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Systems

IBM 4331 Processor Channel Characteristics

IBM

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PREFACE

This manual describes how the effects of imposing loads on the channels of the IBM 4331 processor can be checked. The book is intended for physical planning engineers and systems analysts who wish to check that a proposed configuration of input/output (I/O) devices will work satisfactorily in the IBM 4331 processor.

The first section of the book describes the types of channels to which I/O devices can be connected, the theoretical data rates of the channels, and the possible effects of imposing heavy I/O loads on those channels. The effects considered are: data overrun, loss of device performance, channel interference with the IBM 4331 processor, program overrun, and excessive channel utilization.

The second section gives the procedures for testing data overrun on individual channels, on the integrated channel bus, and on the IBM 4331 processor. The section also includes a description of how to assign priorities to devices on the byte multiplexer channel.

The third section deals with interference with the IBM 4331 processor that is caused by activities on the channels, and describes how the interference can be assessed. Estimates for the effects of this interference on system throughput are given and it is shown how to check for the possibility of program overrun.

The fourth section describes channel interference between I/O devices and how it can be calculated. The concept of channel utilization is given. Examples in this section show how the block multiplexing concept and the rotational position sensing feature reduce channel utilization. In addition, the impact of channel utilization on I/O device access time is described together with its estimated effect on system throughput.

The fifth section gives recommended channel programming conventions. Test procedures in this manual assume that channel programs have been prepared in accordance with these conventions.

Before using this manual, the reader should have a thorough understanding of input/output operations for the IBM 4331 processor as described in:

> IBM 4331 processor Functional Characteristics
> GA33-1526
> and
> IBM 4300 Processor Principles of Operation, for ECPS:
> VSE Mode, GA22-7070.

When testing for data overrun on the byte multiplexer channel, a special worksheet is required:
IBM 4331 Processor Channel Load Sum Worksheet; GA33-1532 (available in pads of 50).

CONTENTS

GENERAL DESCRIPTION OF THE IBM 4331 PROCESSOR CHANNELS

ATTACHMENT CAPABILITIES

Input/Output (I/O) devices can be connected to the IBM 4331 processor on the following standard channels:

- BYTE MULTIPLEXER CHANNEL (27 UNSHARED SUBCHANNELS +4 SHARED)
- BLOCK MULTIPLEXER CHANNEL (32 UNSHARED SUBCHANNELS +8 SHARED)

The block multiplexer channel appears as selector channel to those devices that do not block multiplex.

In addition, certain I/O devices can be connected directly, by using the following adapters instead of the usual channel and control unit combination:

1.) DASD Adapter - for connecting the following series of disk devices:

    - 3310 (up to 4 strings, max. 4 devices/string)
    - 3370 (up to 4 strings, max. 8 devices/string)
    - 3340 (up to 2 strings, max. 8 devices/string)

2.) MAGNETIC-TAPE Adapter - for connecting up to 6 IBM 8809 tape drives.

3.) Communications Adapter (CA) - for connecting up to eight Communication lines with the following rates:
BSC/SDLC: 60 - 64000 BITS/SEC
S/S : 75 - 1200 BITS/SEC
One 64000 BIT/SEC line is exclusive to all other lines

4.) Bus-to-Bus Adapter 1 (BBA-1) - for connecting one 5424 Multifunction card Unit

5.) Bus-to-Bus Adapter 2 (BBA-2) - for connecting local terminals and printers.

- IBM 3278-2A	operator console	
- IBM 3278-2	keyboard/display	
- IBM 3287	terminal printer	80/120 cps
- IBM 3289-4	line printer	155/400 LPM
- IBM 3262-1	line printer	600 LPM
- user diskette		

A maximum of 15 devices plus operator console can be attached, two of which can be line printers.

Although these devices are attached directly to adapters and not to the standard I/O channel interface, the devices appear to the programmer as if they were connected to channels as shown in Figure 1.1

INTEGRATED ADAPTER	CHANNEL	I/O ADDRESSS
Bus-to-Bus Adapter 1, 2	0	09...1F Op Console, displays, terminal printers
Communication Adapter	0	30...37 telecommunication lines
Standard Channel Adapter (Byte MPX)	0	24...3D,3F unshared 80...BF shared byte multiplexer subcha.
Standard Channel Adapter (Block MPX)	1	20...27 unshared 80...FF shared
DASD Adapter	2	40...73 IBM 3310 Disks 00...07 3340 Disks
Magnetic Tape Adapter	3	00...07 IBM 8809 Tapes

Fig. 1.1 Use of channel by integrated adapters

Theoretical Data Rates of Channels

The theoretical maximum data rates, which can be measured under ideal conditions, of the IBM 4331 processor channels are:

Byte multiplexer channel: 500 kilobytes/second (burst mode)
18 kilobytes/second (byte mode)

Block multiplexer channel: 500 kilobytes/second

EFFECT OF CHANNEL LOADING

If the channels of the IBM 4331 processor are too heavily loaded, that is, if the processor attempts to communicate simultaneously with too many devices that have high data rates, the following effects can occur:

- Unbuffered I/O devices may lose data; this is called data overrun. Data overrun occurs when a channel does not accept or transfer data within the required time limits. This data loss may occur if the total channel activity that is started by the program exceeds the channel capabilities. The possibility of data overrun can be checked as described in the section 'Tests for Channel Data Overruns'.

- Processor performance may be reduced. This occurs if channel activities interfere with processor operations and effectively cause the processing of processor instructions to be slowed down. The duration of interference caused by channel activities is given in section 'I/O Interference with processor'. The effect of this I/O interference on system throughput is outlined in section 'effect of I/O interference on system throughput'.

- Certain real-time devices may not receive service from the program fast enough to prevent incorrect device operation; this effect is called program overrun and is described in section 'effect of I/O interference program overrun'.

- Queues may develop for tasks that require channel service, thus leading to loss of throughput; see the section 'Channel Interference between I/O Devices'.

Because of these effects, it is desirable that the loading of a particular configuration of I/O devices be checked, using the procedures in this manual, during the physical planning phase of a system installation. These procedures will determine, in most cases, whether system operation will be satisfactory. More detailed investigation may be necessary for configurations that appear to exceed the IBM 4331 processor input/output capabilities.

The tests assume the worst-case situation that is likely to occur in practice; that is, one in which the most demanding devices in the configuration all make their heaviest demands on the channels simultaneously. Such a situation may not occur frequently, but it is the situation that the procedures in this manual place under test.

The tests also assume that the channel programs are written in accordance with the rules given later in the section, 'Channel Programming Conventions'.

TESTS FOR CHANNEL DATA OVERRUNS

GENERAL

This section describes how the channels can be tested for data overrun. The test procedure involves three basic steps.

The first step is a check on the data rates of the individual I/O devices to find out whether any exceeds the maximum allowable data rate of the channel to which it is connected.

The second step consists in finding the worst case read-to-write ratios which in turn leads to the maximum allowable data rate on the integrated channel bus which multiplexes the data traffic from all channels.

The final and most critical test for data overrun uses the channel loading factors from the Appendix. The addition of the applicable loading factors in priority sequence can be done on a "channel load sum work sheet" and the result will show overrun hazard if the sum amounts to 100 or above.

The validity of the final step depends on a number of assumptions which are explainded in the Appendix. These assumptions include the expectation that certain loops (e.g. search-TIC-search, sense-TIC-sense, etc) are avoided as well as other hazardous techniques (e.g. long chains of immediate or no-op commands). It is especially assumed that the channel programming conventions listed in section 'implicit assumptions' are adhered to.

If actual system behavior is worse than implied by the assumptions, freedom from overrun cannot be predicted with certainty. If, on the other hand, actual system behavior is better than implied by the assumptions, the system may still be overrun-free even when calculations indicate otherwise. In this case, special investigation may be necessary.

TEST OF INDIVIDUAL CHANNELS

Figure 2.1 shows the maximum possible data rates for each individual channel attached to the processor. The individual data rates are limited by the design of each channel, that is, by its internal micro code and hardware structure. Obviously none of the maximum data rates must ever be exceeded otherwise immediate data overrun is incurred.

The channels composed of Communications Adapter, Bus-to-Bus Adapter, DASD Adapter and Magnetic Tape Adapter are customized to accomodate all I/O device combinations within the constraints of the IBM 4331 processor configurator without causing data overrun. The byte multiplexer channel and the block multiplexer channel are capable of transferring data at a maximum rate of 500 kilobytes per sec in burst mode. Input/output devices which transfer data at a higher rate cannot be connected to these channels.

The byte multiplexer channel, when operating in single byte mode is capable of transferring data at a rate of 18 Kilobytes per second. The maximum data rates for channels and direct attachments are shown below:

	Block MPX	DASD Adapt	Byte MPX Burst/Byte Mode	CA up to 8 lines	Magnet Tape Adapter	BBA 1,2 MFCU, Displ,..
CS Priority	1	2	3	-	4	5
KB/sec	500	1859	500/18	8	160	416

<u>Note</u>: The CA does not use the cycle steal facility. Only a single line can operate at 64 kilo bits per sec = 8 Kilobytes per sec.

Figure 2.1: Channel Data Rates

TEST OF THE INTEGRATED CHANNEL BUS

When the individual channels have been verified to cause no data overrun among their own devices, the common interface between these channels and the storage must be tested for overrun. This interface is referred to in the following sections as "IC-bus'.

The data transfer priorities on the IC-bus are as follows:

1. Block Multiplexer Channel (BMPX)
2. DASD Adapter
3. Byte Multiplexer Channel (MPX)
4. Magnetic Tape Adapter
5. Bus-To-Bus Adapter 1,2 (BBA 1,2) (Local Displays, Printers, Diskettes)

If the processor is in trap level ≥ 4, the BBA 1, 2 data transfer on the IC bus is stopped. Processor internal priorities are referred to in the following sections as 'trap level'. For details of these trap level priorities see section 'internal priorities'.

The maximum unidirectional data transfer rates are 3.67 Megabytes/sec for sequential I/O write operations, and 3.33 MB/sec for sequential I/O read operations. The figures include a degradation which is caused by the storage refresh interference.

However, such maximum data rates can rarely be achieved because the more realistic case is one where read and write operations alternate frequently. The IC timings for various read/write sequences are shown in figure 2.2. Based on these times, the maximum aggregate IC-data rates are computed as a function of the worst case read-to-write ratio that can be expected. The curves shown in figure 2.3 apply to the critical case where the processor operates in a trap level higher than level 4, in which case the processor gets control for an average of 0.9 usec each time the IC-bus traffic changes from read to write.

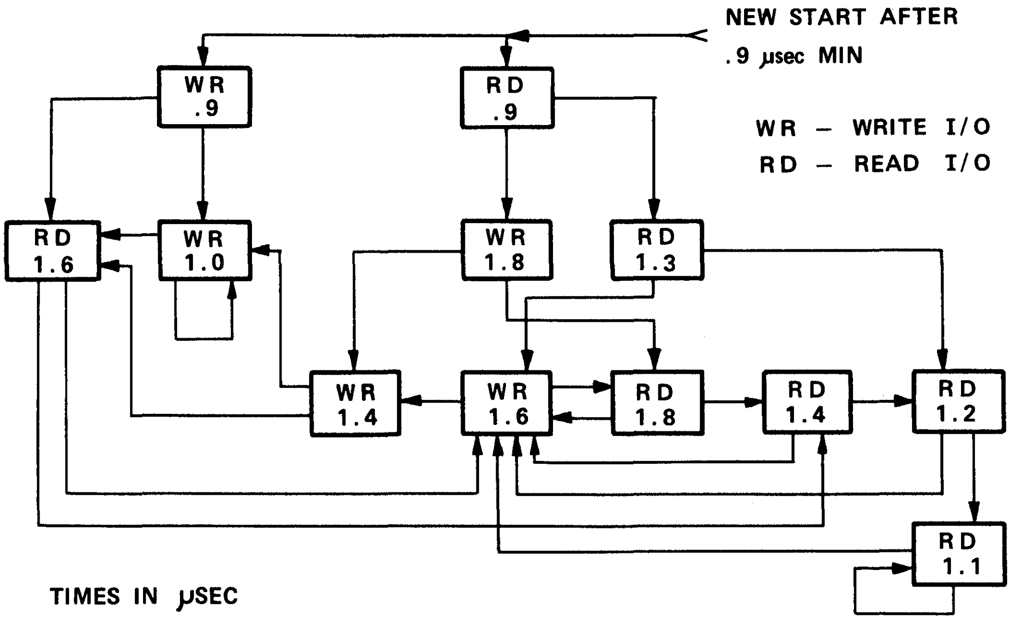


Figure 2.2:: IC Bus Timings, PU Trap level≤ 4

For Traplevel >4 the sequence starts new after every change in diretion of data transfer.

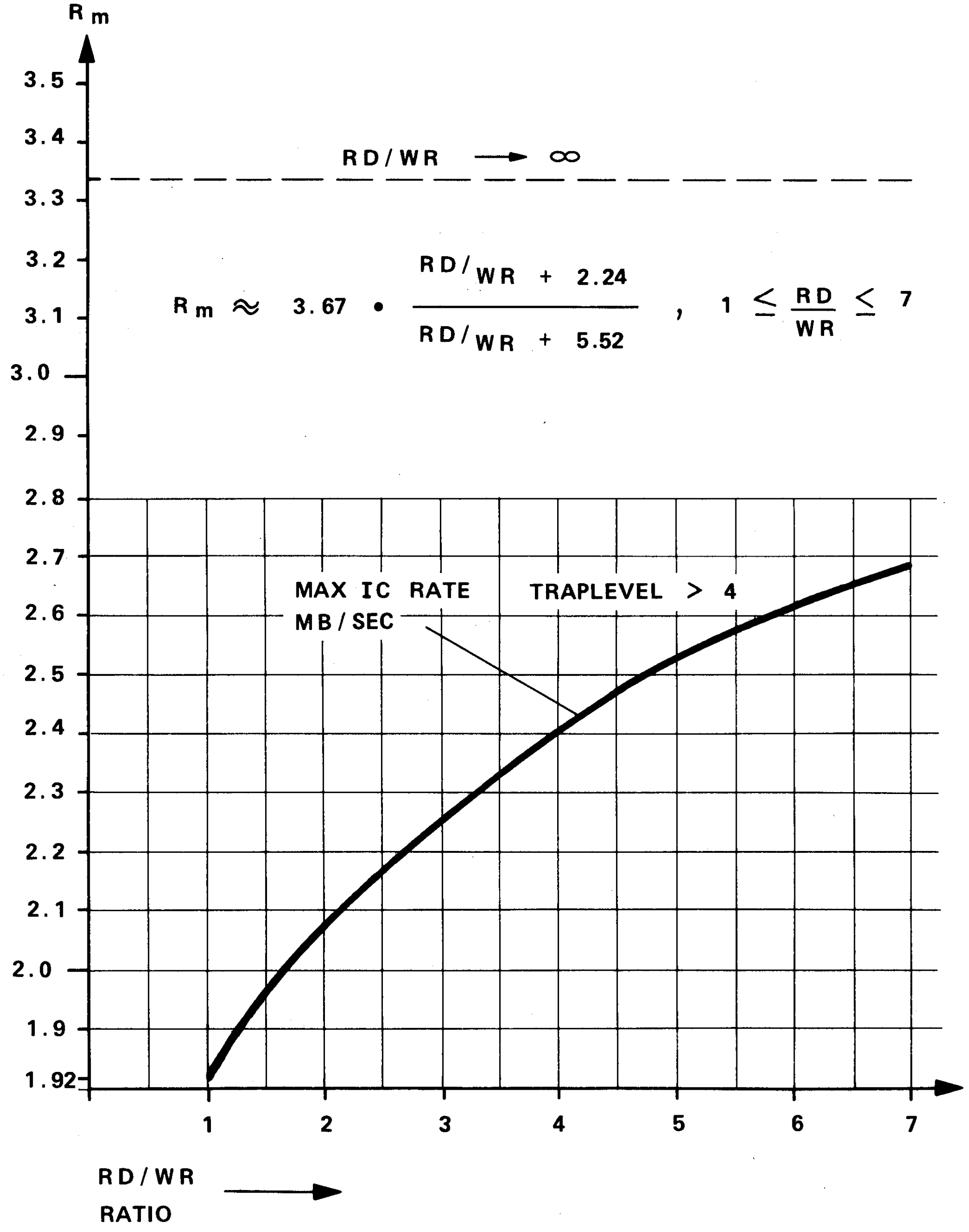


Figure 2.3: Maximum IC Bus Rates

The general method for assessing IC-bus overrun is to use figure 2.3 in the following way:

1. List the maximum data rates Ri, i=1...4 that can occur on BMPX, DASD Adapter, Magnetic Tape Adapter, and on MPX due to burst mode devices.

2. Divide the rates Ri into two classes and form the sum of the rates within each class with the intent to make the ratio between the sums in both classes as close to 1 as possible, but without becoming smaller than 1.

3. The ratio obtained in the preceding step represents the worst case read-to-write ratio that can be expected with the given configuration. Use this ratio to enter figure 2.3 on the abscissa (X-axis), then get the maximum allowable IC-bus data rate from the ordinate (y-axis).

4. If the IC-bus data rate found is smaller than the sum of all rates Ri, then the planned configuration has a potential overrun hazard due to IC-bus interference.

A simpler, more straight-forward method can be used when one adapter has a data rate which is larger than the data rates summed up from all remaining adapters. This situation is quite often encountered, especially with high speed disk storage devices such as IBM 3310 and IBM 3370. Figure 2.4 shows the maximum allowable data rates that remain available on each adapter when high speed disk storage devices are connected.

Type of Disk on DASD adapt	If: data rate on DASD adapter	Then: Max allowable data rates on all other adapters is:
3370	1859 (KB/sec)	500 (KB/sec)
3310	1031 "	850 "
3340	885 "	960 "

Figure 2.4: Maximum allowable data rates for unbuffered burst mode devices on all channels, and buffered devices on block multiplexer channel and byte multiplexer channel, if the Magnetic Tape Adapter has tapes attached.

For other 'predetermined' rates Rp the maximum allowable'remaining' rate Rr can be found by solving the following non-linear equation:

$$Rp+Rr=Rm(Rr)$$

where Rm is the maximum allowable data rate given in figure 2.3 as a function of the read-to-write ratio (RD/WR).

The solution to the equation can be found by varying Rr until Rm (RD/WR)=Rm (Rp/Rr) is equal to Rp+Rr.

By approximating Rm with a simple first order fractional polynomial it was possible to solve above equation in closed form. The result is shown in Figure 2.5, giving Rr as a function of Rp.

The maximum allowable data rates in Figure 2.4 apply to the case where the procesor operates at a trap level higher than 4, which means heavy cycle steal data transfer and chaining activity. The rates clearly show that an 3370 DASD operating together with a 3420-4 magnetic tape unit (data rate 470 KB/sec) will not allow any additional burst mode data transfer from either a direct attached IBM 8809 tape or tape units attached to the byte multiplexer channel.

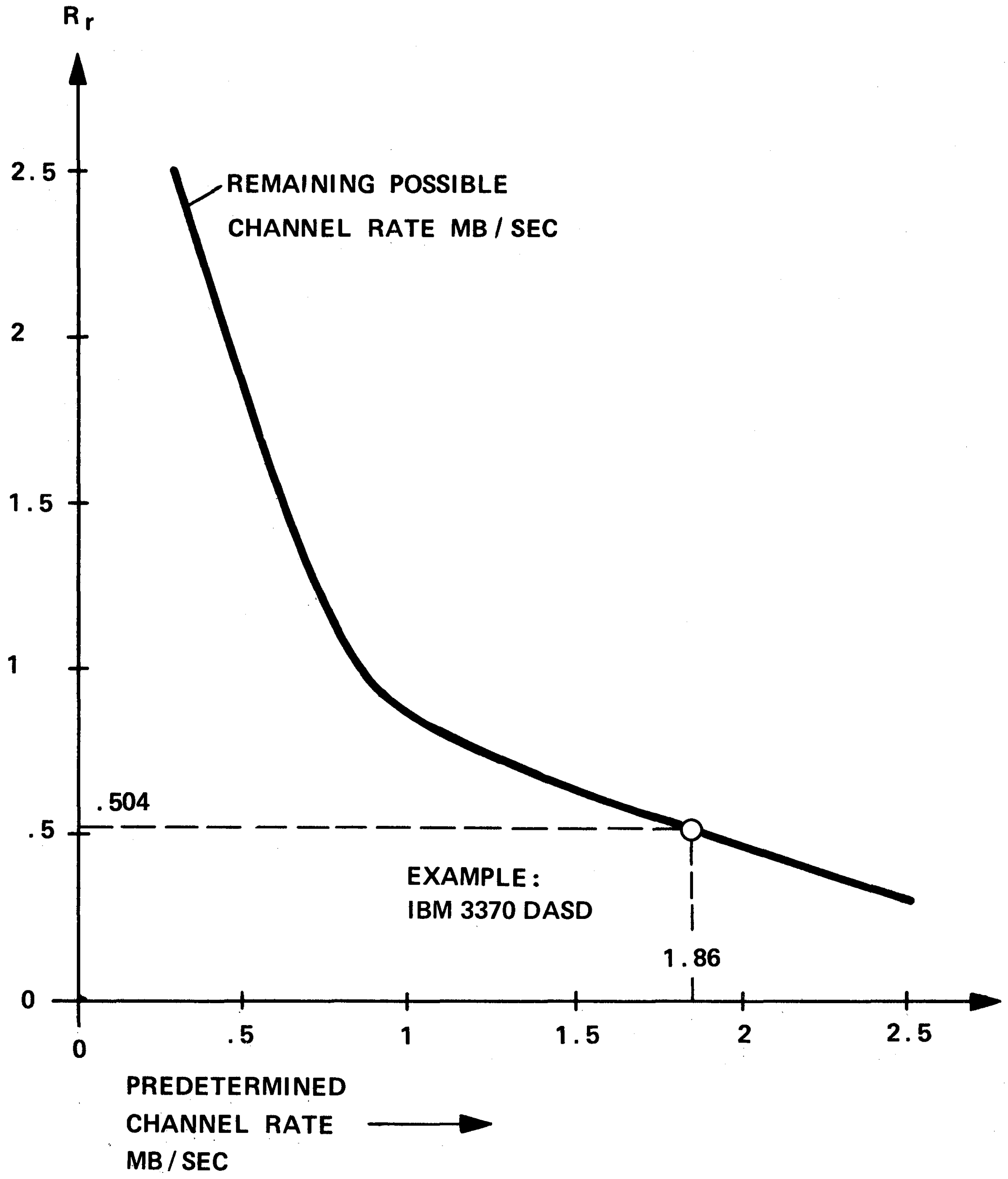


Figure 2.5: Remaining Possible Channel Rates Versus Given, Predetermined Rates

TEST FOR PROCESSOR OVERRUN

When the individual channels and the integrated channel have been checked, the processor must be tested for overrun because it is the central resource for all channel processing activities.

In the processor service is required for address and count updating after every fullword (4-byte) burst transfer. The processor is also needed for byte mode data transfer (byte multiplexer and communication adapter). Besides these service functions in the actual data transfer, the processor is employed in the initiation (Start I/O), termination (interrupt handling) and continuation (command or data chaining) processes on all channels.

To find the most critical device, that is, the device that will experience overrun if not serviced within a given time, it is necessary to look at the internal priority structure of the processor first, and to assign the correct selection priorities to the MPX-attached devices next. In addition, the general methods to calculate overrun based on previous load, priority load, and device load must be understood. The overrun calculation may then be carried out on a load sum worksheet.

INTERNAL PRIORITIES

The following internal priorities are implemented in the processor, as listed in descending order:

		Trap Level
0.	Cycle steal burst mode data transfer	none
1.	Control store load, Microinstruction buffer load	none
2.	DASD/Tape Adapter fast response operations (data chaining)	8
3.	Communications adapter transfer	7(*)
4.	Block multiplexer (not 231x operations)	6
5.	Byte multiplexer	5
6.	Disk/tape adapters (normal response)	4
7.	Bus-to-bus adapters (local displays, etc)	3
8.	Page boundary crossing	2
9.	PU trap handling	1
10.	Instruction processing	0

*) Note: During the time the 231X channel program is in operation, the priority levels of the communication adapter and the block multiplexer channel are interchanged.

Cycle steal operations are hardware controlled, hence, do not employ the PU trapping mechanism but they intercept the micro code (with highest priority).

The cycle steal priorities between the individual channels are given in figure 2.1. Cycle steal operations are here assumed to cause no overruns but they do present a priority load to all channel operations which have a lower priority.

Control store buffer loads or micro code buffer loads which are microcode controlled always take less than 5 usec, and therefore do represent previous loads. (Appendix B)

DASD/Tape Adapter fast response operations have the highest trap-priority but require only 8 micro seconds processor time, hence are not likely to cause overrun. The operations associated with 231x disk devices are normally conducted on trap level 6 except for command chaining or data chaining. For 231x chaining activities the trap levels are swapped between communication adapter and 231x so that the 231x temporarily gets level 7 and the communication adapter gets level 6 assigned. In addition, all burst mode data transfer from other channels is stopped in favor of 231x chaining on the block multiplexer. Obviously, this preference treatment avoids overruns on the 231x but may cause them on devices attached to the Magnetic Tape Adapter or the byte multiplexer channel. The effects of this procedure are separately explained in section '231X on MPX overrun considerations'.

Channel services which run on trap levels lower than 5 do not cause overrun and are, therefore, excluded from further discussion. However, delays in Disk/Tape Adapter-services on trap level 4 can cause additional disk retries after the channel reconnection point if the "disk ready" signal is missed. This non-linear effect on device performance will be discussed in chapter 'channel interference between I/O devices'.

Delays in channel services rendered at trap level 3 (local displays, terminal printers, MFCU) will cause a linear performance degradation, that is, only a gradual slow-down during heavy channel activity is experienced.

Each trap level is allowed to disable higher trap priorities for a duration up to 5 usec. This time represents a certain previous load which is included in the previous loads of the Appendixes.

PRIORITIES ON BYTE MULTIPLEXER CHANNEL

The priority of devices on a byte-multiplexer channel is determined at the time of installation by the sequence in which they are connected to the channel. The cabling facilities provide considerable flexibility in the physical location and logical position of I/O devices.

Devices may have the priority sequence in which they are physically attached to the cable (select-out line priority), or the device most remote from the channel may be connected to have highest priority and the device nearest the channel connected to have lowest priority (select-in priority).

Each device on the byte-multiplexer channel cable may be connected (for selection) either to the select-out line, or to the select-in line. Thus, one or the other of the lines is specified in establishing priority for a desired physical layout of devices.

Priority assignments and machine-room layout should be established during the physical planning phase of an installation so that cables for the I/O devices may be properly specified.

A major consideration in assigning priority to multiplex mode devices is their susceptibility to overrun. Devices are identified in this manual as being in one of three classes:

Class 1: Devices subject to overrun, such as the IBM 2501 Card Reader.

Class 2: Devices that require channel service to be in synchronization with their mechanical operations. For example, the IBM 2540 Card Read Punch has a fixed mechanical cycle. Delay in channel service for such devices usually occasions additional delay due to synchronization lag.

Class 3: Devices that do not require synchronized channel service, such as an IBM 2260 Display Station with a 2248 Display Control. An IBM 1443 Printer is another device that does not require synchronized channel service: it can begin printing as soon as its buffer is full and line spacing is completed. Any loss of performance by devices in this class is limited to that caused by channel delay in providing service.

Devices in the first class need the highest priority. The devices in the last two classes may operate with reduced performance on an overloaded channel but are not subject to overrun: their control units have data buffers or an ability to wait for channel service. Devices in the second class, however, should have higher priority than those in the third class.

