HEWLETT PACKARD

DIGITAL COMPUTERS

CARTRIDGE DISC MEMORY

HP 2870A MOVING HEAD DISC DRIVE HP 2871A DISC CONTROLLER HP 12557A DISC INTERFACE KIT

VERSATILE MASS STORAGE FOR HP COMPUTERS

FEATURES

- **DUAL STORAGE MEDIA**
  USES REMOVABLE CARTRIDGE PLUS FIXED DISC

- **LARGE CAPACITY**
  PROVIDES STORAGE FOR 1.2 MILLION WORDS (16-BIT), EXPANDABLE TO 4.8 MILLION

- **NO DUST PROBLEM**
  ELIMINATES ENVIRONMENTAL CONTAMINATION WITH AN "ABSOLUTE" AIR FILTRATION SYSTEM

- **DATA PROTECTION**
  PROVIDES FILE PROTECT AND SAFETY SENSING

- **DEPENDABILITY**
  ENSURES RELIABILITY THROUGH MECHANICAL SIMPLICITY

DESCRIPTION

This disc memory system provides low-cost, random-access mass storage for HP computing systems.

Each Drive has a removable disc in combination with a fixed disc; together they store 1.2 million words of information. Both discs are served by the same moving head mechanism. The removable disc is permanently enclosed in a cartridge for protection against contamination and damage.

In a typical operating situation, a user has the flexibility of utilizing the cartridge as a removable medium for file storage while using the fixed disc for on-line storage of programs and data. The disc controller allows user-controlled file protection for individual cylinders.

Hewlett-Packard provides full software support for the Cartridge Disc Memory. I/O drivers are available for HP disc operating and real-time systems.

2870A

HEWLETT hp PACKARD

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FROM Jim Holl

DATE December 24, 1969

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SUBJECT Cartridge Disc Memory Diagnostic

Enclosed is the External Reference Specification for the Cartridge Disc Memory Diagnostic.

JH:nm

CARTRIDGE DISC MEMORY DIAGNOSTIC

EXTERNAL REFERENCE SPECIFICATION

December 22, 1969
Jim Holl

This diagnostic test program for the HP2100 series computers confirms proper output, input and control functions for the Cartridge Disc Memory.

Rapid checkout of the controller is provided in addition to exhaustive testing of the drive. The test operator may choose to run under the default mode or define his own tests with teletype and switch register options. Provision is made for checkout of up to four drives serially. Interaction between drives may also be tested.

HARDWARE CONFIGURATION

This diagnostic program is written for an HP2100 series computer with DMA and at least 8192 words of core. The Cartridge Disc Memory has three parts; the HP2870A moving head disc drive, the HP2871A disc controller and the HP12849A Disc Interface Kit. A teletype is required.

OPERATION

The diagnostic requires a configured SIO driver for the teletype. Figure 1 shows the select codes necessary for configuring the diagnostic. Following configuration, the disc is tested according to the options found in Figure 2.

If an error occurs, the program will report the error on the teletype, then halt with the error condition displayed in the A-register.

Unexpected interrupts form a special class of errors. No message is reported on the teletype. The trap location contains 1060XXB where XX is equal to the trap location. Analysis of these errors is beyond the scope of this diagnostic. No recovery mechanism is provided.

SWITCH REGISTER

15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 Ø

BITS

Ø-5	Select code for the I/O channel containing the teletype
6-11	Select code for the I/O channel containing the data interface for the disc.
12-15	Spares

Figure 1. SWITCH REGISTER CHARACTERISTICS DURING CONFIGURATION

SWITCH REGISTER

15 14 13 12 11 1Ø 9 8 7 6 5 4 3 2 1 Ø

BITS	
Ø	Spare
1	If set to one, multiple drives are to be tested.
2	If set to one, alter cylinder table and/or pattern table.
3.	If set to one, execute operator design program.
4.	If set to one, and bit 9 set to one, execute write address test.
5	If set to one, shorten test in section two and section three.
6.	If set to one, restrict cylinder selection.
7.	If set to one, repeat last section.
8	If set to zero, machine is a 2116. If set to one, machine is a 2115 or a 2114.
9	If set to one, halt at end of test.
10	If set to one, all non-error messages for the teletype will be suppressed.
11	If set to one, all messages for the teletype will be suppressed.
12	If set to one, halt after each section of the program.
13	If set to one, loop on last operation.
14	If set to one, program will halt after each error.
15	If set to one, program will come to an orderly halt.

Figure 2. SWITCH REGISTER CHARACTERISTICS FOLLOWING CONFIGURATION.

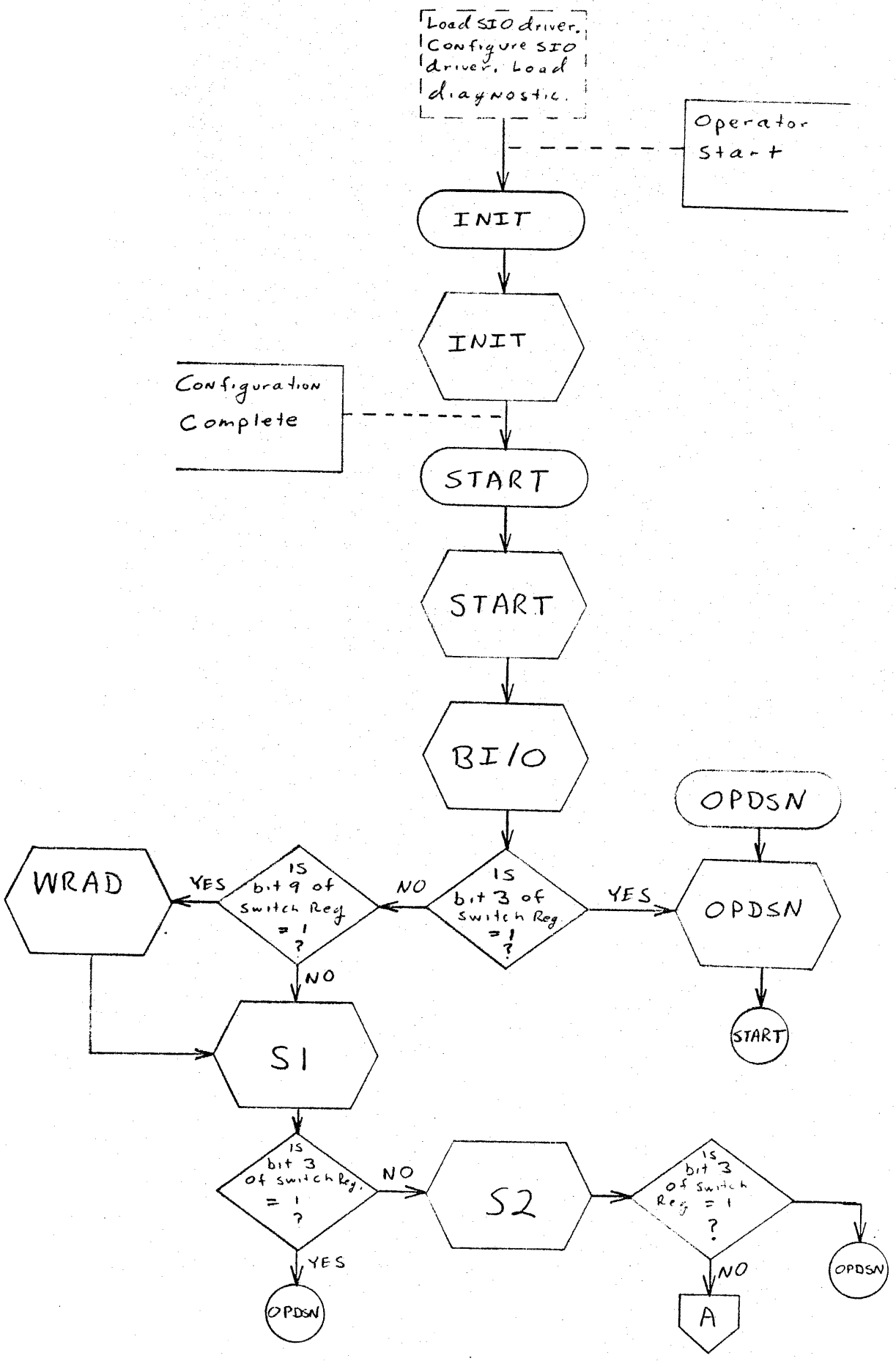


Figure 3 Program Flowchart

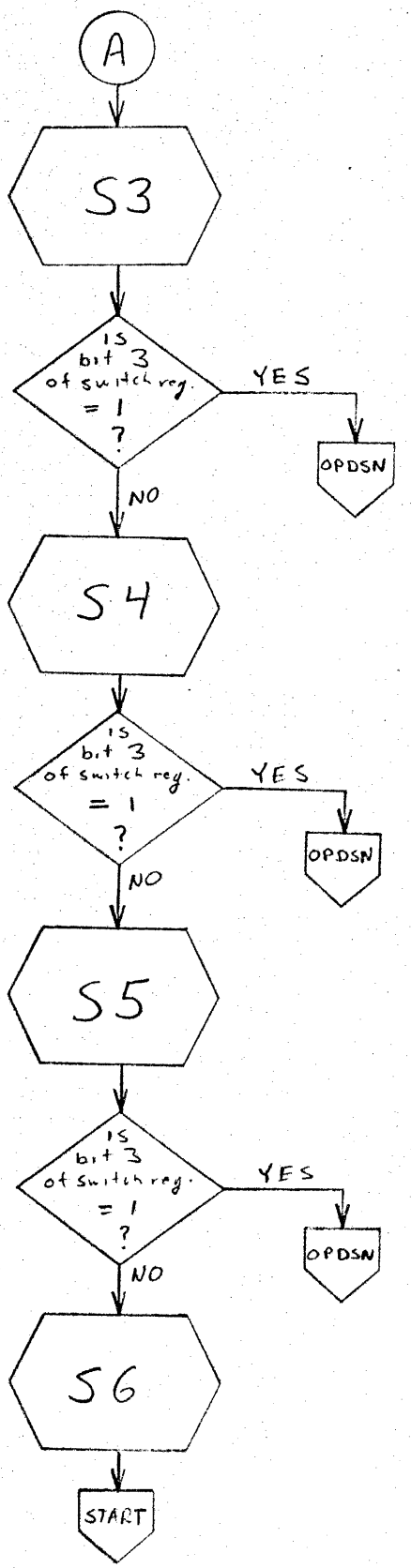


Figure 3(Continued) Program Flowchart

PROGRAM ORGANIZATION

Figure 3 is a flow chart of the diagnostic subroutines and their execution sequence. Each diagnostic subprogram is briefly described.

