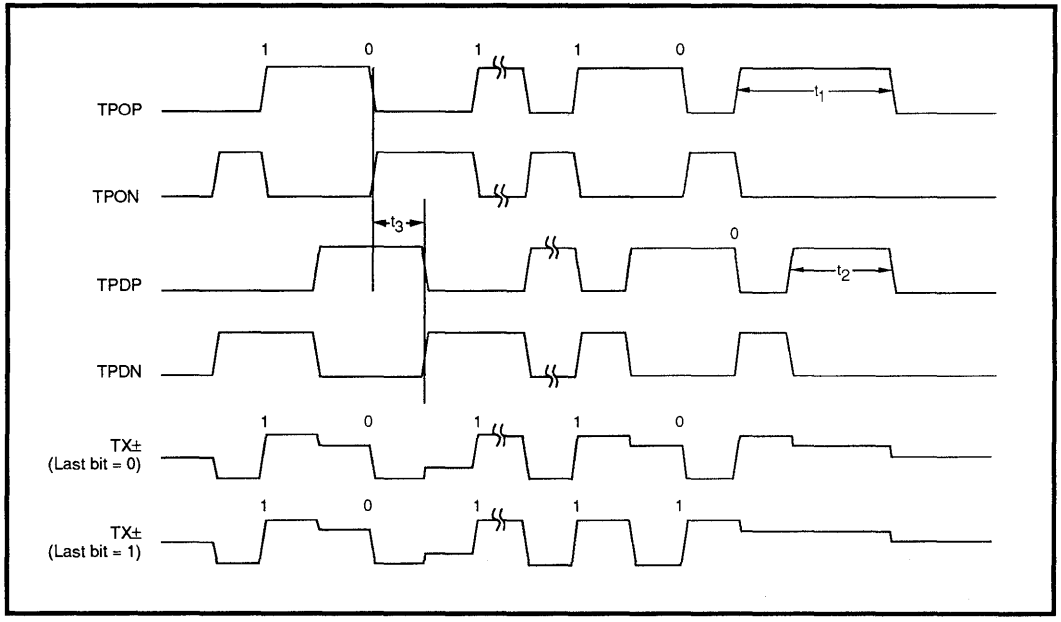


FIGURE 20: Transmit Timing (TP)

TABLE 18: Transmit Timing (TP)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
TPOP/TPON end-of-packet delimiter t_1		250			ns
TPDP/TPDN end-of-packet delimiter t_2		200			ns
TPOP to TPDP and TPON to TPDN delay t_3			50		ns

7

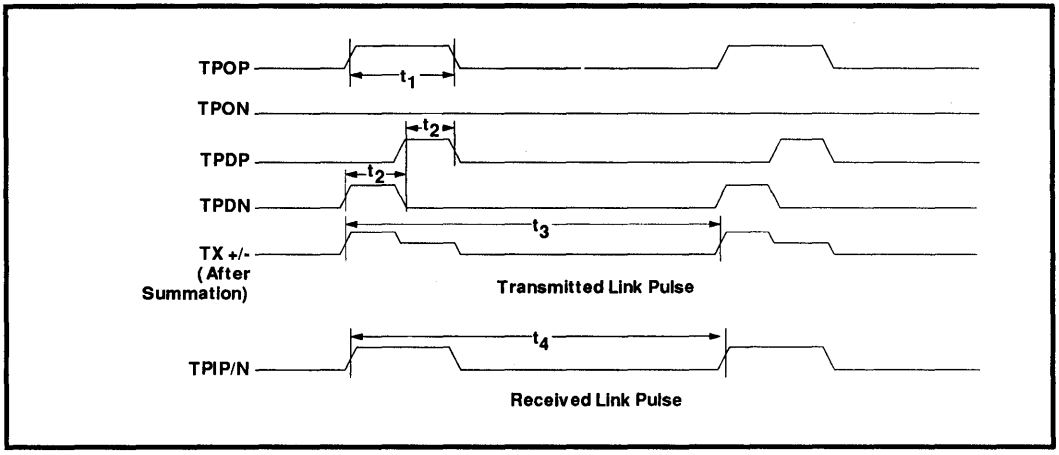


FIGURE 21: Link Test Timing

TABLE 19: Link Test Timing

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
TPOP link pulse width	t_1			150		ns
TPDP/TPDN link pulse width	t_2			100		ns
Duration between transmitted link pulses	t_3		9		11	ms
Duration between received link pulses	t_4		4.1		65	ms

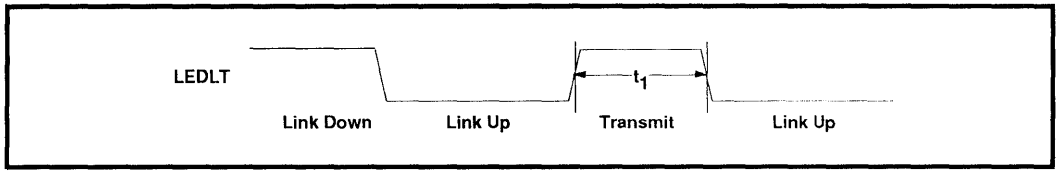


FIGURE 22: LED Timing (TP)

TABLE 20: LED Timing

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
Transmit blink-off timing	t_1	TP selected		100		ms

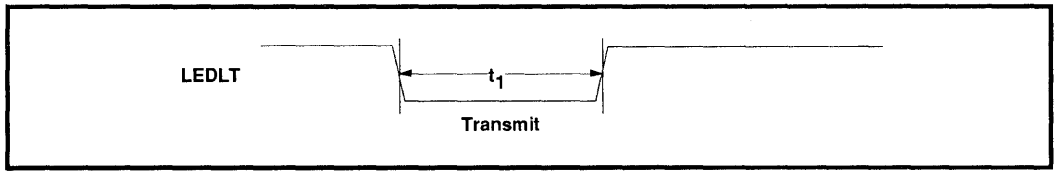


FIGURE 23: LED Timing (AUI)

TABLE 21: LED Timing

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
Transmit blink-on timing	t_1	AUI selected		100		ms

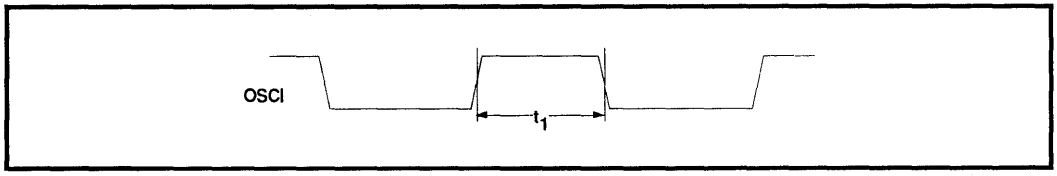


FIGURE 24: Oscillator Duty Cycle

TABLE 22: OSCI Duty Cycle

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
Oscillator duty cycle	t_1		40	50	60	%

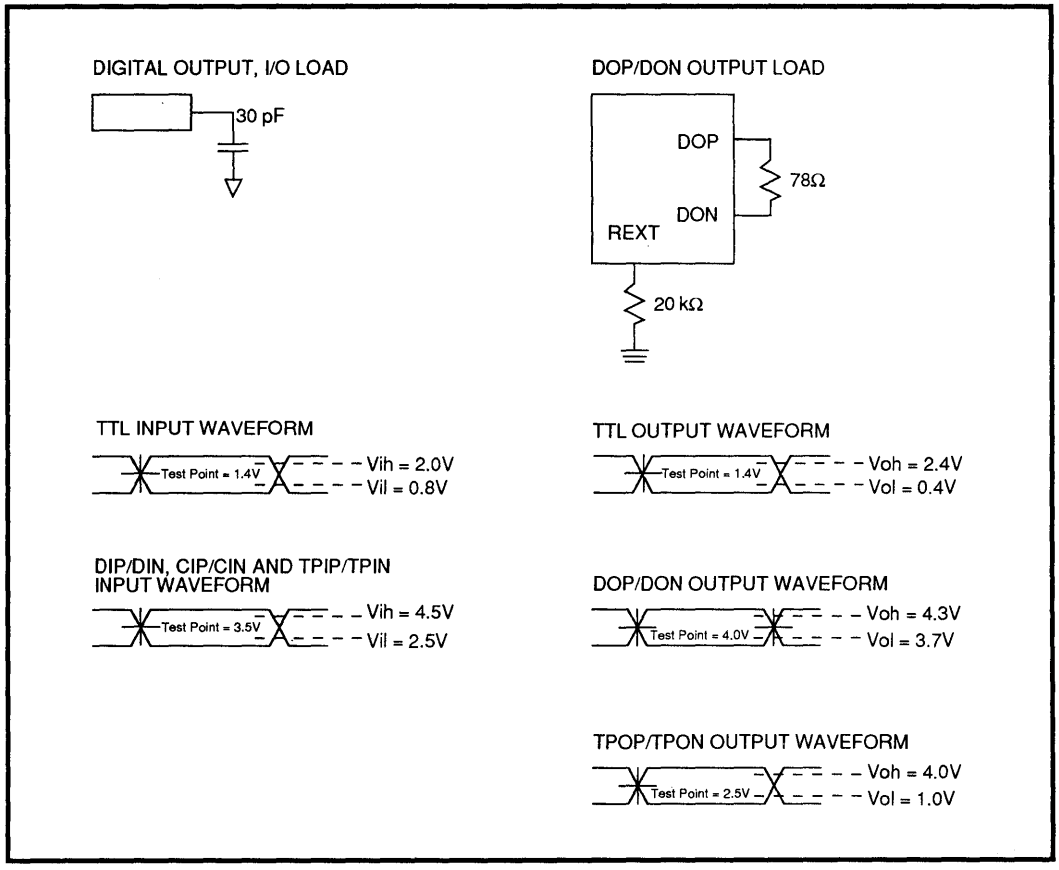
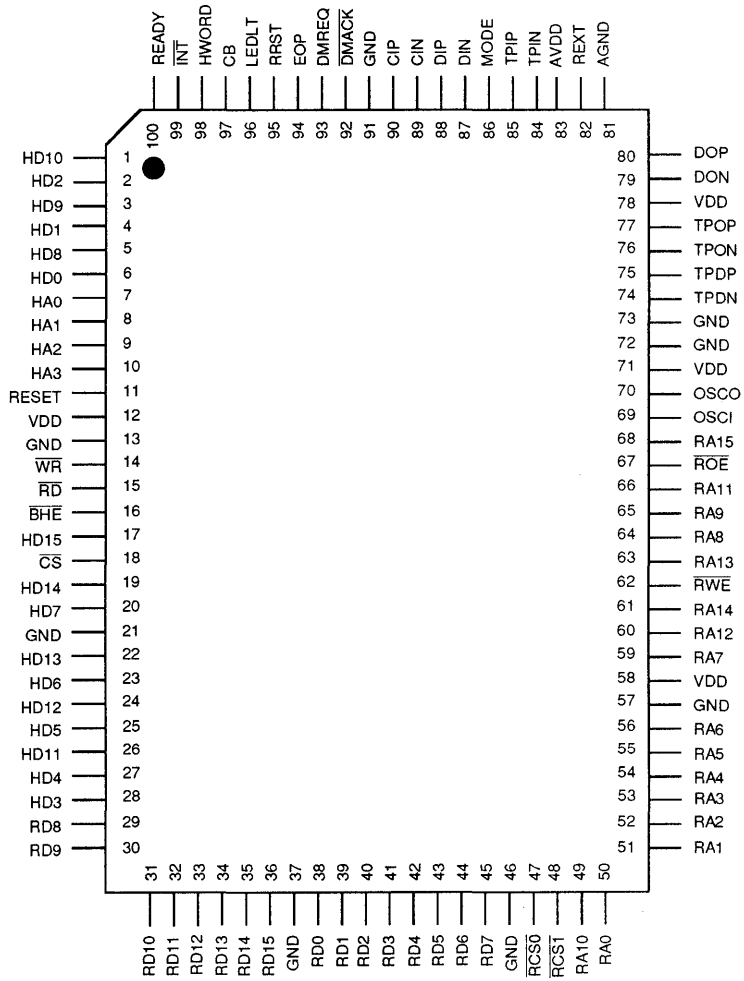


FIGURE 25: Test Conditions

PACKAGE PIN DESIGNATIONS
(Top View)

CAUTION: Use handling procedures necessary for a static sensitive component.



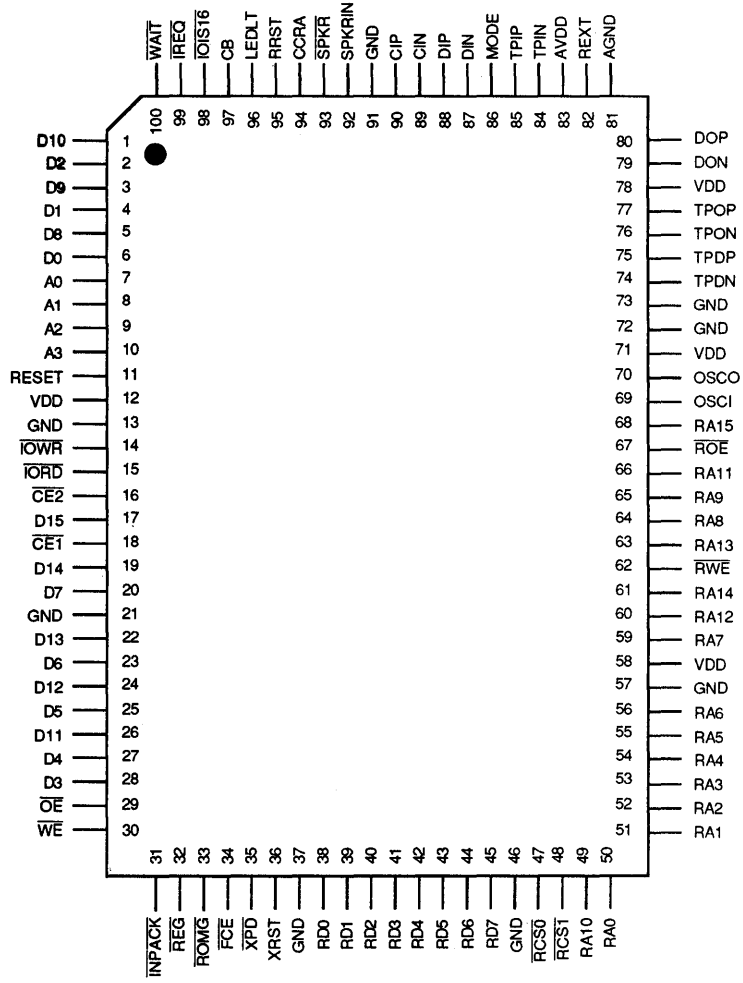
100-Lead QFP
Generic Bus Mode

7

SSI 78Q8373
3V, 5V PCMCIA
Ethernet Combo

PACKAGE PIN DESIGNATIONS
(Top View)

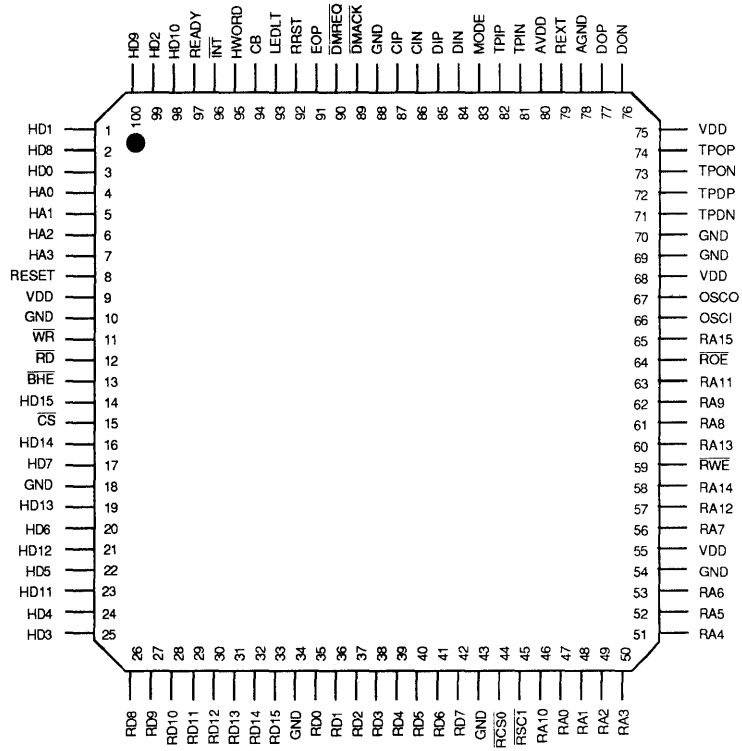
CAUTION: Use handling procedures necessary for a static sensitive component.



100-Lead QFP
PCMCIA Bus Mode

PACKAGE PIN DESIGNATIONS
(Top View)

CAUTION: Use handling procedures necessary for a static sensitive component.



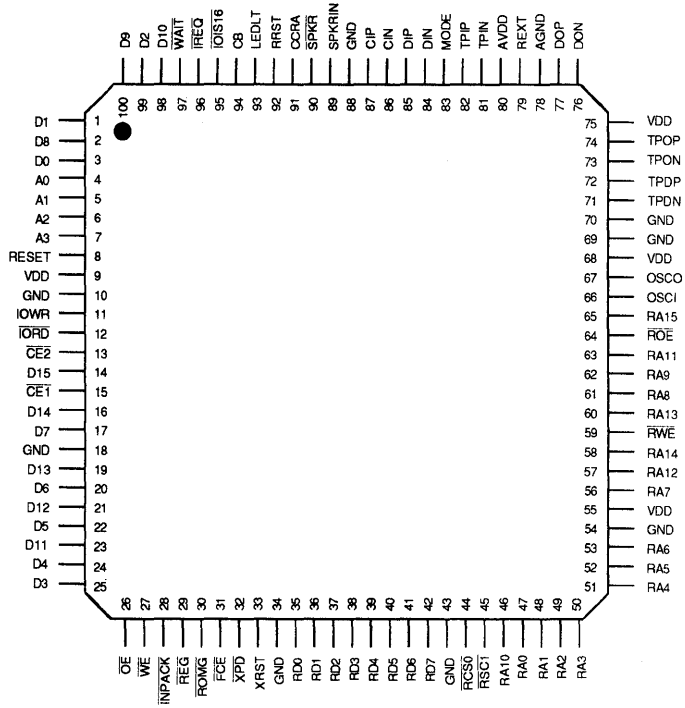
100-Lead TQFP
Generic Bus Mode

7

SSI 78Q8373
3V, 5V PCMCIA
Ethernet Combo

PACKAGE PIN DESIGNATIONS
(Top View)

CAUTION: Use handling procedures necessary for a static sensitive component.



100-Lead TQFP
PCMCIA Bus Mode

ORDERING INFORMATION

PART DESCRIPTION	ORDER NUMBER	PACKAGE MARK
SSI 78Q8373 - PCMCIA Ethernet Combo 100-lead QFP	78Q8373-CG	78Q8373-CG
100-lead78Q8373TQFP	78Q8373-CGT	78Q8373-CGT

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SSI 78Q8392
Ethernet Coaxial Transceiver

December 1994

DESCRIPTION

The SSI 78Q8392 Ethernet Transceiver is a high speed, bipolar coax line transmitter/receiver. The device includes analog transmit and receive buffers, a 10 MHz on-board oscillator, timing logic for jabber and heartbeat functions, output drivers and bandgap reference, in addition to a current reference and collision detector.

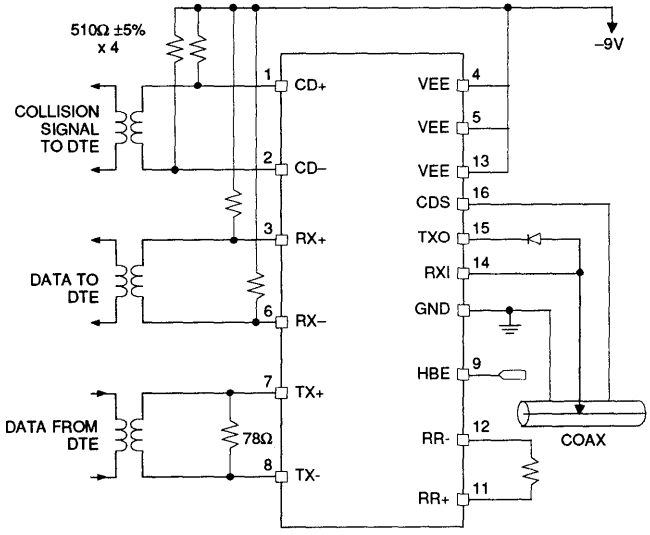
This transceiver provides the interface between the single-ended coaxial cable signals and the Manchester-encoded differential logic signals. Primary functional blocks include the receiver, transmitter, collision detection and jabber timer. This IC may be used in either internal or external MAU environments.

The SSI 78Q8392 is available in 16-pin plastic DIP and 28-pin PLCC packages.

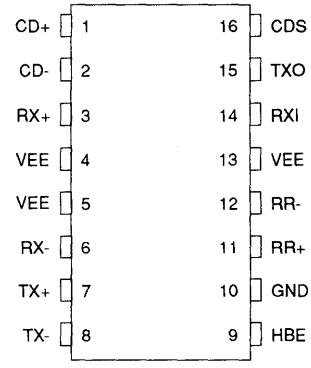
FEATURES

- **Compliant with Ethernet II, IEEE 802.3 10Base5 and 10Base2 (Cheapernet)**
- **Integrates all transceiver functions except signal and power isolation**
- **Innovative design minimizes external components count and power consumption**
- **Jabber timer function integrated on chip**
- **Externally selectable CED heartbeat allows operation with IEEE 802.3 compatible repeaters**
- **Squelch circuitry at all inputs rejects noise**

SSI 78Q8392 CONNECTION DIAGRAM



PIN DIAGRAM



16-Pin DIP

CAUTION: Use handling procedures necessary for a static sensitive component.

7

FUNCTIONAL DESCRIPTION

The SSI 78Q8392 incorporates six basic functions of the Ethernet Transceiver, including receiving, transmitting, collision signaling, collision detection, jabber timing, and the heartbeat function. Refer to Figure 1 for a general system block diagram.

RECEIVER FUNCTIONS

The receiver senses signals through the RXI input, which minimizes reflections on the transmission media using a low capacitance, high resistance input buffer amplifier. The CDS ground input attaches directly to the input buffer from the coaxial shield to eliminate ground loop noise.

In addition to the input buffer, the receiver data path consists of an equalizer, data slicer, receiver squelch circuitry, and an output line driver.

The equalizer improves the jitter margin; the data slicer restores equalized received signals to fast transition signals with binary levels to drive the receiver line driver; and the receiver line driver drives the AUI cable through an isolation transformer that connects to the AUI interface.

Noise on the transmission media is rejected by the receiver squelch circuitry, which determines valid data via two criteria: DC level and pulse width. The DC voltage level is detected and compared to a set level in the receiver comparator circuit. The pulse width must be greater than 20 ns and repeat at valid data rates. It is detected using a pulse detector operating like a retriggerable one-shot that resets at approximately two signal bit times. The pulse width detector disables the receiver line driver at the end of a transmission (Figure 3).

TRANSMITTER FUNCTIONS

The transmitter data path consists of a transmit input buffer, pulse-shaping network (ramp generator), transmit squelch circuitry, a transmit driver, and transmit output line driver.

The self-biasing transmit input buffer receives data through an isolation transformer and translates the AUI differential analog signal to digital signals suitable for driving the pulse shaping network. The pulse shaping network gives equal rise and fall times to the transmit driver, which uses a high impedance current source output to drive the transmission media. The capacitance of the transmit driver is isolated from the transmission media by an external diode with a low capacitance node. The shield of the transmission media serves as the ground return for the transmitter function.

A transmit squelch circuit, which consists of a pulse threshold detector, a pulse width detector, and a pulse duration timer, is used to suppress noise, as well as crosstalk on the AUI cable. The squelch circuitry disables the transmit driver if the signal at TX+ or TX- is smaller than the pulse threshold. Pulse noise is rejected by a pulse width detector that passes only pulses with durations greater than 20 ns. The pulse duration timer disables the transmit driver if no pulses are received for two-bit periods following valid pulses. At the end of a transmission, the pulse duration timer disables the transmitter and triggers the blanking timer, used to block "dribble" bits.

COLLISION SIGNALING

When collision signaling is enabled, a 10-MHz signal is sent to the CD± pins through an isolation transformer to the Manchester encoder/decoder. When the function is disabled, this output goes to a zero differential state. The 10-MHz output from the CD pins indicates a collision on the transmission media, a heartbeat function, or that the transmitter is in jabber mode.

COLLISION DETECTION

A collision occurs when two or more transmitters simultaneously access the transmission media. A collision is detected by comparing the DC level of the transmission media to a collision threshold. The received signal at RXI is buffered and sent through a low pass filter, then compared in the collision threshold circuit. If the DC level exceeds the collision threshold, the 10-MHz oscillator and CD outputs are enabled.

JABBER FUNCTION

When valid data is transmitted, the jabber timer is started. If there is valid data for more than 20 sec, a latch is set which disables the transmitter and enables the 10-MHz output on the CD pins. The latch is reset within 0.5 seconds after the valid data is removed from the transmitter input (TX±). This action resets the jabber timer and disables the 10-MHz oscillator and CD output. The TX± inputs must remain inactive during the 0.5-second reset period.

HEARTBEAT FUNCTION

The 10-MHz oscillator and CD outputs are enabled for about 1 µs at approximately 1.1 µs after the end of each transmissions. The heartbeat signal tells the DTE that the circuit is functioning. This is implemented by starting the heartbeat timer when the valid data signal indicates the end of a transmission.

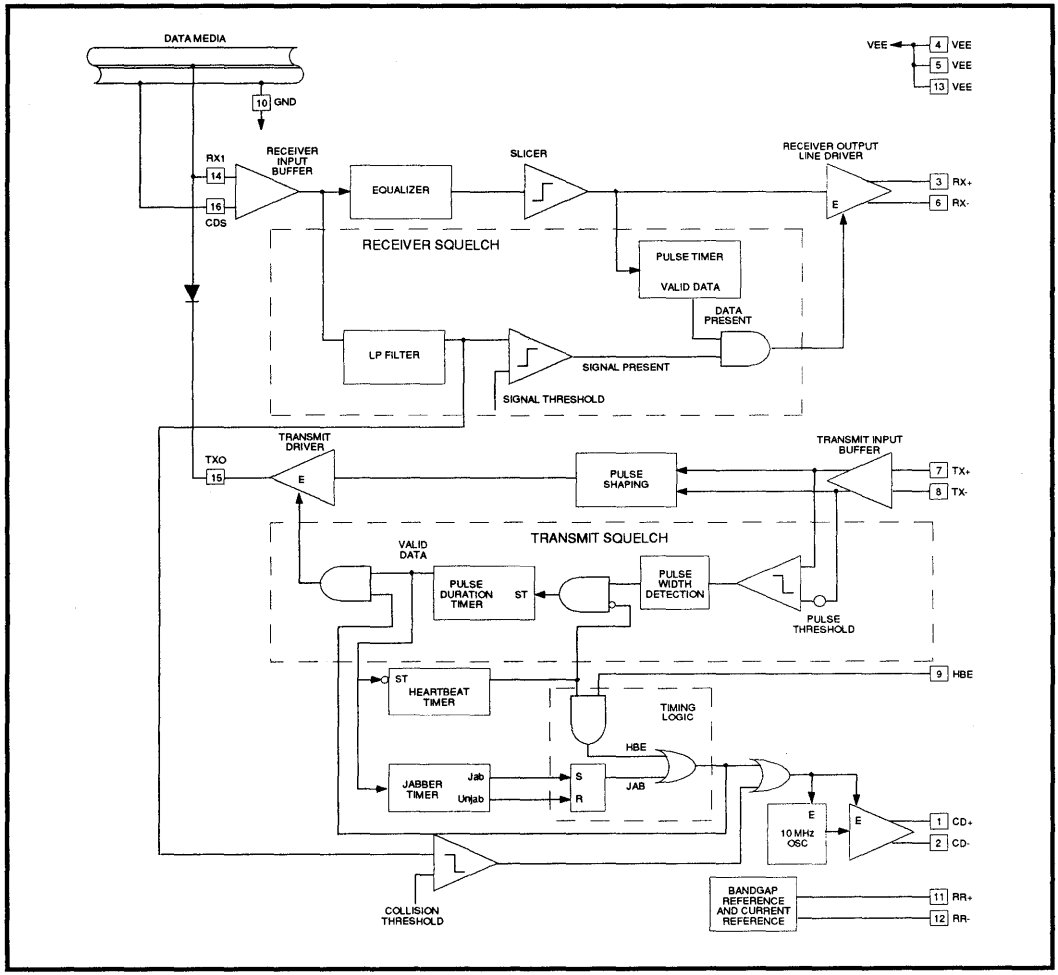


FIGURE 1: SSI 78Q8392 General System Block Diagram

PIN DESCRIPTION

NAME	TYPE	DESCRIPTION
CD+*/CD-	O	Collision Output. Balanced differential line driver outputs from the collision detect circuitry. The 10 MHz signal from the internal oscillator is transferred to these outputs in the event of collision, excessive transmission (jabber), or during CD Heartbeat condition. These outputs are open emitters; pulldown resistors to VEE are required. When operating into a 78Ω transmission line, these resistors should be 510Ω. In Cheapernet applications, where the 78Ω drop cable is not used, higher resistor values (up to 1.5k) may be used to save power.
RX+*/RX-	O	Receive Output. Balanced differential line driver outputs from the Receiver. These outputs also require 510Ω pulldown resistors.
TX+*/TX-	I	Transmit Input. Balanced differential line receiver inputs to the Transmitter. The common mode voltage for these inputs is determined internally and must not be externally established. Signals meeting Transmitter squelch requirements are waveshaped and output at TXO.
HBE	I	Heartbeat Enable. This input enables CD Heartbeat when grounded, disables it when connected to VEE.
RR+/RR-	I	External Resistor. A fixed 1k 1% resistor connected between these pins establishes internal operating currents.
RXI	I	Receive Input. Connects directly to the coaxial cable. Signals meeting Receiver squelch requirements are equalized for inter-symbol distortion, amplified, and output at RX+ and RX- pin.
TXO	O	Transmit Output. Connects either directly (Cheapernet) or via an isolation diode (Ethernet) to the coaxial cable.
CDS	I	Collision Detect Sense. Ground sense connection for the collision detect circuit. This pin should be connected separately to the shield to avoid ground drops from altering the receive mode collision threshold.
GND	–	Positive Supply Pin. A 0.1 µF ceramic de-coupling capacitor must be connected across GND and VEE as close to the device as possible.
VEE	–	Negative Supply Pins. These pins should be connected to a large metal frame area on the PC board to handle heat dissipation.

*IEEE names for CD± = CI±, RX± = DI±, TX± = DO±

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Absolute maximum ratings indicate limits beyond which permanent damage may occur. Continuous operation at these limits is not recommended; operations should be limited to those conditions specified under recommended operating characteristics.

PARAMETER	RATING
Supply Voltage	-12V
Input Voltage	0 to -12V
Storage Temperature	-65 to 150°C
Soldering (Reflow or Dip)	300°C for 10 sec
Package power dissipation	2.5 watts @ 25°C

DC OPERATING CHARACTERISTICS

0°C < T (ambient) < +70°C, VEE = -9V + 5%

PARAMETER		CONDITION	MIN	NOM	MAX	UNIT
I_{EE1}	Supply current out of V_{EE} pin - non-transmitting			-60	-85	mA
I_{EE2}	Supply current out of V_{EE} pin - transmitting			-120	-140	mA
I_{RXI}	Receive input bias current (RXI)	See Note 3	-2		+25	µA
I_{TDC}	Transmit output dc current level (TXO)	See Note 4	37	41	45	mA
I_{TAC}	Transmit output ac current level (TXO)	See Notes 4 & 5	±28		I_{TDC}	mA
V_{CD}	Collision threshold (Receive mode)	See Note 10	-1.581	-1.52	-1.492	V
V_{OD}	Differential output voltage (RX±, CD±)	See Notes 3 & 8	±550		±1200	mV
V_{OC}	Common mode output voltage (RX±, CD±)	See Note 3, 7 & 8	-2.5	-2.0	-1.5	V
V_{OB}	Differential output voltage imbalance (RX±, CD±)	See Notes 3, 8 & 9			±40	mV
V_{TS}	Transmitter squelch threshold (TX±)		-300	-250	-175	mV
C_X	Input capacitance (RXI)			1.2		pF
R_{RXI}	Shunt resistance - non-transmitting (RXI)	See Note 3	1			MΩ
R_{TXO}	Shunt resistance - transmitting (TXO)	See Notes 4 & 6		200		kΩ

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DC OPERATING CHARACTERISTICS (continued)

NOTES

1. Currents into device pins are positive, currents out of device pins are negative. If not specified, voltages are referenced to ground.
2. All typicals are for VEE = -9V, Ta = 25°C.
3. 0 > VEE > -9.5V.
4. The voltage on TXO is -4V < V(TXO) < 0.0V.
5. The AC current measurement is referenced to the DC current level.
6. The shunt resistance does not degrade the ITAC current if five transmitters are simultaneously driving a 50Ω-terminated coax cable.
7. Operating or idle state.
8. Test load as shown in Figure 2.
9. Device measurement taken in idle state.
10. This threshold can be determined by monitoring the CD± output with a DC level in RXI.

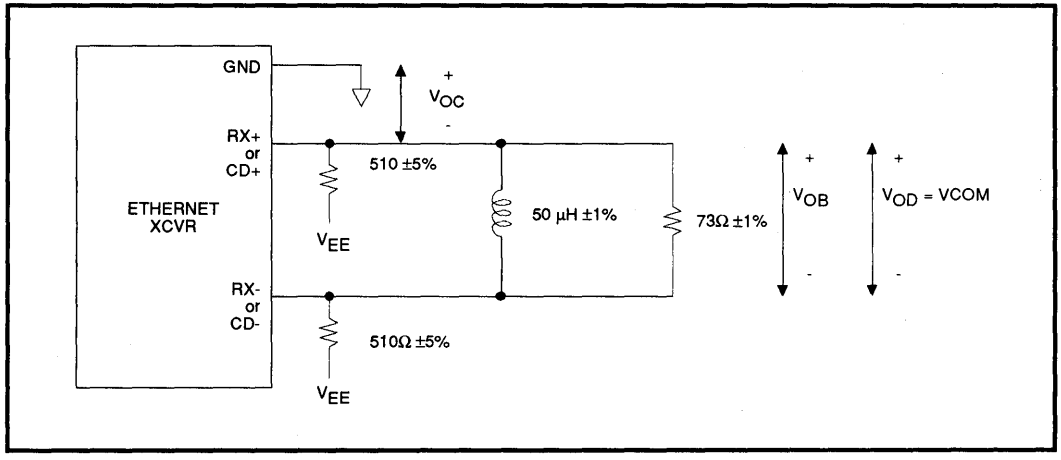


FIGURE 2: Test Load for CD± or RX±

AC OPERATING CHARACTERISTICS

0°C < T(ambient) < +70°C, VEE = 9V ± 5%

PARAMETER	CONDITION	MIN	NOM	MAX	UNIT
t_{RON} Receiver startup delay (RXI to RX±)			4	5	bits
t_{Rd} Receiver propagation delay (RXI to RX±)			15	50	ns
t_{Rr} Differential outputs rise time (RX± , CD±)			4		ns
t_{Rf} Differential outputs fall time (RX± , CD±)			4		ns
t_{RJ} Receiver & cable total jitter			2	4	ns
t_{TST} Transmitter startup delay (TX± to TXO)			1	2	bits
t_{Td} Transmitter propagation delay (TX± to TXO)			25	50	ns
t_{Tr} Transmitter rise time - 10% to 90% (TXO)		20	25	30	ns
t_{Tf} Transmitter fall time - 90% to 10% (TXO)		20	25	30	ns
t_{TM} t_{Tr} and t_{Tf} mismatch			0.5		ns
t_{TS} Transmitter skew (TXO)			±0.5		ns
t_{TON} Transmit turn-on pulse width at V_{TS} (TX±)			20		ns
t_{TOFF} Transmit turn-off pulse width at V_{TS} (TX±)			250		ns
t_{CON} Collision turn-on delay			7		bits
t_{COFF} Collision turn-off delay				20	bits
t_{CD} Collision frequency (CD±)		8.5		11.5	MHz
t_{CP} Collision pulse width (CD±)		35		70	ns
t_{HON} CD Heartbeat delay (TX± to CD±)		0.6		1.6	µs
t_{HW} CD Heartbeat duration (CD±)		0.5	1.0	1.5	µs
t_{JA} Jabber activation delay (TX± to TXO and CD±)		20		75	ms
t_{JR} Jabber reset unjab time (TX± to TXO and CD±)		250	500	750	ms

ELECTRICAL SPECIFICATIONS (continued)

TRANSMIT SPECIFICATIONS

The first bit transmitted from TXO may have data and phase violations. The second through last bit reproduce the TX± signal with less than or equal to specified jitter.

There is no logical signal inversion between Tx± and TXO output. A low level from TX+ to TX- results in more current flowing from the coaxial cable into the TXO pin.

At the end of transmission, when the transmitter changes from the enabled state to the idle state, no spurious pulses are generated, i.e., the transition on TXO proceeds monotonically to zero current.

RECEIVE SPECIFICATIONS

The first bit sent from RX± may have data and phase violations. The second through last bit reproduce the received signal with less than or equal to specified jitter.

There is no logical signal inversion between the RXI input and the RX± output. A high level at RXI produces a positive differential voltage from RX+ to RX-.

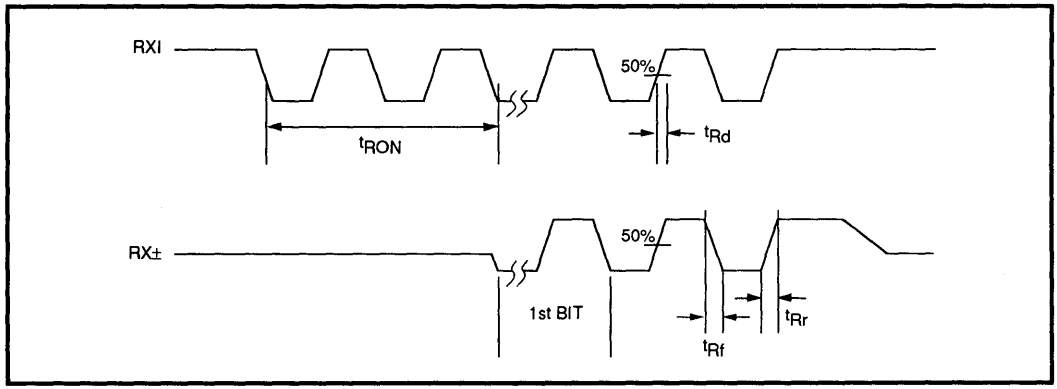


FIGURE 3: Receiver Timing

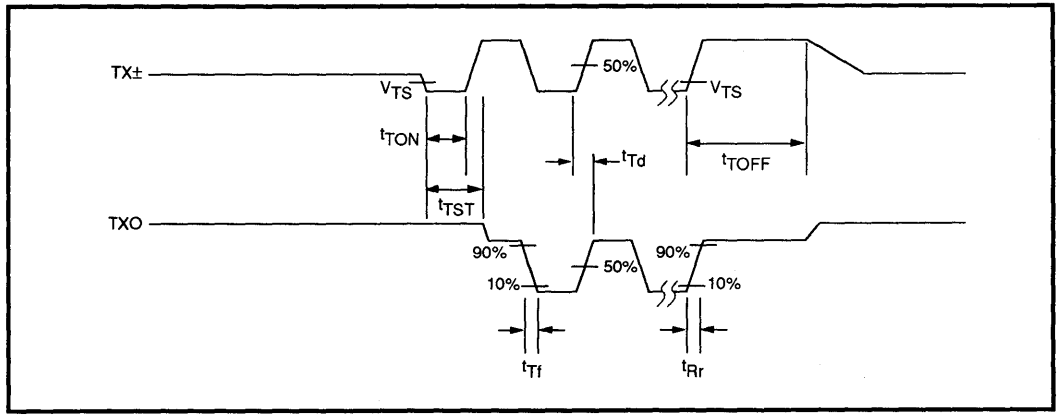


FIGURE 4: Transmitter Timing

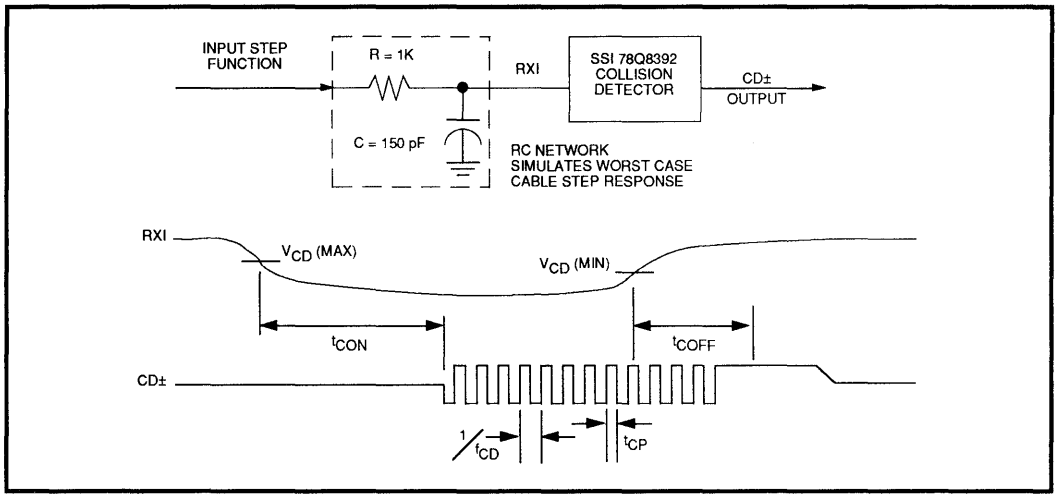


FIGURE 5: Collision Timing

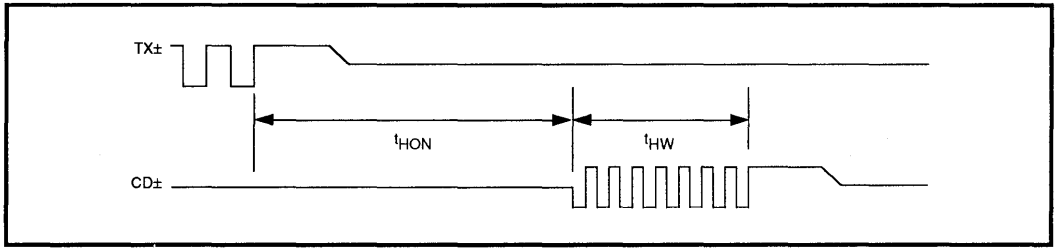


FIGURE 6: Heartbeat Timing

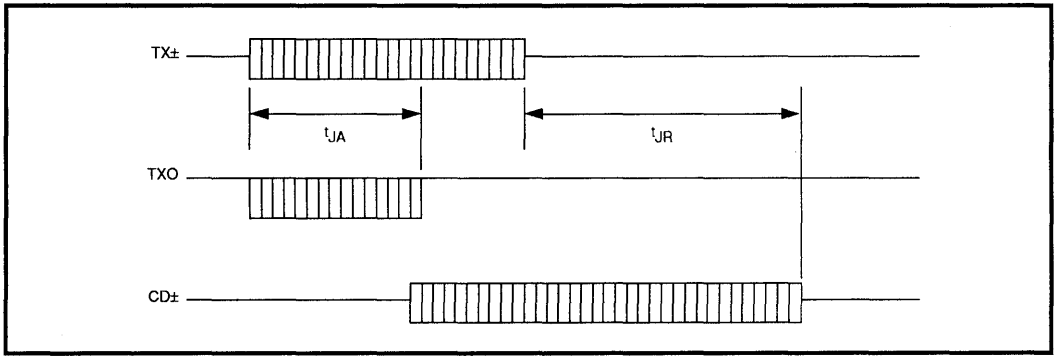


FIGURE 7: Jabber Timing

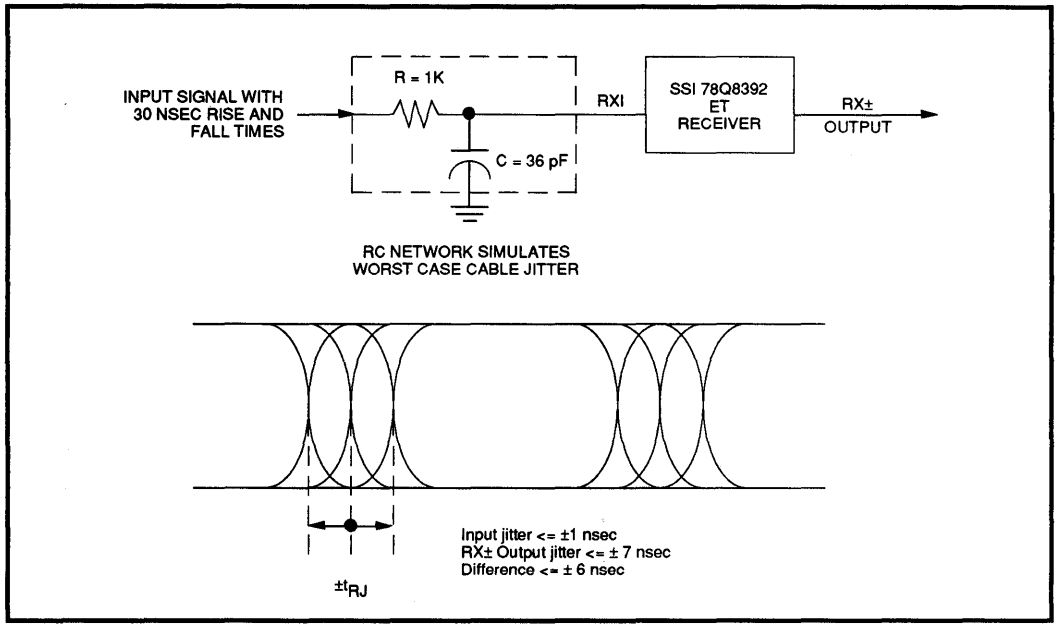


FIGURE 8: Receive Jitter Timing

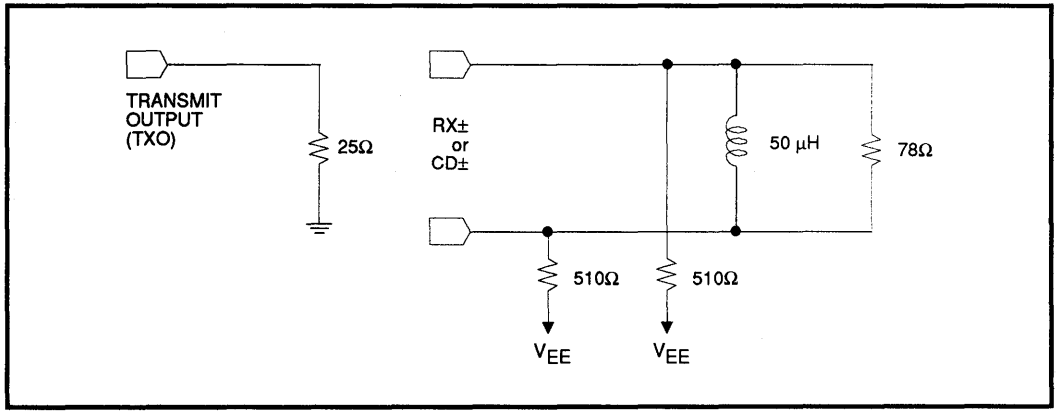
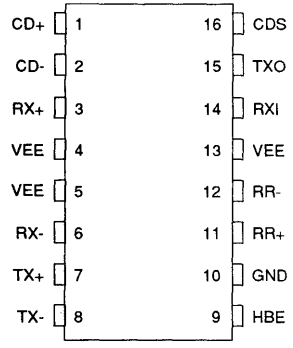


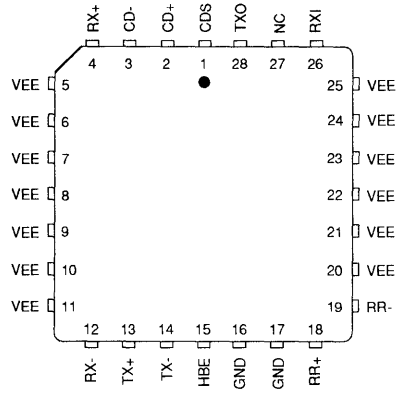
FIGURE 9: Test Loads

PACKAGE PIN DESIGNATIONS

(Top View)



16-Pin DIP



28-Pin PLCC

CAUTION: Use handling procedures necessary for a static sensitive component.

ORDERING INFORMATION

PART DESCRIPTION		ORDER NUMBER	PACKAGE MARK
SSI 78Q8392	16-Pin Plastic DIP	78Q8392-CP	78Q8392-CP
SSI 78Q8392	28-Pin Plastic PLCC	78Q8392-28CH	78Q8392-28CH

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Notes:

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SSI 78Q8392L
Low Power Ethernet Coaxial Transceiver
Advance Information

December 1994

DESCRIPTION

The SSI 78Q8392L Ethernet Transceiver is a low power, BiCMOS coax line transmitter/receiver. The device includes analog transmit and receive buffers, a 10 MHz on-board oscillator, timing logic for jabber and heartbeat functions, output drivers and bandgap reference, in addition to a current reference and collision detector.

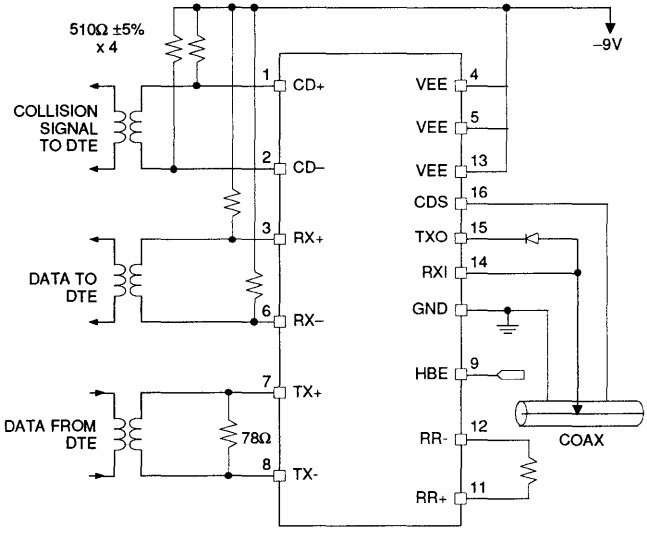
This transceiver provides the interface between the single-ended coaxial cable signals and the Manchester-encoded differential logic signals. Primary functional blocks include the receiver, transmitter, collision detection and jabber timer. This IC may be used in either internal or external MAU environments.

The SSI 78Q8392L is available in 16-pin plastic, 24-pin SOL and 28-pin PLCC packages.

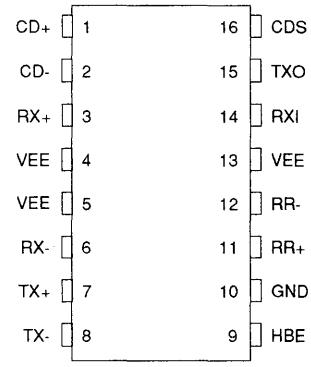
FEATURES

- **Very low power consumption**
- **Compliant with Ethernet II, IEEE 802.3 10Base5 and 10Base2 (Cheapernet)**
- **Integrates all transceiver functions except signal and power isolation**
- **Innovative design minimizes external components count and power consumption**
- **Jabber timer function integrated on chip**
- **Externally selectable CED heartbeat allows operation with IEEE 802.3 compatible repeaters**
- **Squelch circuitry at all inputs rejects noise**

SSI 78Q8392L CONNECTION DIAGRAM



PIN DIAGRAM



16-Pin DIP

CAUTION: Use handling procedures necessary for a static sensitive component.

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SSI 78Q8392L
Low Power Ethernet
Coaxial Transceiver

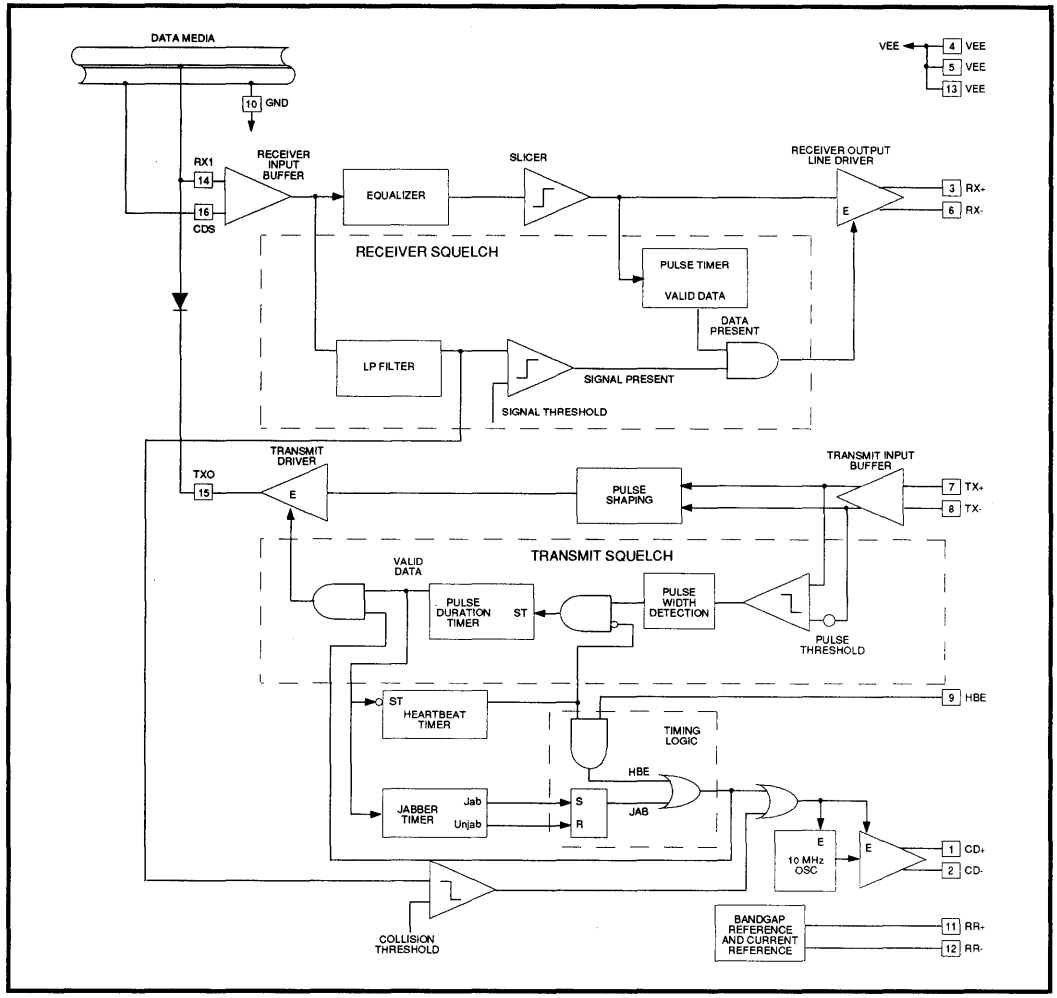

FIGURE 1: SSI 78Q8392L General System Block Diagram

Advance Information: Indicates a product still in the design cycle, and any specifications are based on design goals only. Do not use for final design.

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SSI 78Q8377
10BaseT Ethernet Combo for Plug and Play
Advance Information

November 1994

DESCRIPTION

The SSI 78Q8377 is a highly integrated Ethernet IC for use in Ethernet Network Interface Cards (NICs) in the ISA/Plug and Play (PnP) environment. It contains a full-duplex Media Access Controller (MAC), a 10 Mbit/s Manchester encoder/decoder (ENDEC), a 10BaseT transceiver, ISA-bus interface and an Attachment Unit Interface (AUI). The only external components required to build an Ethernet adapter card with the 78Q8377 are buffer memory and a few passive components. In full duplex operation, transmission line throughput doubles to the theoretical 20 Mbit/s. In this mode, the collision detection, SQE generation and carrier deference are disabled.

The 78Q8377 has an integrated ISA-bus interface that physically connects to the bus without any additional glue logic. The 78Q8377 is defined with "jumperless" configuration in mind. The configuration information is stored in serial EEPROM.

The 78Q8377 fully supports the PnP ISA specification. The PnP logic can also be bypassed through a bit in the EEPROM. When the PnP logic is bypassed, the 78Q8377 will power up active after loading the necessary configuration information from the serial EEPROM.

The popular microwire (4-wire) interface is supported by the 78Q8377 to connect to serial EEPROM, which contains configuration information such as I/O Base address, Boot Device address, IRQ selection, MAC address, etc. Reading of essential configuration information like the I/O Base address and Boot Device address is done automatically by the 78Q8377. The driver software is then responsible to read the rest of the information and program the 78Q8377 registers with the appropriate values read.

The 78Q8377 allows for a diskless station to boot from the installed boot device. It supports 8 memory base addresses for the boot device with 16 Kbytes memory size and 4 memory base addresses with 32 Kbytes size. The boot feature can also be disabled through a bit in the serial EEPROM. Both read-only and read-write (e.g., flash) memory are supported by the 78Q8377. Furthermore, accidental write to the flash can be prevented through a write protect register bit. The 78Q8377 only provides a chip select pin to the boot device and the address, data and control signals of the boot device connect directly to the appropriate ISA bus.

FEATURES

- **Highly integrated Ethernet combo with Plug and Play (PnP) interface**
- **Compliant with plug and play ISA Specification Version 1.0a**
- **Includes complete Ethernet circuitry for 10BaseT: Buffer manager, MAC/DLC, ENDEC, 10BaseT transceiver, AUI, and power management**
- **Register-compatible with SSI 78Q8373**
- **"Glueless" and "jumperless" connection to ISA bus**
- **Supports both PnP and non-Pn P environment**
- **Integrated 16 mA data bus buffer with staggering for reduced noise and ground bounce**
- **Serial EEPROM support via microwire (4-wire) interface**
- **Boot device (either read-only or read-write memory) support. 8 Boot device locations with 16 or 32 Kbytes size**
- **8 interrupt lines selection. Supports edge and level-sensitive interrupts. Tri-state implementation allows sharing of interrupts for both modes**
- **Programmable full-duplex operation in twisted-pair mode**
- **Low power design**
- **128-pin QFP with single 5V supply**

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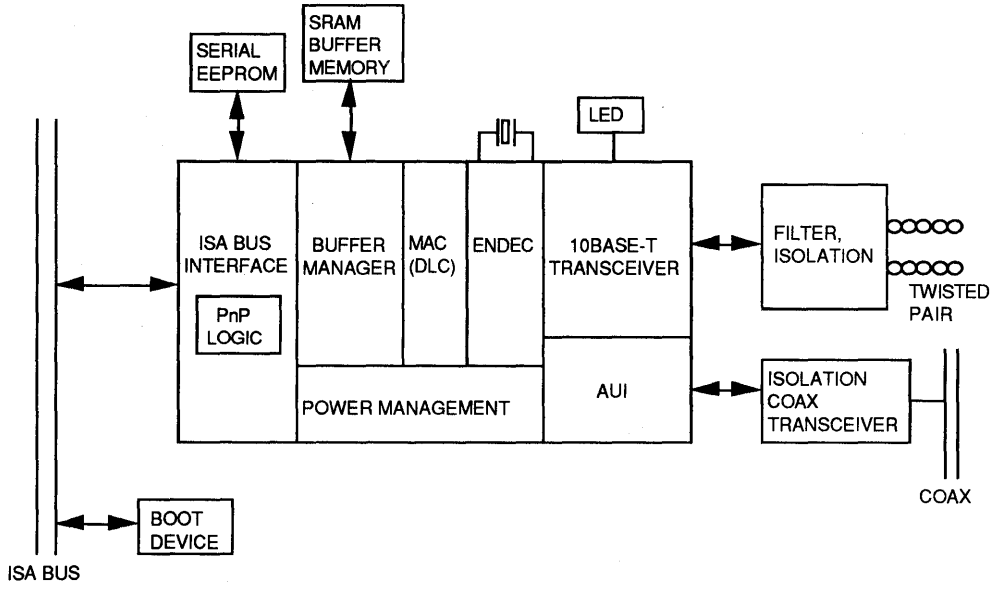
SSI 78Q8377
10BaseT Ethernet Combo for Plug and Play

BLOCK DIAGRAM



Target Specification: The target specification is intended as an initial disclosure of specification goals for the product. The specifications are based on design goals, subject to change and are not guaranteed. Silicon Systems assumes no obligation regarding future manufacture unless agreed to in writing.

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SSI 78Q8378
Enhanced PCMCIA Ethernet Device
Target Specification

December 1994

DESCRIPTION

The SSI 78Q8378 is a highly integrated Ethernet IC for use in PCMCIA (Personal Computer Memory Card International Association) applications with Multi-Function card capability, especially Ethernet/Modem combinations. It contains a full-duplex Media Access Controller (MAC), a 10 Mbit/s Manchester encoder/decoder (ENDEC), a 10BaseT transceiver, PCMCIA bus interface and an Attachment Unit Interface (AUI), and can operate from either a 5-volt or 3.3-volt supply. The only external components required to build a PCMCIA Ethernet adapter card with the 78Q8378 are buffer memory and a few passive components. In full duplex operation, transmission line throughput doubles to the theoretical 20 Mbit/s. In this mode, the collision detection, SQE generation and carrier deference are disabled.

To allow multi-function operation, two sets of Function Configuration Registers (FCR - formerly called Card Configuration Registers or CCR) are provided so that each function can be configured independently of the other. The chip includes the function of mapping and decoding the I/O range for the ethernet (78Q8373) registers and the modem port. The 78Q8378 is also capable of handling multiple interrupts from two sources by saving the second interrupt and generating it later according to the PCMCIA Multifunction spec. A simple modem interface is provided on-chip to eliminate the need for external glue logic when designing an Ethernet/Modem multifunction PCMCIA card. The 78Q8378 interfaces directly to a UART.

FEATURES

- **Highly integrated PCMCIA Ethernet and modem port combo**
- **PCMCIA Multifunction spec compliant. Built-in modem port interface to external UART**
- **Includes all the functional blocks of 78Q8373: Buffer manager, MAC/DLC, ENDEC, 10BaseT transceiver, AUI, power management and 3.3V or 5V operation**
- **Register-compatible with SSI 78Q8373**
- **Interface to parallel EEPROM/Flash memory for PCMCIA CIS (Card Information Structure)**
- **Programmable full-duplex operation in twisted-pair mode**
- **I/O registers are accessible through normal I/O cycle as well as common memory cycle**
- **Low power design**
- **100-Lead TQFP**

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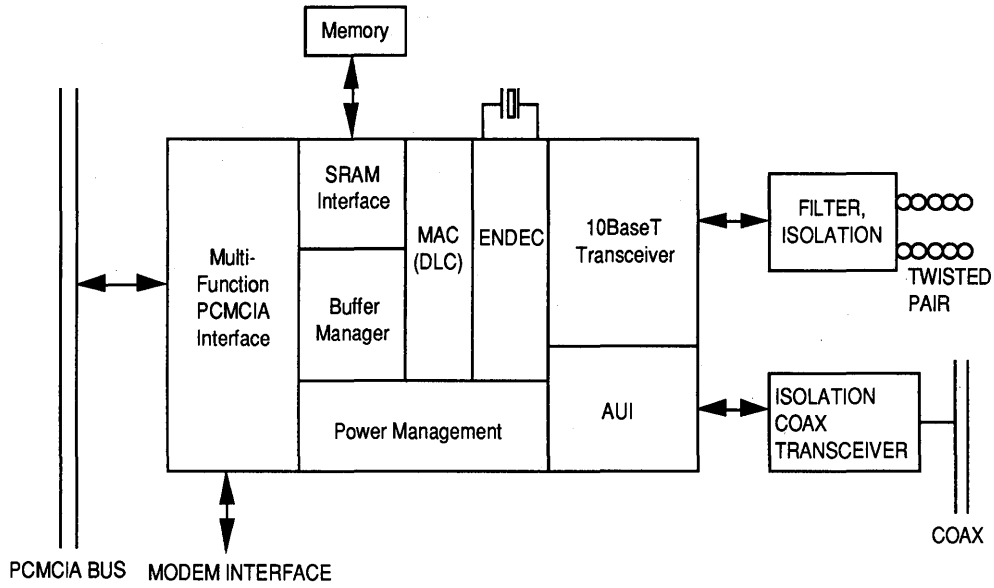
SSI 78Q8378
Enhanced PCMCIA Ethernet Device

BLOCK DIAGRAM



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SSI 78Q2250
155 Mbit/s ATM Line Transceiver
Target Specification

October 1994

DESCRIPTION

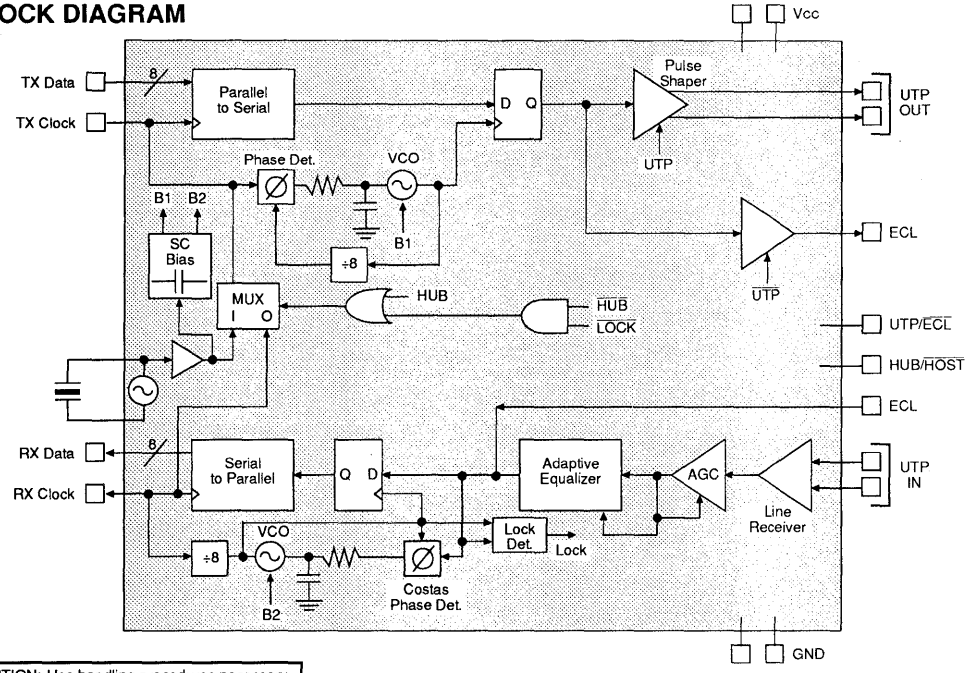
The SSI 78Q2250 is a high-speed line transceiver integrated circuit intended for use in Asynchronous Transfer Mode (ATM) applications. It is used at the interface to Category 5 Unshielded Twisted-Pair (UTP) cabling and is connected to the line via isolation transformers. Interface to digital framer circuits is accomplished via 8-bit parallel CMOS I/O running at 19.44 Mbit/s.

The IC provides full transmit and receive line interface functions with minimum external components required. The receiver provides near-end crosstalk cancellation, adaptive equalization for accurate clock and data recovery, while the transmitter includes on-chip pulse shaping. The 78Q2250 is built in a BiCMOS technology for highest performance and low power operation.

FEATURES

- **155.52 Mbit/s interface for Category 5 Unshielded Twisted Pair (UTP) cable**
- **Compliant with ATM PMD Interface Spec for 155.52 Mbit/s over Twisted Pair Cable**
- **Parallel CMOS logic interface at 19.44 Mbit/s**
- **ECL interfaces for connection to fiber optic receive and transmit modules**
- **On-chip pulse shaping**
- **Automatic gain**
- **Adaptive equalization**
- **Power down mode**
- **Advanced BiCMOS processing**

BLOCK DIAGRAM



CAUTION: Use handling procedures necessary for a static sensitive component.

The target specification is intended as an initial disclosure of specification goals for the product. The specifications are based on design goals, subject to change and are not guaranteed. Silicon Systems assumes no obligation regarding future manufacture unless agreed to in writing.

SSI 78Q2250
155 Mbit/s ATM
Line Transceiver

FUNCTIONAL DESCRIPTION

The transmit section of this IC contains all of the necessary circuitry to convert 8-bit parallel data into a single 155.52 Mbit/s serial data signal and drive the Category 5 UTP cable. It generates the 155.52 MHz using a fixed PLL synthesizer locked to either a local 19.44 MHz crystal oscillator (in a hub application), or the 155.52 Mbit/s clock recovered in the receiver (when used in a host). Data enters the chip via TxDat0-7 and are converted to serial by a parallel-to-serial converter. The single 155.52 Mbit/s data line is then converted to the 1 volt differential signal required at the line interface. Connection to the UTP cable is through a transformer.

On the receive side, data signal enters the chip via the UTP interface after it has gone through up to 100 meters of cable. The connection to the UTP cable is through a transformer. Once on-chip, the signal goes through both an automatic gain circuit and an adaptive equalizer. These circuits look for the amount dispersion and attenuation caused by the cable and restore the received pulses to square waves. The amount of gain and equalization applied to the pulses varies with the detected attenuation and dispersion and therefore with the length of the cable. The clock signal is extracted from the equalized data signal using a Costas loop PLL. The recovered clock is used to retime the data signal and finally it is converted to 8-bit parallel data at 19.44 Mbit/s in a serial to parallel converter.

As noted, the transmitter uses either the local crystal oscillator or the recovered clock from the receiver. When the circuit is in a host, the transmit clock is always derived from the local crystal oscillator. When it is in a hub, the transmit clock is derived from the recovered clock when the receive PLL is locked. When it is not, the transmit clock PLL switches its input to the crystal oscillator. In this way, the transmitter will still operate at the right frequency even if the receiver is not seeing a correct signal. The receive clock RxClk used to clock out the data from the receive side of the chip is normally derived from the receive PLL, when it is locked. When the PLL is unlocked, the RxClk is switched to the crystal oscillator so that it will be at the right frequency. The data leaving the chip from RxDat0-7 will still be timed by RxClk but will not be valid.

The 78Q2250 uses the local crystal oscillator to generate bias voltages for setting the various time dependent circuits on the chip. These include the controlled rise-time for the transmit pulses and the center frequencies of the two on-chip voltage-controlled oscillators. This means that the narrow band PLL circuits won't require frequency discrimination circuits to aid acquisition. It also means the chip will not require the use of the external resistor used in other ICs requiring precision timing, nor will it be necessary to trim the part.

Target Specification: The target specification is intended as an initial disclosure of specification goals for the product. The specifications are based on design goals, subject to change and are not guaranteed. Silicon Systems assumes no obligation regarding future manufacture unless agreed to in writing.

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Section 8

PROGRAMMABLE ELECTRONIC FILTERS

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SSI 32F8001/8002
Low-Power Programmable Electronic Filter

December 1994

DESCRIPTION

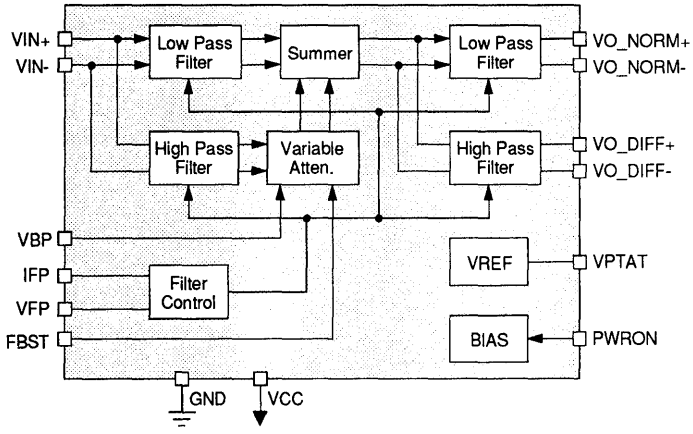
The SSI 32F8001/8002 Programmable Electronic Filter provides an electronically controlled low–pass filter with a separate differentiated low–pass output. A seven–pole, low–pass filter is provided along with a single-pole, single-zero differentiator. Both outputs have matched delays. The delay matching is unaffected by any amount of programmed equalization or bandwidth. This programability combined with low group delay variation make the SSI 32F8001/8002 ideal for use in constant density recording applications. Pulse slimming equalization is accomplished by a two–pole, low–pass with a two–pole, high–pass feed forward section to provide complimentary real axis zeros. A variable attenuator is used to program the zero locations.

The SSI 32F8001/8002 programmable equalization and bandwidth characteristics can be controlled by external DACs. Fixed characteristics are easily accomplished with three external resistors, in addition equalization can be switched in or out by a logic signal. The SSI 32F8001/8002 requires only a +5V supply and are available in 16-lead SON and SOL packages.

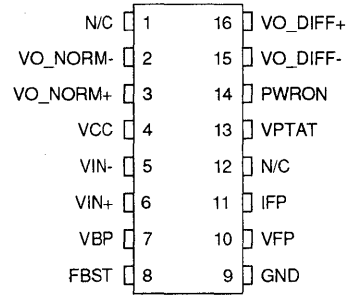
FEATURES

- **Ideal for multi-rate systems applications**
- **Programmable filter cutoff frequency (fc = 9 to 27 MHz, 32F8001; fc = 6 to 18 MHz, 32F8002)**
- **Programmable pulse slimming equalization (0 to 13.5 dB boost at the filter cutoff frequency)**
- **Matched normal and differentiated low-pass outputs**
- **Differential filter inputs and outputs**
- **±12% cutoff frequency accuracy**
- **±2% maximum group delay variation from 0.2 fc to fc**
- **Total harmonic distortion less than 1%**
- **No external filter components required**
- **+5V only operation**
- **16-Lead SON and SOL package**
- **Pin compatible with SSI 32F8011**

BLOCK DIAGRAM



PIN DIAGRAM



16-Lead SOL, SON

CAUTION: Use handling procedures necessary for a static sensitive component.