Within each class, devices are assigned decreasing priority in the order of their increasing wait-time factors: smaller wait-time factors should have higher priority. Wait time factors are listed in the Appendix and explained in section 'method of overrun calculations'.

The control unit determines whether a device operates on the byte-multiplexer channel in burst mode or in byte mode. If unbuffered byte mode devices are connected to the byte-multiplexer channel, all burst mode devices should be connected to the block-multiplexer channel. If no overrunable, unbuffered byte-mode devices are connected to the byte-multiplexer channel, burst mode devices may also be connected to the byte-multiplexer channel.

When burst mode devices are attached to the byte-multiplexer channel, they should have lower priority than buffered byte-mode devices. Low-priority devices take longer to respond to selection than do higher-priority devices: a burst-mode device need be selected only once for an operation, but a byte-mode device must be selected for the transfer of each byte, or a short burst, of data.

Some devices, such as the IBM 2821 Control Unit, may operate on a byte-multiplexer channel in either burst mode or in byte mode, as determined by the setting of a manual switch on the control unit's customer engineer panel. Because of the high interference such devices cause in byte mode on lower priority channels, these devices should always be operated in burst mode instead of byte mode.

A byte-multiplexer channel can transfer data most rapidly in burst mode. Where an application uses only class 2 or 3 devices, that have the mode choice, improved byte-multiplexer-channel efficiency may be obtained by operating the devices in burst mode. Similarly, if a device can operate in single byte mode or in multibyte mode, the multibyte mode should be used for increased data transfer efficieny. Since the IBM 4331 processor can transfer 4 bytes with one memory access, the four byte mode should be choosen whenever available with the device.

Appendix B specifies whether a device operates in burst mode or in byte mode.

The Appendix B gives the wait times for devices that can be connected to the byte multiplexer channel and are liable to data overrun. The following device examples are class-2 or class-3 devices and no information is given in the Appendix because these devices do not overrun:

IBM 1017	Paper Tape Reader
IBM 1018	Paper Tape Punch
IBM 1403	Printer
IBM 1443	Printer
IBM 2150	Console
IBM 2250	Display Unit
IBM 2260	Display Station
IBM 2265	Display Station
IBM 2495	Tape Cartridge Reader
IBM 2540	Card Read Punch
IBM 2671	Paper Tape Reader
IBM 2715	Transmission Control Unit
IBM 3203	Printer
IBM 3211	Printer
IBM 3277	Display Station
IBM 3278-2	Keyboard Displays
IBM 3284	Printer
IBM 3286	Printer
IBM 3287	Terminal Printer
IBM 3288	Printer
IBM 3289	Line Printer
IBM 3505	Card Reader
IBM 3525	Card Punch
IBM 3800	Printer
IBM 3881	Mark Reader
IBM 3886	Char. Reader
IBM 3890	Doc. Processor

Special Cases

Integrated 5424 MFCU attachment and diskette I/O drive are both considered class 3 devices which have the lowest priority on the byte multiplexer channel.

Devices Having Class-1 and Class-2 Components:

Class-1 devices that have an inseparable class-2 component should be assigned a priority according to the class-1 wait time. For example, the IBM 1442 Card Read Punch Model 1 incorporates a class-1 reading component and a class-2 punching component. The priority that is assigned to the 1442 Card Read Punch should be in the sequence of the wait time for the reading (class-1) component.

Burst Mode Devices:

The maximum data rate of the byte multiplexer channel for burst mode operations is reduced to 67 kilobytes/second if data chaining between every 4 bytes is used. Indirect data addressing (370 mode) will further reduce this rate to 52 KB.

Burst mode operation on the byte multiplexer channel is not recommended for concurrent operation with unbuffered byte mode devices, because a burst mode device monopolizes the channel for the duration of an entire operation, a period of time which is long relative to the wait times of typical byte mode devices. Therefore, any class-1 device that has not finished transferring all the bytes of a byte mode operation when the burst mode operation begins, is very likely to overrun. Similarly, class-2 or class-3 devices are likely to lose performance.

Example Priority Sequence:

Figure 2.6 shows an example priority sequence of devices and the arrangement of 'select out' and 'select in' lines to achieve these priorities.

Device Classes and Priority Positions

Device	Class	Wait time (ms)	Priority position
1419 Magnetic Character Reader, with expanded capability feature			
High-priority interface position	1	0.65	1
Low-priority interface position	–	..	2
2520 Card Read Punch Model B1, reading EBCDIC	1	1.02	3
2701 Data Adapter Unit	1	7.70*	4
1442 Card Read Punch Model N1, punching EBCDIC	2	11.00	5
1443 Printer	3	–	6

* Effective wait time for a 2701 serving three lines with wait times of (for example) 63.20 ms, 14.20 ms, and 7.70 ms;

'Select Out' and 'Select In' Lines Connected for Correct Priority Sequence

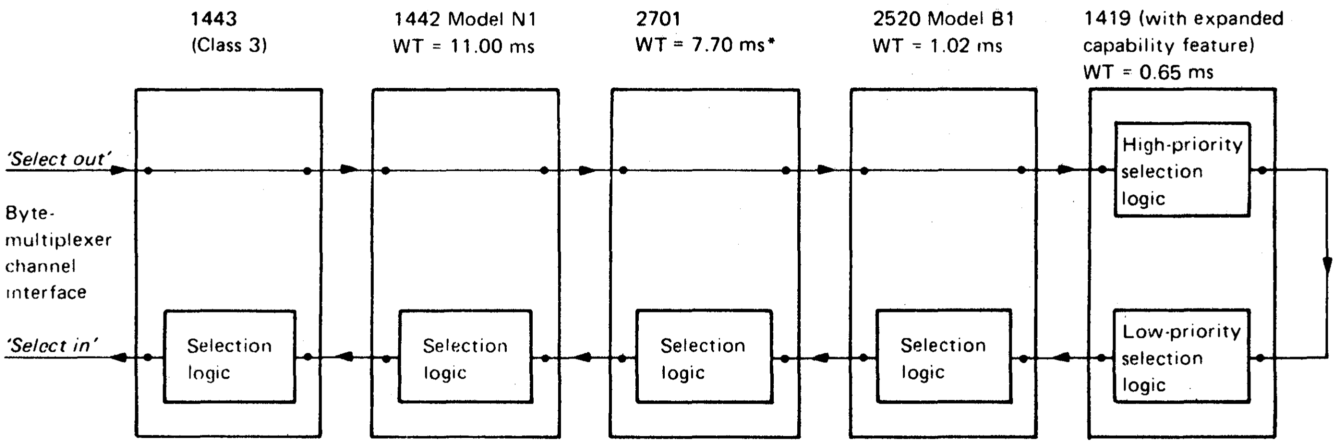


Figure 2.6: Example Priority Sequence of Devices on the Byte Multiplexer Channel, and 'Select In' and 'Select Out' Line Connections

Wait Time and Interference

Each I/O device has a wait time (WT). The wait time is the maximum period that the device can wait for completion of channel service before data overrun occurs (that is, the device loses data) or before its performance is impaired. In this manual, a device that is waiting for the completion of channel service is called a waiting device and any activity that causes a device to wait for channel service is called interference.

The following three types of interference can cause a device to wait for completion of channel service:

Previous load
Priority load
Device load

If the combined effect of these three types of interference causes the completion of channel service for a waiting device to be delayed beyond its wait time, the device may lose data (data overrun) or may suffer loss of performance as shown in Figure 2.7. The procedure for testing data overrun (given later in this section) assumes the worst case, namely that all these factors cause interference with the waiting device.

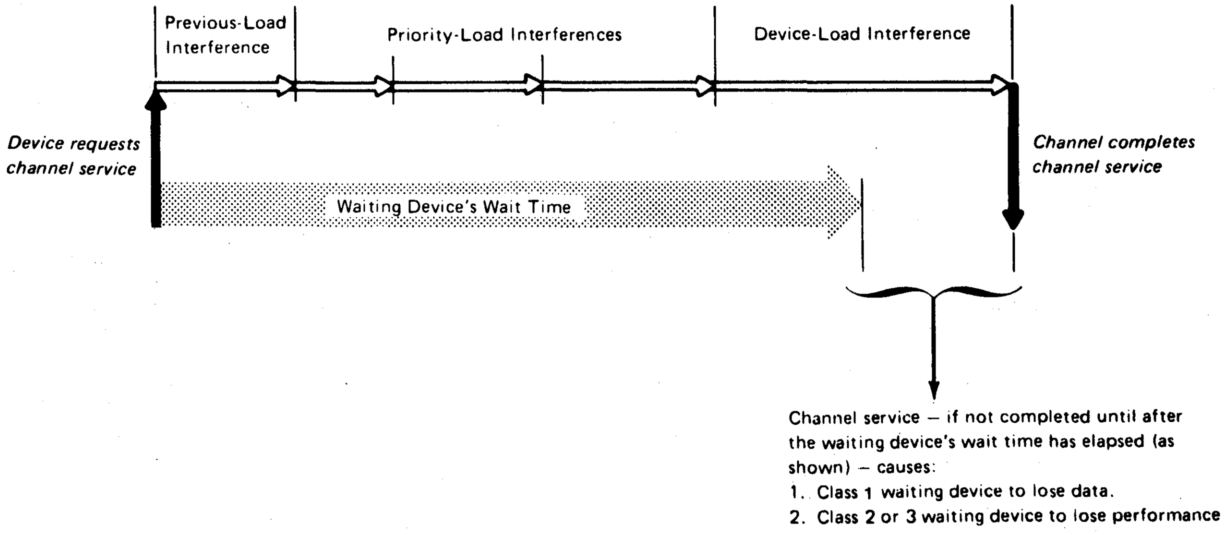


Figure 2.7 Three Kinds of Interference Can Cause Channel Service to be Delayed Beyond a Waiting Device's Wait Time

Previous Load

A device on a channel may be forced to wait for channel service if another device with lower priority is in operation at the moment when the waiting device requests channel service. The lower-priority device must be allowed to finish its operation before channel service can be given to the waiting device. Interference of this type is called a previous load and is assumed to last for at most 0.10 millisecond (ms) (command chaining). The Appendixes to this manual contain tables of channel evaluation factors in which the previous load factor for each waiting device is expressed as a percentage of the wait time for that device.

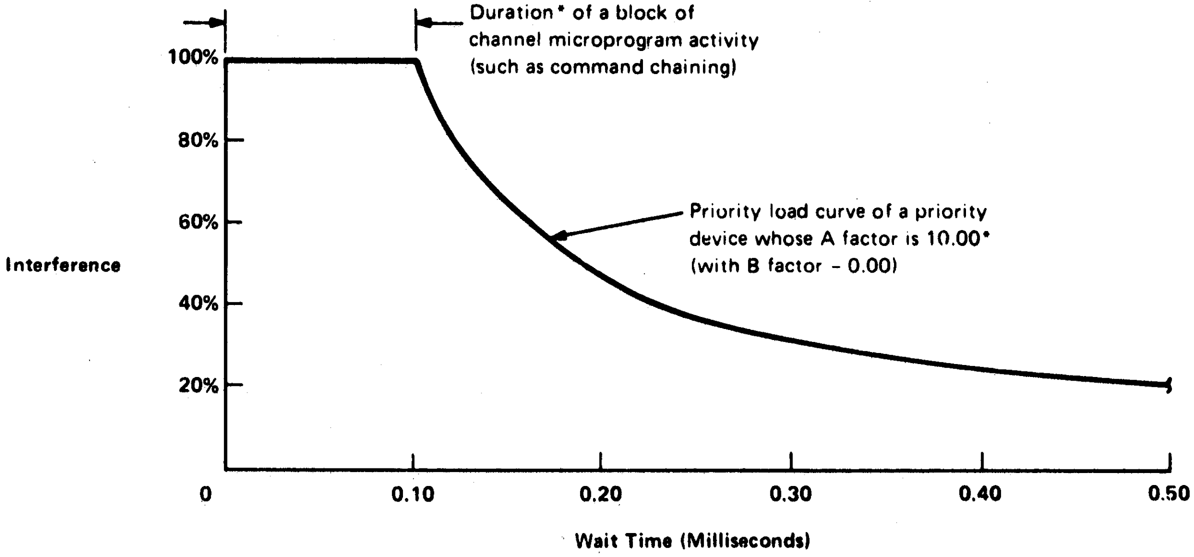
Priority Load

The IBM 4331 processor services all attached devices in order of their priority. A waiting device on the byte multiplexer channel may for instance be forced to wait for channel service while channel service is being given to devices on the block multiplexer channel, and higher-priority devices on the byte multiplexer channel. In this manual, a higher-priority device that can cause a waiting device to wait for channel service is called priority device. The interference from a priority device is called a priority load.

Because of the way in which data overrun is tested, the priority load of each priority device is expressed as a percentage of the waiting device's wait time. Therefore, a priority device does not necessarily have the same priority-load factor for all waiting devices. In the calculation of priority load, the interference is considered to have two distinct components: the A factor and the B factor.

A-FACTOR INTERFERENCE:

A-factor interference is caused by channel microcode activity, such as command chaining, for the priority device. The duration of this type of interference is significant compared with typical wait times. Therefore the priority load, being expressed as a percentage of wait time, depends on the wait time of the waiting device. For example, if a waiting device's wait time is 0.20 millisecond and the microcode activity associated with the priority device lasts for 0.10 millisecond, then the priority load is 50 percent. (In the channel evaluation factor tables, the A factors are expressed in milliseconds multiplied by 100. In the foregoing example, the A factor associated with a microprogram activitiy lasting 0.10 milliseconds is therefore 0.10 x 100 = 10.00.) Figure 2.8 shows how A-factor interference varies with the wait time of the waiting device.



* The A factor given in the channel evaluation factor tables (in the appendixes) is the duration of interference in milliseconds multiplied by 100. If the duration of interference is 0.10 millisecond (as shown in the illustration), the A factor is 0.10 X 100 = 10.00. Thus, for a waiting device having a wait time of 0.2 millisecond, the interference is obtained directly as a percentage thus:

$$\frac{\text{A factor}}{\text{Wait time}} = \frac{10.00}{0.2} = 50\%$$

Figure 2.8: Example of Priority Device Causing Interference by Command Chaining (A-factor Interference)

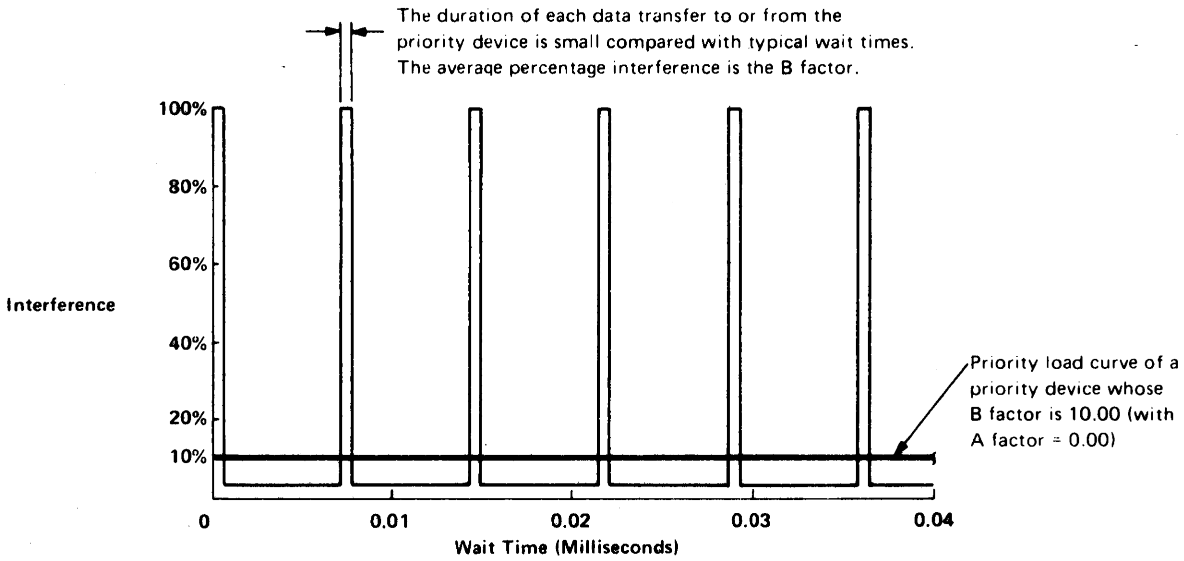


Figure 2.9: Example of Priority Load Curve of a Priority Device Causing Interference by Transferring Data (B-factor Interference)

__B-FACTOR INTERFERENCE__:
B-factor interference is typically caused by data transfers to and from the priority device. As shown by the example in Figure 2.9, the duration of each data transfer is short compared with typical wait times; the data transfers occur frequently enough, however, to have a total effect that can be expressed as a percentage interference, namely, the B factor, that is constant for all wait times.

__A AND B FACTORS COMBINED__:
In actual I/O operations, the pattern of interference tends to be more complex than has been suggested by the example priority load curves in Figures 2.7 and 2.8. Usually, the A and B factors are both nonzero and the total priority load of a priority device is given by:

Priority load = (A/WAIT TIME)+B %

where the wait time is that of the waiting device.

MULTIPLE A AND B FACTORS:

Some devices have only one set of A and B factors but others have more than one set; see the tables in the Appendixes. In these tables (as shown in Figure 2.10) the A and B factors have priority time factors associated with them that show the ranges of wait times (of waiting devices) for which the A and B factors are valid. Figure 2.10 also shows how to choose the appropriate A and B factors according to the wait time of a waiting device. The selection principle is the following: pick the time (in the Time-column) closest to but smaller than the wait time of the waiting device, then use the associated A and B factors. In other words, the wait time of the waiting device must fit between the time factors of the priority device.

Priority device

These priority time factors.........indicate that the corresponding A and B factors are valid for these wait-time ranges

Input/output device	Priority load			
	Time	A	B	
2501 Card Read Model B2				
Read EBCDIC	0.100	10.53	0.00	0.100 ms to 0.325 ms
	0.325	5.65	15.00	0.325 ms to 25.00 ms
	25.00	140	9.57	25.0 ms and longer

Example 1

When considering the priority load which a 2501 Card Reader Model B2, (that is reading EBCDIC) imposes upon a waiting device that has a wait time of 10 ms, use the following priority load factors:

A=5.65 and B=15.0 (because 10 ms is in the range .325 ms to 25 ms)

Example 2

Similarly, for a waiting device that has a wait time of .3 ms, use the following priority load factors:

A=10.53 and B=0.00 (because .3 ms is in the range .100 ms to .325 ms

Figure 2.10: Examples Showing How to Choose Priority Load Factors

Device Load

When channel service to priority devices has finished (see Figure 2.6), channel service to the waiting device then starts and continues until the data byte has been transferred to or from the waiting device. The delay caused by providing this channel service to the waiting device is called the device load and is expressed in the channel evaluation factor tables as a percentage of the device's own wait time.

DATA OVERRUN TEST PROCEDURE

The test for data overrun involves the calculation of a load sum for each waiting device. These calculations are given as a step-by-step procedure in Figure 2.11.

Before starting the step-by-step procedure:

1. Obtain IBM 4331 processor Channel Load Sum Worksheet GA33-1532.

2. Check that the configuration of burst mode devices has been decided and tested for data overrun; see 'Test of Integrated Channel Bus' in this section.

3. Check that the devices to be connected to the byte multiplexer channel have been assigned their priorities as described under 'Priorities on Byte Multiplexer Channel' in this section.

Calculate the load sums as shown in Figure 2.11. Steps (1) through(5) of the procedure consist of copying on to the load sum worksheet all data that are required for the data overrun calculations. Steps (6) through (9) yield the load sum for each class-1 device. From the load sum, the possibility of data overrun can be assessed.

Figures 2.12 and 2.13 give examples of obtaining load sums.

For each waiting device to operate satisfactorily (that is, without data overrun), its load sum must be less than 100. If, however, any of the load sums is greater than 100, the reader is advised either to try an alternative configuration or to consult his local IBM representative for a more detailed analysis.

CAUTION

It is particularly important that the load sum for the communications adapter does not exceed 100 because, if data overrun occurs on output from CA, special programming support is needed for recovery.

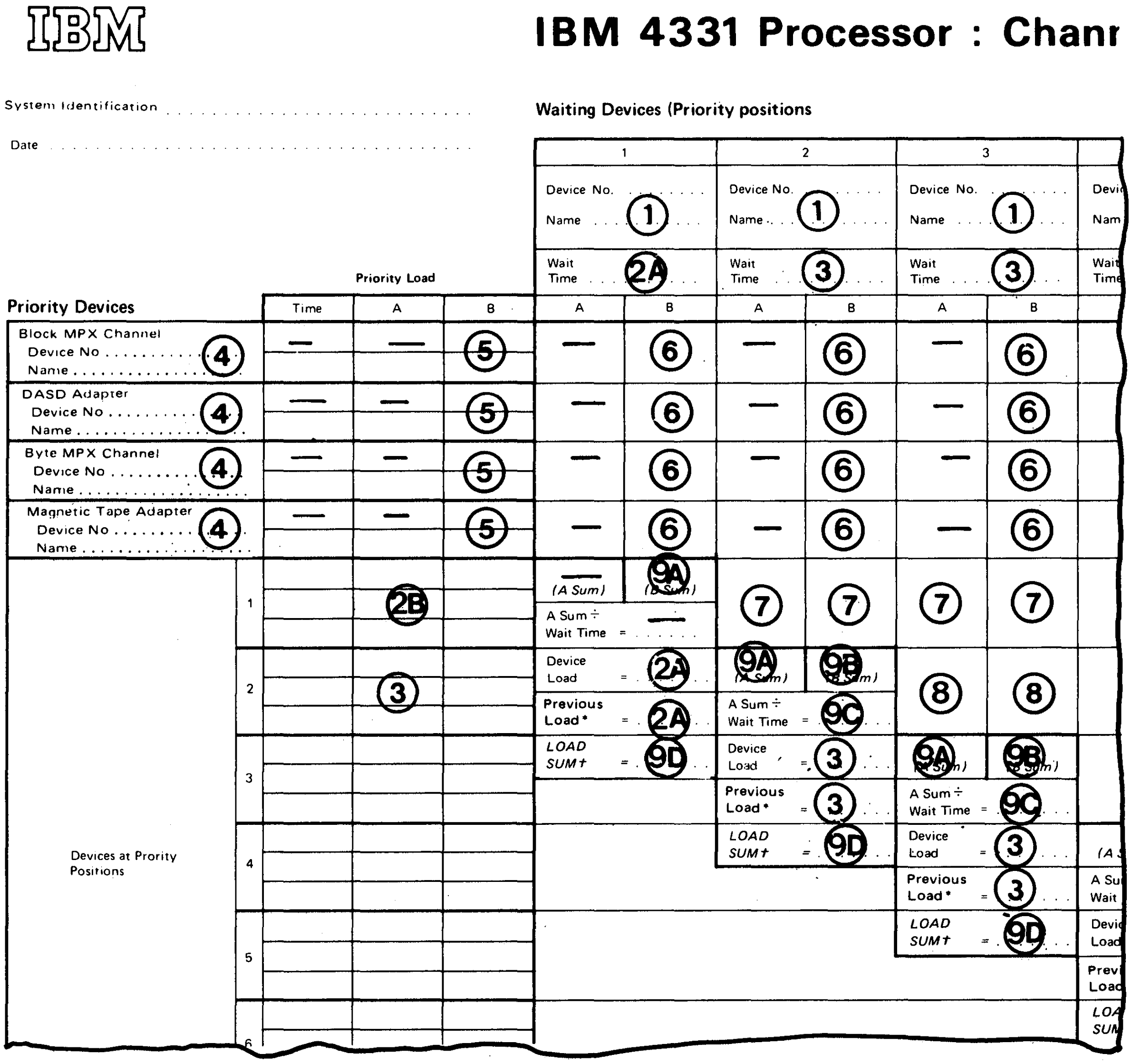
The foregoing procedure for testing data overrun assumes that:

1. Each waiting device makes its request for channel service at the worst possible time, that is, when all the priority devices combine to cause maximum interference during the waiting device's wait time. However, the greater the number of priority devices that contribute to the load sum for a particular waiting device, the less likelihood there is of all worst-case conditions occurring simultaneously.

2. Devices all work at their maximum possible data rates, or at their tolerance limits, whichever is the worst case.

3. Data field lengths and command sequences cause the worst interference that can be reasonably expected in practice.

4. Channel programming conventions have been followed; see the section 'Channel Programming Conventions'.



IBM 4331 Processor : Chanr

System Identification . . . .

Date . . . .

Waiting Devices (Priority positions

		Priority Load		1		2		3		
				Device No. . . . . Name . . . ① . . .		Device No. . . . . Name . . . ①		Device No. . . . . Name . . . ① . . .		Devi Nam
				Wait Time . . . (2A) . . .		Wait Time . . . ③		Wait Time . . . . ③ . . .		Wait Time
Priority Devices	Time	A	B	A	B	A	B	A	B	
Block MPX Channel Device No . . . . ④ Name	—	—	⑤	—	⑥	—	⑥	—	⑥	
DASD Adapter Device No . . . . ④ Name	—	—	⑤	—	⑥	—	⑥	—	⑥	
Byte MPX Channel Device No . . . . ④ Name	—	—	⑤	—	⑥	—	⑥	—	⑥	
Magnetic Tape Adapter Device No . . . . ④ Name	—	—	⑤	—	⑥	—	⑥	—	⑥	

Devices at Prority Positions

					1		2		3		
1		(2B)			— (A Sum)	(9A) (B Sum)	⑦	⑦	⑦	⑦	
					A Sum ÷ Wait Time = —						
2		③			Device Load = . (2A) . .		(9A) (A Sum)	(9B) (B Sum)	⑧	⑧	
					Previous Load* = . (2A) . .		A Sum ÷ Wait Time = . (9C) . . .				
3					LOAD SUM† = . (9D) . .		Device Load = . ③ . . .		(9A) (A Sum)	(9B) (B Sum)	
							Previous Load* = . ③ . . .		A Sum ÷ Wait Time = . (9C) . . .		
4							LOAD SUM† = . (9D) . . .		Device Load = . ③ . . .		(A S
									Previous Load* = . ③ . . .		A Su Wait
5									LOAD SUM† = . (9D) . . .		Devi Load
											Prev Load
6											LOA SUM

Figure 2.11: Procedure for Calculating Load Sums

Procedure for Calculating Load Sums, Using the Load Sum Worksheet of Figure 2.11:

(1) At the top of the 'Waiting Devices' columns numbered 1, 2, 3, and so on, enter the device model numbers of the I/O devices in the priority sequence previously established (according to traplevel priorities and priorities on byte multiplexer bus.)

Notes:

a.) Treat each communication line that is connected to a 2701 Data Adapter Unit as an individual waiting device; see Appendix D.
b.) Class-2 or class-3 devices can be delayed in certain worst-case conditions, but can never overrun, and therefore need not be entered on the worksheet.
c.) Each burst mode device that is attached to a block multiplexer channel should also be entered as a waiting device, to assure proper consideration of its priority load on other devices.

(2) For the waiting device entered in column 1, obtain the following values from the appendixes (rear of this manual):

```
a. Wait time      ¬   Copy these values into the
   Device load    |-> appropriate boxes of the vertical
   Previous load  |   column for the waiting device being
                  ┘   considered, as shown by 2a in Fig. 2.11.
```

For burst mode devices attached to a block-MPX channel this step can be omitted since data overrun due to traplevel interference cannot occur.

b. Priority-load values:

```
   Time           ¬   Copy these values into the boxes
   A              |   of the device position 1 (row
   B              |   number 1) on the byte multiplexer
                  |-> channel, as shown by (2b) in
                  |   Fig. 2.11. Where two or three lines
                  |   of priority-load figures are given
                  |   for a device, copy all of them on the
                  ┘   worksheet.
```

(3) Repeat step (2) for each of the remaining waiting devices entered at step (1).