SUBROUTINE	DESCRIPTION
INIT	This program initializes each I/O instruction. The I/O channels are obtained from the switch register.
START	This program initializes variables and performs preliminary checks.
BI/O	Tests the ability to set and clear flags and control bits, and test interrupt operation of the teletype and the disc.
WRAD	Initializes disc pack and tests UNLOCK and OVERRIDE switches.
S1	Tests most controller functions by means of short reads and writes.
S2	Writes and reads back patterns checking for bad packs or marginal heads.
S3	Writes and reads back random data to check seek and data transfer operations.
S4	Fills pack full of checksummed data for S5.

SUBROUTINE	DESCRIPTION
S5	Reads one sector after random seek and checks checksum.
S6	Runs multiple unit test if at least two units are present.
OPDSN	This program allows the operator to design his own test and then execute it. Table 1 lists the instructions and Appendix 1 contains the operating procedure.

O. The cycle count is incremented and then reported on the teletype. Step K is entered next.

ERROR ANALYSIS

All messages to the operator typed on the teletype are prefixed by a letter and a number. If the letter is an H, the message is an operating instruction or comment. If the letter is an E, the message is an error condition. The number prefix is the condition code. This code will appear in the A-register. If the message is an error message and bit 14 of the switch register is set.

Table 2 contains the program messages by code.

Table 1

OPERATOR INSTRUCTION LIST

Instruction	Function
AR[,[CCC][,[H][,SS]]]	Address Record. This instruction sets up the RAR. Default condition sets RAR to zero. (CCC=cylinder, H=head, SS=sector).
CB[,[XXXX][,YY]]	Compare Buffers. The indicated number of words of the write buffer are compared with the read buffer. Default case is 128 words and 1 error printout. (XXXX=word count). (YYYY=allowed number of error printouts)
CD [,XXXX]	Check Data. A cyclic check of disc data is done on the number of sectors implied by this instruction's word count. First sector checked is that one currently addressed by the RAR. Default case checks 128 words. (XXXX=word count).
DB[,[XXXX][,[XXXXXX][,C]]]	Define Buffer. The write buffer has the indicated number of words filled with the indicated pattern. Default case fills 128 words. Default pattern causes each word to be random. (XXXX=word count, XXXXXX=pattern words in octal. If C is present and pattern is not random, the pattern is complemented in successive words.

Table 1. Operator Instruction List (Continued)

Instruction	Function
DS [,[CCC][,[H][,SS]]]	Decrement Seek. This instruction will do an initial seek to the location specified in this instruction, and will decrement the cylinder by 1 each time it is executed until it reaches cylinder zero. Following cylinder 0, it will seek to cylinder 202. Default condition sets RAR to cylinder 202, head 0 and sector 0.
EE	Erase Entry. Last instruction entered by operator is erased.
EN [,LL]	End. Terminates instruction entry. The label portion of this instruction is the start address. In the default case, the program will execute from the first instruction (LL=label).
GO,LL	GOTO. Go to label (LL=label).
HT [,XXXXXX]	Halt. This instruction halts and displays value in A-register. Zero is displayed in the default case. (XXXXXX=display value in octal).
ID [,[XXXX][,D/P]]	Initialize Data. This instruction requires that the override switch be ON to allow access to the sector address words on the disk. This command results in the contents of the record address register being placed in the sector the RAR currently references. If the defective cylinder indication (D) is added to this instruc-

Table 1. Operator Instruction List (Continued)

	tion, the sector is tagged defective. If the protect cylinder indication (P) is added to this instruction, the sector is tagged as protected. This process is repeated on as many sectors as the word count allows. The default case writes 3072 words. (XXXX=word count).
IS[,[CCC] [,[H][,SS]]]	Incremental Seek. This instruction will do an initial seek to the location specified in this instruction and will increment the cylinder by 1 each time it is executed until it reaches cylinder 202. Following cylinder 202 it will seek to cylinder 0. Default condition sets RAR to zero.
LB,LL	Label. Define location of label. (LL=Label).
RD[,XXXX]	Read Data. Transfer the number of words indicated from the disc to the read buffer. Location on disc is determined by RAR. Default case is 128 words. (XXXX=word count).
RR	Refine Record. A tunnel erase is performed on the sector currently contained in the RAR address.

Table 1. Operator Instruction List (Continued)

Instruction	Function
RS	Random Seek. This command will cause a random cylinder-head-sector combination to be generated and then will seek to the random location.
SC[,XXXXXX]	Status Check. Hardware status is compared against expected status. If the status does not compare, an error is printed. Default status is zero. (XXXXXX=expected status in octal).
SD,X	Select Drive. Indicated drive is selected. (X=drive number; $0 \leq X \leq 3$).
SR[,[CCC][,[H][,SS]]]	Seek Record. This instruction sets up the RAR. A seek is then performed to the disc location defined by the RAR. Default condition sets RAR to zero. (CCC=cylinder, H=head, SS=sector).
WD [,XXXX]	Write Data. Transfer indicated number of words from write buffer to disc. Location on disc is determined by RAR. Default case is 128 words. (XXXX=word count).

Table 2

T-Register	Condition Code A-Register	Message	Test Description
1Ø6ØXX	- - -	(None)	Trap cell interrupt. P = memory address when interrupted, XX=trap cell location.
------	HØ	CARTRIDGE DISC MEMORY DIAGNOSTIC	Preample.
1Ø2ØØ1	E1	PLEASE DISABLE LOADER	Precaution.
1Ø2ØØ1	E2	CLF DID NOT CLEAR FLAG OR SFS CAUSED SKIP WITH FLAG CLEAR - TELETYPE	Test the ability to clear the teletype flag and test the SFS instruction.
1Ø2ØØ1	E3	SFC DID NOT SKIP WITH FLAG CLEAR-TELETYPE	Test the ability of the SFC instruction.
1Ø2ØØ1	E4	STF DID NOT SET FLAG, OR SFC CAUSED SKIP WITH FLAG SET - TELETYPE	Test the ability to set the teletype flag and test the SFC instruction
1Ø2ØØ1	E5	SFS DID NOT SKIP WITH FLAG SET-TELETYPE	Test the SFS instruction.
1Ø2ØØ1	E6	NO INTERRUPT ON TELETYPE	Test the interrupt capability.
1Ø2ØØ1	E7	INCORRECT RETURN ADDRESS-TELETYPE	Test the return address that was placed in the trap cell.
1Ø2ØØ1	E1Ø	CLF DID NOT CLEAR FLAG OR SFS CAUSED SKIP WITH FLAG CLEAR - DATA	Test the ability to clear the data channel flag and test the SFS instruction.
1Ø2ØØ1	E11	SFC DID NOT SKIP WITH FLAG CLEAR - DATA	Test the ability of of the SFC instruction.

Table 2 - Continued

T-Register	Condition Code A-Register	Message	Test Description
1Ø2ØØ1	E12	STF DID NOT SET FLAG, OR SFC CAUSED SKIP WITH FLAG SET-DATA	Test the ability to set the teletype flag and test the SFC instruction.
1Ø2ØØ1	E13	SFS DID NOT SKIP WITH FLAG SET-DATA	Test the SFS instruction.
1Ø2ØØ1	E14	NO INTERRUPT ON DATA CHANNEL	Test the interrupt capability.
1Ø2ØØ1	E15	INCORRECT RETURN ADDRESS-DATA	Test the return address that was placed in the trap cell.
1Ø2ØØ1	E16	CLF DID NOT CLEAR FLAG OR SFS CAUSED SKIP WITH FLAG CLEAR - COMMAND	Test the ability to clear the command channel flag.
1Ø2ØØ1	E17	SFC DID NOT SKIP WITH FLAG CLEAR - COMMAND	Test the ability of the SFC instruction.
1Ø2ØØ1	E2Ø	STF DID NOT SET FLAG, OR SFC CAUSED SKIP WITH FLAG SET - COMMAND	Test the ability to set the teletype flag and test SFC instruction.
1Ø2ØØ1	E21	SFS DID NOT SKIP WITH FLAG SET-COMMAND	Test the SFS instruction.
1Ø2ØØ1	E22	NO INTERRUPT ON COMMAND CHANNEL	Test the interrupt capability.
1Ø2ØØ1	E23	INCORRECT RETURN ADDRESS-COMMAND	Test the return address that was placed in the trap cell.
------	H24	CYLINDER TABLE, XXX,XXX,XXX,XXX,XXX, XXX,XXX,XXX,XXX	Contents of cylinder table (XXX=cylinder).
------	H25	DO YOU WISH TO CHANGE TABLE?	Y or N.