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SSI 32F8001/8002
Low-Power Programmable Electronic Filter

FUNCTIONAL DESCRIPTION

The SSI 32F8001/8002 is a high performance programmable electronic filter. It features a 7-pole 0.05° equiripple linear phase filter with matched normal and differentiated outputs.

CUTOFF FREQUENCY PROGRAMMING

The SSI 32F8001 programmable electronic filter can be set to a filter cutoff frequency from 9 to 27 MHz with no boost. The SSI 32F8002 can set the cutoff frequency from 6 to 18 MHz with no boost.

Cutoff frequency programming can be established using either a current source fed into pin IFP whose output current is proportional to the SSI 32F8001/8002 output reference voltage VPTAT, or by means of an external resistor tied from the output voltage reference pin VPTAT to pin VFP. The former method is optimized using the SSI 32D4661 Time Base Generator, since the current source into pin IFP is available at the DAC F output of the SSI 32D4661. Furthermore, the voltage reference input is supplied to pin VR3 of the SSI 32D4661 by the reference voltage from the VPTAT pin of the SSI 32F8001/8002. This reference voltage is internally generated by a band-gap circuit in conjunction with a temperature varying reference to create a voltage which is proportional to absolute temperature.

The VPTAT voltage will compensate for internal temperature variation of the fc and boost circuits.

The cutoff frequency, determined by the -3 dB point relative to a very low frequency value (< 10 kHz), is related to the current IVFP injected into pin IFP by the following formulas.

fc (ideal, in MHz)

32F8001 = 45.0 • IFP = 45.0 • IVFP • 1.8/VPTAT

32F8002 = 30.0 • IFP = 30.0 • IVFP • 1.8/VPTAT

where IFP and IVFP are in mA, 0.2 < IFP < 0.6 mA, VPTAT is in volts, and Ta = 25°C.

If a current source is used to inject current into pin IFP, pin VFP should be left open.

If the SSI 32F8001/8002 cutoff frequency is set using voltage VPTAT to bias up a resistor tied to pin VFP, the cutoff frequency is related to the resistor value by the following formulas.

fc (ideal, in MHz)

32F8001 = 45.0 • IFP = 45.0 • 1.8/(3 • Rx)

32F8002 = 30.0 • IFP = 30.0 • 1.8/(3 • Rx)

Rx in kΩ

If pin VFP is used to program cutoff frequency, pin IFP should be left open.

MAGNITUDE EQUALIZATION PROGRAMMING

The magnitude equalization, measured in dB, is the amount of high frequency peaking at the cutoff frequency relative to the original -3 dB point. For example, when 12 dB boost is applied, the magnitude response peaks up 9 dB above the DC gain.

The amplitude of the input signal at frequencies near the cutoff frequency can be increased using this feature. Applying an external voltage to pin VBP which is proportional to reference output voltage VPTAT (provided by the VPTAT pin) will set the amount of boost. A fixed amount of boost can be set by an external resistor divider network connected from pin VBP to pins VPTAT and GND. No boost is applied if pin FBST, frequency boost enable, is at a low logic level.

The amount of boost FB at the cutoff frequency Fc is related to the voltage VBP by the formula

FB (ideal, in dB) = 20 $\log_{10}$[3.73(VBP/VPTAT)+1], where 0 < VBP < VPTAT.

POWER ON / OFF

The SSI 32F8001/8002 supports a power down mode for minimal idle mode power dissipation. When PWRON is pulled up to logic 1, the device is in normal operation mode. When PWRON is pulled down to logic 0, or left open, the device is in the power down mode.

PIN DESCRIPTION

NAME	TYPE	DESCRIPTION
VIN+, VIN-	I	Differential Signal Inputs. The input signals must be AC coupled to these pins.
VO_NORM+, VO_NORM-	O	Differential Normal Outputs. The output signals must be AC coupled.
VO_DIFF+, VO_DIFF-	O	Differential Differentiated Outputs. For minimum time skew, these outputs should be AC coupled.
IFP	I	Frequency Program Input. The filter cutoff frequency fc, is set by an external current IFP, injected into this pin. IFP must be proportional to voltage VPTAT. This current can be set with an external current generator such as a DAC. VFP should be left open when using this pin.
VFP	I	Frequency Program Input. The filter cutoff frequency can be set by programming a current through a resistor from VPTAT to this pin. IFP should be left open when using this pin.
VBP	I	Frequency Boost Program Input. The high frequency boost is set by an external voltage applied to this pin. VBP must be proportional to voltage VPTAT. A fixed amount of boost can be set by an external resistor divider network connected from VBP to VPTAT and GND. No boost is applied if the FBST pin is grounded, or at logic low.
FBST	I	Frequency Boost. A high logic level or open enables the frequency boost circuitry. A low input disables this function.
PWRON	I	Power On. A high logic level enables the chip. A low level or open pin puts the chip in a low power state.
VPTAT	O	PTAT Reference Voltage. This pin outputs a reference voltage which is proportional to absolute temperature (PTAT). VBP, VFP or IFP must be referenced to this pin for proper operation.
VCC	O	+5 Volt Supply.
GND	I	Ground

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Operation above maximum ratings may damage the device.

PARAMETER	RATINGS
Storage Temperature	-65°C to +150°C
Junction Operating Temperature, Tj	+130°C
Supply Voltage, VCC	-0.5V to 7V
Voltage Applied to Inputs	-0.5V to VCC

ELECTRICAL SPECIFICATIONS (continued)

RECOMMENDED OPERATING CONDITIONS

PARAMETER		RATINGS
Supply voltage	VCC	4.50V < VCC < 5.50V
Ambient Temperature	Ta	0°C < Ta < 70°C

ELECTRICAL CHARACTERISTICS

Unless otherwise specified recommended operating conditions apply.

Power Supply Characteristics

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
Power Supply Current	ICC	PWRON ≤ 0.8V		0.1	0.5	mA
Power Supply Current	ICC	PWRON ≥ 2V		46	60	mA
Power Dissipation	PD	PWRON ≥ 2V, VCC = 5V		230	300	mW
		PWRON ≥ 2V, VCC = 5.5V		275	330	mW
		PWRON ≤ 0.8V		0.5	2.5	mW

DC Characteristics

High Level Input Voltage	VIH	TTL input	2			V
Low Level Input Voltage	VIL				0.8	V
High Level Input Current	IIH	VIH = 2.7V			20	µA
Low Level Input Current	IIL	VIL = 0.4V	-1.5			mA

Filter Characteristics

Filter Cutoff Frequency *(f -3 dB)	*fc	32F8001 $fc = \frac{45\ \text{MHz}}{\text{mA}}(\text{IVFP})$ IVFP = 0.2 to 0.6 mA, Ta = 25 °C	9		27	MHz
		32F8002 $fc = \frac{30\ \text{MHz}}{\text{mA}}(\text{IVFP})$ IVFP = 0.2 to 0.6 mA, Ta = 25 °C	6		18	MHz
Filter fc Accuracy	FCA	fc = max.	-12		+12	%
VO_NORM Diff Gain	AO	F = 0.67 fc, FB = 0 dB	0.8		1.2	V/V
VO_DIFF Diff Gain	AD	F = 0.67 fc, FB = 0 dB	0.8 AO		1.2 AO	V/V
Frequency Boost at fc	FB	VBP = VPTAT fc = max.	12	13.5	15	dB
		fc = min.	11.5	13	14.5	dB
Frequency Boost Accuracy	FBA	VBP/VPTAT = 1.0 fc = max.	-1.5		+1.5	dB

FILTER CHARACTERISTICS (continued)

PARAMETER		CONDITIONS		MIN	NOM	MAX	UNIT
Group Delay Variation Without Boost	TGDO	fc = max., $\frac{VBP}{VPTAT}=0$	8001	-500		+500	ps
		F = 0.2 fc to fc	8002	-750		+750	ps
		fc = min., $\frac{VBP}{VPTAT}=0$	8001	-1.5		+1.5	ns
		F = 0.2 fc to fc	8002	-2.25		+2.25	ns
Group Delay Variation Without Boost (continued)	TGDO	F = 0.2 fc to fc $\frac{VBP}{VPTAT}=0$		-2		2	%
		F = fc to 1.75 fc $\frac{VBP}{VPTAT}=0$		-4		+4	%
Group Delay Variation with Boost	TGDB	fc = max, VBP = VPTAT		-500		+500	ps
		F = 0.2 fc to fc		-750		+750	ps
		fc = min., VBP = VPTAT		-1.5		+1.5	ns
		F = 0.2 to fc		-2.25		+2.25	ns
		F = 0.2 fc TO fc, VBP = VPTAT		-2.5		+2.5	%
		F = fc to 1.75 fc, VBP = VPTAT		-4		+4	%
Filter Input Dynamic Range	VIF	THD = 1% max, F = 0.67 fc, VBP = 0V (1000 pF across Rx)		1			Vp-p
		THD = 1.7% max, F = 0.67 fc, VBP = 0V, Normal output (1000 pF across Rx)		1.5			Vp-p
Filter Input Dynamic Range	VIF	THD = 3.5% max, F = 0.67 fc, VBP = 0V, Differentiated output (1000 pF across Rx)		1.5			Vp-p
Filter Output Dynamic Range	VOF	THD = 1% max, F = 0.67 fc $R_{LOAD} \geq 1k\Omega$ (1000 pF across Rx)		1			Vp-p
Filter Diff Input Resistance	RIN			3	4.3		kΩ
Filter Input Capacitance	CIN					3	pF
Output Noise Voltage Differentiated Output	EOUT	BW = 100 MHz, Rs = 50Ω	8001		3.5	5.4	mVRms
		fc = max, VBP = 0V	8002		3.3	5.2	mVRms
Output Noise Voltage Normal Output	EOUT	BW = 100 MHz, Rs = 50Ω	8001		2.3	3.45	mVRms
		fc = max, VBP = 0V	8002		2.1	3.15	mVRms
Output Noise Voltage Differentiated Output	EOUT	BW = 100 MHz, Rs = 50Ω	8001		7.7	10.75	mVRms
		fc = max, VBP = VPTAT	8002		4.8	7	mVRms
Output Noise Voltage Normal Output	EOUT	BW = 100 MHz, Rs = 50Ω	8001		3.8	4.75	mVRms
		fc = max, VBP = VPTAT	8002		2.6	3.3	mVRms

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ELECTRICAL SPECIFICATIONS (continued)

FILTER CONTROL CHARACTERISTICS

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
Filter Output Sink Current	IO –		1			mA
Filter Output Source Current	IO +		2			mA
Filter Output Resistance (Single ended)	RO	IO+ = 1.0 mA			60	Ω
Reference Voltage	VPTAT	Tj = 25°C		1.8		V
PTAT Voltage Input	VFP			2/3 VPTAT		V
Programming Current Range	IVFP	Ta = 25°C	0.2		0.6	mA
Programming Voltage Range	V_{VBP}		0		VPTAT	V
Voltage at pin IFP	V_{IFP}	I_{VFP} = 0 mA		2/3 VPTAT		V
Power Up Time		fc = 9 MHz			1.5	µs
		fc = 27 MHz			1	µs
Power Down Time					1	µs

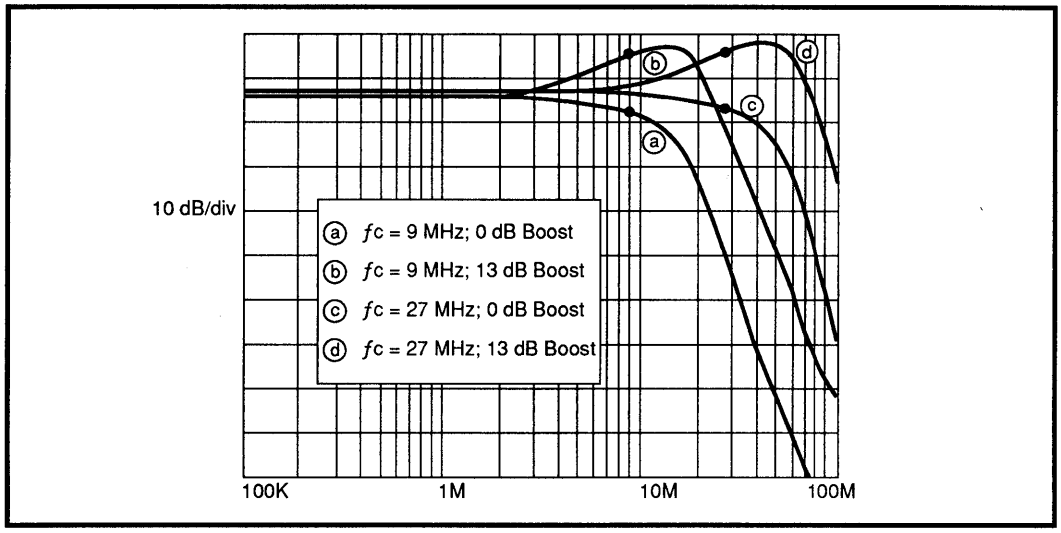

FIGURE 1: 32F8001 Normal Low Pass Response

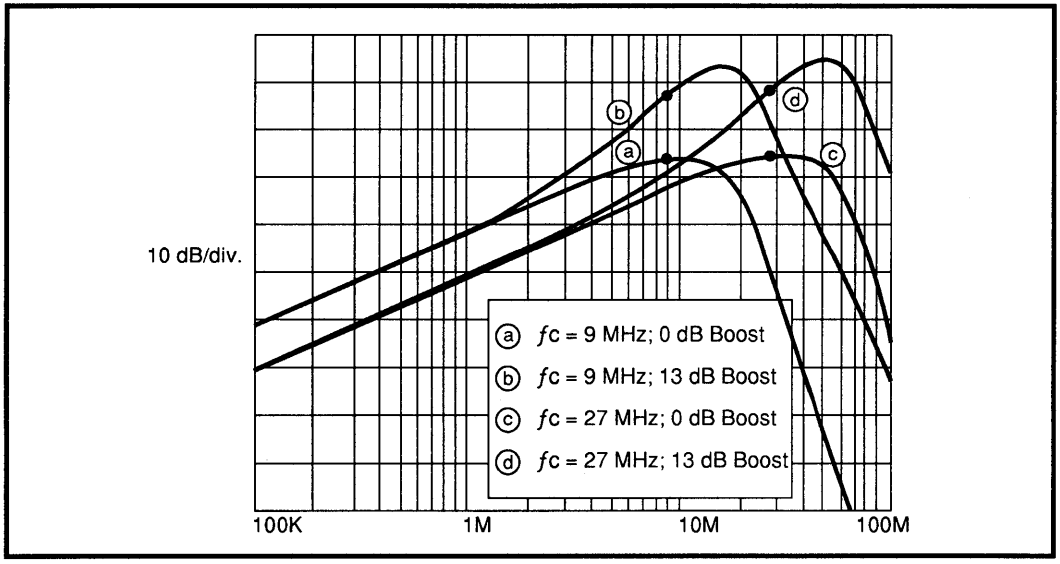

FIGURE 2: 32F8001 Differentiated Low Pass Response

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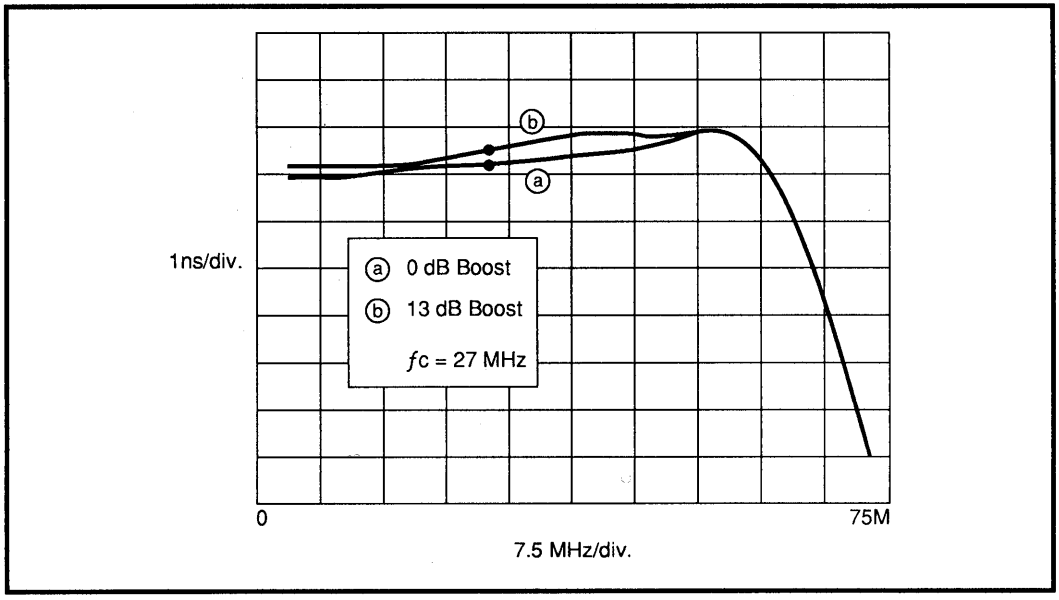
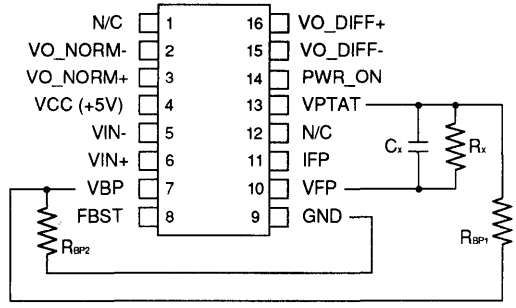


FIGURE 3: 32F8001 Group Delay Response with fc = 27 MHz



VPTAT = 1.8V (25°C)

V_{VFP} = 2/3 (VPTAT)

IVFP range: 0.2 mA to 0.6 mA @25°C

(9 to 27 MHz no boost 32F8001)

(6 to 18 MHz no boost 32F8002)

Fixed frequency programming is accomplished as shown in the drawing above.

In this case IVFP (programming current) is equivalent to $\frac{VPTAT}{3} \cdot \frac{1}{R_X}$

i.e., fc = 27 MHz then

IVFP = 0.6 mA @25°C Rx = 1 kΩ

Fixed boost programming is also accomplished as shown above. In this case V_{VBP} is set by a voltage divider, where V_{VBP} is a fraction of VPTAT.

i.e., boost = 9 dB then,

VBP/VPTAT = 0.488 9 dB = 20 log [3.73 (0.488) + 1]

$$\frac{R_{BP2}}{R_{BP1}} = \frac{1}{\left(\frac{VPTAT}{VBP} - 1\right)} = 0.953$$

Cx = 1000 pF - Cx is needed for lower THD at lower fc.

FIGURE 4: 32F8001/8002 Applications Setup

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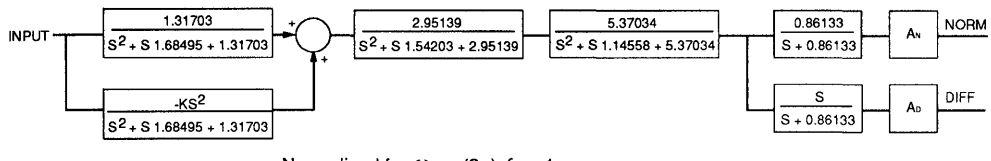
SSI 32F8001/8002
Low-Power Programmable Electronic Filter



Normalized for $\omega c = (2\pi)\, fc = 1$
AN and AD are adjusted for unity gain (0 dB) at $F = 0.67\, fc$
Denormalize the frequency by substituting $S \rightarrow (S/2\pi fc)$
Eq for fc = 27 MHz, $S = S / [(2\pi)(27 \times 10^6)]$

FIGURE 5: 32F8001/8002 Normalized Block Diagram

TABLE 1: 32F8001/8002 Frequency Boost Calculations, K = 1.31703 (10 BOOST (dB)/20 - 1)

Assuming 13 dB boost for VBP = VPTAT

$$\frac{VBP}{VPTAT} \cong \frac{\left(10^{(FB/20)}\right) - 1}{3.73}$$

Boost	K	VBP / VPTAT	Boost	K	VBP / VPTAT
1 dB	0.16	0.033	6 dB	1.31	0.267
2 dB	0.34	0.069	7 dB	1.63	0.332
3 dB	0.54	0.110	8 dB	1.99	0.405
4 dB	0.77	0.157	9 dB	2.40	0.488
5 dB	1.03	0.209	10 dB	2.85	0.580
			11 dB	3.36	0.683
			12 dB	3.43	0.799
			13 dB	4.57	0.929

or,

$$\text{boost in dB} = 20 \log \left[3.37 \left(\frac{VBP}{VPTAT}\right) + 1\right]$$

VBP / VPTAT	Boost	VBP / VPTAT	Boost
0.1	2.753 dB	0.6	10.206 dB
0.2	4.841 dB	0.7	11.153 dB
0.3	6.523 dB	0.8	12.006 dB
0.4	7.391 dB	0.9	12.784 dB
0.5	9.142 dB	1.0	13.5 dB

TABLE 2: Calculations

Typical change in f-3 dB point with boost

Boost (dB)	Gain@fc (dB)	Gain@ peak (dB)	$f$peak/fc	f-3dB/fc
0	-3	0.00	no peak	1.00
1	-2	0.00	no peak	1.21
2	-1	0.00	no peak	1.51
3	0	0.15	0.70	1.80
4	1	0.99	1.05	2.04
5	2	2.15	1.23	2.20
6	3	3.41	1.33	2.33
7	4	4.68	1.38	2.43
8	5	5.94	1.43	2.51
9	6	7.18	1.46	2.59
10	7	8.40	1.48	2.66
11	8	9.59	1.51	2.73
12	9	10.77	1.51	2.80
13	10	11.92	1.53	2.87
14	11	13.06	1.53	2.93

Notes: 1. fc is the original programmed cutoff frequency with no boost

2. f-3 dB is the new -3 dB value with boost implemented

3. $f$peak is the frequency where the amplitude reaches its maximum value with boost implemented

i.e., fc = 9 MHz when boost = 0 dB

if boost is programmed to 5 dB then f-3 dB = 19.8 MHz

$f$peak = 11.07 MHz

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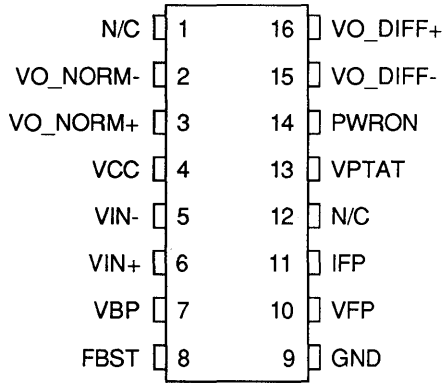
SSI 32F8001/8002
Low-Power Programmable Electronic Filter

PACKAGE PIN DESIGNATIONS
(Top View)



16-Lead SON, SOL

THERMAL CHARACTERISTICS: θja

16-Lead SON (150 mil)	105°C/W
16-Lead SOL (300 mil)	100°C/W

CAUTION: Use handling procedures necessary for a static sensitive component.

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 32F8001		
16-Lead SOL	32F8001-CL	32F8001-CL
16-Lead SON	32F8001-CN	32F8001-CN
SSI 32F8002		
16-Lead SOL	32F8002-CL	32F8002-CL
16-Lead SON	32F8002-CN	32F8002-CN

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SSI 32F8003
Low-Power Programmable Electronic Filter
Preliminary Data

October 1994

DESCRIPTION

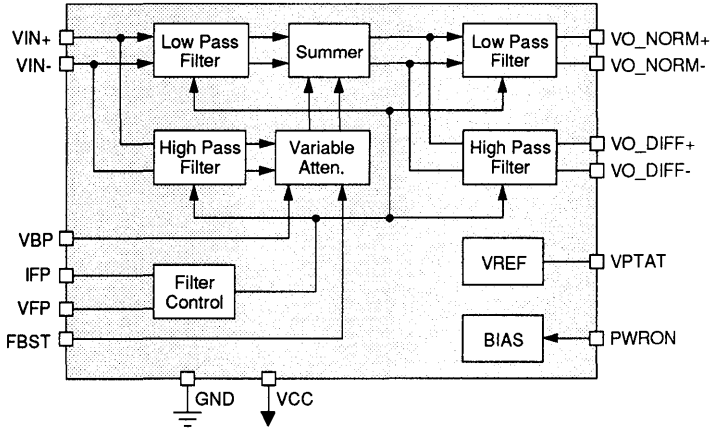
The SSI 32F8003 Programmable Electronic Filter provides an electronically controlled low–pass filter with a separate differentiated low–pass output. A seven–pole, low–pass filter is provided along with a single-pole, single-zero differentiator. Both outputs have matched delays. The delay matching is unaffected by any amount of programmed equalization or bandwidth. This programability combined with low group delay variation makes the SSI 32F8003 ideal for use in constant density recording applications. Pulse slimming equalization is accomplished by a two–pole, low–pass with a two–pole, high–pass feed forward section to provide complimentary real axis zeros. A variable attenuator is used to program the zero locations.

The SSI 32F8003 programmable equalization and bandwidth characteristics can be controlled by external DACs. Fixed characteristics are easily accomplished with three external resistors, in addition equalization can be switched in or out by a logic signal. The SSI 32F8003 requires only a +5V supply and is available in 16-lead SON and SOL packages.

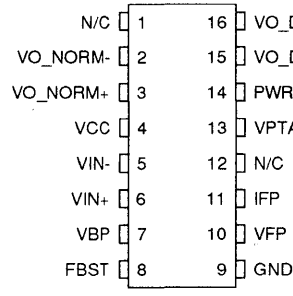
FEATURES

- **Ideal for multi-rate systems applications**
- **Programmable filter cutoff frequency fc = 4 to 13 MHz**
- **Programmable pulse slimming equalization (0 to 13.5 dB boost at the filter cutoff frequency)**
- **Matched normal and differentiated low-pass outputs**
- **Differential filter inputs and outputs**
- **±13% cutoff frequency accuracy**
- **±2% maximum group delay variation from 0.2 fc to fc**
- **Total harmonic distortion less than 1%**
- **No external filter components required**
- **+5V only operation**
- **16-lead SON and SOL package**
- **Pin compatible with SSI 32F8011**

BLOCK DIAGRAM



PIN DIAGRAM



16-Lead SOL, SON

CAUTION: Use handling procedures necessary for a static sensitive component.

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SSI 32F8003
Low-Power Programmable Electronic Filter

FUNCTIONAL DESCRIPTION

The SSI 32F8003 is a high performance programmable electronic filter. It features a 7-pole 0.05° equiripple linear phase filter with matched normal and differentiated outputs.

CUTOFF FREQUENCY PROGRAMMING

The SSI 32F8003 programmable electronic filter can be set to a filter cutoff frequency from 4 to 13 MHz with no boost.

Cutoff frequency programming can be established using either a current source fed into pin IFP whose output current is proportional to the SSI 32F8003 output reference voltage VPTAT, or by means of an external resistor tied from the output voltage reference pin VPTAT to pin VFP. The former method is optimized using the SSI 32D4661 Time Base Generator, since the current source into pin IFP is available at the DAC F output of the SSI 32D4661. Furthermore, the voltage reference input is supplied to pin VR3 of the SSI 32D4661 by the reference voltage from the VPTAT pin of the SSI 32F8003. This reference voltage is internally generated by a band-gap circuit in conjunction with a temperature varying reference to create a voltage which is proportional to absolute temperature.

The VPTAT voltage will compensate for internal temperature variation of the fc and boost circuits.

The cutoff frequency, determined by the -3dB point relative to a very low frequency value (< 10 kHz), is related to the current IVFP injected into pin IFP by the following formulas.

fc (ideal, in MHz) = 21.67 • IFP = 21.67 • IVFP • 1.8/VPTAT

where IFP and IVFP are in mA, VPTAT is in volts, Ta = 25°C and $0.185 \leq IFP \leq 0.6$ mA for F8003.

If a current source is used to inject current into pin IFP, pin VFP should be left open.

If the SSI 32F8003 cutoff frequency is set using voltage VPTAT to bias up a resistor tied to pin VFP, the cutoff frequency is related to the resistor value by the following formulas.

fc (ideal, in MHz) = 21.67 • IFP = 21.67 • 1.8/(3 • Rx)

Rx in kΩ

If pin VFP is used to program cutoff frequency, pin IFP should be left open.

MAGNITUDE EQUALIZATION PROGRAMMING

The magnitude equalization, measured in dB, is the amount of high frequency peaking at the cutoff frequency relative to the original -3 dB point. For example, when 12 dB boost is applied, the magnitude response peaks up 9 dB at fc above the DC gain.

The amplitude of the input signal at frequencies near the cutoff frequency can be increased using this feature. Applying an external voltage to pin VBP which is proportional to reference output voltage VPTAT (provided by the VPTAT pin) will set the amount of boost. A fixed amount of boost can be set by an external resistor divider network connected from pin VBP to pins VPTAT and GND. No boost is applied if pin FBST, frequency boost enable, is at a low logic level.

The amount of boost FB at the cutoff frequency fc is related to the voltage VBP by the formula

FB (ideal, in dB) = 20 $\log_{10}$[3.73(VBP/VPTAT)+1], where 0 < VBP < VPTAT.

POWER ON / OFF

The SSI 32F8003 supports a power down mode for minimal idle mode power dissipation. When PWRON is pulled up to TTL logic high, the device is in normal operation mode. When PWRON is pulled down to TTL logic low, or left open, the device is in the power down mode.

PIN DESCRIPTION

NAME	TYPE	DESCRIPTION
VIN+, VIN-	I	Differential Signal Inputs. The input signals must be AC coupled to these pins.
VO_NORM+, VO_NORM-	O	Differential Normal Outputs. The output signals must be AC coupled.
VO_DIFF+, VO_DIFF-	O	Differential Differentiated Outputs. For minimum time skew, these outputs should be AC coupled.
IFP	I	Frequency Program Input. The filter cutoff frequency fc, is set by an external current IFP, injected into this pin. IFP must be proportional to voltage VPTAT. This current can be set with an external current generator such as a DAC. VFP should be left open when using this pin.
VFP	I	Frequency Program Input. The filter cutoff frequency can be set by programming a current through a resistor from VPTAT to this pin. IFP should be left open when using this pin.
VBP	I	Frequency Boost Program Input. The high frequency boost is set by an external voltage applied to this pin. VBP must be proportional to voltage VPTAT. A fixed amount of boost can be set by an external resistor divider network connected from VBP to VPTAT and GND. No boost is applied if the FBST pin is grounded, or at logic low.
FBST	I	Frequency Boost. A high logic level or open enables the frequency boost circuitry. A low input disables this function.
PWRON	I	Power On. A high logic level enables the chip. A low level or open pin puts the chip in a low power state.
VPTAT	O	PTAT Reference Voltage. This pin outputs a reference voltage which is proportional to absolute temperature (PTAT). VBP, VFP or IFP must be referenced to this pin for proper operation.
VCC	O	+5 Volt Supply.
GND	I	Ground

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Operation above maximum ratings may damage the device.

PARAMETER	RATINGS
Storage Temperature	-65°C to +150°C
Junction Operating Temperature, Tj	+130°C
Supply Voltage, VCC	-0.5V to 7V
Voltage Applied to Inputs	-0.5V to VCC

ELECTRICAL SPECIFICATIONS (continued)

RECOMMENDED OPERATING CONDITIONS

PARAMETER		RATINGS
Supply voltage	VCC	4.50V < VCC < 5.50V
Ambient Temperature	Ta	0°C < Ta < 70°C

ELECTRICAL CHARACTERISTICS

Unless otherwise specified recommended operating conditions apply.

Power Supply Characteristics

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
Power Supply Current	ICC	PWRON ≤ 0.8V		0.1	0.5	mA
Power Supply Current	ICC	PWRON ≥ 2.0V		46	60	mA
Power Dissipation	PD	PWRON ≥ 2.0V, VCC = 5.0V		230	300	mW
		PWRON ≥ 2.0V, VCC = 5.5V		275	330	mW
		PWRON ≤ 0.8V		0.5	2.5	mW

DC Characteristics

High Level Input Voltage	VIH	TTL input	2			V
Low Level Input Voltage	VIL				0.8	V
High Level Input Current	IIH	VIH = 2.7V			20	µA
Low Level Input Current	IIL	VIL = 0.4V	-1.5			mA

Filter Characteristics

Filter Cutoff Frequency *(*f* -3dB)	**fc*	$fc = \frac{21.67\,MHz}{mA}(IVFP)$	4		13	MHz
Filter *fc* Accuracy	FCA	*fc* = max.	-13		+13	%
VO_NORM Diff Gain	AO	F = 0.67 *fc*, FB = 0 dB	0.8		1.2	V/V
VO_DIFF Diff Gain	AD	F = 0.67 *fc*, FB = 0 dB	0.8AO		1.2AO	V/V
Frequency Boost at *fc*	FB	VBP = VPTAT *fc* = max.	12	13.5	15	dB
		fc = min.	11.5	13	14.5	dB
Frequency Boost Accuracy	FBA	VBP/VPTAT = 1.0 *fc* = max.	-1.5		1.5	dB

FILTER CHARACTERISTICS (continued)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
Group Delay Variation TGDO Without Boost (continued)	fc = max, $\frac{VBP}{VPTAT}=0$ F = 0.2 fc to fc	-1		+1	ns
	fc = min, $\frac{VBP}{VPTAT}=0$ F = 0.2 fc to fc	-3		+3	ns
	F = 0.2 fc to fc, $\frac{VBP}{VPTAT}=0$	-2		+2	%
	F = fc to 1.75 fc $\frac{VBP}{VPTAT}=0$	-3		+3	%
Group Delay Variation TGDB With Boost	fc = max, VBP = VPTAT F = 0.2 fc to fc	-1		+1	ns
	fc = min, VBP = VPTAT F = 0.2 to fc	-3		+3	ns
	F = 0.2 fc TO fc, VBP = VPTAT	-2		+2	%
	F = fc to 1.75 fc, VBP = VPTAT	-3		+3	%
Filter Input Dynamic Range VIF	THD = 1% max, F = 0.67 fc, VBP = 0V (1000 pF across Rx)	1			Vp-p
	THD = 1.5% max, F = 0.67 fc, VBP = 0V, Normal output (1000 pF across Rx)	1.5			Vp-p
Filter Input Dynamic Range VIF	THD = 2.0% max, F = 0.67 fc, VBP = 0V, Differentiated output (1000 pF across Rx)	1.5			Vp-p
Filter Diff Input Resistance RIN		3	4.3		kΩ
Filter Input Capacitance CIN				7	pF
Output Noise Voltage EOUT Differentiated Output	BW = 100 MHz, Rs = 50Ω fc = max, VBP = 0V		3		mV rms

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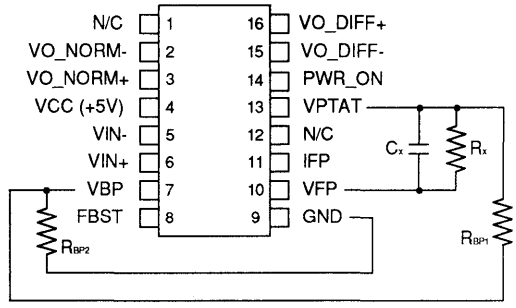
ELECTRICAL SPECIFICATIONS (continued)

FILTER CONTROL CHARACTERISTICS

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
Output Noise Voltage Normal Output	EOUT	BW = 100 MHz, Rs = 50Ω fc = max, VBP = 0V		1.8		mV rms
Output Noise Voltage Differentiated Output	EOUT	BW = 100 MHz, Rs = 50Ω fc = max, VBP = VPTAT		4.3		mV rms
Output Noise Voltage Normal Output	EOUT	BW = 100 MHz, Rs = 50Ω fc = max, VBP = VPTAT		2.2		mV rms
Filter Output Sink Current	IO –		1			mA
Filter Output Source Current	IO +		2			mA
Filter Output Resistance (Single ended)	RO	IO+ = 1.0 mA			60	Ω
Reference Voltage	VPTAT	Tj = 25°C		1.8		V
PTAT Voltage Input	VFP			2/3 VPTAT		V
Programming Current Range	IVFP	Ta = 25°C	0.185		0.6	mA
Programming Voltage Range	V_{VBP}		0		VPTAT	V
Voltage at pin IFP	V_{IFP}	I_{VFP} = 0 mA		2/3 VPTAT		V
Power Up Time		fc = min			1.5	µs
		fc = max			1	µs
Power Down Time					1	µs



VPTAT = 1.8V (25°C)

V_{VFP} = 2/3 (VPTAT)

IVFP range: 0.185 mA to 0.6 mA @25°C

Fixed frequency programming is accomplished as shown in the drawing above.

In this case IVFP (programming current) is equivalent to $\frac{VPTAT}{3} \cdot \frac{1}{R_x}$

i.e., fc = 13 MHz then

IVFP = 0.6 mA @25°C Rx = 1 kΩ

Fixed boost programming is also accomplished as shown above. In this case V_{VBP} is set by a voltage divider, where V_{BP} is a fraction of VPTAT.

i.e., boost = 9 dB then,

VBP/VPTAT = 0.488 9 dB = 20 log [3.73 (0.488) + 1]

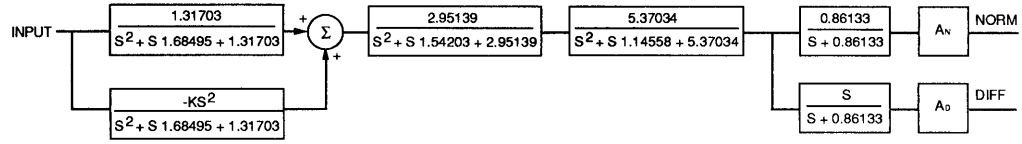
$$\frac{R_{BP2}}{R_{BP1}} = \frac{1}{\left(\frac{VPTAT}{VBP} - 1\right)} = 0.953$$

Cx = 1000 pF - Cx is needed for lower THD at lower fc.

8

FIGURE 4: 32F8003 Applications Setup

SSI 32F8003
Low-Power Programmable Electronic Filter



Normalized for $\omega c = (2\pi)\ fc = 1$
AN and AD are adjusted for unity gain (0 dB) at F = 0.67 fc
Denormalize the frequency by substituting S → $(S/2\pi fc)$
Eq for fc = 27 MHz, S = S / $[(2\pi)(27 \times 10^{6})]$

FIGURE 5: 32F8003 Normalized Block Diagram

TABLE 1: 32F8003 Frequency Boost Calculations, K = 1.31703 ($10^{BOOST\ (dB)/20} - 1$)

Assuming 13.5 dB boost for VBP = VPTAT

$$\frac{VBP}{VPTAT} \cong \frac{(10^{(FB/20)}) - 1}{3.73}$$

Boost	K	VBP/VPTAT	Boost	K	VBP/VPTAT
1 dB	0.16	0.033	6 dB	1.31	0.267
2 dB	0.34	0.069	7 dB	1.63	0.332
3 dB	0.54	0.110	8 dB	1.99	0.405
4 dB	0.77	0.157	9 dB	2.40	0.488
5 dB	1.03	0.209	10 dB	2.85	0.580
			11 dB	3.36	0.683
			12 dB	3.43	0.799
			13 dB	4.57	0.929

or,

$$\text{boost in dB} = 20 \log\left[3.73\left(\frac{VBP}{VPTAT}\right) + 1\right]$$

VBP/VPTAT	Boost	VBP/VPTAT	Boost
0.1	2.753 dB	0.6	10.206 dB
0.2	4.841 dB	0.7	11.153 dB
0.3	6.523 dB	0.8	12.006 dB
0.4	7.391 dB	0.9	12.784 dB
0.5	9.142 dB	1.0	13.5 dB

TABLE 2: Calculations

Typical change in f-3 dB point with boost

Boost (dB)	Gain@fc (dB)	Gain@ peak (dB)	$f$peak/fc	f-3dB/fc
0	-3	0.00	no peak	1.00
1	-2	0.00	no peak	1.21
2	-1	0.00	no peak	1.51
3	0	0.15	0.70	1.80
4	1	0.99	1.05	2.04
5	2	2.15	1.23	2.20
6	3	3.41	1.33	2.33
7	4	4.68	1.38	2.43
8	5	5.94	1.43	2.51
9	6	7.18	1.46	2.59
10	7	8.40	1.48	2.66
11	8	9.59	1.51	2.73
12	9	10.77	1.51	2.80
13	10	11.92	1.53	2.87
14	11	13.06	1.53	2.93

Notes: 1. fc is the original programmed cutoff frequency with no boost

2. f-3 dB is the new -3 dB value with boost implemented

3. $f$peak is the frequency where the amplitude reaches its maximum value with boost implemented

i.e., fc = 9 MHz when boost = 0 dB

if boost is programmed to 5 dB then f-3 dB = 19.8 MHz

$f$peak = 11.07 MHz

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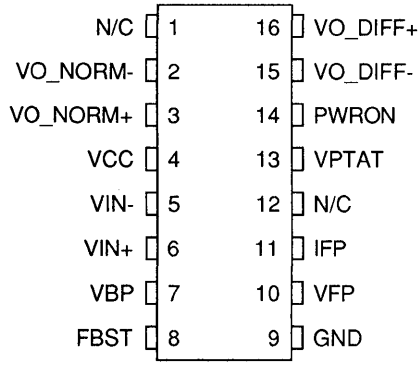
SSI 32F8003
Low-Power Programmable Electronic Filter

PACKAGE PIN DESIGNATIONS
(Top View)



16-Lead SON, SOL

CAUTION: Use handling procedures necessary for a static sensitive component.

THERMAL CHARACTERISTICS: θja

16-lead SON (150 mil)	105°C/W
16-lead SOL (300 mil)	100°C/W

ORDERING INFORMATION

PART DESCRIPTION		ORDER NUMBER	PACKAGE MARK
SSI 32F8003	16-Lead SOL	32F8003-CL	32F8003-CL
	16-Lead SON	32F8003-CN	32F8003-CN

Preliminary Data: Indicates a product not completely released to production. The specifications are based on preliminary evaluations and are not guaranteed. Small quantities are available, and Silicon Systems should be consulted for current information.

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SSI 32F8101
Low-Power Programmable Filter

Preliminary Data

January 1995

DESCRIPTION

The 32F8101 is a high performance, low power, digitally programmable low-pass filter for applications requiring variable-frequency filtering. The device consists of three functional blocks: [1] a 7th-order 0.05° Equiripple Low-Pass filter, [2] two DACs for controlling the filter cutoff frequency and high-frequency peaking (boost), and [3] a Serial Port for programming the *fc* and Boost DACs.

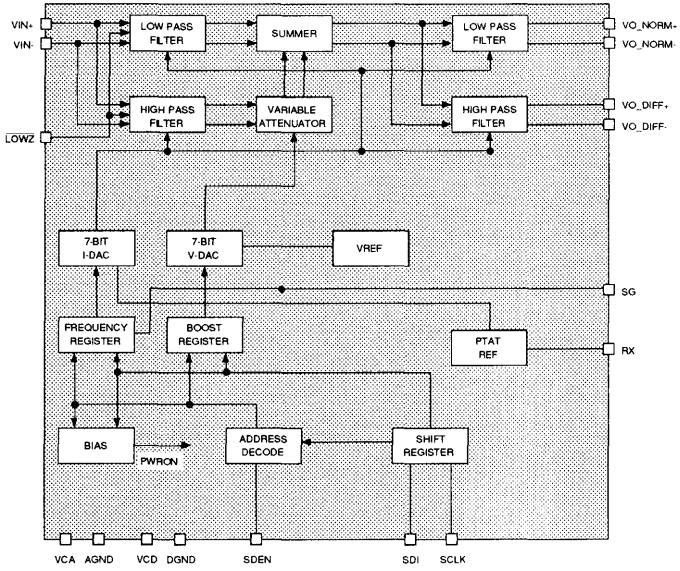
Cutoff frequency and boost are controlled by the two on-chip 7-bit DACs, which are programmed via the 3-line serial interface. Boost is programmable from 0 to 14.6 dB nominally at maximum *fc*, and is implemented using two symmetrical, real-axis zeroes. Both boost and *fc* control do not affect the flat group delay response.

The 32F8101 device is ideal for variable data rate and variable frequency shaping applications. It requires only a +5V supply and has an idle mode for minimal power dissipation. The SSI 32F8101 is available in a 16-lead SON package.

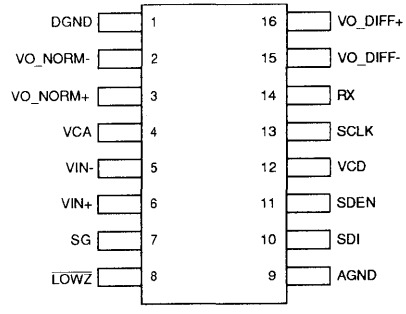
FEATURES

- **Programmable cutoff frequency - 8.9 to 27 MHz**
- **Programmable boost/equalization of 0 to 14.6 dB**
- **Matched normal and differentiated outputs**
- **±15% *fc* accuracy**
- **±2% maximum group delay variation**
- **Less than 1.5% total harmonic distortion**
- **Low-Z input switch controlled by $\overline{\text{LOWZ}}$ pin**
- **No external filter components required**
- **95 mW nominal power, <5 mW idle**

BLOCK DIAGRAM



PIN DIAGRAM



16-Lead SON

CAUTION: Use handling procedures necessary for a static sensitive component.

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SSI 32F8101
Low-Power Programmable Filter

FUNCTIONAL DESCRIPTION

The SSI 32F8101 programmable filter consists of an electronically controlled low-pass filter with a separate differentiated low-pass output. A seven-pole, low-pass filter is provided along with a single-pole, single-zero differentiator. Both outputs have matched delays. The delay matching is unaffected by any amount of programmed equalization or bandwidth. Programmable bandwidth and boost/equalization is provided by internal 7-bit control DACs. High-frequency boost equalization is accomplished by a two-pole, low-pass with a two-pole, high-pass feed forward section to provide complimentary real axis zeros. A variable attenuator is used to program the zero locations.

The filter implements a 0.05 degree equiripple linear phase response. The normalized transfer functions (i.e., $\omega c = 2\pi fc = 1$) are:

$Vnorm/Vi = 13.65983 \cdot [(-Ks^2 + 1.31703)/D(s)] \cdot AN$

and

$Vdiff/Vi = (Vnorm/Vi) \cdot (s/0.86133) \cdot AD$

Where D (s)=

$(S^2+1.68495s+1.31703)(S^2+1.54203\ s+2.95139)$

$(S^2+1\ .4558s+5.37034)(s+0.86133)$,

AN and AD are adjusted for a gain of 1 at $fs=(2/3)fc$.

FILTER OPERATION

Normally AC coupled differential signals are applied to the VIN± inputs of the filter, although DC coupling can be implemented. To improve settling time of the coupling capacitors, the VIN± inputs are placed into a Low-Z state when the $\overline{LOWZ}$ pin is brought low. The programmable bandwidth and boost/equalization features are controlled by internal DACs and the registers programmed through the serial port. The current reference for both DACs is set using a single 13.3 kΩ external resistor connected from pin RX to ground. The voltage at pin RX is proportional to absolute temperature (PTAT), hence the current for the DACs is a PTAT reference current.

Bandwidth Control

The programmable bandwidth is set by the filter cutoff DAC. This DAC has two separate 7-bit registers that can program the DAC value as follows:

$fc = 0.2133 \cdot DACF - 0.094$ (MHz)
where DACF = Cutoff Frequency Control Register value (decimal)

The filter cutoff set by the internal DAC is the unboosted 3 dB frequency. When boost/equalization is added, the actual 3 dB point will move out. Table 1 provides information on boost versus 3 dB frequency.

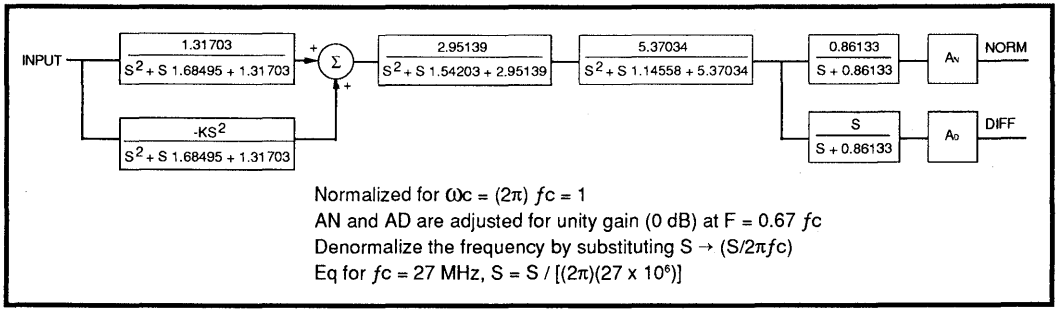

FIGURE 1: 32F8101 Normalized Block Diagram

TABLE 1: Calculations

Typical change in f-3 dB point with boost

Boost (dB)	Gain@fc (dB)	Gain@ peak (dB)	$f$peak/fc	f-3 dB/fc	K
0	-3	no peak	no peak	1.00	0
1	-2	no peak	no peak	1.21	0.16
2	-1	no peak	no peak	1.50	0.34
3	0	0.15	0.70	1.80	0.54
4	1	0.99	1.05	2.04	0.77
5	2	2.15	1.23	2.20	1.03
6	3	3.41	1.33	2.33	1.31
7	4	4.68	1.38	2.43	1.63
8	5	5.94	1.43	2.51	1.97
9	6	7.18	1.46	2.59	2.40
10	7	8.40	1.48	2.66	2.85
11	8	9.59	1.51	2.73	3.36
12	9	10.77	1.51	2.80	3.93
13	10	11.92	1.53	2.87	4.57
14	11	13.06	1.53	2.93	5.28
15	12	14.18	1.56	3.0	6.09

Notes:
1. fc is the original programmed cutoff frequency with no boost
2. f-3 dB is the new -3 dB value with boost implemented
3. $f$peak is the frequency where the amplitude reaches its maximum value with boost implemented

i.e., fc = 9 MHz when boost = 0 dB

if boost is programmed to 5 dB then f-3 dB = 19.8 MHz

$f$peak = 11.07 MHz

4. $K = 1.31703\,(10^{\frac{\text{BOOST (dB)}}{20}} - 1)$

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BOOST/EQUALIZATION CONTROL

The programmable equalization is also controlled by an internal DAC. The 7-bit Filter Boost Control Register (FBCR) determines the amount of equalization that will be added to the 3 dB cutoff frequency, as follows:

Boost =

$20 \log [(0.0239 \cdot DACB) + 7.6 \cdot 10^{-5} \cdot DACB \cdot DACF) + 1.132]$

where DACB = value in FBCR register.

For example, with the DAC set for maximum output (FBCR = 7F hex or 127) at the maximum cutoff frequency (DACF = 7F hex or 127) there will be 14.6 dB of boost added at the 3 dB frequency. This will result in +11 dB of signal boost above the 0 dB baseline.

SERIAL INTERFACE OPERATION

The serial interface is a CMOS bi-directional port for reading and writing programming data from/to the internal registers of the 32F8101. For data transfers SDEN is brought high, serial data is presented at the SDATA pin, and a serial clock is applied to the SCLK pin.

After the SDEN goes high, the first 16 pulses applied to the SCLK pin will shift the data presented at the SDATA pin into an internal shift register on the rising edge of each clock. An internal counter prevents more than 16 bits from being shifted into the register. The data in the shift register is latched when SDEN goes low. If less than 16 clock pulses are provided before SDEN goes low, the data transfer is aborted.

All transfers are shifted into the serial port LSB first. The first byte of the transfer is address and instruction information. The LSB of this byte is the R/W bit which determines if the transfer is a read (1) or a write (0). The remaining seven bits determine the internal register to be accessed. The second byte contains the programming data. At initial power-up, the contents of the internal registers will be in an unknown state and they must be programmed prior to operation. During power down modes, the serial port remains active and register programming data is retained.

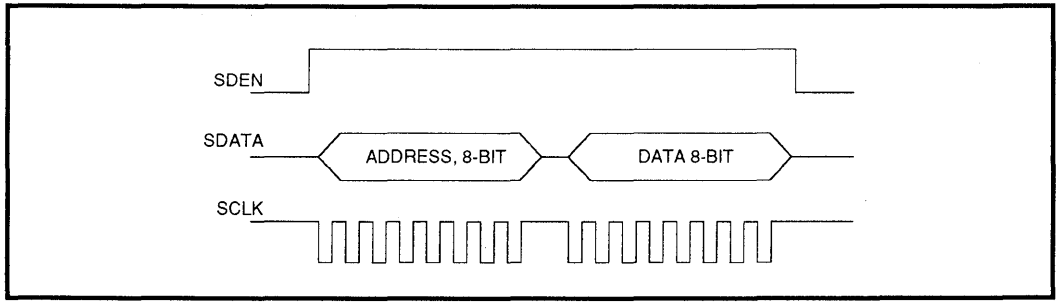

FIGURE 2: Serial Port Data Transfer Format

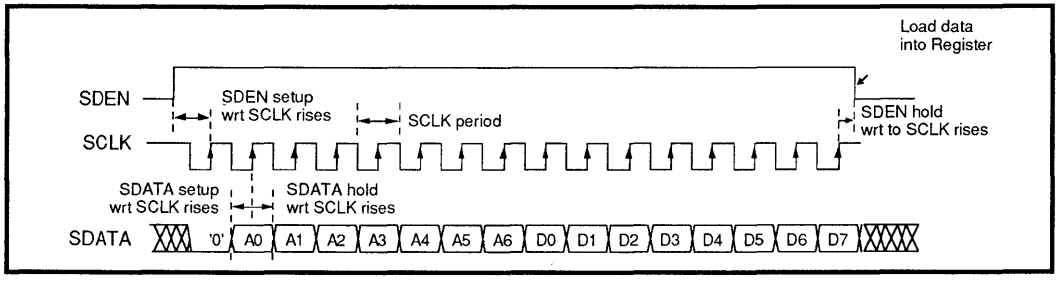

FIGURE 3: Serial Interface Timing Diagram - Writing Control Register

TABLE 2: Serial Port Register Mapping

REGISTER NAME	A6	ADDRESS					A0	R/W	D7	DATA BIT MAP						D0
POWER DOWN CONTROL	0	0	0	0	0	1	0	0	–	–	–	–	–	FILTER 1=DISABLE 0=ENABLE	–	
DATA MODE CUTOFF	0	0	0	0	0	1	1	0	*	DAC BIT 6	DAC BIT 5	DAC BIT 4	DAC BIT 3	DAC BIT 2	DAC BIT 1	DAC BIT 0
SERVO MODE CUTOFF	0	0	1	0	0	1	1	0	*	DAC BIT 6	DAC BIT 5	DAC BIT 4	DAC BIT 3	DAC BIT 2	DAC BIT 1	DAC BIT 0
FILTER BOOST, DATA	0	0	0	1	0	1	1	0	–	DAC BIT 6	DAC BIT 5	DAC BIT 4	DAC BIT 3	DAC BIT 2	DAC BIT 1	DAC BIT 0
FILTER BOOST, SERVO	0	0	1	1	0	1	1	0	–	DAC BIT 6	DAC BIT 5	DAC BIT 4	DAC BIT 3	DAC BIT 2	DAC BIT 1	DAC BIT 0

* These bits are used only for testing. They should be programmed to 0 in actual operation.

PIN DESCRIPTION

POWER SUPPLY PINS

NAME	TYPE	DESCRIPTION
VCA	-	Filter analog power supply pin
VCD	-	Serial port power supply pin
AGND	-	Filter analog ground pin
DGND	-	Serial port digital ground pin

INPUT PINS

VIN+, VIN-	I	FILTER SIGNAL INPUTS: The AGC output signals must be AC coupled into these pins.
SG	I	SERVO GATE: TTL input when high enables servo frequency and boost registers to the control DACs. When low the data frequency and boost registers are enabled.
$\overline{\text{LOWZ}}$	I	LOW_Z CONTROL: TTL input when low reduces the filter input resistance. When high, the input is at high impedance state.

OUTPUT PINS

VO_DIFF+,	O	DIFFERENTIAL DIFFERENTIATED OUTPUTS: Filter differentated VO_DIFF- outputs. These outputs are normally AC coupled.
VO_NORM+,	O	DIFFERENTIAL NORMAL OUTPUTS: Filter normal low pass output signals. VO_NORM- These outputs are normally AC coupled.
RX	-	REFERENCE RESISTOR INPUT: An external 13.3 kΩ, 1% resistor is connected from this pin to ground to establish a precise PTAT (proportional to absolute temperature) reference current for the filter.

SERIAL PORT PINS

SDEN	I/O	SERIAL DATA ENABLE: Serial enable CMOS compatible input. A high level input enables the serial port.
SDI	I/O	SERIAL DATA: Serial data CMOS compatible input. NRZ programming data for the internal registers is applied to this input.
SCLK	I/O	SERIAL CLOCK: Serial clock CMOS compatible input. The clock applied to this pin is synchronized with the data applied to SDATA.

ELECTRICAL SPECIFICATIONS

Unless otherwise specified, the recommended operating conditions are as follows: 4.5V < POSITIVE SUPPLY VOLTAGE < 5.5V, 0°C < T (ambient) < 70°C, and 25°C < T(junction) < 135°C. Currents flowing into the chip are positive. Current maximums are currents with the highest absolute value.
Rx = 13.3 kΩ, Cx = 1000 pF from Rx pin to VCA. Input signals are AC-coupled into VIN±.

ABSOLUTE MAXIMUM RATINGS

Operation beyond the maximum ratings may damage the device.

PARAMETER	RATING
Storage Temperature	-65 to 150°C
Junction Operating Temperature	+130°C
Positive Supply Voltage (Vp)	-0.5 to 7V
Voltage Applied to Logic Inputs	-0.5V to Vp + 0.5V
All other Pins	-0.5V to Vp + 0.5V

POWER SUPPLY CURRENT AND POWER DISSIPATION

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
ICC (VCA,D)	Output pins open DACF = 127 Boost = 0 dB		19	30	mA
PWR Power Dissipation	Output pins open DACF = 127 Boost = 0 dB		95	165	mW
Sleep Mode Power	PWRON = 1			5	mW

TTL COMPATIBLE INPUTS

Input low voltage	VIL		-0.3		0.8	V
Input high voltage	VIH		2		VPD +0.3	V
Input low current	IIL	VIL = 0.4V	-0.4			mA
Input high current	IIH	VIH = 2.4V			100	µA

CMOS COMPATIBLE INPUTS

Input low voltage	Vp = 5V	-0.3		1.5	V
Input high voltage	Vp = 5V	3.5		VCD +0.3	V

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ELECTRICAL SPECIFICATIONS (continued)

SERIAL PORT

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNITS
SCLK period		Read from serial port	140			ns
		Write to serial port	100			ns
SCLK low time	TCKL	Read from serial port	60			ns
		Write to serial port	40			ns
SCLK high time	TCKH	Read from serial port	60			ns
		Write to serial port	40			ns
Enable to SCLK	TSENS		35			ns
SCLK to disable	TSENH		100			ns
Data set-up time	TDS		15			ns
Data hold time	TDH		15			ns
SDATA tri-state delay	TSENDL				50	ns
SDATA turnaround time	TTRN		70			ns
SDEN low time	TSL		200			ns

PROGRAMMABLE FILTER CHARACTERISTICS

Filter cutoff range	fc @ -3 dB point fc = (0.2133 MHz) XDACF - 0.0941, Boost = 0 dB 42 ≤ DACF ≤ 127	8.9		27	MHz
Filter cutoff accuracy	DACF = 42 and 127	-15		15	%
FNP, FNN differential gain AN	f = 0.67xfc, boost = 0 dB	0.7	1.0	1.25	V/V
FDP, FDN differential gain AD	f = 0.67xfc, boost = 0 dB	0.8 AN	1.0 AN	1.2 AN	V/V
Boost accuracy	6.6 dB, DACF = 42, DACS = 37	-1.0		+1.0	dB
Boost = 20 log	7.5 dB, DACF = 127, DACS = 37	-1.0		+1.0	dB
[(0.0239 • DACB) +	9.4 dB, DACF = 42, DACS = 67	-1.25		+1.25	dB
(7.6 • 10^{-5} • DACB • DACF)	10.6 dB, DACF = 127, DACS = 67	-1.25		+1.25	dB
+ 1.132]	13.2 dB, DACF = 42, DACS = 127	1.5		+1.5	dB
	14.6 dB, DACF = 127, DACS = 127	-1.5		+1.5	dB
Data mode group delay	f = 0.2 fc to fc	-2		+2	%
variation, DACF = 42 to 127, DACS = 0 to 127	f = fc to 1.75 fc	-3		+3	%

PROGRAMMABLE FILTER CHARACTERSITICS (continued)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
Data mode group delay variation, DACS = 0 to 127	DACF = 127 f = 0.2 fc to fc	-0.5		+0.5	ns
	DACF = 42 f = 0.2 fc to fc	-1.25		+1.25	ns
	DACF = 127 f = fc to 1.75fc	-0.95		+0.95	ns
	DACF = 42 f = fc to 1.75fc	-1.9		+1.9	ns
Filter differential output dynamic range	THD = 1.5%, f = 0.67fc boost = 0 dB, normal and differentiated outputs	1			Vp-p
Filter differential input resistance	Normal	4			kΩ
	Low-Z		200	400	Ω
Filter differential input capacitance				7	pF
Output Noise Voltage: BW = 100 MHz, Rs = 50Ω					
differentiated output	fc = 27 MHz, boost = 0 dB		4.4	6.6	mV Rms
differentiated output	fc = 27 MHz, DACS = 127		7.7	11.6	mV Rms
normal output	fc = 27 MHz, boost = 0 dB		2.5	3.8	mV Rms
normal output	fc = 27 MHz, DACS = 127		3.7	5.6	mV Rms
Filter output sink current		0.5			mA
Filter output offset voltage		-200		200	mV
Filter output source current		2.0			mA
Filter output resistance	single ended			200	Ω
Rx pin voltage	Ta = 27°C		600		mV
	Ta = 127°C		800		mV
Rx resistance	1% fixed value		13.3		kΩ

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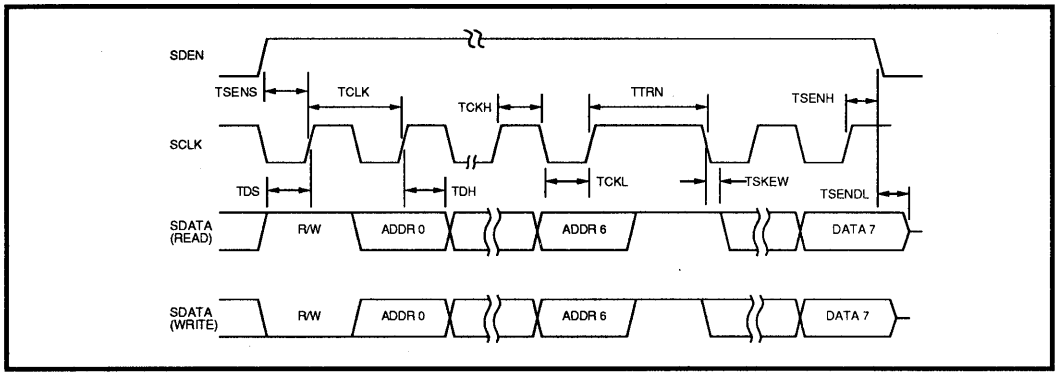
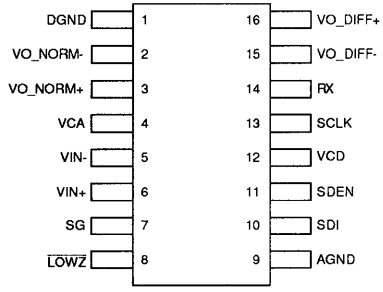


FIGURE 4: Serial Port Timing Information

PACKAGE PIN DESIGNATIONS

(Top View)



16-Lead SON

THERMAL CHARACTERISTICS: θja

16-lead SON	100° C/W

CAUTION: Use handling procedures necessary for a static sensitive component.

ORDERING INFORMATION

PART DESCRIPTION	ORDER NUMBER	PACKAGE MARK
SSI 32F8101 16-Lead SON	32F8101-CN	32F8101-CN

Preliminary Data: Indicates a product not completely released to production. The specifications are based on preliminary evaluations and are not guaranteed. Small quantities are available, and Silicon Systems should be consulted for current information.

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SSI 32F8120
Low-Power Programmable Electronic Filter

January 1994

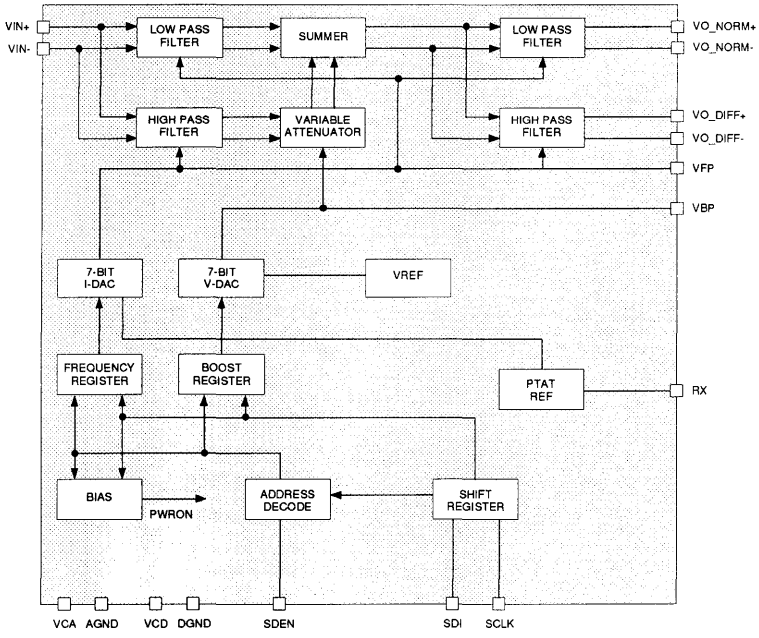
DESCRIPTION

The SSI 32F8120 is a continuous time, low pass filter with programmable bandwidth and high frequency boost. The low pass filter is a 2 zero / 7 pole 0.05° phase equiripple type, featuring excellent group delay characteristics. It features 1.5 - 8 MHz programmable bandwidth and 0-10 dB programmable boost. Both functions are controlled by 7-bit command words, which are input via a 3-line serial interface.

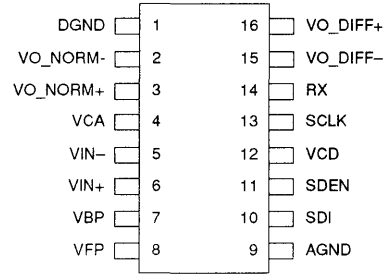
FEATURES

- **Programmable filter cutoff frequency (fc =1.5 to 8 MHz) with no external components**
- **Programmable pulse slimming equalization (0 to 10 dB boost at the filter cutoff frequency)**
- **± 10% cutoff frequency accuracy**
- **Matched normal and differentiated low-pass outputs**
- **Differential filter inputs and outputs**
- **Device Idle mode**
- **+5V only operation**
- **No external filter components required**
- **Supports constant density recording**

BLOCK DIAGRAM



PIN DIAGRAM



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CAUTION: Use handling procedures necessary for a static sensitive component.

SSI 32F8120
Low-Power Programmable Electronic Filter

FUNCTIONAL DESCRIPTION

CUTOFF FREQUENCY PROGRAMMING

The SSI 32F8120 programmable electronic filter can be set to a filter cutoff frequency from 1.5 to 8 MHz. The cutoff frequency can be set by using the serial port through pins SDI, SDEN, and SCLK. SDI is the serial data input for an 8-bit control shift register, SDEN is the control register enable, and SCLK is the control register clock. The data packet is transmitted MSB (D7) first. The first four bits are the register address, the last four are the data bits. Registers larger than four bits must be loaded with two 8-bit data packets. See Table 1.

fc is determined by the equation:

fc (MHz) = 0.061321 (F_Code) + 0.212264

1.5 MHz ≤ fc ≤ 8 MHz

21 ≤ F_ Code ≤ 127

SLIMMER HIGH FREQUENCY BOOST PROGRAMMING

The amplitude of the input signal at frequencies near the cutoff frequency can be increased using this feature. By controlling the V-DAC output, the boost can be determined. The amount of boost at the cutoff frequency is related to the V-DAC output by the following formula:

$$[\text{Output of V-DAC} = VBP = VREF \times \frac{S_Code}{127}]$$

BOOST (dB) = 20•log [0.01703 (S_Code) +1].

TABLE 1

ADDRESS BITS				USAGE	DATA BITS			
D7	D6	D5	D4		D3	D2	D1	D0
X	0	0	0	S-MSB REGISTER	X	S6	S5	S4
X	0	0	1	S-LSB REGISTER	S3	S2	S1	S0
X	0	1	0	F-MSB REGISTER	X	F6	F5	F4
X	0	1	1	F-LSB REGISTER	F3	F2	F1	F0
X	1	1	1	P REGISTER	X	X	X	P0

X = Don't Care
S = 7-bit Boost (Slimming) Control
F = 7-bit Frequency (Bandwidth) Control
P = Power Down Control; PO = 1 for power up; PO = 0 for power down

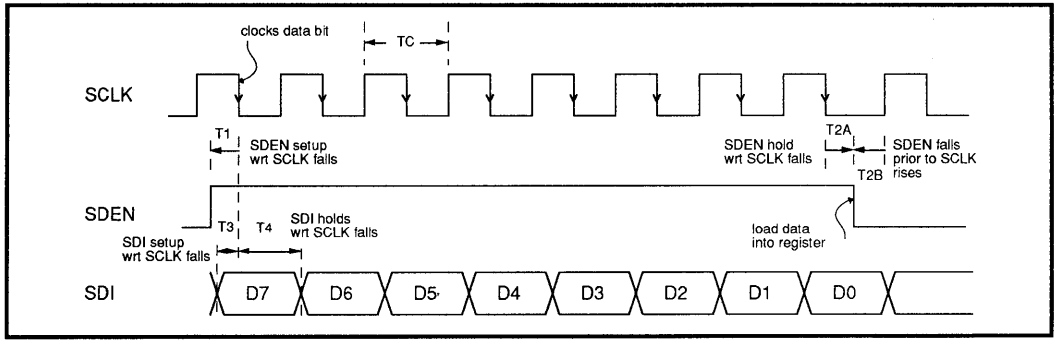

FIGURE 1: Serial Port Timing Diagram

PIN DESCRIPTION

NAME	TYPE	DESCRIPTION
VIN+, VIN–	I	DIFFERENTIAL FILTER INPUTS. The input signals must be AC coupled to these pins.
VO_NORM+, VO_NORM–	O	DIFFERENTIAL NORMAL OUTPUTS. The output signals must be AC coupled to the pulse detector.
VO_DIFF+ VO_DIFF–	O	DIFFERENTIAL DIFFERENTIATED OUTPUTS. For minimum pulse pairing, these outputs should be AC coupled to the pulse detector.
SDEN	I	SERIAL DATA ENABLE. A logic HIGH level allows SERIAL CLOCK to clock data into the control register via the SERIAL DATA input. A logic LOW level latches the register data and issues the information to the appropriate circuitry.
SCLK	I	SERIAL CLOCK. Negative edge triggered clock input for serial register.
SDI	I	SERIAL DATA INPUT.
RX	–	REFERENCE CURRENT SET. With an external resistor (Rx = 5 kΩ ±1%) to ground, this pin gives a voltage proportional to the absolute temperature, setting the range for VFP.
VCA	I	ANALOG +5 VOLT SUPPLY.
VCD	I	DIGITAL +5 VOLT SUPPLY.
AGND	I	ANALOG GROUND.
DGND	I	DIGITAL GROUND.
VBP	O	BOOST PROGRAMMING VOLTAGE. Output of V-DAC which programs the boost.
VFP	O	CUTOFF FREQUENCY PROGRAMMING VOLTAGE. Output of I-DAC which programs the cutoff frequency.*

*A minimum load resistance of 150 kΩ should be used to avoid affecting the total minimum on-chip resistance of 1.35 kΩ.

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ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Operation above maximum ratings may damage the device.

PARAMETER	RATING
Storage Temperature	-65 to +150 °C
Junction Operating Temperature, Tj	+130 °C
Supply Voltage, VCC	-0.5 to 7V
Voltage Applied to Inputs*	-0.5 to VCC V
Maximum Power Dissipation, fc = 8 MHz, Vcc = 5.5V	0.5W
T1 Lead Temperature (1/16" from case for 10 seconds)	260 °C
* Analog input signals of this magnitude shall not cause any change or degradation in filter performance after signal has returned to normal operating range.	

RECOMMENDED OPERATING CONDITIONS

Supply voltage, VCC	4.5V < VCC < 5.5V
Ambient Temperature	0 °C < Ta < 70 °C
Tj Junction Temperature	0 °C < Tj < 130 °C

ELECTRICAL CHARACTERISTICS

Unless otherwise specified recommended operating conditions apply.