(4) Into the first four positions of the leftmost 'Priority Device' Column enter the model number of each burst mode device having the highest nominal data rate (see Appendix A and B) on

a.) the Block Multiplex Channel
b.) the DASD Adapter
c.) Byte Multiplex Channel
d.) the Magnetic Tape Adapter

If no device is connected to one of the channels a...d draw a line across the entire row on the worksheet.

(5) Into the third 'priority load' column, the 'B' column, enter the B-factor associated with the data transfer of the device entered in step (4). The B-factor for the data transfer is obtained by multiplying the nominal data rate of the priority device in Kb/sec (See Appendix A and B) by .023.

All the information needed is now on the worksheet, and steps (6) through (9) can be performed without further reference to the tables of channel evaluation factors.

(6) Into the B columns, numbered (6), of the first four rows copy the appropriate B-factors from left to right, up to, but not including the burst mode device (see (1.), note C) causing this data transfer interference. Through the B-column of the waiting device and all columns to the right of the waiting burst mode device, draw a line accross the remaining part of the row.

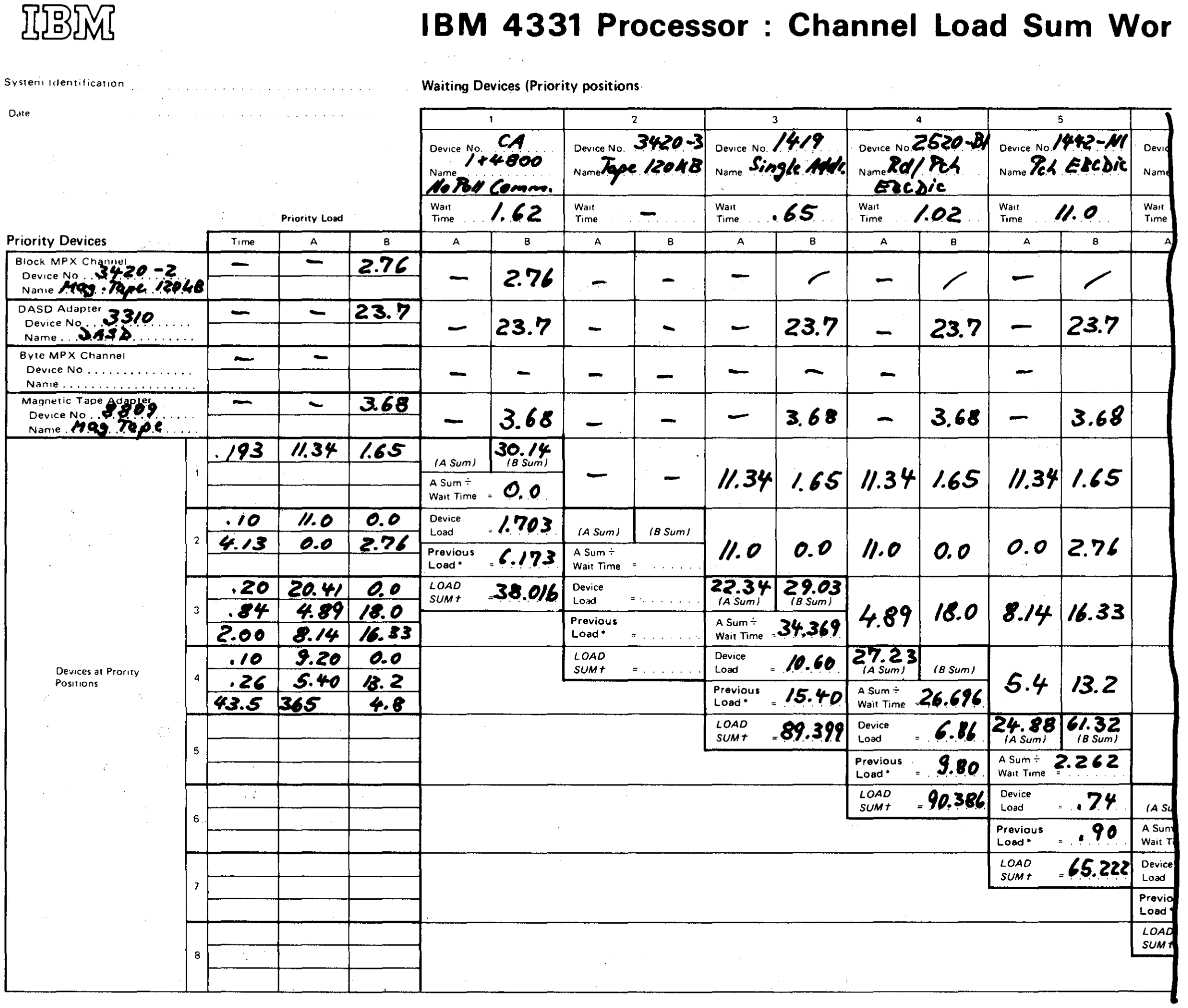
(7) Into the 'A' and 'B' columns, numbered (7), copy the appropriate priority-load A and B factors from the column numbered (2b). Where more than one set of A and B factors are given for one priority device, copy only the set that is appropriate for the wait time of the waiting device being considered. The way to choose the 'appropriate' set of A and B factors for any priority device is shown in Figure 2.10.

(8) For the next waiting device (in column 3) copy the appropriate priority-load A and B factors from the column, numbered (3), similarly as described in (7). Note that these factors can be different from column to column because the wait time of a waiting device may fall into a different time range.

Repeat step (8) for each waiting device up to, but not including the last one having the lowest priority. For example, when copying A and B factors for the device at position 5, include the appropriate A and B factors for the higher priority devices in rows 1, 2, 3 and 4.

(9) Calculate load sums. In the vertical column for each waiting device being considered, proceed thus:

a. Add the values in the 'A' column and enter the result as the A Sum.
b. Add the values in the 'B' column and enter the result as the B Sum.
c. Divide the A Sum by the wait time for the waiting device being evaluated. Enter the quotient in the space provided.
d. Find the LOAD SUM by adding together the following four values: the B Sum, the quotient found in step 9c; the device load and the previous load.



IBM

IBM 4331 Processor : Channel Load Sum Wor

System Identification

Date

Waiting Devices (Priority positions

1: Device No. CA 1+4800 Name No Poll Comm. Wait Time 1.62

2: Device No. 3420-3 Name Tape 120kB Wait Time —

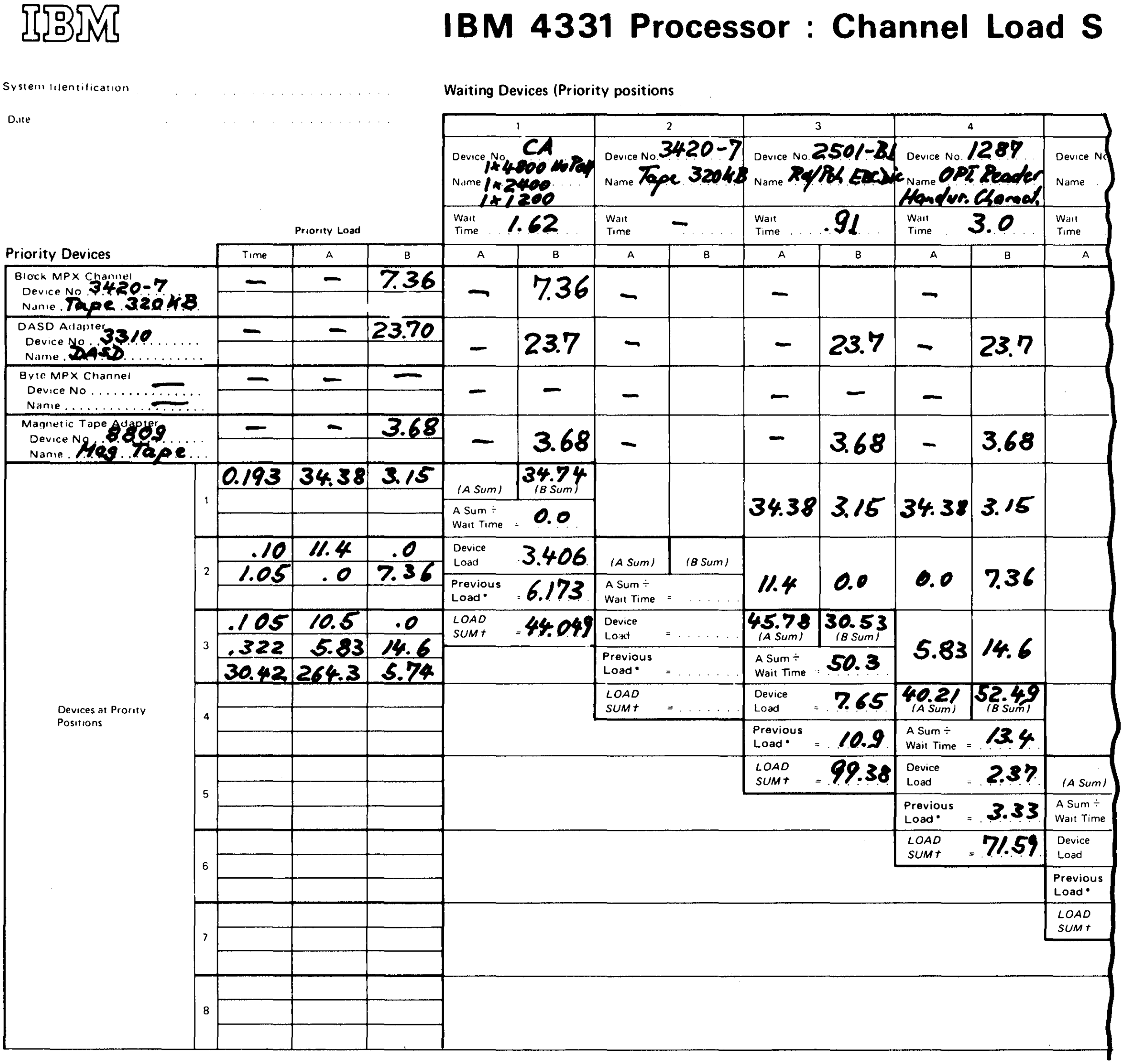
3: Device No. 1419 Name Single Addr. Wait Time .65

4: Device No. 2520-B1 Name Rd/Pch EBCDIC Wait Time 1.02

5: Device No. 1442-N1 Name Pch EBCDIC Wait Time 11.0

Priority Devices		Priority Load			1		2		3		4		5	
		Time	A	B	A	B	A	B	A	B	A	B	A	B
Block MPX Channel Device No 3420-2 Name Mag. Tape 120kB		—	—	2.76	—	2.76	—	—	—	/	—	/	—	/
DASD Adapter Device No 3310 Name DASD		—	—	23.7	—	23.7	—	—	—	23.7	—	23.7	—	23.7
Byte MPX Channel Device No Name		—	—		—	—	—	—	—	—	—		—	
Magnetic Tape Adapter Device No 8809 Name Mag. Tape		—	—	3.68	—	3.68	—	—	—	3.68	—	3.68	—	3.68
Devices at Priority Positions	1	.193	11.34	1.65	(A Sum) A Sum ÷ Wait Time = 0.0	30.14 (B Sum)	—	—	11.34	1.65	11.34	1.65	11.34	1.65
	2	.10 4.13	11.0 0.0	0.0 2.76	Device Load = 1.703 Previous Load* = 6.173 LOAD SUM† = 38.016		(A Sum) A Sum ÷ Wait Time =	(B Sum)	11.0	0.0	11.0	0.0	0.0	2.76
	3	.20 .84 2.00	20.41 4.89 8.14	0.0 18.0 16.33			Device Load = Previous Load* = LOAD SUM† =		22.34 (A Sum) A Sum ÷ Wait Time = 34.369	29.03 (B Sum)	4.89	18.0	8.14	16.33
	4	.10 .26 43.5	9.20 5.40 365	0.0 13.2 4.8					Device Load = 10.60 Previous Load* = 15.40		27.23 (A Sum) A Sum ÷ Wait Time = 26.696	(B Sum)	5.4	13.2
	5								LOAD SUM† = 89.399		Device Load = 6.86 Previous Load* = 9.80		24.88 (A Sum) A Sum ÷ Wait Time = 2.262	61.32 (B Sum)
	6										LOAD SUM† = 90.386		Device Load = .74 Previous Load* = .90	
	7												LOAD SUM† = 65.222	
	8													

Figure 2.12: Example of load sum calculations on load sum worksheet - system with 3310, CA, 3420-3, 1419, 2520, 1442



IBM

IBM 4331 Processor : Channel Load S

System Identification

Date

Waiting Devices (Priority positions

	1	2	3	4	
Device No.	CA	3420-7	2501-B1	1287	Device N
Name	1x4800 NoPoll 1x2400 1x1200	Tape 320kB	Rd/Pch EBCDic	OPT Reader Handwr. Charact.	Name
Wait Time	1.62	—	.91	3.0	Wait Time

Priority Devices	Priority Load Time	A	B	1 A	B	2 A	B	3 A	B	4 A	B	A
Block MPX Channel Device No 3420-7 Name Tape 320KB	—	—	7.36	—	7.36	—		—		—		
DASD Adapter Device No 3310 Name DASD	—	—	23.70	—	23.7	—		—	23.7	—	23.7	
Byte MPX Channel Device No — Name —	—	—	—	—	—	—		—	—	—		
Magnetic Tape Adapter Device No 8809 Name Mag Tape	—	—	3.68	—	3.68	—		—	3.68	—	3.68	
Devices at Priority Positions 1	0.193	34.38	3.15	(A Sum) A Sum ÷ Wait Time = 0.0	34.74 (B Sum)			34.38	3.15	34.38	3.15	
2	.10 1.05	11.4 .0	.0 7.36	Device Load 3.406 Previous Load* = 6.173		(A Sum) A Sum ÷ Wait Time =	(B Sum)	11.4	0.0	0.0	7.36	
3	.105 .322 30.42	10.5 5.83 264.3	.0 14.6 5.74	LOAD SUM† = 44.049		Device Load = Previous Load* =		45.78 (A Sum) A Sum ÷ Wait Time = 50.3	30.53 (B Sum)	5.83	14.6	
4						LOAD SUM† =		Device Load = 7.65 Previous Load* = 10.9		40.21 (A Sum) A Sum ÷ Wait Time = 13.4	52.49 (B Sum)	
5								LOAD SUM† = 99.38		Device Load = 2.37 Previous Load* = 3.33		(A Sum) A Sum ÷ Wait Time
6										LOAD SUM† = 71.59		Device Load Previous Load*
7												LOAD SUM†
8												

Figure 2.13: Example of load sum calculations on load sum worksheet - system with 3310, CA 3420-7, 2501, 1287

231X ON BMPX OVERRUN CONSIDERATIONS

The block multiplexer channel has been designed to give reasonable performance for a relatively low price. To achieve this, compromises had to be made with respect to channel rates and channel chaining capabilities. To achieve the required fast channel turn around times for 231x command chaining and data chaining the following strategy was applied:

As long as 231x chaining is active:

1. The BMPX trap level processing occurs at a priority level one above the communications adapter (instead of one below) and

2. All burst mode data transfers on MPX, DASD Adapter or Magnetic Tape Adapter are stopped.

Note: Data chaining in between the individual bytes of a contiguous 231x field is nevertheless not possible. Data chaining can however be conducted successfully in the field separator gaps, such as the gap between count field and key field or between key field and data field. Attempts to chain data within a field cause overrun.

Strategy (1) will somewhat favour 231x chaining operations with respect to CA data transfer, without necessarily causing CA data overruns. However, Strategy (2), will have an ever present impact on all burst mode transfers with unbuffered devices. For this reason it is not recommended to use unbuffered burst mode devices on the MPX, or operate IBM 8809 tapes or 33xx disks together with 231x disk devices.

The impact of strategy (2) on the new disk devices 3310 and 3370 is not as critical because both have hardware retry facilities built in. Instead of having to go through lengthy software recovery procedures, the disk goes only through one additional rotation before the total data transfer is repeated.

The frequency with which these retries occur depends upon how often 231x chaining coincides with data transfers on the DASD adapter. This frequency will increase with:

- increasing 231x access rate
- decreasing 231x data field length
- increasing disk access rate
- increasing number of bytes transferred per disk access

Interference of I/O traffic with instruction processing is caused by the fact that the processor is employed for most channel operations, such as initiation and termination of burst mode data transfers, handling of MPX and CA byte mode data trasfers, and for the address and count update of every 4 bytes of data transferred via the integrated channel. In addition, I/O traffic is causing CPU interference due to contention at the main storage.

The I/O Interference with the processor is very much application and configuration dependent and has to be calculated on a per workload basis.

This section describes how to calculate the amount of this interference. The procedure involves:

1. Selection of the individual processor times pertaining to the operation of the channel.

2. Finding the frequencies with which the different channel operations occur during a specified interval of time.

3. Multiplying timings with frequencies and summarizing overall time-frequency products.

The next step shows what effects the I/O interference can have on the systems behavior. In particular it will be shown how to assess the possible occurence of program overuns, and how to estimate the effect of decreased CPU power on system throughput.

CHANNEL INTERFERENCE TIMINGS

The figures given in figure 3.1 are average figures for commonly attached devices.

Channel activity	Average CPU Interference time in Micro Sec caused by channel service to:			
	BBA -1,2	CA	MPX	BMPX
Data transfers in byte mode	-	27.5	60 *	-
Data transfers in multibyte mode	225 for each burst of 1...256 Byte	-	60*for 1.BYTE +10 for each add. Byte	-
Data transfers in burst mode /4BYTE	.92	-	.92	.92
Execution of one command-chained CCW	235	86	92 **	92 **
Additional load for: 1.PCI	85	10	30	30
2.Command chained after separate channel-end and device-end signals	110	-	33	33
Execution of one data-chained CCW	125	22	58	58
Execution of 'transfer in channel' command	25	10	10	10
Creation of an interruption-pending condition:				
1. Channel end (with or without device end)	235	40	79	79
2. Device end alone	140	-	45	45
Clearing interruption-pending condition (by exchanging PSWs and storing CSW) ***	210	210	210	210
Start I/O handling [1]	200	150	150	150
Fetching new IDA for page-cross	40	12	17	17

* The MPX byte transfer time can vary from 55 usec, for fast control units, to 81 usec, for slow control units.

** This command chaining time can vary from 90 usec, for fast control units, to 103 usec, for slow control units.

***This time should be included in CPU interference calculations but excluded from calculations of percentage channel utilization.

[1] 70 usec of this time should be included in CPU interference calculation but excluded from perentage channel utilization.

Figure 3.1 Processor Interference Times Caused by Channel Activities for Devices on BBA's, CA, MPX, BMPX

Comments to Fig. 3.1, 3.2, 3.3

The BBA data transfer occurs via a buffer of 256 Bytes (Fig. 3.1). Whenever during an I/O read/write operation the buffer is full or the byte count limit is reached, (whichever comes first), the contents of the buffer are emptied at a rate of 414 KB/SEC. Each such burst transfer requires 90 usec of processor time. In addition, every four-byte transfer requires .92 usec processor time. If MPX devices operate in byte mode, each byte requires about 60 usec of processor time. Depending upon the type of device attached to the MPX this time may vary by about ± 15%.

If a device can operate in multibyte mode, 60 usec are required for the first byte and about 10 usec for each additional byte. If a device operates in burst mode on the byte MPX, only .92 usec are required for every 4 bytes of data transferred.

The .92 usec per 4 bytes of data is considered an average value occuring for typical load situations on the Integrated Channel Bus. Actual times can vary from .9 usec for low loads to 1.9 usec for high IC-bus utilization, and read operations alternating with write operations (compare Fig. 2.2). However, typical IC bus utilization is found to be well below 5%. The time for SIO handling includes the execution of a single CCW. Since instruction rate calculations do not include the 'start I/O' instruction, this SIO handling time should be included in CPU interference calculation. For calculation of channel utilization, however, only the time for the execution of a single CCW should be included for each SIO. For this purpose, use the time needed for the execution of one command-chained CCW.

The processor time needed for disk devices attached to the DASD Adapter was given for a full chain of commands as required for a normal disk access (Fig. 3.2). Since the 3340 uses the 'full track read' and 'search by microcode' strategy, the appropriate timings from Fig. 3.3 have to be added for random accesses. Similarly, the processor time for emulated disk devices consist of two parts:

1. The timings associated with the accesses to the disk attached to the DASD Adapter, giveen in Fig. 3.2, and
2. The timings associated with the fully electronic search and data move done per microcode, given in Fig. 3.3

In addition, all random write accesses to emulated disks require a full track read followed by a full track write. For sequential accesses to emulated disks the data is already contained in buffer. Therefore the SEEK, SEARCH, and READ/WRITE interference times of the normal disk acess are eliminated (Fig. 3.2), in addition to the full track read interference of the emulator (Fig. 3.3).

Channel activity	Average Processor Interference time in usec by channel service to:			
	3310	3370	3340	8809
Data transfers in burst mode/4B	.92	.92	.92	.92
Execution of Typical Command Chain: SEEK, (SEARCH), READ/WRITE	1519	1400	4590	-
Creation of an interruption-pending condition: 1. CH END (With or without device end)	196	196	-	610
Clearing interruption-pending condition (by exchanging PSWs and storing CSW) **	210	210	210	210
Start I/O Handling *	80	80	150	796 (1219)[1]
Time for total access ***	2005	1886	4950 [2]	1616 (2039)[1]
Fetching new IDA	20	20	20	20
Execution of one command-chained CCW	-	-	-	550
Additional load for PCI	30	30	30	30
Execution of one data-chained CCW	85	85	85	-
Execution of 'transfer-in-channel' command	10	10	10	10

See also additional timings due to 3340 Direct Disk Attachment Fig. 3.3)

* 80 usec of this time should be included in interference calculations but excluded from calculations of percentage channel utilization.

** This time should be included in interference calculations but excluded from percentage channel utilization.

*** Time for one complete access to read or write one record.

[1] With initial SPEED SET command

[2] For random write access add 1620 usec to this figure

Figure 3.2 Interference times caused by channel activities for devices on DASD Adapter and Magnetic Tape Adapter.

Emulator activity	Processor Time needed for emulation in usec	
	3340 Direct Disk Attachment	231X Emul. on 3310
Cycle steal interf. for full track read from emulated disk(3)	8368/4 x .92 =1925	T/4 x.92
Initiation of disk emulation (4)	2400	2600
Electronic search over record size R (4)	4184/R (2) x 540 =1103	T/2R x 450
Data move of 1 record with 2048 B (4)	.925xR =1895	.925xR =1895

(1) For 2314 T = 7294, for 2311 T = 3625

(2) R = Logical record size in Byte
Timings given are for R = 2048 B

(3) For a disk write operation, consisting of 1 full track read followed by a full track write, multiply by 2.

(4) processor operating on traplevel 0

Fig. 3.3 Additional CPU interference times caused by random access to emulated disks on DASD Adapter (For basic Disk Adapter times see Fig. 3.2)

CALCULATION OF I/O INTERFERENCE WITH THE PROCESSOR

Sources of I/O interference are the use of processing time by the channels and the use of main storage time by the I/O data transfer.

INTERFERENCE DUE TO CHANNEL ACTIVITIES IN THE PROCESSOR

The channel activities that can cause interference, and the durations of those activities in microseconds, are listed in Figures 3.1, 3.2 and 3.3. To calculate the total duration of interference with the processor for a particular time span, proceed as follows:

1. From Figures 3.1, 3.2, and 3.3 list those channel activities (and their associated interference times) that can occur in the time span being considered.
2. Record also the number of times that each channel activity occurs in the time span.
3. For each channel activity, multiply the interference time by the number of times that the activity occurs; the product is the duration of interference with the processor caused by that activity.
4. Add together the individual interference times to obtain the total duration of I/O interference with the processor.

Example: Figure 3.4 gives an example calculation of total interference time that is caused by a tape-to-printer operation in which:

1. A 1000-byte block is read from tape (burst mode, block multiplexer channel) via ten command-chained CCWs.
2. The 1000 bytes are sent to the printer (byte mode, byte multiplexer channel) via ten command-chained CCW's.
3. The pertinent time span is assumed to be the duration of the entire I/O operation.

Note that the duration of this interference with the processor is not dependent on the data rate of the devices but rather on the characteristics of the channels as shown in Figures 3.1 and 3.2 and 3.3 and on the amount of data being handled.

Channel activities	Interface factors (from Fig. 3.1 and 3.3)	Number of occurrences	Duration of interference
Reading tape on block multiplexer channel			
Data transfers in burst mode / 4BYTE	.92 us	250	230 us
Execution of a CCW with data chaining	58 us	9	522 us
Creation of interruption:			
Channel end with device end	79 us	1	79 us
Clearing interruption	210 us	1	210 us
Writing to printer on byte-multiplexer channel			
Data transfers (in byte mode) /BYTE	60 us	1000	60000 us
Execution of a CCW with command chaining and without PCI	98 us	9	882 us
Creation of interruptions:			
Channel end alone	79 us	1	79 us
Device end alone	45 us	1	45 us
Clearing interruption	210 us	2	420 us
		Total =	62467 us
		=	62.47 ms

Figure 3.4 Duration of Channel Interference, Example Calculation for a Tape-To-Printer Operation

Fig. 3.4 shows how to obtain the actual duration of interference in mircroseconds over a specific time span. This duration of interference figure, when divided by the time span that is pertinent to the application, yields a percentage interference figure.

The significance of the derived percentage interference depends entirely on the reader's choice of the pertinent time span. For example, the percentage interference due to the tape-to-printer operation in Figure 3.4 over the period of time taken to perform the I/O operation is given in Fig. 3.5, once for the case when tape reading and printing occurs sequentially (Example 1), and once for the case where tape reading and printing completely overlap (Example 2).

Example 1

Suppose, in the application being considered, that tape reading and printing occur consecutively (that is, printing does not start until tape reading has finished).

Step 1: Take the pertinent time span to be the duration of the I/O operation:

Time to read 1000 bytes from tape = 24.7 ms

Time to print 10 lines = 545 ms

Time span of I/O operation = 569.7 ms

Step 2: Calculate the percentage interference during this time span thus:

$$\frac{62.47 \text{ ms (from Figure 3.4)}}{569.7 \text{ ms}} = .109 = 10.9\ \%$$

Example 2

Suppose, in the application being considered, that the tape reading and printing operations overlap.

Step 1: Determine the duration of the I/O operation:

Time to print 10 lines (as in example 1) = 545 ms

Step 2: Calculate the percentage interference during this time span thus:

$$\frac{62.47}{545} = .115 = 11.5\ \%$$

I/O operation times are obtained from the reference literature for the device.

Figure 3.5 Percentage Interference, Example Calculation for a Tape-To-Printer Operation

The percentage interference numbers calculated in Fig. 3.5 indicate how much longer a processing function would take for execution (assuming that during the I/O operation the processing would continuously need processor services without ever going into the wait state). For a first pass estimate of actual percentage increase in processor busy time due to I/O interference, one can multiply the interference figures calculated in Fig. 3.5 with the figure for the processor utilization (due to instruction processing). This estimate assumes that channel operations are uniformly distributed over processor busy and wait state.

INTERFERENCE DUE TO I/O UTILIZATION OF MAIN MEMORY

The I/O Operations causing memory interference are:

- FETCH, which requires .9 usec per 4 Bytes, .5 usec of which are overlapped with processor busy time for the same fetch access; during these .5 usec the processor can never ask for memory access. Thus only the remaining .4 usec should be used for calculating effective memory utilization.
- STORE, which requires 1.3 usec per 4 Bytes, none of which is overlapped with processor busy time for the same store access.