Table 2 - Continued

T-Register	Condition Code A-Register	Message	Test Description
------	H26	ENTER CYLINDER NUMBERS SEPARATED BY COMMAS	All on one line.
------	H27	PATTERN TABLE, XXXXXX,XXXXXX,XXXXXX, XXXXXX,XXXXXX,XXXXXX, XXXXXX,XXXXXX,XXXXXX, XXXXXX	Contents of pattern table. (XXXXXX = pattern in octal).
------	H3Ø	ENTER PATTERNS SEPARATED BY COMMAS	All on one line.
------	E31	INPUT ERROR	Bad input.
------	H32	RESET SWITCH 2	
------	H33	RESET SWITCH 1	
------	H34	ENTER UNIT NUMBERS (0-3) SEPARATED BY COMMAS	All on one line.
1Ø2ØØ1	E35	INITIAL STATUS	First status command.
1Ø2ØØ1	E36	WRITE ADDRESS	Write address command.
1Ø2ØØ1	E37	READ ADDRESS	Read address command or data check followin
1Ø2ØØ1	E4Ø	SEEK IN WRAD	Seek command.
1Ø2ØØ1	E41	READ DEFECTIVE TRACK IN WRAD	DCI bits set.
1Ø2ØØ1	E42	WRITE PROTECTED TRACK IN WRAD	Write on a protected cylinder.
1Ø2ØØ1	E43	NOT READY CHECK	Test unlock sense.
1Ø2ØØ1	E44	SEEK IN S1	Seek command.
1Ø2ØØ1	E45	WRITE IN S1	Write command.
1Ø2ØØ1	E46	READ IN S1	Read command.
1Ø2ØØ1	E47	CYCLIC CHECK IN S1	Cyclic check command.

Table 2 - Continued

T-Register	Condition Code A-Register	Message	Test Description
1Ø2ØØ1	E5Ø	OVERRUN IN S1	Force overrun condition.
1Ø2ØØ1	E51	SEEK IN S2	Seek command.
1Ø2ØØ1	E52	WRITE IN S2	Write command.
1Ø2ØØ1	E53	READ IN S2	Read command.
1Ø2ØØ1	E54	SEEK IN S3	Seek command.
1Ø2ØØ1	E55	WRITE IN S3	Write Command.
1Ø2ØØ1	E56	READ IN S3	Read command.
1Ø2ØØ1	E57	SEEK IN S4	Seek command.
1Ø2ØØ1	E6Ø	WRITE IN S4	Write command.
1Ø2ØØ1	E61	SEEK IN S5	Seek command.
1Ø2ØØ1	E62	READ IN S5	Read command.
1Ø2ØØ1	E63	SEEK IN S6	Seek command.
1Ø2ØØ1	E64	READ IN S6	Read command.
------	H65	PASS XXX	Number of cycles completed. (XXX = cycle count).
------	H66	SET OVERRIDE SWITCH, PUSH RUN	Operator request in WRAD.
------	H67	CLEAR OVERRIDE SWITCH, PUSH RUN	Operator request in WRAD.
------	H7Ø	UNLOCK UNIT X, PUSH RUN	Operator should place the indicated unit off-line. (X = unit number).
------	H71	READY UNIT X	Operator should place the indicated unit on-line. (X = unit number).

Table 2 - Continued

T-Register	Condition Code A-Register	Message	Test Description
1Ø2ØØ1	E72	STATUS IS XXXXXX SHOULD BE YYYYYY	The status operation did not return the expected status.
1Ø2ØØ1	E73	NO DATA CHANNEL FLAG	A device flag was expected on the data channel and did not occur.
1Ø2ØØ1	E74	NO COMMAND CHANNEL FLAG	A flag expected on the command channel to indicate operation complete did not occur.
1Ø2ØØ1	E75	LATE DATA CHANNEL FLAG	A device flag was expected on the data channel and did not occur until after time out.
102001	E76	NO DATA CHANNEL FLAG WHILE CHECKING STATUS	This message is typed out by the status routine when the device flag on the data channel was not set to indicate that the status was returned.
1Ø2ØØ1	E77	XXXX WORDS TRANSFERRED YYYY EXPECTED	When the operation complete device flag occurred on the command channel, the DMA transfer was not complete.
1Ø2ØØ1	E1ØØ	NO COMMAND FLAG ON DMA OPERATION	A transfer using DMA was in progress, and a command channel flag indicating operation complete did not occur.
1Ø2ØØ1	E1Ø1	DATA WORD XXXX IS YYYYYY SHOULD BE ZZZZZZ	The data returned on a read operation did not match the expected data. This message is only type

Table 2 - Continued

T-Register	Condition Code A-Register	Message	Test Description
	E1Ø1 Continued		for the first erroneous word in a buffer.
1Ø2ØØ1	H1Ø2	CYL XXX HEAD X SECTOR ZZ WORD COUNT XXXX UNIT X	This message appears with most error printouts.
1Ø2ØØ1	E1Ø3	BUFFER CHECKSUM XXXXXX CYL YYYYYY HD/S ZZZZZZ	The checksum should be zero and the address should match the one typed out in H1Ø2. Either the wrong sector was read or a data error occurred.
------	H1Ø4	AVERAGE MINIMUM SEEK TIME XX.X	Milliseconds. From S2.
------	H1Ø5	AVERAGE RANDOM SEEK TIME XXX.X. AVERAGE RANDOM SEEK LENGTH YY.Y.	Milliseconds. From S5.
------	H1Ø6	ENTER INSTRUCTIONS	From OPDSN.
------	H1Ø7	UNDEFINED LABEL,XX	From OPDSN. Define label or erase reference.

APPENDIX 1

OPERATOR DESIGN PROCEDURE

1. Program will type "H1Ø6 ENTER INSTRUCTIONS".
2. Enter instructions in their execution sequence. Select instructions from Table 1. Commas separate fields. A field is defaulted if it is excluded from the instruction or skipped by the instruction.

   Example: "SR" seeks cylinder 0, head 0 and sector 0
   "SR,,1" seeks cylinder 0, head 1 and sector 0.
   "SR,202,3,11" seeks cylinder 202, head 3 and sector 11.

   Complete the line with a CARRIAGE RETURN and a LINE FEED.
3. If any error has occurred, the message "E31 INPUT ERROR" will be typed. The erroneous entry has been rejected and should be typed again.
4. RUBOUT may be used to erase the present entry before the LINE FEED has been sent. EE (Erase Entry) erases the last line in the input string. The instruction may be repeated to erase multiple lines.
5. The AR, CD, ID, RD, RR, RS, SR and WD instructions include a status check unless they are followed by a SC instruction. The expected status is zero with Attention (bit 15) and First Seek (bit 14) masked out.
6. Field limits are as follows:
   A) $0 \leq$ Cylinder ≤ 202
   B) $0 \leq$ Head ≤ 3
   C) $0 \leq$ Sector ≤ 11
   D) $1 \leq$ Read or Compare Buffer Size ≤ 1536
   E) $1 \leq$ Write Buffer or Check Data Count ≤ 3072
   F) $0 \leq$ Unit Number ≤ 3
7. Anytime bit 3 of the switch register is reset control is given back to START.
8. An EN instruction will be rejected if there exist undefined labels. The message is:
   "H1Ø7 UNDEFINED LABEL XX". The label should be defined or the reference erased.

iomec inc

engineering specification

IODISC 1001 disc drive

NO. 2616

DATE 7/2/70

COPY 016

SCOPE

Specifications to cover IODISC 1001 disc drive. The 1001 is a low-cost, modified-performance version of IODISC 1011 disc drive. It is designed to meet the requirements of the high-volume OEM who can justify the development of a controller and packaging, and who wants to enter the market at the lowest possible price/performance level.

GENERAL DESCRIPTION

The 1001 is a rack-mountable drive, complete with the integral electronics required to address a sector of data, read and write data, separate data, and provide certain status signals.

A voice coil actuator positions both heads (one head for each disc surface).

The single disc has a data capacity of approximately 1.3 million bytes organized into 8 or 12 sectors. It can be furnished in one of three configurations:

1. removable single-disc cartridge (standard)
2. fixed permanently in drive (optional)
3. fixed semi-permanently in drive and accessible only with key (optional)

An interface provides a simple means of attachment to an OEM-designed controller.

FEATURES

* A self-contained air system provides a high volume of air to pressurize the drive enclosure at all times, and to purge and protect removable cartridges.

* A "trackhold" detent system assures absolutely cylindrical data tracks, guarantees interchangeability of discs between drives.

* Virtually total interchangeability of mechanical and power system parts with all IODISC Series 1000 drives.

OPTIONS

* Mounting rails

* Accordion cables

* File protect

* Automatic start

DETAILED DESCRIPTION

Drive. IODISC 1001 is a low-cost, random access mass storage device for use with small to medium size computers. When interfaced with a controller and a power system, it becomes the heart of the disc data storage system.