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
Isupply	VCC = 5.5V, outputs unloaded		55	75	mA
Idle Mode Current			9	13	mA
Idle to Active Mode Recovery Time				50	µs
Serial port program to output response time				50	µs

DC Characteristics

VIH	High Level Input Voltage	TTL input	2.0			V
VIL	Low Level Input Voltage				0.8	V
IIH	High Level Input Current	VIH = 2.7V			20	µA
IIL	Low Level Input Current	VIL = 0.4V	−1.5			mA

Filter Characteristics

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
fc Filter Cutoff Frequency	21 ≤ F_Code ≤ 127	1.5		8	MHz
FCA Filter *fc* Accuracy	F_Code = 127	-10		+10	%
	F_Code = 21	-15		+15	%
Cutoff Resolution	1.5 to 8 MHz	100			kHz
AO VO_NORM Diff Gain	F = 0.67 *fc*	0.7		1.1	V/V
AD VO_DIFF Diff Gain	F = 0.67 *fc*	0.90 AO		1.2 AO	V/V
FB Frequency Boost at *fc*	FB(dB) = 20 log [0.01703 (S_Code) +1]	0		10	dB
FBA Frequency Boost Accuracy	0 to 10 dB, Ta < 22 °C	–1.5		+1.5	dB
FBA Frequency Boost Accuracy	0 to 10 dB, Ta > 22 °C	–1		+1	dB
TGD0 Group Delay Variation Without Boost	0.2 *fc* - *fc*	–2% gdm		+2% gdm	ns
fc = 1.5 - 8 MHz gdm = group delay magnitude	*fc* - 1.75 *fc*	–3% gdm		+3% gdm	ns
TGDB Group Delay Variation With Boost	0.2 *fc* - *fc*	–2% gdm		+2% gdm	ns
fc = 1.5 - 8 MHz	*fc* - 1.75 *fc*	–3% gdm		+3% gdm	ns
Boost Resolution	1.5 to 8 MHz	.25			dB
VOF Filter Output Dynamic Range	THD = 1.5% max, VBP = 0, VO_NORM 1000 pF capacitor across Rx F_Code = 127	1.5			Vppd
VOF Filter Output Dynamic Range	THD = 3.5% max, VBP = 0, VO_DIFF 1000 pF capacitor across Rx F_Code = 127	1.5			Vppd
VOF Filter Output Dynamic Range	THD = 1.5% max, VBP = 0, VO_NORM 1000 pF capacitor across Rx F_Code = 21	1.0			Vppd
VOF Filter Output Dynamic Range	THD = 2.0% max, VBP = 0, VO_DIFF 1000 pF capacitor across Rx F_Code = 21	1.0			Vppd

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ELECTRICAL SPECIFICATIONS (continued)

Filter Characteristics (continued)

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNIT
RIN Filter Diff Input Resistance		3.0			kΩ
CIN Filter Input Capacitance				7	pF
EOUT Output Noise Voltage (VO_NORM)	BW = 100 MHz, 0 dB Boost 50Ω input *fc* = 8 MHz 10 dB Boost		1.8 2.35	3 4	mVRms mVRms
EOUT Output Noise Voltage (VO_DIFF)	BW = 100 MHz, 0 dB Boost 50Ω input *fc* = 8 MHz 10 dB Boost		4.2 5.85	6 9	mVRms mVRms
IO- Filter Output Sink Current		1.0			mA
IO+ Filter Output Source Current		3.0			mA
RO Filter Output Resistance (Single ended)	Output source current, IO+ = 1 mA			60	Ω
TC Period, SCLK		100			ns
T1 SDEN Setup to SCLK Falls		10		TC/2-10	ns
T2A SDEN Hold wrt SCLK Falls		10		TC/4	ns
T2B SDEN Falls prior to SCLK Rises		25			ns
T3 SDI Setup to SCLK Falls		25			ns
T4 SDI Hold to SCLK Falls		25			ns
Power Supply Rejection Ratio	100 mVpp @ 5 MHz on VCA, VCD	40	70		dB
Common Mode Rejection Ratio	Vin = 0 VDC + 100 mVpp @5 MHz	30	50		dB
Bias: Vin+, Vin-	VCC = 5V	2.5	2.9	3.3	V
VO_NORM+, VO_NORM–	VCC = 5V	2.8	3.2	3.6	V
VO_DIFF+, VO_DIFF-	VCC = 5V	2.8	3.2	3.6	V
Output offset Normal and Differentiated		-150		+150	mV

TABLE 2: Calculations

Typical change in f-3 dB point with boost

Boost (dB)	Gain@fc (dB)	Gain@ peak (dB)	$f$peak/fc	f-3dB/fc	K
0	-3	0.00	no peak	1.00	0
1	-2	0.00	no peak	1.21	0.16
2	-1	0.00	no peak	1.51	0.34
3	0	0.15	0.70	1.80	0.54
4	1	0.99	1.05	2.04	0.77
5	2	2.15	1.23	2.20	1.03
6	3	3.41	1.33	2.33	1.31
7	4	4.68	1.38	2.43	1.63
8	5	5.94	1.43	2.51	1.97
9	6	7.18	1.46	2.59	2.40
10	7	8.40	1.48	2.66	2.85

Notes: 1. fc is the original programmed cutoff frequency with no boost

2. f-3 dB is the new -3 dB value with boost implemented

3. $f$peak is the frequency where the amplitude reaches its maximum value with boost implemented

i.e., fc = 2 MHz when boost = 0 dB

if boost is programmed to 5 dB then f-3 dB = 4.40 MHz

$f$peak = 2.46 MHz

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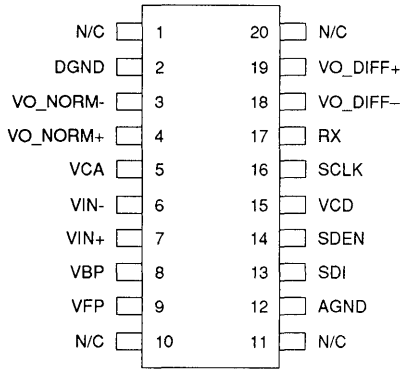
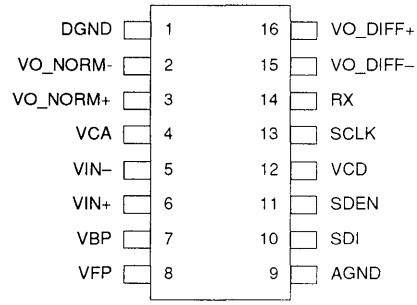
SSI 32F8120
Low-Power Programmable Electronic Filter

PACKAGE PIN DESIGNATIONS
(Top View)



20-Lead SOV



16-Lead SOL

THERMAL CHARACTERISTICS: θja

16-lead SOL	100° C/W
20-lead SOV	125° C/W

CAUTION: Use handling procedures necessary for a static sensitive component.

ORDERING INFORMATION

PART DESCRIPTION		ORDER NUMBER	PACKAGE MARK
SSI 32F8120	16-Lead SOL	32F8120-CL	32F8120-CL
	20-Lead SOV	32F8120-CV	32F8120-CV

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SSI 32F8130/8131
Low-Power Programmable Electronic Filter

January 1995

DESCRIPTION

The SSI 32F8130/8131 Programmable Electronic Filters are digitally controlled low pass filters with a normal low pass output and a time differentiated low pass output. The low pass filter is of a 7-pole / 2-zero 0.05° phase equiripple type, with flat group delay response beyond the passband.

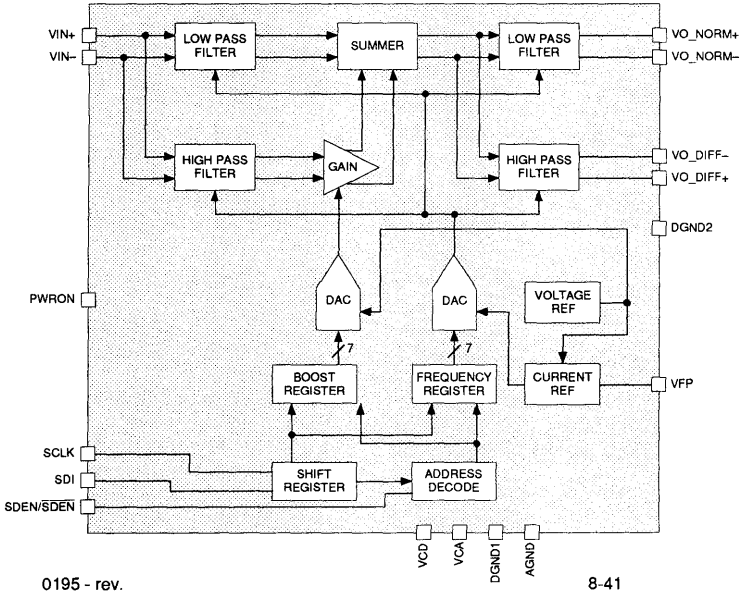
The SSI 32F8130/8131 bandwidth and boost are controlled by two on-chip 7-bit DACs, which are programmed via a 3-line serial interface. The SSI 32F8130 filter bandwidth is programmable from 285 kHz to 2.2 MHz. The SSI 32F8131 is programmable from 150 kHz to 1.4 MHz. The boost is programmable from 0 to 10 dB. Because the boost function is implemented as two zeros on the real axis with opposite sign, the flat group delay characteristic is not affected by the boost programming.

The SSI 32F8130/8131 are ideal for multi-rate, equalization applications. They require only a +5V supply and have a power down mode for minimal idle dissipation. The SSI 32F8130/8131 is available in a 16-lead SOL package.

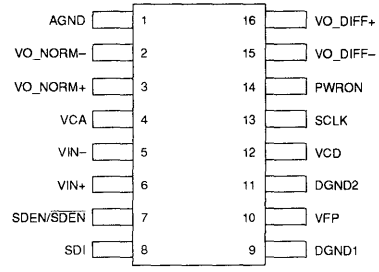
FEATURES

- **Programmable filter cutoff frequency (SSI 32F8130: fc = 0.285 to 2.2 MHz, SSI 32F8131: fc = 0.15 to 1.4 MHz) with no external components, serial data connections to minimize pin count**
- **Power down mode (<5 mW)**
- **Programmable pulse slimming equalization (0 to 10 dB boost at the filter cutoff frequency)**
- **Matched normal and differentiated low-pass outputs**
- **Differential filter inputs and outputs**
- **Programming via internal 7-bit DACs**
- **No external filter components required**
- **+5V only operation**
- **Supports constant density recording**

BLOCK DIAGRAM



PIN DIAGRAM



16-Lead SOL

SSI 32F8130: Lead 7 = SDEN
SSI 32F8131: Lead 7 = $\overline{\text{SDEN}}$

CAUTION: Use handling procedures necessary for a static sensitive component.

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SSI 32F8130/8131
Low-Power Programmable Electronic Filter

FUNCTIONAL DESCRIPTION

The SSI 32F8130/8131, a high performance programmable electronic filter, provides a 7-pole / 2-zero 0.05° equiripple linear phase low pass function with matched normal and time differentiated outputs. The device includes multiple biquads and first-order sections to accomplish the filter function, two 7-bit DACs for bandwidth and boost controls, a 3-line serial interface, and complete bias reference circuits. Only one external precision 8.25 kΩ resistor should be connected from the VFP pin to ground for operation. See Figure 1.

SERIAL INTERFACE

The SSI 32F8130/8131 allows easy digital controls of filter bandwidth and magnitude equalization via a 3-line serial interface. The three pins are SDI, SDEN and SCLK. SDI is the serial data input to an internal 8-bit shift register. SDEN is the shift register enable. SCLK is the shift register clock. Besides the 8-bit shift register which accepts data from the SDI input, there are four 4-bit registers which hold the filter bandwidth and boost controls. Two 4-bit registers are assigned to each control function, because a 7-bit binary control is required for each function.

The S-MSB register, whose address code is X000, holds the 3 MSBs of the boost control. The S-LSB register, whose address code is X001, holds the 4 LSBs of the boost control. The F-MSB register, whose address code is X010, holds the 4 MSBs of the cutoff frequency control. The F-LSB register, whose address code is X011, holds the 4 LSBs of the cutoff frequency control.

The serial interface consists of data packets, which are structured as 4-bit address decode followed by 4-bit data. Figure 2 shows the serial interface timing to successfully program the SSI 32F8130/8131.

CUTOFF FREQUENCY PROGRAMMING

The cutoff frequency, fc, is defined as the -3 dB bandwidth with no magnitude equalization applied, and is programmable from 285 kHz to 2.2 MHz for SSI 32F8130, and 150 kHz to 1.4 MHz for SSI 32F8131. While the fc is controlled by an on-chip 7-bit DAC, the cutoff frequency resolution is better than 20-kHz step.

Let F_Code be the decimal equivalent of the 7-bit control. The cutoff frequency can be determined by the following equations:

SSI 32F8130 fc (kHz) = 16.73 • F_Code + 84

SSI 32F8131 fc (kHz) = 10.81 • F_Code + 37

where $12 \leq F_Code \leq 127$.

MAGNITUDE EQUALIZATION PROGRAMMING

The magnitude equalization, measured in dB, is the amount of high frequency peaking at the cutoff frequency relative to the original -3 dB point. For example, when 10 dB boost is applied, the magnitude response peaks up 7 dB above the DC gain. This equalization function is also controlled by an on-chip 7-bit DAC.

Let S_Code be the decimal equivalent of the 7-bit control. The magnitude equalization can be determined by the equation:

Boost (dB) = $20 \cdot \log_{10} [0.0145 \cdot S_Code + 1]$ for 32F8130

Boost (dB) = $20 \cdot \log_{10} [0.01703 \cdot S_Code + 1]$ for 32F8131

where $0 \leq S_Code \leq 127$.

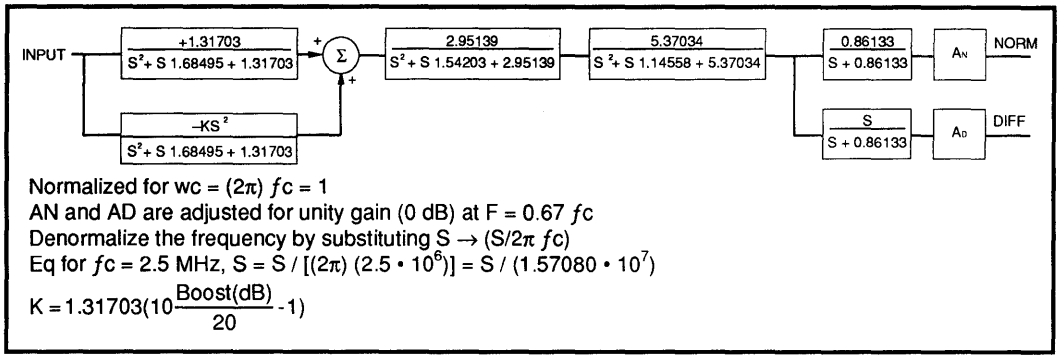

FIGURE 1: Normalized Transfer Function of the SSI 32F8130/8131

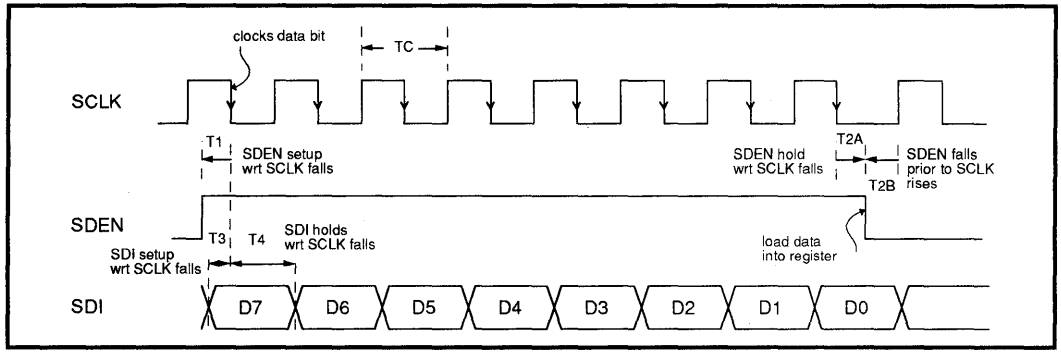

FIGURE 2: Serial Port Timing Relationship

Note:
The serial data enable function of the SSI 32F8130 and that of the SSI 32F8131 are of opposite polarity.

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TABLE 1: Data Packet Fields

	ADDRESS BITS				USAGE	DATA BITS			
	D7	D6	D5	D4		D3	D2	D1	D0
R0	X	0	0	0	S - MSB REGISTER	X	S6	S5	S4
R1	X	0	0	1	S - LSB REGISTER	S3	S2	S1	S0
R2	X	0	1	0	F - MSB REGISTER	X	F6	F5	F4
R3	X	0	1	1	F - LSB REGISTER	F3	F2	F1	F0

X = Don't care bit.

PIN DESCRIPTION

NAME	DESCRIPTION
VIN+, VIN–	DIFFERENTIAL FILTER INPUTS. The input signals must be AC coupled to these pins.
VO_NORM+, VO_NORM–	DIFFERENTIAL NORMAL OUTPUTS. The output signals must be AC coupled to the load.
VO_DIFF+ VO_DIFF–	DIFFERENTIAL DIFFERENTIATED OUTPUTS. These outputs should be AC coupled to the load.
PWR_ON	POWER ON. A TTL high logic level enables the chip. A low level or open circuit puts the chip into a low power state.
$\overline{\text{SDEN}}$ (8130) SDEN (8131)	SERIAL DATA ENABLE. An active level allows SCLK to clock data into the shift register via the SDI input. An inactive level latches the register data and issues the information to the appropriate circuitry. Active level for SSI 32F8130 is HIGH, for SSI 32F8131 is LOW.
SCLK	SERIAL CLOCK. Negative edge triggered clock input for serial register.
SDI	SERIAL DATA INPUT.
VCA	ANALOG +5 VOLT SUPPLY.
VCD	DIGITAL +5 VOLT SUPPLY.
AGND	ANALOG GROUND.
DGND1 DGND2	DIGITAL GROUND.
VFP	CUTOFF FREQUENCY PROGRAMMING REFERENCE. A resistor of 8.25 kΩ should be connected between this pin and AGND.

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Operation above maximum ratings may permanently damage the device.

PARAMETER	RATING
Storage Temperature	-65 to +150°C
Junction Operating Temperature, Tj	+130°C
Supply Voltage, VCC	-0.5 to 7V
Voltage Applied to Inputs*	-0.5 to VCCV
T1 Lead Temperature (1/16" from case for 10 seconds)	260°C

* Analog input signals of this magnitude shall not cause any change or degradation in filter performance after signal has returned to normal operating range.

RECOMMENDED OPERATING CONDITIONS

PARAMETER	RATING
Supply voltage, VCC	4.50 < VCC < 5.50V
Ambient Temperature	0 < Ta < 70°C
Tj Junction Temperature	0 < Tj < 130°C

ELECTRICAL CHARACTERISTICS

Unless otherwise specified recommended operating conditions apply. F_Code = 64, S_Code = 0.

PARAMETER		CONDITIONS		MIN	NOM	MAX	UNIT
Idle Mode Current						1	mA
Isupply					60	70	mA
Power Dissipation		PWR_ON ≤ 0.8V				6	mW
		PWR_ON ≥ 2.0V			303	385	mW
Idle to Active Mode Recovery Time						50	µs
Serial port program to output response time						50	µs
DC Characteristics							
VIH	High Level Input Voltage	TTL input		2			V
VIL	Low Level Input Voltage					0.8	V
IIH	High Level Input Current	VIH = 2.7V				25	µA
IIL	Low Level Input Current	VIL = 0.4V		-1.5			mA
Filter Characteristics							
fc	Filter Cutoff Frequency	12 < F_Code < 127					
		SSI 32F8130		0.285		2.2	MHz
		SSI 32F8131		0.15		1.4	MHz
FCA	Filter *fc* Accuracy	over *fc* range	32F8130	-12		+12	%
			32F8131	-10		+10	%
Cutoff Resolution		$\text{Resolution}=\frac{\text{Max fc}}{127}$	32F8130		17		kHz
			32F8131		11		kHz
AO	VO_NORM Diff Gain	F = 0.67 *fc*	32F8130	0.7		1.1	V/V
			32F8131	0.8		1.2	V/V
AD	VO_DIFF Diff Gain	F = 0.67*fc*	32F8130	0.8 AO		1.15 AO	V/V
			32F8131	1.0 AO		1.2 AO	V/V
FB	Frequency Boost at *fc* (32F8130)	FB(dB) = 20 log [0.0145 • S_Code + 1] 0 ≤ S_Code ≤ 127		0		9	dB
	(32F8131)	FB(dB) = 20 log [0.0173 • S_Code + 1] 0 ≤ S_Code ≤ 127		0		10	dB
FBA	Frequency Boost Accuracy	S_Code = 127		-1.5		+1.5	dB
TGD0	Group Delay Variation Without Boost	0.2 *fc* to *fc*	32F8130	-2.5		+2.5	%
			32F8131	-2		+2	%
		fc to 1.75 *fc*		-3		+3	%
TGDB	Group Delay Variation With Boost	0.2 *fc* to *fc*	32F8130	-2.5		+2.5	%
			32F8131	-2		+2	%
		fc to 1.75 *fc*		-3		+3	%
Boost Resolution				0.25			dB
VOF_N	Filter Output Dynamic Range	THD = 1% max, Normal Output		1			Vp-p

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ELECTRICAL CHARACTERISTICS (continued)
Unless otherwise specified recommended operating conditions apply. F_Code = 64, S_Code = 0.

PARAMETER	CONDITIONS		MIN	NOM	MAX	UNIT
Filter Characteristics (continued)						
VOF_D Filter Output Dynamic Range	THD = 1% max, Differentiated Output		1			Vp-p
RIN Filter Diff Input Resistance			3.0	4.0	5.0	kΩ
CIN Filter Input Capacitance				3.0		pF
EOUT Output Noise Voltage (VO_NORM)	BW = 100 MHz, 50Ω input	0 dB Boost		1.2	1.9	mVRms
	fc = Max fc	max Boost		1.4	2.0	mVRms
EOUT Output Noise Voltage (VO_DIFF)	BW = 100 MHz, 50Ω input	0 dB Boost		2.1	2.7	mVRms
	fc = Max fc	max Boost		2.5	3.4	mVRms
IO– Filter Output Sink Current			1.0			mA
IO+ Filter Output Source Current			3.0			mA
RO Filter Output Resistance (Single ended)	Output source current, IO+ = 1 mA			50	70	Ω
T1 SDEN Set-up WRT SCLK Falls			10		TC/2-10	ns
T2A SDEN Hold WRT SCLK Falls			10		TC/4	ns
T2B SDEN Falls (rises for 8131) prior to SCLK rises			25			ns
T3 SDI Set-up WRT SCLK Falls			25			ns
T4 SDI Hold WRT SCLK Falls			25			ns
SCLK Period, TC			100			ns
Power Supply Rejection Ratio VO_NORM	100 mVp-p from 10 kHz to 10 MHz on VCA, VCD		30	40		dB
Power Supply Rejection Ratio VO_DIFF			20	30		dB
Common Mode Rejection Ratio VO_NORM	Vin = 0VDC + 10 mVp-p from 10 kHz to 10 MHz		30	40		dB
Common Mode Rejection Ratio VO_DIFF			20	30		dB
Bias: VO_NORM±	VCC = 5V		2.40	2.75	3.10	V
Vin±			2.20	2.35	2.80	V
VO_DIFF±			2.40	2.75	3.10	V
Normal Output Offset Variation	F_Code switched from 12-127		-200		200	mV
Differentiated Output Offset Variation	F_Code switched from 12-127		-200		200	mV

TABLE 1: Calculations (Typical change in f-3 dB point with boost)

Boost (dB)	Gain@fc (dB)	Gain@ peak (dB)	$f$peak/fc	f-3dB/fc	K
0	-3	0.00	no peak	1.00	0
1	-2	0.00	no peak	1.21	0.16
2	-1	0.00	no peak	1.51	0.34
3	0	0.15	0.70	1.80	0.54
4	1	0.99	1.05	2.04	0.77
5	2	2.15	1.23	2.20	1.03
6	3	3.41	1.33	2.33	1.31
7	4	4.68	1.38	2.43	1.63
8	5	5.94	1.43	2.51	1.97
9	6	7.18	1.46	2.59	2.40
10	7	8.40	1.48	2.66	2.85

Notes: 1. fc is the original programmed cutoff frequency with no boost

2. f-3 dB is the new -3 dB value with boost implemented

3. $f$peak is the frequency where the amplitude reaches its maximum value with boost implemented

i.e., fc = 1 MHz when boost = 0 dB

if boost is programmed to 5 dB then f-3 dB = 2.20 MHz

$f$peak = 1.23 MHz

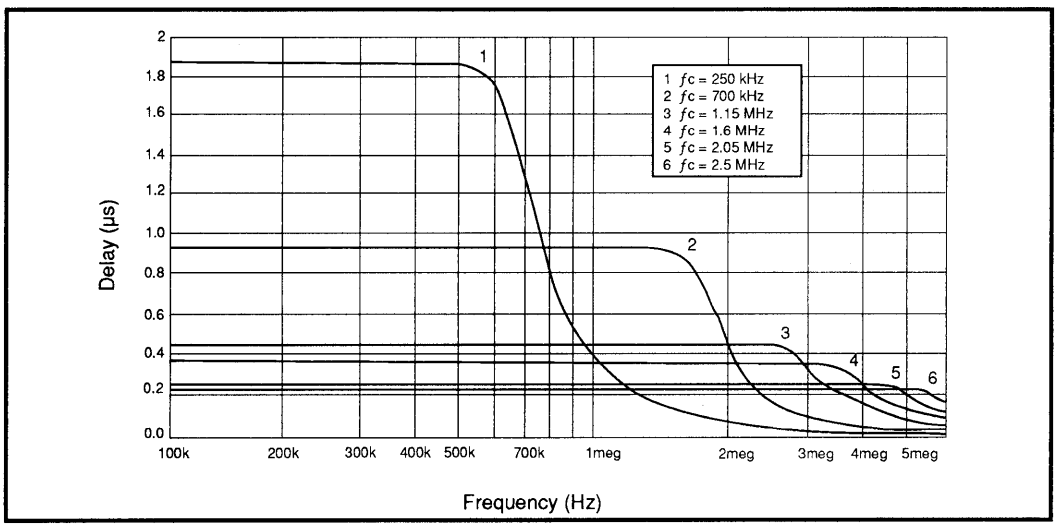

FIGURE 3: Typical Normal/Differentiated Output Group Delay Response

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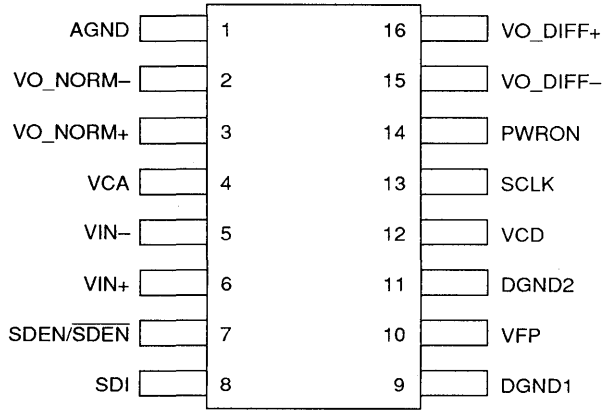
SSI 32F8130/8131
Low-Power Programmable Electronic Filter

PACKAGE PIN DESIGNATIONS
(Top View)

THERMAL CHARACTERISTICS: θjA

16-Lead SOL	100° C/W



16-Lead SOL

SSI 32F8130: Lead 7 = $\overline{SDEN}$
SSI 32F8131: Lead 7 = $\overline{SDEN}$

CAUTION: Use handling procedures necessary for a static sensitive component.

ORDERING INFORMATION

PART DESCRIPTION	ORDER NO.	PKG. MARK
SSI 32F8130 16-Lead SOL	32F8130-CL	32F8130-CL
SSI 32F8131 16-Lead SOL	32F8131-CL	32F8131-CL

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SSI 32F8144
Programmable Electronic Filter

January 1994

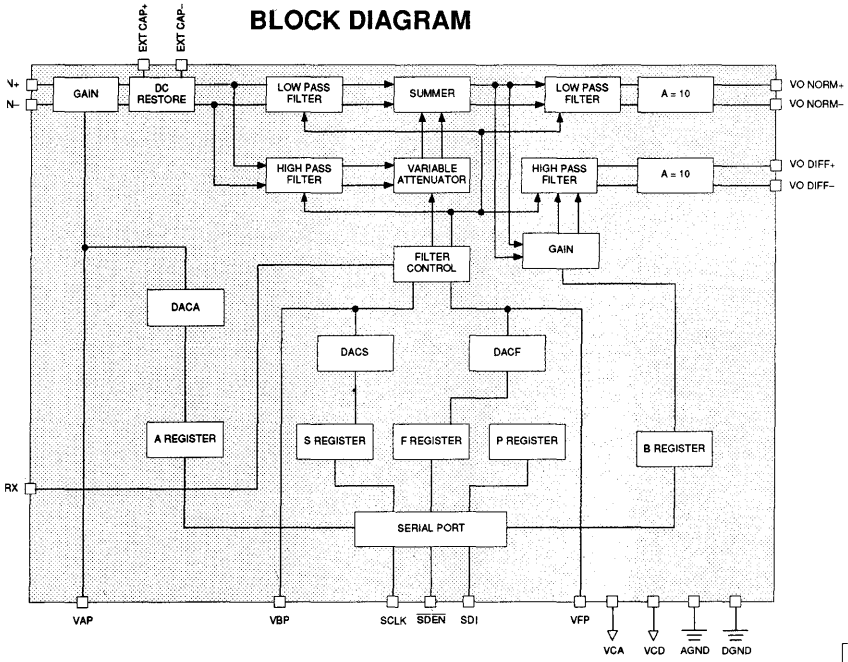
DESCRIPTION

This custom integrated circuit incorporates a pulse equalizer of variable equalization and variable bandwidth with a transfer function of a 2 zero/7 pole linear phase filter, as well as variable gain stages controlled by DACs. Equalization, gain and bandwidth changes are user-programmable via three serial lines to a microprocessor. The equalizer is totally contained and calibrating. It is realized in a high speed fully differential mode. A seven pole linear phase equiripple ± 0.05 degree filter forms the low-pass function. The cutoff frequency of the low-pass section is programmed via a 7-bit serial shift register and can be programmed from 7 to 27 MHz. Pulse slimming equalization uses two programmable magnitude, opposite sign zeroes on the real axis. Pulse slimming boost is from 0 to 9.5 dB at the filter cutoff frequency using a 7 bit serial shift register. Gain can be programmed from 10 V/V to 100 V/V for normal outputs and from 10 V/V to 50 V/V for differentiated outputs.

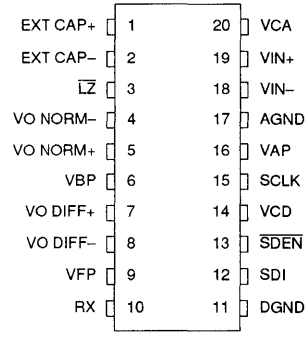
FEATURES

- **Programmable filter cutoff frequency (7 MHz ≤ *fc* ≤ 27 MHz) with no external components**
- **± 10% cutoff frequency accuracy**
- **Programmable pulse slimming equalization (0 to 9.5 dB boost at the filter cutoff frequency)**
- **Matched delay normal and differentiated low-pass outputs**
- **Differential filter inputs and outputs**
- **Device idle mode (45 mW nom.)**
- **+5V only operation**
- **Supports constant density recording**
- **Input stage gain control with DAC**
- **Relative gain between normal and differentiated outputs controlled with serial port**

BLOCK DIAGRAM



PIN DIAGRAM



20-lead SOL

8

CAUTION: Use handling procedures necessary for a static sensitive component.

SSI 32F8144
Programmable
Electronic Filter

FUNCTIONAL DESCRIPTION

The SSI 32F8144, a high performance programmable electronic filter, provides a low pass equiripple type seven pole filter with matched normal and differentiated outputs with variable gain using DACs.

The SSI 32F8144 has seven control registers: A, B, S1, S2, F1, F2 and P registers. Register A contains four bits, B is three bits, and P is one bit. S1, S2, F1, and F2 contain seven bits. Register A controls the gain of the input stage and register B controls the gain between the normal and differentiated outputs. Since the F, S registers contain 7 bits, they require two data packets which must be loaded sequentially. S1-2 registers are for high frequency boost. F1-2 registers are for cutoff frequency control. The P register is for power down command. The structure and command of each register are described as follows.

Data is loaded serially with MSB first. Each data packet contains 8 bits. The first four bits (D7 - D4) are designated as address bits with D7 always a "don't care." The last four bits (D3 - D0) are the data bits (see Table 1).

The registers are loaded by using the serial port through the SDI, $\overline{\text{SDEN}}$ and SCLK pins. The SDI pin is the serial bit input. The $\overline{\text{SDEN}}$ pin is the control register enable. The SCLK is the control register clock. The packet is transmitted MSB (D7) first.

GAIN PROGRAMMING

The input gain stage is programmed with register A (Register 4, R4). The A_Code programs this gain as follows:

$$Av\,(V/V) = 10 \cdot \frac{A_Code}{15}$$

$$1 \le A_Code \le 15$$

This input gain stage is DC coupled to the filter core through DC restore circuitry. A large capacitor (1 µF) is placed between pins EXT_CAP+ and EXT_CAP- to null the input offset to the filter. Register B (Register 5, R5) controls the relative gain between the normal and differentiated outputs. There are three discrete options which are listed as follows:

AN/AD = 1.0 B_Code = 3 (B2 = 0, B1 = 1, B0 = 1)
A_Code = 1

AN/AD = 1.5 B_Code = 5 (B2 = 1, B1 = 0, B0 = 1)
A_Code = 7

AN/AD = 2.0 B_Code = 6 (B2 = 1, B1 = 1, B0 = 0)
A_Code = 15 (B3 is a "don't care")

CUTOFF FREQUENCY PROGRAMMING

The filter cutoff frequency can be set from 7 to 27 MHz. The 7-bit F_Code programs the cutoff frequency as follows:

$$fc(MHz) = 27 \cdot \frac{F_Code}{127} \qquad 33 \le F_Code \le 127$$

SLIMMER HIGH FREQUENCY BOOST PROGRAMMING

The amplitude of the input signal at frequencies near the cutoff frequency can be increased using this feature. By controlling the DACS output, the boost can be determined. The amount of boost at the cutoff frequency is related to the DACS output by the following formula:

BOOST (dB) = 20 • log [0.01563(S_Code) +1].

The 7-bit S_Code is loaded into S1 and S2 registers (registers 0 and 1 - R0, R1).

POWER-DOWN CONTROL

The D0 bit of the P register (register 7, R7) determies the power up/down state of the SSI 32F8144. Upon initial power up, the D0 bit of the P register should be initialized to "1" for normal operation. D3 - D1 are "don't care."

By programming D0 to "0," the SSI 32F8144 is switched into a power-down state, dissipating minimum idle power. The filter is switched off. The serial port remains active awaiting the next command.

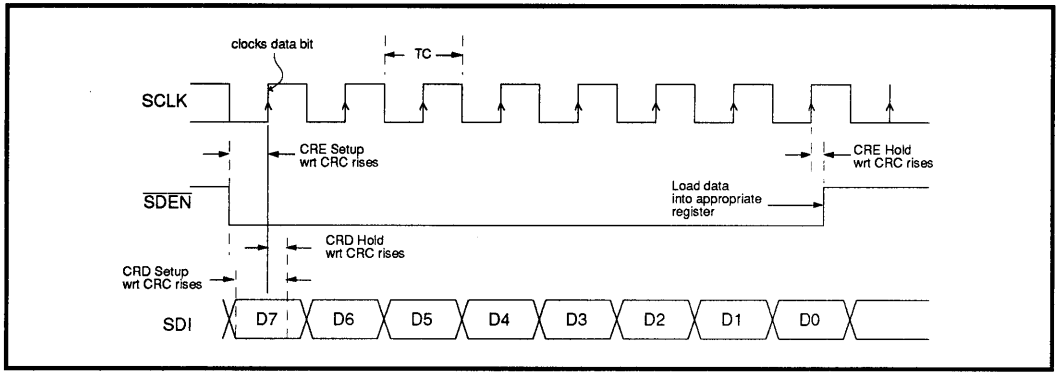


FIGURE 1: Serial Port Timing Relationship

TABLE 1: Control Register Assignment

ADDRESS BITS					USAGE	DATA BITS			
	D7	D6	D5	D4		D3	D2	D1	D0
R0	X	0	0	0	S1 REGISTER	X	S6	S5	S4
R1	X	0	0	1	S2 REGISTER	S3	S2	S1	S0
R2	X	0	1	0	F1 REGISTER	X	F6	F5	F4
R3	X	0	1	1	F2 REGISTER	F3	F2	F1	F0
R4	X	1	0	0	A REGISTER	A3	A2	A1	A0
R5	X	1	0	1	B REGISTER	X	B2	B1	B0
R7	X	1	1	1	P REGISTER	X	X	X	P0

X = Don't Care
S = Boost (Slimming) Control
F = Frequency (Bandwidth) Control
A = Gain Setting (0-10)
B = Gain of VO_DIFF relative to the gain of VO_NORM
P = Sleep Mode Control (P0 = 1, On Mode; P0 = 0, Sleep Mode)

SDI is the serial data input for an 8-bit control shift register. The data packet is transmitted Most Significant Bit (D7) first. The first four bits are the register address, the last four are the data bits. Registers larger than four bits must be loaded with two 8-bit data packets. These packets should be loaded sequentially.

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PIN DESCRIPTION

NAME	DESCRIPTION
VIN+, VIN-	DIFFERENTIAL SIGNAL INPUTS
VO_NORM+, VO_NORM-	DIFFERENTIAL NORMAL OUTPUTS
VO_DIFF+ VO_DIFF-	DIFFERENTIAL DIFFERENTIATED OUTPUTS
$\overline{SDEN}$	CONTROL REGISTER ENABLE. A logic LOW level allows CONTROL REGISTER CLOCK to clock data into the control register via the CONTROL REGISTER DATA input. A logic HIGH level latches the register data and issues the information to the appropriate circuitry. This is a TTL input.
SCLK	CONTROL REGISTER CLOCK. Positive edge triggered clock input for serial register. This is a TTL input.
SDI	CONTROL REGISTER DATA. This is a TTL input (see Figure 1).
RX	CURRENT SET RESISTOR. This external resistor to ground provides a reference current. (RX = 5 kΩ ±1%) A 1000 pF capacitor must be connected in parallel with Rx.
VCA	ANALOG +5V SUPPLY.
VCD	DIGITAL +5V SUPPLY.
AGND	ANALOG GROUND.
DGND	DIGITAL GROUND.
VAP	ANALOG TO DIGITAL TEST VOLTAGE. This is an analog voltage that is proportional to the setting on the digital output on the A/D convertor. This is a test pin related to the variable gain.
VBP	BOOST PROGRAMMING VOLTAGE. A voltage that is related to the boost. A test pin.
VFP	CUTOFF FREQUENCY PROGRAMMING VOLTAGE. A voltage that is related to the cutoff frequency. A test pin.
EXT CAP+ EXT CAP-	EXTERNAL CAPACITOR. These pins are available for an external capacitor which is used in a feedback network to null the input offset. $C_{EXT} \geq 0.47\ \mu F$, 1.0 μF nominal.
$\overline{LZ}$	LOW IMPEDANCE. This is a control signal which causes the input impedance of the filter to be low when this pin is low. The impedance is high if the pin is open or in the high state. This is a TTL input.

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Operation above maximum ratings may damage the device.

PARAMETER	RATINGS
Storage Temperature	-65 to +150°C
Junction Operating Temperature, Tj	+130°C
Supply Voltage, VCC	-0.5 to 7V
Voltage Applied to Inputs*	-0.5 to VCCV
Maximum Power Dissipation, fc = 27 MHz, Vcc = 5.5V	.55W
T1 Lead Temperature (1/16" from case for 10 seconds)	260°C

* Analog input signals of this magnitude shall not cause any change or degradation in filter performance after signal has returned to normal operating range.

RECOMMENDED OPERATING CONDITIONS

Supply voltage, VCC	4.50 < VCC < 5.50	V
Ambient Temperature	0 < Ta < 70	°C
Tj Junction Temperature	0 < Tj < 130	°C

ELECTRICAL CHARACTERISTICS

Unless otherwise specified recommended operating conditions apply.

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
Idle Mode Current	P0 = "0"		11	15	mA
Supply Current	Vcc = 5.5V		85	100	mA
PD Power Dissipation	P0 = "0"		45	71.5	mW
	P0 = "1"		400	550	mW
Idle to Active Mode Recovery Time				50	µs
Serial port program to output response time				50	µs
DC Characteristics					
VIH High Level Input Voltage	TTL input	2.0			V
VIL Low Level Input Voltage				0.8	V
IIH High Level Input Current	VIH = 2.7V			20	µA
IIL Low Level Input Current	VIL = 0.4V			-1.5	mA
Filter Characteristics					
fc Filter Cutoff Frequency	33 ≤ F_Code ≤ 127	7		27	MHz

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ELECTRICAL CHARACTERISTICS (continued)
Unless otherwise specified recommended operating conditions apply.

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNITS
FCA	Filter *fc* Accuracy	Over full *fc* range, 33 ≤ F_Code ≤ 127	-10		10	%
AO	VO_NORM Diff Gain (Note)	F = 0.67 *fc*	10		100	V/V
AD	VO_DIFF Diff Gain (Note)	F = 0.67 *fc*, set with serial port	10		50	V/V
VO_NORM Gain Tolerance		AO = 100	-15		15	%
VO_DIFF Gain Tolerance		AD = 50	-15		15	%
FB	Frequency Boost at *fc*	FB(dB) = 20 log [.01563 (S_Code) +1]	0		9.5	dB
FBA	Frequency Boost Accuracy	0 to 9.5 dB	–1.25		+1.25	dB
TGD0	Group Delay Variation Without Boost	0.2 *fc* - *fc*	–2% gdm		+2% gdm	ns
	gdm = group delay magnitude	*fc* - 1.75 *fc*	–3% gdm		+3% gdm	ns
TGDB	Group Delay Variation With Boost	0.2 *fc* - *fc*	–2% gdm		+2% gdm	ns
		fc - 1.75 *fc*	–3% gdm		+3% gdm	ns
VOF	Filter Output Dynamic Range	Vo_NORM, THD = 1.5%	1			Vpp
		Vo_DIFF, THD = 2.0%	1			Vpp
		Vo_NORM, THD = 2.0%	1.5			Vpp
		Vo_DIFF, THD = 3.0%	1.5			Vpp
RIN	Filter Diff Input Resistance		3.0	3.5	4.0	kΩ
CIN	Filter Input Capacitance				7	pF
EOUT	Output Noise Voltage (VO_NORM)	BW = 100 MHz, 0 dB Boost, 50Ω input		2.5	4.0	mV rms
		fc = 27 MHz 9.5 dB Boost		3.7	10	mV rms
EOUT	Output Noise Voltage (VO_DIFF)	BW = 100 MHz, 0 dB Boost, 50Ω input		4.4	6	mV rms
		fc = 27 MHz 9.5 dB Boost		7.8	14	mV rms
IO–	Filter Output Sink Current		1.0			mA
IO+	Filter Output Source Current		3.0			mA
RO	Filter Output Resistance (Single ended)	IO+ = 1 mA		30	50	Ω
$\overline{\text{SCLK}}$ Period, TC			100			ns
$\overline{\text{SDEN}}$ Set-up WRT $\overline{\text{SCLK}}$ Rising Edge			10		25	ns
$\overline{\text{SDEN}}$ Hold WRT $\overline{\text{SCLK}}$ Rising Edge			5		TC/2-10	ns

Note: The overall gain of VO_DIFF with respect to VIN is 10 to 50 V/V. Additionally, the gain of VO_NORM with respect to VO_DIFF will be adjustable and have gain values of 1.0, 1.5 and 2.0.

ELECTRICAL CHARACTERISTICS (continued)
Unless otherwise specified recommended operating conditions apply.

PARAMETER	CONDITIONS	MIN	NOM	MAX	UNITS
$\overline{SDEN}$ Rises Prior to $\overline{SCLK}$ Falls		15			ns
SDI Set-up WRT $\overline{SCLK}$ Rising Edge		15			ns
SDI Hold WRT $\overline{SCLK}$ Rising Edge		15			ns
Power Supply Rejection Ratio	100 mVpp in VCA, VCD from 100 kHz to 10 MHz	45	70		dB
Common Mode Rejection Ratio	VIN = 0 VDC + 100 mVpp from 100 kHz to 10 MHz	40	65		dB
DC Bias: VO_NORM+, VO_NORM- VO_DIFF+, VO_DIFF-	VCC = 5V, single ended	2.05	2.55	3.05	V
Vin+, Vin-		2.5	3.0	3.5	V
Delay mismatch normal and differentiated outputs				1	ns

TABLE 2: Calculations

Typical change in f-3 dB point with boost

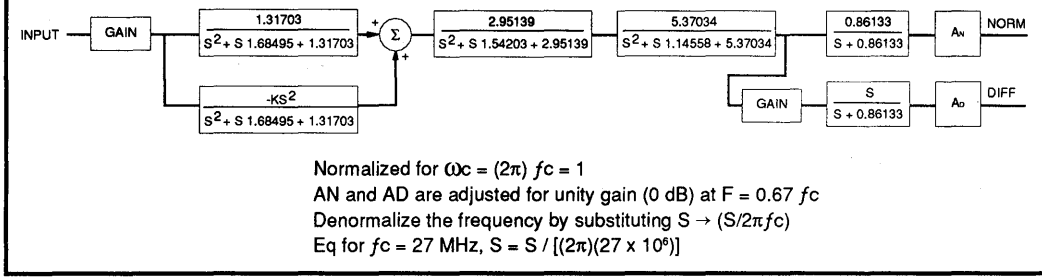
Boost (dB)	Gain@fc (dB)	Gain@ peak (dB)	$f$peak/fc	f-3dB/fc	K
0	-3	0.00	no peak	1.00	0
1	-2	0.00	no peak	1.21	0.16
2	-1	0.00	no peak	1.51	0.34
3	0	0.15	0.70	1.80	0.54
4	1	0.99	1.05	2.04	0.77
5	2	2.15	1.23	2.20	1.03
6	3	3.41	1.33	2.33	1.31
7	4	4.68	1.38	2.43	1.63
8	5	5.94	1.43	2.51	1.97
9	6	7.18	1.46	2.59	2.40
10	7	8.40	1.48	2.66	2.85

Notes: 1. fc is the original programmed cutoff frequency with no boost
2. f-3 dB is the new -3 dB value with boost implemented
3. $f$peak is the frequency where the amplitude reaches its maximum value with boost implemented

e.g., fc = 9 MHz when boost = 0 dB
if boost is programmed to 5 dB then f-3 dB = 19.8 MHz
$f$peak = 11.07 MHz

8

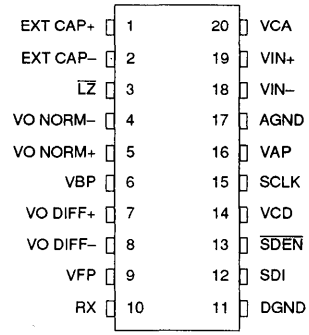
SSI 32F8144
Programmable
Electronic Filter



Normalized for $\omega c = (2\pi)\ fc = 1$
AN and AD are adjusted for unity gain (0 dB) at F = 0.67 fc
Denormalize the frequency by substituting $S \rightarrow (S/2\pi fc)$
Eq for fc = 27 MHz, $S = S / [(2\pi)(27 \times 10^6)]$

FIGURE 2: 32F8144 Normalized Block Diagram

PACKAGE PIN DESIGNATIONS
(Top View)



20-lead SOL, SOV

THERMAL CHARACTERISTICS: θja

20-lead SOL	95°C/W
20-Lead SOV	125°C/W

CAUTION: Use handling procedures necessary for a static sensitive component.

ORDERING INFORMATION

PART DESCRIPTION		ORDERING NUMBER	PACKAGE MARK
SSI 32F8144	20-Lead SOL (300 mil)	32F8144 - CL	32F8144 - CL
SSI 32F8144	20-Lead SOV (220mil)	32F8144 - CV	32F8144 - CV

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Patent Pending: 710, 512

0194 - rev.

Section 9

APPLICATION NOTES & GLOSSARY

January 1994

GENERAL CONSIDERATIONS

Figures 1 and 2 show basic circuit diagrams for K-Series modem integrated circuits. K-Series products are designed to be used in conjunction with a control processor, a UART or RS-232 serial data interface, and a DAA phone line interface to function as a typical intelligent modem. The K-Series ICs interface directly with Intel 8048 and 80C51 microprocessors for control and status monitoring purposes. Two typical DAA arrangements are shown: one for a split ±5 or ±12 volt design and one for a single 5 volt design. These diagrams are for reference only and do not represent production-ready modem designs.

K-Series devices are available with two control interface versions: one for a parallel multiplexed address/data interface, and one for a serial interface. The parallel version is intended for use with 8039/48 or 8031/51 microcontrollers from Intel or many other manufacturers. The serial interface 22-pin version can be used with other microcontrollers or in applications where only a limited number of port lines are available or the application does not lend itself to a multiplexed address/data interface. The parallel versions may also be used in the Serial mode, as explained in the data sheet pin description.

In most applications the controller will monitor the serial data for commands from the DTE and the received data for break signals from the far end modem. In this way, commands to the modem are sent over the same line as the transmitted data. In other applications the RS-232 interface handshake lines are used for modem control.

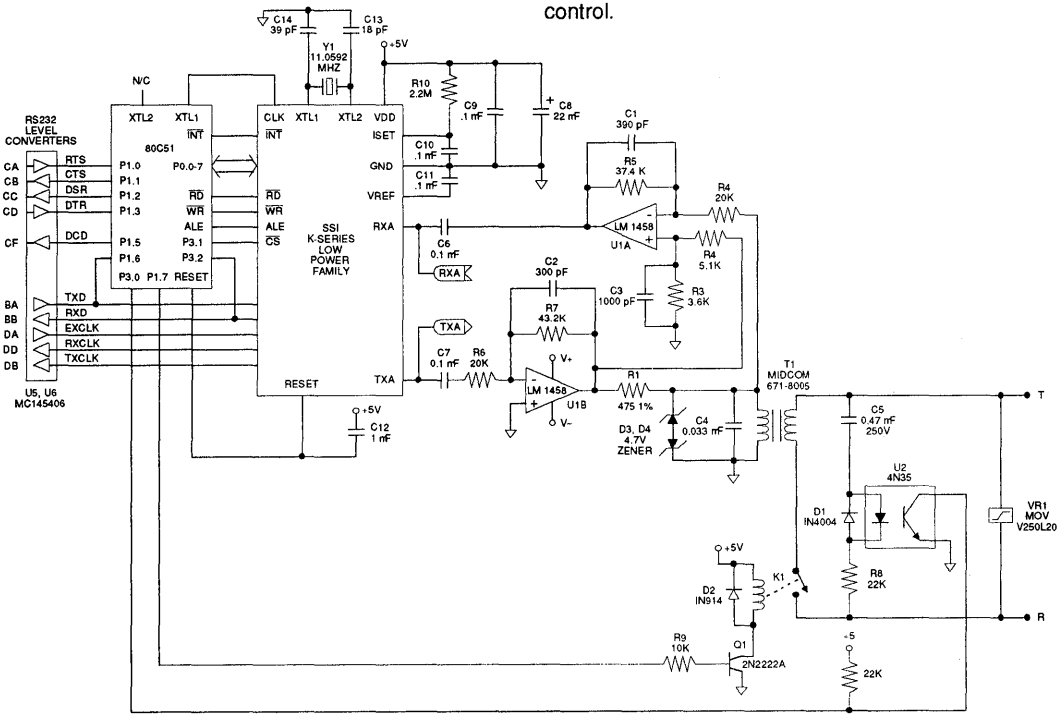

FIGURE 1: Basic Box Modem with Dual-Supply Hybrid

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DIRECT ACCESS ARRANGEMENT (DAA)

The telephone line interfaces show two examples of how the "hybrid" may be implemented. The split supply design (Figure 1) is a typical two op-amp hybrid. The receive op-amp serves two purposes. It supplies gain to amplify the receive signal to the proper level for the modem's detectors and demodulator, and it removes the transmitted signal from the receive signal present at the transformer. This is done by supplying a portion of the transmitted signal to the non-inverting input of the receive op-amp at the same amplitude as the signal appearing at the transformer, making the transmit signal Common mode.

The single-supply hybrid is more complex than the dual-supply version described above, but its use eliminates the need for a second power supply. This circuit (Figure 2) uses a bridged drive to allow undistorted signals to be sent with a single 5 volt supply. Because DTMF tones utilize a higher amplitude than data, these signals will clip if a single-ended drive approach is used. The bridged driver uses an extra op-amp (U1A) to invert the signal coming from the gain setting op-amp (U1B) before sending it to the other leg of the transformer. Each op-amp then supplies half the drive signal to the transformer. The receive amplifier (U1C) picks off its signal at the junction of the impedance matching resistor and the transformer. Because the bottom leg of the transformer is being driven in one direction by U1A and the resistor is driven in the opposite direction at the same time by U1B, the junction of the transformer and resistor remains relatively constant and the receive signal is unaffected.

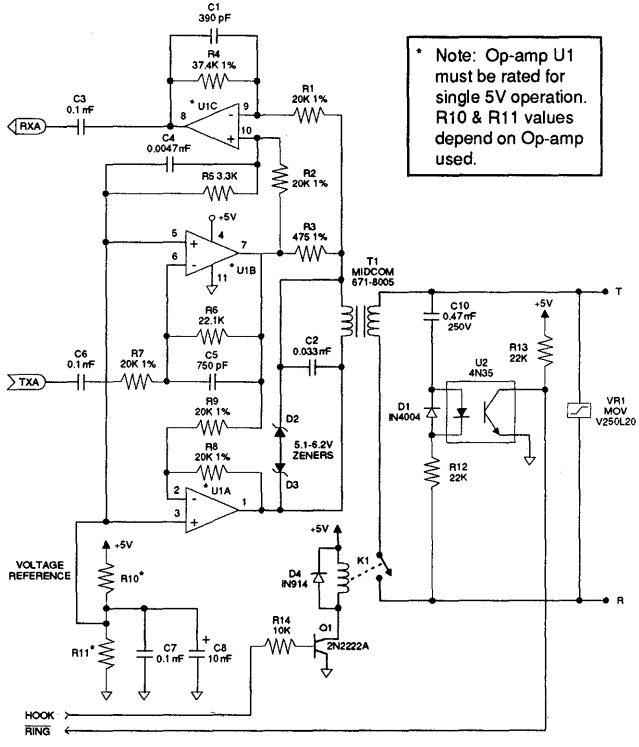

FIGURE 2: Single 5V Hybrid Version

DESIGN CONSIDERATIONS

Silicon Systems 1-chip modem products include all basic modem functions. This makes these devices adaptable for use in a variety of applications, and as easy to control as conventional digital bus peripherals. Unlike digital logic circuitry, however, modem designs must properly contend with precise frequency tolerances and very low level analog signals, to ensure acceptable performance. Using good analog circuit design practices will generally result in a sound design. Following are additional recommendations which should be taken into consideration when starting new designs.

CRYSTAL OSCILLATOR

The K-Series crystal oscillator requires a Parallel mode (antiresonant) crystal which operates at 11.0592 MHz. It is important that this frequency be maintained to within ±0.01% accuracy.

In order for a Parallel mode crystal to operate correctly and to specification, it must have a load capacitor connected to the junction of each of the crystal and internal inverter connections, terminated to ground. The values of these capacitors depend primarily on the crystal's characteristics, and to a lesser degree on the internal inverter circuit. The values used affect the accuracy and start up characteristics of the oscillator.

LAYOUT CONSIDERATIONS

Good analog/digital design rules must be used to control system noise in order to obtain highest performance in modem designs. The more digital circuitry present on the PC board, the more this attention to noise control is needed. The modem should be treated as a high impedance analog device. A 22 mF electrolytic capacitor in parallel with a 0.1 mF ceramic capacitor between VDD and GND is recommended. Liberal use of ground planes and larger traces on power and ground are also highly favored. High speed digital circuits tend to generate a significant amount of EMI (Electro-Magnetic Interference) which must be minimized in order to meet regulatory agency limitations. To accomplish this, high speed digital devices should be locally bypassed, and the telephone line interface and K-Series device should be located close to each other near the area of the board where the phone line connection is accessed. To avoid problems, power supply and ground traces should be routed separately to the analog and digital functions on the board, and digital signals should not be routed near low level or high impedance analog traces. The analog and digital grounds should only connect at one point near the K-Series device ground pin to avoid ground loops. The K-Series modem IC's should have both high frequency and low frequency bypassing as close to the package as possible.

For additional applications information consult the Silicon Systems K-Series Modem Design Manual.

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Notes:

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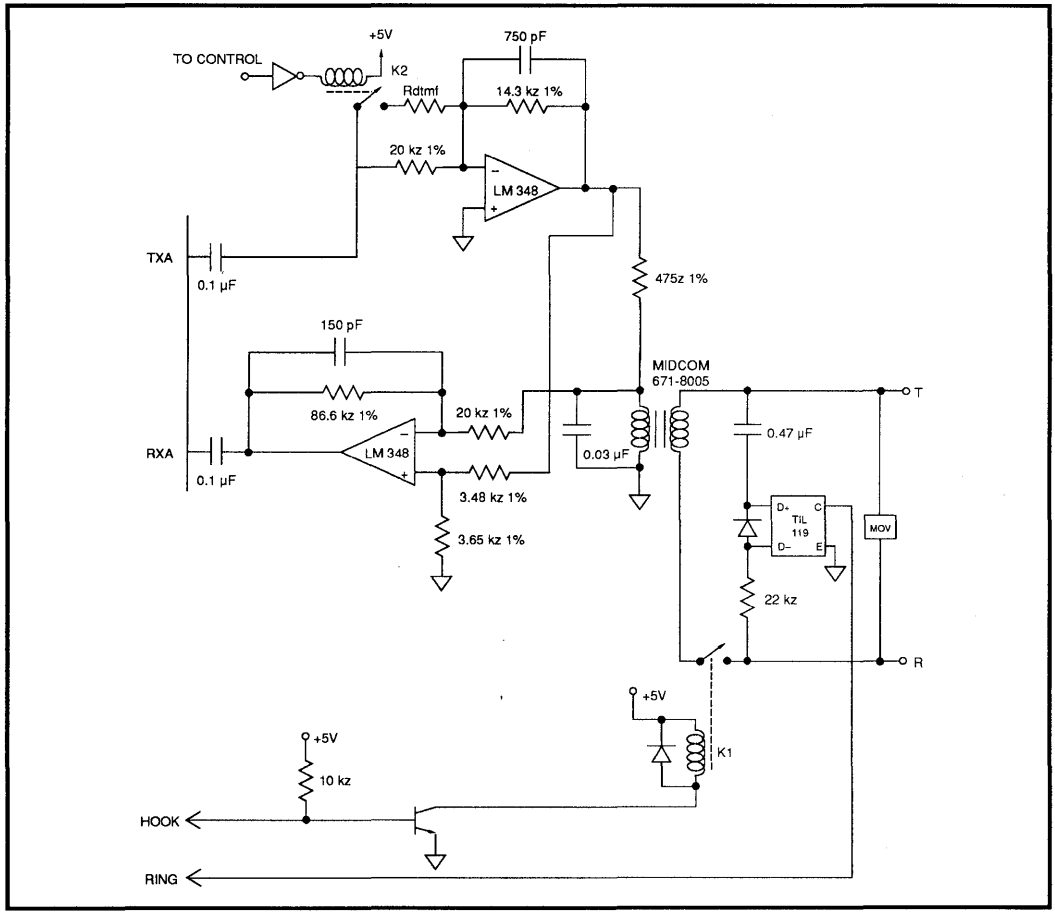
APPLICATION NOTE

Setting DTMF Levels for 1200 Bit/s K-Series Modems

Some applications of the K-series modems without output level adjustment may require setting the DTMF transmit level to something other than the normally transmitted level. This level is nominally about 5 dB higher than during data transmission. If the data is transmitted at -10 dBm, the DTMF levels will be at about -5 dBm, which is adequate in most applications.

The simplest way to change the relative levels of DTMF tones and data is to change the transmit gain during dialing. This can be accomplished as shown below. In this example, it is assumed that the DTMF tones are to be transmitted at a higher level than normal. Closing relay K2 will increase the gain of the transmit op-amp and allow a higher DTMF tone level during dialing. If it is desired to decrease the DTMF level, the relay can be open for dialing and closed for data. The value of the shunt resistor, Rdtmf, will be relatively large compared to the resistor R1, therefore the precision of Rdtmf is not as critical as R1. This means an analog switch or similar device could be used instead of a relay, with the on resistance of the switch not seriously affecting the tolerance of the gain setting.



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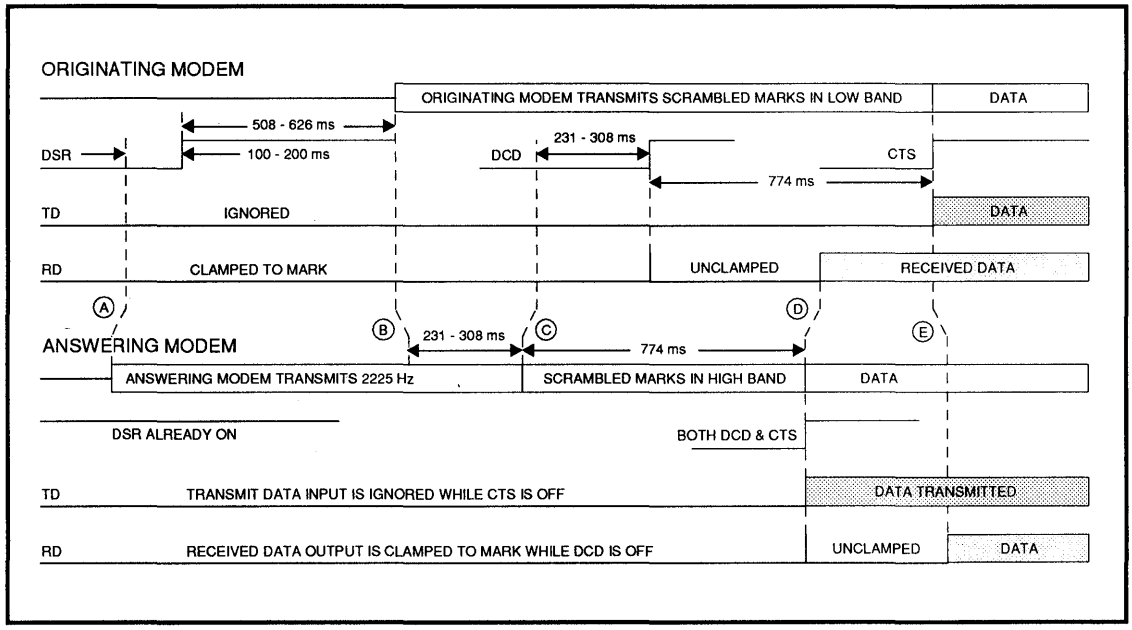
APPLICATION NOTE

SSI 73K212A High Speed Connect Sequence



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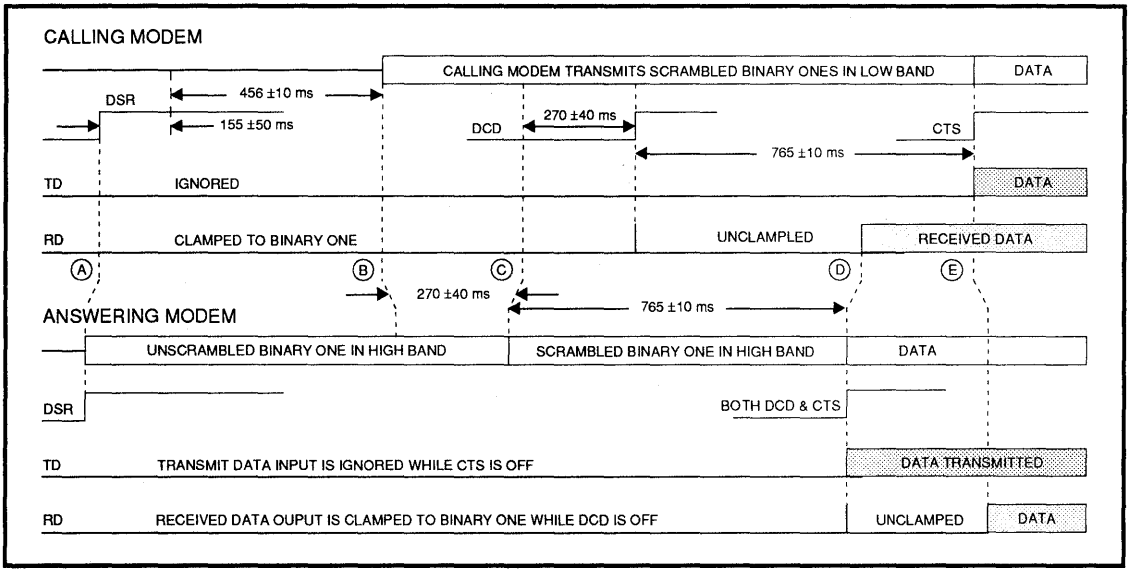
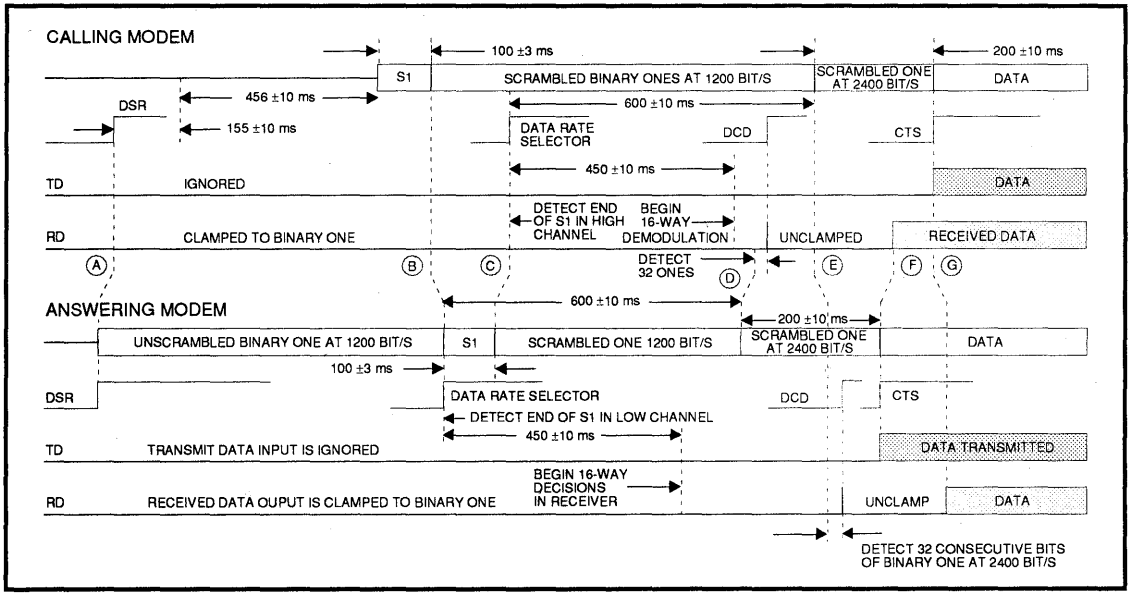
APPLICATION NOTE

V.22 & V.22bis Connect Sequences

V.22



V.22bis



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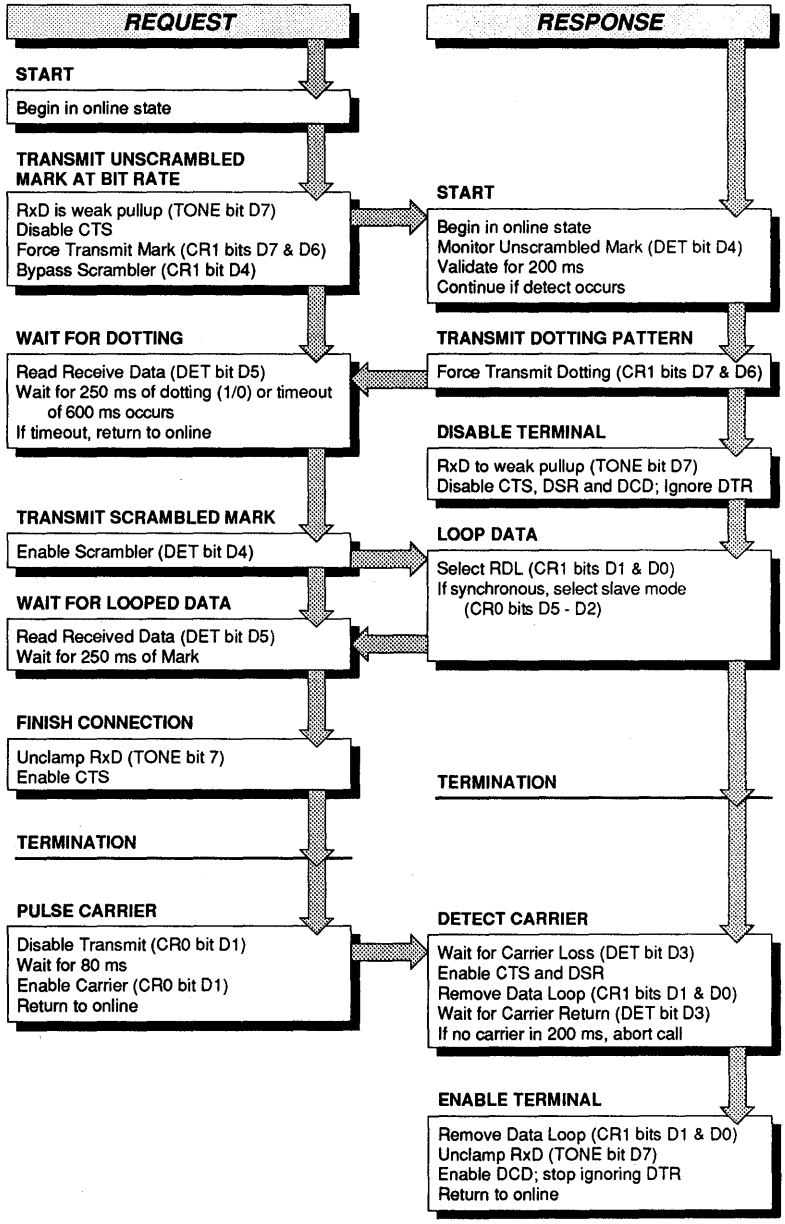
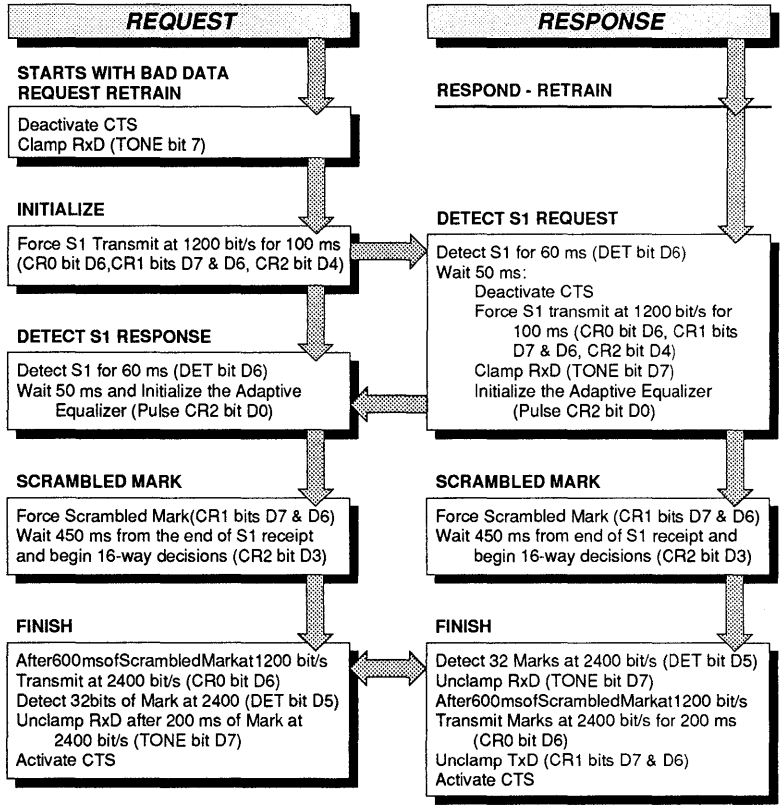
APPLICATION NOTE

Remote Loop Handshake Sequence



SSI 73K224L
Retrain at 2400



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APPLICATION NOTE

SSI 73K212 & 73K222
Originate Handshake Sequence

(RXD is in tri-state mode, TONE bit D7≤1)

DIAL
1. Go off hook
2. Bring out of power down mode (CR0 bits D5-D2)
3. Set DTMF tone (Tone bits D4-D0)
4. Turn on transmitter (Set CR0 bit D1)
5. Wait DTMF on time
6. Turn off transmitter (Clear CR0 bit D1)
7. Wait DTMF off time
8. Repeat 3-7 for all digits

WAIT FOR CARRIER
1. Start S7 (Wait for carrier) timeout
2. Set to Bell 103 originate mode (Set CR0 bits D5-D0 to 110001)
3. Wait for carrier detect bit (DR bit D3) to come on
4. Start sliding window counter (Wait through possible 2100 Hz answer tone period)
5. Qualify RXD mark* for 150 ms (DR bit D5) to detect answer modem (Carrier detect bit must also be on)
6. Raise DSR

FSK
1. Wait 100-200 ms
2. Raise DCD, start 755-774 ms timer; wait 426-446 ms, send FSK marks (Set CR1 bits D7 & D6 to 10, set CR0 bit D1)
3. At end of 755-774 ms timer period (started in #2 above); raise CTS, unclamp RXD & TXD from marking (clear TONE bit D7; clear CR1 bits D7 & D6)

DPSK
1. Wait 456 (V.22) or 508-626 ms (212A), switch to DPSK
2. Send scrambled marks (Set CR1 bits D7 & D6 to 10)
3. Qualify scrambled marks from answer modem for 150 ms
4. Wait for 231-302 ms of scrambled marks, raise DCD
5. Enable RXD (Tone bit D7)
6. Wait 774 ms, raise CTS, enable TXD (Clear CR1 bits D7 & D6)

*This may be either answer tone from a Bell modem or unscrambled marks from a V.22 modem

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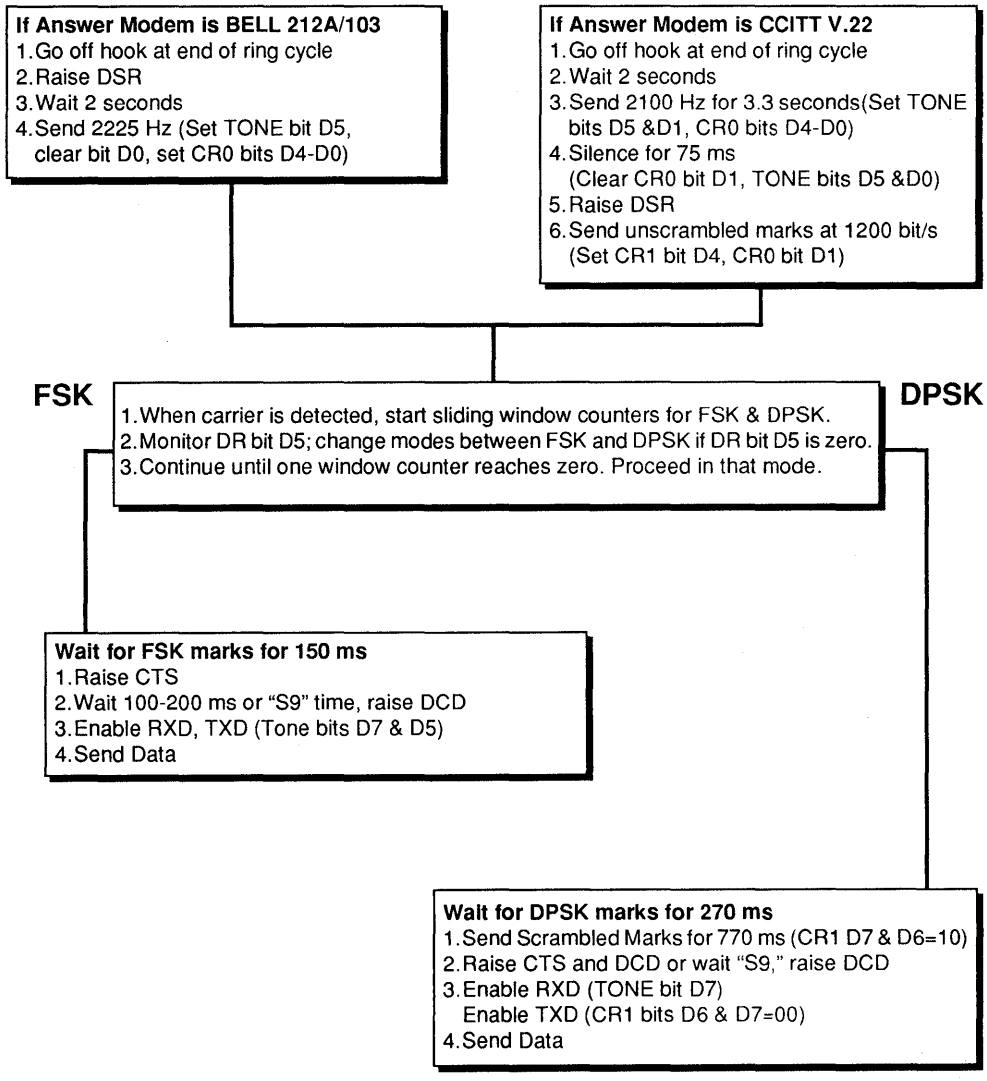
APPLICATION NOTE

SSI 73K212 & 73K222
Answer Handshake Sequence

(RXD is in tri-state mode, TONE bit D7=1)



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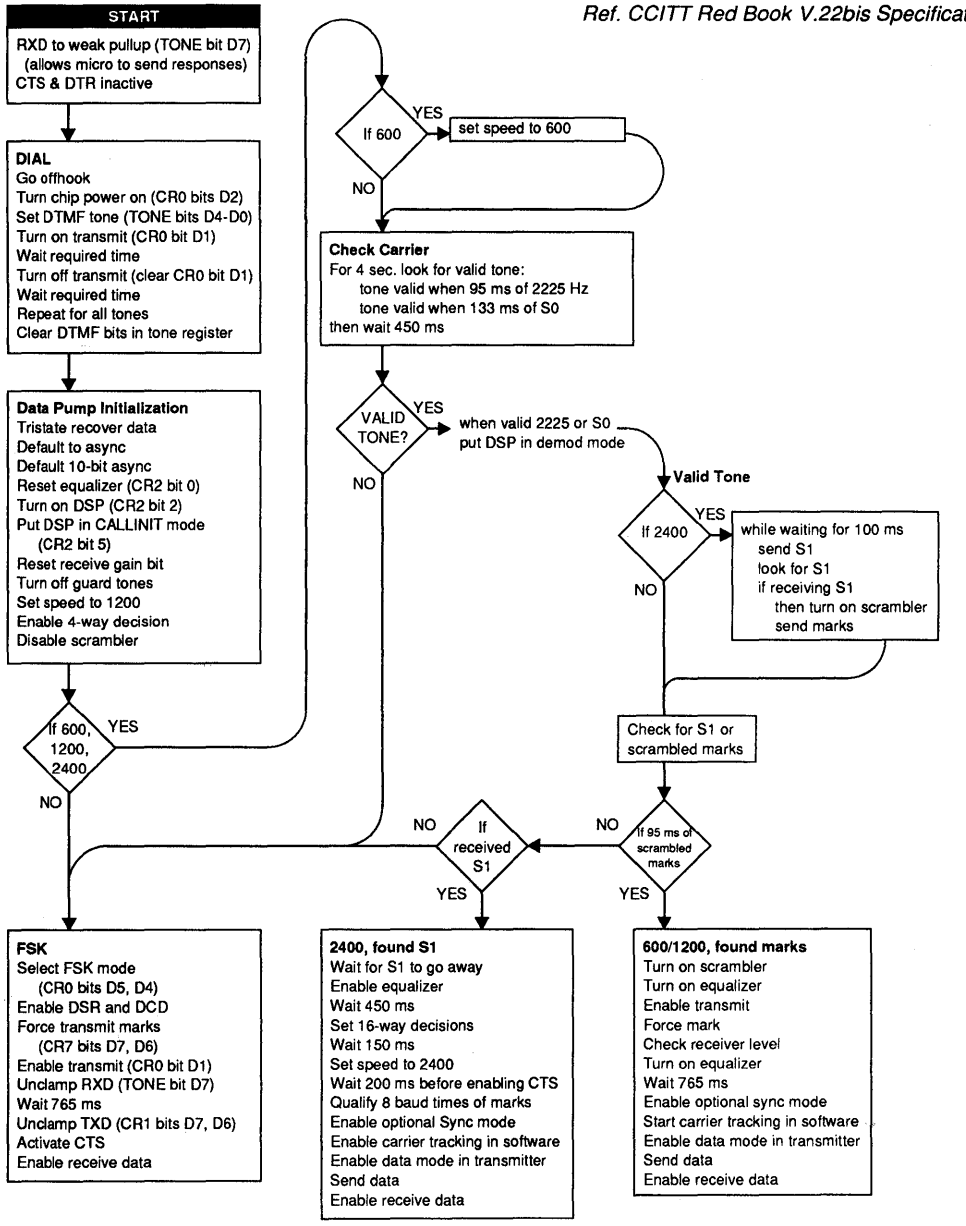
APPLICATION NOTE

SSI 73K224L Originate Handshake Sequence

Ref. CCITT Red Book V.22bis Specification



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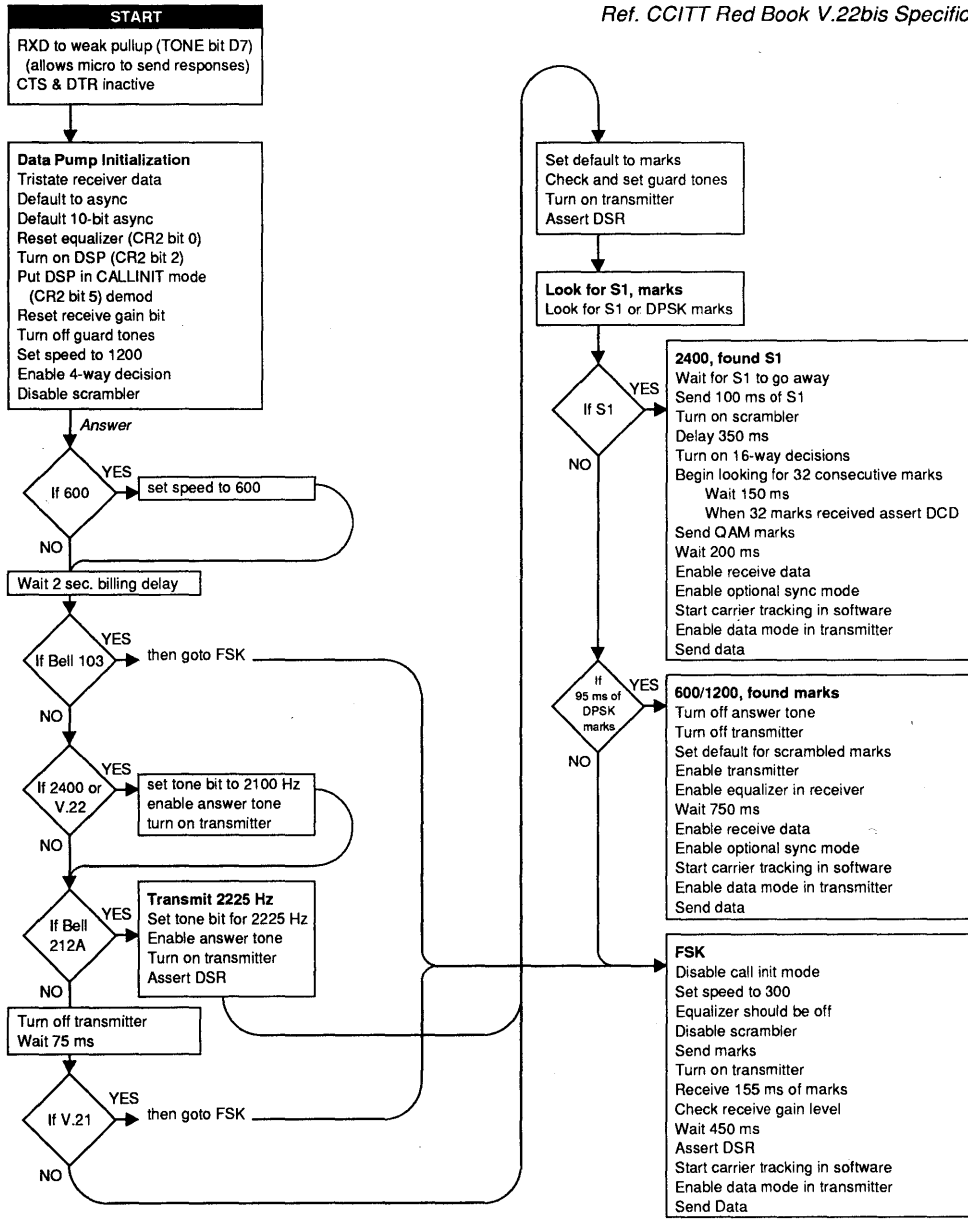
APPLICATION NOTE

SSI 73K224L Answer Handshake Sequence

Ref. CCITT Red Book V.22bis Specification



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APPLICATION NOTE

Troubleshooting the Modem Design

Excerpt from the Silicon Systems ***K-Series Modem Design Manual***

Possible Causes of a Totally Dead System

It is always particularly depressing when you power-up a new design for the first time and absolutely nothing happens. However, this is often the easiest type of fault to find. We will try to think of a few things that could cause this problem (apart from the obvious, like the plug falling out of the wall socket).