The effective time Ti needed per average memory access is calculated as:

Ti = (.9 usec * (number of fetch accesses)+1.3 usec
     * (number of store accesses)) / (number of
     fetches plus number of stores)

<u>Legend</u>: * is the multiplication sign
          / is the division sign

The noticeable percentage interference then is the product of the following factors:

1. The effective memory utilization Ui due to I/O accesses
2. The Time Tp for which an unsuccessful memory access has to wait before memory access is granted, and
3. The number of memory accesses Np the CPU attempts to make within a specific time interval

or Ip = Ui * Tp * Np

The memory utilization due to I/O, Ui, is obtained by multiplying the number of I/O memory accesses per time interval Ni with the average memory access time Ti, or Ui = Ni * Ti.

The average waiting time Tp of a processor access is, assuming low memory utilizations, Ti/2. For higher memory utilizations (Ui > 0.05) a better estimate for Tp is

$$Tp = (Ti/2)/(1 - Ui)$$

This equation is based on Poisson arrival of I/O memory requests.

The number of memory accesses Np can be obtained by multiplying the instruction rate Re with the average number of memory accesses needed per instruction Ne. Both of these values are application dependent. But typical values are Re = 200 K instr./SEC and Ne = 1.5 accesses/instr. Then Np = Re x Ne.

An example of interference due to memory contention is calculated in Fig. 3.6.

Ni = 50000 I/O mem. acc./sec., (E/B = Instr. Execution/BYTE = 1)

Ti = 1.0 usec Time per I/O Memory access:

Ui = Ni * Ti = .05 memory utilization due to I/O

Tp = Ti/2 = .5 usec aver. waiting time of CPU mem. access

Re = 200 K Instr./sec. instr. execution rate

Ne = 1.5 mem. acc./instr.

Np = Re * Ne = 300 000 memory acc./sec

Ip = Ui * Tp x Np = .0075 = .75 %

Legend: * is the multiplication sign.

Fig. 3.6 Calculation of interference due to I/O utilization of memory.

EFFECTS OF I/O INTERFERING WITH THE PROCESSOR

Two effects of I/O interference are of prime importance. The first is the effect of I/O interference on System throughput. The second is the fact that increasing I/O interference may lead to program overruns. A third, less important effect is the slow-down which high priority I/O devices can impose on lower priority buffered I/O devices.

EFFECT OF I/O INTERFERENCE ON SYSTEM THROUGHPUT

The effect of I/O interference on system throughput is very much application dependent and therefore difficult to predict. Comparing an ideal system (without I/O interference) with a real system (having I/O interference), it is easy to see that the I/O interference will have little effect on real system throughput if the processor utilization is low; while the highest effect of interference will occur for high processor utilization. With the reasonable assumption, that all processor times of an ideal system are equally affected by I/O interference, a conservative estimate for the real system throughput is obtained by dividing the system throughput of the ideal system by

1 + (I/O interference) * ((processor time overlapped with I/O) / (total processor time))

where the I/O interference is here obtained by dividing the I/O interference time by the elapsed time of the ideal system.

THE EFFECT OF I/O INTERFERENCE ON PROGRAM OVERRUN

A particular effect of channel interference with processing (see section 3.2) is program overrun. Program overrun results from a program being slowed down to such an extent that the program is late in providing realtime service to a device and, hence, causes incorrect operation of that device.

Program overrun must always be considered for those I/O operations that involve high-speed document-handling devices such as the 1419 Magnetic Character Reader. In program-sort mode, the 1419 reads data into the processor while the document is passing the read station; then, before the document reaches the stacker-select station, the processor must calculate the stacker required and issue the correct stacker-select command. If the stacker-select command arrives too late (because of program overrun), the document is routed to the reject pocket and the channel program stops.

How to Assess Program Overrun

To investigate the possibility of program overrun, proceed as follows:

1. Establish the available program time, that is, the time during which the program must perform its calculations and issue the command. Call this time 'A' (available time).

2. Establish the time that the program takes between reading data and issuing the command. (This time can be established by totaling the execution times of the component instructions, see 'Instruction Timings' in IBM 4331 processor Functional Characteristics, GA33-1526). When establishing this time, take all program activity into account including, for example, the handling of the I/O interruption after the data is read, and any possible supervisor program activity. Call this time 'P' (processing time).

3. Establish the maximum possible interference time that can be caused by simultaneous activities on all channels during the time 'A'. (The calculation of total interference time is described previously in this section). Call this time 'I' (interference time).
   Note: The maximum possible interference time is caused by the combination of channel activities that, during the available time 'A', have the highest interference time 'I'.

4. Calculate P + I and compare the result with A. If P + I is greater than A, program overrun may occur.

Example: Consider the possibility of program overrun with a single-address 1419 and assume that other channel activity consists of (1) a 3310 Disk Storage transferring data on the DASD Adapter in burst mode at the rate of 1031 kilobytes per second, and (2) a 1442 Card Read Punch using 1-byte transfers and punching EBCDIC characters.

For the purpose of this example, it is assumed that the interference with the processor which is caused by these two operations during the available time 'A' is the worst that can occur in the given application; that is, it has the highest interference time 'I'.

Check for program overrun as follows:

1. Establish the available program time 'A'. From IBM 1219 Reader Sorter, IBM 1419 Magnetic Character Reader, GA24-1499, the minimum time available for giving the stacker-select command is 9.50 milliseconds.

2. Establish the processing time 'P' of the program instruction sequence that calculates the stacker required and issues the stacker-select command. For the purpose of this example, assume that the processing time 'P', including possible supervisor activity, is 8.00

milliseconds.

3. Establish the total interference time 'I'.
   a. Calculate the duration of the interference that is caused by the 3310 data transfer within the time span 'A'. At 1031 kilobytes per second, the number of bytes transferred in time 'A' (9.50 milliseconds) is given by:

      $$\text{Number of bytes transferred} = \frac{1031000 \times 9.50}{1000} = 9795 \text{ Bytes}$$

      Taking the duration of interference on the block multiplexer channel in burst mode to be 0.92 microseconds per 4 bytes (from Figure 3.2) the total interference in time 'A' caused by transferring 9795 bytes is given by:

      Interference time
      caused by 3310 = (9795 x .92 : 4) microsec.
      = 2.25 milliseconds

   b. Calculate the duration of the interference that is caused by the 1442 operation. During the time 'A', the channel activity is assumed to be the execution of one command-chained CCW, and two 1-byte data transfers (see Figure 3.1)

	Interference times
Data transfers in byte mode	60 X 2 = 120 us
Execution of a CCW with command chaining	98 X 1 = 98 us
Therefore, interference time caused by the 1442	= 218 us = 0.22 ms

   c. Establish the total interference time 'I' from steps a and b.

      2.25 ms + .22 ms = 2.47 ms

4. Calculate 'P' + 'I' and compare the results with 'A':

   P + I = 8 ms + 2.47 ms = 10.47 ms
   A = 9.50 ms

'P' + 'I' is more than 'A' and, therefore program overrun will occur.

The mutual interference between I/O devices due to contention at the processor was evaluated by checking for data overrun.

Another kind of interference can potentially occur at the individual hardware channels or adapter units such as BBA-1, BBA-2, MPX, BMPX, DASD Adapter and Magnetic Tape Adapter. The effect of this mutual interference of devices attached to a single hardware adapter unit is a gradual slow down of I/O device operation, and thus a certain loss in system throughput.

This slowdown of I/O devices depends on the fraction of time for which a channel (or adapter) is busy and therefore not available for use by other devices. This fraction is called the channel utilization. Excessive channel utilization can cause queues to form for tasks or devices that have to use the channel. In the following it will be shown how to calculate channel utilization, and how to obtain first pass estimates on I/O device response time degradation as well as degradation of system throughput.

CALCULATION OF CHANNEL UTILIZATION

Hardware channel utilization of BBA-1, BBA-2, and MPX is generally very low and unlikely to cause significant I/O device performance degradation. The following discussions are therefore limited to the hight speed channels such as the block MPX, the adapters, and tapes and disks attachable to these channels. The general way to obtain the percentage channel utilization is to calculate the fraction of time within a given period for which the channel or the adapter is busy.

PROCEDURE FOR TAPE DEVICES

1. Estimate the following values:
    a. The number of data bytes in an average-length record.
    b. The average number of records to be transferred per second.

These two values are required in subsequent steps of this procedure.

2. Obtain the channel-busy time per record as follows:

   a. From the table of processor interference times (see Figure 3.1 or 3.2), obtain the time taken to issue a read or write command. Assume this time to be the time needed for the execution of one command-chained CCW on the block multiplexer channel.

   b. From Figure A-2 in Appendix A, obtain the gap time for the particular tape device.

   c. Calculate the time that is needed to transfer all the data bytes in one average-length record at the nominal data rate of the device.

   d. From the table of processor interference figures (see Figure 3.1 or 3.2), obtain the time taken to create a channel-end interruption.

   e. Add up the four times obtained in a, b, c, and d to obtain the channel-busy time per record.

3. Obtain the channel-busy time per second or the channel utilization by multiplying the channel-busy time per record (obtained in step 2e) with the average number of records to be transferred per second.

Figure 4.1 gives example calculations of channel utilization for IBM 3410 Magnetic Tape Units Model 1 and 3 working at nominal data rates of 20 and 80 kilobytes per second, respectively.

```
Assumptions:
  1000 bytes per record; four records to be transferred per second; no command chaining
----------------------------------------------------------------------------------------
Example 1
  3410-1 working at a nominal data rate of 20 kilobytes/second

  I/O activities:
  a. Issue read/write command                                        .098 ms
  b. Gap time                                                      48.00  ms
  c. Transfer 1000 bytes at nominal data rate                      50.00  ms
  d. Create channel-end interruption pending condition               .078 ms
                                                                  ---------
     Channel-busy time for one record                   =          98.176 ms
                                                                  =========
  Therefore, at four records per second,
  the channel-busy time per second                      = 4 X 99.176 ms
                                                        =    392.704 ms
  From which, channel utilization                       = .39 = 39% (approximately)
----------------------------------------------------------------------------------------
Example 2
  3410-3 working at a nominal data rate of 80 kilobytes/second

  I/O activities:
  a. Issue read/write command                                        .098 ms
  b. Gap time                                                      12.000 ms
  c. Transfer 1000 bytes at nominal data rate                      12.500 ms
  d. Create channel-end interruption pending condition               .078 ms
                                                                  ---------
     Channel-busy time for one record                   =          24.676 ms
                                                                  =========
  Therefore, at four records per second,
  the channel-busy time per second                      = 4 X 24.676 ms
                                                        =     98.704 ms
  From which, channel utilization                       = .099 = 9.9% (approximately)
```

Fig. 4.1 Example Calculations of Percentage Channel Utilization for a 3410 Magnetic Tape Unit Model 1 and a 3410 Model 3 having Nominal Data Rates of 20 and 80 Kilobytes per Second.

Notes on the examples in Figure 4.1

1. Channel time spent on handling commands and interruptions (which are microprogram activities) is insignificant. In calculations of this type, these times can normally be ignored.

2. The increased data rate (in Example 2) causes the channel utilization to be reduced. The interference with the processor remains unchanged, however, and, as shown in Figure A-1, the priority loading is greater, a factor which may affect devices on the byte multiplexer channel.

PROCEDURE FOR DIRECT ACCESS STORAGE DEVICES

For the purpose of calculating disk channel utilizations it is necessary to distinguish four basically different modes of disk and channel operation, namely

1. Selector channel mode without seek separation, (and without block multiplexing and rotational position sensing), where the channel is busy from the transfer of the seek command until completion of the command chain with 'channel end' and 'device end' (compare Fig. 4.2).

2. Selector channel mode with seek separation (without block multiplexing and rotational position sensing), where in comparisons to (1) the channel is not busy during execution of the seek command. (Requires additional SIO instruction plus transfer of seek command.)

3. Block multiplex mode (or selector channel mode with seek separation) but without rotational position sensing where in comparison to (1) the channel is not busy during execution of the seek command (similar to (2), but without additional SIO instruction and seek command).

4. Block multiplex mode with rotational position sensing, where in comparison to (1) the channel is not busy during execution of the seek command and not busy during execution of most of the search period.

Illustrations of the various channel busy times for modes (1)...(4) are given in Fig. 4.2 for a typical chain of SEEK, SEARCH, TIC, READ commands.

Selector channel mode (1) is the classical way of operating old disks. It requires the least amount of processor overhead, but gives the highest channel utilization. The cases (2) and (3) selector channel with seek separation and multiplexing mode, gives equivalent channel utilization, but (2) requires less supervisor time. Block multiplexing with RPS (4), gives finally the smallest amount of channel utilization but requires additional supervisor time. This is the reason why, for low channel usage, it may be better for total system performance to use mode (3) without rotational position sensing.

Typical values for the timings of Fig. 4.2. are given in Fig. 4.3 and 4.4 for the disks attachable to the IBM 4331 processor. Two examples of channel utilization were calculated in Fig. 4.5.

1. SELECTOR CHANNEL MODE (least processor overhead)

```
         SEEK TIME                  SEARCH TIME     READ TIME

-------------------------------------------------------------
|///|//////////////////////|//|////////////////|//|/////////|
-------------------------------------------------------------

SEEK                       SEARCH              READ
COMMAND                    TIC                 COMM.
```

2. SELECTOR CHANNEL WITH SEEK SEPARATION (more supervisor time needed for additional SIO/construction)

```
                                    SEARCH TIME     READ TIME

------ - - - - - - - - - -  ----------------------------------
|///|                      |//|//|/////////////|//|/////////|
------ - - - - - - - - - -  ----------------------------------

SEEK                       SEARCH              READ
COMMAND                    TIC                 COMM.
```

3. BLOCK MULTIPLEXING MODE (less supervisor time than (2))

```
                                    SEARCH TIME     READ TIME

------ - - - - - - - - - -  ----------------------------------
|///|                      |//|////////////////|//|/////////|
------ - - - - - - - - - -  ----------------------------------

SEEK                       SEARCH              READ
COMMAND                    TIC                 COMM.
```

4. BLOCK MULTIPLEXING WITH RPS (additional processor time needed to create CCW's)

```
                                                    READ TIME

------ - - - - - - - - - -  ---- - - - - - -  ----------------
|///|                      |//|             |//|//|/////////|
------ - - - - - - - - - -  ---- - - - - - -  ----------------

SEEK                       SET              SEARCH  READ
COMMAND                    SECTOR           TIC     COMM.
```

Fig. 4.2. MODES OF DISK/CHANNEL OPERATION.
(channel busy times marked ///)

ALL TIMES IN MILLISECONDS

FUNCTIONS OF DEVICE	2311-1 -11	2314/19 2311/12	3310	3370	3340 DDA[3]	231X on 3310
AVERAGE SEEK TIME	75	60	23.5	22	25	23.5
AVERAGE SEARCH TIME						
WITHOUT RPS	12.5	12.5	-	-	10.1	9.6
WITH RPS	-	-	1.8	1.6	.89	1.8
READ TIME FOR 2048 BYTE						
WITHOUT RPS	13.13	6.56	-	-	10.1[2]	9.1
WITH RPS	-	-	2400	1580	5.05[1]	-
ADDITIONAL TIME FOR WRITE:						
WITHOUT RPS	0	0	0	0	20.2	11.6
WITH RPS	-	-	0	0	20.2	-

[1] Av. Read 1/4 track

[2] Av. Read 1/2 track

[3] DDA = Direct Disk Attachment

Fig. 4.3 CHANNEL BUSY TIMES DUE TO DEVICE-SPECIFIC FUNCTIONS

	ALL TIMES IN MSEC			
	231X	3310[1]	3370	3340 DDA[3]
SEEK command				
SEEK command	.098	(SEEK)		(DEV.
transfer SEEK address	.010			SEL. +
command chaining at CE[2]	.177	.764		SEEK)
total	.285			2.970
SET SECTOR command:				
SET FILE MASK command	.098	(SEARCH)		(NOT
TIC command	.010			APPLIC.)
SET SECTOR command	.098	.470		
comm. chaining at CE[2]	.177			
total	.383			
READ COMMAND	.098	.360		1.620
WRITE COMMAND	.098	.360		2.240
CH. END/DEV. END	.079	.196		(N. A.)

Fig. 4.4 CHANNEL BUSY TIMES DUE TO COMMAND HANDLING IN CHANNEL

[1] includes hardware busy times overlapped with Traplevel 4
[2] CE = channel end.
[3] DDA = Direct Disk Attachment

Example: 2314 with Block Multiplexing

SEEK command = 0.285 msec
SEARCH = 12.500 msec
READ command = 0.177 msec
2048 B read time = 6.654 msec

total = 19.526 msec/record

Channel busy time for 25 rec./sec = 25 x 19.53 msec/sec
= 488 msec/sec
= 48.8 %

EXAMPLE: 3310 (effectively block multiplexing with RPS)

SEEK command = .680 msec
SET SECTOR = .490 msec
SEARCH time = 1.800 msec
READ command = .595 msec
2048 B read time = 2.400 msec

total = 5.965 msec/record

Channel busy time for 25 rec/sec = 25 x 5.965 msec/sec
= 149 msec/sec
= 14.9 %

Assumptions: 2048 bytes per record, 25 records per sec

Fig. 4.5 EXAMPLE CALCULATIONS OF CHANNEL UTILIZATION FOR 2314 AND 3310

IMPACT OF CHANNEL UTILIZATION ON I/O ACCESS TIME

I/O access time in an unloaded system consists of the following parts

- time to transfer commands over the channel
- time for the device to access the data
- time to transfer the data over the channel

If several devices contend for the usage of the channel, the channel service times for command handling and data transfer have to be incremented by wating times for channel service. For most channel services this waiting will be directly proportional to the channel utilization, or

(effective channel utilization)

x .5 x (average channel service time.)

Channel utilization and average channel service times can be computed with the data given in section 'calculation of channel utilisation'. However, the channel utilization and service times for the device under investigation should be excluded from the computation.

A special kind of I/O response time delay occurs for disks employing the rotational position sensing feature or its equivalent on disks implementing the fixed block architecture. Here the waiting time for the channel's data transfer service is increased by a full rotation provided the disk is ready for data transmission but the channel is still busy with another device. In this case a good estimate for the additional waiting delay is given by

(Disk rotation time)

x (effect. channel util.)/ (1 - effect channel util.)

In Fig. 4.6 an example calculation is given for additional waiting times occuring with a 3310 on a channel with 50% effective utilization by other disks.

<u>EXAMPLE</u>: 3310, effective channel utilization 50%
blocklength 2048 bytes

channel useage time = 5.965 msec
(from Fig. 4.5, Example 2)
av. seek time = 23.5 msec
(from Fig. 4.3)

----

total access time = 29.465 msec

Av. channel serv. time = total channel usage time /3
= 5.965 /3 = 1.99 msec

Av. waiting delays for command transfers
= 2 x (effective ch. util.) x .5 x(aver. ch. service time)
= 2 x .5 x .5 x 1.99 msec = .995 msec

AV wating delays for data transfer
= (Disk rotation time)x (effect. chann. util.)/(1- eff. ch. util.)
= (19.2 x .5) /(1 - 0.5)) msec = 19.2 msec

Total average waiting delays = 20.195 msec

Due to channel contention the av. disk access time
is increased by
20.2/29.5 = 68%

Fig. 4.6 Calculation of disk access time, including waiting times due to channel contention.

EFFECT OF CHANNEL CONTENTION ON SYSTEM THROUGHPUT

The main effect of channel contention is to increase I/O access times. The effect of increased I/O access times on system throughput is discussed here. This effect is of course very much application dependent and therefore in general difficult to predict. Comparing an ideal system (without channel contention) with a real system (having channel contention) it is easy to see that the enlarged I/O access times will have little effect on system throughput of the real system provided the processor utilization is high. While the largest effect of channel contention will occur for low processor utilization.

With the reasonable assumption that all I/O time of the ideal system is equally affected by channel contention, a conservative estimate for the throughput of the real system is obtained by dividing the system throughput of the ideal system by

1 + (relative I/O time increase) x (1 - proc. util. of orig. system)

where the relative I/O time increase of the real system is obtained by dividing the additional I/O time due to channel contention by the original I/O time.

IMPLICIT ASSUMPTIONS

CHANNEL PROGRAMMING CONVENTIONS

The procedures given in this manual for checking data overrun assume that channel programs have command sequences that provide efficient operation of I/O devices, and avoid placing unnecessarily large loads on the channels. This section of the manual gives the permissible ways in which commands may be command chained so that the programmer can prevent or, at least, reduce the possibility of overrun during concurrent I/O operations.

Because overrun is caused by excessive load on the processor, these conventions apply to channel programs for all devices, including those that are not subject to overrun.

The command sequence conventions are recommended for use in the writing of channel programs for the IBM 4331 processor, especially for a system that uses multiprogramming in which the programmer is not aware of the overall load on channel facilities. If a programmer controls or has knowledge of all I/O activity, however, he may establish somewhat less restrictive channel programming conventions that may be particularly suited to his application and configuration.

IMMEDIATE OPERATIONS

When commands that cause immediate (or near-immediate) operations are chained together ('no-op' commands, for example) many commands are executed in a short time, thus imposing a heavy continuous load on the channel and causing interference with other lower-priority devices. Therefore, non-data transferring commands that are completed rapidly should not be chained.

DATA CHAINING

The programmer is free to specify data chaining in channel programs, although a channel is able to transfer data at a faster rate, without overrun, when data chaining is not specified.

The procedures and tables in this manual provide guidance in assessing the effects of data chaining.

CHAINABLE COMMANDS

The channel programming conventions permit only certain commands to be command-chained, as shown in Figures 5.1 through 5.6. Commands that do not appear in these figures should not be command-chained; that is, they can appear only in single-command channel programs.

Note: For diagnostic or device feature-dependent commands, reference should be made to the device-associated manuals.

Figures 5.1 through 5.6 list the chainable commands in classes that define the permitted positions of each command in a channel program. These classes are as follows:

Class-A Commands: Class-A commands are permitted to occur anywhere in a channel program and may be chained in any sequence without restriction.

Class-B Commands: A class-B command is permitted to occur anywhere in a channel program but must not be chained to another class-B command.

Class-C Commands: A class-C command is permitted to appear as the first channel command word (CCW) of a channel program. In general, they provide a function required only once at the beginning of the channel program, and are executed at speeds that impose a somewhat larger load than those of class-B.

Class-D Commands: A class-D command is permitted to appear only as the last CCW of a channel program.

Class A commands (Any position in a channel program, and in any sequence.)		Class B commands (Any position in a channel program, but not chained to to each other.)		Class C commands (First CCW in a channel program.)		Class D commands (Last CCW in a channel program.)	
Command	**Command byte**	**Command**	**Command byte**	**Command**	**Command byte**	**Command**	**Command byte**
Erase	XXXX XX01	Seek	0000 0111 000X 1011			No-op ⓐ	0000 0011
No-op ⓐ	0000 0011	Set sector	0010 0011	The following command *chain* may be treated as a single class-C command:		Restore ⓓ	0001 0111
Read	XXXX XX10	TIC ⓒ	XXXX 1000	Seek ↓ Set file mask ↓ TIC	0000 0111 000X 1011 0001 1111 XXXX 1000		
Recalibrate ⓑ	0001 0011						
Search	XXXX XX01						
Write	XXXX XX01	Each of the following command *chains* may also be treated as a single class-B command:					
		TIC ↓ Seek	XXXX 1000 0000 0111 000X 1011				
		Seek ↓ TIC	0000 0111 0000 1011 XXXX 1000				
		TIC ↓ Seek ↓ Set sector	XXXX 1000 0000 0111 000X 1011 0010 0011				
		Seek ↓ Set sector ↓ TIC	0000 0111 000X 1011 0010 0011 XXXX 1000				

Notes (circled letters):

ⓐ **The 'no-op' command is treated as a class A command when preceded by the 'formatting write' command (0001 XX01 or 0000 0001); otherwise it is treated as a class D command.**

ⓑ **The 'recalibrate' command is not defined for all DASD devices.**

ⓒ **The following chain of commands is not permitted: Search ⟶ TIC ⟶ write.**

ⓓ **The 'restore' command is defined for the IBM 2321 Data Cell Drive only.**

X = 0 or 1, depending on command code for particular device

Figure 5.1. Chainable commands on direct access storage devices, permitted positions in channel program

Class A commands (Any position in a channel program, and in any sequence.)		Class B commands (Any position in a channel program, but not chained to each other.)		Class C commands (First CCW in a channel program.)		Class D commands (Last CCW in a channel program.)	
Command	Command byte	Command	Command byte	Command	Command byte	Command	Command byte
Backspace	0010 X111	TIC	XXXX 1000	Set mode	XXXX X011 (excepting 'no-op': 0000 0011)	No-op	0000 0011
Erase gap	0001 0111					Rewind	0000 0111
Forward space	0011 X111					Rewind and unload	0000 1111
Read	XXXX XX10			The following command *chain* may be treated as a single class-C command:			
Read backward	XXXX 1100						
Write	XXXX XX01			Set mode	XXXX X011		
Write tapemark	0001 1111			TIC	XXXX 1000		

X = 0 or 1, depending on command code for particular device

Figure 5.2. Chainable commands on tape devices - permitted positions in channel program

Class A commands (Any position in a channel program, and in any sequence.)		Class B commands (Any position in a channel program but not chained to each other.)		Class C commands (First CCW in a channel program.)		Class D commands (Last CCW in a channel program.)	
Command	Command byte	Command	Command byte	Command	Command byte	Command	Command byte
Read	XXXX XX10	TIC	XXXX 1000	Control	XXXX XX11	Control	XXXX XX11
Write	XXXX XX01						

X = 0 or 1, depending on command code for particular device

Figure 5.3. Chainable commands on card devices - permitted positions in channel program

Class A commands (Any position in a channel program, and in any sequence.)		Class B commands (Any position in a channel program, but not chained to each other.)		Class C commands (First CCW in a channel program.)		Class D commands (Last CCW in a channel program.)	
Command	Command byte	Command	Command byte	Command	Command byte	Command	Command byte
Write	XXXX XX01	TIC	XXXX 1000	Control	XXXX XX11	Control	XXXX XX11

X = 0 or 1, depending on command code for particular device

Figure 5.4. Chainable commands on printer devices - permitted positions in channel program

Class A commands (Any position in a channel program, and in any sequence.)		Class B commands (Any position in a channel program, but not chained to each other.)		Class C commands (First CCW in a channel program.)		Class D commands (Last CCW in a channel program.)	
Command	**Command byte**	**Command**	**Command byte**	**Command**	**Command byte**	**Command**	**Command byte**
Read inquiry	0000 1010	TIC	XXXX 1000	–	–	Control	XXXX XX11
Write	0000 X001						

X = 0 or 1, depending on command code for particular device

Figure 5.5. Chainable commands on Console Display-Keyboard, permitted positions in channel program

Class A commands (Any position in a channel program, and in any sequence.)		Class B commands (Any position in a channel program, but not chained to each other.)		Class C commands (First CCW in a channel program.)		Class D commands (Last CCW in a channel program.)	
Command	**Command byte**	**Command**	**Command byte**	**Command**	**Command byte**	**Command**	**Command byte**
Break	XXXX XX01	TIC	XXXX 1000	Set mode	0010 0011	No-op	0000 0011
Diagnostic read a	XXXX XX10						
Diagnostic write a	XXXX XX01						
Dial ⓐ	XXXX XX01						
Disable	0010 1111						
Enable	0010 0111						
Inhibit ⓐ	XXXX XX10						
Poll ⓐ	XXXX XX01						
Prepare	XXXX XX10						
Read ⓐ	XXXX XX10						
Search ⓐ	XXXX XX10						
Sense ⓑ	0000 0100						
Write ⓐ	XXXX XX01						
The following command *chain* may be treated as a single class-A command:							
No-op ⓒ ↓	0000 0011						
TIC ⓒ	XXXX 1000						

Notes (circled letters):

ⓐ Channel programming conventions permit data chaining with or without TIC.