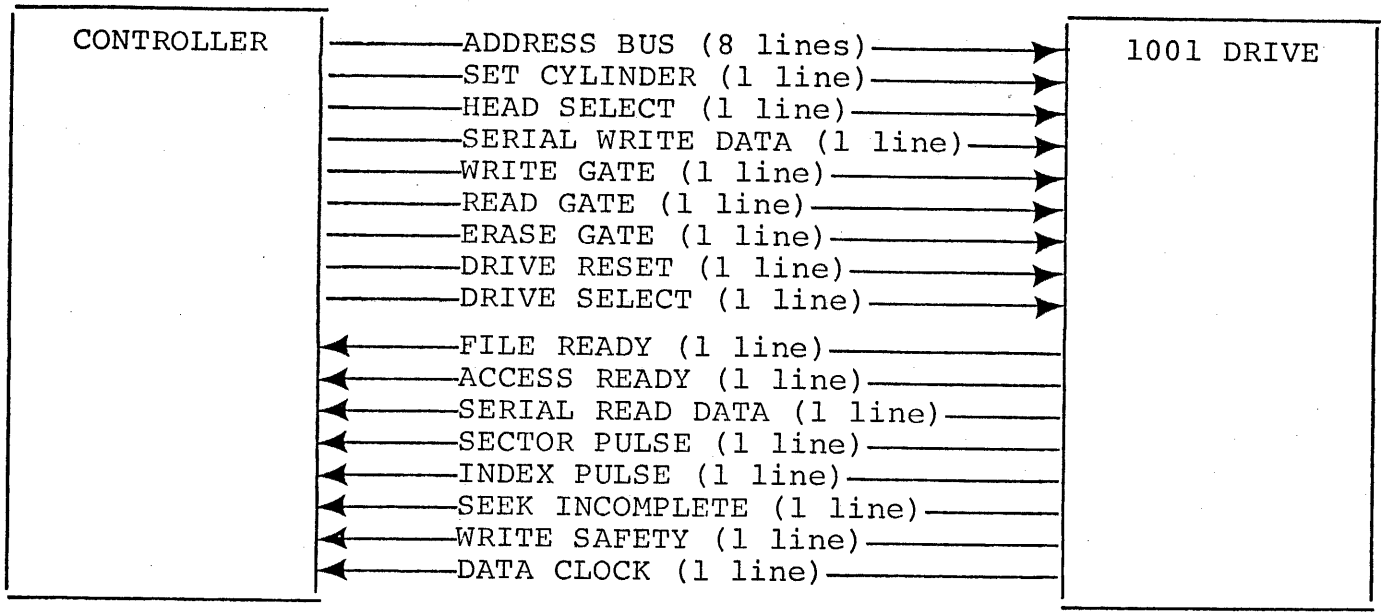
The removable disc cartridge (IBM 2315, or equivalent) provides the using system with approximately 11 million bits of random access on-line storage. The single disc is permanently enclosed in the cartridge for protection against contamination and damage. Unlimited off-line storage is available with extra disc cartridges which may be conveniently stored on shelves or racks. The 1001 is also available with the disc fixed permanently in the drive, or fixed semi-permanently and accessible only by key.

At operating speed, the two magnetic heads are placed in flying position by the head load solenoid. An electromagnetically actuated carriage, controlled by a closed loop servo, moves the heads to any one of the 203 cylinder locations. The carriage is held in position during a read/write operation by an electromechanical detent.

Mounted in the same enclosure and integral with the drive is an electronics assembly consisting of a single gate which contains read/write circuitry, servo electronics, and sensing circuitry.

Interface. IODISC 1001 provides two parallel logic interfaces -- one for file function control and one for data transfer. The file function control interface provides those lines necessary for determining the status of the drive and addressing cylinders and sectors. The data transfer interface provides those lines necessary for transferring data to and from the disc. The controller actuates the read or write gates and supplies data pulses during write operations. The drive supplies clock pulses to the controller in all modes, plus data pulses during read. Both interfaces are designed for connection in either a multiplex (party line) or simplex arrangement. The drive interfaces directly with the using system controller which, in turn, receives all control and data inputs from the host processor. Similarly, all data and drive status signals are sent to the using system via the controller. The disc drive does not perform any operations on data and returns it to the controller exactly as it was originally transmitted.

INTERFACE LINES



All lines from the drive to the controller are driven by open collector NPN transistors. These lines must be terminated in 100 ohm resistors to +5 volts DC.

Lines from the controller to the drive are terminated in 100 ohm resistors to +5 volts DC. The lines must be capable of being driven to 0.4 volt DC (for the line active state) by the controller's line drivers.

All lines in the interface described below are active (logical "1") when they are from 0.0 to 0.8 volts. The lines are inactive (logical "0") when they are from +2.5 to +5.5 volts.

Control to Drive Lines

Address Bus. Eight lines binary weighted. The active state of these lines is stored into an address register in the drive whenever the set cylinder line is activated. The Address Bus lines must be stable for at least 200 nanoseconds before and after the set cylinder pulse.

Set Cylinder. A pulse on this line causes the data on the Address Bus line to be stored into the address register. A set cylinder pulse should not be issued unless the Access Ready line is active. The pulse width of the Set Cylinder can be from .350 to 100 microseconds.

Head Select. This single line is used to select the upper or lower read/write head of the drive. When this line is at a down logic level (gnd) the lower head will be selected; when it is at an up level the upper head will be selected.

Serial Write Data. This line controls the information to be written in the next bit cell to come under the read/write head. The active state of this line causes a "1" to be recorded. In order to insure writing of valid data, this line must be stable within 450 nanoseconds after the leading edge of the Write Data Clock pulse. When the data is stable, the write trigger will be properly activated and the double frequency data written on the disc recording surface.

Write Gate. Activation of this line controls the double frequency write encoder and the write driver in the drive write amplifier electronics. This line should be brought up simultaneously with Erase Gate and both must be active during the write operation. In no case should Write Gate be brought up more than 30 microseconds earlier than Erase Gate.

Read Gate. Activation of this line turns on the disc read amplifier to allow reading of the double frequency data written on the disc. The read amplifier presents separated data on the Serial Read Data line. The Read Gate may be activated at any time the Write or Erase Gates are not active. The Read Gate must remain active for the entire period the disc record is being read. The validity of the Serial Read Data as it relates to Read Gate timing is described under the Serial Read Data line definition.

Erase Gate. Activation of this line controls the tunnel erase driver. The tunnel erase serves to "trim" the written track, thus reducing the track width and preventing crosstalk into adjacent tracks during read operations. This line can be active prior to activation of the Write Gate without generating an error condition. The Erase Gate should remain active for at least 75 microseconds after the drop of Write Gate. This insures a tunnel erase of the last data bits written on the disc.

Drive Reset. This line is used to reset status latches and flip-flops within the drive to insure initialization at start-up time or to allow restart procedures to be implemented.

Drive Select. Activation of this line selects the drive. All of the data transfer lines to and from the drive, and the Sector and Index lines are gated by activation of this line. This allows multiplex connection of drives to a single control unit if required.

Drive to Control Lines

File Ready. This is a status line which indicates to the using system that drive power is on, heads have loaded, the disc is rotating at least 70% of its rated speed, and 90 seconds have elapsed since the disc motor was turned on.

Access Ready. This is a status line which indicates to the using system that the access arm is not in motion. The Access Ready line must be active prior to execution of a Seek, Read, or Write command. Access Ready will also be turned on by Seek Incomplete (see below).

Serial Read Data. The state of this line indicates the contents of the bit cell currently under the read/write heads. The active state indicates that a "1" is being read. Separated read data will appear on this line whenever the Read Gate is active. The read signal will rise within 695 (+180, -110) nanoseconds after the leading edge of the clock pulse at the beginning of the data cell, and fall with the trailing edge of the clock pulse at the end of the data cell. Duration of the read signal is 1045 (+180, -100) nanoseconds.

Sector Pulse. When the disc is rotating at rated speed this line will contain a stream of sector pulses of 5 (±1.0) microsecond duration. Leading edge to leading edge time is determined by the disc installed on the drive as follows:

8 sector disc	5 (±.150) milliseconds
12 sector disc	3.3 (±.100) milliseconds

Index Pulse. When the disc is rotating at rated speed, a pulse of 5 (±1.0) microsecond duration will appear on this line once per disc revolution (40 milliseconds). The Index Pulse trails one of the Sector Pulses by 600 microseconds per revolution.

Seek Incomplete. This is a status line which indicates to the using system that more than 350 milliseconds have elapsed since a set cylinder pulse was issued to the drive without the access becoming "ready". Turn on of Seek Incomplete will turn on Access Ready.