The K-Series Modem IC is Stuck in the Reset State

You will generally get very little cooperation from a K–Series modem IC while it is in the power-down state. It enters this state when a reset operation is performed, either by writing to the Reset bit (bit 2) in Control Register 1 or by taking the RESET input pin to logic ONE. Make sure that your firmware is bringing the part out of this state by writing something other than all ZEROs to bits 5 to 2 in Control Register 0. Also, make sure that this happens after the RESET pin has been returned to logic ZERO. A capacitor from this pin to VDD can hold the part in the reset state for many seconds. Attempts to program the part during this time will not take effect. For products with a DSP, check that the RESET DSP bit (CR2 bit D2) is also written with ONE when appropriate.

Crystal Oscillator Fails to Start

If a complete crystal oscillator is used to directly drive the K-Series modem, any starting problem should be addressed to the manufacturer of that device. If the internal oscillator is used with a crystal, there may be situations in which it will not start. Check the values of the capacitors from XTL1 and XTL2 to ground. If these are too high in value, 40 pF or above, the oscillator may not start. Such large values are not recommended and should not be necessary if the crystal is correctly specified. Also ensure that the circuit board is designed to minimize stray inductance and capacitance in the area of the oscillator. The crystal and both capacitors should be placed as close as possible to the XTL pins of the K-Series modem IC and connected by direct traces. The ground connection of the capacitors should be via wide traces to the digital grounding system. It is also possible that the oscillator will not start or will be slow to start if the risetime of the power supply voltage is very long. The starting properties are helped by the asymmetry in the load capacitor values, the capacitor at XTL1 should be about twice as large as that at XTL2.

Clock to Microcontroller Isn't Getting Through

Using the K-Series modem ICs on-chip clock oscillator to generate timing for the entire system is very efficient from the point of view of component count and EMI generation. However, note that the CLK output of the modem chip is specified only to drive TTL compatible inputs. Many common microcontrollers require clock inputs that rise closer to the supply voltage for logic ONE. We have seen applications which use the CLK pin to drive these inputs without problem, however, the low-power (5V supply) parts may give a lower logic ONE level than is necessary at elevated temperature. We recommend that you use a TTL to CMOS level converting buffer between the CLK pin and the controller clock input in 5V systems. A pull-up resistor to the 5V supply is not effective in increasing the logic high voltage. In some cases capacitive coupling to a CMOS input is also effective if the controller clock input is properly biased.

Connect Handshake Fails

If your system seems to be working well but cannot get into the situation of exchanging data with another modem, it is likely that you have a problem in the connect handshake. It is better to examine handshake problems using a "known good" modem at the remote end rather than another of your own systems. This helps isolate problems if more than one are present. Use a modem from an established and reputable manufacturer, as discounted generic modems may not conform fully to established specifications. Depending on the modulation mode, there may be many or few opportunities to fail so we can only offer general pointers to problems we have encountered in the past. It is very helpful to build extra diagnostic code into the handshake to diagnose unexpected conditions.

If things never start, check that the initial set-up of the chip is correct. The chip must be taken out of power-down before it will do anything and in DSP-based chips the DSP must have been reset after any previous call and then taken out of the reset state. (A DSP–based part cannot be used in a non-DSP socket without many such changes to the controller code; watch this when upgrading a 73K222 system to use a 73K224L.) If in CALLINIT mode the answer tone is not detected, check that you have selected the desired answer tone frequency by programming in the Tone Register. The selectivity of the answer tone detector is quite high, so verify that your answering modem is generating a frequency within the specifications of the modulation standard. You should be able to verify the operation of your various signal detectors with breakpoints in the controller code. If these do not fire at the appropriate point, the handshake is likely to hang-up or get out of step with the other modem. Be especially careful with the S1 detector, if this is failing you may get connections at 1200 bit/s which were supposed to be at 2400 bit/s. With DSP-based chips in QAM or DPSK modes, make sure that you are enabling the adaptive equalizer at the appropriate time. Enabling it too early, when the received signal is unsuitable for training, and too late, when there is too little time left before the gear shift to 2400 bit/s, can both give connect problems. Finally, make sure the crystal oscillator frequency is in specification as a gross error here can cause failure of the handshake.

Errors Committed Immediately After Handshake, With Later Improvement

We have seen situations in which a K-Series modem makes many data errors during the first few seconds of a connection, but then shapes up and performs normally thereafter. This is generally due to some problem in equalizer training in a DSP-based chip. The equalizer must be held in the initial state (bit 0 of CR2 = ZERO) up to the point in the handshake when scrambled DPSK binary ONES first appear at the receiver. It must then be released promptly (bit 0 of CR2 = ONE) and allowed to adapt so that it is fully trained before the gear shift to 2400 bit/s and the transition to data mode occurs. Enabling the equalizer too early will cause it to train on an unsuitable unscrambled signal. Because it adapts more rapidly immediately after being enabled, it may take a long time to recover from a bad solution when the correct receiver signal arrives. Enabling the equalizer too late reduces the time available for training before the received data is relied upon to be correct. If you have to put the equalizer back into the initialized state after a period of training, make sure that Equalizer Enable (bit 0 of CR2) stays at ZERO for at least 2 ms. It is better to have the Receiver Gain Boost bit dealt with before the equalizer is enabled, otherwise transients caused by changing this bit may upset the equalizer solution.

Errors Experienced at High Receive Signal Levels

If the error rate gets worse at high receive signal levels, you should look for some source of clipping in the receive path. Injecting a signal of known level at the line coupling transformer and looking at the RXA pin with an oscilloscope should enable you to isolate any problem in the line interface. Look for excessive gain in the receiver buffer amplifier or other causes of clipping at this point such as badly chosen op-amps for single 5V supply operation. If the signal at RXA looks good and you are using a DSP-based modem chip, it is possible that the controller is incorrectly inserting the 12 dB receiver gain boost even if the Receive Level bit in the Detect Register is set. Note that early data sheets for the 73K224L gave this bit the wrong sense, i.e., ONE for low level. Only set Receive Gain Boost if this bit is ZERO.

Errors Experienced at Low Receive Signal Levels

There can be many causes of data errors at low receive signal levels, almost all associated with the presence of some level of interference or noise in the receive path. If you are performing tests over the telephone network, make sure that the error rate you are experiencing is not to be expected from the background noise level on the line. It is best to use a line simulator or a direct connection through an attenuator if looking for system noise problems. The capacitor across the feedback resistor of the receiver buffer amplifier is important to attenuate out-of-band noise at the modem chip receiver input.

Distortion in the telephone line interface can be located by injecting low-level signals into the line terminals and examining the signal at the RXA pin with a spectrum analyzer. Look for crossover distortion in the receiver buffer amplifier. This can arise from a poorly chosen op–amp type, such as the LM324 which makes a transition from class A to class AB operation at low signal levels and is not suitable for this application. We have found LM348 and LM1458 type op-amps to be free from this problem. It is also possible for the line coupling transformer to introduce harmonic distortion, particularly when a large D.C. holding current is flowing.

In the absence of significant distortion, look for a high noise level at the RXA pin. Another symptom of this problem, apart from data errors, is that the Carrier Detect bit (bit 3 in DR) comes on or blinks when no signal is applied to the modem receiver. The system may also fail to disconnect at the end of a call. If this is

your experience don't confine your search to the normal carrier bandwidth because the modem chip will also be susceptible to higher frequencies. Op-amps may be noisy or may self-oscillate at low level due to poor layout. If the op-amps themselves are not causing the noise, it may be due to poor circuit layout or grounding. If, finally, nothing suspicious is visible at the RXA pin then the noise must be getting into the receive signal inside the modem IC. This can be from the power supply and bias pins or from signals routed under the chip. Check the connections to GND, VDD, VREF and ISET pins for component values and placement and routing of decoupling components. You are more likely to have problems with supply noise if you are using a switching power supply. Look also for fast digital signals routed under the modem IC; these should be re-routed and a ground plane placed under the chip. Serious interference pickup problems can be created by two crystal oscillators producing beat frequencies in-band to the modem. We strongly recommend using one master crystal in the system. Check the gain in the receive path from the line terminals and, in DSP-based parts, the state of the Receive Gain Boost bit set by the controller. If either of these are incorrect, then noise in the chip will appear more significant compared to the signal.

The transmitter of the modem can be a source of noise in the receiver. It should not generate signals that are in-band to the receiver, but this can happen if either the buffer amplifier or the line transformer are causing harmonic distortion. This will be most noticeable in call mode, when the low band transmit signal has harmonics in the high band filter of the receiver. For 5V only systems, the choice of op-amps in the buffer amplifier and their D.C. bias point is crucial to obtaining a sufficient voltage swing without distortion. Because of its internal operation, a small amount of switching noise is present at the TXA pin. The capacitor across the buffer amplifier feedback resistor is important to prevent this signal from reaching the receiver. It is difficult to obtain good rejection of the transmit signal at the receiver for all practical line conditions, but you should check that your four-wire to two-wire hybrid circuit is operating correctly. For most terminations, the transmit signal at the RXA pin minus the receive buffer gain should be 6 dB below the level at the line.

Modem Works in Loopback but Fails to Connect or Makes Errors in Bursts with Some Other Modems

If anything appears "flaky" about the modem operation it is a good idea to check the oscillator frequency with a counter capable of resolving to at least ten parts per million. Using an oscilloscope is of no use whatsoever. Many systems that use crystal oscillators are not very particular about the exact frequency; this is not so of modems. Measure the frequency at the CLK pin and verify that it is between 11.0581 MHz and 11.0603 MHz. Do not measure at the XTL1 or XTL2 pins as the probe capacitance will alter the frequency of oscillation. Some causes of out-of-specification readings are: a) the wrong crystal frequency entirely, b) a series-resonant crystal, or c) a parallel-resonant crystal unmatched to the circuit capacitance.

Problems Unique to FSK Modes

The SSI 73K224L does not permit answer tone detection in FSK modes, so ensure that a mode other than FSK is selected before attempting to detect answer tones.

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SSI 78P236/2361/2362/7200
Demo Board

Application Note

November 1993

DESCRIPTION

The 78P236 demo board is a PC board designed to facilitate the evaluation of the SSI 78P236 series of single chip transceiver ICs. The demo board can be used to test different transceiver ICs by changing various components. The demo board includes all of the necessary discrete components for the interface to a coded AMI line. A DIP switch allows easy control of the option pins on the IC. A loopback function is easily implemented using a slide switch. The same switch allows either an encoded signal (TPOS, TNEG, TCLK) or composite signal (TDATA, TCLK) be input to the transmitter. Simple test patterns can be injected into the data stream. Several jumpers allow the change of the transmitter and receiver clock polarity.

FEATURES

- **Allows easy evaluation of AMI transceiver ICs**
- **Includes all necessary external components**
- **Includes a digital loopback mechanical switch**
- **Generates ALL ONEs and repeated ONE/ZERO patterns**
- **Accepts composite Clock/Data and converts them to AMI pulses (No B3ZS encoding)**
- **Allows the use of either the receive clock or an external clock as the transmitter clock**
- **20-pin edge connector accepts flat coax cables and provides logical signals**

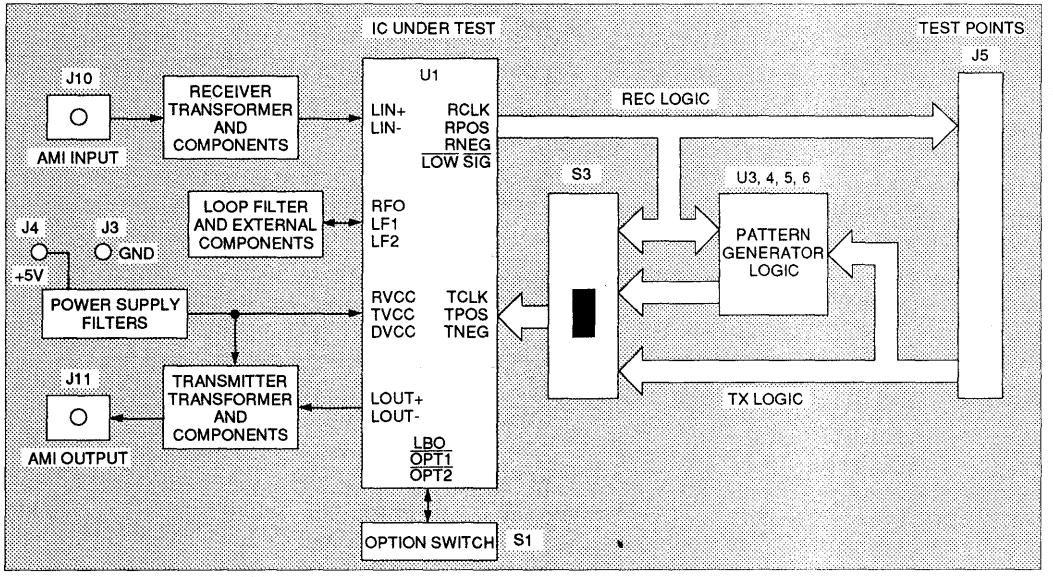

FIGURE 1: Demo Board Block Diagram

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SSI 78P236/2361/2362/7200
Demo Board

POWER SUPPLY CONNECTION

The demo board is constructed as a four layer PC board. The outer two layers carry the signals. The internal two layers are the segmented ground and power supply planes. Three segments separate the receive, transmit and logical ground and supply planes. The three ground planes are connected together using PC board traces at JP2 and JP8 positions. These traces can be cut to isolate the three planes from each other. The power supply planes are connected to a single +5V banana jack (J4) using LC filters of 4.7 µH and 0.1 µF. When a separate digital +5V supply is available, L1 is removed and the DVCC supply can be connected to J2.

RECEIVE SIGNAL PATH

The AMI signal is connected to the BNC connector J10. The maximum recommended distance of the demo board to a DSX crosspoint is 450 feet. The IC can handle added resistive attenuation as referenced by its minimum input signal level specification. The IC recovers clock, positive and negative data from the AMI signal. The following table shows the available receiver logical signals on the test points and edge connector J5:

J5 PIN	TEST POINT
1	LOW SIG/ U1-27
3	RDATA = RPOS .OR. RNEG
5	RPOS U1-25
7	RNEG U1-24
9	RCLK U1-23
11	RCLK/

The AMI input signal should be properly coded to prevent a long run of zeros on the line. The proper code should limit the number of zeros to three. The following table shows the proper coding required:

IC	SPEED Mbit/s	MAX zeros	CODE NAME
78P236	44.736	2	B3ZS
78P7200	44.736	2	B3ZS
78P2361	51.840	2	B3ZS
78P2362	34.368	3	HDB3

The demo board may be loaded with components which form a discrete equalizer for very long cables (R11, R12, R13, C31, L10). The AMI input signal to the IC can be monitored using a high impedance FET probe (TEKTRONIX P4064 or HP 1141A) connected to the TP14, TP15 pair.

The input signal is coupled through a 1:1 wideband transformer. The following table shows some of the suggested manufacturers of this part:

MANUFACTURER	PART NO.
Pulse Engineering	PE-65966
Coilcraft	WB1010-PC
Mini Circuit	T1-1

The AMI line is terminated at 75 ohms using R10.

Table 1 shows the required external components for different ICs used for receiving AMI signals at different speeds. Resistor R2 sets the center frequency of the oscillator. Capacitor C6 is used to bypass any noise on R2. Resistors R3,R20 and capacitor C26 controls the jitter characteristic of the IC.

SINGLE ENDED INPUT

It is possible to directly couple the IC to the AMI signal without a transformer using two capacitors (C29, C30) for isolation. In this case jumpers in locations R11, R12 should be cut and the transformer T1 should be bypassed by connecting pins 1 to 6 and 3 to 4 at the back of the demo board. The minimum input level should be higher than the transformer coupled circuit. The positive effect of the transformer in rejecting common mode noise is not achieved in this case.

TRANSMIT SIGNAL PATH

The IC accepts CMOS level NRZ logical inputs (TCLK,TPOS,TNEG) and converts them to the proper AMI signal. As shown in Table 2, the three position switch S3 and jumpers JP1,5,6 allow selection of different sources for these logical signals. In its simplest case, placing S3 in the bottom position allows a digital loopback. The following table shows the test points and J5 edge connector pins used for the transmitter.

J5 PIN	TEST POINT	
15	TCLK	clock input
17	TNEG	negative data
19	TPOS	positive data
19	TDATA	composite data

The outputs of the IC, LOUT+ and LOUT-, are connected to a 1:1:1 wideband transformer. The following table shows some of the suggested transmitter transformers:

MANUFACTURER	PART NO.
Pulse Engineering	PE-65969
Minicircuit	T4-1

The transformer center tap is connected to the +5V supply through a filter comprised of a 4.7 µH inductor and a 0.1µF capacitor. The capacitor C27, when added to the PC board trace and the transformer input capacitances, will effect the pulse shape. This capacitor should be selected for individual PC boards. The objective is to meet a pulse template at any cable length up to a maximum of 450 feet. The generated AMI signal is available on the BNC connector, J11, and it can be monitored on TP12, TP13 pair using a high impedance probe.

OPTION PINS CONTROL

Switch S1 changes the logic level of the option pins on the IC which controls the transmitter. Table 3 shows the function of this switch.

PERFORMING TESTS WITH DEMO BOARD

The general test setup using the demo board is shown in Figure 2. When the switch S3 is placed in its bottom position (loopback), the receiver logical output signals (RCLK, RPOS, RNEG) from the IC are connected to the transmitter logical input (TCLK, TPOS, TNEG). As a result, the received AMI signal is transmitted back to the test equipment. Bit error rate testing will indicate the ability of the IC to receive and transmit the AMI signal with no errors.

As shown in Figure 2, 450 feet of 75 ohm coaxial cable (type RG59B) and resistive attenuation is inserted in the receive path to exercise the IC for its lowest input level. The following tests are performed on the receiver:

BIT ERROR RATE TEST

A pseudo-random pattern is generated by the test equipment. This pattern is created using a shift register of N bits. Preventing an all zero pattern, a combination of 2**N-1 patterns of N bits is created in a random manner. This pattern is used to simulate the live traffic on the AMI line. The following table shows the mostly used patterns to test the IC:

IC	RANDOM PATTERN	FIXED PATTERN
78P236	2**15-1	100100...
78P7200	2**15-1	100100...
78P2361	2**15-1	100100...
78P2362	2**23-1	10001000

When running these patterns, no bit errors are expected in the absence of any noise. The test is repeated for fixed patterns to exercise the IC for any pattern sensitivity.

JITTER TOLERANCE

Telecommunication equipments should be able to recover clock and correct data even if the AMI signal includes a reasonable amount of timing jitter. For this test, the test equipment adds jitter to the random AMI signal. For jitter at a set frequency, the amplitude of the jitter is slowly increased until bit errors are observed. This process is repeated at different frequencies and a plot of the maximum tolerated jitter vs the jitter frequency is made as shown in Figure 3. The IC should tolerate jitter in excess of specified requirements.

SSI 78P236/2361/2362/7200 Demo Board

INTRINSIC JITTER

The jitter generated by the IC in the absence of any jitter on its transmitter logical input (TCLK, TPOS TNEG), should be minimal.

JITTER TRANSFER FUNCTION

The IC should not cause any amplification of the system jitter, i.e., no peaking should be observed in the jitter transfer function. This objective is achieved by selecting the PLL filter components for an overdamped response. The test equipment adds jitter to the AMI signal received by the IC. Measuring the jitter transmitted by the IC in the digital loopback mode indicates the shape of the transfer function. As shown in Figure 4, the IC adds no peaking and higher frequency jitter is attenuated.

TRANSMITTER TESTS

The AMI pulse generated by the IC can be tested for its shape, amplitude and frequency content over different lengths of cable. The demo board is usually placed in the loopback mode (S3 in bottom position).

PULSE FREQUENCY CONTENTS

For an AMI signal with an all ones pattern, the transmitted signal should have a frequency spectrum with the main component at half of the bit rate. The signal power at the harmonics including the component at the bit rate should be at least 20 dB lower than the main component. A spectrum analyzer is used for this purpose.

PULSE AMPLITUDE

The pulse amplitude for a pattern of 100100... is measured at different cable lengths by connecting the end of the cable to the scope using a 75 ohm termination adaptor (POMONA 4119). Except for the 78P2362, whose transmitted pulse amplitude is needed to be fairly exact (2 Vp-p ± 5%), other IC's transmit amplitude may fall in a wide range of amplitudes from 0.72 to 1.7 Vp-p.

PULSE TEMPLATE

The shape of the signal is examined by comparing it to the published templates. The test setup is shown in Figure 2. The program resident in the computer reads the transmitter waveform from the scope, scales it vertically, and plots it together with the published template masks. The pulse shape should meet the mask for all cable lengths from zero to 450 feet. The LBO pin as controlled by switch S1-1 should be properly set. For cable length of less than 225 feet this switch is open and for longer cables this switch should be closed. A typical pulse shapes for the 78P236 at the end of 450 feet of cable is shown in Figure 5.

PULSE IMBALANCE

The AMI pulse generated by the IC includes pulses of both negative and positive polarities. The pulse imbalance is examined by inverting the negative pulse using the scope and overlaying it on a typical positive pulse. No significant imbalance is observed.

TABLE 1: External Components List for Different ICs

Data sheet ref. -> / Demo board ref. -> / Unit ->		RFO R2 kΩ	RLF1 R3 kΩ	RLF2 R20 kΩ	CLF1 C26 µF	RTR R10 Ω	RTT R6 Ω	CTT C2 pF
78P236	44.736	5.23	20	100	0.22	75	None	10
78P7200	44.736	5.23	6.04	100	0.22	75	301	10
78P2361	51.840	4.53	20	100	0.22	75	None	10
78P2362	34.368	6.81	20	100	0.22	75	None	5

TABLE 2: Sources of the Transmitter Logical Signals

Switch S3	Source of: TPOS/TNEG		Source of: TCLK		Polarity of: TCLK	
			JP5 2-1	JP5 2-3	JP1 2-1	JP1 2-3
Top	External		RCLK	EXT	Buffered	Inverted
Middle	JP6 2-1	Converted from TDATA	RCLK	EXT	Buffered	Inverted
	JP6 2-3	Internally generated	RCLK	EXT	Buffered	Inverted
Bottom	RPOS / RNEG		RCLK	RCLK	RCLK	RCLK

TABLE 3: Function of the DIP Switch S1

Position	IC Pin	Function	Open	Closed
S1-1	LBO	TX cable length	L < 225'	L > 225'
S1-2	$\overline{\text{OPT1}}$	TX amplitude	Normal	Boost 2.7 dB
S1-3	$\overline{\text{OPT2}}$	TX disable	Enable	Disable
S1-4	None	test pattern JP6 2-3, S3 Mid.	1010 ...	111 ...

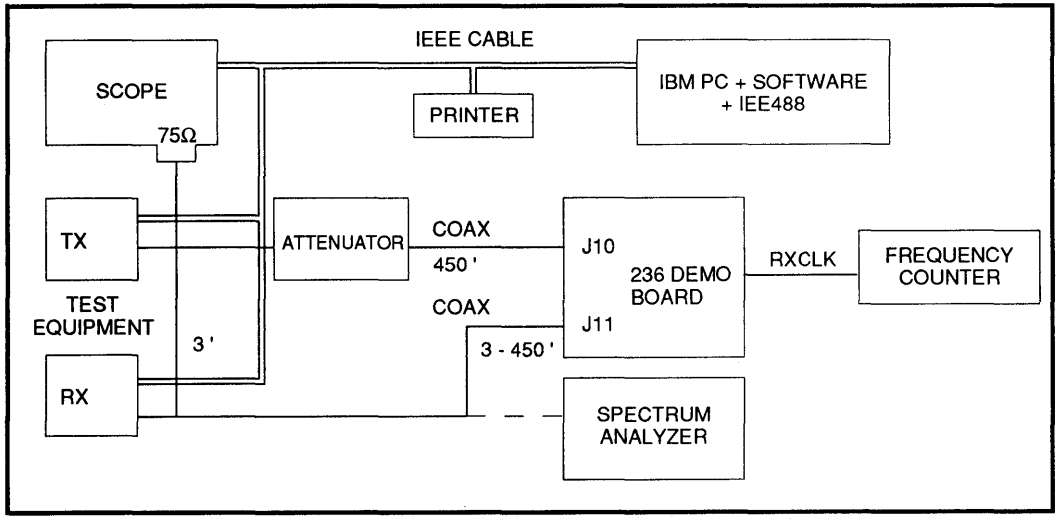

FIGURE 2: General Test Setup

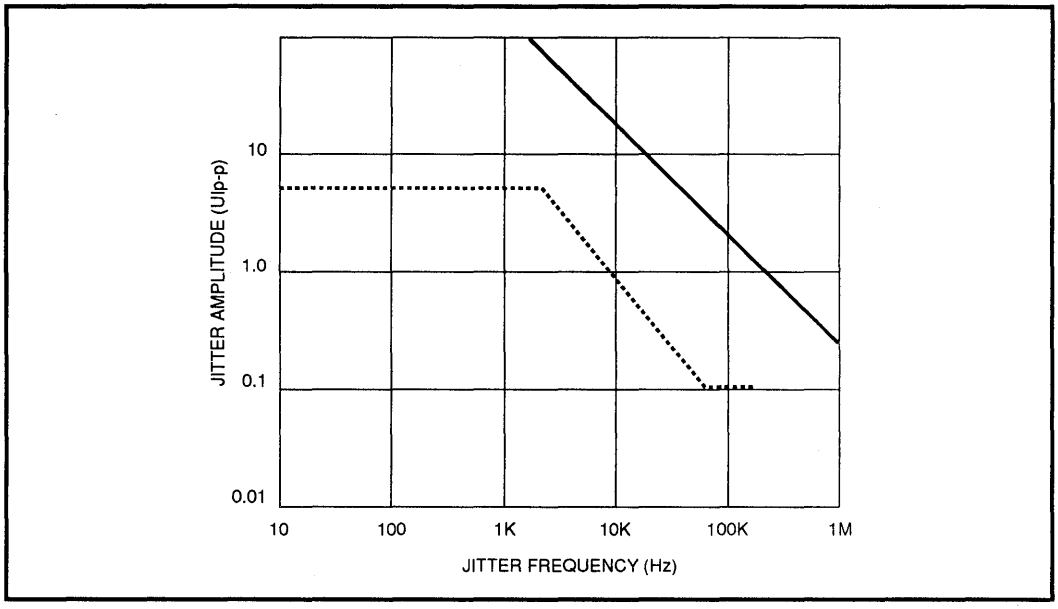

FIGURE 3: Jitter Tolerance for 78P236

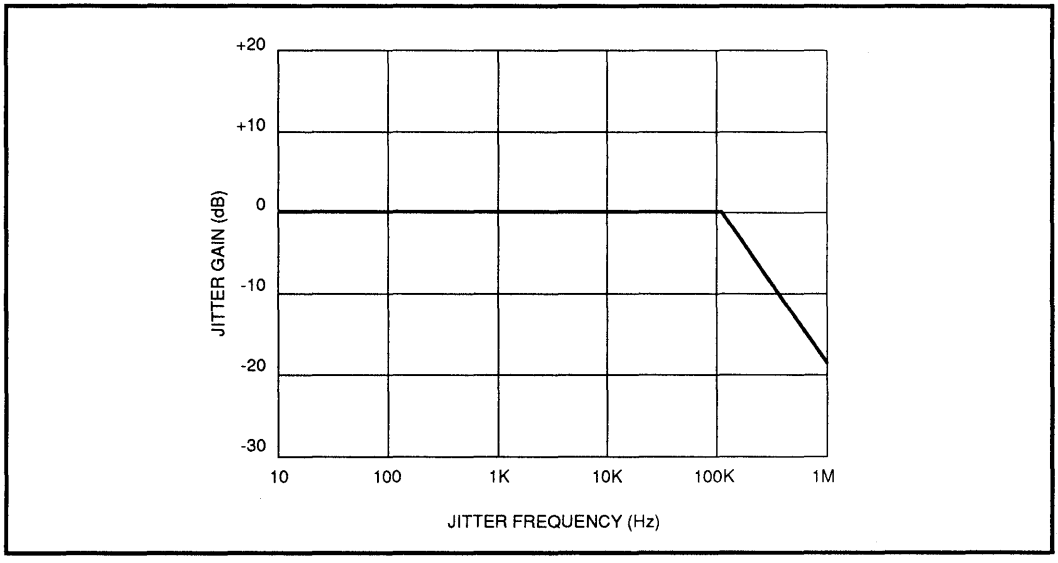

FIGURE 4: 78P236 Jitter Transfer Function
Loop Filter BW = 165 kHz

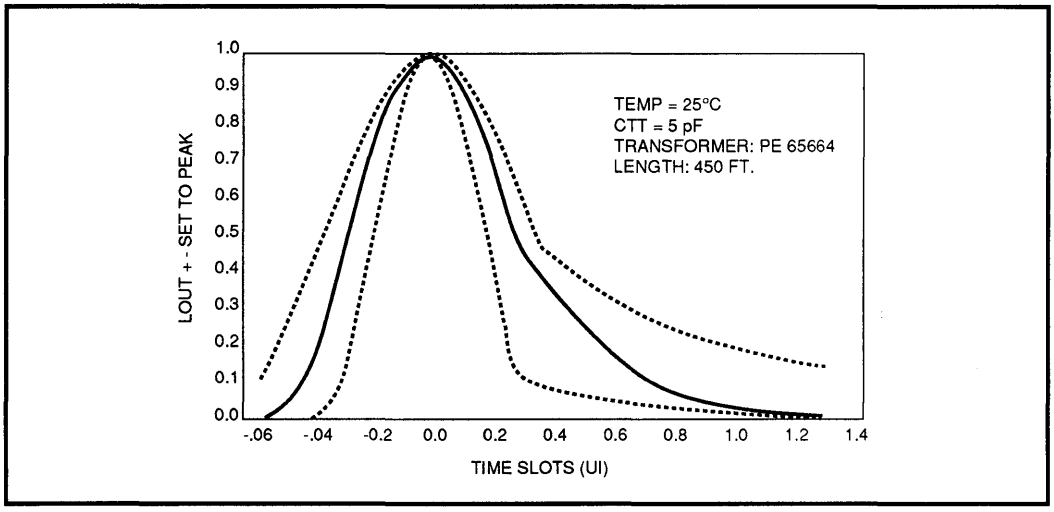

FIGURE 5: Transmitter Pulse Shape for 78P236

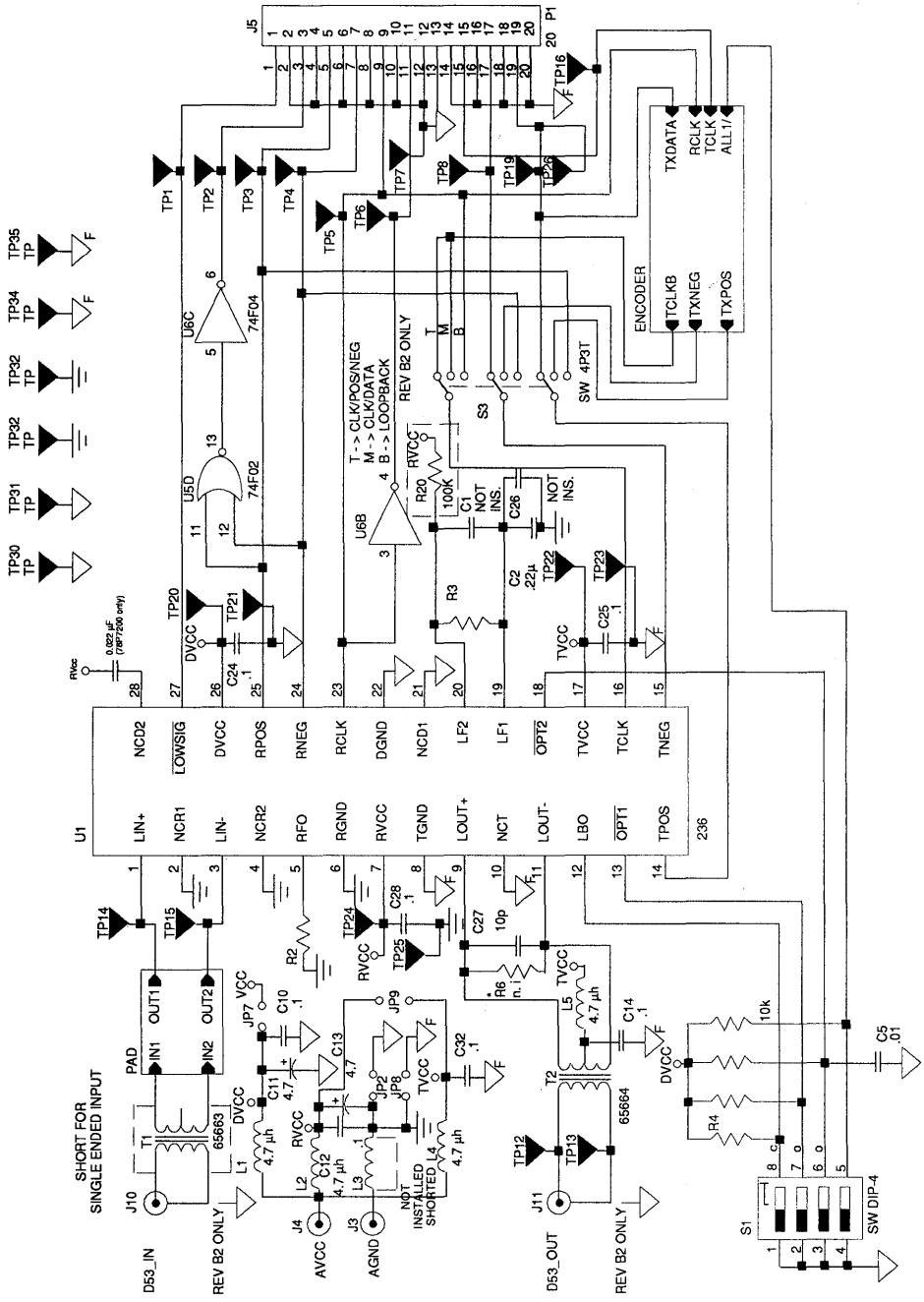

FIGURE 6: Demo Board Schematics

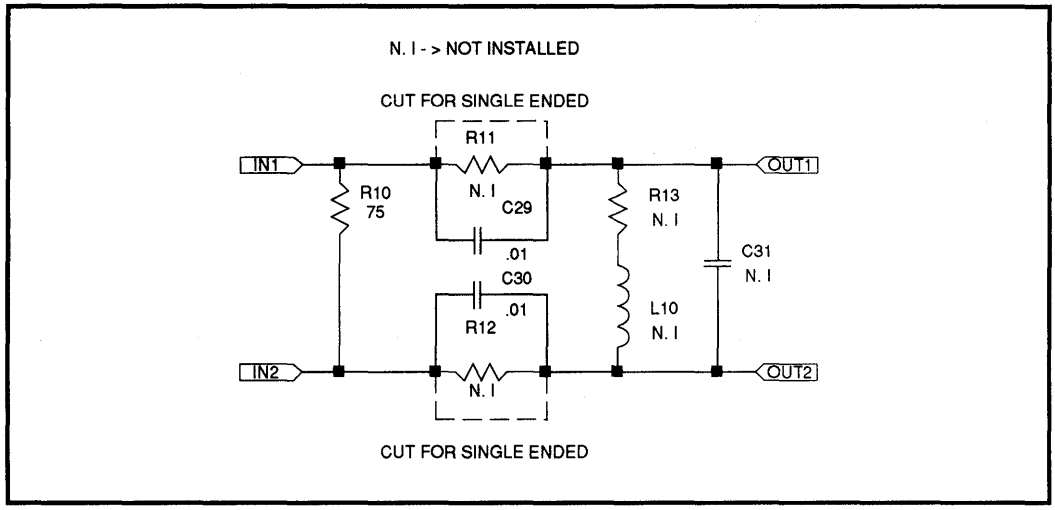

FIGURE 7: Pad / Equalizer

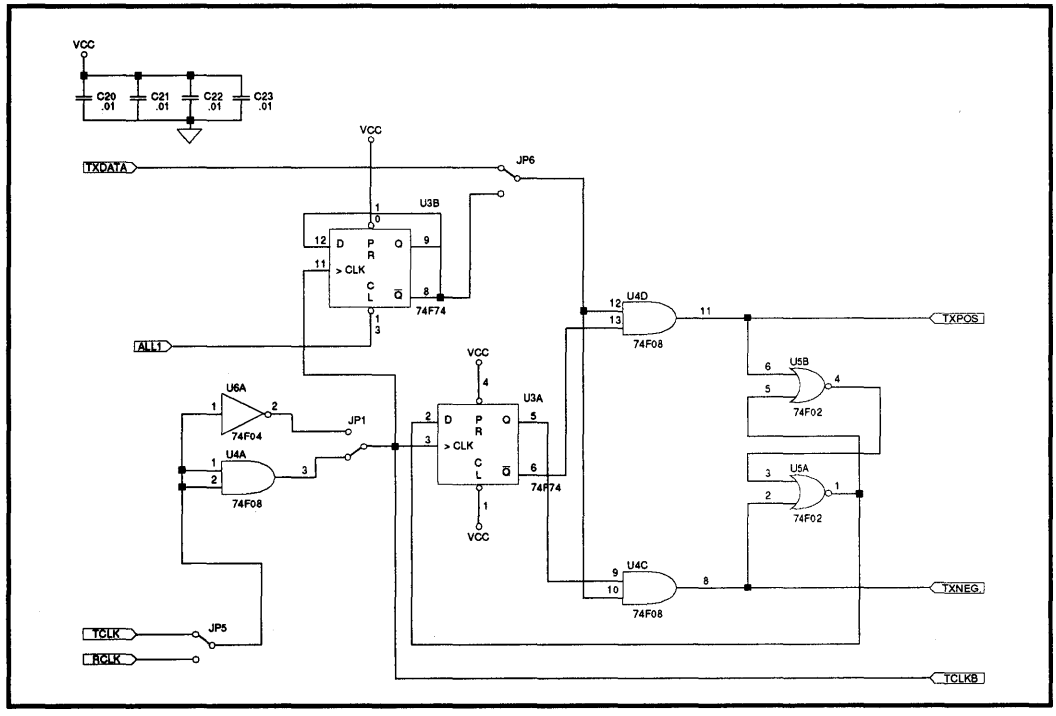

FIGURE 8: Encoder

SSI 78P236/2361/2362/7200
Demo Board

ORDERING INFORMATION

AMI SPEED Mbit/s		DEMO BOARD PART NUMBER
SSI 78P236/2361/2362/7200 Demo Board		
44.736	DS-3	78P236-DB
44.736	DS-3	78P7200-DB
51.840	STS-1	78P2361-DB
34.368	E-3	78P2362-DB

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SSI 78Q8373

Technical Reference Guide

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OVERVIEW

1 INTRODUCTION

The SSI 78Q8373 is a device for Ethernet LAN applications that consists of an Ethernet protocol controller, Manchester Encoder/ Decoder, 10BaseT transceiver, AUI port, and PCMCIA Bus Interface logic on one chip. It can operate using a 5-volt or 3.3-volt supply. This document contains detailed descriptions of key parts of the protocol controller block, namely, the Buffer Manager block and the Data Link Controller block, along with bit descriptions of all of the control and status registers. In addition, there is information on the power management capabilities of the SSI 78Q8373, how to configure the part for host and medium connections, information about how a host processor would handle packet transmission and reception on a network, and descriptions of the media interfaces (10BaseT and AUI) and PCMCIA Bus Interface. For detailed pin descriptions, electrical and timing parameters, please refer to the SSI 78Q8373 Data Sheet.

2 GENERAL DESCRIPTION

The SSI 78Q8373 combines the Ethernet network interface together with packet data management and consists of six major blocks:

- Buffer Manager (and SRAM Interface)
- Data Link Controller
- Host/PCMCIA Interface
- Manchester data Encoder/Decoder (ENDEC)
- Twisted-pair Transceiver
- Power Management

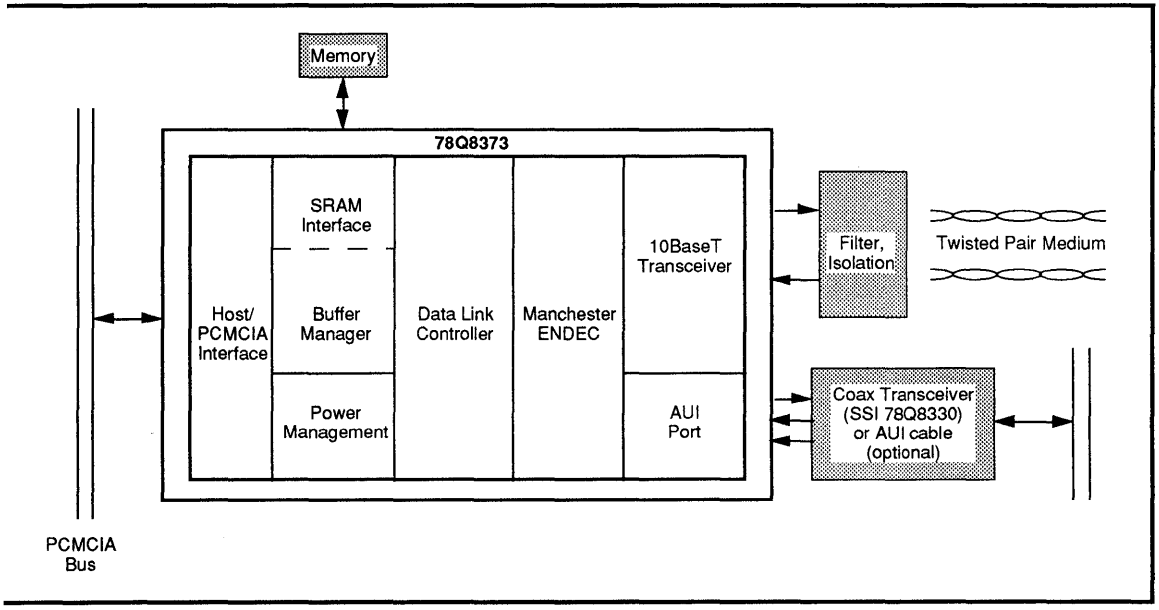


Figure 1-1: Block Diagram (78Q8373)

.2.1 Buffer Manager

The Buffer Manager manages all accesses to the buffer memory through the SRAM interface. The buffer memory is connected directly to the Data Link Controller (DLC), thus eliminating the need for a local microprocessor. The Buffer Manager also keeps track of all buffer memory pointers automatically; simplifying the software driver task. Together with intelligent arbitration, the SSI 78Q8373 is a high performance LAN controller.

The buffer memory is divided into a transmit memory section and a receive memory section. The transmit memory section can be partitioned into 2K, 4K, 8K or 16Kbyte buffer sizes. If the transmit buffer size is greater than 2KB, then the transmit buffer is

1.2.1 Buffer Manager (continued)

configured into two banks of equal size. There is only one transmit bank if a 2KB buffer size is selected. With the two ban configuration, one transmit bank may be tied up during transmission but the host can still continue to load data packets into the secon transmit bank to be tranmitted later. The receive buffer has a ring architecture which can be configured from 4K to 62KB dependin on the buffer memory configuration, which can range in size from 8K to 64KB.

A central arbitrator inside the Buffer Manager prioritizes and services requests for access to the buffer memory from four sources the Transmitter, the Receiver, Host Read and Host Write. If necessary, the SSI 78Q8373 will assert a 'not ready' handshake to th host while servicing the Transmitter and/or Receiver. The SSI 78Q8373 arbitration mechanism provides packet management b interleaving packet data accesses to the buffer memory such that the operation appears to be simultaneous.

For instance, in the situation where 2 transmit banks are configured, the host can load the first transmit bank and initiate transmission. While the first transmit bank is being transmitted, the host can continue to load packets in the second transmit bank At this stage, the SSI 78Q8373 can potentially be receiving data from the medium and loading it into the receive buffer (if the SS 78Q8373 is in a loopback mode or if self-reception occurs).

1.2.2 Data Link Controller

The Data Link Controller (DLC) implements the ISO/ANSI/IEEE 8802-3 CSMA/CD protocol. It consists of a Transmitter and Receiver, each with its own independent CRC logic. Automatic generation and stripping of the 64-bit preamble and the 32-bit CRC code are provided on-chip.

1.2.3 Host/PCMCIA Interface

The Host Interface provides connection to the host system. It consists of the various registers, DMA circuits and ready logic. Both word and byte interfaces are supported as well as big endian and little endian data ordering. Host access to the buffer memory i through BMR8 (and BMR9). Reading from BMR8 will read a byte or word from the receive buffer and writing to BMR8 will writ a byte or word to the transmit buffer. The ready logic is capable of delaying host access to the buffer memory with a time-ou mechanism. Both single and burst DMA transfer modes are supported.

The PCMCIA interface circuitry builds on top of the SSI 78Q8373 generic host interface and is only active if the MODE pin is lef unconnected (internally pulled-up). The SSI 78Q8373 can thus connect directly to a PCMCIA release 2.1 compliant bus. It alsc supports decoding for the external CIS memory (both ROM and Flash types). The SSI 78Q8373 pinout has been defined to minimiz criss-crossing connections to the PCMCIA connector. This allows for a cost effective 2-layer PCB design.

1.2.4 Manchester ENDEC

This block implements Manchester encoding and decoding. Serial NRZ data from the DLC is converted to Manchester encodec data and sent to either the twisted-pair transceiver block or to the Attachment Unit Interface (AUI) driver, depending on which i active. The decoder section performs three functions: clock recovery, carrier detection and Manchester decoding. The recoverec receive clock will be low at the end of reception and during idle to save power. Jitter of up to ±18 nsec can be tolerated by the decoder This block also translates a 10MHz collision signal to a logic-level signal before sending it to the DLC block if the AUI port i selected.

1.2.5 Twisted-Pair Transceiver

The on-chip Twisted-Pair module consists of the following functions. It has a smart squelch circuitry to determine valid data presen on the differential receive inputs (TPIP/N). Its transmit and pre-distortion drivers connect to the twisted-pair network via th summing resistors and transformer/filter. The link detector/generator circuitry checks the integrity of the cable connection the twc twisted-pair MAUs. Collision, jabber and SQE are also incorporated.

1.2.6 Power Management

One very useful and important feature that the SSI 78Q8373 offers is intelligent power management. It supports three differen power saving modes: Intelligent, Standby, and Full Shutdown. All modes are configurable through registers. In the Intelligen mode, clocks are active only when they are needed. For example, when not transmitting, the clock supplied to the transmitte circuit in the DLC block is not active while host read from buffer memory may be active. In Standby mode, the oscillator clock is disconnected from the rest of the circuits, so that only the oscillator circuits draw power. Full Shutdown turns off the oscillator resulting in maximum power savings. Note that this mode is not available when using an external clock source.

1.2.7 Pin Assignments

Following are the pin assignments for both the QFP and TQFP versions of the SSI 78Q8373.

TABLE 1: Pin Assignment Table - PCMCIA Bus Mode - 100-Lead TQFP

PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE
1	D1	IO4	26	$\overline{OE}$	I	51	RA4	O4	76	DON	AO
2	D8	IO4U	27	$\overline{WE}$	I	52	RA5	O4	77	DOP	AO
3	D0	IO4	28	$\overline{INPACK}$	O4	53	RA6	O4	78	AGND	P
4	A0	I	29	$\overline{REG}$	I	54	GND	P	79	REXT	R
5	A1	I	30	$\overline{ROMG}$	O4	55	VDD	P	80	AVDD	P
6	A2	I	31	$\overline{FCE}$	O4	56	RA7	O4	81	TPIN	AI
7	A3	I	32	$\overline{XPD}$	O4	57	RA12	O4	82	TPIP	AI
8	RESET	SI	33	XRST	O4	58	RA14	O4	83	MODE	TI
9	VDD	P	34	GND	P	59	$\overline{RWE}$	O4	84	DIN	AI
10	GND	P	35	RD0	IO4U	60	RA13	O4	85	DIP	AI
11	$\overline{IOWR}$	I	36	RD1	IO4U	61	RA8	O4	86	CIN	AI
12	$\overline{IORD}$	I	37	RD2	IO4U	62	RA9	O4	87	CIP	AI
13	$\overline{CE2}$	I	38	RD3	IO4U	63	RA11	O4	88	GND	P
14	D15	IO4U	39	RD4	IO4U	64	$\overline{ROE}$	O4	89	SPKRIN	SI
15	$\overline{CE1}$	I	40	RD5	IO4U	65	RA15	O4	90	$\overline{SPKR}$	O8
16	D14	IO4U	41	RD6	IO4U	66	OSCI	CI	91	CCRA	I
17	D7	IO4	42	RD7	IO4U	67	OSCO	O	92	RRST	O4
18	GND	P	43	GND	P	68	VDD	P	93	LEDLT	OD16
19	D13	IO4U	44	$\overline{RCS0}$	O4	69	GND	P	94	CB	O4
20	D6	IO4	45	$\overline{RCS1}$	O4	70	GND	P	95	$\overline{IOIS16}$	O4
21	D12	IO4U	46	RA10	O4	71	TPDN	AO	96	$\overline{IREQ}$	O8
22	D5	IO4	47	RA0	O4	72	TPDP	AO	97	$\overline{WAIT}$	O4
23	D11	IO4U	48	RA1	O4	73	TPON	AO	98	D10	IO4U
24	D4	IO4	49	RA2	O4	74	TPOP	AO	99	D2	IO4
25	D3	IO4	50	RA3	O4	75	VDD	P	100	D9	IO4U

Legend:

I:	Input (TTL level)
O4, O8:	Output with IOL = 4 or 8 mA
OD16:	Output Open Drain with IOL = 16 mA
IO4, IO4U:	Input (TTL level) and Output with IOL = 4 mA; IO4U refers to IO4 with an internal pull-up resistor
CI:	CMOS level input
SI:	Schmitt trigger input
TI:	Three-state input. May be connected to low, high, or left open.
AI:	Analog input
AO:	Analog output
P:	Power
R:	Resistor to ground
O:	Output

TABLE 2: Pin Assignment Table - PCMCIA Bus Mode - 100-Lead QFP

PIN #	PIN NAME	TYPE	PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE
1	D10	IO4U	26	D11	IO4U	51	RA1	O4	76	TPON	AO
2	D2	IO4	27	D4	IO4	52	RA2	O4	77	TPOP	AO
3	D9	IO4U	28	D3	IO4	53	RA3	O4	78	VDD	P
4	D1	IO4	29	$\overline{OE}$	I	54	RA4	O4	79	DON	AO
5	D8	IO4U	30	$\overline{WE}$	I	55	RA5	O4	80	DOP	AO
6	D0	IO4	31	$\overline{INPACK}$	O4	56	RA6	O4	81	AGND	P
7	A0	I	32	$\overline{REG}$	I	57	GND	P	82	REXT	R
8	A1	I	33	$\overline{ROMG}$	O4	58	VDD	P	83	AVDD	P
9	A2	I	34	$\overline{FCE}$	O4	59	RA7	O4	84	TPIN	AI
10	A3	I	35	$\overline{XPD}$	O4	60	RA12	O4	85	TPIP	AI
11	RESET	SI	36	XRST	O4	61	RA14	O4	86	MODE	TI
12	VDD	P	37	GND	P	62	$\overline{RWE}$	O4	87	DIN	AI
13	GND	P	38	RD0	IO4U	63	RA13	O4	88	DIP	AI
14	$\overline{IOWR}$	I	39	RD1	IO4U	64	RA8	O4	89	CIN	AI
15	$\overline{IORD}$	I	40	RD2	IO4U	65	RA9	O4	90	CIP	AI
16	$\overline{CE2}$	I	41	RD3	IO4U	66	RA11	O4	91	GND	P
17	D15	IO4U	42	RD4	IO4U	67	$\overline{ROE}$	O4	92	SPKRIN	SI
18	$\overline{CE1}$	I	43	RD5	IO4U	68	RA15	O4	93	$\overline{SPKR}$	O8
19	D14	IO4U	44	RD6	IO4U	69	OSCI	CI	94	CCRA	I
20	D7	IO4	45	RD7	IO4U	70	OSCO	O	95	RRST	O4
21	GND	P	46	GND	P	71	VDD	P	96	LEDLT	OD16
22	D13	IO4U	47	$\overline{RCS0}$	O4	72	GND	P	97	CB	O4
23	D6	IO4	48	$\overline{RCS1}$	O4	73	GND	P	98	$\overline{IOIS16}$	O4
24	D12	IO4U	49	RA10	O4	74	TPDN	AO	99	$\overline{IREQ}$	O8
25	D5	IO4	50	RA0	O4	75	TPDP	AO	100	$\overline{WAIT}$	O4

Legend:

I:	Input (TTL level)
O4, O8:	Output with IOL = 4 or 8 mA
OD16:	Output Open Drain with IOL = 16 mA
IO4, IO4U:	Input (TTL level) and Output with IOL = 4 mA; IO4U refers to IO4 with an internal pull-up resistor
CI:	CMOS level input
SI:	Schmitt trigger input
TI:	Three-state input. May be connected to low, high, or left open.
AI:	Analog input
AO:	Analog output
P:	Power
R:	Resistor to ground
O:	Output

TABLE 3: Pin Assignment Table - Generic Bus Mode - 100-Lead TQFP

PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE
1	HD1	IO4	26	RD8	IO4U	51	RA4	O4	76	DON	AO
2	HD8	IO4U	27	RD9	IO4U	52	RA5	O4	77	DOP	AO
3	HD0	IO4	28	RD10	IO4U	53	RA6	O4	78	AGND	P
4	HA0	I	29	RD11	IO4U	54	GND	P	79	REXT	R
5	HA1	I	30	RD12	IO4U	55	VDD	P	80	AVDD	P
6	HA2	I	31	RD13	IO4U	56	RA7	O4	81	TPIN	AI
7	HA3	I	32	RD14	IO4U	57	RA12	O4	82	TPIP	AI
8	RESET	SI	33	RD15	IO4U	58	RA14	O4	83	MODE	TI
9	VDD	P	34	GND	P	59	$\overline{RWE}$	O4	84	DIN	AI
10	GND	P	35	RD0	IO4U	60	RA13	O4	85	DIP	AI
11	$\overline{WR}$	I	36	RD1	IO4U	61	RA8	O4	86	CIN	AI
12	$\overline{RD}$	I	37	RD2	IO4U	62	RA9	O4	87	CIP	AI
13	$\overline{BHE}$	I	38	RD3	IO4U	63	RA11	O4	88	GND	P
14	HD15	IO4U	39	RD4	IO4U	64	$\overline{ROE}$	O4	89	$\overline{DMACK}$	SI
15	$\overline{CS}$	I	40	RD5	IO4U	65	RA15	O4	90	DMREQ	O8
16	HD14	IO4U	41	RD6	IO4U	66	OSCI	CI	91	EOP	I
17	HD7	IO4	42	RD7	IO4U	67	OSCO	O	92	RRST	O4
18	GND	P	43	GND	IO4U	68	VDD	P	93	LEDLT	OD16
19	HD13	IO4U	44	$\overline{RCS0}$	P	69	GND	P	94	CB	O4
20	HD6	IO4	45	$\overline{RCS1}$	O4	70	GND	P	95	HWORD	O4
21	HD12	IO4U	46	RA10	O4	71	TPDN	AO	96	$\overline{INT}$	O8
22	HD5	IO4	47	RA0	O4	72	TPDP	AO	97	READY	O4
23	HD11	IO4U	48	RA1	O4	73	TPON	AO	98	HD10	IO4U
24	HD4	IO4	49	RA2	O4	74	TPOP	AO	99	HD2	IO4
25	HD3	IO4	50	RA3	O4	75	VDD	P	100	HD9	IO4U

Legend:

I: Input (TTL level)
O4, O8: Output with IOL = 4 or 8 mA
OD16: Output Open Drain with IOL = 16 mA
IO4, IO4U: Input (TTL level) and Output with IOL = 4 mA; IO4U refers to IO4 with an internal pull-up resistor
CI: CMOS level input
SI: Schmitt trigger input
TI: Three-state input. May be connected to low, high, or left open.
AI: Analog input
AO: Analog output
P: Power
R: Resistor to ground
O: Output

TABLE 4: Pin Assignment Table - Generic Bus Mode -100-Lead QFP

PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE	PIN#	PIN NAME	TYPE
1	HD10	IO4U	26	HD11	IO4U	51	RA1	O4	76	TPON	AO
2	HD2	IO4	27	HD4	IO4	52	RA2	O4	77	TPOP	AO
3	HD9	IO4U	28	HD3	IO4	53	RA3	O4	78	VDD	P
4	HD1	IO4	29	RD8	IO4U	54	RA4	O4	79	DON	AO
5	HD8	IO4U	30	RD9	IO4U	55	RA5	O4	80	DOP	AO
6	HD0	IO4	31	RD10	IO4U	56	RA6	O4	81	AGND	P
7	HA0	I	32	RD11	IO4U	57	GND	P	82	REXT	R
8	HA1	I	33	RD12	IO4U	58	VDD	P	83	AVDD	P
9	HA2	I	34	RD13	IO4U	59	RA7	O4	84	TPIN	AI
10	HA3	I	35	RD14	IO4U	60	RA12	O4	85	TPIP	AI
11	RESET	SI	36	RD15	IO4U	61	RA14	O4	86	MODE	TI
12	VDD	P	37	GND	P	62	$\overline{\text{RWE}}$	O4	87	DIN	AI
13	GND	P	38	RD0	IO4U	63	RA13	O4	88	DIP	AI
14	$\overline{\text{WR}}$	I	39	RD1	IO4U	64	RA8	O4	89	CIN	AI
15	$\overline{\text{RD}}$	I	40	RD2	IO4U	65	RA9	O4	90	CIP	AI
16	$\overline{\text{BHE}}$	I	41	RD3	IO4U	66	RA11	O4	91	GND	P
17	HD15	IO4U	42	RD4	IO4U	67	$\overline{\text{ROE}}$	O4	92	$\overline{\text{DMACK}}$	SI
18	$\overline{\text{CS}}$	I	43	RD5	IO4U	68	RA15	O4	93	DMREQ	O8
19	HD14	IO4U	44	RD6	IO4U	69	OSCI	CI	94	EOP	I
20	HD7	IO4	45	RD7	IO4U	70	OSCO	O	95	RRST	O4
21	GND	P	46	GND	P	71	VDD	P	96	LEDLT	OD16
22	HD13	IO4U	47	$\overline{\text{RCS0}}$	O4	72	GND	P	97	CB	O4
23	HD6	IO4	48	$\overline{\text{RCS1}}$	O4	73	GND	P	98	HWORD	O4
24	HD12	IO4U	49	RA10	O4	74	TPDN	AO	99	$\overline{\text{INT}}$	O8
25	HD5	IO4	50	RA0	O4	75	TPDP	AO	100	READY	O4

Legend:

I:	Input (TTL level)
O4, O8:	Output with IOL = 4 or 8 mA
OD16:	Output Open Drain with IOL = 16 mA
IO4, IO4U:	Input (TTL level) and Output with IOL = 4 mA; IO4U refers to IO4 with an internal pull-up resistor
CI:	CMOS level input
SI:	Schmitt trigger input
TI:	Three-state input. May be connected to low, high, or left open.
AI:	Analog input
AO:	Analog output
P:	Power
R:	Resistor to ground
O:	Output

2 BUFFER MANAGER

The Buffer Manager manages accesses to the buffer memory through the SRAM interface. The buffer memory is connected directly to the Data Link Controller (DLC), thus eliminating the need for a local microprocessor. The Buffer Manager keeps track of all buffer memory pointers automatically, simplifying the software driver task. Together with intelligent arbitration for accesses to the buffer memory, this makes the SSI 78Q8373 a high performance LAN controller.

2.1 BUFFER MEMORY CONFIGURATION

There are 13 different ways in which to configure the transmit and receiver buffer SRAM for the SSI 78Q8373. This is done using 4 register bits, DLCR6<3:0>. DLCR6<1:0> sets the total buffer memory size and DLCR6<3:2> sets the transmit buffer size. If the transmit buffer is greater than 2KBytes, it is divided into two transmit banks as shown in the table below.

BS1 DLCR6(1)	BS0 DLCR6(0)	TS1 DLCR6(3)	TS0 DLCR6(2)	TOTAL BUFFER MEMORY	TRANSMIT BUFFER MEMORY		RECEIVE BUFFER MEMORY
					TX BANK #1	TX BANK #2	
0	0	0	0	8KBYTES	2KBYTES	--	6KBYTES
0	0	0	1	8KBYTES	2KBYTES	2KBYTES	4KBYTES
0	0	1	0	Illegal set-up			
0	0	1	1	Illegal set-up			
0	1	0	0	16KBYTES	2KBYTES	--	14KBYTES
0	1	0	1	16KBYTES	2KBYTES	2KBYTES	12KBYTES
0	1	1	0	16KBYTES	4KBYTES	4KBYTES	8KBYTES
0	1	1	1	Illegal set-up			
1	0	0	0	32KBYTES	2KBYTES	--	30KBYTES
1	0	0	1	32KBYTES	2KBYTES	2KBYTES	28KBYTES
1	0	1	0	32KBYTES	4KBYTES	4KBYTES	24KBYTES
1	0	1	1	32KBYTES	8KBYTES	8KBYTES	16KBYTES
1	1	0	0	64KBYTES	2KBYTES	--	62KBYTES
1	1	0	1	64KBYTES	2KBYTES	2KBYTES	60KBYTES
1	1	1	0	64KBYTES	4KBYTES	4KBYTES	56KBYTES
1	1	1	1	64KBYTES	8KBYTES	8KBYTES	48KBYTES

The remaining buffer memory that is not used by the transmit memory will be used as the receive memory. Figure 2-1 shows an example of a buffer memory configuration of 64 KBytes.

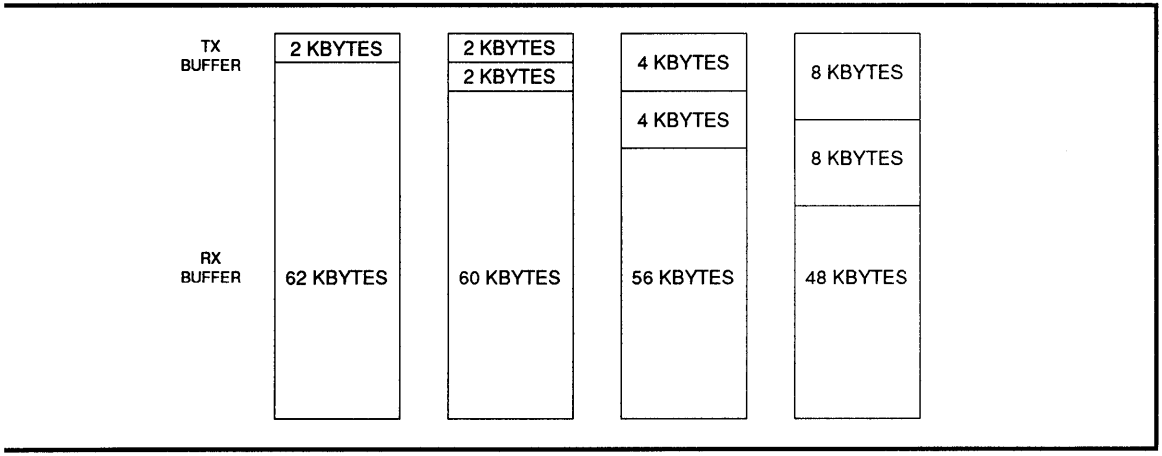


Figure 2-1: Maximum Buffer Size (64 KBytes) for Transmit and Receive Buffers

2.1 BUFFER MEMORY CONFIGURATION (continued)

The buffer memory path of the SSI 78Q8373 is 8 bits wide in PCMCIA Bus mode and can be either 8 or 16 bits wide in Generic Bus mode (The 8-bit path in PCMCIA mode is imposed due to the lack of enough pins). In the Generic Bus mode, the buffer memory data path width is selected through DLCR6<4>. If DLCR6<4> is set to a 1, then the SSI 78Q8373 data path will be byte-wide. There are eight different SRAM configurations depending on whether the data path is 8- or 16-bit (refer to Figure 2-2). The $\overline{RCS0}$ and $\overline{RCS1}$ are the SRAM chip select pins. In the 8 bit-data bus for 8KByte and 32KByte configurations, only $\overline{RCS0}$ is used and the address least significant bit starts from A0. Figure 2-2 shows the configurations possible for the SRAM.