ⓑ The 'sense' command is class A only when it is used instead of a program-controlled interruption to signal that a program has reached a particular point.

ⓒ The no-op → TIC chain is treated as a single class-A command only when it is used as a modifiable switch.

X = 0 or 1, depending on command code for particular device

Figure 5.6. Chainable commands on communications adapters (2701, 2702, 2703, and CA), permitted positions in Channel Program

APPENDIX A. CHANNEL EVALUATION FACTORS FOR DEVICES ATTACHED TO BMPX AND DASD/MAGNETIC TAPE ADAPTERS.

The following tables contain the A and B load factors for devices attachable to the block multiplexer channel and to the DASD/Magnetic Tape adapters for worst case load conditions including command chaining operations.

Priority load factors for the data transfer only (first 4 rows of Load SUM Worksheet) can be computed from:

B = .023 x Data Rate in KB/sec

The B-factors of Fig. A-1 are not valid if there is data chaining, unless the data chaining is used on DASD devices and the data chaining takes place in the gap time only.

To account for the additional load when data chaining is used (other than in DASD Gap Time), add

5.8 x (Data Rate in KB/sec)/(smallest byte count
being data chained)

to the B factor obtained from Figure A-1.

Name	Nominal data rate (kilobytes/second)	Rotation time (milliseconds)	Priority Load		
			Time	A	B
2250 Display Unit	526.0	-	.114	9.97	12.3
2311 Disk Storage Drive Models 1, 11, and 12	156.0	25.0	.114 .400	2.05 30.00	82.0 12.5
2314 Direct Acess Storage Facility - Series A and B 2319 Disk Storage Model A1	312.0	25.0	.114 .400	2.96 28.40	74.0 16.5
3270 Information Display System	500.0	-	.114	11.4	0.00
3340 Disk Storage	885.3	20.2	.10	0.00	20.36
3310 Disk Storage	1031.0	19.2	.10	0.00	23.70
3370 Disk Storage	1859.0	20.2	.10 .275	0.00 3.52	42.7 29.7

Figure A-1: Block Multiplexer and DASD Adapter Devices Channel Evaluation Factors

Name	Density B/Inch	Data Conv.	Data Rate KB/Sec	Gap Time M/Sec	Priority Load		
					Time	A	B
2401 Model 1	200	No	7.5	20.0	.10	11.40	0.00
					19.47	8.04	.17
		Yes	5.6	20.0	.10	11.40	0.00
					19.29	8.92	.13
	556	No	20.8	20.0	.10	11.40	0.00
					19.81	1.92	.48
		Yes	15.6	20.0	.10	11.40	0.00
					19.74	4.32	.36
	800	No	30.0	26.0*	.10	11.40	0.00
					15.87	.45	.69
		Yes	22.5	20.0	.10	11.40	0.00
					19.82	1.14	.52
2401 Model 2	200	No	15.0	10.0	.10	11.40	0.00
					9.73	8.04	.34
		Yes	11.3	10.0	.10	11.40	0.00
					9.65	8.89	.26
	556	No	41.7	10.0	.10	11.40	0.00
					9.90	2.04	.95
		Yes	31.1	10.0	.10	11.40	0.00
					9.87	4.34	.72
	800	No	60.0	8.0*	.10	11.40	0.00
					7.93	.45	1.38
		Yes	45.0	10.0	.10	11.40	0.00
					.91	1.14	1.03
2401 Model 3	200	No	22.5	6.7	.10	11.40	0.00
					6.52	8.02	.52
		Yes	16.9	6.7	.10	11.40	0.00
					6.46	8.89	.39
	556	No	62.5	6.7	.10	11.40	0.00
					.64	1.86	1.44
		Yes	46.9	6.7	.10	.40	0.00
					6.62	4.26	1.08
	800	No	90.0	5.3*	.10	11.40	0.00
					5.26	.52	2.02
		Yes	67.5	6.7	.10	11.40	0.00
					6.64	1.09	1.55
2401 Model 4	800	+	30.0	16.0	.10	11.40	0.00
					15.87	.45	.69
	1600	+	60.0	16.0	.10	11.40	0.00
					8.26	0.00	1.38

* Nine Track Gap Time
\+ Data Conversion not used in this model

Figure A-2: (Part 1 of 3) Channel Evaluation Factors for Magnetic Tape Drives

Name	Density B/Inch	Data Conv.	Data Rate KB/Sec	Gap Time M/Sec	Priority Load		
					Time	A	B
2401 Model 5	800	+	60.0	8.0	.10	11.40	0.00
					7.93	.45	1.38
	1600	+	120.0	8.0	.10	11.40	0.00
					4.13	0.00	2.76
2401 Model 6	800	+	90.0	5.3	.10	11.40	0.00
					5.26	.52	2.07
	1600	+	180.0	5.3	.10	11.40	0.00
					2.75	0.00	4.14
2401 Model 8	200	No	15.0	10.0	.10	11.40	0.00
					9.73	8.04	.34
		Yes	11.3	10.0	.10	11.40	0.00
					9.65	8.89	.26
	556	No	41.7	10.0	.10	11.40	0.00
					9.90	1.90	.96
		Yes	31.3	10.0	.10	11.40	0.00
					9.87	4.29	.72
	800	No	60.0	10.0	.10	11.40	0.00
					8.26	0.00	1.38
		Yes	45.0	10.0	.10	11.40	0.00
					9.91	1.14	1.03
2415 and control unit 1...6	200	No	3.8	40.0	.10	11.40	0.00
					39.95	8.00	.09
		Yes	2.8	40.0	.10	11.40	0.00
					38.57	8.92	.06
	556	No	10.4	40.0	.10	11.40	0.00
					39.62	1.92	.24
		Yes	7.8	40.0	.10	11.40	.00
					39.49	4.32	.18
	800	No	15.0	32.0*	.10	11.40	.00
					31.73	.45	.34
		Yes	11.3	40.0	.10	11.40	.00
	1600	+	30.0	32.0*	.10	11.40	.00
3410 Model 1	1600	+	20.0	48.0	.10	11.40	.09
					20.79	0.00	.46
3410 Model 2	800	+	20.0	24.0	.10	11.40	0.00
					23.80	.45	.46
	1600	+	40.0	24.0	.10	11.40	0.00
					12.3	0.00	.92

* Nine Track Gap Time
\+ Data Conversion not used in this model

Figure A-2: (Part 2 of 3) Channel Evaluation Factors for Magnetic Tape Drives

Name	Density B/Inch	Data Conv.	Data Rate KB/Sec	Gap Time M/Sec	Priority Load		
					Time	A	B
3410	800	+	40.0	12.0	.10	11.40	0.00
Model 3					11.90	.45	.92
	1600	+	80.0	12.0	.10	11.40	0.00
					6.26	0.00	1.84
3420	556	No	41.7	10.0	.10	11.40	0.00
Model 3					9.90	9.90	.96
		Yes	31.3	10.0	.10	11.40	0.00
					9.87	4.29	.72
	800	No	60.0	8.0*	.10	11.40	0.00
					7.93	.45	1.38
		Yes	45.0	10.0	.10	11.40	0.00
					9.91	1.14	1.03
	1600	+	120.0	8.0	.10	11.00	0.00
					4.13	0.00	2.76
3420	1600	+	120.0	8.0	.10	11.00	0.00
Model 4					4.13	0.00	2.76
	6250	+	470.0	4.0	.10	11.40	0.00
					1.05	0.00	10.81
3420	556	No	69.5	6.0	.10	11.40	0.00
Model 5					5.94	1.90	1.60
		Yes	52.1	6.0	.12	11.40	0.00
					5.92	4.30	1.20
	800	No	100.0	4.8*	.10	11.40	0.00
					4.76	.45	2.3
		Yes	75.0	6.0	.10	11.40	0.00
					5.95	1.14	1.72
	1600	+	200.0	4.8	.10	11.40	0.00
					2.48	0.00	4.60
3420	556	No	11.2	3.75	.10	11.40	0.00
Model 7					3.71	1.90	2.56
		Yes	83.4	3.75	.10	11.40	0.00
					3.70	4.30	1.92
	800	No	160.0	3.0	.10	11.40	0.00
					2.98	.45	3.68
		Yes	120.0	3.75	.10	11.40	0.00
					3.72	1.14	2.76
	1600	+	320.0	3.0	.10	11.40	0.00
					1.55	0.00	7.36
8809	1600	+	160.0	6.0	.10	10.98	3.68

* Nine Track Gap Time
\+ Data Conversion not used in this model

Figure A-2: (Part 3 of 3) Channel Evaluation Factors for Magnetic Tape Drives

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APPENDIX B. BYTE MULTIPLEXER DEVICES CHANNEL EVALUATION FACTORS

The following tables contain the wait times, device loads, previous loads, and priority load factors A and B for class 1 devices attachable to the Byte Multiplexer Channel. This data is needed to perform the calculation with the load worksheet.

INPUT/OUTPUT DEVICE	CLASS	DATA RATE KB/S	CYCLE TIME MSEC.	WAIT TIME MSEC.	DEVICE LOAD	PREV. LOAD	PRIORITY LOAD		
							TIME	A	B
1255 Magnetic Character Reader Model 1, 21	1M	0.33	120	0.68	10.15	14.7	.204 .91 1.22	20.4 0 24.5	0 22.5 2.4
1255 Magnetic Character Reader, Model 2, 3, 22, 23	1M	0.50	80	0.68	10.15	14.7	.204 .91 1.22	20.4 0 22.9	0 22.5 3.7
1287 Optical Reader 1428 & ASCS OCR font	1M	2.50	var	0.40	17.75	25.0	.296 1.34 7.69	29.60 5.55 19.17	0.00 18.00 16.23
1428 & ASCS OCR font with blank detection	1M	2.50	var	0.13	54.60	76.9	.296 .70 40.00	29.60 4.50 47.14	0.00 36.00 25.34
1428 & ASCS OCR font with imprinting	1M	0.50	var	2.00	3.55	5.0	.296	28.36	4.15
7B/Gothic font	1M	0.40	var	2.50	2.84	4.0	.296 25.00	28.70 20.20	3.00 3.34
Alphanumeric Mode	1M	1.0	var	1.0	7.1	10.0	.296 .67	28.94 23.10	0.00 8.42
Numeric handwritten characters	1M	0.33	var	3.0	2.37	3.33	.296 28.60	28.85 20.26	2.50 2.80
Handwritten with blank detection	1M	0.33	var	1.50	4.73	6.67	.296 2.50	29.60 16.95	0.00 5.22
Mark read 10 positions	1M	1.00	var	1.00	7.10	10.00	.296 20.00	28.40 20.00	3.80 4.20
Mark read 12 positions	1M	0.86	var	2.30	3.09	4.35	.296 3.30	28.70 26.50	3.00 3.70

Figure B-1: (Part 1 of 5) Byte Multiplexer Devices Channel Evaluation Factors

INPUT/OUTPUT DEVICE	CLASS	DATA RATE KB/S	CYCLE TIME MSEC.	WAIT TIME MSEC.	DEVICE LOAD	PREV. LOAD	PRIORITY LOAD		
							TIME	A	B
1287 Optical Reader							.10	9.90	0.00
Roll form	1M	2.50	var	0.40	17.75	25.00	.23	5.76	18.00
							18.20	67.00	14.63
Roll form with							.10	9.90	0.00
separate mark	1M	2.50	var	0.40	17.75	25.00	.23	5.31	18.30
line command							23.38	81.54	14.90
Roll form with							.10	9.90	0.00
blank detection	1M	2.50	var	0.20	35.50	58.00	.23	5.76	18.00
							18.20	67.00	14.63
Roll form with blank							.10	9.90	0.00
detection and sepa-	1M	2.50	var	0.20	35.50	58.00	.23	5.31	18.30
rate mark line comm.							23.38	81.54	14.90
1288 Optical Page							.26	26.1	0.0
Reader Formattet	1M	1.00	var	1.00	5.3	10.0	1.09	0.0	24.0
alphanumeric							1.32	23.0	6.5
Unformattet							.26	26.1	0.0
alphanumeric	1M	0.33	var	1.50	3.5	6.7	1.52	0.0	17.2
							1.82	26.4	2.7
Handwritten/							.26	26.1	0.0
Gothic font	1M	0.67	var	1.50	3.5	6.7	1.52	0.0	17.2
							1.82	26.4	2.7
							.26	26.1	0.0
Mark read 1 position	1M	1.00	var	1.00	5.3	5.3	1.09	0.0	24.0
							1.32	23.1	6.5
							.26	26.1	0.0
Mark read 2 positions	1M	0.56	var	1.77	3.0	5.6	1.72	0.0	15.2
							2.08	24.0	3.7
							.26	26.1	0.0
Mark read 3 positions	1M	0.39	var	2.54	2.1	3.9	2.44	0.0	10.8
							2.86	23.5	2.6
							.26	26.1	0.0
Mark read 4 positions	1M	0.30	var	3.31	1.6	3.0	3.03	0.0	8.6
							3.92	26.0	2.0
							.26	26.1	0.0
Mark read 5 positions	1M	o.49	var	4.08	1.3	2.5	3.62	0.0	7.2
							4.40	24.6	1.6

Figure B-1: (Part 2 of 5) Byte Multiplexer Devices Channel Evaluation Factors

INPUT/OUTPUT DEVICE	CLASS	DATA RATE KB/S	CYCLE TIME MSEC.	WAIT TIME MSEC.	DEVICE LOAD	PREV. LOAD	PRIORITY LOAD		
							TIME	A	B
1288 Optical Page Mark read 6 positions	1M	0.41	var	4.85	1.1	2.1	.26 4.35 5.19	26.1 0.0 24.2	0.0 6.0 1.3
Mark read 7 positions	1M	0.36	var	5.62	.9	1.8	.26 5.03 5.95	26.1 0.0 24.6	0.0 5.2 1.2
Mark read 8 positions	1M	0.31	var	6.39	.8	1.6	.26 5.56 6.67	26.1 0.0 24.5	0.0 4.7 1.0
Mark read 9 positions	1M	0.28	var	7.16	.7	1.4	.26 6.21 7.46	26.1 0.0 24.5	0.0 4.2 .9
Mark read 10 positions	1M	0.25	var	7.93	.7	1.3	.26 6.87 8.20	26.1 0.0 24.3	0.0 3.8 .8
Mark read 11 positions	1M	0.23	var	8.70	.6	1.1	.26 7.46 9.09	26.1 0.0 24.9	0.0 3.5 .8
Mark read 12 positions	1M	0.21	var	9.47	.6	1.1	.26 8.13 9.80	26.1 0.0 24.6	0.0 3.2 .7
1419 Magnetic Character Reader S/360 Adapter -Single Address	1M	1.25	32.3	0.65	10.60	15.40	.20 .84 2.00	20.41 4.89 8.14	0.00 18.00 16.33
S/360 Adapter- Single Address,and Batch Numbering	1M	1.25	32.3	0.65	10.60	15.40	.40 .95	39.79 22.39	0.00 17.20
S/360 Adapter- Dual Address,as supported by DOS	1M	1.25	32.3	0.65	10.60	15.40	.32 1.0 16.70	32.3 16.0 115.3	0.00 15.20 10.80
1442 Card Read Punch Model N1 Punch only EBCDIC	2M	0.12	656.0	11.00	.74	.90	.10	10.56	1.32
Punch only column binary	2M	0.24	656.0	11.00	.92	.90	.100	10.60	1.02

Figure B-1: (Part 3 of 5) Byte Multiplexer Devices Channel Evaluation Factors

INPUT/OUTPUT DEVICE	CLASS	DATA RATE KB/S	CYCLE TIME MSEC.	WAIT TIME MSEC.	DEVICE LOAD	PREV. LOAD	PRIORITY LOAD		
							TIME	A	B
1442 Card Read Punch							.100	8.93	15.00
Read/punch	1/2M	0.35	806.0	0.80	8.87	12.50	3.390	30.50	8.00
EBCDIC							68.400	32.90	3.60
Read/punch							.100	8.21	22.00
column binary	1/2M	1.07	806.0	0.80	11.00	12.50	2.380	34.50	10.50
							68.500	411.00	4.50
2501 Card Reader							.100	10.50	0.00
Model B1	1M	0.80	100.0	0.91	7.65	10.90	.322	5.83	14.60
EBCDIC							30.420	264.30	5.74
							.100	10.50	0.00
Column binary	1M	1.60	100.0	0.91	8.20	10.90	.268	6.35	15.70
							25.000	300.00	6.14
2501 Card Reader							.100	10.53	0.00
Model B2	1M	1.33	60.0	0.91	7.65	10.90	.325	5.65	15.00
EBCDIC							25.000	140.00	9.57
							.100	10.35	0.00
Column binary	1M	2.67	60.0	0.91	8.20	10.90	.272	6.13	16.20
							25.000	151.00	10.20
2520 Card Read Punch							.100	9.20	0.00
Model B1	1/2M	1.33	120.0	1.02	6.86	9.80	.260	5.40	13.20
Read/punch EBCDIC							43.500	365.00	4.80
Read/punch							.100	9.20	0.92
column binary	1/2M	2.67	120.0	1.02	7.75	9.80	.158	6.56	14.80
							43.500	409.00	5.40
2520 Card Read Punch									
Model B1 and 2520							.100	0.00	100.00
Card Punch Model B2	2M	0.67	120.0	9.00	21.10	1.11	3.450	3.45	2.87
Punch-only EBCDIC									
Punch-only							.100	0.00	100.00
column binary	2M	1.33	120.00	9.00	42.2	1.11	6.770	639.00	5.64
2520 Card Punch							.100	0.00	100.00
Model B3	2M	0.40	200.00	15.00	36.9	0.67	3.450	338.00	1.70
Punch-only EBCDIC									
Punch-only							.100	0.00	100.00
column binary	2M	0.80	200.00	15.00	73.8	0.67	6.770	654.00	3.34

Figure B-1: (Part 4 of 5) Byte Multiplexer Devices Channel Evaluation Factors

INPUT/OUTPUT DEVICE	CLASS	DATA RATE KB/S	CYCLE TIME MSEC.	WAIT TIME MSEC.	DEVICE LOAD	PREV. LOAD	PRIORITY LOAD		
							TIME	A	B
2701 DATA ADAPTER UNIT	1M	SEE APPENDIX D							
2702 TRANSMISSION CTRL.	1M	SEE APPENDIX E							
2703 TRANSMISSION CTRL.	1M	SEE APPENDIX F							
7770 AUDIO RESP. UNIT	1M								
8 lines		.096	Var.	9.02	.76	1.11	.10	8.22	5.53
							11.10	62.50	.64
16 lines		.192	Var.	4.49	1.54	2.23	.10	8.22	5.53
							23.70	108.70	1.28
24 lines		.288	Var.	2.99	2.31	3.34	.10	8.22	5.53
							36.20	138.90	1.92
32 lines		.384	Var.	1.48	4.66	6.76	.10	8.22	5.53
							48.80	153.10	2.56
40 lines		.480	Var.	1.48	4.66	6.76	.10	8.22	5.53
							61.40	151.30	3.20
48 lines		.576	Var.	1.48	4.66	6.76	.10	8.22	5.53
							74.00	133.30	3.84

Figure B-1: (Part 5 of 5) Byte Multiplexer Devices Channel Evaluation Factors

APPENDIX C. COMMUNICATIONS ADAPTER CHANNEL EVALUATION FACTORS

This appendix describes how to obtain the following factors for the CA and how to enter them on the byte multiplexer channel load sum worksheet:

Wait time
Device load
Previous load
Priority-load time, A, and B factors.
These factors are needed at step 2 of the step-by-step procedure for testing channel data (see Figure 2.11).

WAIT TIME:
In Figure C-1, find those entries that relate to the line types and data rates of the proposed CA configuration. From these entries, identify those that contain the shortest wait time. Enter this wait time at the top of the CA column, on the worksheet as shown in the examples in Figure C-2, column 1).

DEVICE LOAD:
From the entries in Figure C-1 that contain the shortest wait time, select one that has the highest device load. Multiply this device-load figure by the number of communication lines to be used minus one (regardless of type and speed of line) and enter the result in the 'Device Load' box in column 1 of the worksheet. (See Example C-2).

PREVIOUS LOAD:
From the applicable entries in Figure C-1 select the one having the largest previous load. Enter this figure in the 'previous load' box in column 1 of the worksheet.

PRIORITY-LOAD A AND B FACTORS:
In Figure C-1, find the priority-load A and B factors that relate to the line types and data rates of the proposed CA configuration. From these entries:

1. Add up all the A factors for every communication line that is to be used in the configuration. Enter the sum in the 'Priority Load' A column in the box corresponding to device position 1 (row number 1) of the worksheet, as shown in Figure C-3.

2. Add up all the B factors for every communication line that is to be used in the configuration. Enter the sum in the 'Priority Load' B column in the box corresponding to device position 1 (row number 1) of the worksheet.

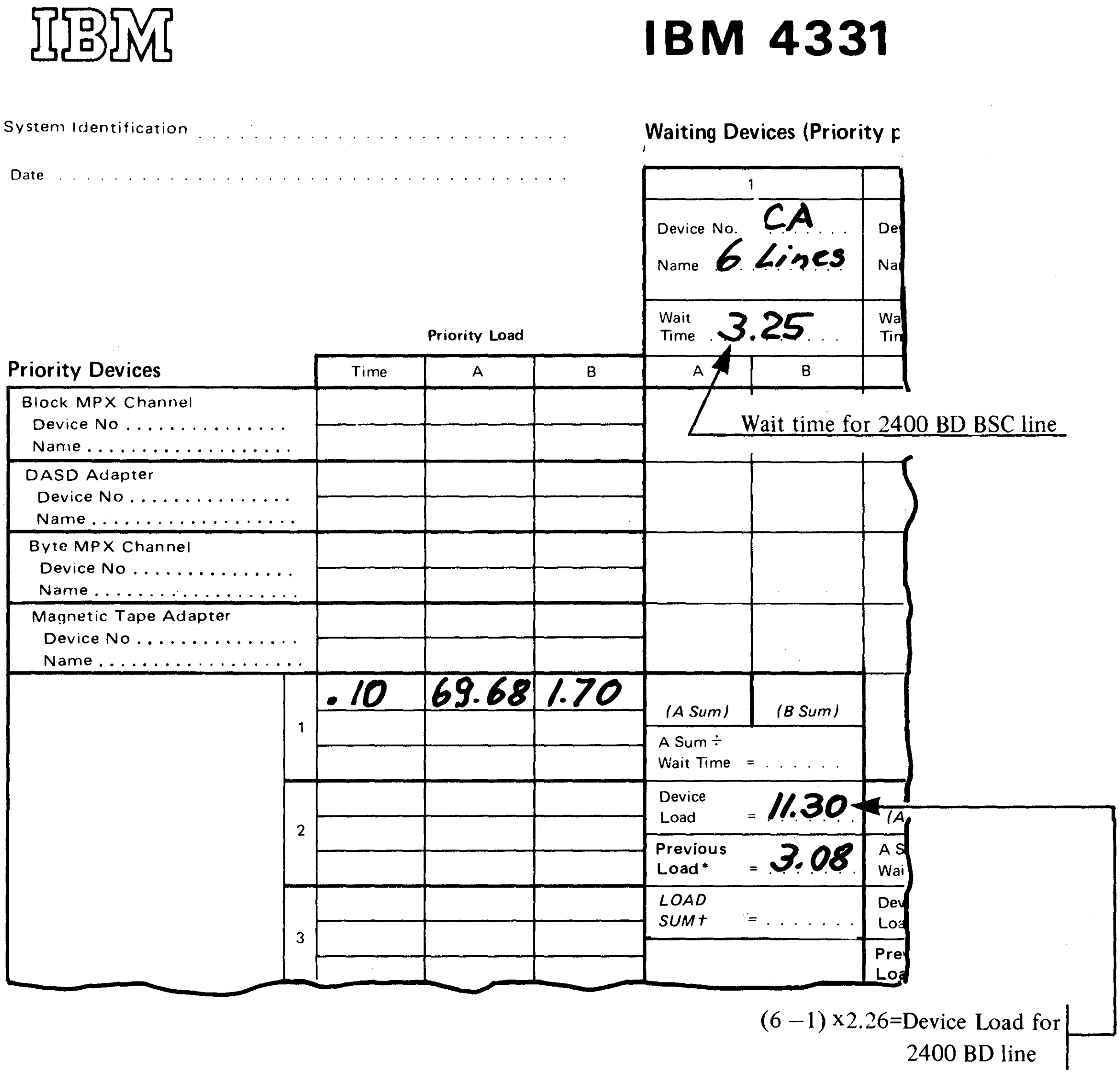
These A and B factors are valid for all waiting devices. Therefore, enter the figure 0.10 in the 'Priority Load' time subcolumn of the CA row (row 1).

Line control	Mode of Operation	Bit Rate b/sec	Data Rate B/sec	Wait Time ms	CA Dev. Load	CA ** Prev. Load	Priority load		
							Time	A	B
BSC/ SDLC *	with autopolling	600	75	13.30	0.55	0.75	0.19	11.61	0.25
	with autopolling	1200	150	6.60	1.12	1.52	0.19	11.57	0.50
	with autopolling	2400	300	3.25	2.26	3.08	0.19	11.47	1.00
	with autopolling	3600	450	2.15	3.42	4.65	0.19	11.37	1.50
	with autopolling	4800	600	1.60	4.60	6.25	0.19	11.27	2.00
	without autopolling	4800	600	1.62	1.70	6.17	0.19	11.34	1.65
	with autopolling	7200	900	1.03	7.15	9.71	0.19	11.10	3.00
	without autopolling	7200	900	1.06	2.60	9.43	0.19	11.75	2.48
	with autopolling	9600	1200	0.75	9.81	13.33	0.19	10.00	8.25
							1.11	15.50	3.31
	without autopolling	9600	1200	0.78	3.54	12.82	0.19	11.00	3.31
	without autopolling	19200	2400	0.78	3.54	12.82	0.19	10.35	6.62
	without autopolling	56000	7000	0.23	12.00	43.50	0.19	7.82	19.32
	without autopolling	64000	8000	0.20	13.80	2.50	0.19	7.26	22.10
SS	-	134.5	14.8	67.70	0.11	0.15	0.19	11.66	0.05
	-	300	33.4	30.00	0.25	0.33	0.19	11.65	0.10
	-	600	66.7	15.00	0.49	0.67	0.19	11.63	0.20
	-	1200	133.3	7.40	0.99	1.35	0.19	11.59	0.40

* No polling with SDLC lines

** These values are valid if more than one line is used. For a single communication line use Prev.Load= .5/(Wait Time in msec)

Figure C-1: Communication Adapter Channel Evaluation Factors



IBM

IBM 4331

System Identification . . . .

Date . . . .

Waiting Devices (Priority p

1

Device No. CA

Name 6 Lines

Wait Time 3.25

Wait time for 2400 BD BSC line

Priority Devices

		Priority Load				
		Time	A	B	A	B
Block MPX Channel Device No . . . . Name						
DASD Adapter Device No . . . . Name						
Byte MPX Channel Device No . . . . Name						
Magnetic Tape Adapter Device No . . . . Name						
	1	.10	69.68	1.70	(A Sum)	(B Sum)
					A Sum ÷ Wait Time = ...	
	2				Device Load = 11.30	
					Previous Load* = 3.08	
	3				LOAD SUM† = ...	