Write Safety. This is a status line which indicates to the using system that a failure has been detected in the Write Amplifier. The failure modes monitored by this line include:

1. Write or Erase Gates turned on without Access Ready.

2. Two heads selected simultaneously.

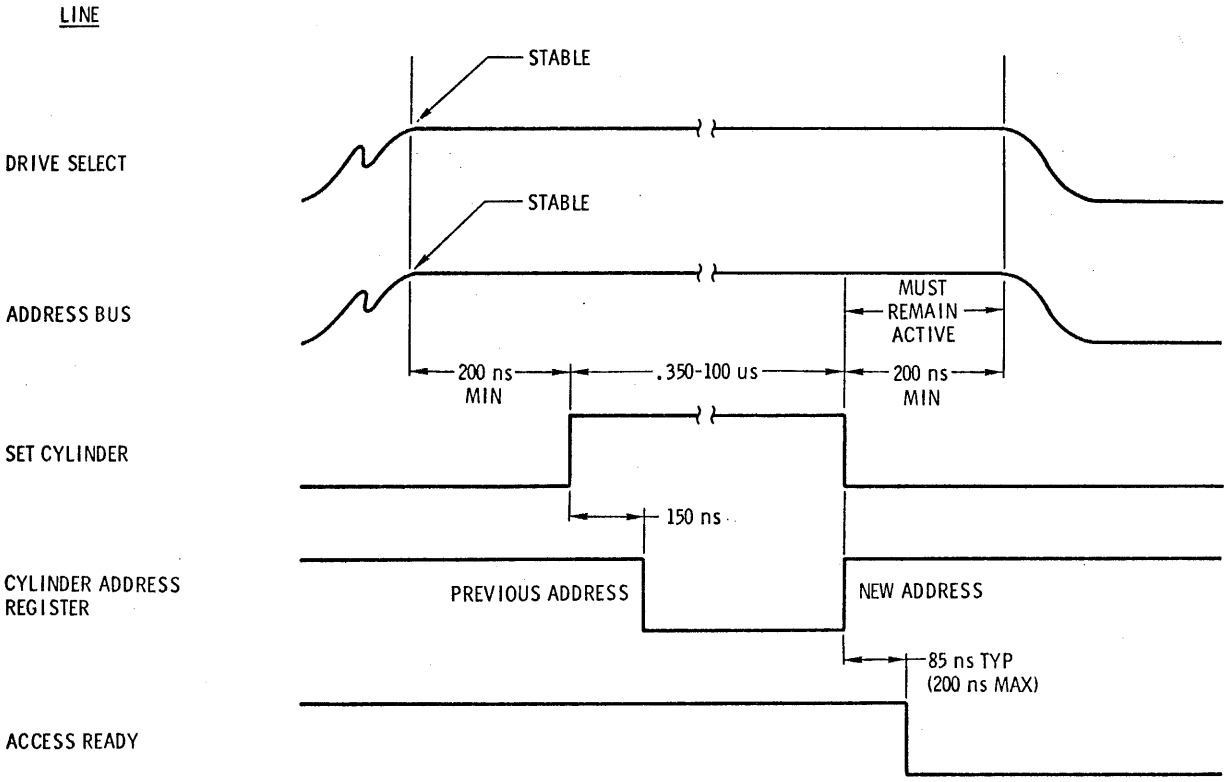
The Write Safety condition is reset by turning off the drive motor and allowing it to come to a full stop.

Data Clock. When either the Read or Write Gate is active, a pulsed signal will appear on this line for each serial data bit which is read or written. When the Read Gate is active, the pulse width will be 350 (±50) nanoseconds. When the Write Gate is active, the pulse width will be 700 (±100) nanoseconds. In both cases leading edge to leading edge of the Data Clock pulses will be one bit cell time.

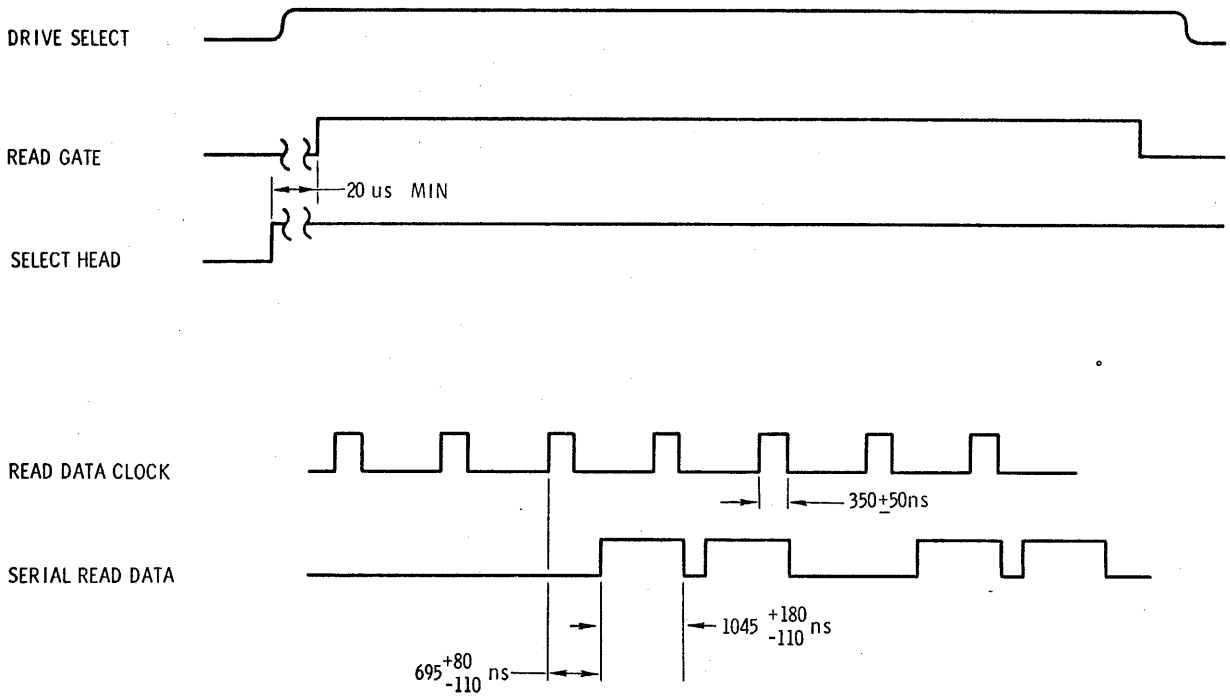
TIMING

All signals are illustrated as positive and do not indicate polarity.

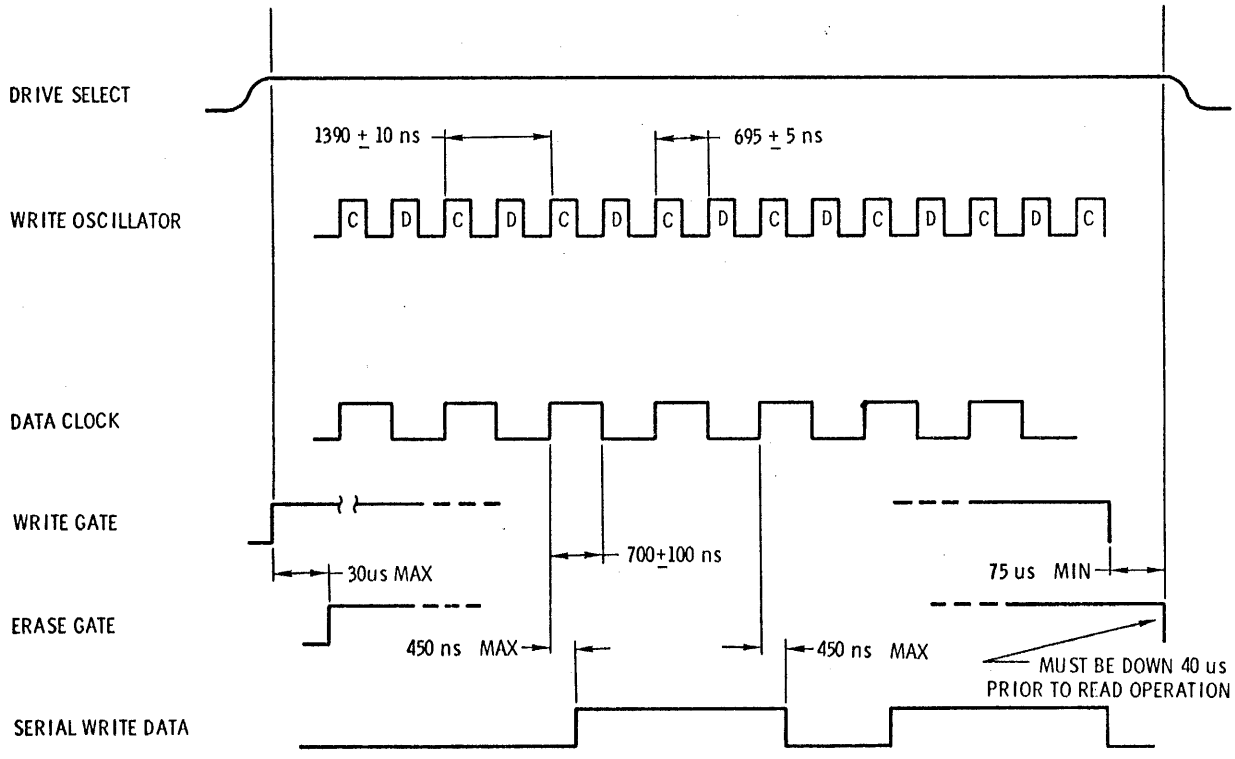
Seek Cylinder Operation Signal Timing



Read Data Operation



Write Data Operation



SPECIFICATIONS

Capacity

203 cylinders (includes 3 spares)
406 tracks (includes 6 spares)
3,200 sectors (8-sector/track mode)
4,800 sectors (12-sector/track mode)