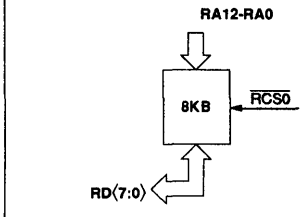
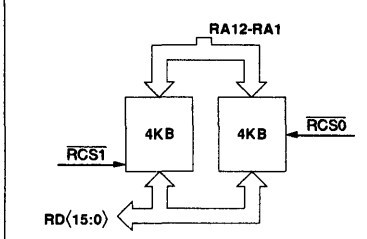
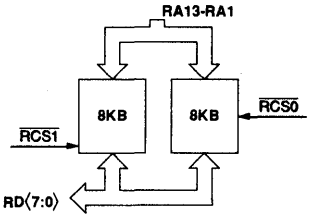
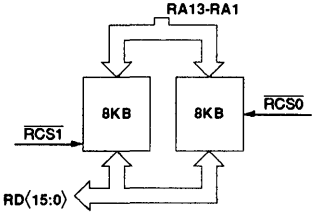
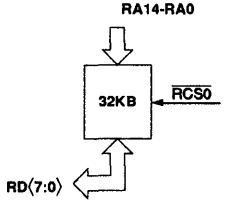
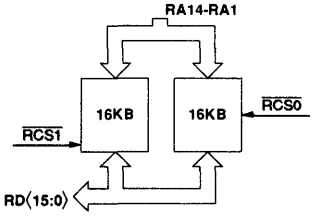
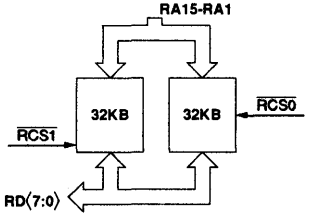
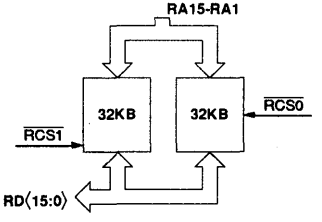
DLCR6 ⟨1:0⟩	8 Bit RAM Data Bus: DLCR6 ⟨4⟩ RBYTE = 1 DLCR6 ⟨5⟩ HBYTE = 0 OR 1	16 Bit RAM Data Bus: available in Generic Bus mode only DLCR6 ⟨4⟩ RBYTE = 0 DLCR6 ⟨5⟩ HBYTE = 0
BS1,0 = 0,0		
BS1,0 = 0,1		
BS1,0 = 1,0		
BS1,0 = 1,1		

Figure 2-2: SRAM Configurations

TRANSMIT OPERATION

The SSI 78Q8373 complies with the IEEE 802.3 CSMA/CD specifications with a transfer rate of 10Mbit/s through the transmission medium. It will assemble all packets from the host and append a 64-bit preamble and a 32-bit CRC to the head and tail of each packet respectively before transmitting to the medium. As mentioned in the Buffer Memory Configuration section, one or more packets can be written by the system within a transmit memory bank until the remaining space is insufficient for another packet. The host can then issue a signal, called "Transmit start" which is stored in BMR10<7> to initiate a transmission to the medium. All packets within the same bank will thus be transmitted and followed by the status update or an interrupt if it is enabled. With the two transmit banks configuration, one bank can be transmitting and the second bank can be loading data from the system. This concurrent operation of transmitting and host writing will improve transmission throughput.

If the transmit packet encounter a collision in the medium, the SSI 78Q8373 will perform a truncated binary exponential backoff routine up to 16 attempts. After the 16th attempt, the SSI 78Q8373 will either skip the current packet or re-transmit the packet again depending on the status of BMR11<2:0>.

TRANSMIT PACKET DATA FORMAT

The packet to be transmitted is first loaded into the transmit buffer together with a 2-byte header of data length in bytes. Figure 2-3 shows an example of how 3 packets are stored within a single transmit buffer:

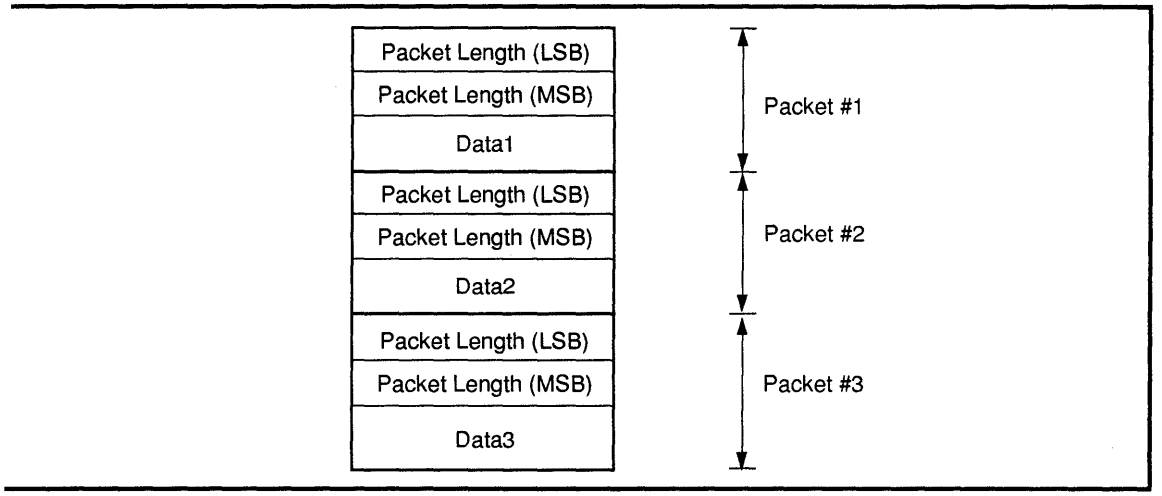


Figure 2-3: Packet Format in Transmit Buffer

After the packets are loaded, the host will write the number of packets to be transmitted into BMR10 and initiate transmission. At this stage, if a two transmit banks configuration is chosen, any new packets can now be loaded into the second bank.

RECEIVE OPERATION

The receive memory is configured as a ring structure which means the bottom of the memory is wrapped around to the top of the receive memory. There are two pointers to handle incoming packet management and they are the receive pointer and the host read pointer. The receive pointer will always point to the next empty location in the receive memory. The host read pointer is used by the host to retrieve accepted packets from the receive memory.

Initially, the values of the two pointers are equal which implies that the receive buffer is empty. As soon as data is loaded into the receive bank from the medium, the receive pointer will move away from the host read pointer. The preamble and the CRC bits are automatically removed by the data link controller (DLC) before storing the data to the receive buffer. While accepting the data, the size of the packet is checked. Under the IEEE specifications, the valid packet size is between 60 bytes to 1500 bytes (minus the preamble and CRC portions). However, if set to 1, the SSI 78Q8373 can accept packet sizes ranging from 6 bytes (by setting "accept short packet" in DLCR5<3> [ENA_SRTPKT] to a 1) to 2047 bytes. When a packet is successfully stored in the receive memory, the host can begin to read this packet. However, if there is more than one incoming packet or the packet size is too large, the receive pointer may override the host read pointer after wrapping around the ring structure. This situation is avoided with a buffer overflow flag, OVRFLO. When this flag is high, the receive pointer will not store any more data until the host read has cleared the memory.

2.4 RECEIVE OPERATION (continued)

Figure 2-4 shows the configuration of the transmit and receive buffer memory in the situation where the 2 transmit banks are selected and explains the concept of a ring architecture of the receive buffer. The received packets are stored as they are accepted by the SSI 78Q8373. The unused buffer space in the diagram shows that the host have read packets before 'Packet P-1' hence relieving that buffer space. Therefore the received packet 'Packet P+2' can be wrapped around the end of the receive buffer to the start once again.

The SSI 78Q8373 also checks the incoming packet for short packet errors, alignment errors and/or CRC errors. After one successful packet reception, the SSI 78Q8373 will perform an 8-byte re-alignment for the next packet in the receive buffer.

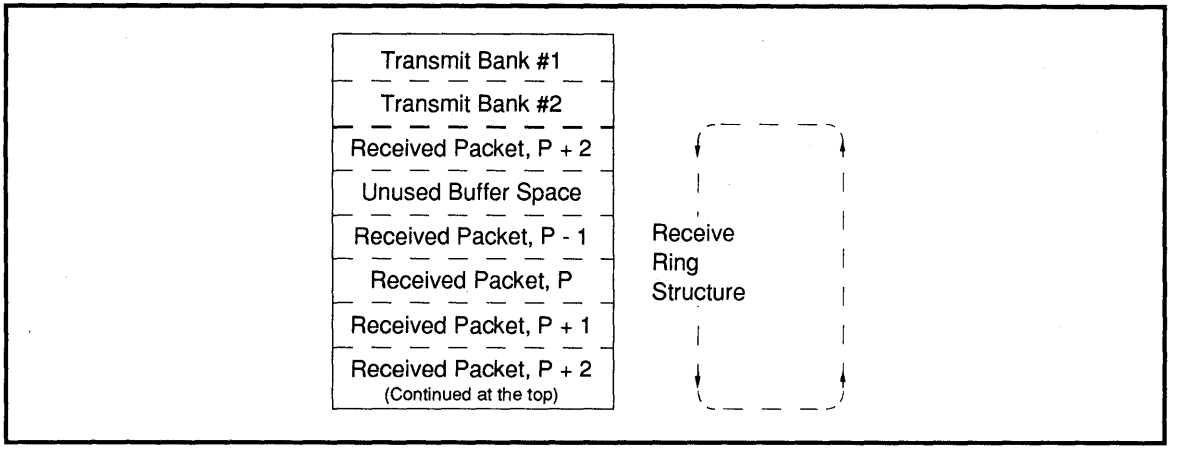


Figure 2-4: Transmit and Receive Buffer Organization

2.4.1 RECEIVER BUFFER DATA FORMAT

The receive packet has a 4-byte header which consists of the status of the receive packet, a reserved byte, and the 2 bytes of data length. Regardless of the SRAM word or byte configuration, the data length is always in terms of bytes. The data packets are linked by the internal pointers which use the data length value in the header to calculate the length of the data packet. Then the receiver will perform an 8-byte boundary alignment and the new address is generated. Under normal operation, any packets that have errors will be discarded. Figure 2-5 shows how accepted packets are stored in the receive buffer.

The SSI 78Q8373 provides a means to accept erroneous packets, mainly for testing purposes. If the DLCR5<5> bit (ACPT_BADPKT) is set to a 1, short packets or packets with alignment or CRC errors will be accepted. In these circumstances, the respective bits of the receive status registers will not be set. But the status byte to the host will still indicate that the packet has error(s).

The format of the status byte is as shown below. Note that the bit names are similar to that of the DLC register bits. However, some of these bits are not a mirror image of the corresponding register bits and this is elaborated on in the Status Byte Format section.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	*PACKET OK*	*REMOTE RESET*	*SHORT ERROR*	*ALIGN ERROR*	*CRC ERROR*	*OVER FLOW*

2.5 DMA OPERATION

Data transfer via Direct Memory Access is available only in the Generic Bus mode. The DMA write or DMA read operation is similar to the I/O write or I/O read except that the handshake is done using DMREQ, $\overline{\text{DMACK}}$ and EOP signals. The DMREQ signal is used to request for DMA transfers and the $\overline{\text{DMACK}}$ signal acts like the CS to access the BMR8 and BMR9 register pair. The $\overline{\text{WR}}$ or $\overline{\text{RD}}$ signals accompany the $\overline{\text{DMACK}}$ to perform host write or host read operations respectively.

An EOP signal is asserted during the last data word or byte transfer to terminate the process (the DMA_EOP register bit [DLCR1<5>] will be set when EOP is asserted). The SSI 78Q8373 will not assert further DMREQs when EOP has been asserted by the host DMA. If the DMA interrupts are enabled, the assertion of the EOP will also cause the SSI 78Q8373 to generate an interrupt to the host.

DMA OPERATION (continued)

Single or burst DMA operations are supported for data transfer between the host and the SSI 78Q8373. In single byte or word accesses, the SSI 78Q8373 asserts the DMREQ signal and waits for the host to respond with a $\overline{\text{DMACK}}$ acknowledge and a $\overline{\text{WR}}$ or $\overline{\text{RD}}$ signal. Upon acknowledgment, the SSI 78Q8373 negates the DMREQ until the host completes the data transfer. The $\overline{\text{DMACK}}$ signal is set high when the transfer is complete. To start another DMA cycle, the SSI 78Q8373 will assert the DMREQ signal again. This continues until the host asserts the EOP signal during the last access cycle after which the SSI 78Q8373 will not make further DMREQ requests.

In burst modes, the DMA operation can be programmed for 4, 8 or 12 data transfers per DMREQ request. In these cases, the SSI 78Q8373 will negate DMREQ two cycles before the end of each burst. An EOP assertion will terminate a DMA operation anytime during the burst data transfer.

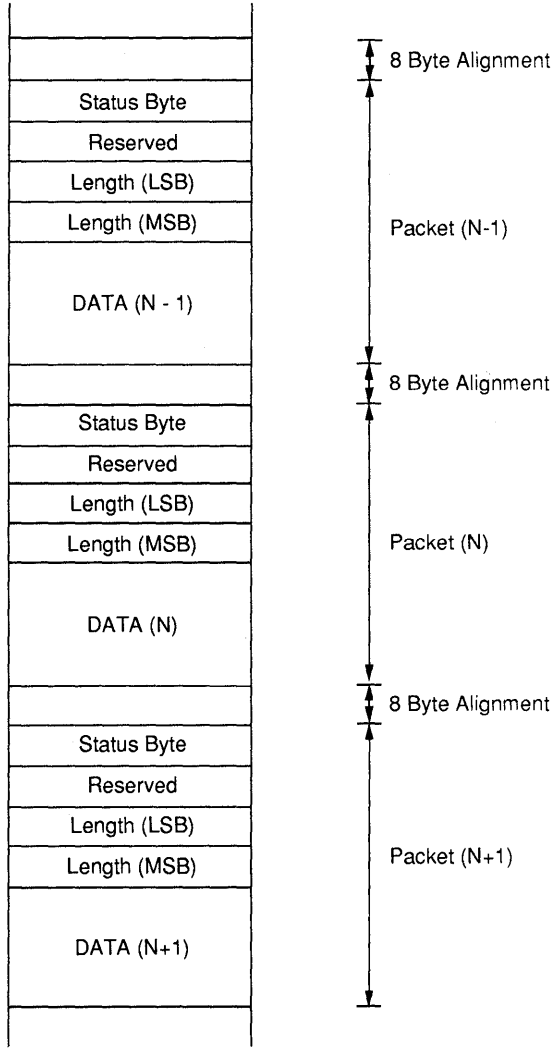


Figure 2-5: Packet Format in Receive Buffer

2.5.1 DMA WRITE (TRANSMIT)

In a DMA write mode, the host performs the same function as an I/O write to load the transmit bank with one or multiple packets of data. Typically the host has its own DMA controller which it programs to handshake with the DMA operation in the SSI 78Q8373. The host can use a combination of I/O and DMA to write a packet into the transmit buffer.

The following depicts an example of how to perform a DMA write mode using a combination of I/O and DMA operation. First, the host determines the size of the packet and writes the byte length into the SSI 78Q8373's transmit buffer using I/O access. Subsequently, the host DMA is programmed with this length information. To start a DMA transfer, the host writes a 1 to the DMA_TENA bit (BMR12<0>). The SSI 78Q8373 will assert a DMREQ request and wait for the $\overline{\text{DMACK}}$ acknowledgment to start the DMA write process. When the acknowledgment is confirmed by the host DMA, the data packets are transferred into the transmit buffer. An EOP signal is asserted when the last byte is written to the SSI 78Q8373. If the DMA_EOP interrupt (DLCR1<5>) is enabled, the SSI 78Q8373 will interrupt the host upon completion. Writing a 0 to the DMA_TENA bit disables the DMA write operation. The host can then initiate the next DMA transfer.

When the host interface is configured for word mode, the packet length value written to the SSI 78Q8373 will still be in bytes. Hence, the host has to program the host DMA with half the byte count for word transfer. If the byte count is odd, the host should round it up before halving it. This results in an extra byte written to the transmit buffer which the SSI 78Q8373 discards during the transmit process. The internal transmit buffer alignment for odd size packets are automatically handled by the SSI 78Q8373.

2.5.2 DMA READ (RECEIVE)

In a DMA read mode, the host performs the same function as an I/O read to retrieve the data from the SSI 78Q8373's receive buffer. The following depicts an example of how to perform a DMA read mode using a combination of I/O and DMA operation.

If the receive buffer is not empty, the host will read the status and packet length information in the 4-byte header of the receive packet using I/O access. This length information is then programmed into the host DMA. To initiate a DMA transfer, the host writes a 1 to the DMA_RENA bit (BMR12<1>). The SSI 78Q8373 will assert the DMREQ request and wait for the $\overline{\text{DMACK}}$ acknowledgment to start the DMA read process. Upon the $\overline{\text{DMACK}}$ acknowledgment, the packets are retrieved from the receive buffer. The EOP signal is asserted on the last byte read from the receive buffer. If DMA_EOP interrupt (DLCR1<5>) is enabled, the SSI 78Q8373 will interrupt the host. The host will write a 0 to the DMA_RENA bit to disable the DMA read operation. It can then initiate the next DMA transfer.

When the host interface is configured for word mode, the host DMA is programmed with the half the byte length as described in the DMA write section. In the case of an odd packet length, the host will read an extra byte and discard it. The SSI 78Q8373 will also manage its internal receive buffer alignment for odd size packets.

DATA LINK CONTROLLER

The Data Link Controller (DLC) implements the ISO/ANSI/IEEE 8802-3 CSMA/CD protocol. It consists of a Transmitter and a Receiver, each with its own independent CRC logic. Automatic generation and stripping of the 64-bit preamble and the 32-bit CRC code are provided on-chip.

IEEE PACKET FORMAT

The DLC of the SSI 78Q8373 complies with the international standards for Ethernet, ISO/ANSI/IEEE 8802-3. The IEEE 802.3 Media Access Control (MAC) frame format is shown in Figure 3-1.

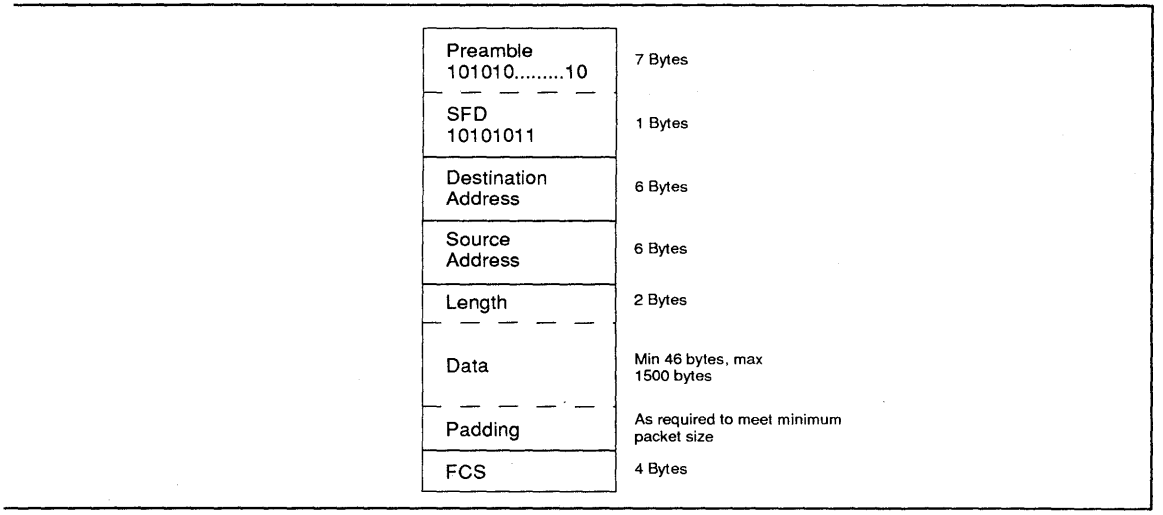


Figure 3-1: IEEE 802.3 Media Access Control (MAC) Frame Format

1.1 ELEMENTS OF THE MAC FRAME

The MAC frame size is defined to cover the Destination and Source Address fields, Length Field, Data Field, Padding (if necessary) and Frame Check Sequence Field (CRC Code). The minimum frame size defined in the IEEE Media Access Control Protocol is 64 bytes and the maximum frame size is 1518 bytes.

Preamble Field:

This is a 7-byte field consisting of alternating 1's and 0's to allow synchronization of phase lock loop (PLL) circuitry in the receiver.

Start Frame Delimiter (SFD) Field:

The SFD sequence is 10101011. This immediately follows the preamble and the double 1's signify the start of the frame.

Address Fields:

Each MAC frame consists of two address fields. The Destination Address Field specifies the destination address(es) for which the frame is intended and the Source Address Field specify the node that is transmitting the packet. The first bit (LSB) of the Destination Address is used to identify individual or group addressing. LSB = 0 indicates an individual address and LSB = 1 indicates a group address. The SSI 78Q8373 offers 3 types of group addressing called multicast group, multicast hash and broadcast addressing. A broadcast address consists of all 1's in the Destination Address field and is used to broadcast to all active stations on the network. Please refer to Node ID and Hash Table Configuration Registers for detailed information on the other two multicast addresses.

Length Field:

This is a 2-byte field whose value indicates the number of data bytes in the Data Field. The Length Field is transmitted with the high order byte first. However, some protocols use this field for other purposes (Ethernet calls this a **Type Field** instead). This is achieved by using values greater than the allocated values for a valid Length Field (value < 1500) to distinguish the protocol used. The SSI 78Q8373 does not perform a consistency check on the length of the data field that follows this field.

Data and PAD Fields:

The data field may contain any data from a minimum of 46 bytes to a maximum of 1500 bytes. If necessary, the data field is extended to meet the minimum frame size requirement. These extra bits are called Padding. The SSI 78Q8373 does not perform automatic padding. Upper layer software is responsible for this task.

Frame Check Sequence Field:

A cyclic redundancy check (CRC) is used by the transmit and receive algorithms to generate a CRC value for the FCS field. This is a 32-bit sequence that is computed as a function of the addresses, length, data (and pad) fields. The SSI 78Q8373 has a CRC circuitry that generates the CRC for the packet to be transmitted and checks the CRC of the received packets for transmission errors.

3.2 TRANSMITTER CIRCUITS

Circuits within the transmitter include a transmit state machine, pseudo-random number generator, preamble generator, inter-frame gap timer, exponential backoff generator and a time domain reflectometry counter. The CRC logic is shared by the transmitter and the receiver. Any transmit errors will be reported via the DLCR status registers.

The CRC logic calculates the IEEE 32-bit Frame Check Sequence (FCS) for the entire data packet (from the destination address to the end of the data field) and appends the FCS to the end of the packet. In the event of self-reception in 'accept all packets' modes or loop back, the CRC logic is used by the transmitter only.

3.2.1 Transmit Media Access Management

The SSI 78Q8373's DLC block implements the ISO/ANSI/IEEE 8802-3 Media Access Protocol called the CSMA/CD. This is the acronym for Carrier Sense Multiple Access with Collision Detect. Abiding by this protocol requires the controller to monitor the presence of a carrier from other nodes on the network and deferring any transmission if a carrier is 'sensed' on the network. A collision is defined by the situation whereby two nodes transmit at nearly the same time and try to drive the network together which results in garbled data. In the event that a collision occurs, this is detected via the collision detection mechanism. A node that is involved in a collision will transmit a 32-bit Jam Pattern to reinforce the collision such that every node on the network detects it. It will then cease its transmission and wait a pseudo-random backoff interval before attempting to transmit the packet again.

According to the ISO/ANSI/IEEE 8802-3, there must be a 9.6 msec interval between the transmission of packets for the network to recover. This is called the Inter-Frame Gap (IFG) and the SSI 78Q8373's DLC utilizes the IFG timer in the transmitter to record the interval starting from the end of the last packet on the network. The DLC will not transmit before this interval expires. If another node happens to transmit during the first 2/3 of the IFG interval, the SSI 78Q8373 will reset its IFG counter and start again at the end of this new transmission. However during the last 1/3 of the IFG interval, the SSI 78Q8373 will ignore any transmission on the network that occurs during that time in accordance with the IEEE standard. This is to assure fairness and equality in accessing the network. With two nodes transmitting at nearly the same time, a collision would occur resulting in pseudo-random backoff intervals for each node to resolve the contention.

The SSI 78Q8373's TDR counter keeps track of the number of bits that has been transmitted. The counter maintains the count of the actual number of bits transmitted just before a collision or loss of carrier occurs. The count can then be used to diagnose the medium as shown.

Estimating the distance, D (m) from the transmitting node to a fault:

N = number of bits transmitted (TDR Count)

R = transfer rate, 10 Mbit/s

S = signal propagation for coaxial cable (in the region of 2×10^8 m/sec

D = (N x S)/(2 x R) meters

A pseudo-random number generator is used for collision backoffs. The range of the random number interval increases with each collision with the maximum range occurring for the 10th collision through the 16th collision. Hence it is called the truncated binary exponential backoff. The value obtained from the pseudo-random number generator is counted down every slot-time (512 bits). When the interval expires, the SSI 78Q8373 will check the IFG timer and attempt to re-transmit.

.2 Transmit Errors

There are 4 transmit error status bits in DLCR0. These cover the loss of carrier during collision, collision on the network, 16 consecutive collisions and host write error. The loss of carrier usually indicates a fault on the network (open or shorted medium). The 16 collisions error indicates that host intervention may be necessary pertaining to the next step that the SSI 78Q8373 should take. Please refer to Buffer Memory Registers Section (BMR11<2:0>). Host write error occurs when the host tries to write beyond the end of the allocated transmit buffer. Interrupts can be generated for the collision, 16 collisions and host write errors.

The collision counter DLCR4<7:4> with DLCR4<7> as the most significant bit, automatically increments every time a collision occurs. Upon the 16th collision, it will roll over to zero and set the 16COL bit (DLCR0<1>) to 1. The 16 collisions error could be an indication of a faulty medium or an overloaded network.

.3 Encoder/Decoder

The SSI 78Q8373 includes an internal Manchester Encoder/Decoder (ENDEC) which converts the serial NRZ bit stream for transmission to a format used on the network. This conversion is known as Manchester Encoding which uses edges at the mid-point of a bit interval to signify a 1 or a 0. A low-to-high transition at the mid-point indicates a 1 and a high-to-low transition indicates a 0.

RECEIVER CIRCUITS

Circuits within the receiver include a receive state machine, preamble and start of frame delimiter recognition, address recognition, error detection logic, byte alignment checking, serial to parallel converter and receive FIFO. Receive errors such as short packet error, CRC error, alignment error, and buffer overflow error are reported via the DLCR status registers and the status byte header preceding each packet stored in the RAM.

The receive FIFO provides buffering while the Buffer Manager is servicing another resource and enables the loading of data into the SRAM only when necessary, i.e., on the acceptance of a packet. The preamble and start of frame delimiter is stripped from the packet before loading it into the receive buffer. The last four bytes of the packet (CRC) remain in the receive FIFO and are not transferred to the receive buffer.

The CRC logic calculates the IEEE 32-bit Frame Check Sequence (FCS) for the entire data packet (from the destination address to the end of the packet including the transmitted CRC) and the resultant should be a fixed constant if no errors occurred during the transmission.

3.1 Receive Media Access Management

As a bit stream is present on the network, the PLL in the internal ENDEC of the SSI 78Q8373 will lock-on to the stream of alternating 1's and 0's (the preamble pattern). The ENDEC performs the decoding function of the Manchester encoded data on the network for the receiver. The receiver monitors the decoded bit stream (NRZ format) for the end of the preamble pattern i.e. the start of frame delimiter byte pattern which is '10101011'. The two consecutive 1's in this pattern signifies the start of the first bit of the first byte of the destination address field.

The SSI 78Q8373 allows the acceptance of packets with physical or logical addressing. Physical addressing requires the exact matching of the entire 6 bytes of destination address and the Node ID. Logical addressing comes in three forms for the SSI 78Q8373: broadcast, multicast group and multicast hash addressing. The first bit of the 48-bit destination address is a 0 if the address is a physical address . If the address is a logical address then the first bit of destination address is a 1. Broadcast messages are messages that are meant for all nodes on the network and the destination address of a broadcast packet consists of all 1's. A multicast group address has the first bit of the destination address as a 1 and the receiver will only match the first 3 bytes of the incoming address before deciding to accept or reject the packet. For multicast hash addressing, the CRC logic performs the calculation for the 48-bit address and the least significant 6 bits are used to hash into the SSI 78Q8373's 64 element hash table. If the hashed element has been set to a 1 then the packet will be accepted. If the hashed element has been set to a 0, the packet will be rejected.

During initialization, appropriate bits are set in the Address Mode registers (DLCR5<1:0>) and command bits in DLCR5 for 'bad packet' (packets with errors) acceptance and so forth. As a packet is received from the network, its destination address will be matched following the criteria of the Address Mode and DLCR5 registers. Once the destination address matches according to that criteria, the packet is accepted and is loaded into the receive buffer. The last 4 bytes of the received packet (32-bit CRC) are not transferred to the receive buffer. If the destination address fails to meet the criteria, the packet is rejected and the receiver continues to monitor the network.

.3.2 Receive Errors

There are 5 receive status errors in DLCR1. These include the host read error, short packet error, alignment error, CRC error and buffer overflow error. Host read error results when the host attempts to read from an empty receive buffer. RX_BUFMTY bit in DLCR5<6> is set to 1 by the SSI 78Q8373 when the receive buffer is empty. Short packet error occurs when a packet is less than the IEEE minimum of 60 bytes in length is received. This packet will not be accepted unless the ENA_SRTPKT bit (DLCR5<3>)

has been activated. Packets with alignment or CRC or short packet errors are accepted only if the ACPT_BADPKT bit (DCLR5<5 is set to a 1. Alignment error indicates an incomplete byte frame at the end of a packet and CRC error indicates an error has occurr during transmission. A CRC error occurs when the received packet is checked by the CRC logic (from destination address to t end of the packet including the appended CRC) and the resultant is not the fixed constant expected in a no-error transmission. Sh packet error is set if the received packet is less than the minimum length of 60 bytes. Buffer overflow error signals insufficient spa in the receive buffer for the current packet and requires the host to read packets from the receive buffer to relieve more buffer spa

3.3.3 Encoder/Decoder

The internal ENDEC performs the recovery of the receive clock RXC, carrier detection and Manchester decoding of the data strea from the network. The received data stream is transferred to the ENDEC circuit block via either the on-board twisted-pair transceiv circuit or the AUI circuit, depending on which is active. When the ENDEC block receives a signal from the twisted-pair transceiv or the AUI circuit, it converts this carrier detection into the CRS signal for the controller. The recovered clock, RXC is achiev through the digital phase lock loop (DPLL) in the ENDEC which tries to synchronize to the incoming 5 MHz stream. (The preamb consists of alternating 1's and 0's when converted to Manchester encoding produces this waveform). The data stream is then decod to NRZ format with the recovered RXC. This is passed to the controller as the received data, RXD. During idle periods, the RX is not active.

3.4 LOOP BACK MODES

The SSI 78Q8373 provides for 2 types of loop back testing. They are defined as follows:

i) ENDEC Loop Back

ii) Media Loop Back (Twisted-pair transceiver or AUI Port)

Loop back i is used for testing functionality of the Manchester Encoder/Decoder (ENDEC). This can be invoked by setting th appropriate bit in the DLCR4<1>, but is intended for diagnostic testing only, and should not be set during normal operation. Th Media Loop Backs are basically a normal transmission with a self-addressed packet or setting the Address Modes to an "accept a packets" mode (i.e. promiscuous mode occurs when AM<1,0> = 11). All of these loopbacks are illustrated in Figure 3-2.

For the ENDEC loop back, data is routed from the transmit buffer to the transmitter of the DLC, through the Manchester Encod which loops the decoded data back to the Manchester decoder. The decoder decodes the Manchester code and passes the NR data to the receiver of the DLC which then stores it in the receive buffer. The $\overline{\text{EDLOOP}}$ bit (DLCR4<1>) is set to 0 for this loo back mode. This permits testing of the DLC's transmit and receive sections and the Manchester encoding and decoding section. The host software can then read and verify the received data.

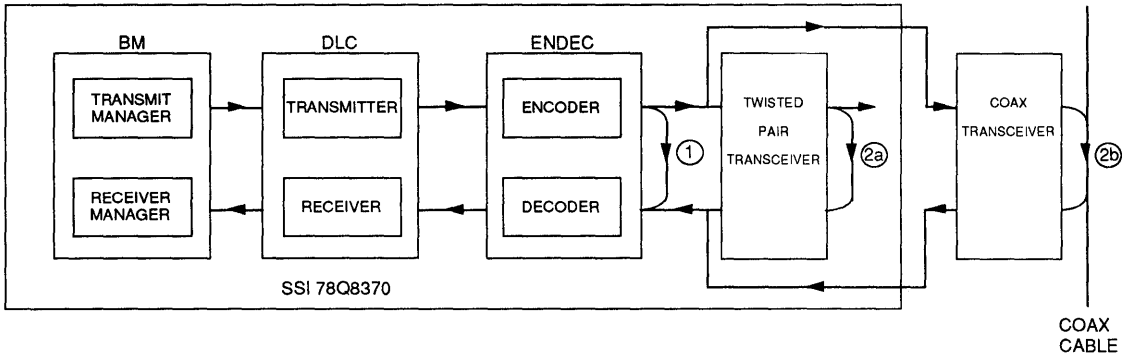
For the Media loop backs, data is routed from the transmit buffer to the transmitter of the DLC through the ENDEC and the mediur (via either the internal twisted-pair transceiver or the AUI port, depending on which interface is selected) then back to the receive of the DLC. This occurs when the SSI 78Q8373 is in the 'accept all packets' mode (promiscuous) where all packets that th transmitting node sends are accepted. Another way of achieving this effect is to send a packet with the destination address equa to the source address. This permits testing of the entire loop starting from the DLC to the medium and back. The host software ca then read and verify the received data.

3.4.1 Self-Reception Criteria

In a normal operating mode, self-reception is only possible when the destination address of the transmitted packet matches th transmitting station's Node ID (physical address match). In this case, the transmitting station will not receive its own multicas (group or hash) or broadcast messages.

If the ENDEC Loopback mode is activated, the address recognition logic in the receiver will treat the loop back message as if it wa coming from the medium. Thus if a match occurs (physical, multicast or broadcast), self-reception will take place.

In the 'accept all packets' mode, self-reception is guaranteed to happen for any transmission.



(1) ENDEC Loopback

(2a) Media (TP connection) Loopback

(2b) Media (AUI connection) Loopback

Figure 3-2: 78Q8373 Loop Back Modes

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4 POWER MANAGEMENT

SSI 78Q8373 provides 3 modes of intelligent power management:

1) Auto power down mode through BMR11<6>.

This mode is the default at reset/power up. The clocks are active only when they are needed. This auto power down mode ca be disabled by programming a 1 which can be useful for chip debugging and maximum power consumption estimation.

2) Standby mode through DLCR7<5> or through CCR1<2>.

Set DLCR7<5> = 0 to enter this mode, or, if the SSI 78Q8373 is in PCMCIA mode, set CCR1<2> = 1. This de-gates the oscillato clock without shutting it off. All the internal clocks are not active with the oscillator still running. Using full static design, th SSI 78Q8373 remembers all of the register settings, memory pointer values and the status of the state machines prior to enterin standby mode. It can resume normal operation again when this bit is disabled.

3) Oscillator shut off through BMR11<7>.

WARNING: This bit may only be set if using the internal oscillator. Setting this bit while using an external canned oscillato can damage the chip.

Due to the above danger, this bit can only be set (hardware protected) after the standby mode has been entered. Thus, accidenta write can be prevented. The users need to be aware that the oscillator needs some time to stabilize. This startup time is typicall 2 msec for SSI 78Q8373.

The following programming sequence is recommended for entering this mode:

i) Check that SSI 78Q8373 is idle (i.e. not in the middle of an operation).

ii) Set DLCR7<5> to '0' to enter standby mode.

iii) Set BMR11<7> to '1' to shut off the internal oscillator.

(SSI 78Q8373 is now in its lowest power consumption configuration).

The 'wake up' sequence is as follows:

i) Set BMR11<7> to '0' to turn on the internal oscillator.

ii) Allow some time for the internal oscillator to stabilize. This is typically 2 msec.

iii) Set DLCR7<5> to '1' to go back to the normal mode.

CONTROL AND STATUS REGISTERS

The registers in the SSI 78Q8373 can be divided into six groups: 1) Data Link Control Registers (DLCR0-7); 2) Node ID registers (IDR8-13); 3) Time Domain Reflectometry Registers (TDR14-15); 4) Hash Table Registers (HTR8-15); 5) Buffer Memory Registers (BMR8-15); 6) PCMCIA Registers (CCR0-1).

The Data Link Control Registers contain the transmit and receive status information, interrupt enable, SSI 78Q8373 setup and software reset bit (DLCR6<7>). They are accessed through direct register addresses xxx0H through xxx7H. The Ethernet Node ID is stored in IDR(8-15). The TDR(14-15) registers are used to provide the count value of the number of bits transmitted for each packet. This value can indicate whether a packet has completed its transmission or has encountered a collision. Both the Node ID and the Time Domain Reflectometry Registers can be accessed through direct register addresses xxx8H through xxxFH.

The Hash Table Registers (HTR8-15) provides a means for filtering incoming multicast packets. Any packet that does not match the hash table coding will be rejected. The HTR8-15 can be accessed by the bank-switching addresses RBNK1,0 (DLCR7<3:2>).

The tasks performed by the Buffer Memory Registers (BMR8-15) include transferring of packets between the host and SSI 78Q8373 (via BMR8-9), collision control, DMA operations and activation of the transmit operation including control of the internal 10BaseT transceiver.

The final group of the registers belongs to the PCMCIA Registers (CCR0-1), which are used for controls specific to operation in a PCMCIA card environment.

A summary table of the registers and their addresses are tabulated below:

CCRA	RBNK1, 0	HA3	HA2	HA1	HA0	ADDRESS	DESCRIPTION
X	XX	0	0	0	0	DLCR0	Transmit Status
X	XX	0	0	0	1	DLCR1	Receive Status
X	XX	0	0	1	0	DLCR2	Transmit Interrupt Mask
X	XX	0	0	1	1	DLCR3	Receive Interrupt Mask
X	XX	0	1	0	0	DLCR4	Transmit Mode
X	XX	0	1	0	1	DLCR5	Receive Mode
X	XX	0	1	1	0	DLCR6	Configuration 0
X	XX	0	1	1	1	DLCR7	Configuration 1
X	00	1	0	0	0	IDR8	NODE ID 0
X	00	1	0	0	1	IDR9	NODE ID 1
X	00	1	0	1	0	IDR10	NODE ID 2
X	00	1	0	1	1	IDR11	NODE ID 3
X	00	1	1	0	0	IDR12	NODE ID 4
X	00	1	1	0	1	IDR13	NODE ID 5
X	00	1	1	1	0	TDR14	TDR 0 (LSB)
X	00	1	1	1	1	TDR15	TDR 1 (MSB), select 3V
X	01	1	0	0	0	HTR8	Hash Table 0
X	01	1	0	0	1	HTR9	Hash Table 1
X	01	1	0	1	0	HTR10	Hash Table 2
X	01	1	0	1	1	HTR11	Hash Table 3
X	01	1	1	0	0	HTR12	Hash Table 4
X	01	1	1	0	1	HTR13	Hash Table 5
X	01	1	1	1	0	HTR14	Hash Table 6
X	01	1	1	1	1	HTR15	Hash Table 7
X	10	1	0	0	0	BMR8	Buffer Memory I/O Port
X	10	1	0	0	1	BMR9	Buffer Memory I/O Port (word mode)
X	10	1	0	1	0	BMR10	Transmit Start + Packet Count
X	10	1	0	1	1	BMR11	16 Collisions Control
X	10	1	1	0	0	BMR12	DMA Enable
X	10	1	1	0	1	BMR13	DMA Burst & Transceiver Mode
X	10	1	1	1	0	BMR14	Receiver Filter & Interrupt Enable
X	10	1	1	1	1	BMR15	Transceiver Status
X	11	X	X	X	X	–	RESERVED
1	XX	0	0	0	0	CCR0	PCMCIA Configuration Option
1	XX	0	0	0	1	CCR1	PCMCIA Card Config. & Status

Note: All registers are both word and byte accessible. In word mode, register bytes are paired up. In the case of odd-byte packet, the odd-address byte becomes the high byte of the word. In byte mode, only BMR8 will be used. IDR and HTR can only be accessed when $\overline{\text{ENADLC}}$ (DLCR6<7>) is a '1.' The CCR0 and CCR1 registers are visible only if the chip is configured in PCMCIA mode.

A register bit-map is also included for the Data Link Controller Registers, Buffer Manager Registers, and PCMCIA registers. Also shown are the default values for each register. Shaded bits are non-writeable.

Register Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit3	Bit 2	Bit 1	Bit0
Transmit Status **DLCR0**	TXOK 0	NET_BSY 0	SELF_RX 0	TX_ERR 0	JABBER 0	COL 0	16COL 0	HWR_ERR 0
Receive Status **DLCR1**	PKT_RDY 0	HRD_ERR 0	DMA_EOP 0	RMTRST 0	SRT_ERR 0	ALG_ERR 0	CRC_ERR 0	OVRFLO 0
Tx Interrupt Enable **DLCR2**	TXOK INT ENABLE 0	RESERVED BIT 0	SELF_RX INT ENABLE 0	RESERVED BIT 0	JABBER INT ENABLE 0	COL INT ENABLE 0	16COL INT ENABLE 0	HWR_ERR INT ENABLE 0
Rx Interrupt Enable **DLCR3**	PKT_RDY INT ENABLE 0	HRD_ERR INT ENABLE 0	DMA_EOP INT ENABLE 0	RMTRST INT ENABLE 0	SRT_ERR INT ENABLE 0	ALG_ERR INT ENABLE 0	CRC_ERR INT ENABLE 0	OVRFLO INT ENABLE 0
Transmit Mode **DLCR4**	COL 3 0	COL 2 0	COL 1 0	COL 0 0	NO_BACK 0	NOT_CB 1	$\overline{\text{EDLOOP}}$ 1	DSC 0
Receive Mode **DLCR 5**	RESERVED BIT 0	$\overline{\text{RX}}$ BUFMTY 1	ACPT_ BADPKT 0	ADD_SIZE 0	ENA_ SRTPKT 0	ENA_ RMTRST 0	AM1 0	AM0 0
Config. 0 **DLCR6**	$\overline{\text{ENADLC}}$ 1	RAMSP 0	HBYTE 1	RBYTE 1	TS1 0	TS0 1	BS1 1	BS0 0
Config. 1 **DLCR7**	CTM 1 0	CTM 0 0	NOT_ STDBY 1	RDYSEL 0	RBNK1 0	RBNK0 0	EOPSEL 0	INTLMOT 0
Tx Packet Counter **BMR10**	TXST 0	PACKET CNT 6 0	PACKET CNT 5 0	PACKET CNT 4 0	PACKET CNT 3 0	PACKET CNT 2 0	PACKET CNT 1 0	PACKET CNT 0 0
16 Collision Control **BMR11**	OSC_OFF 0	$\overline{\text{AUTOPD}}$ 0	RESERVED BIT 0	RESERVED BIT 0	RESERVED BIT 0	$\overline{\text{HALT}}$ 0	RESTART 0	SKIP 0
DMA Enable **BMR12**	RESERVED BIT 0	RESERVED BIT 0	RESERVED BIT 0	RESERVED BIT 0	RESERVED BIT 0	RESERVED BIT 0	DMA_RENA 0	DMA_TENA 0
DMA Burst Control **BMR13**	$\overline{\text{APOL}}$ 0	RTH 0	$\overline{\text{ENLI}}$ 0	PORT_SEL 0	$\overline{\text{ASEL}}$ 0	DMT 0	DMAB1 0	DMAB0 0
Rx Pointer Control **BMR14**	RESERVED BIT 0	LD INT ENABLE 0	RESERVED BIT 0	RESERVED BIT 0	RESERVED BIT 0	SKP_RX 0	SQE INT ENABLE 0	RXF 1
Tranceiver Status **BMR15**	RESERVED BIT 0	LD 0	OWCOL 0	RESERVED BIT 0	RPI 0	RESERVED BIT 0	SQE 0	RESERVED BIT 0
Config. Option **CCR0**	SRESET 0	LEVIREQ 0	CI 5 0	CI 4 0	CI 3 0	CI 2 0	CI 1 0	CI 0 0
Card Config. & Status **CCR1**	RESERVED BIT 0	RESERVED BIT 0	IOIS8 0	RESERVED BIT 0	AUDIO 0	PWRDWN 0	INTR 0	RESERVED BIT 0

LEGEND DESCRIPTION

The legend (column L in the register tables) used to describe register initial values, readability and writeability are denoted by the following abbreviations:

R: READABLE
W: WRITABLE
C: CLEARABLE: Writing a '1' clears this bit; writing a '0' has no effect
H: CONDITIONALLY WRITABLE: The default values can only be changed depending on other conditions
0/1: Power-up/Reset Default value

DATA LINK CONTROLLER REGISTERS

There are 8 Data Link Controller registers that will provide the status and control signals between the SSI 78Q8373 and host. In the following sections, each register bit will be explained.

DLCR0 - Transmit Status Register

This register provides the transmit status to the host. These status bits can also produce interrupts if DLCR2 interrupt enable signals are set (see DLCR2 for details). The status bits can be cleared by writing a '1' to the respective bit but writing a '0' has no effect on it. Note that more than one status bit can produce a common interrupt signal. Hence it is advisable for the host to check this register to find out how many of the status bits could have caused the generation of the interrupt signal.

BIT	SYMBOL	L	DESCRIPTION
7	TXOK	R,C,0	TRANSMIT OK: When the packet is transmitted through the medium without any errors or skipped due to excessive collisions, this bit is set high. If DLCR2<7> is enabled, then the bit can trigger an interrupt to the host.
6	NET_BSY	R,0	NET BUSY: If this bit is read as 1, it indicates that the network is busy at the receiver. This bit reflects the status of the CRS signal.
5	SELF_RX	R,C,0	SELF RECEPTION: The bit is used to indicate that self-reception has occurred. Writing a 1 or power reset will clear this bit. If DLCR2<5> is enabled, it can trigger an interrupt to the host.
4	TX_ERR	R,0	TRANSMIT ERROR: When read as a 1, this bit indicates a possible collision on the network or a loss of carrier during transmission. Automatically cleared on the next transmission. Writing a '1' or a '0' has no effect.
3	JABBER	R,0	JABBER: When high, it indicates that excessive transmit length is detected by the internal jabber timer. This is a serious error condition which only occurs when the chip malfunctions. Can generate interrupts if enabled by the corresponding interrupt enable bit in DLCR2. This jabber error can only be cleared by hardware or software reset through DLCR6<7>.
2	COL	R,C,0	COLLISION: This bit is set high when a collision occurs on the data packet during transmission. The 78Q8373 performs up to 16 re-transmissions. If DLCR2<2> is enabled, it can trigger an interrupt to the host. The number of collisions is stored in DLCR4<7:4>.
1	16COL	R,C,0	16 COLLISIONS: If a data packet has suffered 16 unsuccessful transmission then this bit will set high. Generates an interrupt to the host if DLCR2<1> is enabled.
0	HWR_ERR	R,C,0	HOST WRITE ERROR: When the host attempts to write data to the transmit buffer memory and did not get the response from 78Q8373 after 2.4 msec, this flag is set. This is to indicate that the transmit buffer is full. If DLCR2<0> is enabled, it can trigger an interrupt to the host.

5.2.2 DLCR1 - Receive Status Register

This register provides the receive status to the host. These status bits can also produce interrupts if DLCR3 interrupt enable signa are set (see DLCR3 for details). The status bits can be cleared by writing a '1' to the respective bit. Writing a '0' has no effect the register bit. Note that more than one status bits can produce a common interrupt signal. Therefore it is best for the host to che this register to find out how many of the status bits could have caused the generation of the interrupt signal.

In this register, DLCR1<3:0> are status bits for the current received packet. If any of these bits are set then the packet will discarded. However, 'bad packets' can be accepted by the SSI 78Q8373 under the following settings:

(1). DLCR5<5>, ACPT_BADPKT set to high allows the acceptance of short packets and packets with alignment or CRC erro

(2). DLCR5<3>, ENA_SRTPKT set to high allows the acceptance of packets with length between 6 bytes and 2047 bytes.

BIT	SYMBOL	L	DESCRIPTION
7	PKT_RDY	R,C,0	PACKET READY: When a data packet is successfully loaded into the buffer memory, this bit is set. Can generate an interrupt if DLCR3<7> is enabled.
6	HRD_ERR	R,C,0	HOST READ ERROR: If the receive buffer is empty and the host has waited for the response from 78Q8373 for more than 2.4 msec during host read then this bit is set. Can generate an interrupt if DLCR3<6> is set.
5	DMA_EOP	R,0	DMA END OF PROCESS: When a DMA process is over, the host will assert a high to the EOP pin to indicate the end of process. Can generate an interrupt if DLCR3<5> is set. To clear this bit, a value of 00H must be written into BMR12. Writing either a '1' or '0' has no effect.
4	RMTRST	R,C,0	REMOTE RESET PACKET RECEIVED: This bit is set if a packet received contains the pattern 0900H in its Type Field and ENA_RMTRST (DLCR5<2>) is set to a 1. Can generate an interrupt if enabled by DLCR3<4>. The value on this bit is mirrored onto the pin RRST (pin 96).
3	SRT_ERR	R,C,0	SHORT PACKET ERROR: This bit is set when the received packet is less than 60 bytes (excluding preamble and CRC). 60 bytes is the IEEE minimum frame size. Can generate an interrupt if enabled by DLCR3<3>.
2	ALG_ERR	R,C,0	ALIGNMENT ERROR: Set when the receive packet has 1 to 7 extra bits at the end of the packet. This may be due to collision or faulty transceiver. Can generate an interrupt if enabled by DLCR3<2>.
1	CRC_ERR	R,C,0	CRC ERROR: Set when the packet has CRC errors indicating that the packet is corrupted. Can generate an interrupt if enabled by DLCR3<1>.
0	OVRFLO	R,C,0	RECEIVE BUFFER OVERFLOW: Set when the receive buffer is full. Can generate an interrupt if enabled by DLCR3<0>.

5.2.3 DLCR2 - Transmit Interrupt Enable Register

This register contains the bits to enable the status bits in DLCR0 to generate interrupts to the host.

BIT	SYMBOL	L	DESCRIPTION
7	TXOK INT ENABLE	R,W,0	TXOK INTERRUPT ENABLE: When set high, it enables transmit OK signal, TXOK to generate an interrupt.
6	0	N,0	RESERVED BIT.
5	SELF_RECP INT ENABLE	R,W,0	SELF RECEPTION INTERRUPT ENABLE: Enables the transmit receive in loop back to produce an interrupt.
4	0	N,0	RESERVED BIT.
3	JABBER INT ENABLE	R,W,0	JABBER INTERRUPT ENABLE: When high, enables JABBER to generate an interrupt.
2	COLLISION INT ENABLE	R,W,0	COLLISION INTERRUPT ENABLE: When high, enables COL to generate an interrupt.
1	16 COL INT ENABLE	R,W,0	16 COLLISION INTERRUPT ENABLE: When high, enables 16COL to generate an interrupt.
0	HWR_ERR INT ENABLE	R,W,0	HWR_ERR INTERRUPT ENABLE: When high, enables host write error signal, HWR_ERR to produce an interrupt.

2.4 DLCR3 - Receive Interrupt Enable Register

This register contains the bits to enable the status bits in DLCR1 to generate interrupts to the host.

BIT	SYMBOL	L	DESCRIPTION
7	PKT_RDY INT ENABLE	R,W,0	PKT_RDY INTERRUPT ENABLE: When this bit is set high, it will enable PKT_RDY (Packet Ready signal) to generate an interrupt.
6	HRD_ERR INT ENABLE	R,W,0	HRD_ERR INTERRUPT ENABLE: When high, enables HRD_ERR (Host Read Error) to generate an interrupt.
5	DMA_EOP INT ENABLE	R,W,0	DMA_EOP INTERRUPT ENABLE: When high, enables the DMA_EOP to generate an interrupt.
4	RMTRST INT ENABLE	R,W,0	RMTRST INTERRUPT ENABLE: When high, allows the RMTRST (Remote Reset Packet Received) to generate an interrupt.
3	SRT_ERR INT ENABLE	R,W,0	SRT_ERR INTERRUPT ENABLE: When high, enables SRT_ERR (Received Short Packet) to generate an interrupt.
2	ALG_ERR INT ENABLE	R,W,0	ALG_ERR INTERRUPT ENABLE: When high, enables ALG_ERR (Alignment Error) to generate an interrupt.
1	CRC_ERR INT ENABLE	R,W,0	CRC_ERR INTERRUPT ENABLE: When high, enables CRC_ERR to generate an interrupt.
0	OVRFLO INT ENABLE	R,W,0	OVRFLO INTERRUPT ENABLE: When high, enables OVRFLO (Receive Buffer Over flow) flag to generate an interrupt.

2.5 DLCR4 - Transmit Mode Register

This register contains the collision count value (up to 16 collisions). SSI 78Q8373 will attempt to re-transmit the current packet up to 16 times. After which, depending on the values setting in BMR11<2:0>, the host can either skip the current packet and continue to transmit remaining packets in the transmit buffer or re-transmit the current packet again.

BIT	SYMBOL	L	DESCRIPTION
7-4	COL3-0	R,0	COLLISION COUNT: These 4 bits store the collision counter value. Bit 3 is the most significant bit of the count.
3	NO_BACK	R,W,0	NO BACKOFF ENABLE: When set to 1, it will disable the binary exponential backoff circuitry.
2	NOT_CB	R,W,1	NOT_CONTROL BIT: The inverse of this bit is available for general use on th CB pin.
1	EDLOOP	R,W,1	ENDEC LOOP BACK: Active low. This bit enables the loop back function of the 78Q8370-ENDEC. Loop back is active when this bit is set to '0'.
0	DSC	R,W,0	DISREGARD CARRIER: Program this bit to zero for normal network operation. When set to high, the transmitter will not defer to traffic on the network.

5.2.6 DLCR5 - Receive Mode Register

This register controls the way that SSI 78Q8373 receives a packet. DLCR5<5> set high allows SSI 78Q8373 to accept packets th contains alignment or CRC errors. DLCR5<3> set high allows SSI 78Q8373 to accept packets with packet length that is betwee 6 bytes and 2047 bytes (excluding preamble and CRC). Allowing the acceptance of a 6-byte packet is usually a diagnostic mod The Receive Buffer Empty (DLCR5<6>) informs the host when there is no more data in the receive buffer memory.

<table>
<tr><th>BIT</th><th>SYMBOL</th><th>L</th><th>DESCRIPTION</th></tr>
<tr><td>7</td><td>RESERVED</td><td>0</td><td>RESERVED BIT.</td></tr>
<tr><td>6</td><td>RX_BUFMTY</td><td>R,1</td><td>RECEIVE BUFFER EMPTY: When the receive bufffer has no data for the host, this is set to a high by 78Q8373.</td></tr>
<tr><td>5</td><td>ACPT_BADPKT</td><td>R,W,0</td><td>ACCEPT BAD PACKET: If this bit is set high, short packets and packets with alignment and/or CRC errors will be accepted. Otherwise, errorneous packets are rejected.</td></tr>
<tr><td>4</td><td>ADD_SIZE</td><td>R,W,0</td><td>ADDRESS SIZE: When set high, only the first 40 bits of the destination address are compared to the Node ID (normal mode requires the comparison of all 48 bits).</td></tr>
<tr><td>3</td><td>ENA_SRTPKT</td><td>R,W,0</td><td>ENABLE SHORT PACKET: When set high, allows short packets (packet length between 6 and 2047 bytes minus the preamble and CRC) to be stored in the receive buffer memory. When this bit is set low, any packets with less than 60 bytes in length will be rejected.</td></tr>
<tr><td>2</td><td>ENA_RMTRST</td><td>R,W,0</td><td>ENABLE REMOTE RESET: When set to a 1, enables other nodes on the network to reset external peripheral(s) connected to this node. If set to a 0, a received packet with the 0900h pattern in the Type Field will not succeed in resetting these peripherals</td></tr>
<tr><td>1,0</td><td>AM1,0</td><td>R,W,0,1</td><td>ADDRESSING MODE BITS: These two bits control the address filtering of the incoming packets.
<table>
<tr><th>AM1</th><th>AM0</th><th>ADDRESSES ACCEPTANCE MODES</th></tr>
<tr><td>0</td><td>0</td><td>REJECT ALL PACKETS</td></tr>
<tr><td>0</td><td>1</td><td>NODE ID, BROADCAST and MULTICAST GROUP</td></tr>
<tr><td>1</td><td>0</td><td>NODE ID, BROADCAST and MULTICAST HASH TABLE</td></tr>
<tr><td>1</td><td>1</td><td>ACCEPT ALL PACKETS</td></tr>
</table>
</td></tr>
</table>

.7 DLCR5 - Configuration Register 0

IT	SYMBOL	L	DESCRIPTION
7	ENADLC	R,W,1	ENABLE DATA LINK CONTROLLER: Active low. Enables the receiver and transmitter of 78Q8373. Setting this bit to high will reset all the state machines to their idle states and allows access to Node ID and Hash Table registers (depending on DLCR7<3:2> settings).
6	RAMSP	R,W,0	RAM SPEED: When set to 1, selects 100 nsec cycle SRAM. Otherwise, the SRAM is of 150 nsec cycle.
5	HBYTE	R,W1	HOST BYTE/WORD SELECT: If set high, host system bus will operate in byte mode. If set to 0, it will operate in word mode.
4	RBYTE	R,H,1	RAM BYTE: When set high, the RAM databus will operate in byte mode, otherwise it will be word mode. In PCMCIA mode, this bit will be internally hard set to 1. This is because PCMCIA pinout makes use of the higher RAM databus. The following table is valid ONLY for Generic Bus mode:
3,2	TS1,0	R,W,0,1	TRANSMIT BUFFER SIZE: Sets configuration of transmit buffer.
1,0	BS1,0	R,W,0,1	BUFFER MEMORY SIZE: Sets configuration of total Buffer Size.

HBYTE	RAMBUS	HOST	BUFFER
0	0	word	word
0	1	word	byte
1	0	DO NOT USE	
1	1	byte	byte

TS1,0	TX BANKS	SIZE OF TX BANK	TOTAL TX BUFFER
00	1	2 KB	2 KB
01	2	2 KB	4 KB
10	2	4 KB	8 KB
11	2	8 KB	16 KB

BS1	BS0	SRAM SIZE
0	0	8 KB
0	1	16 KB
1	0	32 KB
1	1	64 KB

5.2.8 DLCR7 - Configuration Register 1

BIT	SYMBOL	L	DESCRIPTION
7,6	CTM1,0	R,H,00	CONTROLLER TEST MODES: Write 00 for normal operation.
5	NOT_STBY	R,W,1	NOT STANDBY (POWER DOWN): Active low. The power down mode is for energy saving. If set high, it enables power to the chip for all functions.
4	RDYSEL	R,—	READY SELECT: Reflects the real time image of the RDYSEL pin (pin 94). If RDYSEL pin is high, READY interface with the host is active high. Otherwise it is active low.
3,2	RBNK1,0	R,W,0,0	REGISTER BANK SELECT: To select the upper 8 registers as shown below:
1	EOPSEL	R,W,0	END OF PROCESS PIN SIGNAL POLARITY: When high, EOP pin is active high. When low, EIP pin is active low.
0	INTLMOT	R,W,0	INTEL or MOTOROLA MODE: System must be in word mode. This applies to the non-transmitted buffer header and the packet data. When this bit is low (INTEL MODE), the least significant byte will occupy the even address. Otherwise, the most significant bytes will occupy the even address (MOTOROLA MODE).

RBNK1	RBNK0	REGISTERS
0	0	DLCR0-7 + IDR8-13 + TDR14,15
0	1	DLCR0-7 + HTR8-15
1	0	DLCR0-7 + BMR8-15
1	1	RESERVED

5.3 NODE ID REGISTERS

5.3.1 IDR 8:15 - Node ID Registers

IDR	BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
8	ID7	ID6	ID5	ID4	ID3	ID2	ID1	ID0
9	ID15	ID14	ID13	ID12	ID11	ID10	ID9	ID8
10	ID23	ID22	ID21	ID20	ID19	ID18	ID17	ID16
11	ID31	ID30	ID29	ID28	ID27	ID26	ID25	ID24
12	ID39	ID38	ID37	ID36	ID35	ID34	ID33	ID32
13	ID47	ID46	ID45	ID44	ID43	ID42	ID41	ID40

The Node ID registers (IDR8-13) are located in register bank '00' (DLCR7<3:2> = 00) at address xxx8H through xxxDH. Th unique Ethernet address is written into these registers during the initialization of the node with the first byte of the Ethernet addres at IDR8. The IDR registers are readable and writeable only when $\overline{\text{ENADLC}}$ = 1 (DLCR6<7>). When $\overline{\text{ENADLC}}$ = 0, normal networ operations resume with the DLC controller.

During the reception of a packet, the destination address of the packet is matched with the Node ID in the IDR registers. Dependin on the Address Mode (DLCR5<1:0>) selected for the node, either all or some of the six bytes of the incoming destination addres are compared to the Node ID. If they match then the packet is accepted. Any mismatch in the addresses would result in the rejectio of the packet.

5.4 TIME DOMAIN REFLECTOMETRY REGISTERS

5.4.1 TDR 14,15 - Time Domain Reflectrometry (TDR) Registers

TDR	BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
14	TD7	TD6	TD5	TD4	TD3	TD2	TD1	TD0
15	SELECT 3V		TD13	TD12	TD11	TD10	TD9	TD8

The Time Domain Reflectometry (TDR14-15) registers provide a means of locating a fault on the network. The TDR registers are located in the same register bank as the IDR8-13 but at address xxxEH through xxxFH. This 14-bit diagnostic counter keeps a count of the number of bits that has been transmitted during transmission of a packet starting from the preamble and including the CRC bits. TDR14 is the least significant byte and TDR15 is the most significant byte of the counter. Fourteen bits are sufficient for the packet transmission of an IEEE compliant LAN. The remaining 2 bits (TDR15<7:6>) are used to select 3-volt operation of the 78Q8373.

IT	SYMBOL	L	DESCRIPTION
,6	SELECT3V	R,W,0	SELECT 3V. Programming these bits to 11 will select the 3-volt operating mode. All other combinations will select the default 5-volt operating mode.

The TDR count is cleared on the transmission of the next packet. A short or open on the network would cause reflections of the signal on the network that can be detected as a loss of carrier sense or a false collision respectively. In the event that a fault occurs on the network, the error messages in DLCR0<2> or DLCR0<4> will be able to indicate the type of fault. The TDR count can then be used to estimate the distance from the node to the fault location along the network cable.

HASH TABLE REGISTERS

.1 HTR 8:15 - Hash Table Registers

HTR	BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
8	HT7	HT6	HT5	HT4	HT3	HT2	HT1	HT0
9	HT15	HT14	HT13	HT12	HT11	HT10	HT9	HT8
10	HT23	HT22	HT21	HT20	HT19	HT18	HT17	HT16
11	HT31	HT30	HT29	HT28	HT27	HT26	HT25	HT24
12	HT39	HT38	HT37	HT36	HT35	HT34	HT33	HT32
13	HT47	HT46	HT45	HT44	HT43	HT42	HT41	HT40
14	HT55	HT54	HT53	HT52	HT51	HT50	HT49	HT48
15	HT63	HT62	HT61	HT60	HT59	HT58	HT57	HT56

The Hash Table Registers (HTR8-15) are located in register bank '01' (DLCR7<3:2> = 01) at address xxx8H through xxxFH. The Hash Table allows group addressing by filtering multicast addressed packets on the network. The 64-element table provides the host to select which of the the node should belong to and sets the appropriate groups to a 1. If the host does not want to belong to any groups, the entire table will be set to 0.

As a packet is received, the bit stream goes through the CRC block. If the incoming address is a multicast address (least significant bit of the destination address is a 1) then the following occurs. After the last bit of the 48-bit destination address has passed through the CRC block, the least significant 6 bits of the CRC at that point is used to index one of the 64 elements of the Hash Table. If that Hash Table element is set to a 1 then the packet is accepted. If it is set to a 0 the packet is rejected.

The Hash Table is readable and writeable when $\overline{\text{ENADLC}}$ = 1 and the DLCR7<3:2> = 01. Selecting the Address Mode to include multicast hash addressing would enable this filtering. For instance, AM<1:0> = 10 (DLCR5<1:0>) allows for physical, broadcast and multicast hash addressing but AM<1:0> = 01 does not i.e. the hash filter would not be utilized in these situations. (AM<1:0> = 01 only allows for physical, broadcast and multicast group addressing).

5 BUFFER MEMORY REGISTERS

There are 8 registers for buffer memory interface, 16 collision control and DMA control in this set of register bank. Each bit is explained in the following sections.

5.1 BMR8, 9 - Buffer Memory Port

Reading or writing between the host and SSI 78Q8373 buffer memory is done via these two registers. The location for the buffer memory is dependent on the address unit of SSI 78Q8373. When SSI 78Q8373 is configured as byte mode, only BMR8 is used. Both BMR8 and BMR9 are used when the SSI 78Q8373 is set to word mode configuration.

BIT	SYMBOL	L	DESCRIPTION
7-0	BMR8<7:0> BMR9<7:0>	R,W,_	PACKET RECEIVE and TRANSMIT REGISTERS for the host and 78Q8360.

5.6.2 BMR10 - Transmit Packet Counter

This register consists the TRANSMIT START BIT (TXST) and the total packet count for the SSI 78Q8373 to transmit. The pac count is the number of packets that the host wants to transmit. To activate transmission, the packet count must be written the sa time that the TXST bit is set to a 1. The user should not write into this register until the packet count has reached zero.

BIT	SYMBOL	L	DESCRIPTION
7	TXST	R,W,0	TRANSMIT START BIT: When the packet(s) in the transmit buffer is ready for transfer to the network, this bit is set to 1 in order to activate the transmit operation. Always read as a 0.
6-0	PACKET CNT<6:0>	R,W,0	TRANSMIT PACKET COUNT: The total number of packets to be transmitted to the network. Each time a packet is successfully transmitted, the packet count is decremented. The host can read this register to check how many packets have not been transmitted.

5.6.3 BMR11 - 16 Collision Control

The setting of this register determines the actions of the controller to be taken after 16 consecutive attempts to transmit a pack There are four modes (controlled by $\overline{\text{HALT}}$, RESTART and SKIP bits in the register) to be selected:

(1) automatic re-transmission of colliding packet
(2) automatic skip of the colliding packet after 16 attempts
(3) Halt for host intervention and retry transmission of colliding packet
(4) Halt for host intervention and discontinue transmission of colliding packet.

<table>
<tr><th>BIT</th><th>SYMBOL</th><th>L</th><th>DESCRIPTION</th></tr>
<tr><td>7</td><td>OSC_OFF</td><td>R,H,0</td><td>OSCILLATOR SHUTOFF: When enabled ('1'), this bit shuts off the internal oscillator. Setting this bit while using an external canned oscillator can damage the chip. For this reason, this bit can only be set after the standby mode is entered (by setting DLCR7<2> = '1')</td></tr>
<tr><td>6</td><td>AUTOPD</td><td>R,W,0</td><td>AUTO POWER: Upon power-up/reset, the chip is in automatic power management mode. This mode can be disabled by writing a '1' to this bit.</td></tr>
<tr><td>5-3</td><td>RESERVED</td><td>-</td><td>RESERVED BIT.</td></tr>
<tr><td>2
1
0</td><td>HALT
RESTART
SKIP</td><td>R,W,0</td><td>16 COLLISION CONTROL: These three bits control the action to be taken by 78Q8373 in the event that 16 collisions occur in the transmission of a packet. Host intervention is possible as shown below.
<table>
<tr><th>HALT</th><th>RE-START</th><th>SKIP</th><th>DESCRIPTION OF ACTION TAKEN</th></tr>
<tr><td>1</td><td>X</td><td>1</td><td>Do not halt. Skip colliding packet and continue transmitting.</td></tr>
<tr><td>1</td><td>X</td><td>0</td><td>Do not halt. Retry transmission of colliding packet.</td></tr>
<tr><td>0</td><td>X</td><td>X</td><td>Halt and await instruction from host for BMR11<1:0>. 11' : results in colliding packet skipped and transmission resumed.10': results in colliding packet re-transmitted.</td></tr>
</table>
</td></tr>
</table>

.4 BMR12 - DMA Enable

The DMA RENA and DMA TENA activates the DMA operation as follows:

BIT	SYMBOL	L	DESCRIPTION
7-2	RESERVED	-	RESERVED BIT.
1	DMA_RENA	R,W,0	RECEIVE READ DMA ENABLE: When enabled (active high), it activates receive read DMA from the host.
0	DMA_TENA	R,W,0	TRANSMIT WRITE DMA ENABLE: When enabled (active high), it activates transmit write DMA from the host to ICE's buffer memory.

.5 BMR13 - DMA Burst & Transceiver Mode Register

BIT	SYMBOL	L	DESCRIPTION
7	APOL	R,W,0	AUTO POLARITY: When set to 0, it enables the automatic polarity correction of the received data. The reverse polarity is identified from either the start of idle signal or link pulses.
6	RTH	R,W,0	REDUCED THRESHOLD: When set high, twisted pair receive threshold is reduced by 3 dB (for longer than the recommended 100 meters cable).
5	ENLI	R,W,0	ENABLE LINK INTEGRITY: When set low, both transmit and receive link test functions are enabled. When high, no link test is performed and the link status is assumed to be up and twisted pair port is selected if auto select mode is enabled. When this bit is enabled, the transmit link pulses function is always active regardless fo the status of the link.
4	PORT_SEL	R,W,0	PORT SELECT: This bit manually selects between Twisted Pair (when 0) or AUI (when 1) and is only applicable when ASEL bit (BMR13<3>) is high (disabled).
3	ASEL	R,W,0	AUTO PORT SELECT: When set to 0, automatic port selection mode is in effect. The selection is based on the state of link integrity status. Twisted pair port is selected or a good link and AUI port is selected for a link down condition. When set to 1, manual port selection is in effect through POrT_SEL bit (BMR13<4>).
2	DMT	R,W,0	DMA DMREQ DROP TIME: When set low, DMREQ drops at the next-to-last transfer of DMA burst (same with 78Q8360). When set high, DMREQ drops at the last transfer of the burst.
1,0	DMAB1,0	R,W,0	DMA BURST: This two bits select the burst length for DMA operation. The burst length transfer can either be byte mode or word mode depending on the system bus setting (SYSBUS in DLCR6<5>).

DMAB1	DMAB0	BURST LENGTH
0	0	1
0	1	4
1	0	8
1	1	12

5.6.6 BMR14 - Receive Filter & Interrupt Enable Register

BIT	SYMBOL	L	DESCRIPTION
7	RESERVED	-	RESERVED BIT.
6	INT ENABLE	R,W,0	LINK DOWN INTERRUPT ENABLE: When high, enables LD (BMR15<6>) to generate an interrupt. Since LD cannot be cleared, the interrupt can be deactivated by clearing this enable bit.
5-3	RESERVED	-	RESERVED BIT.
2	SKP_RX	R,W,0	SKIP RECEIVE PACKET: If the host is reading the received packets in the buffer and decides to skip the current packet then this bit is set to high. The 78Q8373 controller will perform a hardware skip on the internal pointer within 200 ns to the next packet start address if there is another packet in the buffer.
1	INT ENABLE	R,W,0	SQE INTERRUPT ENABLE: When high, enables SQE (BMR15<1>) to generate an interrupt.
0	RXF	R,W,1	RECEIVE FILTER: When set to 1, disables the reception of own transmitted packet in the ACCEPT ALL PACKETS mode. When set to 0, enables the reception of own transmitted packet in the ACCEPT ALL PACKETS mode. (1)

(1) *Power up value for this bit is a '1' for SSI 78Q8373 and '0' for SSI 78Q8360. This may be used by the software driver t differentiate between the two chips.*

5.6.7 BMR15 - Transceiver Status Register

BIT	SYMBOL	L	DESCRIPTION
7	RESERVED	-	RESERVED BIT.
6	LD	R,0	LINK DOWN: When high, it indicates that the twisted pair port is in link down condition. Can generate an interrupt if enabled by BMR14<6>. The chip powers up in link up condition. When ENLI (BMR13<5>) is high (disabled), this bit is forced to a '0' (link up condition).
5	OWCOL	R,C,0	OUT OF WINDOW COLLISION: Indicates that a collision occurred after the slot time (51.2 μs). Transmissions terminated and rescheduled as in normal collision. Writing a '1' will clear this bit. For software compatibility with the 78Q8360, writing a '1' to the COL bit (DLCR0<2>) will also clear this bit.
4	RESERVED	-	RESERVED BIT.
3	RPI	R,0	REVERSE POLARITY INDICATION: When high, it indicates that inverted data is being received over the twisted pair wire due to wiring error. This bit is only applicable when APOL (BMR13<2>) is low (enabled). When APOL is high (disables) this bit can never be set.
2	RESERVED	-	RESERVED BIT.
1	SQE	R,C,0	SIGNAL QUALITY ERROR: When high, indicates detection of SQE signal at the end of a transmission. This bit applies to both the AUI and TP ports. Can generate interrupt if enabled by BMR14<1>. Writing a '1' clears this bit.
0	RESERVED	-	RESERVED BIT.

PCMCIA REGISTERS

There are 2 registers for the PCMCIA interface. Each bit is explained in the following sections.