(6 −1) x2.26=Device Load for 2400 BD line

Above entries relate to the following configuration:

4 Start Stop lines with 134.5 bps each
1 Binary Synchronous Comun. line with 1200 bps
1 Binary Synchronous Comun. line with 2400 bps

Figure C-2: Example Entries in Load Sum Worksheet For a Typical CA Configuration.

		Associated	
No.	Type of Line	A-Factor	B-Factor
1	134.5 bps, SS	11.66	.05
2	134.5 bps, SS	11.66	.05
3	134.5 bps, SS	11.66	.05
4	134.5 bps, SS	11.66	.05
5	1200 bps, BSC	11.57	.50
6	2400 bps, BSC	11.47	1.00
	Totals	69.68	1.70

Figure C-3: Generation of A and B Factors For A Typical CA Configuration

APPENDIX D. IBM 2701 DATA ADAPTER UNIT: PRIORITY ASSIGNMENT AND CHANNEL EVALUATION FACTORS

This appendix describes:

1. How to assign the priority of a 2701 Data Adapter Unit in relation to other devices (including other 2701s) on the byte multiplexer channel.

2. How to enter 2701 priority information on the byte multiplexer channel load sum worksheet. This information is needed at step 1 of Figure 2.11 when testing byte multiplexer channel data overrun.

3. How to obtain the following channel evaluation factors for each line connected to a 2701:

   Wait time
   Device load
   Previous load
   Priority-load time, A, and B factors

   This information is needed at steps 2 and/or 3 of Figure 2.11.

HOW TO ASSIGN PRIORITY POSITION OF A 2701

A 2701 may serve several communication lines, each with a different wait time. The effective wait time to be used in assigning the priority position of the 2701 relative to other devices on the byte multiplexer channel is determined by:

1. Refer to Figure D-1 and find those entries that relate to the types and speeds of communication lines proposed for the 2701.

2. Choose the entry that has the shortest wait time. For example, consider a 2701 that will serve the following communication lines:

   IBM Terminal Adapter Type I Model II at 134.5 bps.
   (Wait time = 63.20 ms.)

   IBM Terminal Adapter Type Model II, at 600 bps.
   (Wait time = 14.20 ms.)

   Synchronous Data Adapter Type II, operating with eight-bit code, without autopolling, at 200 bps.
   (Wait time = 7.70 ms.)

On this 2701, the shortest wait time is 7.70 ms; this figure is used in assigning the priority position of the 2701 as a whole.

HOW TO ENTER 2701 PRIORITY INFORMATION ON LOAD SUM WORKSHEET

In step 1 of Figure 2.11 when testing for byte multiplexer channel data overrun, enter 2701 communication lines on the load sum worksheet as if they were individual waiting devices. Make the entries in a continuous block and, within the block, assign decreasing priorities to the communication lines in the order of their increasing wait times; the communication lines with the shorter wait times must get the higher priorities. Figure D-1 gives wait times for all types and speeds of 2701 communication lines.

Figure D-2 shows how a typical 2701 and its attached communication lines should appear in the 'Waiting Devices' columns of the load sum worksheet in relation to other devices.

HOW TO OBTAIN CHANNEL EVALUATION FACTORES FOR EACH 2701 COMMUNICATION LINE

In steps 2 and/or 3 of Figure 2.11, when testing byte multiplexer channel data overrun, treat each communication line as a separate waiting device; obtain the wait time, device load, previous load, and priority-load time, and A and B factors for each of the 2701 communication lines direct from Figure D-1.

Features of 2701	Bit rate (bps)	Data rate (cps)	Wait time (ms)	Device load	Previous load	Priority load		
						Time	A	B
IBM Terminal Adapter Type I Model II	134.5	14.80	63.20	0.087	0.16	0.11	0.11	0.00
						17.06	7.61	0.08
	600	66.70	14.20	0.39	0.70	0.11	9.0	0.00
						3.89	7.57	0.37
IBM Terminal Adapter Type II	600	60.00	14.20	0.39	0.70	0.11	9.0	0.00
						4.31	7.58	0.33
IBM Terminal Adapter Type III	1200	120.00	8.30	0.66	1.20	0.11	9.0	0.00
						2.59	7.29	0.66
	2400	240.00	4.20	1.13	2.38	0.11	9.0	0.00
						1.19	7.43	1.32
Synchronous Data Adapter Type I	1200	150.00	5.80	0.95	1.72	0.11	9.0	0.00
						1.81	7.51	0.82
	2000	250.00	3.50	1.57	2.86	0.11	9.0	0.00
						1.15	7.43	1.37
	2400	300.00	2.90	1.90	3.45	0.11	9.0	0.00
						0.98	7.38	1.65
	19200	2400.00	0.36	12.40	27.78	0.11	9.0	0.00
						0.25	5.71	13.20
	40800	5100.00	0.17	32.35	58.82	0.11	9.0	0.00
						0.14	4.93	28.05
Synchronous Data Adapter Type II Operating with eight-bit code, without autopolling	600	75.00	25.80	0.21	0.39	0.105	9.5	0.00
						3.47	8.07	0.41
	1200	150.00	12.90	0.43	0.78	0.105	9.5	0.00
						1.70	8.10	0.82
	2000	250.00	7.70	0.71	1.30	0.105	9.5	0.00
						1.15	7.92	1.37
	2400	300.00	6.40	0.86	1.56	0.105	9.5	0.00
						0.89	7.88	1.65
	3600	450.00	4.27	1.29	2.34	0.105	9.5	0.00
						0.71	7.75	2.47
	4800	600.00	3.20	1.72	3.13	0.105	9.5	0.00
						0.57	7.63	3.30
	7200	900.00	2.13	2.58	4.69	0.105	9.5	0.00
						0.43	7.38	4.95
	19200	2400.00	0.81	6.79	12.35	0.105	9.5	0.00
						0.25	6.14	13.20
	40800	5100.00	0.38	14.47	26.32	0.105	9.5	0.00
						0.20	3.92	28.05
	50000	6250.00	0.31	17.74	32.26	0.105	9.5	0.00
						0.19	4.34	34.47

Figure D-1 (Part 1 of 2). 2701 Evaluation Factors

Features of 2701	Bit rate (bps)	Data rate (cps)	Wait time (ms)	Device load	Previous load	Priority load		
						Time	A	B
Synchronous Data Adapter Type II, operating with six-bit code, without autopolling	600	100.00	19.20	0.29	0.52	0.11	9.5	0.00
						2.14	8.32	0.55
	1200	200.00	9.60	0.57	1.04	0.11	9.5	0.00
						1.40	7.96	1.10
	2000	333.00	5.70	0.96	1.75	0.11	9.5	0.00
						0.906	7.84	1.83
	2400	400.00	4.80	1.14	2.08	0.11	9.5	0.00
						0.78	7.79	2.20
	19200	3200.00	0.60	9.17	16.67	0.11	9.5	0.00
						0.23	5.47	17.60
	40800	6800.00	0.28	19.64	35.71	0.11	9.5	0.00
						0.15	3.89	37.40
	50000	8333.00	0.23	23.91	43.48	0.11	9.5	0.00
						0.15	2.63	45.83
Synchronous Data Adapter Type II, operating with eight-bit code, with autopolling	600	60.00	14.20	0.39	0.70	0.11	9.5	0.00
						3.49	8.06	0.41
	1200	150.00	7.10	0.77	1.41	0.11	9.5	0.00
						1.82	8.00	0.82
	2000	250.00	4.20	1.19	2.38	0.11	9.5	0.00
						1.15	7.92	1.37
	2400	300.00	3.50	1.57	2.86	0.11	9.5	0.00
						0.89	7.88	1.65
	4800	600.00	1.80	3.05	5.56	0.11	9.5	0.00
						0.57	7.62	3.30
Synchronous Data Adapter Type II, operating with six-bit code, with autopolling	600	100.00	10.80	0.51	0.93	0.11	9.5	0.00
						2.65	8.04	0.55
	1200	200.00	5.40	1.01	1.85	0.11	9.5	0.00
						1.40	7.96	1.10
	2000	333.00	3.20	1.72	3.13	0.11	9.5	0.00
						0.906	7.84	1.83
	2400	400.00	2.70	2.04	3.70	0.11	9.5	0.00
						0.78	7.79	2.20
Telegraph Adapter Type I	45.5	6.00	141.30	0.04	0.07	0.105	9.0	0.00
	56.9	7.50	113.20	0.05	0.09	0.105	9.0	0.00
	74.2	10.00	86.90	0.06	0.12	0.105	9.0	0.00
Telegraph Adapter Type II	110	10.00	85.80	0.06	0.12	0.105	9.0	0.00
World Trade Telegraph	50	6.60	128.70	0.04	0.08	0.105	9.0	0.00
	75	10.00	85.80	0.06	0.12	0.105	9.0	0.00
World Trade Telegraph Single-Current Adapter	50	6.60	128.70	0.04	0.08	0.105	9.0	0.00
	75	10.00	85.80	0.06	0.12	0.105	9.0	0.00

Figure D-1 (Part 2 of 2). 2701 Channel Evaluation Factors

The entries below (for step 1 in Figure 2.11) relate to the following byte-multiplexer channel devices:

1. IBM 2520 Card Read Punch Model B1, reading/punching EBCDIC. (Wait time = 1.02 ms.)

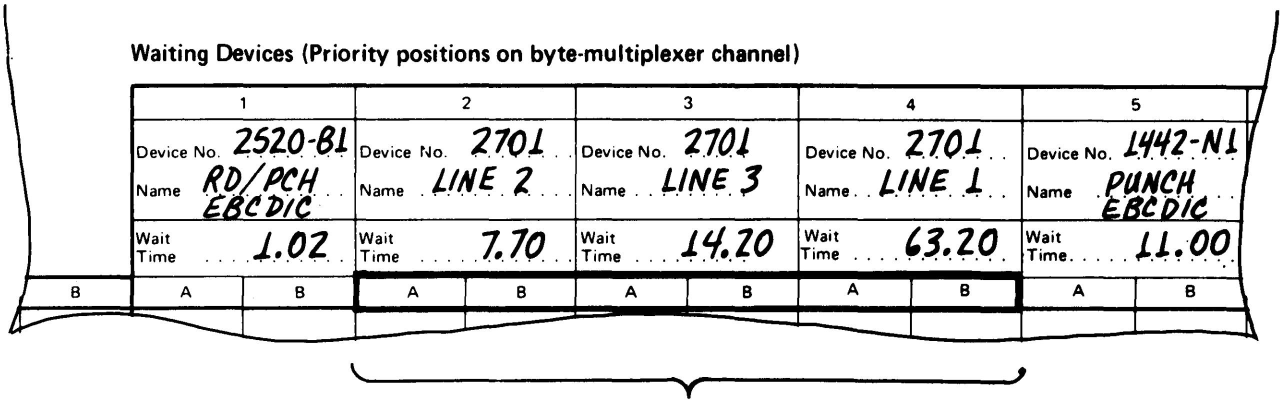
2. IBM 2701 Data Adapter Unit serving communication lines which use the following ty pes of line control:

   Line 1. IBM Terminal Adapter Type I Model II, at 134.5 bits/second. (Wait time = 63.20 ms.)

   Line 2. Synchronous Data Adapter Type II, Operating with eight-bit code, without autopolling, at 200 bits/second. (Wait time = 7.70 ms.)

   Line 3. IBM Terminal Adapter Type I Model II at 600 bits/second. (Wait time = 14.20 ms.)

3. IBM 1442 Card Read Punch Model N1, punching EBCDIC. (Wait time = 11.00 ms.)



Waiting Devices (Priority positions on byte-multiplexer channel)

1	2	3	4	5
Device No. 2520-B1	Device No. 2701	Device No. 2701	Device No. 2701	Device No. 1442-N1
Name RD/PCH EBCDIC	Name LINE 2	Name LINE 3	Name LINE 1	Name PUNCH EBCDIC
Wait Time 1.02	Wait Time 7.70	Wait Time 14.20	Wait Time 63.20	Wait Time 11.00
A B	A B	A B	A B	A B

Communication lines with shorter wait times are given higher priorities

Figure D-2. Example Showing How the 2701 and its Attached Communication Lines Should Appear in the 'Waiting Devices' Columns of the Load Sum Worksheet

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APPENDIX E. IBM 2702 TRANSMISSION CONTROL: PRIORITY ASSIGNMENT AND CHANNEL EVALUATION FACTORS

This appendix describes:

1. How to assign the priority of a 2702 Transmission Control in relation to other devices (including other 2702s) on the byte-multiplexer channel, for use in step 1 of Figure 2.11 when testing byte-multiplexer channel data overrun.
2. How to obtain the following channel evaluation factors of a 2702 for use in steps 2 and/or 3 of Figure 2.11.

    Wait time
    Device load
    Previous load
    Priotiry-load time, A, and B factors.

In this appendix, reference is made to the tables of channel evaluation factors given in Figures E-1 through E-26. The following guide is included to help the reader find the correct table(s):

Type of Terminal Control	Figure
IBM Terminal Control Type I	
75 bps, with autopolling	E-1 & E-2*
75 bps, without autopolling	E-3 & E-4*
134.5 bps, with autopolling	E-5 & E-6*
134.5 bps, without autopolling	E-7 & E-8*
600 bps, with autopolling	E-9
600 bps, without autopolling	E-10
IBM Terminal Control Type II	
600 bps, with autopolling	E-11
600 bps, without autopolling	E-12
Telegraph Terminal Control I	
45.5 bps	E-13 & E-14*
56.9 bps	E-15 & E-16*
74.2 bps	E-17 & E-18*
Telegraph Terminal Control Type II	
110 bps	E-19 & E-20*
World Trade Telegraph Terminal Control	
50 bps	E-21 & E-22*
75 bps	E-23 & E-24*
100 bps	E-25 & E-26*

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* When the 31-Line Expansion feature is installed, use the second of the two numbers listed.

PROCEDURE WHEN TERMINAL CONTROLS AND SPEEDS ARE ALIKE

When all the communication lines connected to the 2702 are to be served by identical terminal control features at the same speed, see the foregoing list. Then find the entry relating to the number of communication lines to be served. Use the wait time in that entry when assigning the priority position of the 2702 on the byte-multiplexer channel, as described under "How to Assign Priorities of Byte-Multiplexer Channel Devices" in the section "Data Overrun".

Also from the same entry, record the wait time, device load, previous load, and all the priority-load time, A, and B factors on the byte-multiplexer channel load sum worksheet as shown in the exaple in Figure E-27.

PROCEDURE WHEN TERMINAL CONTROLS AND SPEEDS ARE DIFFERENT

When the communication lines connected to the 2702 are to be served by different terminal control features at different speeds, assign the 2702 priority and obtain the priority and channel evaluation factors by the following procedures.

HOW TO ASSIGN PRIORITY POSITION OF A 2702

The different types of communication line conneted to the 2702 may well have different wait times. Therefore, calculate the effective wait time for determining the priority position of the 2702 relative to other devices on the byte-multiplexer channel as follows:

1. Refer to those channel evaluation factor tables that relate to the types and speeds of lines to be served; see the foregoing list. In each relevant table, note the wait time in the first entry, that is, in the entry corresponding to one available line.
2. Select the shortest wait time found in step 1 and divide it by the total number of communication lines to be served by the 2702, regardless of their types and speeds.

The resultant figure is the effective wait time used for assigning the priority position of the 2702 in relation to other devices.

For example, consider a 2702 that will serve the following communication lines:

Lines 1 through 10, IBM Terminal Control Type II, at 75 bps, with autopolling, without the 31-line expansion feature.

Lines 11 through 15, IBM Terminal Control Type II, at 600 bps, with autopolling.

From Figures E1 and E11, the "one available line" wait times are 115.66ms and 14.38 ms respectively. The total number of cummunication lines is 15. The effective wait time - used only for assigning a priority position to the 2702 - is, therefore, 14.38 divided by 15 = .958ms.

HOW TO OBTAIN CHANNEL EVALUATION FACTORS OF A 2702

1. Refer to the channel evaluation factor table that yielded the shortest "one available line" wait time, as described in "How to Assign Priority Position of 2702". In this table, find the entry that corresponds to the total number of lines being served by the 2702 - regardless of their type and speed.

2. From this entry, take the wait time, device load, previous load, and priority-load time, A and B factors for use in steps 2 and/or of Figure 2.11 when testing for byte-multiplexer channel data overrun.

   For instance, to obtain the channel evaluation factors for the 2702 desribed in the previous example, refer to Figure E-11 because this table yielded the shortest "one available line" wait time. From this table, take the factors belonging to the 15-line entry.

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
1	115.664	.078	.086	.100	9.000	10.742
				.535	14.747	.046
2	57.584	.156	.174	.100	7.418	17.578
				.758	12.597	10.742
				1.527	28.860	.092
3	38.384	.234	.261	.100	7.418	17.578
				1.320	16.440	10.742
				2.519	43.154	.137
4	28.784	.313	.347	.100	7.418	17.578
				1.882	20.284	10.742
5	23.024	.391	.434	.100	7.418	17.578
				2.444	24.128	10.742
				4.503	71.468	.229
6	19.184	.469	.521	.100	7.418	17.578
				3.007	27.972	10.742
				5.495	85.489	.275
7	16.304	.552	.613	.100	7.418	17.578
				3.569	31.815	10.742
				6.487	99.419	.321
8	14.384	.626	.695	.100	7.418	17.578
				4.131	35.659	10.742
				7.479	113.258	.367
9	12.464	.722	.802	.100	7.418	17.578
				4.694	39.503	10.742
				8.471	127.006	.412
10	11.504	.782	.869	.100	7.418	17.578
				5.256	43.347	10.742
				9.463	140.663	.458
11	10.064	.894	.994	.100	7.418	17.578
				5.818	47.190	10.742
				10.455	154.229	.504
12	9.584	.939	1.043	.100	7.418	17.578
				6.380	51.034	10.742
				11.447	167.704	.550
13	8.624	1.044	1.160	.100	7.418	17.578
				6.943	54.878	10.742
				12.439	181.088	.596
14	8.144	1.105	1.228	.100	7.418	17.578
				7.505	58.722	10.742
				13.431	194.382	.642
15	7.664	1.174	1.305	.100	7.418	17.578
				8.067	62.565	10.742
				14.423	207.584	.687

Figure E-1: 2702 Channel Evaluation Factors, IBM Terminal Control Type I (75 bps), with Autopolling, without 31-Line Expansion

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
1	115.056	.078	.087	.100	9.000	5.371
				1.047	14.624	.046
2	57.520	.156	.174	.100	8.209	8.789
				1.270	12.548	5.371
				3.063	28.719	.092
3	37.680	.239	.265	.100	8.209	8.789
				2.344	16.220	5.371
				5.079	42.802	.137
4	28.752	.313	.348	.100	8.209	8.789
				3.418	19.892	5.371
				7.095	56.699	.183
5	22.800	.395	.439	.100	8.209	8.789
				4.492	23.564	5.371
				9.111	70.412	.229
6	18.832	.478	.531	.100	8.209	8.789
				5.567	27.236	5.371
				11.127	83.940	.275
7	15.856	.568	.631	.100	8.209	8.789
				6.641	30.908	5.371
				13.143	97.283	.321
8	13.872	.649	.721	.100	8.209	8.789
				7.715	34.580	5.371
				15.159	110.442	.367
9	11.888	.757	.841	.100	8.209	8.789
				8.790	38.251	5.371
				17.175	123.415	.412
10	10.896	.826	.918	.100	8.209	8.789
				9.864	41.923	5.371
				19.191	136.204	.458
11	9.904	.909	1.010	.100	8.209	8.789
				10.938	45.595	5.371
				21.207	148.808	.504
12	8.912	1.010	1.122	.100	8.209	8.789
				12.012	49.267	5.371
				23.223	161.227	.550
13	7.920	1.136	1.263	.100	8.209	8.789
				13.087	52.939	5.371
				25.239	173.462	.596
14	7.920	1.136	1.263	.100	8.209	8.789
				14.161	56.611	5.371
				27.255	185.511	.642
15	6.928	1.299	1.443	.100	8.209	8.789
				15.235	60.283	5.371
				29.271	197.376	.687
16	6.928	1.299	1.443	.100	8.209	8.789
				16.310	63.955	5.371
				31.287	209.056	.733

Figure E-2: 2702 Channel Evaluation Factors, IBM Terminal Control Type I (75 bps), with Autopolling, with 31-Line Expansion (part 1 of 2)

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
17	5.936	1.516	1.685	.100	8.209	8.789
				17.384	67.626	5.371
				33.303	220.551	.779
18	5.936	1.516	1.685	.100	8.209	8.789
				18,458	71.298	5.371
				35.319	231.862	.825
19	5.936	1.516	1.685	.100	8.209	8.789
				19.532	74.970	5.371
				37.335	242.987	.871
20	4.944	1.820	2.023	.100	8.209	8.789
				20.607	78.642	5.371
				39.351	253.928	.917
21	4.944	1.820	2.023	.100	8.209	8.789
				21.681	82.314	5.371
				41.367	264.684	.962
22	4.944	1.820	2.023	.100	8.209	8.789
				22.755	85.986	5.371
				43.383	275.255	1.008
23	4.944	1.820	2.023	.100	8.209	8.789
				23.830	89.658	5.371
				45.399	285.642	1.054
24	3.952	2.277	2.530	.100	8.209	8.789
				24.904	93.330	5.371
				47.415	295.843	1.100
25	3.952	2.277	2.530	.100	8.209	8.789
				25.978	97.001	5.371
				49.431	305.860	1.146
26	3.952	2.277	2.530	.100	8.209	8.789
				27.052	100.673	5.371
				51.447	315.692	1.192
27	3.952	2.277	2.530	.100	8.209	8.789
				28.127	104.345	5.371
				53.463	325.340	1.237
28	3.952	2.277	2.530	.100	8.209	8.789
				29.201	108.017	5.371
				55.479	334.802	1.283
29	3.952	2.277	2.530	.100	8.209	8.789
				30.275	111.689	5.371
				57.495	344.080	1.329
30	2.960	3.041	3.378	.100	8.209	8.789
				31.350	115.361	5.371
				59.511	353.172	1.375
31	2.960	3.041	3.378	.100	8.209	8.789
				32.424	119.033	5.371
				61.527	362.080	1.421

Figure E-2: 2702 Channel Evaluation Factors, IBM Terminal Control Type I (75 bps), with Autopolling, with 31-Line Expansion (part 2 of 2)

LINE	WAIT	DEVICE	PREV.	PRIORITY - LOAD		
NO.	TIME	LOAD	LOAD	TIME	A	B
1	115.664	.048	.086	.100	9.000	.046
2	57.584	.096	.174	.100	7.418	17.578
				.602	17.945	.092
3	38.384	.143	.261	.100	7.418	17.578
				1.114	26.847	.137
4	28.784	.191	.347	.100	7.418	17.578
				1.626	35.702	.183
5	23.024	.239	.434	.100	7.418	17.578
				2.138	44.510	.229
6	19.184	.287	.521	.100	7.418	17.578
				2.650	53.271	.275
7	16.304	.337	.613	.100	7.418	17.578
				3.162	61.986	.321
8	14.384	.382	.695	.100	7.418	17.578
				3.674	70.653	.367
9	12.464	.441	.802	.100	7.418	17.578
				4.186	79.273	.412
10	11.504	.478	.869	.100	7.418	17.578
				4.698	87.847	.458
11	10.064	.547	.994	.100	7.418	17.578
				5.210	96.373	.504
12	9.584	.574	1.043	.100	7.418	17.578
				5.722	104.853	.550
13	8.624	.638	1.160	.100	7.418	17.578
				6.234	113.286	.596
14	8.144	.675	1.228	.100	7.418	17.578
				6.746	121.671	.642
15	7.664	.718	1.305	.100	7.418	17.578
				7.258	130.010	.687

Figure E-3: 2702 Channel Evaluation Factors, IBM Terminal Control Type I (75 bps), without Autopolling, without 31-Line Expansion

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
1	115.056	.048	.087	.100	9.000	.046
2	57.520	.096	.174	.100	8.209	8.789
				1.114	17.898	.092
3	37.680	.146	.265	.100	8.209	8.789
				2.138	26.706	.137
4	28.752	.191	.348	.100	8.209	8.789
				3.162	35.420	.183
5	22.800	.241	.439	.100	8.209	8.789
				4.186	44.041	.229
6	18.832	.292	.531	.100	8.209	8.789
				5.210	52.567	.275
7	15.856	.347	.631	.100	8.209	8.789
				6.234	61.000	.321
8	13.872	.396	.721	.100	8.209	8.789
				7.258	69.339	.367
9	11.888	.463	.841	.100	8.209	8.789
				8.282	77.584	.412
10	10.896	.505	.918	.100	8.209	8.789
				9.306	85.735	.458
11	9.904	.555	1.010	.100	8.209	8.789
				10.330	93.792	.504
12	8.912	.617	1.122	.100	8.209	8.789
				11.354	101.755	.550
13	7.920	.694	1.263	.100	8.209	8.789
				12.378	109.625	.596
14	7.920	.694	1.263	.100	8.209	8.789
				13.402	117.400	.642
15	6.928	.794	1.443	.100	8.209	8.789
				14.426	125.082	.687
16	6.928	.794	1.443	.100	8.209	8.789
				15.450	132.670	.738

Figure E-4: 2702 Channel Evaluation Factors, IBM Terminal Control Type I (75 bps), with Autopolling, without 31-Line Expansion (part 1 of 2)

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
17	5.936	.927	1.685	.100	8.209	8.789
				16.474	140.164	.779
18	5.936	.927	1.685	.100	8.209	8.789
				17.498	147.564	.825
19	5.936	.927	1.685	.100	8.209	8.789
				18.522	154.870	.871
20	4.944	1.112	2.023	.100	8.209	8.789
				19.546	162.083	.917
21	4.944	1.112	2.023	.100	8.209	8.789
				10.570	169.201	.962
22	4.944	1.112	2.023	.100	8.209	8.789
				21.594	176.226	1.008
23	4.944	1.112	2.023	.100	8.209	8.789
				22.618	183.157	1.054
24	3.952	1.392	2.530	.100	8.209	8.789
				23.642	189.994	1.100
25	3.952	1.392	2.530	.100	8.209	8.789
				24.666	196.737	1.146
26	3.952	1.392	2.530	.100	8.209	8.789
				25.690	203.386	1.192
27	3.952	1.392	2.530	.100	8.209	8.789
				26.714	209.941	1.237
28	3.952	1.392	2.530	.100	8.209	8.789
				27.738	216.403	1.283
29	3.952	1.392	2.530	.100	8.209	8.789
				28.762	222.771	1.329
30	2.960	1.858	3.378	.100	8.209	8.789
				29.786	229.044	1.375
31	2.960	1.858	3.378	.100	8.209	8.789
				30.810	235.224	1.421

Figure E-4: 2702 Channel Evaluation Factors, IBM Terminal Control Type I (75 bps), with Autopolling, without 31-Line Expansion (part 2 of 2)