Capacities shown below are true data storage capacities. Additional capacity is available for data formatting. (For example, the total of 9,830,400 bits for the 12-sector/track mode is augmented by 230,400 bits for data formatting, yielding a total capacity in this mode of 10,060,800 bits.

	full-track mode	8-sector/track mode	12-sector/track mode
drive			
bits	10,860,800	10,240,000	9,830,400
bytes	1,357,600	1,280,000	1,228,800
words (16-bit)	678,800	640,000	614,400
cylinder			
bits	54,304	51,200	49,152
bytes	6,788	6,400	6,144
words (16-bit)	3,394	3,200	3,072
track			
bits	27,152	25,600	24,576
bytes	3,394	3,200	3,072
words (16-bit)	1,697	1,600	1,536
sector			
bits	--	3,200	2,048
bytes	--	400	256
words (16-bit)	--	200	128

Access Times (Including Head Settling)

track-to-track:	35 ms
average random move:	140 ms
average rotation delay:	20 ms

Recording Technology

bit density:	1,080 bpi (innermost track)
track density:	100 tpi
recording format:	double frequency
data transfer rate:	720,000 bits/second
clock frequency:	720,000 pulses/second
bit cell time:	1,389 nanoseconds nom.
disc rotation speed:	1,500 rpm
cartridge diameter:	15.0 inches
disc diameter:	14.0 inches
number of heads:	2

Electrical/Mechanical

power requirements:
- AC: 115 or 208/230 Vac, 60 Hz, single phase
- DC: +5 V ±1%, 3.0 A
  +36 V ±1%, 1.5 A
  -36 V ±5%, 1.5 A
  (These voltages must be applied and removed in the proper sequence)

With optional DC power unit (includes power sequencer and line filter)
- AC: 115 or 208/230 Vac, 60 Hz, single phase, 550 volt-amps

disc drive motor:	1/12 hp
blower motor:	1/15 hp
access mechanism:	
actuator:	electromagnetic voice coil motor
detent:	electromechanical
mounting:	cast aluminum base plate with shock mounting

Controls/Indicators

disc motor switch:	toggle switch turns drive motor on and off; turning off unloads heads and causes access arm to move heads to track 000
disc unlock:	illuminated switch controls disc removal interlock
ready:	illuminated switch indicates ready status

Environment

temperature	
operating:	+15°C to +35°C (60°F to 95°F)
non-operating/power off:	-15°C to +71°C (5°F to 160°F)
humidity (without condensation)	
operating:	8% to 80%
non-operating/power off:	0% to 95%
shock and vibration	
frequencies less than 14 Hz:	0.01 inch peak-peak (sustained) 0.1 inch peak-peak (intermittent)
frequencies of 14 Hz and greater:	0.1G peak (sustained) 0.25G peak (intermittent)
cooling:	forced room air, ambient at installed location
air circulation:	40 to 60 CFM (ducted)

Specifications subject to change without notice.

OEM PRICE SCHEDULE

IODISC 1001 disc drive

Quantity	Discount	Net Price	Competition
1 - 14	OEM List	$4925	_____
15 - 49	25%	3690	_____
50 - 99	30%	3450	_____
100 - 199	35%	3200	_____
200 - 499	40%	2955	_____
500 - 999	45%	2700	_____
1000 plus	49%	2525	_____

IODISC 0711 power system

1 - 14	OEM List	750	_____
15 - 49	25%	565	_____
50 - 99	30%	525	_____
100 - 199	35%	490	_____
200 - 499	40%	450	_____
500 - 999	43%	425	_____
1000 plus	50%	375	_____

"Iomec" Inc
345 MATHEW STREET
SANTA CLARA, CALIF. 95050
PHONE (408) 246-2950

EXHIBIT I

FUNCTIONAL SPECIFICATIONS

HEWLETT PACKARD - IOMEC CONTROLLER

FOR

IODISC 1011 AND 1012 DRIVES

HOWARD H. STODDARD

October 6, 1969

TABLE OF CONTENTS

1.0 INTRODUCTION

IODISC 1011 and 1012 drives will be attached to Hewlett-Packard computers via the IODISC 18ØØ1 Common Control with IODISC 9ØØØ3 Channel Adapter. This specification details the functional operation of the drive-control-adapter combination and will be used by IOMEC in the design of hardware and by Hewlett-Packard in the development of supporting software. In the descriptions used here, the IOMEC control-adapter is referred to as the CU and the Hewlett-Packard system is called the CPU.

2.0 GENERAL DESCRIPTION

The CU will attach up to four drives (any combination of 1011's and 1012's) to the CPU; CU-CPU interfacing is accomplished through two Hewlett-Packard MICROCIRCUIT duplex cards. One card is used for data, status and certain control information and is called the data channel (all data transfer between the CU and CPU is in 16-bit words). The other card is used for commands and drive selection and is termed the command channel.

Each disc in the system stores 2Ø3 cylinders of information. Each cylinder contains 24 sectors---twelve on the top surface of the disc and twelve on the bottom. Within a cylinder, sectors are addressed by specifying a head number and a sector number. The head number ranges between zero and three for the 1012 drive (head zero serves the top surface of the disc cartridge, head three the bottom surface of the fixed disc, etc.) and between zero and one for the 1011. Sector numbers range between zero and eleven. Each sector contains a sector address field and a data field. The sector address field contains the cylinder, head and sector numbers of the sector, as well as indicators for defective and protected cylinder; the data field stores 128 16-bit words of data. Only the data field is transferred to and from the CPU; the sector address field is generated and checked in the CU. Both fields are cyclic checked by the CU.

3.0 COMMAND CHANNEL OPERATION

3.1 Command Word and Responses

To initiate a disc operation, the CPU places a command word in the output register of the command interface card and sets the Encode signal on that interface. The rise of the Encode line

indicates the presence of a new command, causing the CU to decode the command word and initiate the operation specified on the drive selected. When the command issued is Status Check, Seek Record or Address Record, the CU will be free to accept another command as soon as the required data interface information transfer has been completed. For all other commands, the command word must remain unchanged on the interface until the CU signals completion by setting the interface Device Flag signal.

The command word always contains four bits of command information plus two bits of drive selection information. The format is as follows:

15 12	11 2	1 0
COMMAND CODE		DRIVE SELECT

Certain of the commands require other information bits in the command word; these are described below under the command descriptions.

The two-bit drive select field contains the number (zero through three) of the drive which is to execute the command. The four-bit command field contains the binary code of the command to be executed. The command codes used are shown below:

CODE				COMMAND
BIT 15	14	13	12	
Ø	Ø	Ø	Ø	Status Check
Ø	Ø	Ø	1	Write Data
Ø	Ø	1	Ø	Read Data
Ø	Ø	1	1	Seek Record
Ø	1	Ø	1	Refine Sector
Ø	1	1	Ø	Check Data
1	Ø	Ø	1	Initialize Data
1	Ø	1	1	Address Record

Only the four low-order positions of the command interface input register are used. These bit positions indicate the state of the Attention condition for each of the four drives. Attention for drive zero is in bit position zero, Attention for drive one in position one and so forth. The four bits provide a valid indication of drive Attentions from the set of interface Device Flag to the rise of Encode for the next command.

3.2 Command Set

3.2.1 Status Check (ØØØØ)

The Status Check command is used to transfer a word of status information from the CU to the CPU. When the command is issued, the CU selects the drive specified, assembles the status word and transfers it to the CPU via the data interface. The word details status of the selected drive, as well as conditions detected by the CU during data operations with the drive. Status word bit definitions are given in Section 4.2. Command execution is completed when the CPU accepts the status word on the data interface; Device Flag is not set on the command interface.

3.2.2 Write Data (ØØØ1)

Write Data is the normal command used for writing after the pack has been initialized. When the command is issued, the CU selects the drive specified and waits for the addressed sector to come into position. (In all cases, the "addressed sector" is that sector specified by the contents of the control unit record address register--referred to from here on as the RAR.) When the addressed sector comes into position, the CU examines the cylinder condition indicators and address information in the address field and cyclic checks the entire sector. If the address compares properly and the cylinder is not protected or defective, the CU starts writing in the next sector. The CU assembles and writes the address field, then initiates data transfer from the data interface. The CU always writes 128 data words in a sector; if the CPU sends less than 128, the CU fills the remainder of the sector with zeroes before setting Device Flag on the command interface. If the CPU has more than 128 words to write, the CU adds one to the contents of RAR and continues writing in the next sector. Data transfer is suspended as the CU assembles and writes the sector address field. The address information is taken from RAR; the cylinder indicator information is written as it was read from the first sector. Data transfer resumes with the first data word of the sector. Writing continues until the CPU has no more data to transfer or the CU detects an End of Cylinder or error condition. In either case, Device Flag is set on the command interface to signal completion.

If during the address checking phase of the command, the address does not compare with the contents of RAR, the defective cylinder indicator (DCI) is on, or the protected cylinder indicator (PCI) is on with the Override Switch off, Device Flag is set on the command interface and no writing or data transfer occurs. A Status Check command will receive status detailing the cause for termination.