.1 CCR0 - Configuration Option Register

BIT	SYMBOL	L	DESCRIPTION
7	SRESET	R,W,0	SYSTEM RESET: Setting this bit high is equivalent to assertion of hardware reset (except that this bit is not cleared). This bit is also reflected at the XRST pin to reset the rest of the devices on the card.
6	LevIREQ	R,W,0	LEVEL MODE INTERRUPT REQUEST: When high, level mode interrupt is selected. When low, pulse mode interrupt is selected.
5:0	CI(5:0)	R,W,0	CONFIGURATION INDEX: This field is written with the index number of the entry in the Card's Configuration Table that corresponds to the configuration which the system chooses for the card. When CI(5:0) is 0, the chip does not respond to any I/O cycle, but will use the memory cycle.

'.2 CCR1 - Card Configuration and Status Register

BIT	SYMBOL	L	DESCRIPTION
7	NI	R,0	NOT IMPLEMENTED
6	NI	R,0	NOT IMPLEMENTED
5	IOis18	R,W,0	I/O is 8 bit: This bit set high indicates to the host that the system is only capable of 8-bit transfer on its data bus. Since the 78Q8373 can support 16-bit transfer, the default value of this bit is '0.' This bit does not affect the host byte/word mode setting of the 8373 which is set by HBYTE (DLCR6<5> bit).
4	RESERVED	R,0	RESERVED.
3	Audio	R,W,0	Audio Enable: This bit set to one will enable signals from SPKRIN to SPKR.
2	PwrDwn	R,W,0	Power Down: This bit has the same function as the NOT_STBY bit (DLCR7<5>) but with different polarity. The chip will be powered down if either this bit is set to '1' or NOT_STBY bit is set to '0.' When configured for PCMCIA interface mode and power down is activated, the $\overline{XPD}$ pin will indicate it by going low.
1	Intr	R,0	Interrupt Request Status: This bit represents the internal state of the interrupt request. This signal remains true (high) until the condition which caused the interrupt request has been serviced.
0	RESERVED	R,0	RESERVED.

6 78Q8373 & HOST INTERFACE CONFIGURATION

6.1 PCMCIA INTRODUCTION

PCMCIA is an acronym for Personal Computer Memory Card International Association. Its goal is to promote interchangeabili of PC Cards among a variety of computer and other electronic products.

PC Cards are approximately 54 by 85 millimeters, but differ in thickness. Type 1 cards are 3.3 mm thick and type 2 cards a 5.0 mm. All have a 68-pin interface at one end.

6.1.1 Memory and I/O Address Space

A Memory Address Space of 64 Mbytes (A0-A25) is permitted for each memory card installed in a system. The Memory Addre Space consists of Common Memory and Attribute Memory. The Common Memory may be accessed by a host for memory re and write operations.

There is an additional 64 Mbytes address space for Attribute Memory which is selected by the $\overline{REG}$ signal at the interface. Tl Attribute Memory is divided into

- Card Information Structure (CIS) - contains the manufacturer's description of card capabilities and specifications.
- Card Configuration Registers (CCR) - a set of registers that allows the card to be configured by the host.

The I/O Address Space of 64 Mbytes is shared and divided among all cards installed in the system. The I/O interface requires th the Memory-Only Interface also be implemented within the same socket, and that the Memory-Only Interface be selected in tl socket when no card is inserted and immediately following Card reset and the application of Vcc to the card. The I/O interface al supports additional signals like $\overline{IREQ}$, $\overline{IOIS16}$, $\overline{IOWR}$, $\overline{IORD}$, $\overline{SPKR}$, $\overline{INPACK}$ and $\overline{STSCHG}$.

The following diagram summarizes which address space that the host is accessing depending on the logic values of REG, I/O rea write and Memory read/write signals.

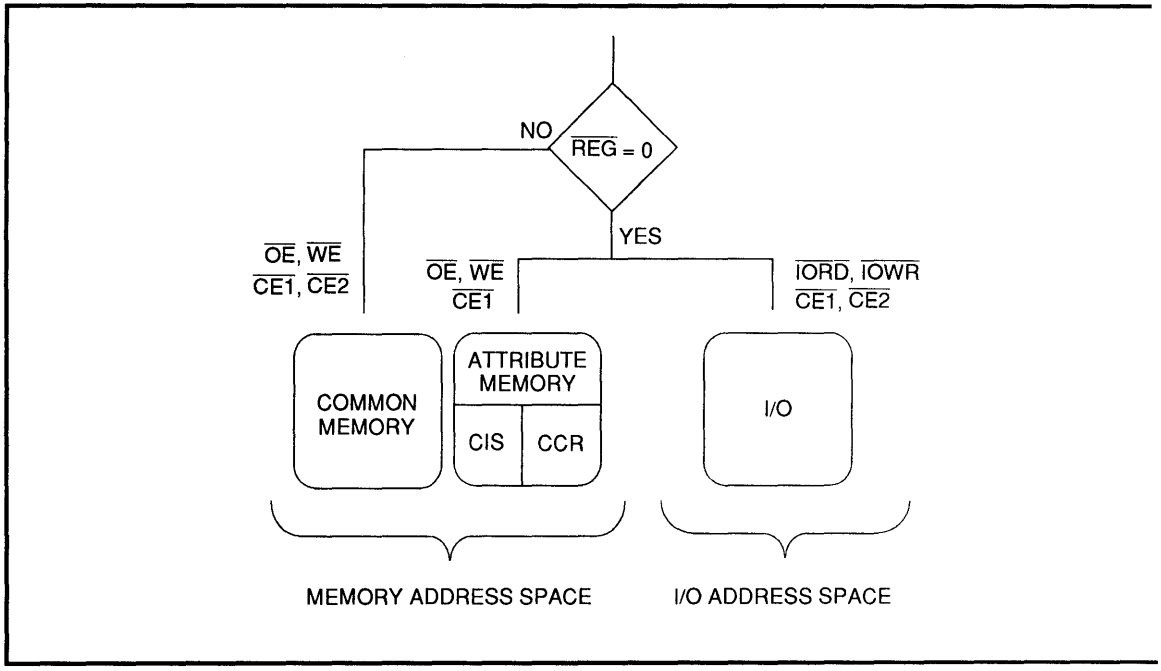

Figure 6-1. Host Address Space Accessing

PCMCIA INTERFACE FOR SSI 78Q8373

SSI 78Q8373 complies to the PCMCIA Release 2.1 Specifications and powers up as a memory card when in PCMCIA mode. To enter the I/O mode, the Configuration Index CI(5:0) in the CCR0 register must be written with a non-zero value. Only then can the other registers of SSI 78Q8373 be accessed by the host.

In the Attribute Memory Address Space, the CIS is located at address 0 and the CCR is located at an offset value determined by the CCRA pin, illustrated in Figure 6-2 below.

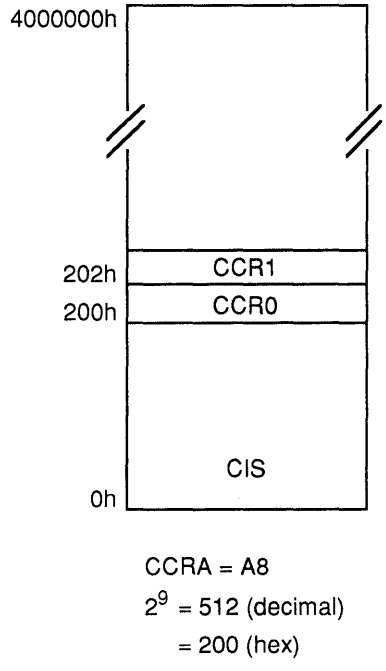

Figure 6-2. Attribute Memory Address Space

CCRA pin must be connected to another address pin apart from A(3:0). For instance, if CCRA is connected to A8, then CCR(located at address 200h, an offset of 200h from address 0. An example of how to use the SSI 78Q8373 with a Flash Memory EEPROM is shown below.

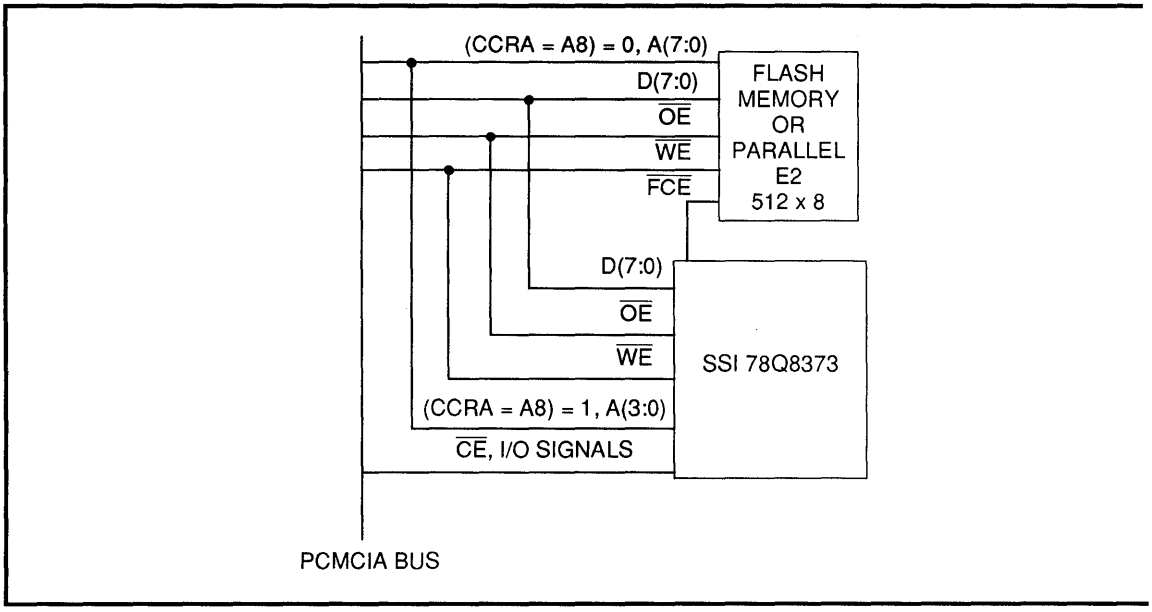

Figure 6-3. SSI 78Q8373 Interface to Flash Memory or EEPROM

6.3 GENERIC BUS INTERFACE FOR SSI 78Q8373

For non-PCMCIA applications, the SSI 78Q8373 can interface with the host via a 'generic' bus interface. Transferring of dat packet status, packet sizes and so on can be accessed easily by the host either by using programmed I/O or DMA modes. Packe to be transferred to the network must first be stored in the buffer memory via a register called Buffer Memory Register 8 (BMR8 Similarly, packets to be read by the host is retrieved via the BMR8. Thus BMR8 acts as a window to the buffer memory.

To interface with the host, the SSI 78Q8373 has 4 host address pins (HA<3:0>), 16 host data pins (HD<15:0>), 3 status pi (SWSB, EOP, INT) and handshake/chip select signals (CS, DMREQ, DMACK, RD, WR, READY). The host is also able access the SSI 78Q8373's internal registers to retrieve more information (refer to the Register section).

78Q8373 & MEDIUM INTERFACE CONFIGURATION

The SSI 78Q8373 has an integrated twisted pair transceiver and supports interface to coax transceiver through AUI signaling. The two port selection (either AUI or TP) is done automatically based on the status of link integrity. In a link-good state, the TP port is selected and in a link-fail state, the AUI port is selected. This automatic selection can be disabled by writing a '1' to register bit BMR13<3> and manual selection is in effect. In manual selection mode, the AUI or TP port may be selected by writing appropriate value to BMR13<4>.

TWISTED PAIR TRANSCEIVER

The TP transceiver supports complete IEEE 10BASE-T functionality as well as several enhanced functions such as autopolarity detection and correction, smart-squelch logic and long distance mode.

.1 Link Integrity

During idle periods, link pulses are generated and received by both MAUs (Medium Attachment Units) at either end of the twisted pair to ensure that the cable has not been broken or shorted. A positive, 100 ns Link Integrity signal is generated and transmitted by the SSI 78Q8373 every 13 ms during idle periods. The chip assumes a link-good state if it receives valid link pulses or a packet. If neither is received for 105 ms, the SSI 78Q8373 enters a link-fail state. It then needs 4 consecutive positive link pulses (or 8 negative link pulses) to resume link-good state. Only link pulses spaced between 3 ms and 105 ms are considered valid.

In a link-fail state, the SSI 78Q8373 disables normal Transmit, Receive, Collision, loopback and SQE test functions. The reception of a packet will put the device in a link-good state. However, that packet will not be relayed to the Manchester ENDEC unit. Subsequent packets will be relayed as per normal as long as the device remains in a link-good state.

The link status is flagged by register bit BMR15<6> as well as the LEDLTR pin. The Link Integrity function can be disabled by writing a '1' to BMR13<5> which forces the SSI 78Q8373 into a link-good state.

.2 Autopolarity

Because twisted pair differential signals can easily be inverted due to wiring errors, the SSI 78Q8373 incorporates autopolarity detection and correction circuitry. Polarity circuitry monitors the polarity of the received SOI (Start Of Idle) and link pulses and corrects the data internally if the signal is inverted. The inverted polarity is flagged by register bit BMR15<3> and the autopolarity function may be disabled by writing a '1' to BMR13<7>.

.3 Smart Squelch Logic

The twisted pair squelch logic dynamically adjusts the sensitivity and threshold of the receiver. Before signals begin to arrive at the TPIP/TPIN pins, the SSI 78Q8373 is in a high noise rejection, squelch state and no data is passed through. A valid incoming data needs to trip the threshold detectors with three peaks of alternating polarity occurring within a 400 ns window. Once a signal has been qualified by the squelch circuitry, the SSI 78Q8373 assumes an unsquelch state with reduced threshold. See the datasheet for the squelch and unsquelch threshold levels.

At the beginning of each packet there is a preamble consisting of alternating ones and zeros resulting in a 5 MHz Manchester signal on the twisted pair. The SSI 78Q8373 uses the standard 10BASE-T specified threshold levels to unsquelch the incoming preamble. As data begins to arrive, the 10 MHz component of the Manchester encoded signal may have less amplitude since it is attenuated more than the 5 MHz component. For this reason, the threshold levels are reduced in the unsquelch state. This greatly reduces the chance of prematurely detecting the SOI by the threshold detectors.

The twisted pair smart squelch circuitry is returned to a squelch state by any of these conditions: a normal SOI signal, an inverted SOI signal or a missing SOI signal. A missing SOI signal is assumed when no transitions crossing the threshold detectors have occurred for 250 ns after a packet has been received. In this case, a normal SOI signal is generated and appended to the received data.

1.4 Long Mode

Writing a '1' to BMR13<6> places the SSI 78Q8373 in long mode where the thresholds of the detectors are lowered to support longer cable length than the recommended 100 meters. Dynamic squelch circuitry is still functional in long mode. The squelch threshold of the long mode is the same as the unsquelch threshold of the normal mode and the unsquelch threshold of the long mode is another 3 dB down.

1.5 Collision Detection

A collision happens when both transmitting and receiving functions occur simultaneously in the twisted pair transceiver. The collision signal originating from the twisted pair transceiver is multiplexed together with the collision signal from the AUI module and is relayed to the controller. Collisions will not be reported when the device is in a link-fail state. The internal collision signal is also activated when a jabber condition occurs or when the SQE test is being performed.

7.1.6 SQE Test

An internal Signal Quality Error (SQE) test is also provided on chip. After each packet transmission, an SQE signal (also referr to as "heartbeat" signal) is sent internally to the controller. This feature is provided to match the coax transceiver functionality

7.1.7 Jabber

An independent circuit monitors the length of each transmission and inhibits it if it surpasses a 26.2 ms maximum allowed transn time. This function keeps a damaged node from continuously transmitting on the network. When jabber occurs, the transceiver al discontinues loopback and sends a collision signal to the controller. The jabber status is flagged by register bit DLCR0<3>.

7.1.8 Normal Loopback

The twisted pair transceiver provides the normal loopback function specified by the 10BASE-T standard. The normal loopba function is disabled when a collision occurs during which the received data from TPIP/N is passed through instead. Link fail a jabber states also disable the normal loopback.

7.1.9 LED

The LEDLT pin serves functions. A connected LED lights up during link-good state and blinks off temporarily during transmissi activity.

7.1.10 TP Driver

The transmit driver consists of four differential signals, the true and complement transmit data TPOP, TPON and their respecti 50 ns delayed signals TPDP, TPDN. These drivers, when combined with the resistor network shown in Fig 7.1, provide the sign pre-equalization required by the 10BASE-T standard.

A Manchester encoded data consists of 10 MHz (50 ns) component as well as 5 MHz (100 ns) pulses. A twisted pair cable attenuat a 10 MHz signal more than a 5 MHz signal. Equalization is required to decrease the relative power in the 5 MHz compone transmitted by the SSI 78Q8373. This causes the 10 MHz and 5 MHz components of the signal to have approximately the same pow

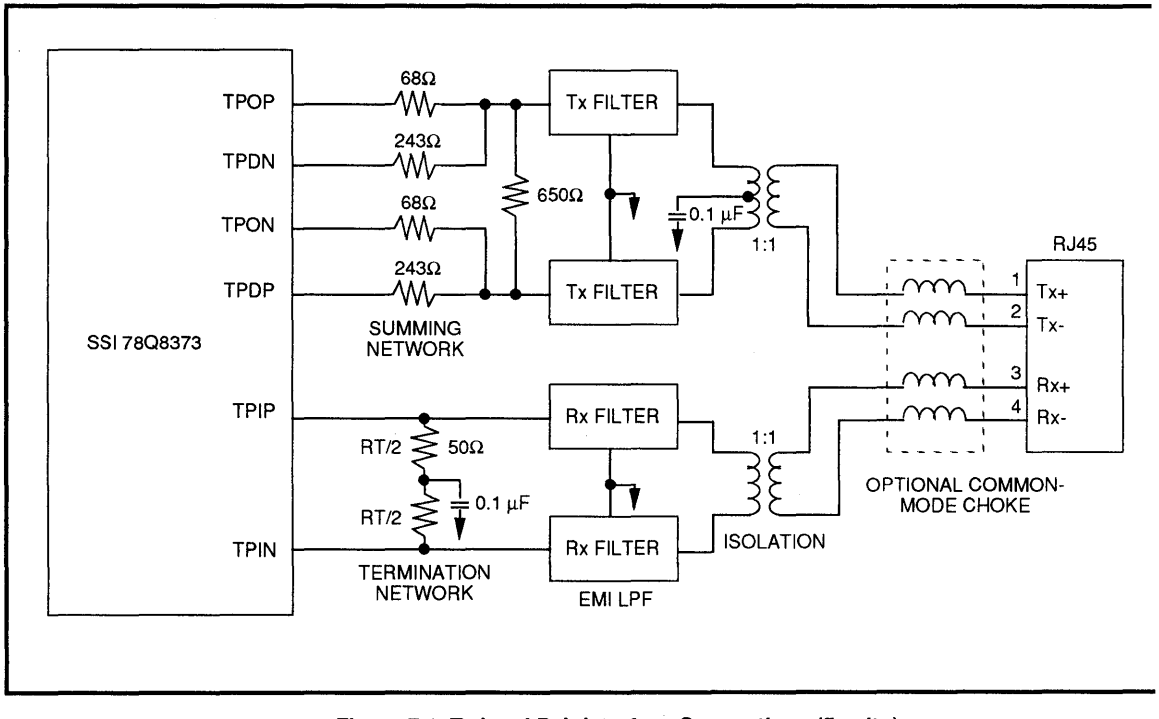

Figure 7.1. Twisted Pair Interface Connections (5 volts)

(contact Silicon Systems for 3-volt connections)

content at the far end of the twisted pair. To achieve the power reduction of the 5 MHz component, the four transmit signals are summed resistively as shown in Fig 7.2. The values of the five network resistors are selected to allow the twisted pair line to be terminated in 100 ohm.

The drivers are designed to have equal rise/fall times as well as balanced low-to-high and high-to-low propagation delays to minimize common-mode energy. It is also important to maintain equal load capacitance from the board layout for each data output so as to maintain the equal rise/fall times and propagation delays.

The twisted pair magnetics and filters shown in Fig 7.2 isolate the SSI 78Q8373 from the twisted pair media and reduce the radiated emissions. As a result of the well matched drivers, the common-mode choke is optional and the device still meets the 10BASE-T standard of +/- 50 mV of common-mode energy. Various integrated modules are available with different level of integration from a few vendors listed in Table 7.1.

'able 7.1

ption	Resistor Network	EMI Filter & Isolation	Common-mode Choke
1	Discrete	1) Pulse PE65421 2) Valor PT3877 3) BelFuse A556-2006-DE 4) FilMag 78Z1120B	(Optional)
2	Discrete	1) Pulse PE65431 2) Valor FL1012 3) Bel Fuse 0556-2006-01, 0556-3392-00	
3	1) Pulse PE65485 2) PCA EPE6052G		

.11 TP Receiver

The SSI 78Q8373 twisted pair receiver uses a high-speed differential comparator designed to preserve the edge timing of the incoming data. The comparator architecture significantly minimizes the bit jitter added by the transceiver. Dual threshold detectors are used by the twisted pair smart squelch circuitry to qualify both positive and negative signal peaks. The threshold levels are dynamically controlled to further enhance the immunity to noise. Refer to the smart squelch logic section.

! ATTACHMENT UNIT INTERFACE (AUI)

AUI is a standard Ethernet interface that connects Data Terminal Equipment (DTE) to a Medium Attachment Unit (MAU). There are 3 pairs of differential signals that connect to an AUI: one pair for transmission, one pair for reception and the other one pair for collision indication. A typical AUI connection diagram is given in Fig 7.2.

².1 AUI Driver

The SSI 78Q8373 AUI drivers have been designed to provide balanced differential voltage levels when signaling. The drivers have equal low-to-high and high-to-low propagation delays to provide minimal skew.

At the end of transmission, the AUI drivers ramp to VDD slowly to avoid undershoot. An internal digital to analog converter ensures that the driver ramp-up occurs over approximately 8 µs resulting in a smooth transition into an idle state.

².2 AUI Receiver

The AUI receiver uses high-speed differential comparator to preserve the edges and duty cycle of the incoming data. A threshold detector and squelch circuit are used to qualify valid data from noise. During idle, the AUI is in a high noise rejection squelch state. When the first negative edge crosses the threshold of the threshold detector, the AUI enters into unsquelch state and begins receiving data. The AUI reverts back to squelch state by a normal Start-Of-Idle (SOI) signal or a missing SOI signal. A missing SOI signal is assumed when no transitions have occured on the receiver inputs for 175 ns. In this case, an SOI signal is generated and appended to the received data.

7.2.3 Termination and Isolation

The AUI cable is specified by the standard to have characteristic impedance of 78 ohms. For minimal reflection, the AUI cable h to be terminated with a 78 ohm resistance at the far end. A 0.1 µF capacitor connected to the mid value point of the termination resis helps to bypass common mode noise picked up by the AUI cable. This capacitor is optional for on-board transceiver because th will be minimum common mode noise.

The SSI 78Q8373 AUI supports both transformer coupling as well as capacitive coupling as shown in the figure. Please note th for capacitive coupling, the termination resistors have to reside at the inputs of the SSI 78Q8373 AUI receivers.

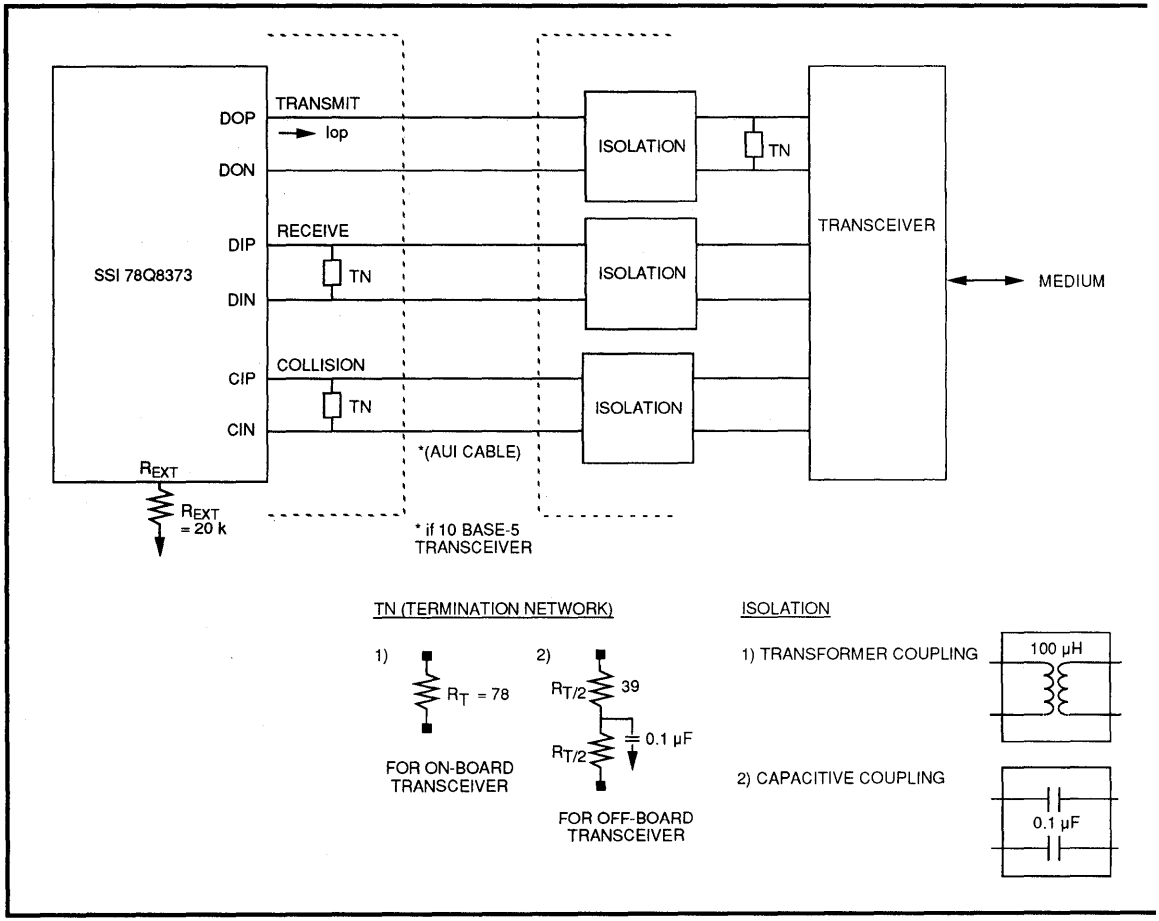

Figure 7.2. Attachment Unit Interface (AUI) Connections

USING THE SSI 78Q8373 ON THE NETWORK

This section deals with the transmission of data using the SSI 78Q8373 from the host point of view. It will cover the interaction of register configurations and the actual transmission executed. For more detailed information on the function of the Data Link Controller in this respect (with regards to Inter-Frame Gap, fairness and equality of the line, Jam Pattern, Backoff Algorithm etc.), please refer to the Transmitter Circuits Section.

INITIALIZATION

Initialization begins with a hardware reset immediately after power on. A pulse with a minimum of 200 nanosecond duration is required to be applied to the RESET pin. This resets ICE's internal pointers and registers to their initial state. $\overline{\text{ENADLC}}$, DLCR6<7> = 1 acts as a software reset resetting all buffer memory pointers. The software reset does not change the contents of the status and control registers or the DLCR 0-7, IDR8-13, TDR14-15, HTR8-15 and BMR10-15 registers. Hardware reset sets the $\overline{\text{ENADLC}}$ bit high.

The initialization of the 8373 by the host include the loading of the Ethernet Address of the node into IDR8-13 with IDR8 as the least significant byte of the address and group addressing in the Hash Table registers (if desired). To access the Node ID registers, (or any of the other bank of registers) the following is executed. Please note that all register values are in hexadecimal notation unless otherwise stated.

a) Disable the DLC by setting DLCR6<7> = 1

b) Select the register bank by setting DLCR7<3:2> as required.

DLCR7<3:2> = 00 (default setting after hardware)
DLCR7<3:2> = 01 (selects Hash Table registers)
DLCR7<3:2> = 10 (selects Buffer Memory registers)
DLCR7<3:2> = 11 (Reserved)

The host should load the Ethernet Address and Hash Table Configurations at this stage.

c) The default settings of DLCR0-7 after a hardware reset or power on are as follows:

DLCR0 = 00 (Transmit Status)
DLCR1 = 00 (Receive Status)
DLCR2 = 00 (Transmit Interrupt Mask)
DLCR3 = 00 (Receive Interrupt Mask)
DLCR4 = 06 (Transmit Mode)
DLCR5 = 41 (Receive Mode)
DLCR6 = B6 (Configuration Register 1)
DLCR7 = 20 (Configuration Register 2)

The host can now select the type of interrupt enables that should be activated in DLCR2-3. Unless a loop back mode is required in a testing environment, DLCR4 need not be changed.

d) The default setting of DLCR5 allows the reception of normal packets i.e. packets that meet the IEEE requirements and does not contain any errors. The host can enable the 'remote reset' capability of SSI 78Q8373 or enable the reception of 'bad packets' with the activation of appropriate bits in this register. The Address Mode bits can be reprogrammed for hash table acceptance if necessary. Please refer to the Data Link Controller Registers Section for details.

e) DLCR6 configures the size of the transmit buffer and overall buffer size. This should be changed according to the host's requirements. DLCR6<7> is reset to 0 for transmission and reception activities and set to 1 for access to the Node ID and Hash Table Register Banks.

f) DLCR7 configures the access to the 3 register banks. To access the Node ID and Hash Table Register Banks, DLCR6<7> = 1 must be set to 1. DLCR7<0> sets the big endian and little endian byte ordering depending on the host's configuration.

g) BMR11 denotes the action to be taken by SSI 78Q8373 should a 16 collision happen on the network. This should be programmed accordingly before transmission or the default setting will be used.

9

PACKET TRANSMISSION USING THE SSI 78Q8373

Transmission Without Contention

Before initiating a transmission, the host will load in the data packet(s) into the transmit buffer via BMR8 (and BMR9 if in word mode). Each data packet will contain a 2-byte header of the total packet length, destination and source addresses and the data to be transmitted. The host initiates transmission by writing the number of packets into BMR10 and setting TXST bit = 1 (BMR10<7>).

The 2-byte header is loaded into a counter within the transmit circuit. The counter will decrement its value as each byte is transmit to the medium. When it reaches zero, this signifies that an entire data packet has been transmitted. At the same time, the pac count value (PACKET CNT<6:0>) in BMR10 will decrement by 1 each time a data packet is transmitted. When packet coun zero, this indicates that there are no more packets in the transmit buffer. SSI 78Q8373 will enter its idle state and wait for the TX bit to be set high again and the process is repeated.

SSI 78Q8373 will wait for a 'free' medium before transmitting to the network. When the network is free, SSI 78Q8373 will gener and append the preamble and start frame delimiter to the beginning of the packet (the 2-byte header is stripped off and not transmitt and generate the CRC for the packet. The entire packet starting from the preamble to the CRC is encoded by the ENDEC Manchester Encoding and output to the external transceiver via the TDN and TDP pins.

The HWR_ERR bit (DLCR0<0>) indicates a host write error if it is a 1. This means that the transmit bank is full and has insufficie buffer space for the next packet that the host is writing. When this happens, the host will have to initiate a TXST to start transmissi hence clearing the transmit bank. In the case of a single transmit bank, the host will have to wait until this bank is cleared bef writing another packet into the transmit buffer. SSI 78Q8373 can also be configured into two transmit banks. In this case, wh the first bank is being transmitted (by initiating TXST), the host can continue writing to the second transmit bank. Similarly, wh the second transmit bank is being transmitted (by initiating another TXST), the host can write to the first bank that had been clear It should be noted that the TXST can be initiated whenever the host wishes to transmit (even when the transmit banks are not fu

8.2.2 Collision and Recovery

While transmitting, SSI 78Q8373 monitors the network for collisions. In the event of a collision, the collision counter DLCR4<7:4> is incremented and the transmission terminated. The COL bit (DLCR0<2>) will be set to indicate that at least o collision has occurred during the transmission of that packet. After the random interval deferment, SSI 78Q8373 will attempt re-transmit the collided packet and all other packets in the transmit buffer until the PACKET CNT in BMR10<6:0> reaches ze In the event of 16 collisions, SSI 78Q8373 will take appropriate action according to the 16 collision control register set in BMR1 There are four different actions for SSI 78Q8373 to choose when a packet has attempted 16 re-transmissions. The actions and settings are shown in the register section for BMR11. The 16COL bit (DLCR0<1>) will be set when 16 attempts was reache Otherwise if SSI 78Q8373 successfully transmits all the packets in the transmit buffer, the TXOK (DLCR0<7>) bit will be set signal a transmission completion and the collision counter will be reset to zero.

8.2.3 How the SSI 78Q8373 Handles Other Situations

Whether the buffer memory setup is in a word or byte mode, SSI 78Q8373 will always access the buffer memory in byte format a convert it into a serial bit stream before transmitting to the network. In the situation where a packet is of odd byte length for a wo mode system, SSI 78Q8373 will transmit this packet properly and perform an even byte alignment. This will ensure that the ne packet will always start at the even address location.

In reference to the DLCR7<0> bit for the INTEL or MOTOROLA format, the data order swapping only applies to the host that configured in word format. DLCR7<0> set to 0 refers to the INTEL format and DLCR7<0> = 1 refers to the MOTOROLA form In the INTEL format, the least significant byte is transmitted first then followed by the most significant byte. In the MOTOROL format, the data order is reversed. Note that all the data stored in the buffer memory is affected, including the non-transmitted byte headers for the length of the data packet. Only BMR8 and BMR9 are affected by this control bit.

The following tables describe the ordering of the packets depending on which format the host is configured. SSI 78Q8373 defau to the INTEL format upon power up.

TRANSMIT PACKET:

INTEL FORMAT	
HIGH BYTE	LOW BYTE
TX MSB length	TX LSB length
Destination address 2nd byte	Destination address 1st byte
Source address 2nd byte	Source address 1st byte
Length field LSB	Length field MSB
Data field 2nd byte	Data field 1st byte

MOTOROLA FORMAT	
HIGH BYTE	LOW BYTE
TX LSB length	TX MSB length
Destination address 1st byte	Destination address 2n byte
Source address 1st byte	Source address 2nd byte
Length field MSB	Length field LSB
Data field 1st byte	Data field 2nd byte

ECEIVE PACKET:

INTEL FORMAT	
IGH BYTE	LOW BYTE
eserved	Packet status
ata length high byte	Data length low byte
estination address 2nd yte	Destination address 1st byte
ource address 2nd byte	Source address 1st byte
ength field LSB	Length field MSB
ata field 2nd byte	Data field 1st byte

MOTOROLA FORMAT	
HIGH BYTE	LOW BYTE
Packet status	Reserved
Data length low byte	Data length high byte
Destination address 1st byte	Destination address 2nd byte
Source address 1st byte	Source address 2nd byte
Length field MSB	Length field LSB
Data field 1st byte	Data field 2nd byte

PACKET RECEPTION USING THE SSI 78Q8373

.1 Reception Without Contention

When not transmitting, SSI 78Q8373 will consistently monitor the network. To determine if a packet on the network is for the node, SSI 78Q8373 will check the destination address of the packet. Depending on the Address Modes (DLCR5<1:0>) of the node (set during initialization), SSI 78Q8373 will accept the packet if the destination address meets the criteria.

Upon a successful reception, the received packet is stored in the receive buffer. An internal counter in SSI 78Q8373 keeps track of the length of the packet. SSI 78Q8373 allocates 4 bytes in the receive buffer before storing the accepted packet in the receive buffer. This is for a 4-byte header of the accepted packet to the host (refer to Receive Buffer Data Format Section). The 4-byte header contains the packet length and the status (CRC error, alignment error etc.) of the packet. At the end of the packet reception, SSI 78Q8373 writes the status of the accepted packet in the allocated space. By default, if a packet contains any errors, it will be discarded and the receive buffer pointers will be restored automatically.

When a packet is accepted, the PKT_RDY (DLCR1<7>) bit is set and the RX_BUFMTY (DLCR5<6>) bit is cleared to indicate to the host that there is a packet in the Receive Buffer. The host will then proceed to read the packet from the buffer memory. When all the data packets in the receive buffer are read, the RX_BUFMTY (DLCR5<6>) is set to '1' again. An OVRFLO, DLCR1<0> error occurs when the receive buffer is full or has insufficient space for the next accepted packet. This will result in the rejection of the packet and the host would have to read the receive buffer to free some buffer space. Due to the ring structure of the receive buffer, once the host has read some packets, that buffer space becomes available for the future packets.

After accepting a packet, the receiver will perform an 8-byte alignment in the receive buffer. An 8-byte alignment means that the start address of the next packet will always begin at the 8-byte boundary (for example at address locations: 0000H, 0008H, 0010H....etc.). The execution of 8 byte alignment must be consistent between the receiver and the host read circuit. In the host read circuit, there is a counter that loads the packet length value from the 4-byte header of the receive packet (3rd and 4th bytes of the 4-byte header). In a byte configuration, the counter will decrement each time a byte has been read out by the host. When the counter reaches zero, this signifies that the entire packet has been read by the host. The host can continue to read the next packet if no other resource requires the attention of SSI 78Q8373.

.2 Collision and Recovery

In the event of a collision, the receiver accepts the fragmented bits of the collision and decodes it just like a valid frame. A CRC check would inform the host that the received packet has CRC errors by setting the CRC_ERR (DLCR1<1>) to a 1. The host will then discard this packet and the receive buffer memory pointers will be adjusted accordingly for the reception of the next packet.

.3 How the SSI 78Q8373 Handles Other Situations

When the host is configured as word mode, there will be a situation whereby there are packets in the receive buffer are of odd byte length. The host should discard the excess byte of the last word. SSI 78Q8373 maintains an internal counter and re-aligns accordingly.

SSI 78Q8373 has the capability of accepting packets with errors or perform an extra group addressing mode depending on the bits set in the Receive Mode Register, DLCR5. The effects on packet reception with reference to each specific bit is elaborated below.

If ACPT_BADPKT (DLCR5<5>) is activated, SSI 78Q8373 will accept short packets or packets with alignment and/or CRC errors. These errors may be due to network corruption or packet collision. In this case, the corresponding bits are not set when the packet is accepted. However, the status byte to the host in the receive buffer will continue to indicate these errors as they occur.

SSI 78Q8373 may be programmed to accept packets with a minimum length of 6 bytes to a maximum of 2047 bytes (excluding CRC bits). If ENA_SRTPKT is set to a 1, packets that are less than 60 bytes in length (from destination address to end of data field) will

be accepted by SSI 78Q8373. The SRT_ERR bit (DLCR1<3>) will not be set when the packet is accepted in this case. Simila the case of ACPT_BADPKT, the status byte to the host will continue to indicate the error. If ENA_SRTPKT is set to 0, SSI 78Q8 will reject this packet setting SRT_ERR bit (DLCR1<3>) to 1 to indicate the error. It should be noted that SSI 78Q8373 does check for long packet errors (greater than the IEEE maximum length) and has no error flags for such packets .

The ADD_SIZE bit (DLCR5<4>) allows the multiplexing of the last byte of the destination address. When activated, it configu SSI 78Q8373 to match only 5 bytes of the destination address before deciding to accept the incoming packet.

The ENA_RMTRST bit (DLCR5<2>) enables other nodes on the network to remotely reset an external peripheral connected to t node. This is achieved by sending a packet to this node (using individual/physical addressing only)with a Type Field containi the 0900H pattern. The least significant bit (LSB) of the most significant byte (MSBYTE) of Type Field is transmitted first. Th the 0900H pattern (09H is the most significant byte) would be transmitted as follows from left to right:

1001 0000 0000 0000

8.3.4 Status Byte Format

The status byte to the host has several bits that flag error messages or report the status of the accepted packet. It should be not that these error and status bits do not reflect the settings of the corresponding register bits in DLCR0 and DLCR1. This is outlin below.

The format of the status byte is as follows:

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	*PACKET OK*	*REMOTE RESET*	*SHORT ERROR*	*ALIGN ERROR*	*CRC ERROR*	*OVRFLO*

Bit 7 and 6 are not used and always set at '0.' The settings of the status bits: 5, 3, 2 and 1 depend very much on the settings ACPT_BADPKT (DLCR5<5>) and ENA_SRTPKT (DLCR5<3>). When ACPT_BADPKT is set to a 1, a packet that has any erro (such as short packet, alignment or CRC errors), will set the respective status bits (*SHORT ERROR, ALIGN ERROR, CRC ERRO* to a 1 and the *PACKET OK* (bit 5) to a 0. The value in DLCR1 will not indicate any errors and DLCR1<7> is set to 1. Hence, t status byte of the RAM is not a mirror image of DLCR1. Similarly, this applies when ENA_SRTPKT (DLCR5<3>) is set to enab SSI 78Q8373 to accept short packets.

As for the *OVRFLO* bit, it will be set under the following conditions. When the receive buffer memory is too small to accommoda any in-coming packet, then DLCR1<0> will be set (but not bit0 of the status byte as the packet has already rejected). Later, if subsequent packet is successfully loaded into the receive buffer memory then the *OVRFLO* bit in the status byte will be set (but n DLCR1<0>). This is to indicate to the host that one or more packets have been reject by the receiver due to memory overflo problems.

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Application Guide
Monolithic Dual-Tone Multi-Frequency (DTMF) Receivers

January 1993

INTRODUCTION

The Silicon Systems integrated DTMF Receivers and Transceivers are complete Touch-Tone™ detection and generation systems. Each can operate in a stand-alone mode for the majority of telecommunications applications, thereby providing the most economical implementation of DTMF signaling systems possible. Each combines precision active filters and analog circuits with digital control logic on a monolithic CMOS integrated circuit. SSI DTMF chip use is straightforward and the external component requirements are minimal. This application guide describes device operation, performance, system requirements and typical application circuits for the SSI DTMF chips.

HOW THE SILICON SYSTEMS DTMF CIRCUITS WORK

GENERAL DESCRIPTION OF OPERATION

The task of a DTMF Receiver is to detect the presence of a valid DTMF signal on a telephone line or other transmission medium. The presence of a valid DTMF signal indicates a single dialed digit; to generate a valid digit sequence, each DTMF signal must be separated by a valid pause.

Table 1 gives the established Bell system standards for a valid DTMF signal and a valid pause. The SSI DTMF Receivers meet or exceed these standards.

Similar device architecture is used in all SSI DTMF Receivers. Figure 1 shows the SSI 75T202 Block Diagram. This architecture is implemented in all Silicon Systems single chip receivers, as well as SSi Transceivers. In general terms, the detection scheme is as follows: The input signal is pre-filtered and then split into two bands, each of which contains only one DTMF tone group. The output of each band-split filter is amplified and limited by a zero-crossing detector. The limited signals, in the form of square waves, are passed through tone frequency bandpass filters. Digital logic is then used to provide detector sampling and determine detection validity, to present the digital output data in the correct format, and to provide device timing and control.

PARAMETER	VALUE
One Low-Group Tone, and	697, 770, 852 or 941 Hz
One High-Group Tone	1209, 1336, 1477 or 1633 Hz
Frequency Tolerance	fo ± (1.5% + 2 Hz)
Amplitude Range	-24 dB ≤ A ≤ 6 dBm @ 600Ω (Dynamic Range 30 dB)
Relative Amplitude (Twist)	$-8\,\text{dB} \le \frac{\text{High Group Tone}}{\text{Low Group Tone}} \le +4\,\text{dB}$
Duration	40 ms or longer
Inter-tone Pauses	40 ms or longer

TABLE 1: Bell System Standards

9

PERFORMANCE CONSTRAINTS

SPEECH IMMUNITY AND NOISE TOLERANCE

The two largest problems confronting a DTMF Receiver are:

1) Distinguishing between valid DTMF tone pairs and other speech or stray signals that contain DTMF tone pair frequencies. This is referred to as Speech Immunity.

2) Detecting valid tone pairs in the presence of noise, which is typically found in the telephone (or other transmission medium) environment. This is referred to as Noise Tolerance.

The SSI DTMF Receivers use several techniques to distinguish between valid tone pairs and other stray signals. These techniques are explained in later sections. Briefly, the techniques are:

1) Pre-filtering of audio signal. Removes supply noise and dial tone from input audio signal and emphasizes the voice frequency domain.

2) Zero-cross detection. Limits the acceptable level of noise during detection of a tone pair. Important for speech rejection.

3) Valid tone pair/pause sampling. Samples the detection filters and checks for consistency before a valid tone is declared.

DETAILED DESCRIPTION OF OPERATION

AUDIO PREPROCESSOR

The Audio Preprocessor is an analog filter that band limits the input analog signal between 500 Hz and 6 kHz. In addition, it emphasizes the 2 kHz to 6 kHz voice region.

Band limiting suppresses power supply and dial tone frequencies, and high frequency noise. The emphasized voice region helps to equalize the audio response since many phone lines tend to roll off at about 1 kHz. In addition, preservation of the upper voice frequencies is important in providing speech immunity.

TONE BAND SPLITTING

After the analog signal is preprocessed, it is split into two bands, each of which contains only one DTMF tone

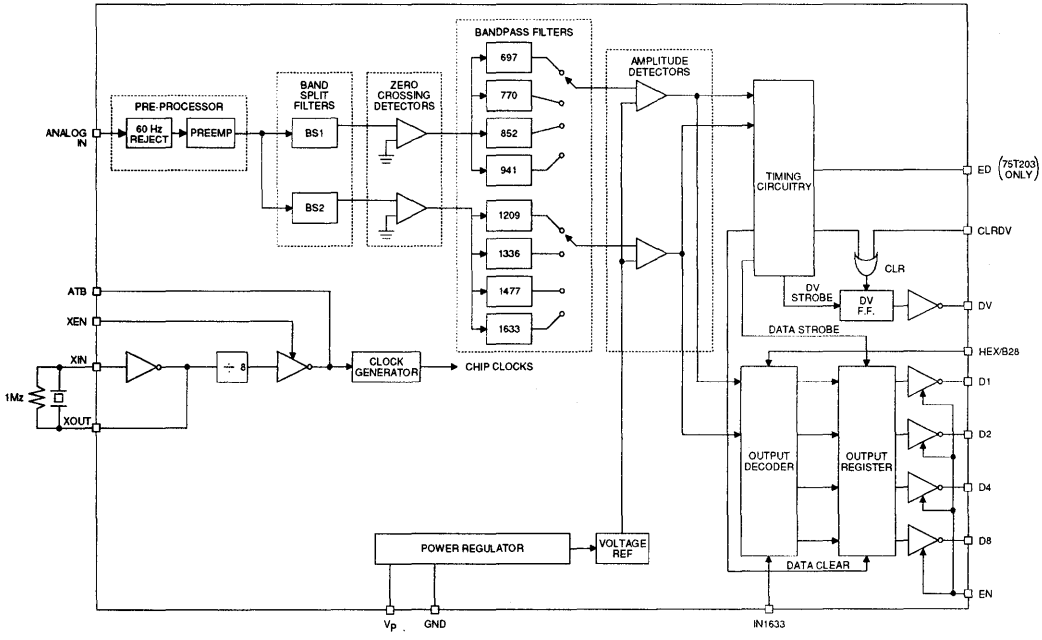


FIGURE 1: SSI 75T202 Block Diagram

group. The band-split filters are actually band-stop filters to maintain all frequencies except the *other* tone group; this is done to maintain all analog information to enhance speech immunity but not allow the other tone group to act as interfering noise for the band being detected. These band-stop filters have "floors" that limit the amount of tone pair twist which further enhances speech immunity. See device data sheets for acceptable twist limits.

ZERO-CROSSING DETECTORS

The output of each band-split filter is amplified and limited by a zero-crossing detector (limiter). The function of the zero-crossing detector is to produce a square wave at the prime frequency emanating from the band-split filter. If a pure tone is not present, as in the case of voice or other interfering noise, a rectangular wave with a variable period will result. Proportional to the interference, the limiter output power is spread over a broad frequency range as the zero crossings "dither." When a high level of noise or speech occurs, no single bandpass filter pair will contain significant power long enough to result in a tone detection. On the other hand, when a pure DTMF tone exists with acceptable noise levles, the output of the limiter will not have any significant dither and tone detection will occur. The zero-crossing detector also acts as AGC (Automatic Gain Control) in that the output amplitude is independent of input amplitude; this additionally establishes an acceptable signal-to-noise ratio not dependent on tone amplitude.

BANDPASS FILTERS & AMPLITUDE DETECTORS

The bandpass filters perform tone frequency discrimination. Their responses are tailored so that if the frequency of the limited square wave from the zero-crossing detector is within the tone frequency tolerance, the fitler output will exceed the amplitude detector threshold. The amplitude detectors are interrogated periodically by the digital control circuitry to acertain the presence of only one tone in each band for the required duration. In a similar fashion, valid pauses are measured by the absence of valid tone pairs for the specified time.

TIMING AND LOGIC

During the qualification process, the output decoder gererates the proper digital code for the received DTMF tone pair. After the fidelity and duration of this signal have been verified, the timing circuitry latches this code into the output register and raises the data valid (DV) flag.

The only precision external element needed for the SSI DTMF Receivers is a 3.58 MHz parallel resonant crystal (color-burst frequency) with a .01% tolerance for the on-board oscillator. A 1 MΩ 10% resistor should be connected in parallel with the crystal. This generates the precise clock for the filters and for the logic timing and control of the chip.

CIRCUIT IMPLEMENTATION

Standard CMOS technology is used for the entire circuit. Logic functions use standard low-power circuitry while the analog circuits use precision switched-capacitor-filter technology.

HOW TO USE THE SSI DTMF RECEIVERS

PRECAUTIONS

Although static protection devices are provided on the high-impedance inputs, normal handling precautions observed for CMOS devices should be used.

All CMOS parts are prone to a destructive latch-up mode. This behavior is inherent to these parts due to their physical structure. The latch-up mode can best be described as a low impedance, high current state existing between the power supply connections on a CMOS chip. This is also referred to as triggering of parasitic SCR behavior.

The most common cause of a latch-up mode is operating a CMOS part outside its rated power supply voltage. This over-voltage need not be applied at power supply pins only to cause latch-up. Latch-up can occur when over-voltage is applied at any input or output. For the SSI DTMF Receivers & Transceivers, the pin voltages should be constrained to the range between VN – 0.5V and VP + 0.5V (except the analog input pin whose conditions are discussed below). Clamping diodes should be utilized wherever necessary to ensure that voltage ratings are not exceeded.

Another cause for latch-up is fast dv/dt transients affecting the chip. These transients are encountered in applications that require the connection/disconnection of "live" boards. While these applications are very rare and their implementation is best avoided, it must be mentioned that whenever they are necessary, they present a severe environment for CMOS parts. Care must be taken in such instances to ensure that ground planes and rails are connected first and disconected last. This will go a long way in eliminating voltage transients.

Voltage transients that exist on power lines must also be eliminated. High voltage transients caused by switching of high current devices can trigger latch-up. High frequency decoupling is a requirement for the proper operation of the SSI DTMF devices. A 0.01μF to a 0.1μF ceramic decoupling capacitor should be connected to the power supply pin at the chip.

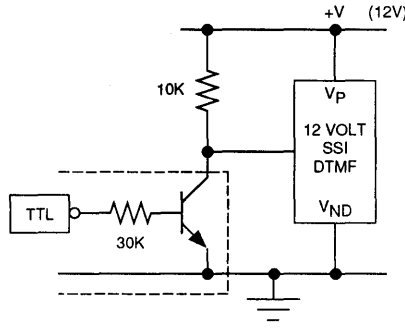


FIGURE 2: Interface Circuit for Conversion from TTL Output Levels to 12V SSI DTMF Input Levels

POWER SUPPLY

Excessive power supply noise should be avoided, and to aid the user in this regard, power supply hook-up options are provided on some devices.

Since the digital circuitry of the devices possess the high noise immunity characteristics of CMOS logic, it is the analog section that is affected most by power supply noise. On those SSI DTMF Receivers that have separate Analog Negative and Digital Negative supply connections (grounds), namely VNA and VND, an unfiltered supply may be used at VND. It is necessary that VND and VNA differ no more than 0.5V.

The analog circuitry of the devices require low power supply noise levels as specified on the device data sheet. The effects of excessive power supply noise are decreased tone amplitude sensitivity and less tone detection frequency bandwidth. Power supply noise can be significantly reduced by decoupling the chip with a 0.1µF ceramic capacitor. Power supply noise effects will be slightly less if the analog input is referenced to VP. This is normally accomplished by connecting VP to ground and utilizing a negative power supply.

DIGITAL INPUTS

The digital inputs are directly compatible with standard CMOS logic devices powered by VP and VN (or VND). The input logic levels should swing within 30% of VP or VN to insure detection. Any unused input must be tied to VN or VP. Figure 2 shows a method for interfacing TTL outputs to 12V SSI DTMF Receivers.

ANALOG INPUT

The analog input is the signal input pin for the devices, and is specially biased to facilitate its connection to external circuitry, as shown in Figure 3. The signal level at the analog input pin must not exceed the positive supply as stated on the device data sheets. If this condition cannot be guaranteed by the external circuitry, the signal must be AC coupled into the chip with a .01µF ± 20% capacitor.

ANALOG INPUT NOISE

The SSI DTMF Receivers will tolerate wide-band input noise of up to 12 dB below the lowest amplitude tone component during detection of a valid tone pair. Any single interference frequency (including tone harmonics) between 1 kHz and 6 kHz should be at least 20 dB below the lowest amplitude tone component. Adherence to these conditions will ensure reliable detection and full tone detection frequency bandwidth. Because of the internal band limiting, noise with frequencies above 8 kHz can remain unfiltered. However, noise near the 56 kHz internal switched-capacitor-filter sampling frequency will be aliased (folded back) into the audio spectrum; noise above 28 kHz therefore should be low-pass filtered with a circuit as shown in Figure 4 using a cut-off frequency (fc) of 6.6 kHz.

A 1 kHz cut-off frequency filter can be used on "normal" phone lines for special applications. When a phone line is particularly noisy, tone pair detection may be unreliable. A 1 kHz low pass filter will remove much of the noise energy but maintain the tone groups; however, a decreased speech immunity will result. This usage should only be considered for applications where speech immunity is not important, such as control paths that carry no speech.

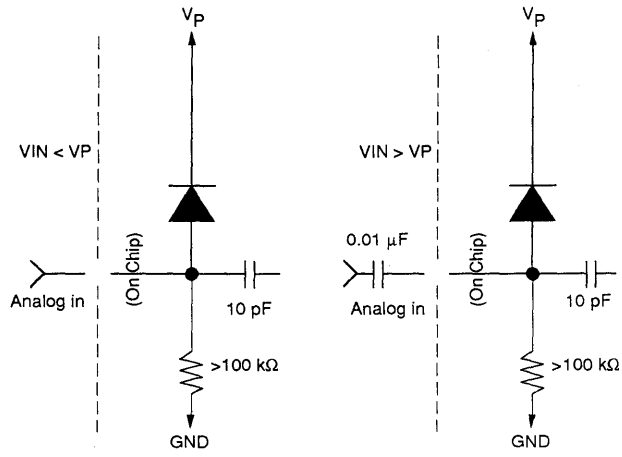


FIGURE 3: Direct and AC Coupled Configurations

Some DTMF tone pair generators output distorted tones which the SSI DTMF Receivers may not detect reliably (inexpensive extension telephones are an example). Most of the interfering harmonics of these may be removed by the use of a 3 kHz low-pass filter as in Figure 4. Some speech immunity degradation will result. It should be mentioned that when using low-pass filters, a higher cut-off frequency will preserve more of the speech immunity advantages.

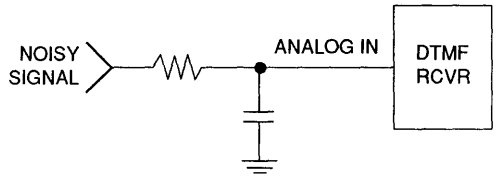
The SSI DTMF Receivers provide superior speech immunity and noise rejection. The analog signals are subjected to stringent criteria and rigorous qualification in order to assure that only true DTMF tone pairs are detected and decoded properly. Stray signal and noise with sufficient amplitude will cause a DTMF receiver to disqualify a DTMF tone pair.

Such a condition can be occasionally encountered when using DTMF "beepers." Beepers are normally used to transmit DTMF signals from dial-pulse phones. It has been observed that the non-linearity in the response of carbon microphones in telephone handsets introduces intermodulation products, which actually produce new frequency components. These components happen to fall direclty into the useful bandwidths of some of the basic tones that the receiver must detect. Because of the presence of these components (normally referred to as third-tone) with a valid DTMF tone, detection is disabled. To inhibit the more common higher frequency third tones from arriving to the receiver, the circuit shown in Figure 5 is suggested.

TELEPHONE LINE INTERFACE

In applications that use an SSI DTMF Receiver to decode DTMF signals from a phone line, a DAA (Direct Access Arrangement) must be implemented. Equipment intended for connection to the public telephone network must comply with and be registered in accordance to FCC Part 68. For PBX applications refer to EIA Standard RS-464.
Some of the basic guidelines are:

1) Maximum voltage and current ratings of the SSI DTMF Receivers must not be exceeded; this calls for protection from ringing voltage, if applicable, which ranges from 80 to 120V RMS over a 20 to 80 Hz frequency range.
2) The interface equipment must not breakdown with high-voltage transient tests (including a 2500V peak surge) as defined in the applicable document.
3) Phone line termination must be less than 200Ω DC and approximately 600Ω AC (200-3200 Hz).
4) Termination must be capable of sustaining phone line lop current (off-hook condition) which is typically 18 to 120 mA DC.
5) The phone line termination must be electrically balanced with respect to ground.
6) Public phone line termination equipment must be registered in accordance to FCC Part 68 or connected through registered protection circuitry. Registration typically takes about six months.



FC (kHz)	R (kΩ) (=5%)	C (μF) (=20%)
1.0	1.6	0.1
3.1	5.1	0.01
6.6	2.4	0.01

SUGGENSTED COMPONENT VALUES

FIGURE 4: Filter for Use in Noisy Environments

Ready made DAA devices are also available. The SSI 73M9001 is a DAA Micromodule housed in a 30-pin DIP footprint.

Figure 6 shows a simplified phone line interface using a 600Ω 1:1 line transformer. Transformers specially designed for phone line coupling are available from many transformer manufacturers.
Figure 7 shows a more enhanced version of Figure 6. These added features include:

1) A 150V surge protector to eliminate high voltage spikes.
2) A Texas Instruments TCM 1520A ring detector, optically isolated from the supervisory circuitry.
3) Back-to-back Zener diodes to protect the DTMF (and optional multiplexer Op-Amp) from ringer voltage.
4) Audio multiplexer which allows voice or other audio to be placed on the line (a recorded message, for example) and not interfere with incoming DTMF tone detection.

OUTPUTS

The digital outputs of the SSI DTMF Receivers (except XOUT) swing between VP and VN (or VND) and are fully compatible with standard CMOS logic devices powered from VP and VN. The 5V DTMF devices will also interface directly to LSTTL. The 12V DTMF devices can interface to TTL or low voltage MOS with the circuit in Figure 8.

Data Outputs D8, D4, D2 and D1 are three-state enabled to facilitate interface to a three-state bus. Figure 9 shows the equivalent circuit for the data outputs in the high impedance state. Care must be taken to prevent either substrate diode in Figure 9 from becoming forward biased or damage may result.

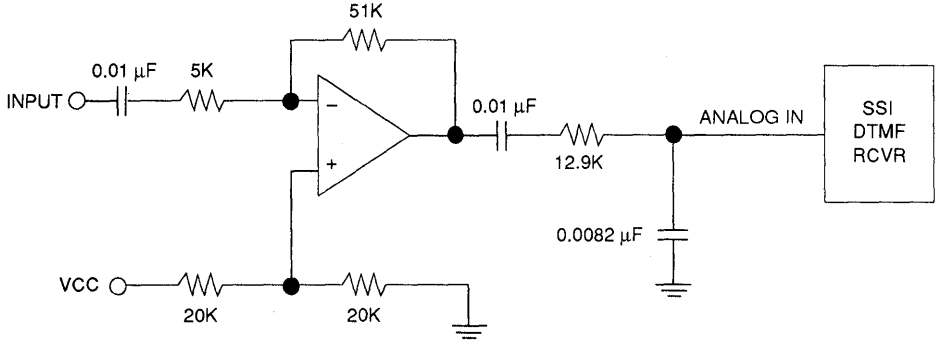


FIGURE 5: Filter for Use in Environments where a Third Tone Exists

TIMING

Within 40 ms of a valid tone pair appearing at the DTMF Receiver Analog Input, the Data Outputs D8, D4, D2 and D1 will become valid. Seven microseconds after the data outputs have become valid DV will be raised. DV will remain high and the outputs valid while the valid tone pair remains present. Refer to individual data sheets for the timing of signals.

SYSTEM INTERFACE

Provision has been made on the SSI DTMF Receivers (with the exception of SSI 75T204) for handshake interface with an outside monitoring system. In this mode, the DV strobe is polled by the monitoring system at least once every 40 ms to determine whether a new valid tone pair has been detected. If DV is high, the coded data is stored in the monitoring system and the CLRDV is pulsed high. With some systems operating in the handshake mode, it may be desirable to know when a valid pause has occurred. Ordinarily this would be indicated by the falling edge of DV. However, in the handshake mode, DV is cleared by the monitoring system each time a new valid tone pair is detected and, therefore, cannot be used to determine when a valid pause is detected. The detection of a valid pause in this case may be observed by detecting the clearing of the Data Outputs. Since, in hexadecimal format (the mode normally used with a handshake interface), the all zero state represents a commonly unused tone pair (D), the detection of a valid pause may be detected by connecting a four-input NOR gate to the device outputs and sensing the all zero state.

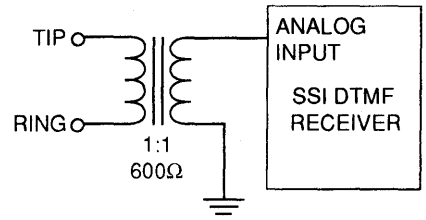


FIGURE 6: Simplified Phone Line Interface

TIME BASE

The SSI DTMF Receivers contain an on-chip oscillator for a 3.5795 MHz parallel resonant quartz crystal or ceramic resonator. The crystal (or resonator) is placed between XIN and XOUT in parallel with a 1 MΩ resistor, while XEN is tied high. Since the switched-capacitor-filter time base is derived from the oscillator, the tone detect band frequency tolerance is proportional to the time base tolerance. The SSI DTMF Receiver frequency response and timing is guaranteed with a time base accuracy of at least ± 0.01%. To obtain this accuracy the CTS Part No. MP036 or Workman Part No. CY1-C or

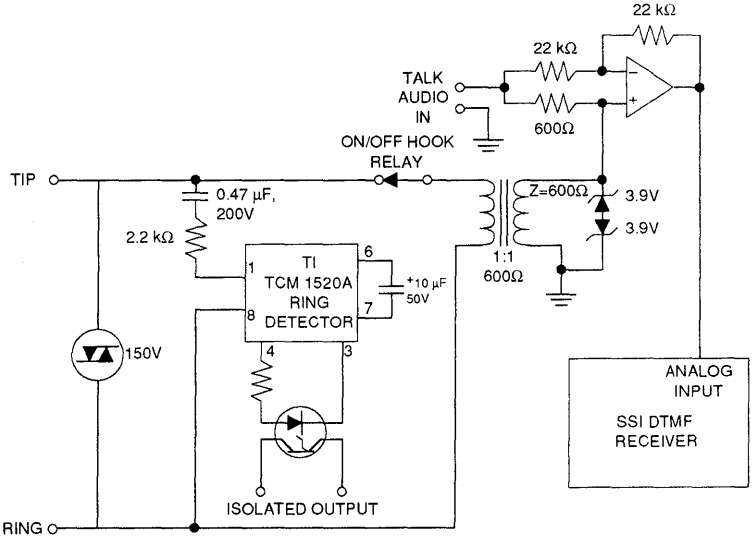


FIGURE 7: Full Featured Phone Line Interface

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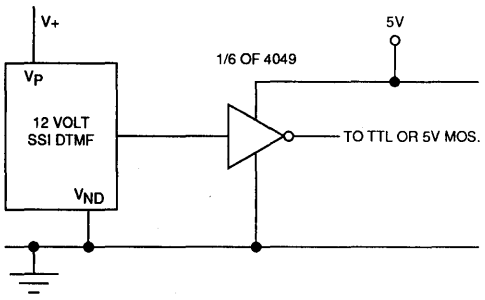


FIGURE 8: SSI 12V DTMF to TTL Level Interface

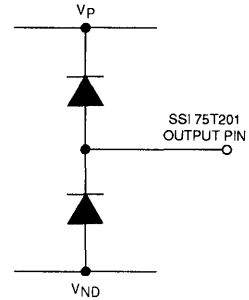


FIGURE 9:Equivalent Circuit of SSI DTMF Receiver Data Output in High Impedance State

equivalent quartz crystal is recommended. In less critical applications a suitable ceramic resonator may be implemented.

The use of a ceramic resonator requires the addition of two 30 pF ± 10% capacitors; one between XIN and VN (or VND) and the other between XOUT and VN (or VND). Extra caution should be used to avoid stray capacitance on the resonant circuit when using a ceramic resonator instead of a quartz crystal.

When the oscillator is connected as above and XEN is tied high, the ATB (Alternate Time Base) pin delivers a square wave output at one-eighth the oscillator frequency (447.443 kHz nominal). The ATB pin can be converted to a time base input by tying XEN low; ATB can then be externally driven from another device such as the ATB output of another DTMF. No crystal is required for the ATB input device; XIN must be tied high if unused. Several SSI DTMF Receivers can be driven with a single crystal (refer to device data sheet for fan-out limit).

XOUT is designed to drive a resonant circuit only and is not intended to drive additional devices. If a 3.58 MHz clock is needed for more than one device and it is desirable to use only one resonant device, an outside inverter should be used for the time base, buffered by a second inverter or buffer. The buffer output would then drive XIN of the SSI DTMF Receiver as well as the other device(s); XOUT must be left floating and XEN tied high.

DIAL TONE REJECTION

The SSI DTMF Receivers incorporate enough dial tone rejection circuitry to provide dial tone tolerance of up to 0 dB. Dial tone tolerance is defined as the total power of precise dial tone (350 Hz and 440 Hz as equal amplitudes) relative to the lowest amplitude tone in a valid tone pair. The filter of Figure 10 may be used for further dial tone rejection. This filter exhibits an elliptic highpass response that provides a minimum of 18 dB rejection at 350 Hz, and 24 dB rejection at 440 Hz so long as the component tolerances indicated are observed. The DTMF on-chip filter rejects 350 Hz at least 6 dB more than 440 Hz. Therefore, employing the filter of Figure 10 yields a dial tone tolerance of +24 dB.

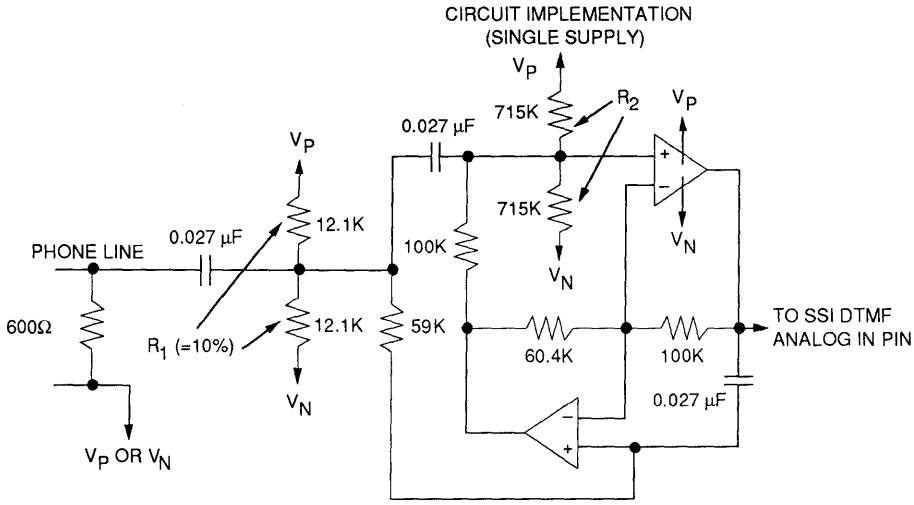
PRINTED CIRCUIT BOARD IMPLEMENTATION

The SSI DTMF Receivers are analog in nature and should be treated as such; circuit noise should be kept to a minimum. To be certain of this, all input and output lines should be kept away from noise sources (high frequency data or clock lines); this is especially true for the Analog Input. Noise in the ground or power supply lines can be avoided by running separate traces to supportive logic circuits or by running thicker (lower resistance) busses. Capacitance power supply bypassing should be performed at the device. Refer to the Power Supply section above.

PERFORMANCE DATA

A portion of the final SSI DTMF Receiver device characterization uses the Mitel CM7290 tone receiver test tape. The evaluation circuit shown in Figure 11 was used to characterize the SSI 75T201. The speed and output level of the tape deck must be adjusted so that the calibration tone at the beginning of the tape is at exactly 1000 Hz and 2V rms.

The Mitel tape tests yield similar results on all of the SSI DTMF Receivers. Test results for the SSI 75T201 are summarized in Table 2. In short, the measured performance data demonstrates that the SSI DTMF Receivers are monolithic realizations of a full "central office quality" DTMF Receiver.



Note: All resistors 1%, all caps 5%, unless noted, op-amps: 1/2 LM1458 or equivalent

FIGURE 10: Dial Tone Reject Filter

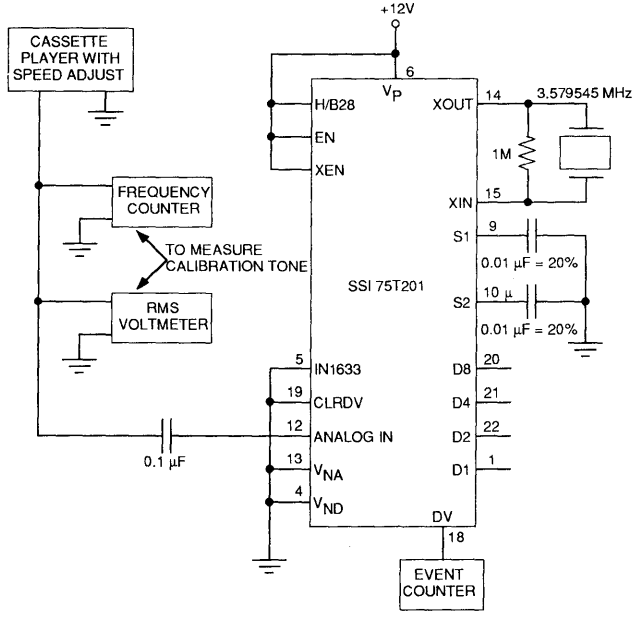


FIGURE 11: Circuit for Receiver Evaluation

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TEST #	RESULTS
2a, b	B.W. = 5.0% of fo
2c, d	B.W. = 5.0% of fo
2e, f	B.W. = 5.3% of fo
2g, h	B.W. = 4.9% of fo
2i, j	B.W. = 5.0% of fo
2k, l	B.W. = 5.3% of fo
2m, n	B.W. = 5.3% of fo
2o, p	B.W. = 4.8% of fo
3	160 decodes
4	Acceptable Amplitude Ratio (Twist) = –19.1 dB to +15.2 dB
5	Dynamic Range = 32.5 dB
6	Guard Time = 23.3 ms
7	100% Successful Decodes at N/S Ratio of –12 dBV
8	2-3 Hits Typical on Talk-Off Test

TABLE 2: Mitel #CM7290 Tape Test Results for SSI 75T201 (Averaged for 10 parts)

APPLICATIONS

CREATING HEXADECIMAL "0" OUTPUT UPON DIGIT "0" DETECTION

To be consistent with pulse-dialing systems, the SSI DTMF Receivers provide a hexadecimal "10" output upon the detection of a digit "0" tone pair when in the hexadecimal code format. However, some applications may instead require a hexadecimal "0" with a digit "0" detection. The circuit of Figure 12 shows an easy method to recode the hexadecimal outputs to do this using only 4 NOR gates.

Note that this circuit will not give proper code for the " * ", "B", or "C" digits and will cause both digits "D" and "0" to output hexadecimal "0." This circuit should therefore be considered for numeric digits only. The output code format is shown in Table 3.

This circuit is useful for applications that require a display of dialed digits; the digit display usually requires a hexadecimal "0" input for a "0" to be displayed.

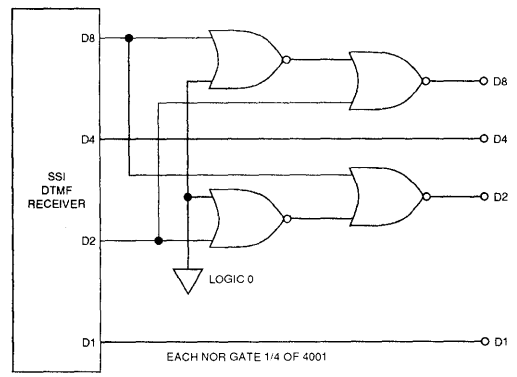

FIGURE 12: Hex "0" Out with Digit "0" Detect Conversion Circuit

16-CHANNEL REMOTE CONTROL

DTMF signaling provides a simple, reliable means of transmitting information over a 2-wire twisted pair. The complete schematic of a 16-channel remote control is shown in Figure 13. When one of the key pad buttons is depressed, a tone pair is sent over the transmission medium to the SSI DTMF Receiver.

The 4514 raises one of its 16 outputs in response to the 4-bit output code from the DTMF. The output at the 4514 will remain high until the next button is depressed.