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
1	64.304	.140	.156	.100	9.000	10.742
				.535	14.747	.082
2	32.144	.280	.311	.100	7.418	17.578
				.758	12.597	10.742
				1.527	28.749	.164
3	21.104	.426	.474	.100	7.418	17.578
				1.320	16.440	10.742
				2.519	42.879	.247
4	15.824	.569	.632	.100	7.418	17.578
				1.882	20.284	10.742
				3.511	56.846	.329
5	12.464	.722	.802	.100	7.418	17.578
				2.444	24.128	10.742
				4.503	70.649	.411
6	10.544	.854	.948	.100	7.418	17.578
				3.007	27.972	10.742
				5.495	84.290	.493
7	9.104	.989	1.098	.100	7.418	17.578
				3.569	31.815	10.742
				6.487	97.768	.575
8	7.664	1.174	1.305	.100	7.418	17.578
				4.131	35.659	10.742
				7.479	111.082	.658
9	6.704	1.342	1.492	.100	7.418	17.578
				4.694	39.503	10.742
				8.471	124.234	.740
10	6.224	1.446	1.607	.100	7.418	17.578
				5.256	43.347	10.742
				9.463	137.222	.822
11	5.744	1.567	1.741	.100	7.418	17.578
				5.818	47.190	10.742
				10.455	150.047	.904
12	5.264	1.710	1.900	.100	7.418	17.578
				6.380	51.034	10.742
				11.447	162.709	.986
13	4.784	1.881	2.090	.100	7.418	17.578
				6.943	54.878	10.742
				12.439	175.209	1.069
14	4.304	2.091	2.323	.100	7.418	17.578
				7.505	58.722	10.742
				13.431	187.545	1.151
15	3.824	2.354	2.615	.100	7.418	17.578
				8.067	62.565	10.742
				14.423	199.718	1.233

Figure E-5: 2702 Channel Evaluation Factors, IBM Terminal Control Type I (134.5 bps), with Autopolling, without 31-Line Expansion

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
1	64.464	.140	.155	.100	9.000	5.371
				1.047	14.624	.082
2	31.728	.284	.315	.100	8.209	8.789
				1.270	12.548	5.371
				3.063	28.496	.164
3	20.816	.432	.480	.100	8.209	8.789
				2.344	16.220	5.371
				5.079	42.248	.247
4	15.856	.568	.631	.100	8.209	8.789
				3.418	19.892	5.371
				7.095	55.667	.329
5	12.880	.699	.776	.100	8.209	8.789
				4.492	23.564	5.371
				9.111	68.756	.411
6	9.904	.909	1.010	.100	8.209	8.789
				5.567	27.236	5.371
				11.127	81.513	.493
7	8.912	1.010	1.122	.100	8.209	8.789
				6.641	30.908	5.371
				13.143	93.938	.575
8	7.920	1.136	1.263	.100	8.209	8.789
				7.715	34.580	5.371
				15.159	106.032	.658
9	6.928	1.299	1.443	.100	8.209	8.789
				8.790	38.251	5.371
				17.175	117.795	.740
10	5.936	1.516	1.685	.100	8.209	8.789
				9.864	41.923	5.371
				19.191	129.226	.822
11	4.944	1.820	2.023	.100	8.209	8.789
				10.938	45.595	5.371
				21.207	140.326	.904
12	4.944	1.820	2.023	.100	8.209	8.789
				12.012	49.267	5.371
				23.223	151.094	.986
13	4.944	1.820	2.023	.100	8.209	8.789
				13.087	52.939	5.371
				25.239	161.531	1.069
14	3.952	2.277	2.530	.100	8.209	8.789
				14.161	56.611	5.371
				27.255	171.637	1.151
15	3.952	2.277	2.530	.100	8.209	8.789
				15.235	60.283	5.371
				29.271	181.411	1.233
16	3.952	2.277	2.530	.100	8.209	8.789
				16.310	63.955	5.371
				31.287	190.854	1.315

Figure E-6: 2702 Channel Evaluation Factors, IBM Terminal Control Type I (134.5 bps), with Autopolling, with 31-Line Expansion (part 1 of 2)

LINE	WAIT	DEVICE	PREV.	PRIORITY - LOAD		
NO.	TIME	LOAD	LOAD	TIME	A	B
17	2.960	3.041	3.378	.100	8.209	8.789
				17.384	67.626	5.371
				33.303	199.966	1.397
18	2.960	3.041	3.378	.100	8.209	8.789
				18.458	71.298	5.371
				35.319	208.746	1.479
19	2.960	3.041	3.378	.100	8.209	8.789
				19.532	74.970	5.371
				37.335	217.194	1.562
20	2.960	3.041	3.378	.100	8.209	8.789
				20.607	78.642	5.371
				39.351	225.311	1.644
21	2.960	3.041	3.378	.100	8.209	8.789
				21.681	82.314	5.371
				41.367	233.097	1.726
22	1.968	4.573	5.081	.100	8.209	8.789
				22.755	85.986	5.371
				43.383	240.551	1.808
23	1.968	4.573	5.081	.100	8.209	8.789
				23.830	89.658	5.371
				45.399	247.674	1.890
24	1.968	4.573	5.081	.100	8.209	8.789
				24.904	93.330	5.371
				47.415	254.466	1.973
25	1.968	4.573	5.081	.100	8.209	8.789
				25.978	97.001	5.371
				49.431	260.926	2.055
26	1.968	4.573	5.081	.100	8.209	8.789
				27.052	100.673	5.371
				51.447	267.055	2.137
27	1.968	4.573	5.081	.100	8.209	8.789
				28.127	104.345	5.371
				53.463	272.852	2.219
28	1.968	4.573	5.081	.100	8.209	8.789
				29.201	108.017	5.371
				55.479	278.318	2.301
29	1.968	4.573	5.081	.100	8.209	8.789
				30.275	111.689	5.371
				57.495	283.453	2.384
30	1.968	4.573	5.081	.100	8.209	8.789
				31.350	115.361	5.371
				59.511	288.256	2.466
31	1.968	4.573	5.081	.100	8.209	8.789
				32.424	119.033	5.371
				61.527	292.727	2.548

Figure E-6: 2702 Channel Evaluation Factors, IBM Terminal Control Type I (134.5 bps), with Autopolling, with 31-Line Expansion (part 2 of 2)

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
1	64.304	.086	.156	.100	9.000	.082
2	32.144	.171	.311	.100	7.418	17.578
				.602	17.901	.164
3	21.104	.261	.474	.100	7.418	17.578
				1.114	26.725	.247
4	15.824	.348	.632	.100	7.418	17.578
				1.626	35.465	.329
5	12.464	.441	.802	.100	7.418	17.578
				2.138	44.121	.411
6	10.544	.522	.948	.100	7.418	17.578
				2.650	52.693	.493
7	9.104	.604	1.098	.100	7.418	17.578
				3.162	61.181	.575
8	7.664	.718	1.305	.100	7.418	17.578
				3.674	69.584	.658
9	6.704	.820	1.492	.100	7.418	17.578
				4.186	77.903	.740
10	6.224	.884	1.607	.100	7.418	17.578
				4.698	86.139	.822
11	5.744	.958	1.741	.100	7.418	17.578
				5.210	94.289	.904
12	5.264	1.045	1.900	.100	7.418	17.578
				5.722	102.356	.986
13	4.784	1.150	2.090	.100	7.418	17.578
				6.234	110.339	1.069
14	4.304	1.278	2.323	.100	7.418	17.578
				6.746	118.237	1.151
15	3.824	1.438	2.615	.100	7.418	17.578
				7.258	126.051	1.233

Figure E-7: 2702 Channel Evaluation Factors, IBM Terminal Control Type I (134.5 bps), without Autopolling, without 31-Line Expansion

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
1	64.464	.085	.155	.100	9.000	.082
2	31.728	.173	.315	.100	8.209	8.789
				1.114	17.817	.164
3	20.816	.264	.480	.100	8.209	8.789
				2.138	26.473	.247
4	15.856	.347	.631	.100	8.209	8.789
				3.162	34.960	.329
5	12.880	.427	.776	.100	8.209	8.789
				4.186	43.280	.411
6	9.904	.555	1.010	.100	8.209	8.789
				5.210	51.431	.493
7	8.912	.617	1.122	.100	8.209	8.789
				6.234	59.413	.575
8	7.920	.694	1.263	.100	8.209	8.789
				7.258	67.227	.658
9	6.928	.794	1.443	.100	8.209	8.789
				8.282	74.873	.740
10	5.936	.927	1.685	.100	8.209	8.789
				9.306	82.351	.822
11	4.944	1.112	2.023	.100	8.209	8.789
				10.330	89.660	.904
12	4.944	1.112	2.032	.100	8.209	8.789
				11.354	96.801	.986
13	4.944	1.112	2.023	.100	8.209	8.789
				12.378	103.774	1.069
14	3.952	1.392	2.530	.100	8.209	8.789
				13.402	110.578	1.151
15	3.952	1.392	2.530	.100	8.209	8.789
				14.426	117.214	1.233
16	3.952	1.392	2.530	.100	8.209	8.789
				15.450	123.682	1.315

Figure E-8: 2702 Channel Evaluation Factors, IBM Terminal Control Type I (134.5 bps), without Autopolling, with 31-Line Expansion (part 1 of 2)

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
17	2.960	1.858	3.378	.100	8.209	8.789
				16.474	129.981	1.397
18	2.960	1.858	3.378	.100	8.209	8.789
				17.498	136.112	1.479
19	2.960	1.858	3.378	.100	8.209	8.789
				18.522	142.074	1.562
20	2.960	1.858	3.378	.100	8.209	8.789
				19.546	147.869	1.644
21	2.960	1.858	3.378	.100	8.209	8.789
				10.570	153.494	1.726
22	1.968	2.795	5.081	.100	8.209	8.789
				21.594	158.952	1.808
23	1.968	2.795	5.081	.100	8.209	8.789
				22.618	164.241	1.890
24	1.968	2.795	5.081	.100	8.209	8.789
				23.642	169.362	1.973
25	1.968	2.795	5.081	.100	8.209	8.789
				24.666	174.315	2.055
26	1.968	2.795	5.081	.100	8.209	8.789
				25.690	179.099	2.137
27	1.968	2.795	5.081	.100	8.209	8.789
				26.714	183.715	2.219
28	1.968	2.795	5.081	.100	8.209	8.789
				27.738	188.163	2.301
29	1.968	2.795	5.081	.100	8.209	8.789
				28.762	192.442	2.384
30	1.968	2.795	5.081	.100	8.209	8.789
				29.786	196.553	2.466
31	1.968	2.795	5.081	.100	8.209	8.789
				30.810	200.495	2.548

Figure E-8: 2702 Channel Evaluation Factors, IBM Terminal Control Type I (134.5 bps), without Autopolling, with 31-Line Expansion (part 2 of 2)

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
1	14.384	.626	.695	.100	9.000	10.742
				.535	14.747	.367
2	7.184	1.253	1.392	.100	7.418	17.578
				.758	12.597	10.742
				1.527	27.880	.733
3	4.784	1.881	2.090	.100	7.418	17.578
				1.320	16.440	10.742
				2.519	40.729	1.100
4	3.344	2.691	2.990	.100	7.418	17.578
				1.882	20.284	10.742
				3.511	52.851	1.467
5	2.864	3.142	3.492	.100	7.418	17.578
				2.444	24.128	10.742
				4.503	64.244	1.833
6	2.384	3.775	4.195	.100	7.418	17.578
				3.007	27.972	10.742
				5.495	74.911	2.200
7	1.904	4.727	5.252	.100	7.418	17.578
				3.569	31.815	10.742
				6.487	84.850	2.567
8	1.424	6.320	7.022	.100	7.418	17.578
				4.131	35.659	10.742
				7.479	94.062	2.933
9	1.424	6.320	7.022	.100	7.418	17.578
				4.694	39.503	10.742
				8.471	102.546	3.300
10	1.424	6.320	7.022	.100	7.418	17.578
				5.256	43.347	10.742
				9.463	110.302	3.667
11	.944	9.534	10.593	.100	7.418	17.578
				10.455	117.331	4.033
12	.944	9.534	10.593	.100	7.418	17.578
				6.380	51.034	10.742
				11.447	123.633	4.400
13	.944	9.534	10.593	.100	7.418	17.578
				6.943	54.878	10.742
				12.439	129.207	4.767
14	.944	9.534	10.593	.100	7.418	17.578
				7.505	58.722	10.742
				13.431	134.054	5.133
15	.944	9.534	10.593	.100	7.418	17.578
				8.067	62.565	10.742
				14.423	138.174	5.500

Figure E-9: 2702 Channel Evaluation Factors, IBM Terminal Control Type I (600 bps), with Autopolling

LINE	WAIT	DEVICE	PREV.	PRIORITY - LOAD		
NO.	TIME	LOAD	LOAD	TIME	A	B
1	14.384	.382	.695	.100	9.000	.367
2	7.184	.766	1.392	.100	7.418	17.578
				.602	17.559	.733
3	4.784	1.150	2.090	.100	7.418	17.578
				1.114	25.775	1.100
4	3.344	1.645	2.990	.100	7.418	17.578
				1.626	33.615	1.467
5	2.864	1.920	3.492	.100	7.418	17.578
				2.138	41.080	1.833
6	2.384	2.307	4.195	.100	7.418	17.578
				2.650	48.170	2.200
7	1.904	2.889	5.252	.100	7.418	17.578
				3.162	54.884	2.567
8	1.424	3.862	7.022	.100	7.418	17.578
				3.674	61.223	2.933
9	1.424	3.862	7.022	.100	7.418	17.578
				4.186	67.186	3.300
10	1.424	3.862	7.022	.100	7.418	17.578
				4.698	72.774	3.667
11	.944	5.826	10.593	.100	7.418	17.578
				5.210	77.986	4.033
12	.944	5.826	10.593	.100	7.418	17.578
				5.722	82.823	4.400
13	.944	5.826	10.593	.100	7.418	17.578
				6.234	87.285	4.767
14	.944	5.826	10.593	.100	7.418	17.578
				6.746	91.371	5.133
15	.944	5.826	10.593	.100	7.418	17.578
				7.258	95.081	5.500

Figure E-10: 2702 Channel Evaluation Factors, IBM Terminal Control Type I (600 bps), without Autopolling

LINE	WAIT	DEVICE	PREV.	PRIORITY - LOAD		
NO.	TIME	LOAD	LOAD	TIME	A	B
1	14.384	.626	.695	.100	9.000	10.742
				.535	14.747	.330
2	7.184	1.253	1.392	.100	7.418	17.578
				.758	12.597	10.742
				1.527	27.992	.660
3	4.784	1.881	2.090	.100	7.418	17.578
				1.320	16.440	10.742
				2.519	41.006	.990
4	3.344	2.691	2.990	.100	7.418	17.578
				1.882	20.284	10.742
				3.511	53.365	1.320
5	2.864	3.142	3.492	.100	7.418	17.578
				2.444	24.128	10.742
				4.503	65.070	1.650
6	2.384	3.775	4.195	.100	7.418	17.578
				3.007	27.972	10.742
				5.495	76.120	1.980
7	1.904	4.727	5.252	.100	7.418	17.578
				3.569	31.815	10.742
				6.487	86.515	2.310
8	1.424	6.320	7.022	.100	7.418	17.578
				4.131	35.659	10.742
				7.479	96.255	2.640
9	1.424	6.320	7.022	.100	7.418	17.578
				4.694	39.503	10.742
				8.471	105.341	2.970
10	1.424	6.320	7.022	.100	7.418	17.578
				5.256	43.347	10.742
				9.463	113.772	3.300
11	.944	9.534	10.593	.100	7.418	17.578
				5.818	47.190	10.742
				10.455	121.548	3.630
12	.944	9.534	10.593	.100	7.418	17.578
				6.380	51.034	10.742
				11.447	128.670	3.960
13	.944	9.534	10.593	.100	7.418	17.578
				6.943	54.878	10.742
				12.439	135.137	4.290
14	.944	9.534	10.593	.100	7.418	17.578
				7.505	58.722	10.742
				13.431	140.949	4.620
15	.944	9.534	10.593	.100	7.418	17.578
				8.067	62.565	10.742
				14.423	146.106	4.950

Figure E-11: 2702 Channel Evaluation Factors, IBM Terminal Control Type II (600 bps), with Autopolling

LINE	WAIT	DEVICE	PREV .	PRIORITY - LOAD		
NO.	TIME	LOAD	LOAD	TIME	A	B
1	14.384	.382	.695	.100	9.000	.330
2	7.184	.766	1.392	.100	7.418	17.578
				.602	17.603	.660
3	4.784	1.150	2.090	.100	7.418	17.578
				1.114	25.897	.990
4	3.344	1.645	2.990	.100	7.418	17.578
				1.626	33.854	1.320
5	2.864	1.920	3.492	.100	7.418	17.578
				2.138	41.472	1.650
6	2.384	2.307	4.195	.100	7.418	17.578
				2.650	48.753	1.980
7	1.904	2.889	5.252	.100	7.418	17.578
				3.162	55.696	2.310
8	1.424	3.862	7.022	.100	7.418	17.578
				3.674	62.301	2.640
9	1.424	3.862	7.022	.100	7.418	17.578
				4.186	68.568	2.970
10	1.424	3.862	7.022	.100	7.418	17.578
				4.698	74.497	3.300
11	.944	5.826	10.593	.100	7.418	17.578
				5.210	80.088	3.630
12	.944	5.826	10.593	.100	7.418	17.578
				5.722	85.341	3.960
13	.944	5.826	10.593	.100	7.418	17.578
				6.234	90.256	4.290
14	.944	5.826	10.593	.100	7.418	17.578
				6.746	94.833	4.620
15	.944	5.826	10.593	.100	7.418	17.578
				7.258	99.073	4.950

Figure E-12: 2702 Channel Evaluation Factors, IBM Terminal Control Type II (600 bps), without Autopolling

LINE	WAIT	DEVICE	PREV.	PRIORITY - LOAD		
NO.	TIME	LOAD	LOAD	TIME	A	B
1	159.824	.034	.063	.100	9.000	.031
2	79.664	.069	.126	.100	7.418	17.578
				.602	17.963	.062
3	53.264	.103	.188	.100	7.418	17.578
				1.114	26.897	.093
4	39.824	.138	.251	.100	7.418	17.578
				1.626	35.799	.124
5	31.664	.174	.316	.100	7.418	17.578
				2.138	44.669	.155
6	26.384	.208	.379	.100	7.418	17.578
				2.650	53.508	.186
7	22.544	.244	.444	.100	7.418	17.578
				3.162	62.315	.217
8	19.664	.280	.509	.100	7.418	17.578
				3.674	71.091	.247
9	17.744	.310	.564	.100	7.418	17.578
				4.186	79.834	.278
10	15.824	.348	.632	.100	7.418	17.578
				4.698	88.547	.309
11	14.384	.382	.695	.100	7.418	17.578
				5.210	97.227	.340
12	12.944	.425	.773	.100	7.418	17.578
				5.722	105.876	.371
13	11.984	.459	.834	.100	7.418	17.578
				6.234	114.493	.402
14	11.024	.499	.907	.100	7.418	17.578
				6.746	123.078	.433
15	10.544	.522	.948	.100	7.418	17.578
				7.258	131.632	.464

Figure E-13: 2702 Channel Evaluation Factors, Telegraph Terminal Control Type I (45.5 bps), without 31-Line Expansion

LINE	WAIT	DEVICE	PREV.	PRIORITY - LOAD		
NO.	TIME	LOAD	LOAD	TIME	A	B
1	159.696	.034	.063	.100	9.000	.031
2	79.344	.069	.126	.100	8.209	8.789
				1.114	17.931	.062
3	52.560	.105	.190	.100	8.209	8.789
				2.138	26.802	.093
4	39.664	.139	.252	.100	8.209	8.789
				3.162	35.609	.124
5	31.728	.173	.315	.100	8.209	8.789
				4.186	44.352	.155
6	25.776	.213	.388	.100	8.209	8.789
				5.210	53.033	.186
7	22.800	.241	.439	.100	8.209	8.789
				6.234	61.650	.217
8	19.824	.277	.504	.100	8.209	8.789
				7.258	70.204	.247
9	16.848	.326	.594	.100	8.209	8.789
				8.282	78.694	.278
10	15.856	.347	.631	.100	8.209	8.789
				9.306	87.121	.309
11	13.872	.396	.721	.100	8.209	8.789
				10.330	95.485	.340
12	12.880	.427	.776	.100	8.209	8.789
				11.354	103.785	.371
13	11.888	.463	.841	.100	8.209	8.789
				12.378	112.022	.402
14	10.896	.505	.918	.100	8.209	8.789
				13.402	120.195	.433
15	9.904	.555	1.010	.100	8.209	8.789
				14.426	128.305	.464
16	9.904	.555	1.010	.100	8.209	8.789
				15.450	136.352	.495

Figure E-14: 2702 Channel Evaluation Factors, Telegraph Terminal Control Type I (45.5 bps), with 31-Line Expansion (part 1 of 2)

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
17	8.912	.617	1.122	.100	8.209	8.789
				16.474	144.336	.526
18	7.920	.694	1.263	.100	8.209	8.789
				17.498	152.256	.557
19	7.920	.694	1.263	.100	8.209	8.789
				18.522	160.113	.588
20	7.920	.694	1.263	.100	8.209	8.789
				19.546	167.906	.619
21	6.928	.794	1.443	.100	8.209	8.789
				20.570	175.636	.650
22	6.928	.794	1.443	.100	8.209	8.789
				21.594	183.303	.681
23	6.928	.794	1.443	.100	8.209	8.789
				22.618	190.906	.712
24	5.936	.927	1.685	.100	8.209	8.789
				23.642	198.446	.742
25	5.936	.927	1.685	.100	8.209	8.789
				24.666	205.922	.773
26	5.936	.927	1.685	.100	8.209	8.789
				25.690	213.336	.804
27	4.944	1.112	2.023	.100	8.209	8.789
				26.714	220.685	.835
28	4.944	1.112	2.023	.100	8.209	8.789
				27.738	227.972	.866
29	4.944	1.112	2.023	.100	8.209	8.789
				28.762	235.195	.897
30	4.944	1.112	2.023	.100	8.209	8.789
				29.786	242.355	.928
31	4.944	1.112	2.023	.100	8.209	8.789
				30.810	249.451	.959

Figure E-14: 2702 Channel Evaluation Factors, Telegraph Terminal Control Type I (45.5 bps), with 31-Line Expansion (part 2 of 2)

LINE	WAIT	DEVICE	PREV.	PRIORITY - LOAD		
NO.	TIME	LOAD	LOAD	TIME	A	B
1	126.224	.044	.079	.100	9.000	.039
2	62.864	.087	.159	.100	7.418	17.578
				.602	17.953	.078
3	41.744	.137	.240	.100	7.418	17.578
				1.114	26.869	.118
4	31.184	.176	.321	.100	7.418	17.578
				1.626	35.745	.157
5	24.944	.220	.401	.100	7.418	17.578
				2.138	44.581	.196
6	20.624	.267	.485	.100	7.418	17.578
				2.650	53.377	.235
7	17.744	.310	.564	.100	7.418	17.578
				3.162	62.133	.274
8	15.344	.358	.652	.100	7.418	17.578
				3.674	70.848	.313
9	13.904	.396	.719	.100	7.418	17.578
				4.186	79.524	.353
10	12.464	.441	.802	.100	7.418	17.578
				4.698	88.159	.392
11	11.024	.499	.907	.100	7.418	17.578
				5.210	96.754	.431
12	10.064	.547	.994	.100	7.418	17.578
				5.722	105.309	.470
13	9.584	.574	1.043	.100	7.418	17.578
				6.234	113.824	.509
14	8.624	.638	1.160	.100	7.418	17.578
				6.746	122.299	.549
15	8.144	.675	1.228	.100	7.418	17.578
				7.258	130.734	.588

Figure E-15: 2702 Channel Evaluation Factors, Telegrah Terminal Control Type I (56.9 bps), without 31-Line Expansion

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
1	125.968	.044	.079	.100	9.000	.039
2	62.480	.088	.160	.100	8.209	8.789
				1.114	17.913	.078
3	41.648	.132	.240	.100	8.209	8.789
				2.138	26.749	.118
4	30.736	.179	.325	.100	8.209	8.789
				3.162	35.504	.157
5	24.784	.222	.403	.100	8.209	8.789
				4.186	44.180	.196
6	20.816	.264	.480	.100	8.209	8.789
				5.210	52.775	.235
7	17.840	.308	.561	.100	8.209	8.789
				6.234	61.290	.274
8	14.864	.370	.673	.100	8.209	8.789
				7.258	69.725	.313
9	13.872	.396	.721	.100	8.209	8.789
				8.282	78.079	.353
10	11.888	.463	.841	.100	8.209	8.789
				9.306	86.353	.392
11	10.896	.505	.918	.100	8.209	8.789
				10.330	94.547	.431
12	9.904	.555	1.010	.100	8.209	8.789
				11.354	102.661	.470
13	8.912	.617	1.122	.100	8.209	8.789
				12.378	110.694	.509
14	8.912	.617	1.122	.100	8.209	8.789
				13.402	118.647	.549
15	7.920	.694	1.263	.100	8.209	8.789
				14.426	126.520	.588
16	6.928	.794	1.443	.100	8.209	8.789
				15.450	134.313	.627

Figure E-16: 2702 Channel Evaluation Factors, Telegraph Terminal Control Type I (56.9 bps), with 31-Line Expansion (part 1 of 2)

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
17	6.928	.794	1.443	.100	8.209	8.789
				16.474	142.025	.866
18	6.928	.794	1.443	.100	8.209	8.789
				17.498	149.657	.705
19	5.936	.927	1.685	.100	8.209	8.789
				18.522	157.209	.745
20	5.936	.927	1.685	.100	8.209	8.789
				19.546	164.681	.784
21	5.936	.927	1.685	.100	8.209	8.789
				20.570	172.072	.823
22	4.944	1.112	2.023	.100	8.209	8.789
				21.594	179.383	.862
23	4.944	1.112	2.023	.100	8.209	8.789
				22.618	186.614	.901
24	4.944	1.112	2.023	.100	8.209	8.789
				23.642	193.765	.940
25	4.944	1.112	2.023	.100	8.209	8.789
				24.666	200.835	.980
26	3.952	1.392	2.530	.100	8.209	8.789
				25.690	207.825	1.019
27	3.952	1.392	2.530	.100	8.209	8.789
				26.714	214.735	1.058
28	3.952	1.392	2.530	.100	8.209	8.789
				27.738	221.564	1.097
29	3.952	1.392	2.530	.100	8.209	8.789
				28.762	228.314	1.136
30	3.952	1.392	2.530	.100	8.209	8.789
				29.786	234.983	1.176
31	3.952	1.392	2.530	.100	8.209	8.789
				30.810	241.572	1.215

Figure E-16: 2702 Channel Evaluation Factors, Telegraph Terminal Control Type I (56.9 bps), with 31-Line Expansion (part 2 of 2)

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
1	95.984	.057	.104	.100	9.000	.052
2	47.984	.115	.208	.100	7.418	17.578
				.602	17.938	.103
3	31.664	.174	.316	.100	7.418	17.578
				1.114	26.828	.155
4	23.984	.229	.417	.100	7.418	17.578
				1.626	35.665	.206
5	19.184	.287	.521	.100	7.418	17.578
				2.138	44.449	.258
6	15.824	.348	.632	.100	7.418	17.578
				2.650	53.180	.309
7	13.424	.410	.745	.100	7.418	17.578
				3.162	61.859	.361
8	11.984	.459	.834	.100	7.418	17.578
				3.674	70.484	.412
9	10.544	.522	.948	.100	7.418	17.578
				4.186	79.057	.464
10	9.584	.574	1.043	.100	7.418	17.578
				4.698	87.578	.516
11	8.624	.638	1.160	.100	7.418	17.578
				5.210	96.045	.567
12	7.664	.718	1.305	.100	7.418	17.578
				5.722	104.460	.619
13	7.184	.766	1.392	.100	7.418	17.578
				6.234	112.821	.670
14	6.704	.820	1.492	.100	7.418	17.578
				6.746	121.130	.722
15	6.224	.884	1.607	.100	7.418	17.578
				7.258	129.386	.773

Figure E-17: 2702 Channel Evaluation Factors, Telegraph Terminal Control Type I (74.2 bps), without 31-Line Expansion