3.2.3 Read Data (ØØ1Ø)

Read Data is the normal command used for reading. When the command is issued, the CU adds one to the contents of RAR, selects the drive specified and waits for the addressed sector to come into position. With the sector in position, the CU examines the flag and address information in the address field and then initiates data transfer to the data interface. The CU always reads 128 data words from the data field of the sector; if the CPU accepts less than 128, the CU continues to the end of the sector to complete the cyclic check before signaling completion on the command interface. If the CPU tries to accept more than 128 words, the CU adds one to the contents of the RAR and continues reading in the next sector. Data transfer is suspended while the CU examines the address field; data transfer resumes with the first data word of the sector. Reading continues until the CPU stops accepting data or the CU detects End of Cylinder or an error condition. In either case, Device Flag is set on the command interface to signal completion.

If during examination of the sector address field, the address does not compare with the contents of RAR or the DCI is on, the read operation continues normally to the end of the current sector. At this point, the CU halts data transfer and sets Device Flag on the command interface. Status Check to the drive being read will produce status detailing the cause for early termination. If the PCI is encountered, the Read Data command proceeds normally. Status Check at command termination will indicate the presence of PCI.

3.2.4 Seek Record (ØØ11)

Seek Record is the command used to initiate a head positioning operation in the drive. When the command is issued, the CU selects the drive specified and accepts two words of address information from the data interface. The first word contains the cylinder number to which the positioner is to move:

15	8 7	Ø
	CYLINDER NUMBER	

The second word contains the head-sector number:

15	10 9	8 7	4 3	Ø
	HEAD NUMBER		SECTOR NUMBER	

As the CU accepts each of these words, it assembles a new record address in the RAR (previous contents of the RAR are lost), transfers cylinder and head-sector numbers to the selected drive and initiates the head positioning operation in the drive. The command interface Device Flag is not set until the head positioning operation is complete and the addressed sector is 3.3 msec. away from the read-write head. However, the CU is free to perform other operations as soon as the second word of address information has been accepted.

If the selected drive has a head positioning operation already in progress when Seek Record is issued, the CU will execute the new command normally, except that the new head positioning operation will not be initiated. The positioning operation in progress will complete normally. The Seek Check error condition is set in the drive.

If the command addresses a cylinder number greater than 2ØØ2 or if the heads are already positioned at the addressed cylinder, Seek Record is executed normally, but no head positioning operation is initiated in the selected drive. (Average execution time--command initiation through set of command interface Device Flag--will be 35 msec.) In the case of cylinder address greater than 2ØØ2, the Seek Check error condition is set in the drive.

3.2.5 Refine Sector (ØØ1Ø1)

Refine Sector is a special recovery command the CU performs on a sector to improve the characteristics of the data. The command should be used only after re-try procedures have failed to recover the data (see Error Recovery Procedures, Section 6.6). When the command is issued, the CU adds one to the contents of the RAR, selects the drive specified and waits for the addressed sector to come into position. No communications occur on the data interface; Device Flag is set on the command interface when the end of the addressed sector is reached. The command operates on one sector at a time only; no check is made for address comparison, DCI or PCI.

3.2.6 Check Data (ØØ11Ø)

The Check Data command performs a cyclic check of file data to verify recoverability of the data. The CU executes the command much as it does Read Data; however, no transfer of file data occurs either to or from the CPU. When the command is issued, the CU accepts a single word of count information from the data interface. The word contains the positive count of sectors to be checked in the following format:

15	5 4	Ø
		SECTOR COUNT

The CU adds one to the contents of RAR, selects the drive specified and waits for the addressed sector to come into position. With the sector in position, the CU examines the flag and address information and cyclic checks the entire sector. The CU subtracts one from the sector count. If the count is non-zero, the checking operation is repeated in the next sector. This process continues until the sector count reaches zero or the CU detects an End of Cylinder or error condition. At this point, Device Flag is set on the command interface to signal completion.

If during examination of the sector address field, the address does not compare with the contents of RAR or the DCI is on, the CU halts the checking operation at the end of the current sector and sets Device Flag on the command interface. Status Check to the drive in operation will detail the cause for early termination. If the PCI is encountered, the Check Data command proceeds normally. Status Check at command termination will indicate the presence of PCI.

3.2.7 Initialize Data (1ØØ1)

Initialize Data is the command used to initialize unwritten tracks and to generate the defective cylinder or protected cylinder indicators (DCI, PCI). This command is accepted only when the Override Switch is on; if the Override Switch is off, the command interface Device Flag is set immediately and the CU makes no attempt to execute the command. Command execution is much like that for Write Data, except that the CU does not check the first sector for address and cylinder indicator information. When the command is issued, the CU adds one to the contents of RAR, selects the drive specified and waits for the addressed sector to come into position. With the sector in position, the CU assembles and writes the address field. The address information is that in the RAR. The cylinder indicator information is written according to the state of bits eight and nine of the command word. If bit eight is on, the DCI is set; if bit nine is on, the PCI is set. (The CU never sets both indicators; if both bits eight and nine are on in the command word, only the DCI is set.) Data transfer from the CPU begins with the first data word. The CU always writes 128 data words in a sector; if the CPU sends less than 128, the CU fills the remainder of the sector with zeroes before setting Device Flag on the command interface. If the CPU has more than 128 words to write, the CU adds one to the contents of RAR and continues writing in the next sector. Data transfer is suspended as the CU assembles and writes the sector address field again using the command word to determine the state of the

cylinder indicators. Data transfer resumes with the first data word of the sector. Writing continues until the CPU has no more data to transfer or the CU detects an End of Cylinder or error condition. In either case, Device Flag is set on the command interface to signal completion.

3.2.8 Address Record (1911)

The Address Record command is used to alter the contents of the record address register (RAR). Command execution is much like that for Seek Record, except that no operation is initiated on the drive specified (hence, the CU makes no use of the drive select information in the command word). When the command is issued, the CU accepts two words of address information from the data interface. The format of the address words is that described in Section 3.2.4. As the CU accepts each of these words, it assembles a new record address in the RAR (previous contents of the RAR are lost). When the second address word has been accepted, command execution terminates and Device Flag is set on the command interface.

4.0 DATA CHANNEL OPERATION

4.1 Transfer to the CU

The CPU transfers information to the CU by placing a word in the output register of the data interface and setting the interface Encode line. When it has accepted the data, the CU signals by setting the interface Device Flag. The CPU may place a new word on the interface any time after Device Flag has set.

4.2 Transfer from the CU

The CPU sets the interface Encode line to indicate readiness for transfer from the CU. When ready, the CU places a word in the input register of the data interface and sets the interface Device Flag. When it has accepted the data and is ready for another word, the CPU signals by again setting the Encode line. The CU may place a new word on the interface any time after Encode has set.

4.3 Timing Considerations During File Data Transfer

During data transfer to or from the CU, the CPU must transfer data at an average rate equal to the data rate of the disc drive. This transfer rate is maintained by the request-response nature

of the CPU, CU communication on the data interface. The CU transfers a word of data and sets Device Flag to request interface service. The CPU, in turn, services the interface and sets Encode to respond to the CU request.

In order to maintain data transfer with the drive, the CPU must respond to the CU request within a certain length of time--termed the Overrun Time. If the CPU fails to respond within the Overrun Time, the CU terminates data transfer with the CPU. No further communications occur on the data interface. The CU completes processing of the current sector (if a write is in process, zeroes are written in the remainder of the data field; if a read is in process, the remainder of the field is cyclic checked) before setting Device Flag on the command interface. If the CPU responds with Encode after the termination of data transfer, but before the set of the command interface Device Flag, the CU sets the Data Overrun error latch. This is to warn the program that the CPU may have failed to transfer as much data as intended.

For Series 1ØØØ drives, the following parameters apply:

DATA RATE: Greater than - 40.5×10^3 words/sec.
Less than - 49.5×10^3 words/sec.

OVERRUN TIME: Greater than - 19.2 µsec.
Less than - 25.6 µsec.

Note that the restrictions of this section apply only to transfer of file data and not to transfers involving address, count or status information.

5.0 STATUS WORD DEFINITIONS

5.1 Bit Ø: Any Error

The bit will be on whenever any of the following status word bits are on:

Bit 1: Data Error
Bit 2: Drive Busy
Bit 4: Address Error
Bit 5: End of Cylinder
Bit 6: Not Ready
Bit 8: Seek Check
Bit 9: Seek Incomplete
Bit 10: Access Hunting
Bit 11: Access Unsafe
Bit 12: Read/Write Unsafe
Bit 13: Overrun
Bit 14: First Seek

The bit is also turned on whenever Bit 3, Flagged Cylinder, is on as a result of a Write Data or Initialize Data command. Flagged cylinder does not generate Any Error when it occurs as a result of a Read Data or Check Data command.

5.2 Bit 1: Data Error

An error has been detected in the data transfer between the CU and disc drive during a read, write or check operation.

During the initial sector checking phase of Write Data, or during Read Data or Check Data: The condition is generated when the CU is unable to synchronize the data clocking channel with the file data stream or when the CU detects an error through cyclic checking.

During Write Data, Read Data, Refine Record, Check Record or Initialize Write: The condition is generated if the drive becomes not-ready during a data handling operation.

During the writing phase of Write Data or Initialize Data: The condition occurs when the CU detects an error in the generation of the cyclic code field.

The condition is reset with the execution of Status Check to the drive on which the condition occurred.

5.3 Bit 2: Drive Busy

The selected drive is busy executing a Seek Record command. (A drive remains busy from the time the last word of the Seek Record command is acknowledged until the head positioning operation is complete and the addressed sector is 3.3 msec. away from the read-write head.)