Hexadecimal					Hexadecimal & Figure 12 Circuit				
Digit	D8	D4	D2	D1	Digit	D8	D4	D2	D1
1	0	0	0	1	1	0	0	0	1
2	0	0	1	0	2	0	0	1	0
3	0	0	1	1	3	0	0	1	1
4	0	1	0	0	4	0	1	0	0
5	0	1	0	1	5	0	1	0	1
6	0	1	1	0	6	0	1	1	0
7	0	1	1	1	7	0	1	1	1
8	1	0	0	0	8	1	0	0	0
9	1	0	0	1	9	1	0	0	1
0	1	0	1	0	0	0	0	0	0
*	1	0	1	1	*	0	0	0	1
#	1	1	0	0	#	1	1	0	0
A	1	1	0	1	A	1	1	0	1
B	1	1	1	0	B	0	1	0	0
C	1	1	1	1	C	0	1	0	1
D	0	0	0	0	D	0	0	0	0

TABLE 3: Output Code of Figure 13

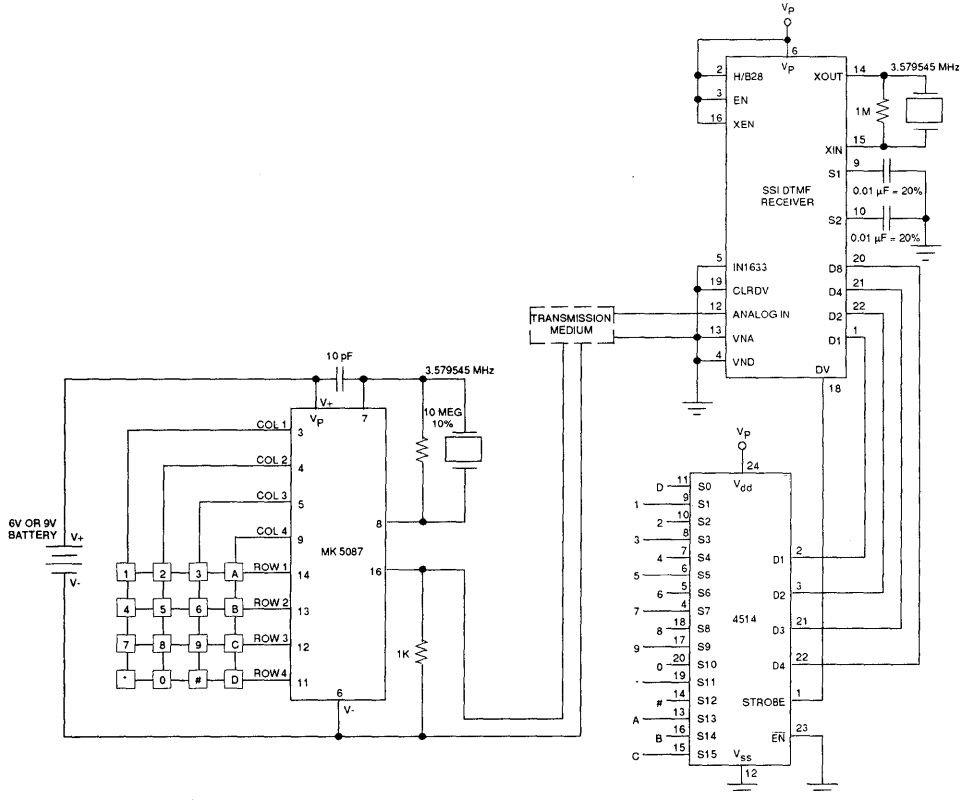

FIGURE 13: 16-Channel Remote Control

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2-0F-8 OUTPUT DECODE

The circuit shown in Figure 14 can be used to convert the binary coded 2-of-8 to the actual 2-of-8 code (or 2-of-7 if detection of 1633 Hz tone is inhibited). The output data will be valid while DV is high. If it is desired to force the eight outputs to zero when a valid tone is not present, DV should be inverted and connected to both E–NOT inputs of the 4555.

DTMF TO ROTARY DIAL PULSE CONVERTER

The 2-of-8 output of Figure 14 can be modified to interface with a pulse dialer as shown in Figure 15. If a 12V DTMF is used the 4049 will translate the 12V outputs to the 5V swings required for the MK5099 pulse dialer.

Figure 16 shows the interface for adding pulse detection and counting to a SSI DTMF Receiver.

The loop detector provides a digital output representing the telephone loop circuit "make" and "break" condition associated with rotary pulse dialing. For the circuit of Figure 16, ground represents a "make" and VP a "break." The loop detector feeds dial pulses to IC-1, a binary counter, and to IC-2A, a re-triggerable "one-shot." When a dial pulse appears the Q1-NOT output of IC-2A immediately goes low, resetting IC-1. The clock input to IC-1 is delayed by R1-C1 so that reset and count input do not overlap. The binary outputs of IC-1 will reflect the pulse count and 0.2 seconds after the last pulse the Q1-NOT output will go high. C3-R3 differentiate this pulse and clock the output latch, IC-3, holding the output pulse until the next digit.

The 0.2 second timeout of IC-2A indicates the end of dial pulsing since even a slow (8 pps) dial would input another pulse every 0.125 seconds. The binary outputs of IC-1 are paralleled with those of the SSI DTMF Receiver circuit through diodes to the inputs of IC-3. A pulldown resistor is necessary on each IC-3 input pin. IC-1 must be a binary, not BCD, counter.

With a 4175 for IC-3 the output data is latched until the next valid input, whether from a rotary dial or dual tone instrument. A unique situation exists, however, when going on-hook. The loop detector will output a continuous level of VP which would trigger IC-2A and put a single count into IC-1. A high level from the loop detector also turns on Q1, pulling the clock input of IC-3 to ground. Since the loop detector output will be low at the completion of dialing, all outputs are valid even when the telephone is placed on-hook, an important consideration if output data is recorded.

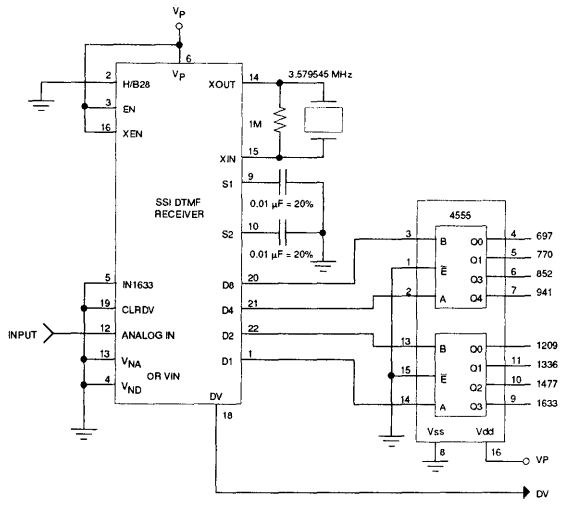

FIGURE 14: Touch-Tone™ to 2-of-8 Output Converter

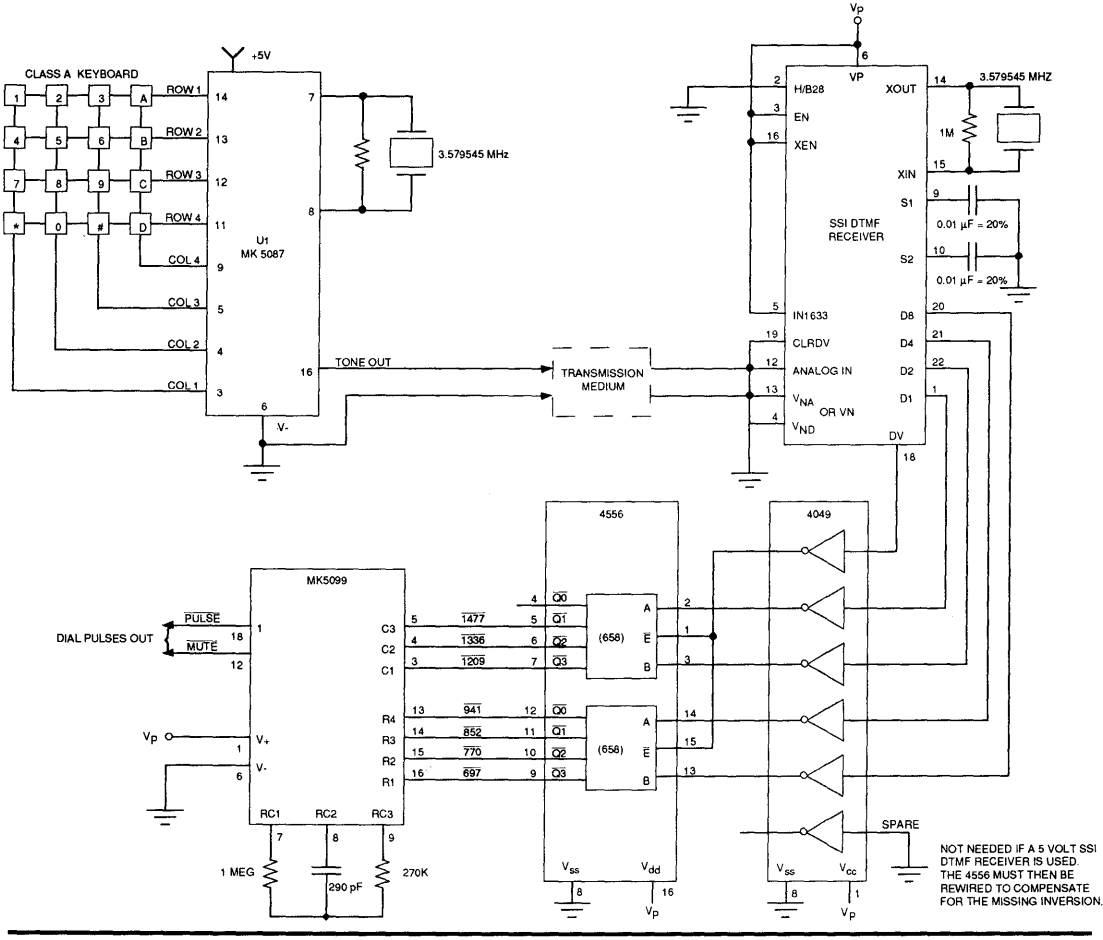

FIGURE 15: Touch-Tone™ to Rotary Dial Pulse Converter Adding Rotary Dial Pulse Detection Capabilities

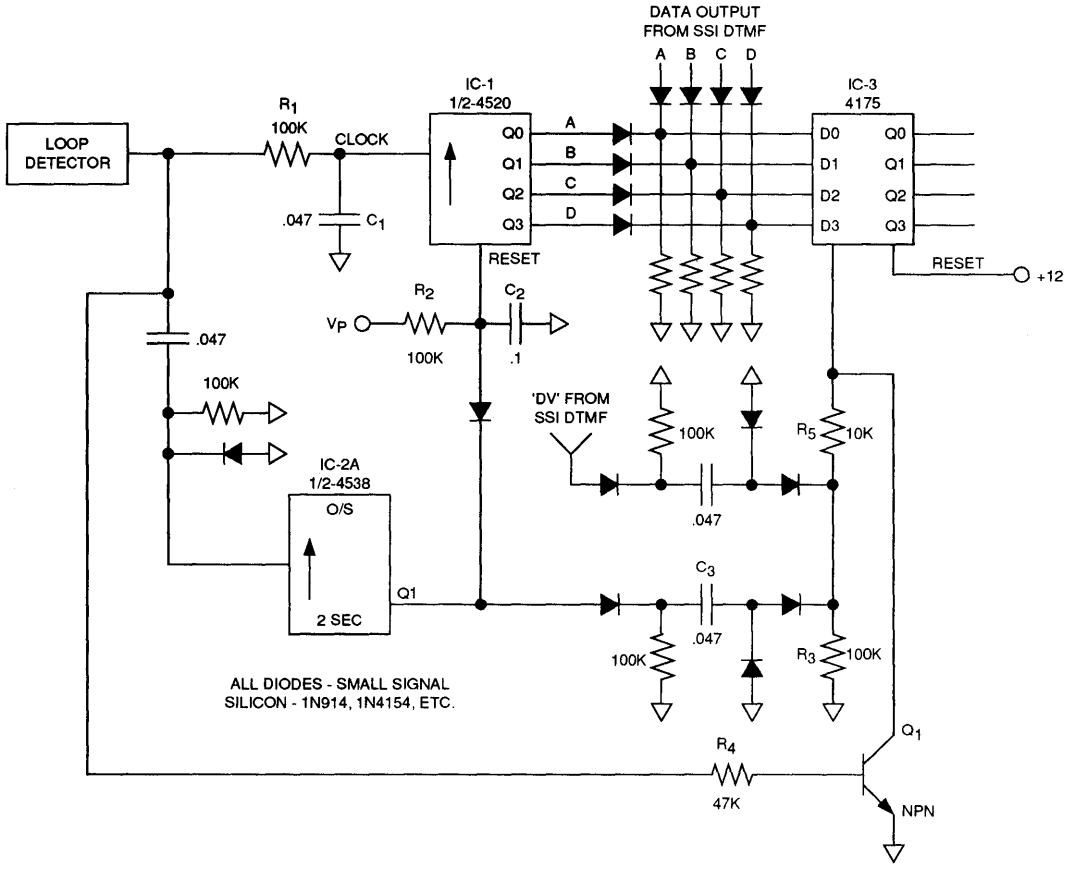

FIGURE 16: Adding Pulse Detection and Counting to the SSI DTMF Receiver

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Glossary

A

ACK - "Acknowledge" character. A transmission control character transmitted by a station as an affirmative response to the station with which a connection has been set up. An acknowledge character may also be used as an accuracy control character.

ACOUSTIC COUPLER - A type of low-speed modem interface frequently used with portable terminals. It sends and receives data using a conventional telephone handset and does not require an electrical connection to the line.

ADAPTIVE DIFFERENTIAL PULSE CODE MODULATION (ADPCM) - An encoding technique, standardized by the CCITT, that allows an analog voice conversation to be carried within a 32K bps digital channel. Three or four bits are used to describe each sample, which represents the difference between two adjacent samples. Sampling is done 8,000 times per second.

ALGORITHM - A prescribed set of well-defined rules for the solution of a problem in a finite number of steps, e.g., A full statement of an arithmetic procedure for evaluating sine x to a stated precision.

AMPLITUDE - Magnitude or size. In waveforms or signals occurring in a data transmission, a complete definition of the waveform can be made if the voltage level is known at all times. In this case, the voltage level is called the amplitude.

AMPLITUDE MODULATION - Method of modifying the amplitude of a sine wave signal in order to encode information.

ANALOG LOOPBACK - A technique used for testing transmission equipment that isolates faults to the analog signal receiving or transmitting circuitry. Basically, where a device, such as a modem, echoes back a received (test) signal that is then compared with the original signal.

ANALOG SIGNAL - Signal in the form of a continuously varying physical quantity such as voltage, which reflects variations in some quantity.

ANSI - American National Standards Institute. A highly active group affiliated with the International Standards Organization (ISO) that prepares and establishes standards for transmission codes (e.g., ASCII), protocols (e.g., ADCCP), media (tape and diskette), and high level languages (e.g., Fortran and Cobol), among other things.

ANSWERBACK - A reply message from a terminal that verifies that the correct terminal has been reached and that it is operational.

APPLICATION LAYER - The top of the seven-layer OSI model, generally regarded as offering an interface to, and largely defined by, the network user; in IBM's SNA, the end-user layer.

ASCII - American Standard Code for Information Interchange. A 7-bit binary code that defines 128 standard characters for use in data communications.

ASYNCHRONOUS - Occurring without a regular or predictable time relationship to a specified event, e.g., The transmission of characters one at a time as they are keyed. Contrast with synchronous.

ASYNCHRONOUS TRANSMISSION - Transmission in which each information character, or sometimes each word or small block, is individually synchronized, usually by the use of start and stop elements. Also called start-stop or character asynchronous transmission.

ATTENUATION - A decrease in the power of a current, voltage, or power of a received signal in transmission between points because of loss through lines, equipment or other transmission devices. Usually measured in decibels.

AUI - Attachment unit interface. The electrical interface between the traditional line electronics (transceiver) and the DTE components (ENDEC & MAC).

AUTO-ANSWER - Automatic answering; the capability of a terminal, modem, computer, or a similar device to respond to an incoming call on a dial-up telephone line, and to establish a data connection with a remote device without operator intervention.

AUTOBAUD - The generally used term for automatically detecting the bit rate of a start/stop (character asynchronous) communication format by measuring the length of the start bit of the first character transmitted. Some modems extend this to additionally determine the parity in use by stipulating that the first two characters from the DTE should be "AT." The word autobaud comes from a popular misuse of baud rate to mean the same as bit rate.

AUTODIAL - Automatic dialing; the capability of a terminal, modem, computer, or a similar device to place a call over the switched telephone network, and establish a connection without operator intervention.

AUTOMATIC DIALER, OR AUTODIALER - Device which allows the user to dial preprogrammed numbers simply by pushing a single button.

B

BANDPASS FILTER - A circuit designed to allow a single band of frequencies to pass; neither of the cut-off frequencies can be zero or infinite.

BANDWIDTH - 1) The range of frequencies that can pass over a given circuit. The bandwidth determines the rate at which information can be transmitted through the circuit. The greater the bandwidth, the more information that can be sent through the circuit in a given amount of time. 2) Difference, expressed in hertz (Hz), between the highest and lowest frequencies of a transmission channel.

10Base-T - Ethernet on unshielded twisted pair.

10Base-2 - Ethernet on thin coax.

10Base-5 - Ethernet on thick coax.

BASEBAND - Pertaining or referring to a signal in its original form and not changed by modulation. A baseband signal can be analog or digital.

BASEBAND SIGNALING - Transmission of a digital or analog signal at its original frequencies, i.e., a signal in its original form, not changed by modulation; can be an analog or digital signal.

BAUD - A measure of data rate, often misused to denote bits per second. A baud is equal to the number of discrete conditions or signal events per second. There is disagreement over the appropriate use of this word, since at speeds above 2400 bit/s, the baud rate does not always equal the data rate in bits per second.

BELLCORE - Bell Communications Research; organization established by the AT&T divestiture, representing and funded by the BOCs and RBOCs, for the purposes of establishing telephone network standards and interfaces; includes much of former Bell Labs.

BERT - Bit Error Rate Test. A test conducted by transmitting a known, pattern of bits (commonly 63, 511, or 2047 bits in length), comparing the pattern received with the pattern transmitted, and counting the number of bits received in error. Also see bit error rate. Contrast with BLERT.

BINARY CODE - Representation of quantities expressed in the base-2 number system.

BINARY SYNCHRONOUS COMMUNICATIONS - A half-duplex, character-oriented data communications protocol originated by IBM in 1964. It includes control characters and procedures for controlling the establishment of a valid connection and the transfer of data. Also called bisync and BSC. Although still enjoying widespread usage, it is being replaced by IBM's more efficient protocol, SDLC.

BIPOLAR - 1) The predominant signaling method used for digital transmission services, such as DDS and T1, in which the signal carrying the binary value successfully alternates between positive and negative polarities. Zero and one values are represented by the signal amplitude at either polarity, while no-value "spaces" are at zero amplitude. 2) A type of integrated circuit (IC or semiconductor) that uses NPN, PNP, and junction FET's as the primary active devices, as opposed to CMOS, which uses MOS FET's. See Alternate Mark Inversion.

BISDN - Broadband integrated services digital network.

BIT - The smallest unit of information used in data processing. It is a contraction of the words "binary digit."

BIT ERROR RATE (BER) - In data communications testing, the ratio between the total number of bits transmitted in a given message and the number of bits in that message received in error; a measure of the quality of a data transmission.

BITS PER SECOND (BIT/S) - Basic unit of measure for serial data transmission capacity; Kbit/s, or kilobits, for thousands of bits per second; Mbit/s, or megabit/s, for millions of bits per second, etc.

BOC - Bell Operating Company. One of 22 local telephone companies spun off from AT&T as a result of divestiture. The 22 operating companies are divided into seven regions and are held by seven RBHCs (Regional Bell Holding Company).

BROADBAND - Referring or pertaining to an analog circuit that provides more bandwidth than a voice grade telephone line, i.e., a circuit that operates at a frequency of 20 kHz or greater. Broadband channels are used for high-speed voice and data communications, radio and television broadcasting, some local area data networks, and many other services. Also called wideband.

BUFFER - A storage medium or device used for holding one or more blocks of data to compensate for a difference in rate of data flow, or time of occurrence of events, when transmitting data from one device to another.

BUS - 1) Physical transmission path or channel. Typically an electrical connection, with one or more conductors, wherein all attached devices receive all transmissions at the same time. Local network topology, such as used in Ethernet and the token bus, where all network nodes listen to all transmissions, selecting certain ones based on address identification. Involves some type of contention-control mechanism for accessing the bus transmission medium. In data communications, a network topology in which stations are arranged along a linear medium (e.g., a length of cable). 2) In computer architecture, a path over which information travels internally among various components of a system.

BYTE - Group of bits handled as a logical unit; usually 8.

C

CABLE - Assembly of one or more conductors within a protective sheath; constructed to allow the use of conductors separately or in groups.

CALL PROGRESS DETECTION (CPD) - A technique for monitoring the connection status during initiation of a telephone call by detecting presence and/or duty cycle of call progress signaling tones such as dial-tone or busy signals commonly used in the telephone network.

CALL PROGRESS TONES - Audible signals returned to the station user by the switching equipment to indicate the status of a call; dial tones and busy signals are common examples.

CAP MODEM - Carrierless amplitude phase modem.

CCITT - Comite Consultatif International de Telephonie et de Telegraphie. Telegraph and Telephone Consultive Committee. An advisory committee to the International Telecommunications Union (ITU) whose recommendations covering telephony and telegraphy have international influence among telecommunications engineers, manufacturers, and administrators.

CDPD - Cellular digital packet data 19.2 Kbit/s wireless modem.

CENTRAL OFFICE (CO) - See Exchange

CHANNEL BANK - Equipment typically used in a telephone central office that performs multiplexing of lower speed, digital channels into a higher speed composite channel. The channel bank also detects and transmits signaling information for each channel, and transmits framing information so that time slots allocated to each channel can be identified by the receiver.

CHANNEL SERVICE UNIT (CSU) - A component of customer premises equipment (CPE) used to terminate a digital circuit, such as DDS or T1 at the customer site; performs certain line-conditioning functions, ensures network compliance per FCC rules and responds to loopback commands from central office; also, ensures proper ones density in transmitted bit stream and performs bipolar violation correction.

CHANNEL, VOICE GRADE - Channel suitable for transmission of speech, analog data, or facsimile, generally with a frequency range of about 300 to 3000 Hz.

CHARACTER - Letter, figure, number, punctuation, or other symbol contained in the message. In data communication, common characters are defined by 7- or 8-bit binary codes, such as ASCII.

CHIP - A commonly used term which refers to an integrated ciruit.

CIRCUIT, TWO-WIRE - A circuit formed by two conductors insulated from each other that can be used as either a one-way or two-way transmission path.

CLOCK - In logic or transmission, repetitive, precisely timed signal used to control a synchronous process.

CMOS - Complementary Metal-Oxide Semiconductor. A type of transistor, typicallly used in low-power integrated circuits.

COAXIAL CABLE - Cable consisting of an outer conductor surrounding an inner conductor, with a layer of insulating material in between. Such cable can carry a much higher bandwidth than a wire pair.

CPE - Customer Premises Equipment

CROSSPOINT - 1) Switching array element in an exchange that can be mechanical or electronic. 2) Two-state semiconductor switching device having a low transmission system impedance in one state and a very high one in the other.

CROSSTALK - Interference or an unwanted signal from one transmission circuit detected on another, usually an adjacent circuit.

CYCLIC REDUNDANCY CHECK (CRC) - A powerful error detection technique. Using a polynomial, a series of two 8-bit block check characters are generated that represent the entire block of data. The block check characters are incorporated into the transmission frame, then checked at the receiving end.

D

DATA COMMUNICATIONS EQUIPMENT (DCE) - Equipment that performs the functions required to connect data terminal equipment (DTE) to the data circuit. In a communications link, equipment that is either part of the network, an access-point to the network, a network node, or equipment at which a network circuit terminates; in the case of an RS-232C connection, the modem is usually regarded as DCE, while the user device is DTE, or data terminal equipment; in a CCITT X.25 connection, the network access and packet-switching node is viewed as the DCE.

DATA LINK - Any serial data communications transmission path, generally between two adjacent nodes or devices and without any intermediate switching nodes.

DATA SET - A synonym for modem used by AT&T and a few other vendors.

DATA SERVICE UNIT (DSU) - A device that replaces a modem on a Digital Data Service (DDS) line. The data service unit regenerates the digital signals for transmission over digital facilities.

DATA TERMINAL EQUIPMENT (DTE) - Equipment which is attached to a network to send or receive data, generally end-user devices, such as terminals and computers, that connect to DCE, which either generate or receive the data carried by the network; in RS-232C connections, designation as either DTE or DCE determines signaling role in handshaking; in a CCITT X.25 interface, the device or equipment that manages the interface at the user premises; see DCE.

dB - Decibel; unit for measuring relative strength of a signal parameter such as power, voltage, etc. The number of decibels is twenty times the logarithm (base 10) of the ratio of the power of two signals, or ratio of the power of one signal to a reference level.

dBm - Decibels relative to one milliwatt.

DDS - 1) Digital Data Service. A digital transmission service supporting speeds up to 56 Kbit/s. 2) Dataphone Digital Service. An AT&T leased line service offering digital transmission at speeds ranging from 2400 to 56 Kbit/s.

DECT - Digital European cordless telephone.

DJCT - Digital Japanese cordless telephone.

DELAY DISTORTION - The change in a signal from the transmitting end to the receiving end resulting from the tendency of some frequency components within a channel to take longer to be propagated than others.

DIAL-UP - The process of, or the equipment or facilities involved in, establishing a temporary connection via the switched telephone network.

DIAL TONE (DT) - Signal sent to an operator or subscriber indicating that the switch is ready to receive dial pulses.

DIGITAL - Referring to communications procedures, techniques, and equipment whereby information is encoded as either binary "1" or "0"; the representation of information in discrete binary form, discontinuous in time, as opposed to the analog representation of information in variable, but continuous, waveforms.

DIGITAL LOOPBACK - A technique for testing the digital processing circuitry of a communications device. It may be initiated locally, or remotely via a telecommunications circuit. The device being tested will echo back a received test message, after first decoding and then re-encoding it, the results of which are compared with the original message.

DIGITAL SIGNAL - Discrete or discontinuous signal; one whose various states are discrete intervals apart.

DIP - Dual-In-Line Package. Method of packaging electronic components for mounting on printed circuit boards.

DISTORTION - The modification of the waveform or shape of a signal caused by outside interference or by imperfections of the transmission system. Most forms of distortion are the result of the characteristics of the transmission system to the different frequency components.

DOTTING, DOUBLE DOTTING, PATTERN - The term "dotting" was coined by Bell to describe a data pattern consisting of alternate marks and spaces. The CCITT uses the full description of "alternating binary ones and zeros" on first needing this idea in a recommendation, but then abbreviate this to "reversals." By extrapolation, "double dotting" has come into use to refer to the data pattern termed "S1" which is used in V.22bis to indicate 2400 bit/s capability. The full description is "unscrambled double dibit 00 and 11 at 1200 bit/s for 100 ± 3 ms."

DS-1 - Digital Signal level 1; telephony term describing a digital transmission format in which 24 voice channels are multiplexed into one 1.544 Mbit/s (U.S.) T1 digital channel.

DS-3 - Digital Signal level 3; telephony term describing the 44.736 Mbit/s digital signal carried on a T3 facility.

DSP RTOS - Digital signal processing real time operating system.

DTMF - Dualtone Multifrequency (DTMF) - Basis for operation of most push button telephone sets. An in-band signalling technique in which a matrix combination of two frequencies, each from a group of four, are used to transmit numerical address information; it encodes 16 possible combinations of tone pairs using two groups of four tones each. The two groups of four frequencies are 697 Hz, 770 Hz, 852 Hz, and 941 Hz, and 1209 Hz, 1336 Hz, 1477 Hz, and 1633 Hz. DTMF is used primary for call initiation in GSTN telephone applications.

E

ECHO - The distortion created when a transmitted signal is reflected back to the originating station.

ECHO CANCELLER - A devise used to reduce or eliminate echo. It operates by placing a signal that is equal and opposite to the echo signal on the return transmission path.

ECHO SUPPRESSOR - A mechanism used to suppress echoes on long-distance analog connections. The device suppresses the transmission path opposite in direction to the one being used. This feature, although necessary for voice transmission, often interferes with data transmission.

EIA - Electronic Industries Association

EIA INTERFACE, EIA232D, RS 232C - The logical, electrical and physical characteristics of the connection between a DTE and a modem is set out in EIA specification 232D. Previously this has been known as RS232C. The logical characteristics are essentially similar to those specified in CCITT recommendation V.24 and the electrical characteristics to those in V.28.

ELECTROMAGNETIC INTERFERENCE (EMI) - Radiation leakage outside a transmission medium that results mainly from the use of high-frequency wave energy and signal modulation. EMI can be reduced by appropriate shielding.

EMI - See Electromagnetic Interference.

ENDEC - Encoder/Decoder. The 10 Mbit/s Manchester encoder and decoder circuit for Ethernet signalling.

ENVELOPE DELAY - An analog line impairment involving a variation of signal delay with frequency across the data channel bandwidth.

EQUALIZATION - The introduction of components to an analog circuit by a modem to compensate for the attenuation (signal loss) variation and delay distortion with frequency (attenuation equalization) and propagation time variations with frequency (delay equalization). Generally, the higher the transmission rate, the greater the need for equalization.

ERROR - In data communications, any unwanted change in the original contents of a transmission.

ERROR BURST - A concentration of errors within a short period of time as compared with the average incidence of errors. Retransmission is the normal correction procedure in the event of an error burst.

ERROR CONTROL - A process of handling errors, which includes the detection and in some cases, the correction of errors.

ETHERNET - A media-access specification for local area networks, developed by IEEE and known as the IEEE 802.3 spec.

EXCHANGE - Assembly of equipment in a communications system that controls the connection of incoming and outgoing lines, and includes the necessary signaling and supervisory functions. Different exchanges, or switches, can be costed to perform different functions, e.g., Local exchange, trunk exchange, etc. See Class of Exchange. Also known as Central Office (U.S. Term).

EXCHANGE, PRIVATE AUTOMATIC BRANCH (PABX) - Private automatic telephone exchange that provides for the switching of calls internally and to and from the public telephone network.

EXCHANGE, PRIVATE BRANCH (PBX) - Private, manually operated telephone exchange that provides private telephone service to an organization and that allows calls to be transmitted to or from the public telephone network.

EXCHANGE AREA - Area containing subscribers served by a local exchange.

F

FILTER - Circuit designed to transmit signals of frequencies within one or more frequency bands and to attenuate signals of other frequencies.

FIRMWARE - Permanent or semi-permanent control coding implemented at a micro-instruction level for an application program, instruction set, operating routine, or similar user-oriented function.

FLOW CONTROL - The use of buffering and other mechanisms, such as controls that turn a device on and off, to prevent data loss during transmission.

FOUR-WIRE CIRCUIT OR CHANNEL - A circuit containing two pairs of wire (or their logical equivalent) for simultaneous (i.e., full-duplex) two-way transmission. Contrast with two-wire channel.

FRAME - 1) A group of bits sent serially over a communications channel; generally a logical transmission unit sent between data-link-layer entities that contain its own control information for addressing and error checking. 2) A piece of equipment in a common carrier office where physical cross connections are made between circuits.

FRAMING - Control procedure used with multiplexed digital channels such as T1 carriers, whereby bits are inserted so the receiver can identify the time slots allocated to each subchannel. Framing bits can also carry alarm signals indicating specific alarm conditions.

FREQUENCY - Rate at which an event occurs, measured in hertz, kilohertz, megahertz, etc.

FREQUENCY BANDS - Frequency bands are defined arbitrarily as follows:

Range (MHz)	Name
0.03-0.3	Low frequency (LF)
0.3-3.0	Medium frequency (MF)
3-30	High frequency (HF)
30-300	Very High frequency (VHF)
300-3000	Ultra high frequency (UHF)
3000-30,000	Super high frequency (SHF) (micro wave)
30,000-300,000	Extremely high frequency (EHF)(millimeterwave)

FSK - Frequency Shift Keying. A method of modulation that uses two different frequencies, usually phase continous, to distinguish between a mark (digital 1) and a space (digital 0) when transmitting on an analog line. Used in modems operating at 1200 bit/s or slower.

FULL-DUPLEX - Pertaining to the capability to send and receive simultaneously.

G

GAIN - Denotes an increase in signal power in transmission from one point to another, usually expressed in dB.

GUARD TONE - In CCITT recommendations V.22 and V.22bis, guard tones may optionally be transmitted along with the data signal from the answering modem. A single frequency of either 1800 or 550 Hz is used and the data signal power must be reduced to keep the overall energy level the same as for transmission without guard tone. The purpose of the guard tone is to prevent the high-band data signal from interfering with the operation of billing apparatus in certain countries.

GSTN - General Switched Telephone Network

H

HALF-DUPLEX - Pertaining to the capability to send and receive but not simultaneously.

HANDSHAKE - An exchange of control sequences between two locations to set up the correct parameters for transmission.

HDLC - High-level Data Link Control. Bit-oriented communication protocol developed by the ISO (International Standards Organization).

HARMONIC DISTORTION - A waveform distortion, usually caused by the nonlinear frequency response of a transmission.

HERTZ (Hz) - A measure of electromagnetic frequency; one hertz is equal to one cycle per second.

HF - High Frequency.

HIGH FREQUENCY (HF) - Portion of the electromagnetic spectrum, typically used in short-wave radio applications. Frequencies in the 3 to 30 MHz range.

Hz - See Hertz.

I

IEEE - Institute of Electrical and Electronics Engineers.

IEEE 802.11 - Wireless local area network IEEE standard.

INITIALIZE - To set counters, switches, addresses, or contents of storage to zero or other starting values at the beginning of, or at prescribed points in, the operation of a computer routine.

INTERFACE - A hardware and/or software link between two devices. The interface defines all signal characteristics and other specifications for physical interconnection of the devices.

INTEROFFICE TRUNK - Direct trunk between local central offices (Class 5 offices), or between Class 2, 3, or 4 offices; also called intertoll trunk.

IS54 - Interim standard 54 - half analog/digital, second-generation North American standard.

ISO - International Organization for Standardization.

ITU - International Telecommunications Union. The parent organization of the CCITT.

J

JITTER - Slight movement of a transmission signal in time or phase that can introduce errors and loss of synchronization for high-speed synchronous communications. See Phase jitter.

K

KEY PULSING (KP) - Manual method of sending numerical and other signals by the operation of nonlocking pushkeys. Also called Key Sending.

KEY SERVICE UNIT (KSU) - Main operating unit of a key telephone system.

KEY TELEPHONE SYSTEM (KTS) - When more than one telephone line per set is required, pushbutton or key telephone systems offer flexibility and a wide variety of uses, e.g., pickup of several exchange lines, PABX station lines, private lines, and intercommunicating lines. Features of the system include pickup and holding intercommunications, visual and audible signals, cutoff, exclusion, and signaling.

KP - Key Pulse (signaling unlocking signal). See Key Pulsing.

kHz - Kilohertz, kilocycles per second.

KTU - Key Telephone Unit. See Key Service Unit.

L

LEASED LINE - A line rented exclusively to one customer for voice or data communications; dedicated circuit, typically supplied by the telephone company or transmission authority, that permanently connects two or more user locations and is for the sole use of the subscriber. Such circuits are generally voice grade in capacity and in range of frequencies supported, are typically analog, are used for voice or data, can be point-to-point, or multipoint, and can be enhanced with line conditioning. Also called private line, tie line, or dedicated facility.

LED - Light-Emitting Diode.

LIGHT-EMITTING DIODE (LED) - Semiconductor junction diode that emits radiant energy and is used as a light source for fiber optic communications, particularly for short-haul links.

LIMITED-DISTANCE MODEM - A short-haul modem or line driver that operates over a limited distance. Some limited-distance modems operate at higher speeds than modems that are designed for use over analog telephone facilities, since line conditions can be better controlled.

LINE HIT - A transient disturbance causing a detectable error on a communications line.

LINE-LOADING - The process of installing loading coils in series with each conductor on a transmission line. Usually 88 milliHenry coils installed at 6,000 foot intervals.

LINK - 1) A physical circuit between two points. 2) A logical circuit between two users of a packet switched (or other) network permitting them to communicate (although different physical paths may be used).

LINK LAYER - The logical entity in the OSI model concerned with transmission of data between adjacent network nodes. It is the second layer processing in the OSI model, between the physical and the network layers.

LOADING COILS - An inductance coil installed at regular intervals along a transmission line. Used to improve the quality of voice grade circuits.

LOCAL EXCHANGE - Exchange in which subscribers' lines terminate. The exchange has access to other exchanges and to national trunk networks. Also called local central office, end office.

LOCAL LOOP - The part of a communications circuit between the subscriber's equipment and the equipment in the local exchange.

LOCAL TRUNK - Trunks between local exchanges.

LOSS (TRANSMISSION) - Decrease in energy of signal power in transmission along a circuit due to the resistance or impedance of the circuit or equipment.

M

MAC - Media access controller - a protocol controller IC that implements the 802.3 CSMA/CO protocol.

MARK - The signal (communications channel state) corresponding to a binary one. The marking condition exists when current flows (current-loop channel) or when the voltage is more negative than -3 volts (EIA RS-232 channel).

MATRIX - In switch technology, that portion of the switch architecture where input leads and output leads meet, any pair of which may be connected to establish a through circuit. Also called switching matrix.

MAU - Media attachment unit - a transceiver that connects to the AUI port on an Ethernet interface card.

Mbit/s - Megabits per second.

MEGAHERTZ (MHz) - A unit of frequency equal to one million cycles per second.

MF - 1) Medium Frequency. 2) Multifrequency. See Dualtone Multifrequency Signaling (DTMF).

MODEM - A contraction of modulate and demodulate; a conversion device installed in pairs at each end of an analog communications line. The modem at the transmitting end modulates digital signals received locally from a computer or terminal; the modem at the receiving end demodulates the incoming signal, converting it back to its original (i.e., digital) format, and passes it to the destination business machine.

MODULATION - The application of information onto a carrier signal by varying one or more of the signal's basic characteristics (frequency, amplitude, or phase); the conversion of a signal from its original (e.g., digital) format to analog format.

MODULATION, PULSE CODE (PCM) - Digital transmission technique that involves sampling of an analog information signal at regular time intervals and coding the measured amplitude value into a series of binary values, which are transmitted by modulation of a pulsed, or intermittent, carrier. A common method of speech digitizing using 8-bit code words, or samples, and a sampling rate of 8 kHz.

ms - Millisecond. One-thousandth of a second.

MULTIPLEXER - Device that enables more than one signal to be sent simultaneously over one physical channel.

MULTIPLEXING - Division of a transmission facility into two or more channels either by splitting the frequency band transmitted by the channel into narrower bands, each of which is used to constitute a distinct channel (frequency-division multiplex), or by allotting this common channel to several different information channels, one at a time (time-division multiplexing).

MUX - See Multiplexer.

N

NAK - "Negative acknowledge" character. A transmission control character that indicates a block of data was received incorrectly.

NOISE - Undesirable energy in a communications path, which interferes with the reception or processing of a signal.

ns - Nanosecond; also nsec. One-billionth of a second.

O

OFF HOOK - By analogy with the normal household telephone, a modem is off-hook when it is using the telephone line to make a call. This is similar to raising the telephone handset, or taking it off the hook. Going off-hook is also known as "seizing the line."

ON-HOOK - By analogy with the normal household telephone, a modem is on-hook when it is not using the telephone line. As with a telephone where the handset is on the hook, the line may be used by other equipment to make a call. Going on-hook is also known as "dropping the line."

OSI - Open Systems Interconnection. Referring to the reference model, OSI is a logical structure for network operations standardized within the ISO; a seven-layer network architecture being used for the definition of network protocol standards to enable any OSI-compatible computer or device to communicate with any other OSI-compliant computer or device for a meaningful exchange of information.

OVERFLOW - Excess traffic on a particular route, which is offered to another (alternate) route.

P

PABX - Private Automatic Branch Exchange. See Exchange, Private Automatic Branch (PABX).

PACKET - A group of binary digits including data and call control signals that is switched as a composite whole. The data, call control signals, and error control information are arranged in a specified format.

PBX - Private Branch Exchange. See Exchange, Private Branch.

PCMCIA - Personal Computer Memory Card International Association. Type 1: 3.3 mm thick
Type 2: 5.0 mm thick

PHASE JITTER - In telephony, the measurement, in degrees out of phase, that an analog signal deviates from the referenced phase of the main data-carrying signal. Often caused by alternating current components in a telecommunications network; or: a random distortion of signal lengths caused by the rapid fluctuation of the frequency of the transmitted signal. Phase jitter interferes with interpretation of information by changing the timing.

PHASE MODULATION - One of three ways of modifying a sine wave signal to make it carry information. The sine wave or "carrier" has its phase changed in accordance with the information to be transmitted.

PROPAGATION DELAY - The period between the time when a signal is placed on a circuit and when it is recognized and acknowledged at the other end. Propagation delay is of great importance in satellite channels because of the great distances involved.

PROTOCOL - A set of procedures for establishing and controlling communications. Examples include BSC, SDLC, X.25, V.42, V.42bis, MNP, V.22bis handshake, etc.

PSK - Phase Shift Keying. A method of modulation that uses the differences in phase angle between two symbols to encode information. A reference oscillator determines the phase angle change of the incoming signal, which in turn determines which bit or dibit is being transmitted. DPSK (Differential Phase Shift Keying) is a variation of PSK which changes the phase relative to the previous phase.

PULSE CODE MODULATION (PCM) - A method of transmitting information by varying the characteristics of a sequence of pulses, in terms of amplitude, duration, phase, or number. Used to convert an analog signal into a digital bit stream for transmission.

R

REGENERATIVE REPEATER - 1) Repeater utilized in telegraph applications to retime and retransmit the received signal impulses and restore them to their original strength. These repeaters are speed- and code-sensitive and are intended for use with standard telegraph speeds and codes. 2) Repeater used in PCM or digital circuits which detects, retimes, and reconstructs the bits transmitted.

REGENERATOR - Equipment that takes a digital signal that has been distorted by transmission and produces from it a new signal in which the shape, timing, and amplitude of the pulses are that same as those of the original before distortion.

REPEATER - 1) In analog transmission, equipment that receives a pulse train, amplifies it and retimes it for retransmission. 2) In digital transmission, equipment that receives a pulse train, reconstructs it, retimes it, and often then amplifies the signal for retransmission. 3) In fiber optics, a device that decodes a low-power light signal, converts it to electrical energy, and then retransmits it via an LED or laser-generating light source. See also Regenerative Repeater.

REVERSE CHANNEL - A simultaneous low speed data path in the reverse direction over a half-duplex facility. Normally, it is used for positive/negative acknowledgements of previously received data blocks.

RINGER EQUIVALENCE NUMBER - This is a number that the FCC assigns to approved telecom equipment that measures how much load it places on the network during ringing. In the U.S.A., you can connect telephones, modems, FAX machines etc. In parallel to the same telephone line only as long as the sum of their ringer equivalence numbers is less than five. Most countries have a similar regulating system in force, although the methods used to arrive at the number vary widely.

RINGING SIGNAL - Any AC or DC signal transmitted over a line or trunk for the purpose of alerting a party at the distant end of an incoming call. The signal can operate a visual or sound-producing device.

RINGING TONE - Tone received by the calling telephone indicating that the called telephone is being rung. Also called Ringback.

RSSI - Receive signal strength indicator (i.e., go to gain control in AM signal).

S

SCRAMBLER/DESCRAMBLER - A scrambler function uses a defined method for modifying a data stream, in order to make the altered data stream appear random. A descrambler reverses the effect of the scrambler using the previously defined method to recover the original data stream. Most often used for data encryption, or to avoid transmitting repetitive data patters that can adversely affect data recovery in modems and other data transmission equipment.

SDLC - Synchronous Data Link Control. IBM bit oriented protocol providing for half-duplex transmission; associated with IBM's System Network Architecture (SNA).

SHIELDED PAIR - Two insulated wires in a cable wrapped with metallic braid or foil to prevent interference and provide noise-free transmission.

SIGNAL-TO-NOISE RATIO - The relative power of a signal as compared to the power of noise on a line. As the ratio decreases, it becomes more difficult to distinguish between information and interference.

SIMPLEX - Pertaining to the capability to move in one direction only. Contrast with half-duplex and full-duplex.

SIGNALING - Process by which a caller or equipment on the transmitting end of a line informs a particular party or equipment at the receiving end that a message is to be communicated.

SMART IF - Microcontroller bus interface for program control of RF components.

SONET - Synchronous optical network.

SPACE - Opposite signal condition to a "mark." The signal (communications channnel state) corresponding to a binary zero. In an EIA RS-232 channel, the spacing condition exists when the voltage is more positive than +3 volts.

SS - Spread spectrum.

ST - Start (signal to indicate end of outpulsing).

STS1 - 51.84 Mbit/s.

START-STOP (SIGNALING) - Signaling in which each group of code elements corresponding to a character is preceded by a start signal that serves to prepare the receiving mechanism for the reception and registration of character, and is followed by a stop signal that serves to bring the receiving mechanism to rest in preparation for the reception of the next character. Also known as asynchronous transmission.

STOP-BIT - In asynchronous transmission, the quiescent state following the transmission of a character; usually 1-, or 2-bit times long.

STOP ELEMENT - Last bit of a character in asynchronous serial transmission, used to ensure recognition of the next start element.

SUBSCRIBER LINE - Telephone line connecting the exchange to the subscriber's station. Also called (U.S. term) access line and subscriber loop.

SW56 - Switched 56 Kbit/s digital transmission.

SYNCHRONOUS - Having a constant time interval between successive bits, characters, or events. Synchronous transmission doesn't use non-information bits (such as the start and stop bits in asynchronous transmission) to identify the beginning and end or characters, and thus is faster and more efficient than asynchronous transmission. The timing is achieved by transmitting sync characters prior to data or by extracting timing information from the carrier or reference.

SYNCHRONOUS NETWORK - Network in which all the communications links are synchronized to a common clock.

SYNCHRONOUS TRANSMISSION - Transmission process where the information and control characters are sent at regular, clocked intervals so that the sending and receiving terminals are operating continuously in step with each other.

T

T-CARRIER - A time-division multiplexed, digital transmission facility, operating at an aggregate data rate of 1.544 Mbit/s and above. T-carrier is a PCM system using 64 Kbit/s for a voice channel.

T1 - A digital facility used to transmit a DS-1 formatted digital signal at 1.544 Mbit/s; the equivalent of 24 voice channels.

T1C/T2/T3/T4 - Digital carrier facilities used to transmit signals at 3.152M, 6.312M, 44.736M, 274.176 Mbit/s, respectively.

T3 - A digital carrier facility used to transmit a DS-3 formatted digital carrier signal at 44.736 Mbit/s; the equivalent of 672 voice channels.

TACS - Total access communications system. (U.K. analog cellular standard).

TDMA - Time division multiple access.

TCVCXO - Temperature-compensated, voltage - controlled crystal oscillator.

TOUCH-TONE - An AT&T trademark for dualtone multifrequency signaling equipment. Use of tones simplifies the switching system design and greatly expands the potential for adding features to telephone systems. It also speeds up the dialing operation for a person making a call.

TRANSCEIVER - Device that can transmit and receive traffic.

TRUNK - Transmission paths that are used to interconnect exchanges in the main telephone network, two switching centers, or a switching center and a distribution point, such as a telephone exchange line that terminates in a PABX network.

TTL - Transistor-Transistor Logic. Digital logic family having common electrical characteristics.

TURNAROUND TIME - The time required to reverse the direction of transmission, e.g; to change from receive mode to transmit mode in order to acknowledge on a half-duplex line. When individual blocks are acknowledged, as is required in certain protocols (e.g., IBM BSC) the turnaround time has a major effect on throughput, particularly if the propagation delay is lengthy, such as on a satellite channel.

TWO-WIRE CIRCUIT - Circuit formed of two conductors insulated from each other, providing a send and return path. Signals may pass in one or both directions.

V

VIDEOTEX - An interactive data communications application designed to allow unsophisticated users to converse with remote databases, enter data for transactions, and retrieve textual and graphics information for display on subscriber television sets or low-cost terminals.

VSLI - Very Large Scale Integration.

V SERIES RECOMMENDATIONS - (CCITT V.xx Standards)
Also see Voiceband Modem Standards chart on page 9-12.

V.1 - Definitions of key terms for binary symbol notation, such as binary 0 = space, binary 1 = mark.

V.2 (1) - Specification of power levels for data transmission over telephone line.

V.4 - Definition of the order of bit transmission, the use of a parity bit, and the use of start/stop bits for asynchronous transmission.

V.5 - Specification of data-signaling rates (bit/s) for synchronous transmission in the switched telephone network.

V.6 - Specification of data signaling rates (bit/s) for synchronous transmission on leased telephone circuits.

V.7 - Definitions of other key terms used in the V-series recommendations.

V.10 - Description of an unbalanced physical level interchange circuit (unbalanced means one active wire between transmitter and receiver with ground providing the return).

V.11 - Description of a balanced physical level interchange circuit (balanced means two wires between the transmitter and receiver with both wires' signals constant with respect to Earth).

V.15 - Description of use of acoustic couplers for data transmission.

V.16 - Description of the transmission of ECG (electrocardiogram) signals on the telephone channel.

V.19 - Description of one-way parallel transmission modems using push-button telephone sets.

V.20 - Description of one-way parallel transmission modems, excluding push-button telephone sets.

V.22 - Operating at 1.2 Kbit/s, encodes two consecutive bit (dibits); the dibits are encoded as a change relative to the previous signal element.

V.22bis - Operating at 2.4 Kbit/s, encodes four consecutive bits (quadbits); the first two bits are encoded relative to the quadrant of the previous signal element, the last two bits are associated with the point in new quadrant.

V.24 - Definition of the interchange circuit pins between DTEs (data terminal equipment) and DCEs (data circuit-terminating equipment).

V.25 - (2) - Specifications for automatic-answering equipment.

V.25bis - (2) - Specifications for automatic-answering equipment.

V.28 - Description of unbalanced interchange circuits operating below 20 Kbit/s.

V.29 - Operating at 9.6 Kbit/s, encodes four consecutive bits (quadbits); the first bit determines the amplitude, the last three bits use the encoding scheme of V.27.

V.29 - Operating at 4.8 Kbit/s, encodes two consecutive bits (dibits); amplitude is constant and phase changes are the same as V.26.

V.31 - Description of low-speed interchange circuits (up to 75 Bit/s).

V.31bis - Description of low-speed interchange circuits (up to 1.2 Kbit/s).

V.32 - Operating at 9.6 Kbit/s, encodes four consecutive bits (quadbits); the bits are mapped to a QAM signal.

V.32 - Operating at 9.6 Kbit/s with Trellis-coded modulation (TCM), encodes four consecutive bits, two of which are used to generate a fifth bit; the bits are mapped to a QAM signal.

V.32 - Operating at 4.8 Kbit/s, encodes two consecutive bits (dibits), which are mapped to a QAM signal.

V.42 - Defines a method of error control.

V.42bis - Defines a method of data compression.

Note: In the United States, EIA RS-496 specifies these measurements and RS-366 specifies these procedures.

VOICE-GRADE CHANNEL - a channel with a frequency range from 300 to 3000 Hz and suitable for the transmission of speech, data, or facsimile.

W

WORD - A group of bits handled as a logical unit; usually 16.

Voiceband Modem Standards

CCITT Standard	Data Rate (Bit/s)	Full- or Half-Duplex	Channel Separation	Carrier Frequency (Hz)	Modulation Method	Modulation Rate (Baud)	Bits Encoded	Synchronous or Asynchronous	Back Channel	GSTN	Leased Lines	Equalization	Scrambler
V.21	300	Full	Frequency Division	1080, & 1750	Frequency Shift	300	1:1	Either	ND	Yes	No	ND	ND
V.22	1200	Full	Frequency Division	1200, & 2400	Phase Shift	600	2:1	Either	ND	Yes	Point-to-Point 2-Wire	Fixed	Yes
V.22	600	Full	Frequency Division	1200, & 2400	Phase Shift	600	1:1	Either	ND	Yes	Point-to-Point 2-Wire	Fixed	Yes
V.22bis	2400	Full	Frequency Division	1200, & 2400	Quadrature-Amplitude Modulation	600	4:1	Either	ND	Yes	Point-to-Point 2-Wire	Fixed/ Adaptive	Yes
V.23	600 (1)	Half	N/A	1300, & 1700	Frequency Modulation	600	N/A	Either	Yes	Yes	No	ND	ND
V.23	1200 (1)	Half	N/A	1300, & 2100	Frequency Modulation	1200	N/A	Either	Yes	Yes	No	ND	ND
V.25	2400	Full	4-Wire	1800	Phase Shift	1200	2:1	Synchronous	Yes	No	Point-to-Point Multipoint 4-Wire	ND	ND
V.26bis	2400	Half	N/A	1800	Phase Shift	1200	2:1	Synchronous	Yes	Yes	No	Fixed	ND
V.26bis	1200	Half	N/A	1800	Phase Shift	1200	1:1	Synchronous	Yes	Yes	No	Fixed	ND
V.26ter	2400	Either	Echo Cancellation	1800	Phase Shift	1200	2:1	Either	ND	Yes	Point-to-Point 2-Wire	Either	Yes
V.26ter	1200	Either	Echo Cancellation	1800	Phase Shift	1200	1:1	Either	ND	Yes	Point-to-Point 2-Wire	Either	Yes
V.27	4800	Either	ND (3)	1800	Phase Shift	1600	3:1	Synchronous	Yes	No	Yes (3)	Manual	Yes
V.27bis	4800	Either	4-Wire (4)	1800	Phase Shift	1600	3:1	Synchronous	Yes	No	2-Wire, 4-Wire	Adaptive	Yes
V.27bis	2400	Either	4-Wire (4)	1800	Phase Shift	1200	2:1	Synchronous	Yes	No	2-Wire, 4-Wire	Adaptive	Yes
V.27ter	4800	Half	None	1800	Phase Shift	1800	3:1	Synchronous	Yes	Yes	No	Adaptive	Yes
V.27ter	2400	Half	None	1800	Phase Shift	1200	2:1	Synchronous	Yes	Yes	No	Adaptive	Yes
V.29	9600	Either	4-Wire	1700	Quadrature-Amplitude Modulation	2400	4:1	Synchronous	No	No	Point-to-Point 4-Wire	Adaptive	Yes
V.29	7200	Either	4-Wire	1700	Phase Shift (5)	2400	3:1	Synchronous	ND	No	Point-to-Point 4-Wire	Adaptive	Yes
V.29	4800	Either	4-Wire	1700	Phase Shift (5)	2400	2:1	Synchronous	ND	No	Point-to-Point 4-Wire	Adaptive	Yes
V.32	9600	Full	Echo Cancellation	1800	Quadrature-Amplitude Modulation	2400	4:1	Synchronous	ND	Yes	Point-to-Point 2-Wire	Adaptive	Yes
V.32bis	14400	Full	Echo Cancellation	1800	Trellis-Coded Modulation	2400	6:1	Synchronous	ND	Yes	Point-to-Point 2-Wire	Adaptive	Yes
V.32	9600	Full	Echo Cancellation	1800	Quadrature-Amplitude Modulation	2400	4:1	Synchronous	ND	Yes	Point-to-Point 2-Wire	Adaptive	Yes
V.32	4800	Full	Echo Cancellation	1800	Quadrature-Amplitude Modulation	2400	2:1	Synchronous	ND	Yes	Point-to-Point 2-Wire	Adaptive	Yes
V.33	14400	Half						Synchronous	ND	Yes		Adaptive	Yes
V.34	28800	Full	Echo Cancellation	1800	Trellis-Coded Modulation	2400	12:1	Synchronous	ND	Yes	Point-to-Point 2-Wire	ND	Yes
Bell (U.S.) Standard													
103	300	Full	Frequency Division	2225 & 1270(m) 2025 & 1070(s)	Frequency Shift	300	1:1	Either	No	Yes	No	Fixed	No
201	2400	Half	None	1800	Phase Shift	1200	2:1	Synchronous	No	Yes	Point-to-Point 2-Wire	Adaptive	Yes
202	1200	Half	None	1200 & 2200	FSK	1200	1:1	Either	Yes	Yes	Point-to-Point 2-Wire	Fixed	No
208	4800	Half	None	1800	Quadrature-Amplitude Modulation	1600	3:1	Synchronous	No	Yes	Point-to-Point 2-Wire	Adaptive	Yes
212	1200	Full	Frequency Division	1200 & 2400	Phase Shift	600	2:1	Either	No	Yes	No	Fixed	Yes

1. Bit/s not used in specification; rate stated in baud. Low speed 75 bit/s back channel for asymetric full-duplex

2. Half-duplex may still use a backward channel

3. Makes no mention of 4-wire (must be assumed)

4. For half-duplex, 2-wire used

5. Amplitude is constant on a relative basis

ND = Not defined (i.e., not specified in the recommendation)

Notes:

Section 10

PACKAGING/ORDERING INFORMATION

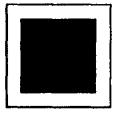
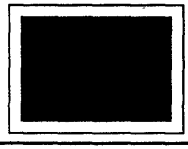
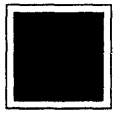
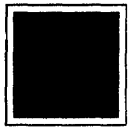
Silicon Systems
Packaging Index

DUAL-IN-LINE PACKAGE (DIP)	PINS	PAGE NO.
Plastic	8, 14, 16 & 18	10-4
	20, 22, 24 & 24S	10-5
	28, 32 & 40	10-6
Ceramic	8, 14, 16 & 18	10-7
	22, 24 & 28	10-8
SURFACE MOUNTED DEVICES (SMD)		
Quad (PLCC)	20, 28	10-9
	32 & 44	10-10
	52 & 68	10-11
Quad Flatpack (QFP)	52 & 100	10-12
	128	10-13
Thin Quad Flatpack (TQFP)	32 & 48	10-14
	64, 80 & 100	10-15
	120 & 128	10-16
	144	10-17
Very Thin Quad Flatpack (VTQFP)	32, 48 & 64	10-18
	100	10-19
	120	10-20
Ultra Thin Quad Flatpack (UTQFP)	64 & 100	10-21
Small Outline (SOIC)	8, 14 & 16 SON	10-22
	16, 18, 20, 24 & 28 SOL	10-23
	34 SOL	10-24
	32 SOW	10-24
	36 SOM	10-24
	44 SOM	10-25
Very Small Outline Package (VSOP)	20 & 24	10-25
Very Thin Small Outline Package (VTSOP)	16 & 20	10-26
Ultra Thin Small Outline Package (UTSOP)	24 & 36	10-27

Package	Width (mil)	Pitch (mil)
SON	150	
SOL	300	
SOW	400	
SOM	300	0.8

Small Form Factor Package Selector Guide

Quad Flatpack Packages

PACKAGE TYPE	ACTUAL SIZE (AREA)	BODY SIZE (PITCH) mm	LAYOUT AREA mm^2	ACTUAL SIZE (THICKNESS)	THICKNESS mm
52 G (QFP)		10.0 x 10.0 (0.65)	13.9 x 13.9 = 193.21		2.2
100 G (QFP)		20.0 x 14.0 (0.65)	23.9 x 17.9 = 427.81		2.9
128 G (QFP)		20.0 x 14.0 (0.5)	23.2 x 17.2 = 399.04		2.9
32 GT (TQFP)		7.0 x 7.0 (0.8)	9.0 x 9.0 = 81		1.4
48 GT (TQFP)		7.0 x 7.0 (0.5)	9.0 x 9.0 = 81		1.4
64 GT (TQFP)		10.0 x 10.0 (0.5)	12.0 x 12.0 = 144		1.4
80 GT (TQFP)		12.0 x 12.0 (0.5)	14.0 x 14.0 = 196		1.4
100 GT (TQFP)		14.0 x 14.0 (0.5)	16 x 16 = 256		1.4

= Actual Body Size

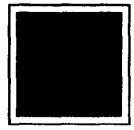
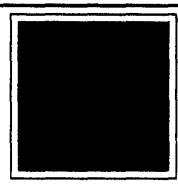
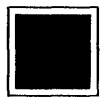
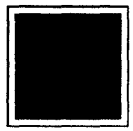
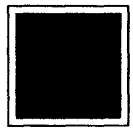
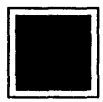
= Full Layout Area

All dimensions are nominal values.

10

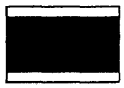
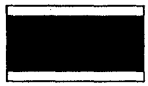
Small Form Factor Package Selector Guide

Quad Flatpack Packages

PACKAGE TYPE	ACTUAL SIZE (AREA)	BODY SIZE (PITCH) mm	LAYOUT AREA mm^2	ACTUAL SIZE (THICKNESS)	THICKNESS mm
120 GT (TQFP)		14.0 x 14.0 (0.4)	16.0 x 16.0 = 256		1.4
128 GT (TQFP)		20.0 x 14.0 (0.5)	22.0 x 16.0 = 352		1.4
144 GT (TQFP)		20.0 x 20.0 (0.5)	22.0 x 22.0 = 484		1.4
48 GV (VTQFP)		7.0 x 7.0 (0.5)	9.0 x 9.0 = 81		1.0
64 GV (VTQFP)		10.0 x 10.0 (0.5)	12.0 x 12.0 = 144		1.0
100 GV (VTQFP)		14.0 x 14.0 (0.5)	16.0 x 16.0 = 256		1.0
120 GV (VTQFP)		14.0 x 14.0 (0.4)	16.0 x 16.0 = 256		1.0
64 GU (UTQFP)		10.0 x 10.0 (0.5)	12.0 x 12.0 = 144		0.7

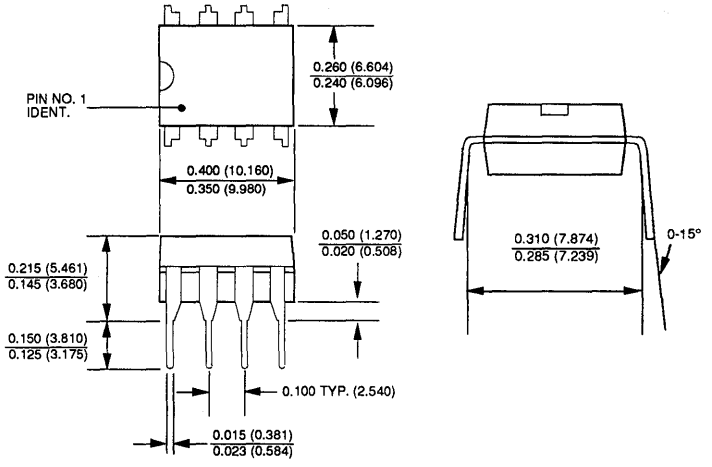
Small Form Factor Package Selector Guide

Small Outline Packages

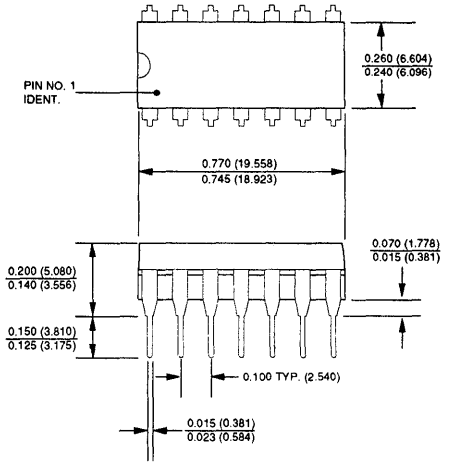
PACKAGE TYPE	ACTUAL SIZE (AREA)	BODY SIZE (PITCH) mm	LAYOUT AREA mm^2	ACTUAL SIZE (THICKNESS)	THICKNESS mm
16 SON		9.8 x 3.9 (1.27)	9.8 x 6.0 = 58.8		1.65
16 SOL		10.2 x 7.5 (1.27)	10.2 x 10.2 = 104		2.54
20 SOL		12.8 x 7.5 (1.27)	12.8 x 10.2 = 130.6		2.54
24 SOL		15.4 x 7.5 (1.27)	15.4 x 10.2 = 157		2.54
20 SOV (VSOP)		7.2 x 5.4 (0.65)	7.9 x 7.2 = 56.9		1.9
24 SOV (VSOP)		7.8 x 5.6 (0.65)	7.8 x 7.6 = 59.28		1.15
36 SOM (SSOP)		15.1 x 7.5 (0.8)	15.1 x 10.2 = 154		2.54
44 SOM (SSOP)		18.3 x 7.5 (0.8)	18.3 x 10.2 = 186.7		2.54
16 VT (VTSOP)		5.0 x 4.4 (0.65)	6.4 x 5.0 = 32		0.9
20 VT (VTSOP)		6.5 x 4.4 (0.65)	6.5 x 6.4 = 41.6		0.9

= Actual Body Size = Full Layout Area All dimensions are nominal values.