5.4 Bit 3: Flagged Cylinder

The cylinder being processed is write protected or defective; or the Initialize Data command has been issued with the Override Switch off.

During the initial sector checking phase of Write Data, or during Read Data or Check Data: The condition is generated when the CU detects the presence of PCI or DCI (if DCI is detected, Address Error is also set). The Flagged Cylinder condition is suppressed if the CU detects ~~a data error or~~ an actual address error ~~(or both)~~ in the same sector.

When the CPU issues Initialize Data: The condition is generated if the Override Switch is off.

The condition is reset with the execution of Status Check.

5.5 Bit 4: Address Error

The address read from the track does not compare with the contents of RAR, or (when set with ~~Address Error~~ Flagged Cyl.) the cylinder being processed is flagged defective.

During the initial sector checking phase of Write Data, or during Read Data or Check Data: The condition is generated when the cylinder, head and sector addresses read from the sector address field do not compare with the contents of RAR; or (when set with ~~Address Error~~ Flagged Cyl.) to indicate that the cylinder being processed is flagged defective.

The condition is reset with the execution of Status Check.

5.6 Bit 5: End of Cylinder

The CPU has attempted to extend a data command across a cylinder boundary.

During the data transfer portion of Write Data, Read Data or Initialize Data: The condition is generated when the CU has reached the end of data for sector 11, head one or three, and the CPU has signaled for continuation of data transfer into the next sector.

During the cyclic check phase of Check Data: The condition is generated when the CU has reached the end of data for sector 11, head one or three, has subtracted one from the sector count and found the count non-zero.

The condition is reset with the execution of Status Check.

5.7 Bit 6: Not Ready

The selected drive is not attached to the CU, is not sequenced up with disc spinning and heads loaded or is in an unsafe condition (in the latter case, Bits 11 and/or 12 will also be present).

Normally, manual intervention is required to bring a drive from the not-ready to ready state.

5.8 Bit 8: Seek Check

The selected drive has been issued a Seek Record command calling for a cylinder number greater than 2ß2 (Seek Incomplete is also set); or Seek Record has been issued while a servo positioning operation was still in progress on the selected drive.

The condition is reset by the next properly issued Seek Record to the drive in question.

5.9 Bit 9: Seek Incomplete

A servo positioning operation failed to complete normally on the selected drive.

The condition is reset by the next Seek Record issued to the drive.

5.10 Bit 10: Access Hunting

Checking circuits in the selected drive have detected misadjustment in the drive servo system.

The condition is reset by the next Seek Record issued to the drive.

5.11 Bit 11: Access Unsafe

Checking circuits in the selected drive have detected an unusual condition in the drive access system. Bit 6, Not Ready, will also be set.

The condition is reset by recycling power to the drive in question.

5.12 Bit 12: Read/Write Unsafe

Checking circuits in the selected drive have detected an unusual condition in the drive read/write electronics. Bit 6, Not Ready, will also be set.

The condition is reset by unlocking the disc cartridge on the drive in question.

5.13 Bit 13: Overrun

Checking circuits in the CU have detected a late data transfer response or a failure in the CU data clocking circuits.

During the data transfer portion of Write Data, Read Data, or Initialize Data: The condition is generated when the data transfer response from the CPU occurs after termination of data transfer, but before the CU has signaled completion of the operation. See Section 4.3.

During Write Data, Read Data, Check Data or Initialize Data: The condition is generated when the sector pulse occurs before the CU has detected the end of the sector data area.

The condition is reset with the execution of Status Check.

5.14 Bit 14: First Seek

The selected drive has gone from the not-ready to ready state. Bit 15, Attention, is also set.

The condition is reset with the execution of Status Check to the drive for which the condition occurred.

5.15 Bit 15: Attention

An operation previously in progress on the selected drive has terminated either through normal completion or due to occurrence of an error or other unusual condition.

During execution of all commands except Status Check: The condition is generated when command execution terminates regardless of the cause for termination.

During execution of the spin-motor turn-on, head-load and position sequence: The condition is generated as soon as the heads load and the initial positioning operation terminates. Bit 14, First Seek, is also set.

Presence of the Attention condition generates a command interface Device Flag signal if the interface Encode line is active. The attention condition is reset with the execution of Status Check to the drive for which the condition occurred.

6.0 PROGRAMMING RECOMMENDATIONS

6.1 Design Considerations

The CU has been designed primarily to function with an interrupt driven program. In most cases, the best level of system performance will be achieved when the program issues one or more disc storage commands and then goes on to other tasks, relying on the CU to generate a command channel interrupt whenever a command is completed. Following each interrupt, the program issues Status Check to the drive which completed and verifies that the Any Error condition is not set in the status word. A new command can then be issued to any of the drives in the system. Although the CU has no capability to queue or execute more than one read/write command at a time, provisions have been made to allow overlap of Seek Record commands on multiple drive systems. In applications where more than one drive is active, such overlap should be used to minimize the effects of accessing delays.

6.2 RAR Control

Although the "one ahead" nature of the RAR operation seems to imply a need for plus one or minus one addressing, such is not the case. The program need only insure that whenever a data handling command (Write, Read, Refine, Check, or Initialize) is issued the RAR contains the complete address of the first sector to be processed. If the RAR is set to cylinder six, head one, sector three when a Write Data is issued then the same data will be read back if the RAR is at six, one, three and a Read Data is issued.

Use can be made of the fact that the RAR address is updated by the CU when multiple sectors are processed. If the program needs to read sectors two and three into one memory location and sectors four and five into another, two Read Data commands are used. The RAR sector address must be at two when the first Read Data is issued (with data channel word count of 256). When the command completes, the program executes Status Check to test for errors, modifies the data channel starting memory address and issues a second Read Data command. Similar techniques may be used for writing successive sectors from several different memory locations.

6.3 Write Checking

When records are written on a disc drive, some form of program check should be executed to insure that the record was written exactly as it existed in memory and that the record can be recovered without error from the disc. Where data integrity is crucial, each record written should be read back from the disc into memory and compared word for word with the original record

transferred during writing. This provides a check, not only on the serial data transfer between CU and disc drive, but also on the parallel transfer between CPU and CU. The latter is important since the system provides no hardware check of parallel data transfer.

Where data integrity is less critical, it will be sufficient to execute the Check Data command against each record that is written on the drive. This provides a check on the serial data transfer between CU and disc.

Write checking should be eliminated from the program only in those situations where data integrity is not important.

6.4 Cartridge Initialization

Presumably, all disc cartridges will have have been analyzed for defects by the disc manufacturer according to accepted industry standards. Prior to use on a system, new (unwritten) cartridges should be processed by a disc initialization program. The program should initialize all sectors (to generate the sector address fields), should provide for flagging any cylinders found defective by the disc manufacturer, and should execute additional data testing to help isolate defects which may have developed after manufacture.

The additional pack testing should include the following routine executed six times on each cylinder:

1. Write a fixed data pattern in all data words of the cylinder.

2. Execute Check Data 10 times on all data words of the cylinder.

On each of the six passes, a different data pattern should be used. Below, in hexidecimal, are the six data words recommended:

1. ØØØØ
2. 1111
3. AAAA
4. 5555
5. E5E5
6. FØFØ

If data error occurs more than once in executing the routine on a cylinder, the cylinder should be flagged defective.

6.5 Cylinder Flagging, Defective Cylinder Processing

As discussed earlier, the CU provides the program with the ability to flag cylinders of disc storage as either write protected or defective. In either case, the entire cylinder (all 24 sectors) must be so flagged to avoid erroneous responses from the CU during subsequent operations on the cylinder. The Initialize Data command should be used for the flagging operation.

There are several workable schemes for handling defective cylinders. Regardless of the method employed, the following recommendations should be considered:

1. The system should allow up to three defective cylinders per disc (leaving 200 cylinders for active data storage).

2. If the system relys on reading an alternate cylinder address from the defective cylinder, the address should be written in several different (preferably in all) sectors of the defective cylinder.

6.6 Error Recovery Procedures

Certain errors which occur in the storage system are often correctable through retry procedures. Using programs should include provisions for retry to reduce the frequency of errors which impact the application.

Listed below are the correctable error conditions and recommended retry procedures for each.

6.6.1 Data Error During Read Data

Read the same record 16 times. If the error persists after 16 retries, issue Seek Record to cylinder zero, Seek Record to cylinder 202, Seek Record to the failing record and re-read up to 16 times. If error persists, issue refine record command and re-read 16 times. If error persists, terminate retry. (See Section 6.6.3 for Data Error handling during write check.)

6.6.2 Data Error During Write or Initialize Data

Retry the Write or Initialize Data once. If error persists, terminate retry.

6.6.3 Errors During Write Check

If Data Error occurs during the Read Data or Read Check command used in a write check routine (See Section 6.3) the complete write; write check routine should be retried up to 16 times. If the error persists, the cylinder may be defective. The cylinder should either be flagged immediately or logged for future checking and possible flagging.

If an error is detected during the in-memory word for word comparison; the write, write check routine should be retried once.

6.6.4 Address Error, Seek Incomplete or Access Hunting

Seek Record to cylinder zero, Seek Record to cylinder 2ƒ2, Seek Record to failing cylinder. If error persists, terminate retry.

6.6.5 Overrun

Retry the operation once; if error persists, terminate retry.