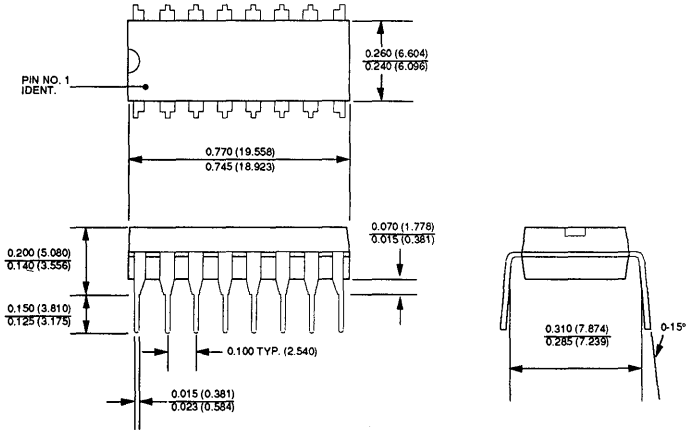
10



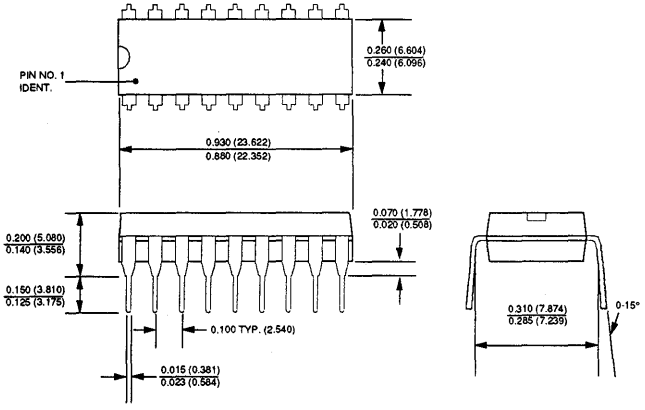
8-Pin Plastic



14-Pin Plastic

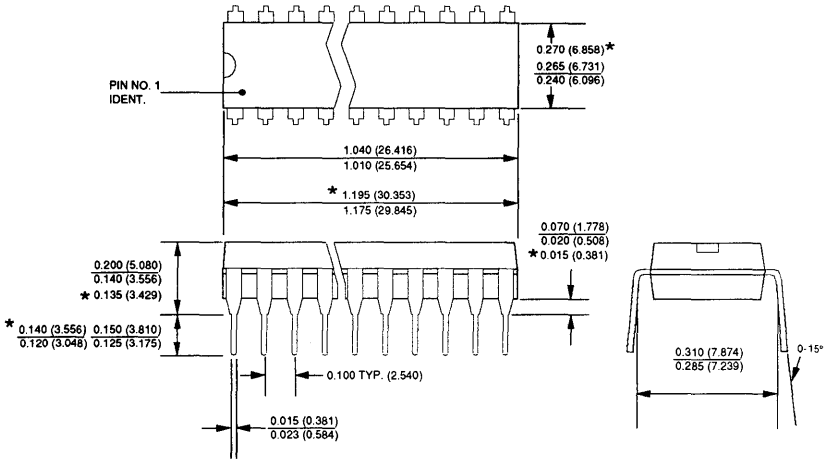


16-Pin Plastic

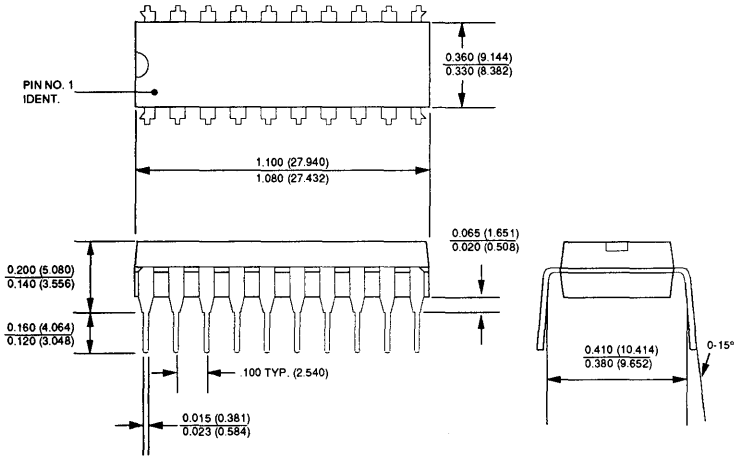


18-Pin Plastic

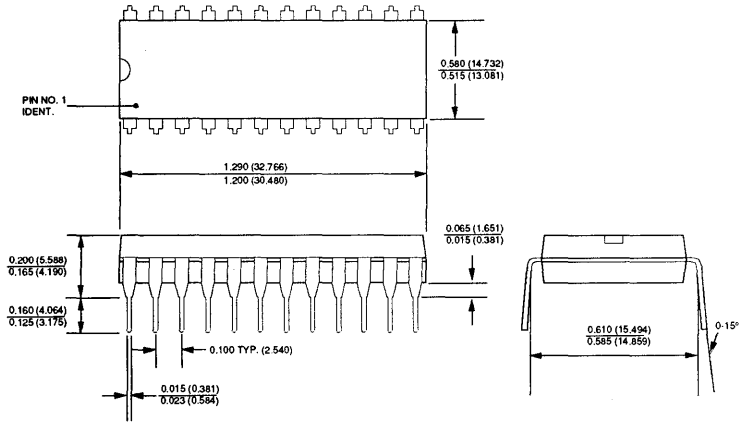
Package Information



20 Pin Plastic
***24S Pin Plastic**



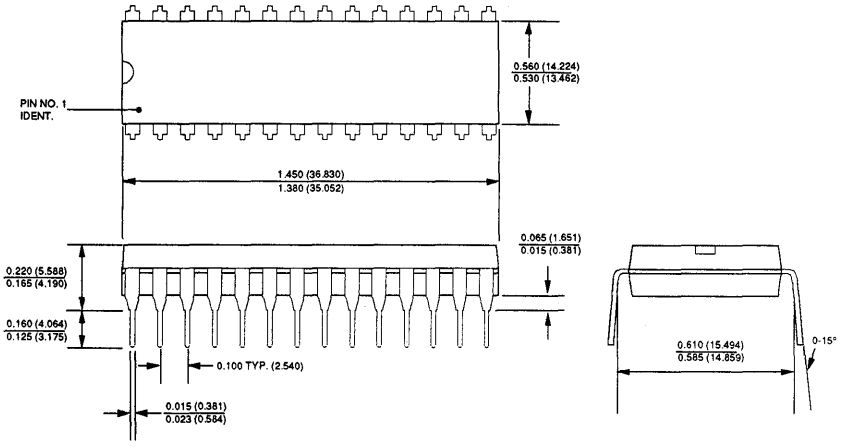
22-Pin Plastic



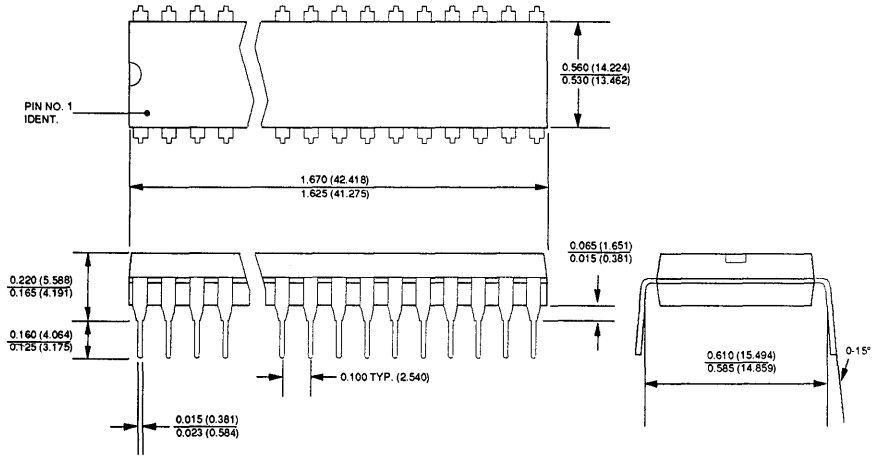
24-Pin Plastic

10

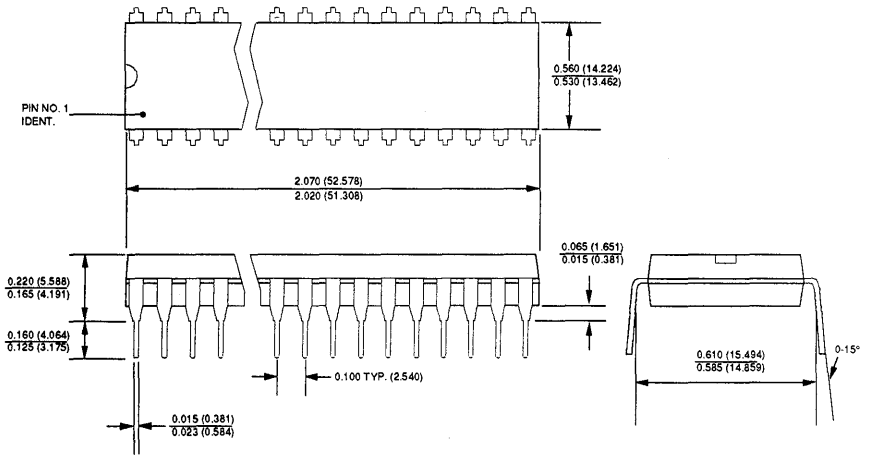
Package Information



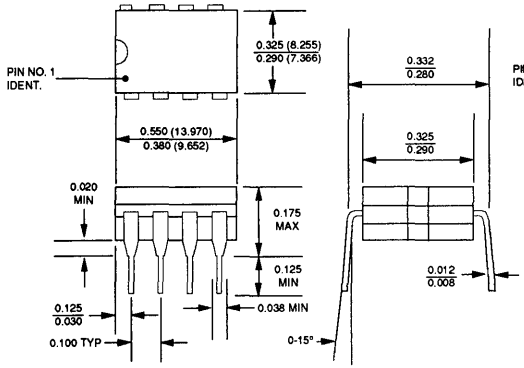
28-Pin Plastic



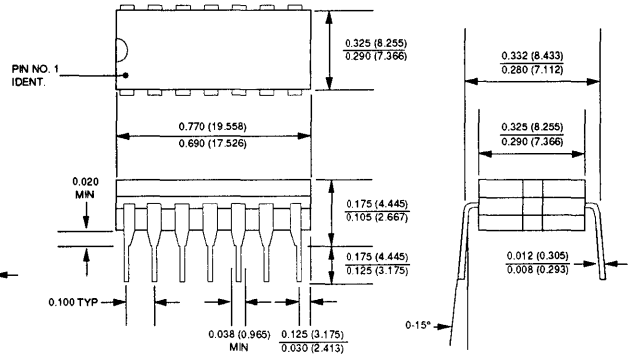
32-Pin Plastic



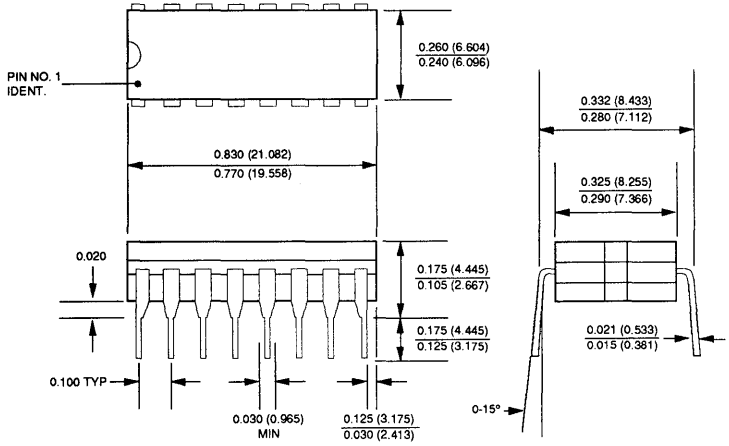
40-Pin Plastic



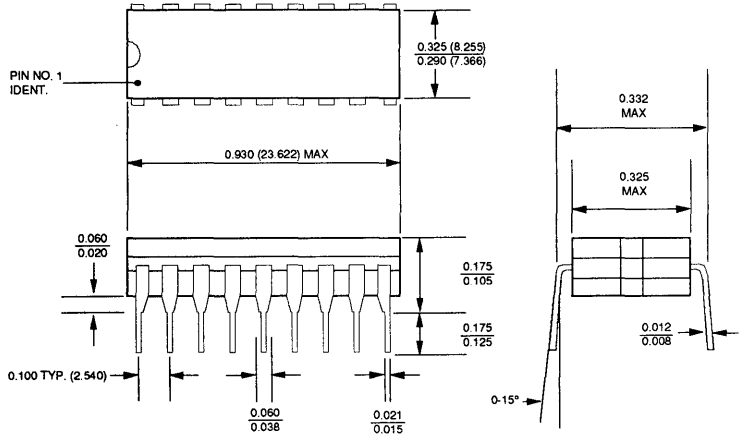
8-Pin Cerdip



14-Pin Cerdip



16-Pin Cerdip



18-Pin Cerdip

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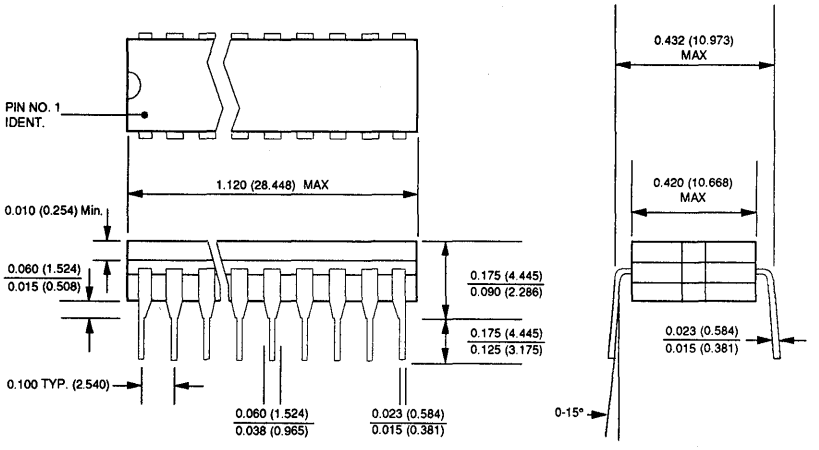
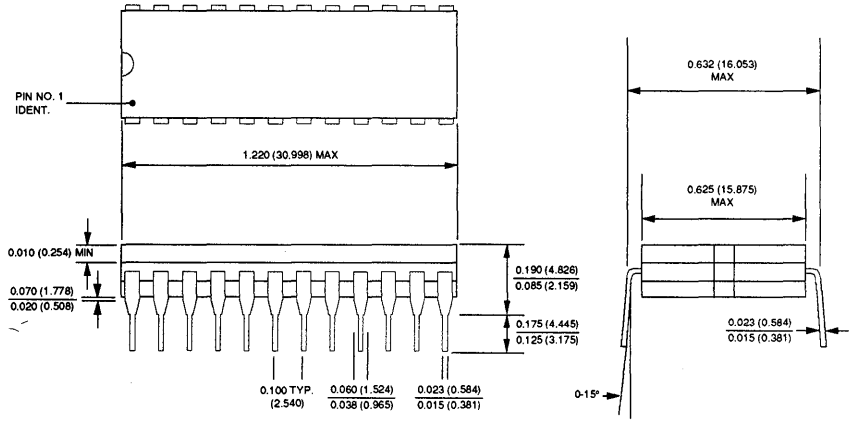
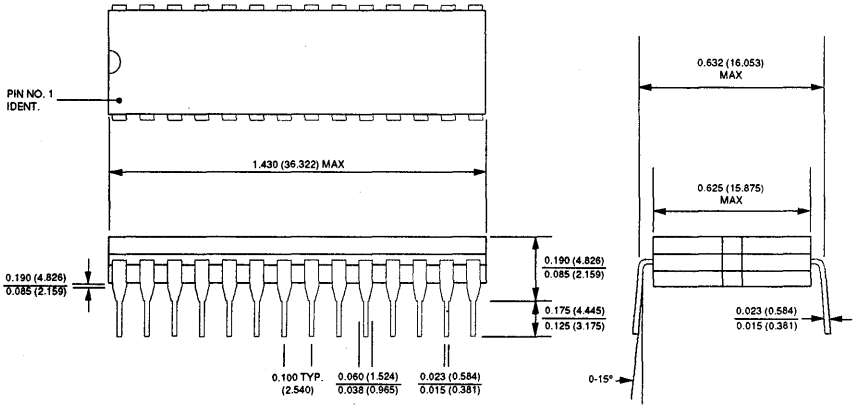
Package Information



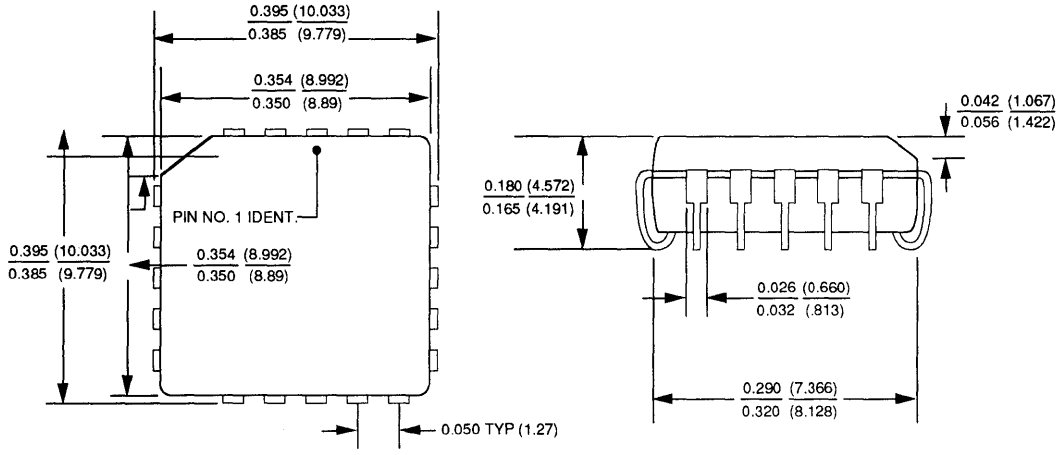
22-Pin Cerdip



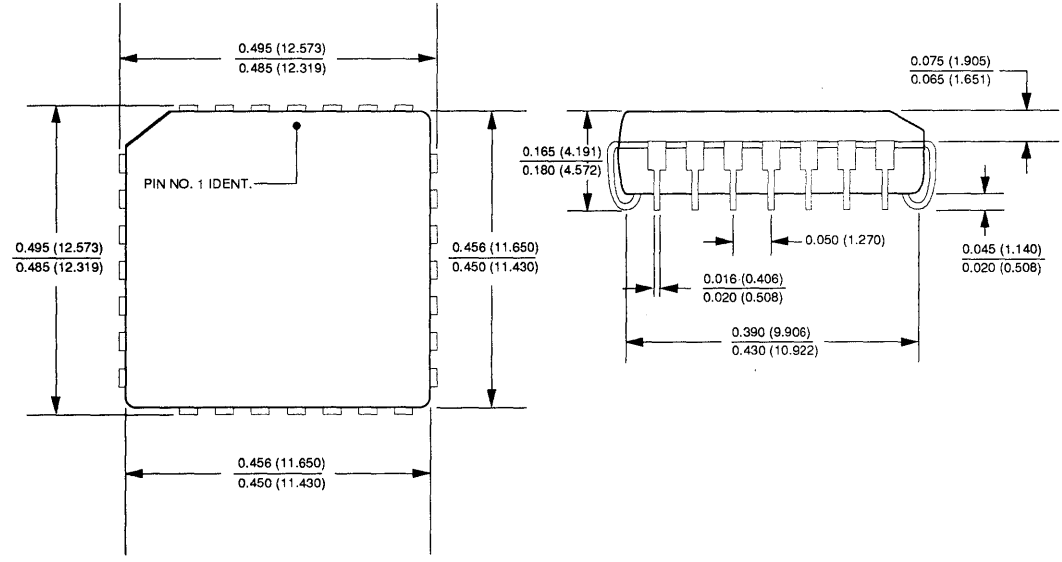
24-Pin Cerdip



28-Pin Cerdip



20-Pin Quad PLCC



28-Pin Quad PLCC

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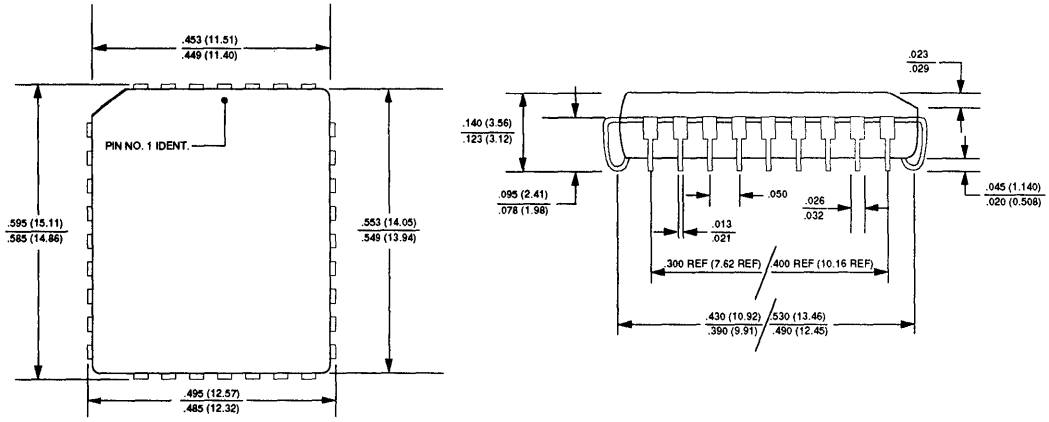
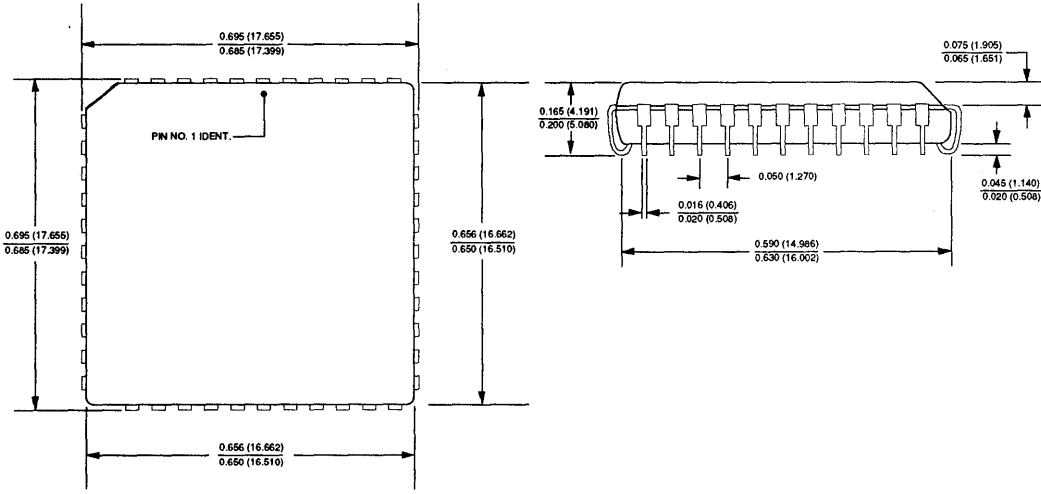
Package Information

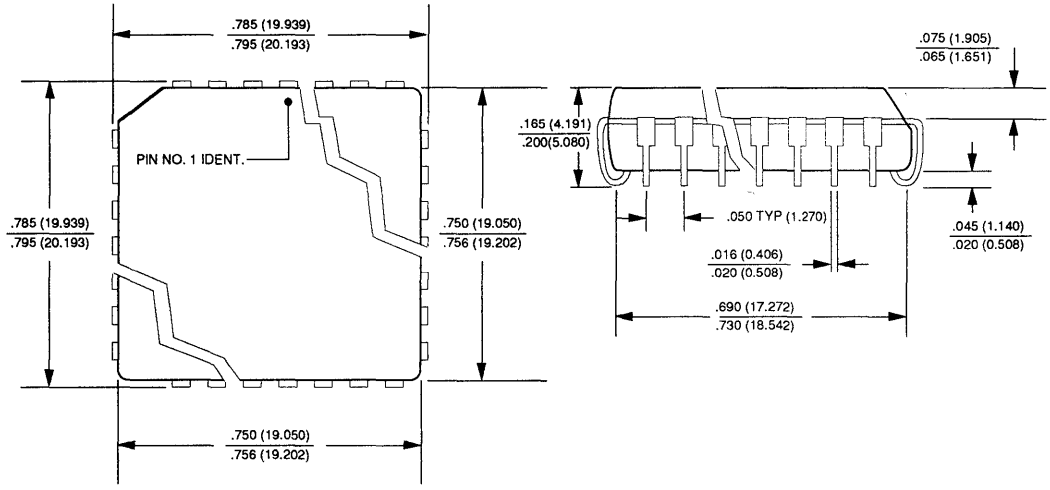


32-Pin Quad PLCC

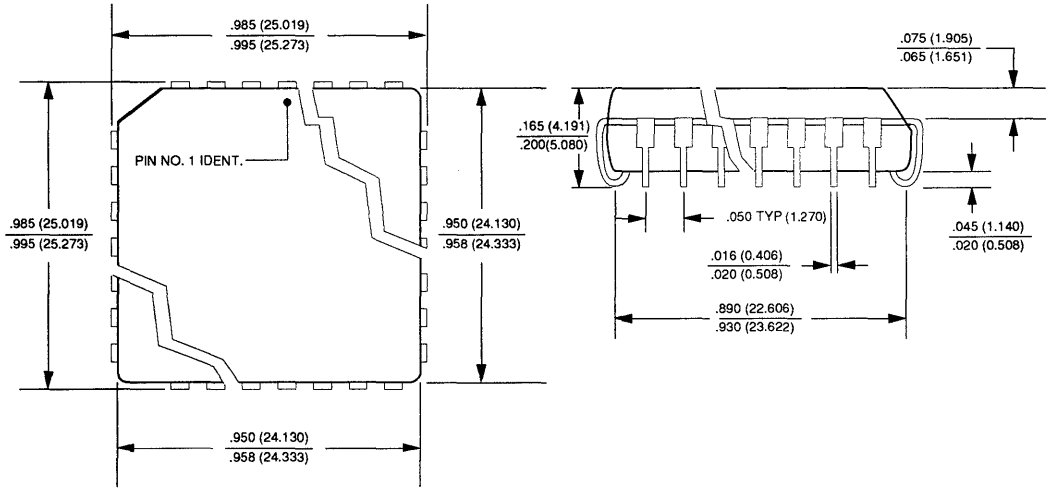


44-Pin Quad PLCC

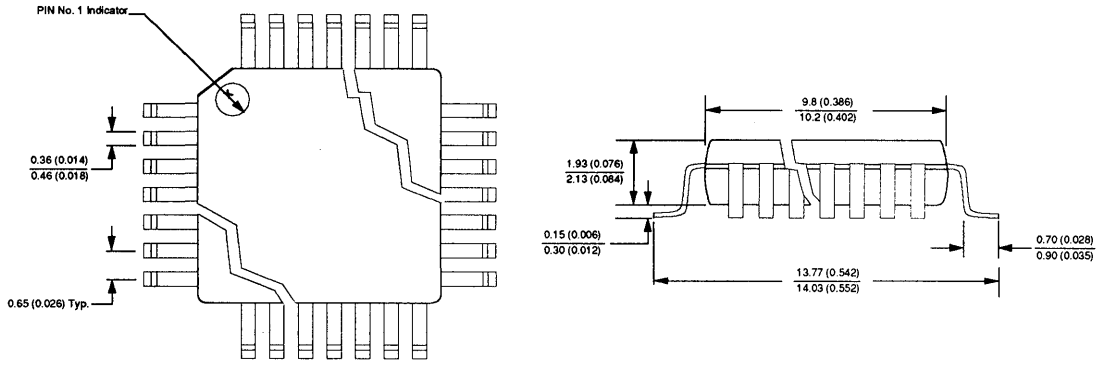
Package Information



52-Pin Quad PLCC

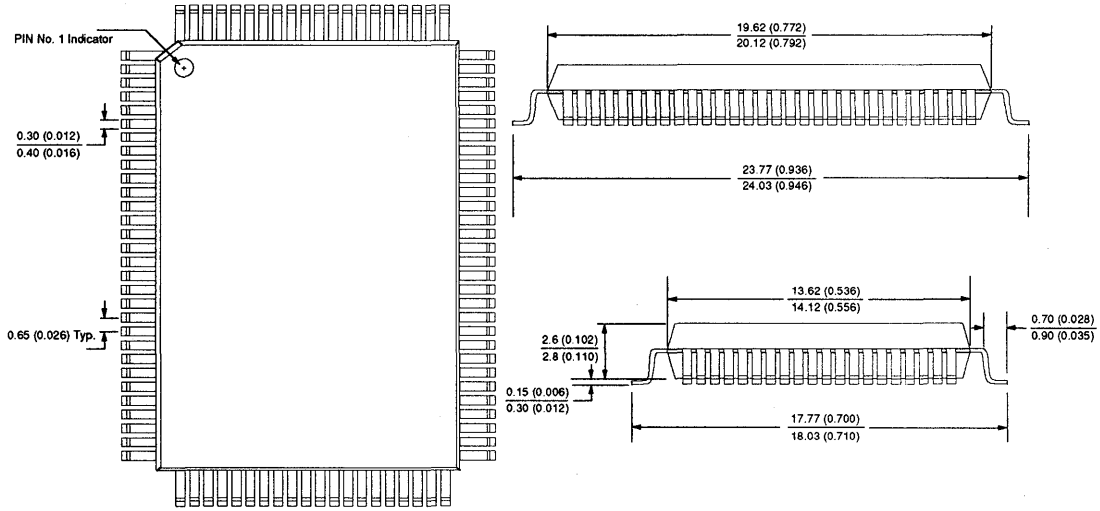


68-Pin Quad PLCC



52-Lead Quad Flatpack

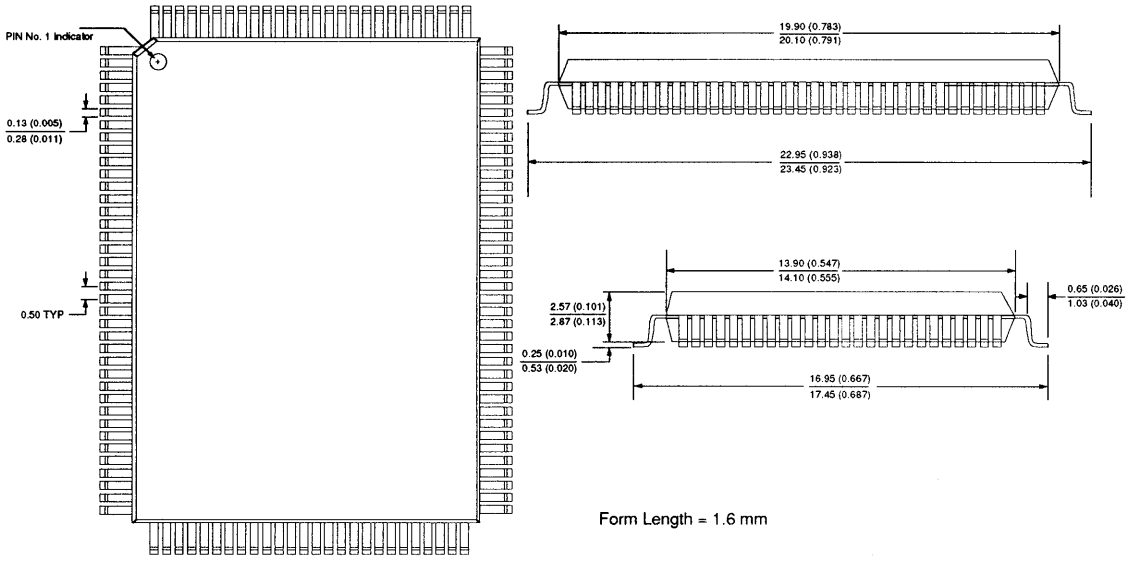
NOTE: Controlling dimensions are in mm



100-Lead Quad Flatpack

NOTE: Controlling dimensions are in mm

Package Information

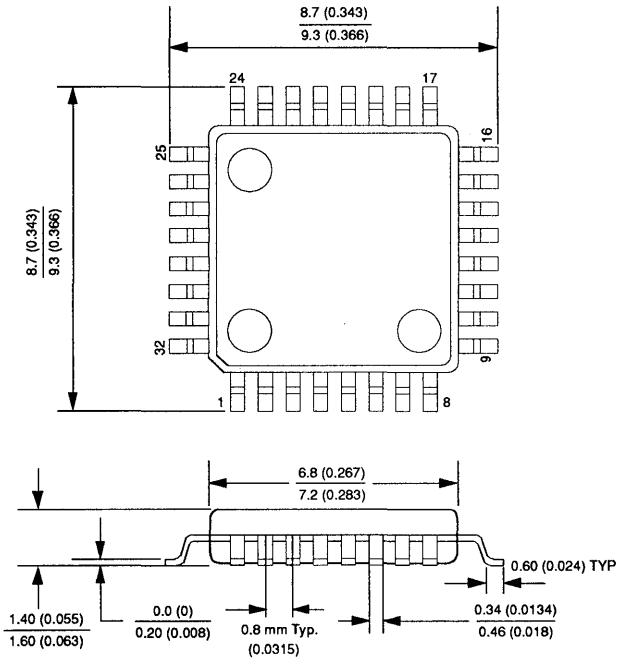


128-Lead Quad Flatpack

NOTE: Controlling dimensions are in mm

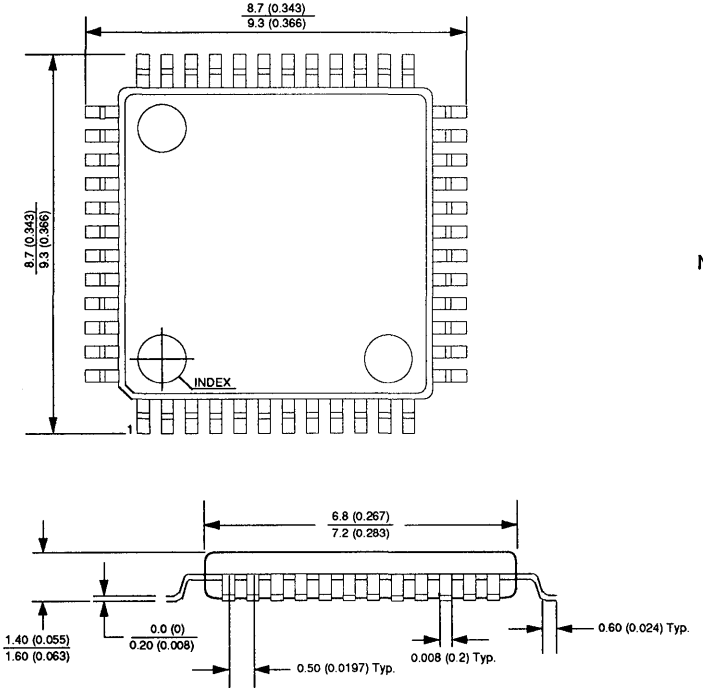
10

Package Information Thin Quad Flatpack (TQFP)



32-Lead Thin Quad Flatpack

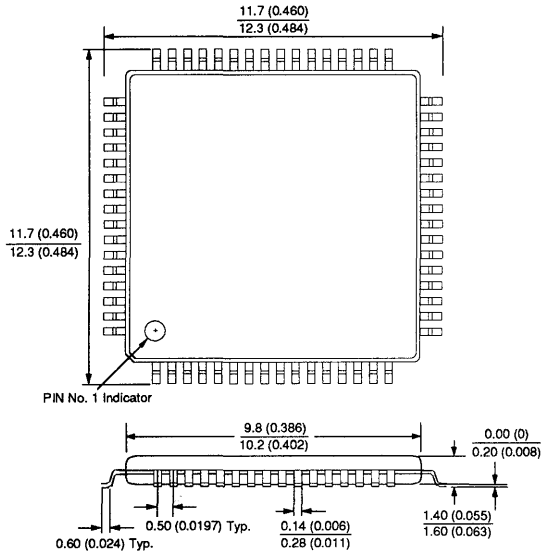
NOTE: Controlling dimensions are in mm



48-Lead Thin Quad Flatpack

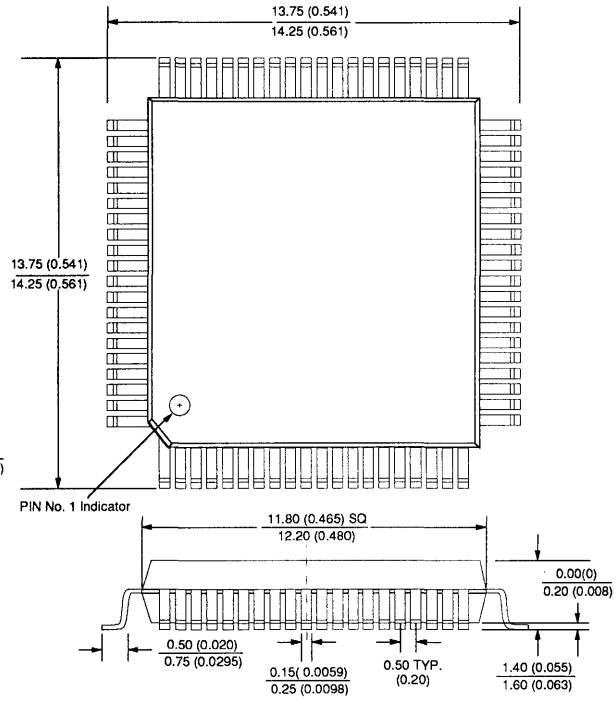
NOTE: Controlling dimensions are in mm

Package Information



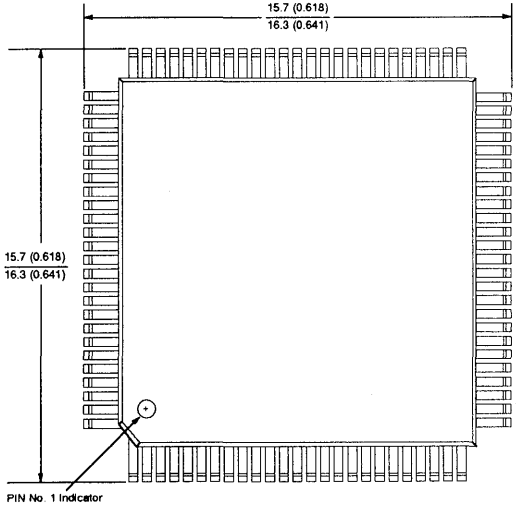
64-Lead Thin Quad Flatpack

NOTE: Controlling dimensions are in mm



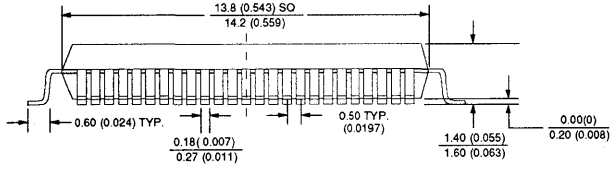
80-Lead Thin Quad Flatpack

NOTE: Controlling dimensions are in mm

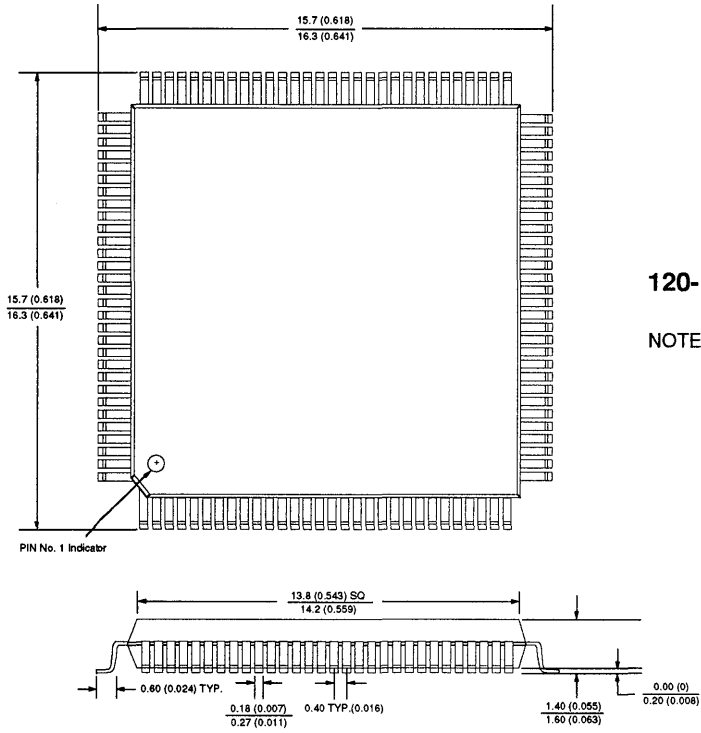


100-Lead Thin Quad Flatpack

NOTE: Controlling dimensions are in mm

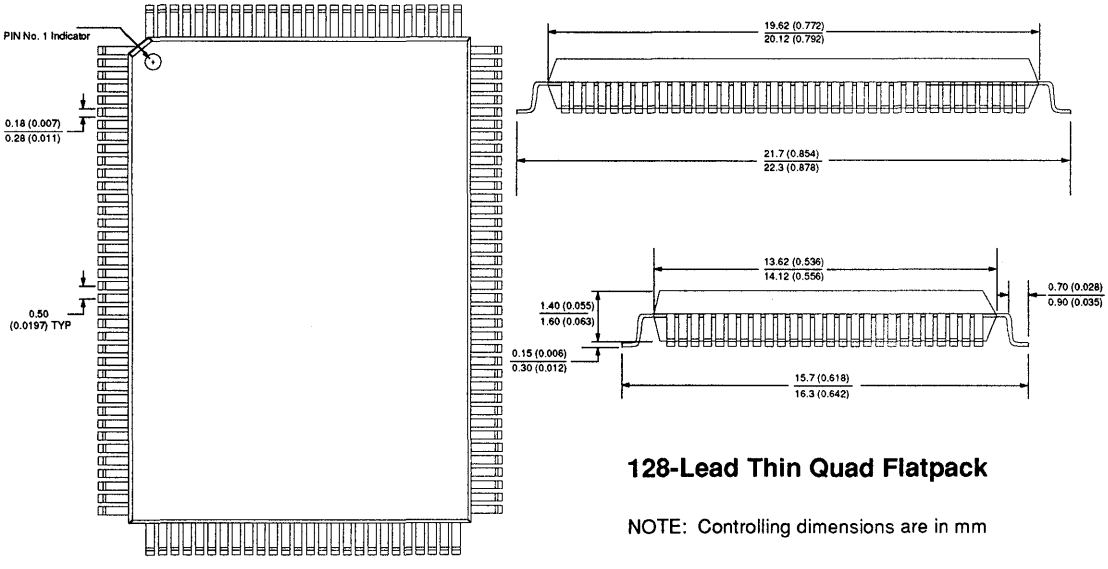


Package Information



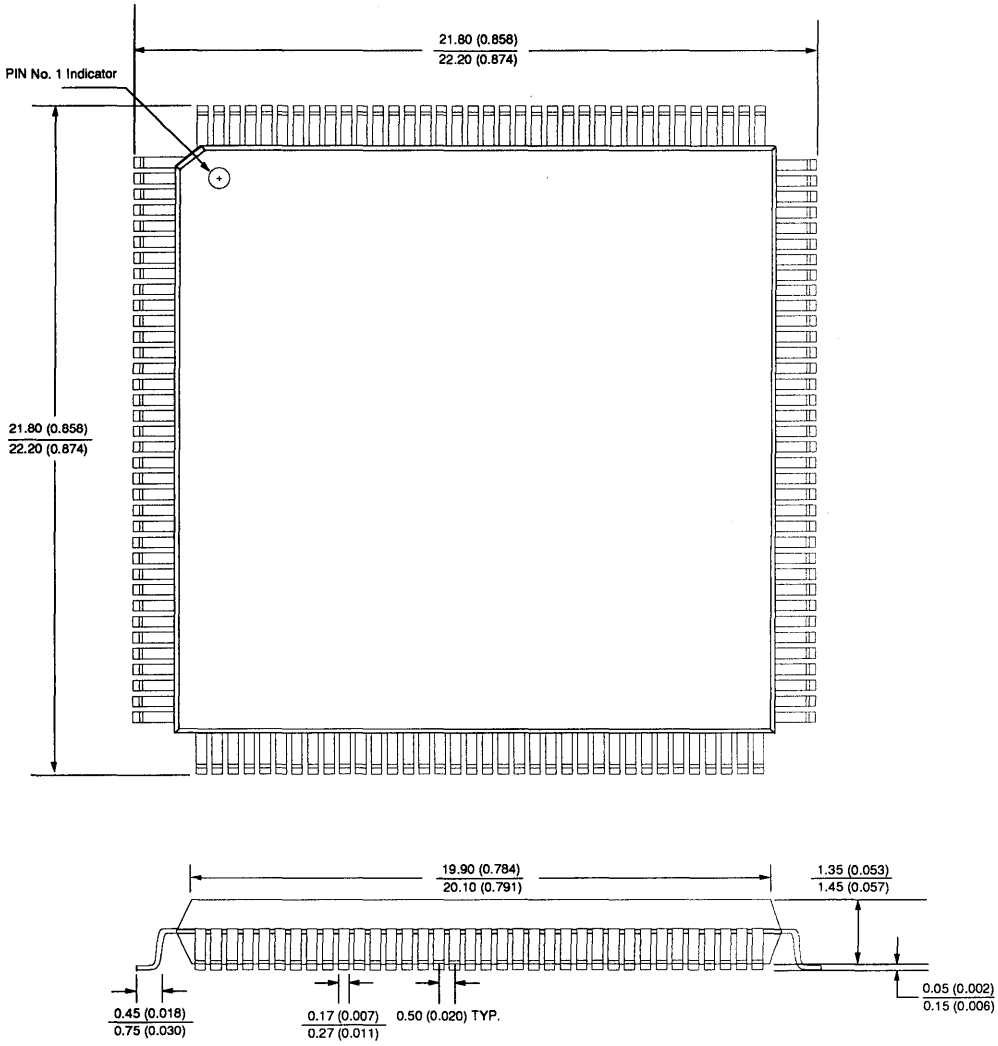
120-Lead Thin Quad Flatpack

NOTE: Controlling dimensions are in mm



128-Lead Thin Quad Flatpack

NOTE: Controlling dimensions are in mm

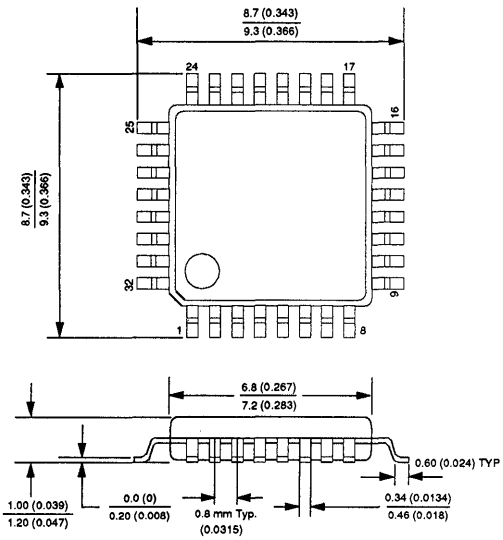


144-Lead Thin Quad Flatpack

NOTE: Controlling dimensions are in mm

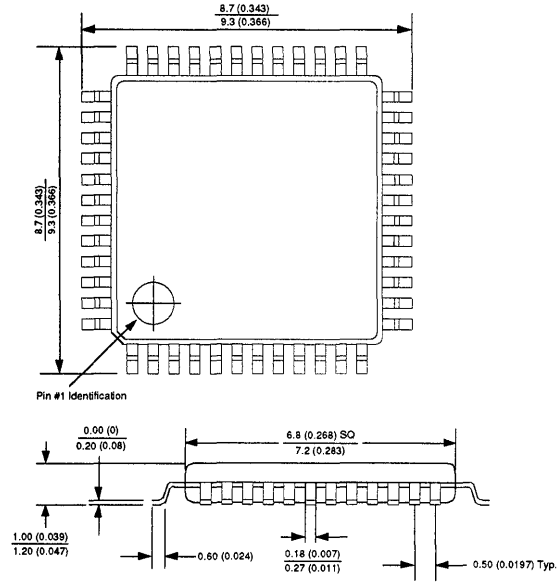
10

Package Information Very Thin Quad Flatpack (VTQFP)



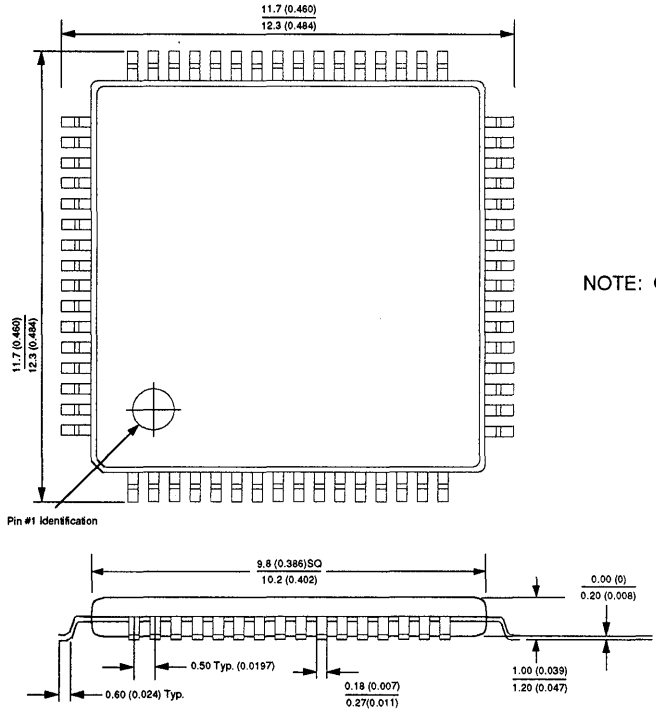
32-Lead VTQFP

NOTE: Controlling dimensions are in mm



48-Lead VTQFP

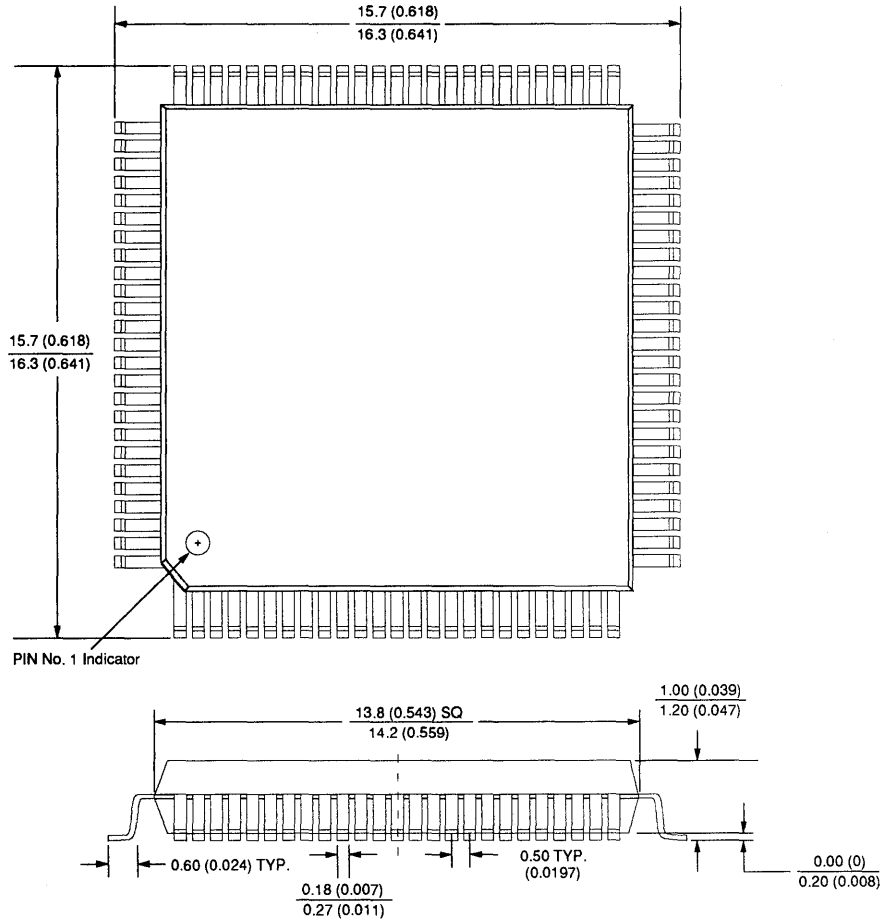
NOTE: Controlling dimensions are in mm



64-Lead VTQFP

NOTE: Controlling dimensions are in mm

Package Information

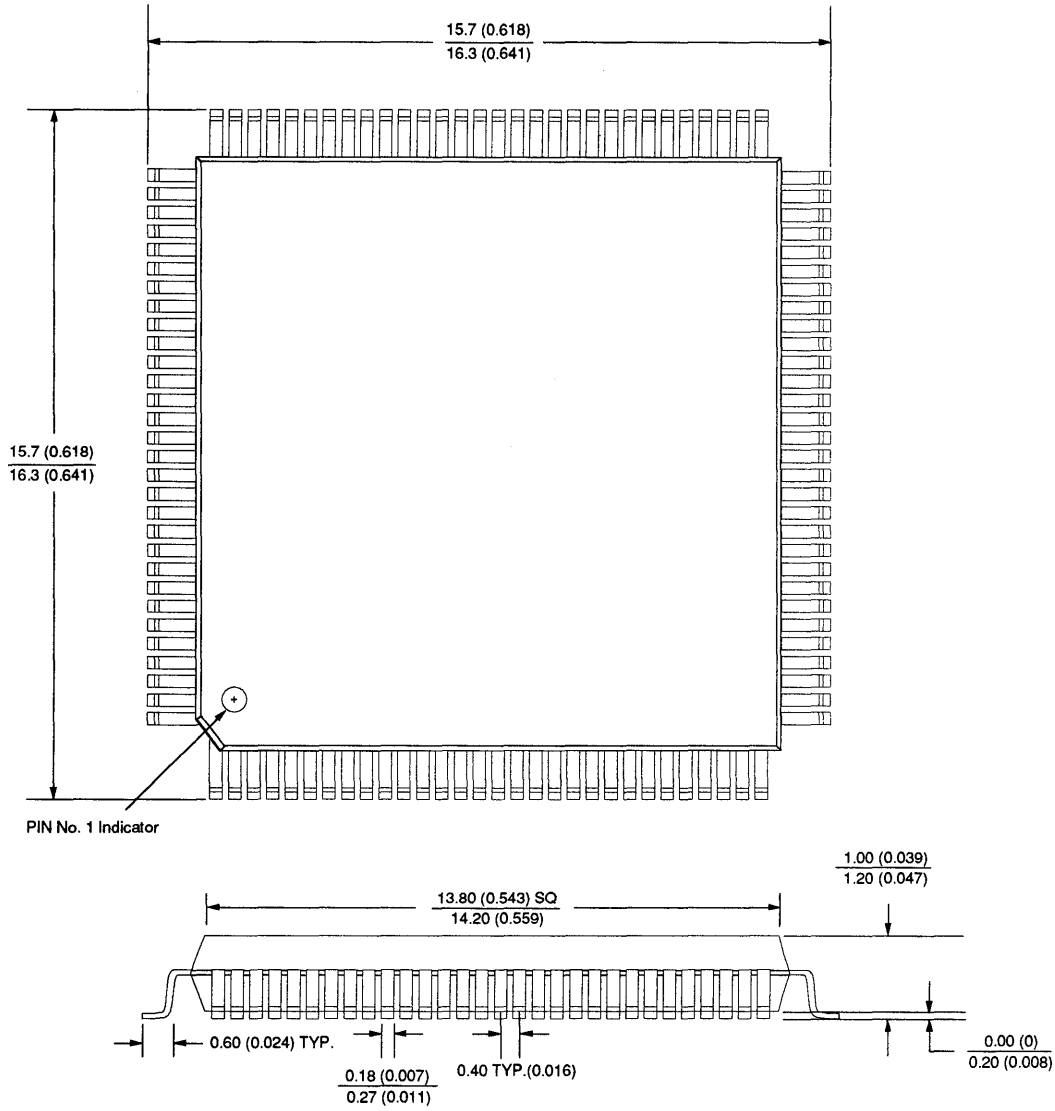


100-Lead VTQFP

NOTE: Controlling dimensions are in mm

10

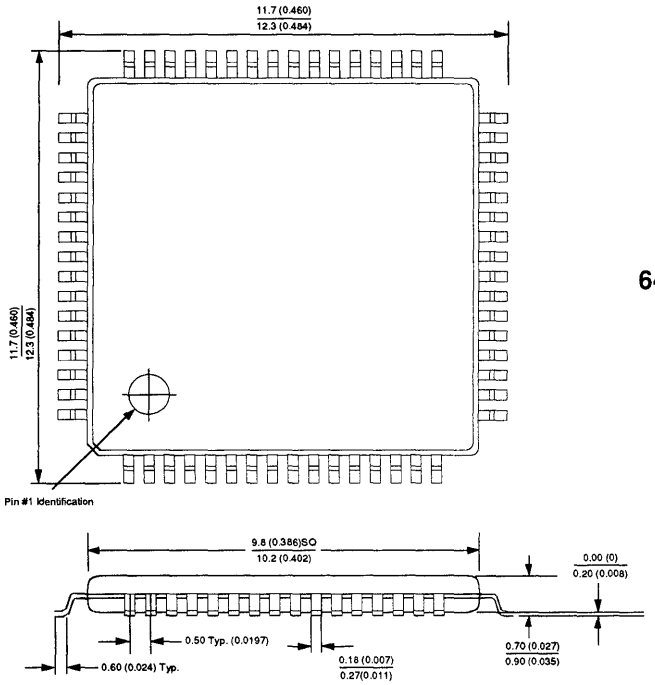
Package Information



120-Lead VTQFP

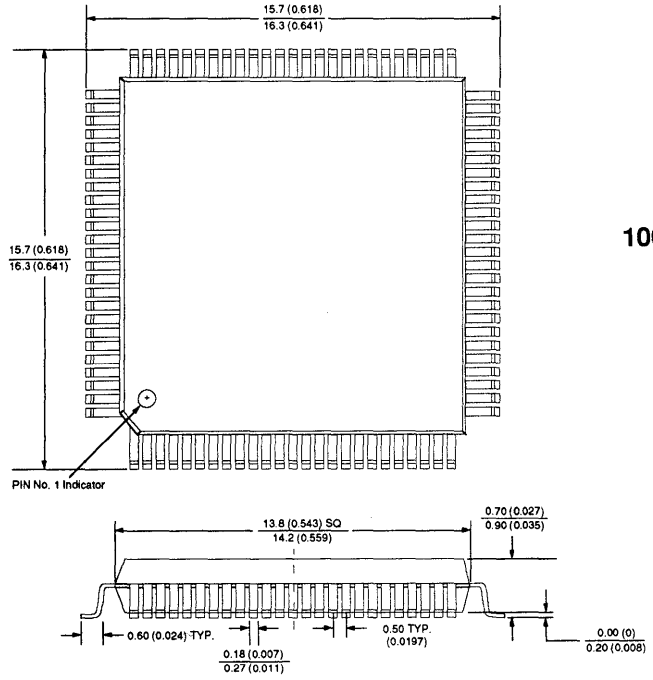
NOTE: Controlling dimensions are in mm

Package Information Ultra Thin Quad Flatpack (UTQFP)



64-Lead Ultra Thin Quad Flatpack

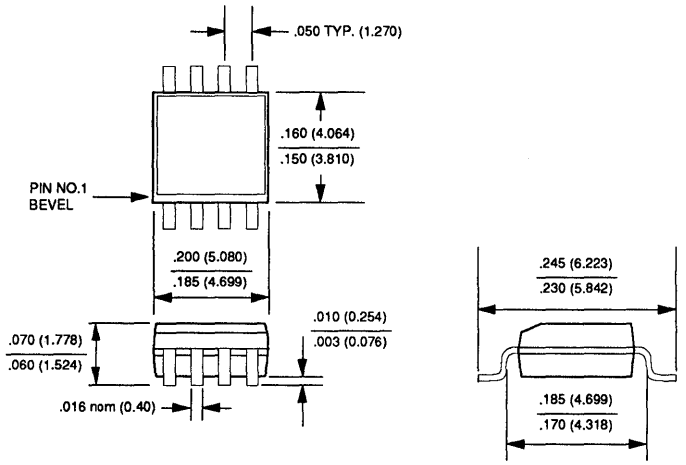
NOTE: Controlling dimensions are in mm



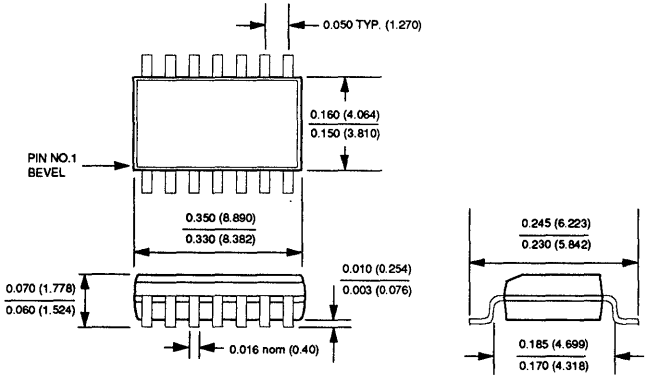
100-Lead Ultra Thin Quad Flatpack

NOTE: Controlling dimensions are in mm

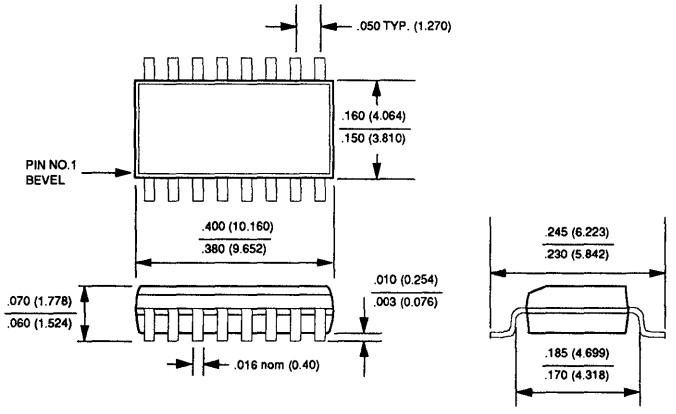
10



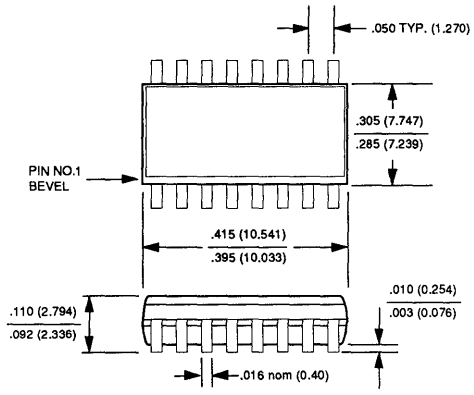
8-Lead SON



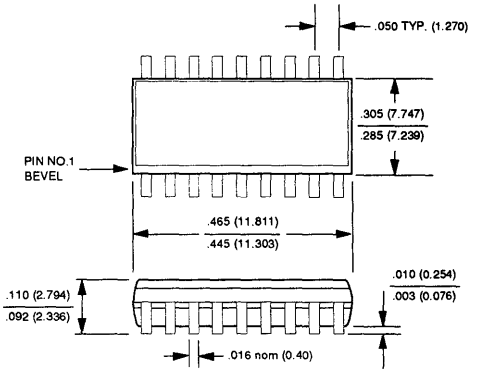
14-Lead SON



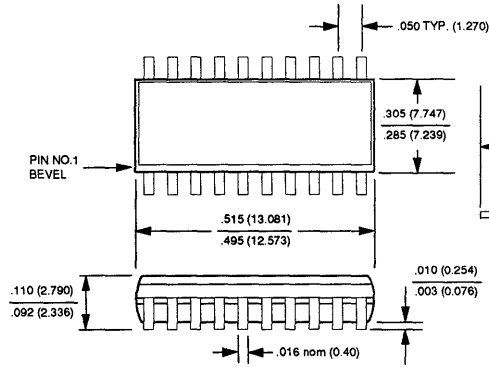
16-Lead SON



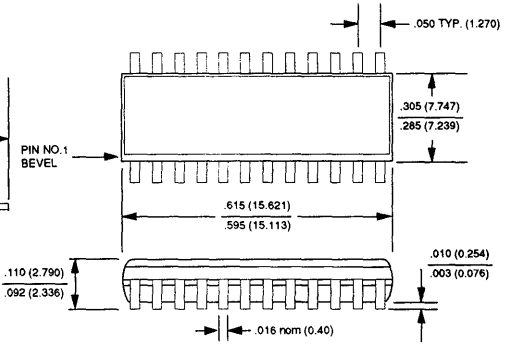
16-Lead SOL



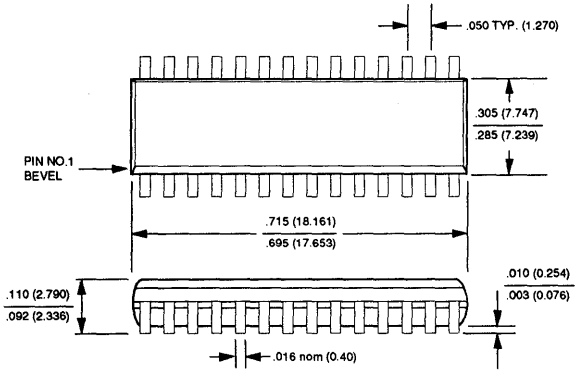
18-Lead SOL



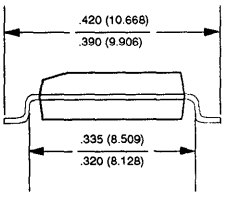
20-Lead SOL



24-Lead SOL



28-Lead SOL



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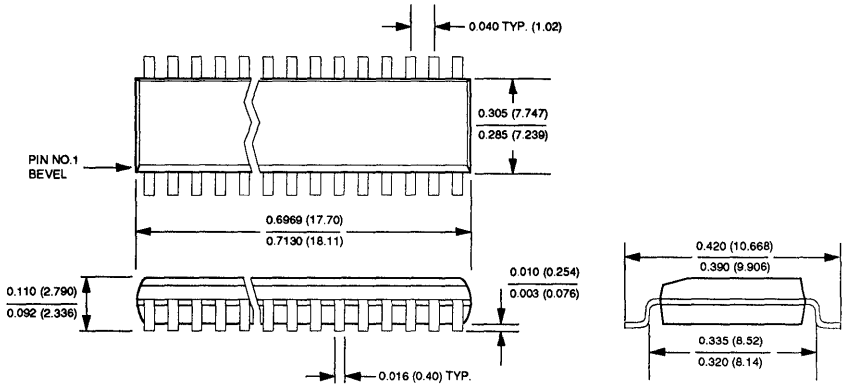
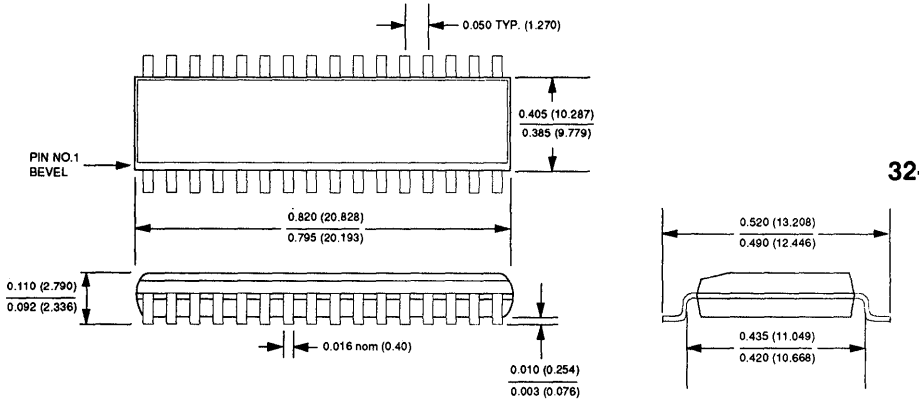
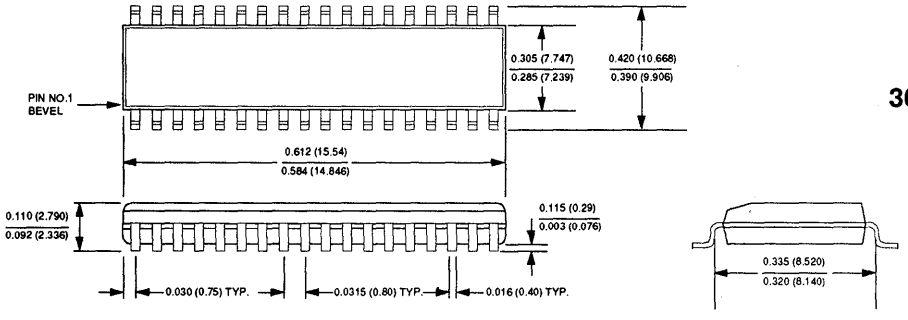


34-Lead SOL

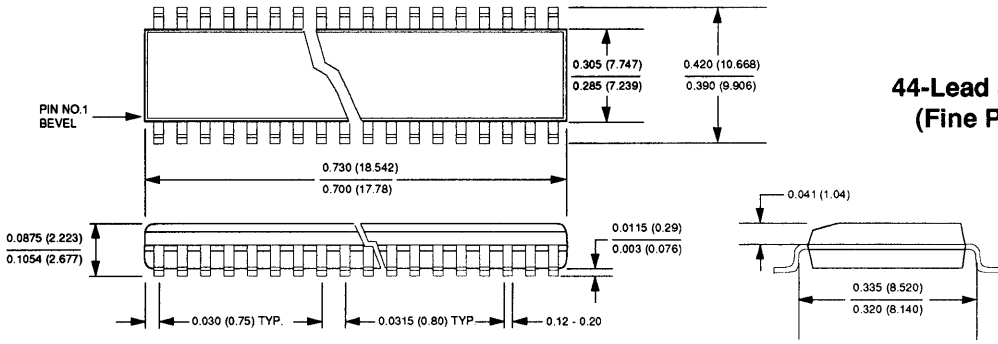


32-Lead SOW



36-Lead SOM (Fine Pitch)

Package Information

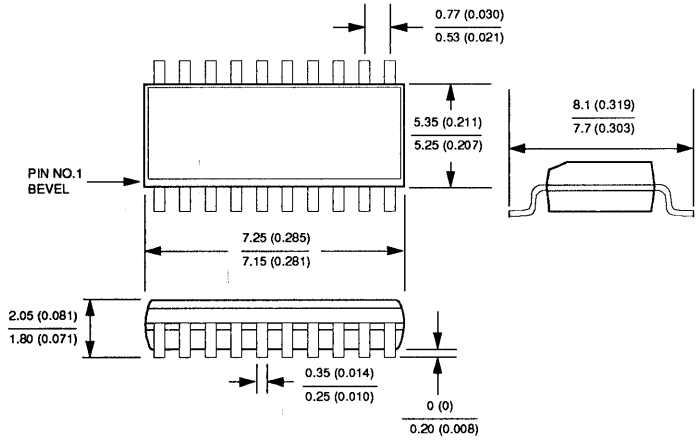


44-Lead SOM (Fine Pitch)

Package Information

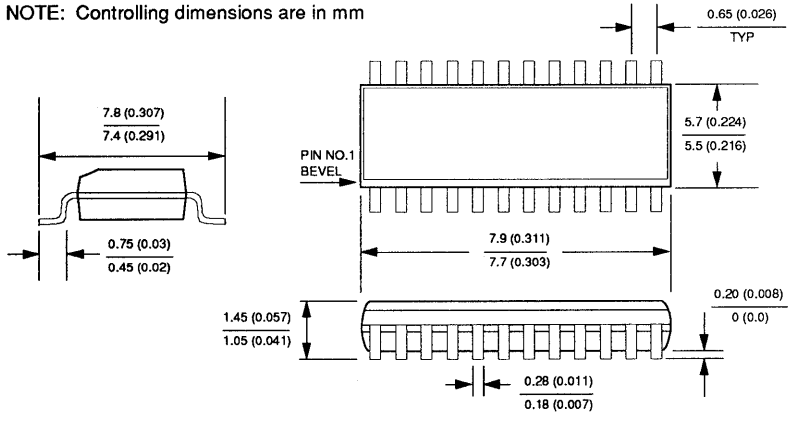
VSOP

NOTE: Controlling dimensions are in mm



20-Lead VSOP

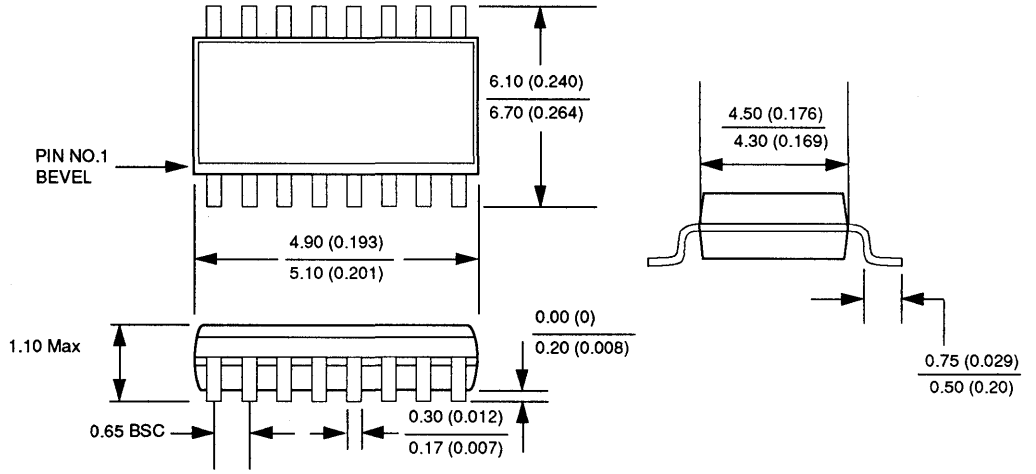
NOTE: Controlling dimensions are in mm



24-Lead VSOP

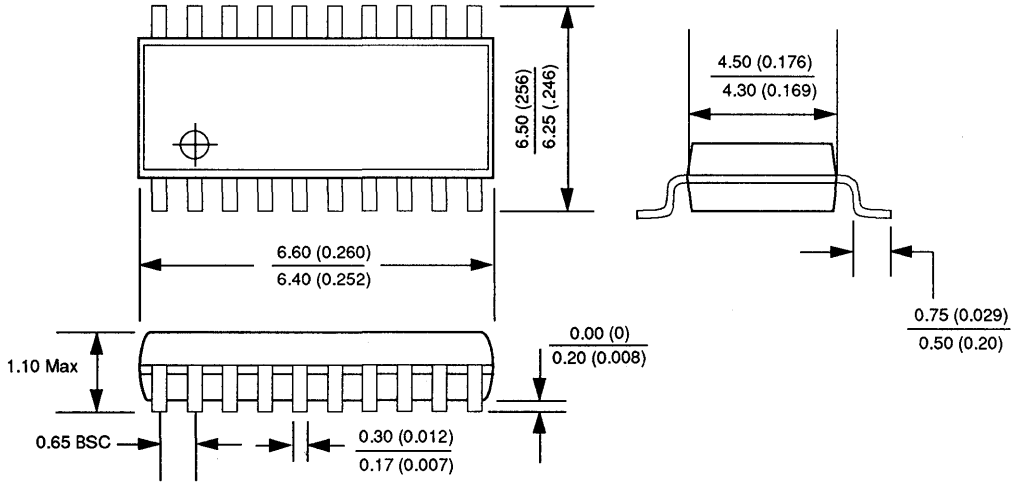
10

NOTE: Controlling dimensions are in mm



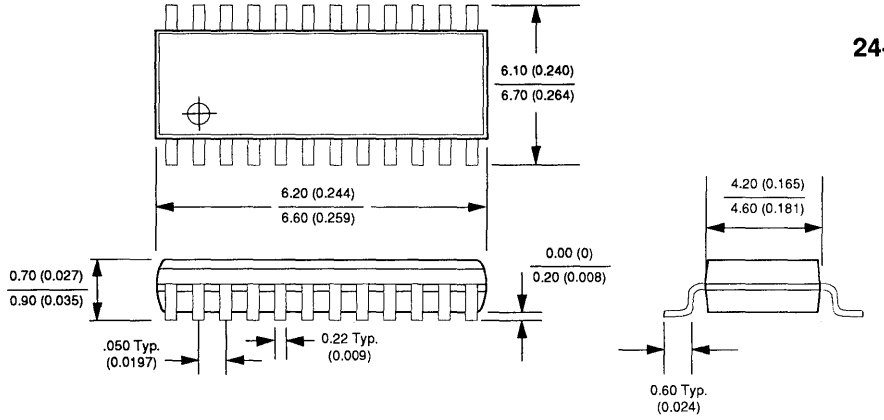
16-Lead VTSOP

NOTE: Controlling dimensions are in mm

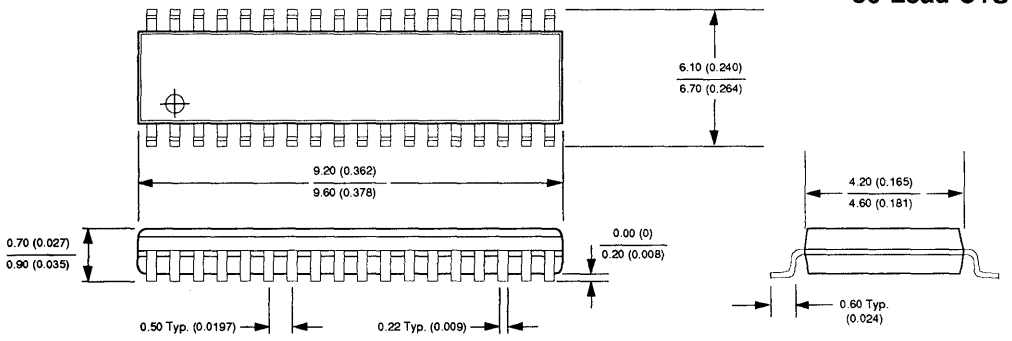


20-Lead VTSOP

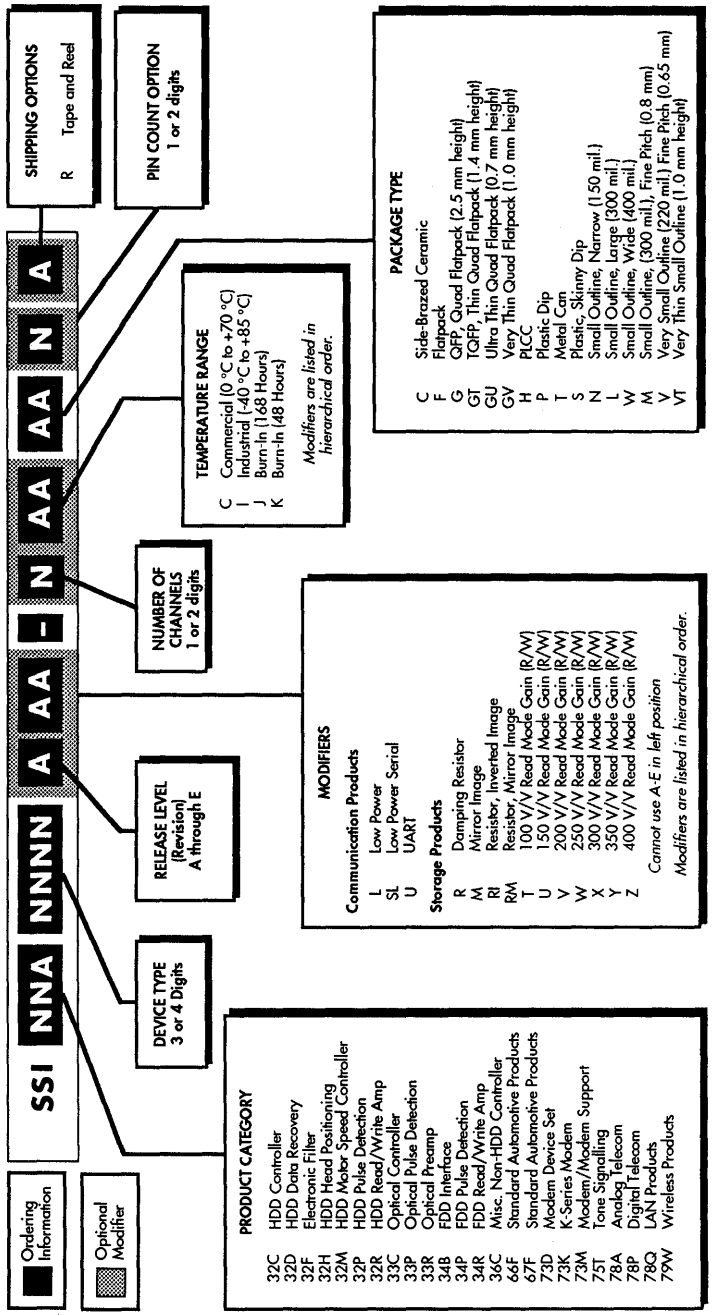
24-Lead UTSOP



36-Lead UTSOP



10


Ordering Information
Optional Modifier
SSI NNA NNNN A AA - N AA AA N A
DEVICE TYPE 3 or 4 Digits
RELEASE LEVEL (Revision) A through E
NUMBER OF CHANNELS 1 or 2 digits
TEMPERATURE RANGE
C Commercial (0 °C to +70 °C)
I Industrial (-40 °C to +85 °C)
J Burn-In (168 Hours)
K Burn-In (48 Hours)
Modifiers are listed in hierarchical order.
PIN COUNT OPTION 1 or 2 digits
SHIPPING OPTIONS
R Tape and Reel
PACKAGE TYPE
C Side-Brazed Ceramic
F Flatpack
G QFP, Quad Flatpack (2.5 mm height)
GT TQFP, Thin Quad Flatpack (1.4 mm height)
GU Ultra Thin Quad Flatpack (0.7 mm height)
GV Very Thin Quad Flatpack (1.0 mm height)
H PLCC
P Plastic Dip
T Metal Can
S Plastic, Skinny Dip
N Small Outline, Narrow (150 mil.)
L Small Outline, Large (300 mil.)
W Small Outline, Wide (400 mil.)
M Small Outline, (300 mil.), Fine Pitch (0.8 mm)
V Very Small Outline (220 mil.) Fine Pitch (0.65 mm)
VT Very Thin Small Outline (1.0 mm height)
MODIFIERS
Communication Products
L Low Power
SL Low Power Serial
U UART
Storage Products
R Damping Resistor
M Mirror Image
RI Resistor, Inverted Image
RM Resistor, Mirror Image
T 100 V/V Read Mode Gain (R/W)
U 150 V/V Read Mode Gain (R/W)
V 200 V/V Read Mode Gain (R/W)
W 250 V/V Read Mode Gain (R/W)
X 300 V/V Read Mode Gain (R/W)
Y 350 V/V Read Mode Gain (R/W)
Z 400 V/V Read Mode Gain (R/W)
Cannot use A-E in left position
Modifiers are listed in hierarchical order.
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32C HDD Controller
32D HDD Data Recovery
32F Electronic Filter
32H HDD Head Positioning
32M HDD Motor Speed Controller
32P HDD Pulse Detection
32R HDD Read/Write Amp
33C Optical Controller
33P Optical Pulse Detection
33R Optical Preamp
34B FDD Interface
34P FDD Pulse Detection
34R FDD Read/Write Amp
36C Misc. Non-HDD Controller
66F Standard Automotive Products
67F Standard Automotive Products
73D Modem Device Set
73K K-Series Modem
73M Modem/Modem Support
75T Tone Signalling
78A Analog Telecom
78P Digital Telecom
78Q LAN Products
79W Wireless Products

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