LINE	WAIT	DEVICE	PREV.	PRIORITY - LOAD		
NO.	TIME	LOAD	LOAD	TIME	A	B
1	95.216	.058	.105	.100	9.000	.052
2	47.600	.116	.210	.100	8.209	8.789
				1.114	17.885	.103
3	31.728	.173	.315	.100	8.209	8.789
				2.138	26.669	.155
4	23.792	.231	.420	.100	8.209	8.789
				3.162	35.348	.206
5	18.832	.292	.531	.100	8.209	8.789
				4.186	43.921	.258
6	15.856	.347	.631	.100	8.209	8.789
				5.210	52.388	.309
7	12.880	.427	.776	.10	8.209	8.789
				6.234	60.750	.361
8	11.888	.463	.841	.100	8.209	8.789
				7.258	69.006	.412
9	9.904	.555	1.010	.100	8.209	8.789
				8.282	77.157	.464
10	8.912	.617	1.122	.100	8.209	8.789
				9.306	85.202	.516
11	7.920	.694	1.263	.100	8.209	8.789
				10.330	93.141	.567
12	7.920	.694	1.263	.100	8.209	8.789
				11.354	100.975	.619
13	6.928	.794	1.443	.100	8.209	8.789
				12.378	108.703	.670
14	5.936	.927	1.685	.100	8.209	8.789
				13.402	116.325	.722
15	5.936	.927	1.685	.100	8.209	8.789
				14.426	123.842	.773
16	5.936	.927	1.685	.100	8.209	8.789
				15.450	131.254	.825

Figure E-18: 2702 Channel Evaluation Factors, Telegraph Terminal Control Type I (74.2 bps), with 31-Line Expansion (part 1 of 2)

LINE	WAIT	DEVICE	PREV.	PRIORITY - LOAD		
NO.	TIME	LOAD	LOAD	TIME	A	B
17	4.944	1.112	2.023	.100	8.209	8.789
				16.474	138.560	.877
18	4.944	1.112	2.023	.100	8.209	8.789
				17.498	145.760	.928
19	4.944	1.112	2.023	.100	8.209	8.789
				18.522	152.854	.980
20	3.952	1.392	2.530	.100	8.209	8.789
				19.546	159.843	1.031
21	3.952	1.392	2.530	.100	8.209	8.789
				20.570	166.727	1.083
22	3.952	1.392	2.530	.100	8.209	8.789
				21.594	173.504	1.134
23	3.952	1.392	2.530	.100	8.209	8.789
				22.618	180.176	1.186
24	3.952	1.392	2.530	.100	8.209	8.789
				23.642	186.743	1.237
25	2.960	1.858	3.378	.100	8.209	8.789
				24.666	193.204	1.289
26	2.960	1.858	3.378	.100	8.209	8.789
				25.690	199.559	1.341
27	2.960	1.858	3.378	.100	8.209	8.789
				26.714	205.809	1.392
28	2.960	1.858	3.378	.100	8.209	8.789
				27.738	211.953	1.444
29	2.960	1.858	3.378	.100	8.209	8.789
				28.762	217.992	1.495
30	2.960	1.858	3.378	.100	8.209	8.789
				29.786	223.925	1.547
31	2.960	1.858	3.378	.100	8.209	8.789
				30.810	229.752	1.598

Figure E-18: 2702 Channel Evaluation Factors, Telegraph Terminal Control Type I (74.2 bps), with 31-Line Expansion (part 2 of 2)

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
1	96.944	.057	.103	.100	9.000	.053
2	48.464	.113	.206	.100	7.418	17.578
				.602	17.937	.105
3	32.144	.171	.311	.100	7.418	17.578
				1.114	26.824	.158
4	23.984	.229	.417	.100	7.418	17.578
				1.626	35.658	.210
5	19.184	.287	.521	.100	7.418	17.578
				2.138	44.438	.263
6	15.824	.348	.632	.100	7.418	17.578
				2.650	53.164	.316
7	13.424	.410	.745	.100	7.418	17.578
				3.162	61.836	.368
8	11.984	.459	.834	.100	7.418	17.578
				3.674	70.454	.421
9	10.544	.522	.948	.100	7.418	17.578
				4.186	79.018	.473
10	9.584	.574	1.043	.100	7.418	17.578
				4.698	87.528	.526
11	8.624	.638	1.160	.100	7.418	17.578
				5.210	95.985	.579
12	7.664	.718	1.305	.100	7.418	17.578
				5.722	104.388	.631
13	7.184	.766	1.392	.100	7.418	17.578
				6.234	112.736	.684
14	6.704	.820	1.492	.100	7.418	17.578
				6.746	121.031	.737
15	6.224	.884	1.607	.100	7.418	17.578
				7.258	129.272	.789

Figure E-19: 2702 Channel Evaluation Factors, Telegraph Terminal Control Type II (110 bps), without 31-Line Expansion

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
1	97.200	.057	.103	.100	9.000	.053
2	48.592	.113	.206	.100	8.209	8.789
				1.114	17.883	.105
3	31.728	.173	.315	.100	8.209	8.789
				2.138	26.663	.158
4	23.792	.231	.420	.100	8.209	8.789
				3.162	35.335	.210
5	18.832	.292	.531	.100	8.209	8.789
				4.186	43.899	.263
6	15.856	.347	.631	.100	8.209	8.789
				5.210	52.355	.316
7	13.872	.396	.721	.100	8.209	8.789
				6.234	60.704	.368
8	11.888	.463	.841	.100	8.209	8.789
				7.258	68.945	.421
9	9.904	.555	1.010	.100	8.209	8.789
				8.282	77.079	.473
10	8.912	.617	1.122	.100	8.209	8.789
				9.306	85.104	.526
11	7.920	.694	1.263	.100	8.209	8.789
				10.330	93.022	.579
12	7.920	.694	1.263	.100	8.209	8.789
				11.354	100.832	.631
13	6.928	.794	1.443	.100	8.209	8.789
				12.378	108.535	.684
14	6.928	.794	1.443	.100	8.209	8.789
				13.402	116.129	.737
15	5.936	.927	1.685	.100	8.209	8.789
				14.426	123.616	.789
16	5.936	.927	1.685	.100	8.209	8.789
				15.450	130.995	.842

Figure E-20: 2702 Channel Evaluation Factors, Telegraph Terminal Control Type II (110 bps), with 31-Line Expansion (part 1 of 2)

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
17	4.944	1.112	2.023	.100	8.209	8.789
				16.474	138.267	.894
18	4.944	1.112	2.023	.100	8.209	8.789
				17.498	145.430	.947
19	4.944	1.112	2.023	.100	8.209	8.789
				18.522	152.486	1.000
20	3.952	1.392	2.530	.100	8.209	8.789
				19.546	159.434	1.052
21	3.952	1.392	2.530	.100	8.209	8.789
				20.570	166.275	1.105
22	3.952	1.392	2.530	.100	8.209	8.789
				21.594	173.007	1.157
23	3.952	1.392	2.530	.100	8.209	8.789
				22.618	179.632	1.210
24	3.952	1.392	2.530	.100	8.209	8.789
				23.642	186.149	1.263
25	2.960	1.858	3.378	.100	8.209	8.789
				24.666	192.559	1.315
26	2.960	1.858	3.378	.100	8.209	8.789
				25.690	198.861	1.368
27	2.960	1.858	3.378	.100	8.209	8.789
				26.714	205.055	1.420
28	2.960	1.858	3.378	.100	8.209	8.789
				27.738	211.141	1.473
29	2.960	1.858	3.378	.100	8.209	8.789
				28.762	217.119	1.526
30	2.960	1.858	3.378	.100	8.209	8.789
				29.786	222.990	1.578
31	2.960	1.858	3.378	.100	8.209	8.789
				30.810	228.753	1.631

Figure E-20: 2702 Channel Evaluation Factors, Telegraph Terminal Control Type II (110 bps), with 31-Line Expansion (part 2 of 2)

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
1	143.984	.038	.069	.100	9.000	.037
2	71.984	.076	.139	.100	7.418	17.578
				.602	17.956	.073
3	47.984	.115	.208	.100	7.418	17.578
				1.114	26.877	.110
4	35.984	.153	.278	.100	7.418	17.578
				1.626	35.762	.147
5	28.784	.191	.347	.100	7.418	17.578
				2.138	44.608	.183
6	23.984	.229	.417	.100	7.418	17.578
				2.650	53.417	.220
7	20.144	.273	.496	.100	7.418	17.578
				3.162	62.188	.257
8	17.744	.310	.564	.100	7.418	17.578
				3.674	70.922	.293
9	15.824	.348	.632	.100	7.418	17.578
				4.186	79.619	.330
10	14.384	.382	.695	.100	7.418	17.578
				4.698	88.277	.367
11	12.944	.425	.773	.100	7.418	17.578
				5.210	96.899	.403
12	11.984	.459	.834	.100	7.418	17.578
				5.722	105.482	.440
13	11.024	.499	.907	.100	7.418	17.578
				6.234	114.028	.477
14	10.064	.547	.994	.100	7.418	17.578
				6.746	122.537	.513
15	9.584	.574	1.043	.100	7.418	17.578
				7.258	131.008	.550

Figure E-21: 2702 Channel Evaluation Factors, World Trade Telegraph Terminal Control (50 bps), without 31-Line Expansion

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
1	143.824	.038	.070	.100	9.00	.037
2	71.408	.077	.140	.100	8.209	8.789
				1.114	17.918	.073
3	47.600	.116	.210	.100	8.209	8.789
				2.138	26.765	.110
4	35.696	.154	.280	.100	8.209	8.789
				3.162	35.536	.147
5	28.752	.191	.348	.100	8.209	8.789
				4.186	44.233	.183
6	23.792	.231	.420	.100	8.209	8.789
				5.210	52.854	.220
7	19.824	.277	.504	.100	8.209	8.789
				6.234	61.400	.257
8	17.840	.308	.561	.100	8.209	8.789
				7.258	69.871	.293
9	15.856	.347	.631	.100	8.209	8.789
				8.282	78.267	.330
10	13.872	.396	.721	.100	8.209	8.789
				9.306	86.588	.367
11	12.880	.427	.776	.100	8.209	8.789
				10.330	94.834	.403
12	11.888	.463	.841	.100	8.209	8.789
				11.354	103.004	.440
13	10.896	.505	.918	.100	8.209	8.789
				12.378	111.100	.477
14	9.904	.555	1.010	.100	8.209	8.789
				13.402	119.120	.513
15	8.912	.617	1.122	.100	8.209	8.789
				14.426	127.066	.550
16	8.912	.617	1.122	.100	8.209	8.789
				15.450	134.936	.587

Figure E-22: 2702 Channel Evaluation Factors, World Trade Telegraph Terminal Control (50 bps), with 31-Line Expansion (part 1 of 2)

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
17	7.920	.694	1.263	.100	8.209	8.789
				16.474	142.731	.623
18	7.920	.694	1.263	.100	8.209	8.789
				17.498	150.451	.660
19	6.928	.794	1.443	.100	8.209	8.789
				18.522	158.096	.697
20	6.928	.794	1.443	.100	8.209	8.789
				19.546	165.666	.733
21	5.936	.927	1.685	.100	8.209	8.789
				20.570	173.161	.770
22	5.936	.927	1.685	.100	8.209	8.789
				21.594	180.581	.807
23	5.936	.927	1.685	.100	8.209	8.789
				22.618	187.925	.843
24	5.936	.027	1.685	.100	8.209	8.789
				23.642	195.195	.880
25	4.944	1.112	2.023	.100	8.209	8.789
				24.666	202.389	.917
26	4.944	1.112	2.023	.100	8.209	8.789
				25.690	209.509	.953
27	4.944	1.112	2.023	.100	8.209	8.789
				26.714	216.553	.990
28	4.944	1.112	2.023	.100	8.209	8.789
				27.738	223.522	1.027
29	4.944	1.112	2.023	.100	8.209	8.789
				28.762	230.416	1.063
30	3.952	1.392	2.530	.100	8.209	8.789
				29.786	237.235	1.100
31	3.952	1.392	2.530	.100	8.209	8.789
				30.810	243.979	1.137

Figure E-22: 2702 Channel Evaluation Factors, World Trade Telegraph Terminal Control (50 bps), with 31-Line Expansion (part 2 of 2)

LINE	WAIT	DEVICE	PREV .	PRIORITY - LOAD		
NO.	TIME	LOAD	LOAD	TIME	A	B
1	95.984	.057	.104	.100	9.000	.055
2	47.984	.115	.208	.100	7.418	17.578
				.602	17.934	.110
3	31.664	.174	.316	.100	7.418	17.578
				1.114	26.816	.165
4	23.984	.229	.417	.100	7.418	17.578
				1.626	35.642	.220
5	19.184	.287	.521	.100	7.418	17.578
				2.138	44.412	.275
6	15.824	.348	.632	.100	7.418	17.578
				2.650	53.125	.330
7	13.424	.410	.745	.100	7.418	17.578
				3.162	61.783	.385
8	11.984	.459	.834	.100	7.418	17.578
				3.674	70.383	.440
9	10.544	.522	.948	.100	7.418	17.578
				4.186	78.928	.495
10	9.584	.574	1.043	.100	7.418	17.578
				4.698	87.416	.550
11	8.624	.638	1.160	.100	7.418	17.578
				5.210	95.848	.605
12	7.664	.718	1.305	.100	7.418	17.578
				5.722	104.223	.660
13	7.184	.766	1.392	.100	7.418	17.578
				6.234	112.543	.715
14	6.704	.820	1.492	.100	7.418	17.578
				6.746	120.806	.770
15	6.224	.884	1.607	.100	7.418	17.578
				7.258	129.012	.825

Figure E-23: 2702 Channel Evaluation Factors, World Trade Telegraph Terminal Control (75 bps), without 31-Line Expansion

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
1	95.216	.058	.105	.100	9.000	.055
2	47.600	.116	.210	.100	8.209	8.789
				1.114	17.877	.110
3	31.728	.173	.315	.100	8.209	8.789
				2.138	26.647	.165
4	23.792	.231	.420	.100	8.209	8.789
				3.162	35.304	.220
5	18.832	.292	.531	.100	8.209	8.789
				4.186	43.849	.275
6	15.856	.347	.631	.100	8.209	8.789
				5.210	52.281	.330
7	12.880	.427	.776	.100	8.209	8.789
				6.234	60.600	.385
8	11.888	.463	.841	.100	8.209	8.789
				7.258	68.806	.440
9	9.904	.555	1.010	.100	8.209	8.789
				8.282	76.900	.495
10	8.912	.617	1.122	.100	8.209	8.789
				9.306	84.882	.550
11	7.920	.694	1.263	.100	8.209	8.789
				10.330	92.750	.605
12	7.920	.694	1.263	.100	8.209	8.789
				11.354	100.506	.660
13	6.928	.794	1.443	.100	8.209	8.789
				12.378	108.150	.715
14	5.936	.927	1.685	.100	8.209	8.789
				13.402	115.680	.770
15	5.936	.927	1.685	.100	8.209	8.789
				14.426	123.099	.825
16	5.936	.927	1.685	.100	8.209	8.789
				15.450	130.404	.880

Figure E-24: 2702 Channel Evaluation Factors, World Trade Telegraph Terminal Control (75 bps), with 31-Line Expansion (part 1 of 2)

LINE	WAIT	DEVICE	PREV.	PRIORITY - LOAD		
NO.	TIME	LOAD	LOAD	TIME	A	B
17	4.944	1.112	2.023	.100	8.209	8.789
				16.474	137.597	.935
18	4.944	1.112	2.023	.100	8.209	8.789
				17.498	144.677	.990
19	4.944	1.112	2.023	.100	8.209	8.789
				18.522	151.645	1.045
20	3.952	1.392	2.530	.100	8.209	8.789
				19.546	158.499	1.100
21	3.952	1.392	2.530	.100	8.209	8.789
				20.570	165.242	1.155
22	3.952	1.392	2.530	.100	8.209	8.789
				21.594	171.871	1.210
23	3.952	1.392	2.530	.100	8.209	8.789
				22.618	178.388	1.265
24	3.952	1.392	2.530	.100	8.209	8.789
				23.642	184.793	1.320
25	2.960	1.858	3.378	.100	8.209	8.789
				24.666	191.084	1.375
26	2.960	1.858	3.378	.100	8.209	8.789
				25.690	197.263	1.430
27	2.960	1.858	3.378	.100	8.209	8.789
				26.714	203.330	1.485
28	2.960	1.858	3.378	.100	8.209	8.789
				27.738	209.283	1.540
29	2.960	1.858	3.378	.100	8.209	8.789
				28.762	215.125	1.595
30	2.960	1.858	3.378	.100	8.209	8.789
				29.786	220.853	1.650
31	2.960	1.858	3.378	.100	8.209	8.789
				30.810	226.469	1.705

Figure E-24: 2702 Channel Evaluation Factors, World Trade Telegraph Terminal Control (75 bps), with 31-Line Expansion (part 2 of 2)

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
1	71.984	.076	.139	.139	9.000	.073
2	35.984	.153	.278	.100	7.418	17.578
				.602	17.912	.147
3	23.984	.229	.417	.100	7.418	17.578
				1.114	26.755	.220
4	17.744	.310	.564	.100	7.418	17.578
				1.626	35.523	.293
5	14.384	.382	.695	.100	7.418	17.578
				2.138	44.216	.367
6	11.984	.459	.834	.100	7.418	17.578
				2.650	52.834	.440
7	10.064	.547	.994	.100	7.418	17.578
				3.162	61.377	.513
8	8.624	.638	1.160	.100	7.418	17.578
				3.674	69.845	.587
9	7.664	.718	1.305	.100	7.418	17.578
				4.186	78.237	.660
10	7.184	.766	1.392	.100	7.418	17.578
				4.698	86.555	.733
11	6.224	.884	1.607	.100	7.418	17.578
				5.210	94.797	.807
12	5.744	.958	1.741	.100	7.418	17.578
				5.722	102.965	.880
13	5.264	1.045	1.900	.100	7.418	17.578
				6.234	111.057	.953
14	4.784	1.150	2.090	.100	7.418	17.578
				6.746	119.074	1.027
15	4.784	1.150	2.090	.100	7.418	17.578
				7.258	127.016	1.100

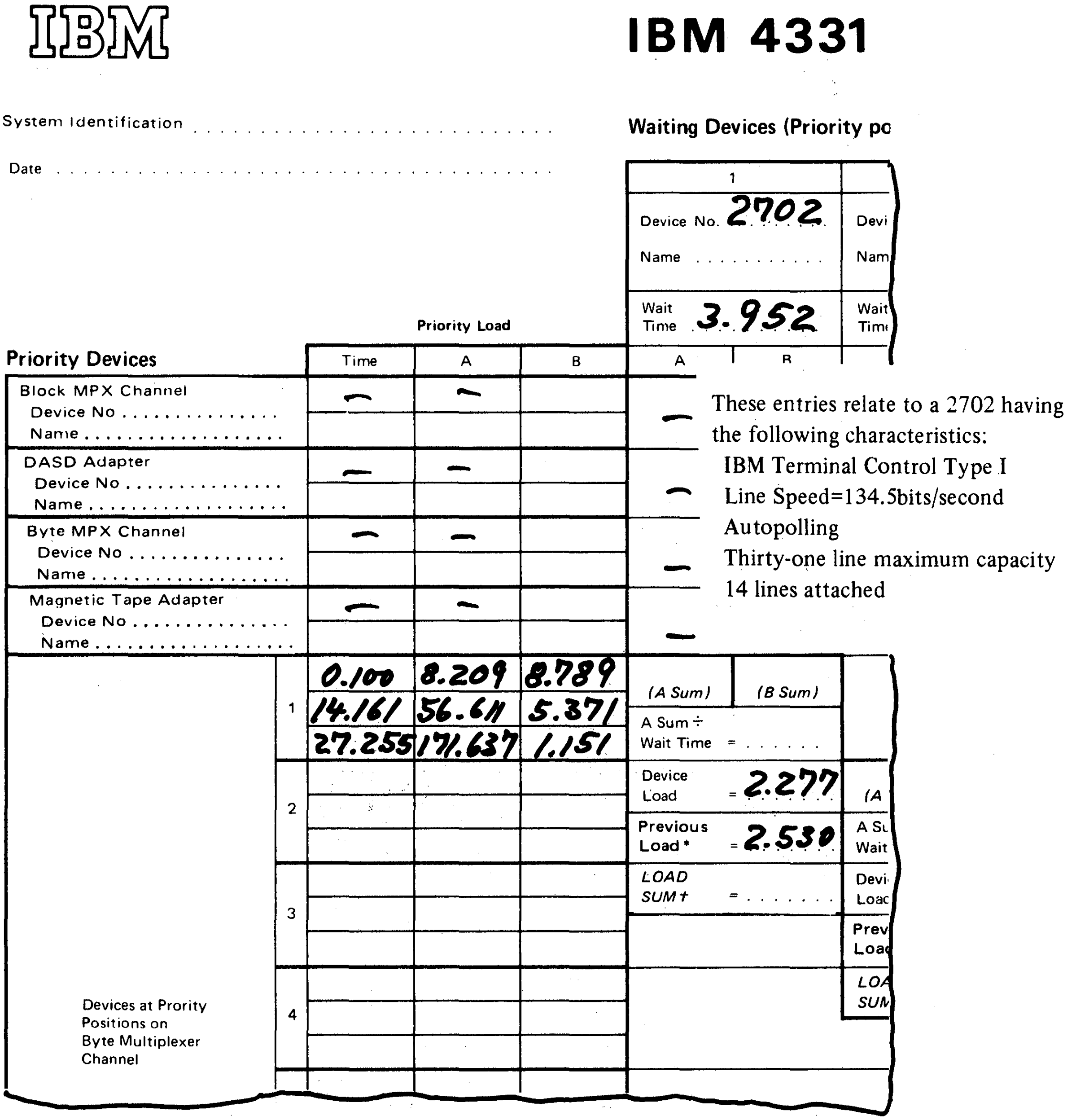
Figure E-25: 2702 Channel Evaluation Factors, World Trade Telegraph Terminal Control (100 bps), without 31-Line Expansion

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
1	71.408	.077	.140	.100	9.000	.073
2	35.696	.154	.280	.100	8.209	8.789
				1.114	17.837	.147
3	23.792	.231	.420	.100	8.209	8.789
				2.138	26.530	.220
4	17.840	.308	.561	.100	8.209	8.789
				3.162	35.072	.293
5	13.872	.396	.721	.100	8.209	8.789
				4.186	43.465	.367
6	11.888	.463	.841	.100	8.209	8.789
				5.210	51.708	.440
7	9.904	.555	1.010	.100	8.209	8.789
				6.234	59.800	.513
8	8.912	.617	1.122	.100	8.209	8.789
				7.258	67.742	.587
9	7.920	.694	1.263	.100	8.209	8.789
				8.282	75.534	.660
10	6.928	.794	1.443	.100	8.209	8.789
				9.306	83.176	.733
11	5.936	.927	1.685	.100	8.209	8.789
				10.330	90.667	.807
12	5.936	.927	1.685	.100	8.209	8.789
				11.354	98.008	.880
13	4.944	1.112	2.023	.100	8.209	8.789
				12.378	105.200	.953
14	4.944	1.112	2.023	.100	8.209	8.789
				13.402	112.241	1.027
15	3.952	1.392	2.530	.100	8.209	8.789
				14.426	119.131	1.100
16	3.952	1.392	2.530	.100	8.209	8.789
				15.450	125.872	1.173

Figure E-26: 2702 Channel Evaluation Factors, World Trade Telegraph Terminal Control (100 bps), with 31-Line Expansion (part 1 of 2)

LINE NO.	WAIT TIME	DEVICE LOAD	PREV. LOAD	PRIORITY - LOAD		
				TIME	A	B
17	3.952	1.392	2.530	.100	8.209	8.789
				16.474	132.462	1.247
18	3.952	1.392	2.530	.100	8.209	8.789
				17.498	138.903	1.320
19	2.960	1.858	3.378	.100	8.209	8.789
				18.522	145.193	1.393
20	2.960	1.858	3.378	.100	8.209	8.789
				19.546	151.333	1.467
21	2.960	1.858	3.378	.100	8.209	8.789
				20.570	157.322	1.540
22	2.960	1.858	3.378	.100	8.209	8.789
				21.594	163.162	1.613
23	2.960	1.858	3.378	.100	8.209	8.789
				22.618	168.851	1.687
24	2.960	1.858	3.378	.100	8.209	8.789
				23.642	174.390	1.760
25	1.968	2.795	5.081	.100	8.209	8.789
				24.666	179.779	1.833
26	1.968	2.795	5.081	.100	8.209	8.789
				25.690	185.018	1.907
27	1.968	2.795	5.081	.100	8.209	8.789
				26.714	190.106	1.980
28	1.968	2.795	5.081	.100	8.209	8.789
				27.738	195.045	2.053
29	1.968	2.795	5.081	.100	8.209	8.789
				28.762	199.833	2.127
30	1.968	2.795	5.081	.100	8.209	8.789
				29.786	204.471	2.200
31	1.968	2.795	5.081	.100	8.209	8.789
				30.810	208.959	2.273

Figure E-26: 2702 Channel Evaluation Factors, World Trade Telegraph Terminal Control (100 bps), with 31-Line Expansion (part 2 of 2)



IBM

IBM 4331

System Identification . . . .

Date . . . .

Waiting Devices (Priority po

1

Device No. 2702

Name . . . .

Wait Time 3.952

Devi

Nam

Wait Tim

Priority Load

Priority Devices		Time	A	B	A	B
Block MPX Channel Device No . . . . Name		—	—		—	
DASD Adapter Device No . . . . Name		—	—		—	
Byte MPX Channel Device No . . . . Name		—	—		—	
Magnetic Tape Adapter Device No . . . . Name		—	—		—	
Devices at Prority Positions on Byte Multiplexer Channel	1	0.100	8.209	8.789	(A Sum)	(B Sum)
		14.161	56.611	5.371	A Sum ÷ Wait Time = ...	
		27.255	171.637	1.151		
	2				Device Load = 2.277	
					Previous Load* = 2.530	
	3				LOAD SUM† = ...	
	4					

(A

A Su Wait

Devi Loac

Prev Loa

LOA SUM

These entries relate to a 2702 having the following characteristics:

IBM Terminal Control Type I

Line Speed=134.5bits/second

Autopolling

Thirty-one line maximum capacity

14 lines attached

Figure E-27: Example of load sum worksheet entries for a 2702 (with all communication lines of the same type)

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APPENDIX F. IBM 2703 TRANSMISSION CONTROL: PRIORITY ASSIGNMENT AND CHANNEL EVALUATION FACTORS

This appendix describes:

1. How to assign the priority of a 2703 Transmission Control in relation to other devices on the byte-multiplexer channel, for use in step 1 of Figure 2.11 when testing byte-multiplexer channel data overrun.

2. How to obtain the following channel evaluation factors of a 2703 for use in steps 2 and/or 3 of Figure 2.11.

   Wait time
   Device load
   Previous load

For configurations having more than one 2703 on the byte-multiplexer channel, consult your local IBM representative.

How to Assign Priority Position of a 2703

Assign to the 2703 the lowest priority of the class-1 devices, regardless of relative wait times.

How to Calculate Channel Evaluation Factors for a 2703

The procedure for calculating the channel evaluation factors has two stages:

1. To determine the "critical" base.

2. To obtain the required channel evaluation factors from simple formulas by using factors that are associated with the critical base.

How to Determine the "Critical" Base

For the purpose of this procedure, call the installed bases A, B, and C. Using the calculation format shown in Figure F-1, proceed by:

1. Enter the number of lines N(A), N(B), N(C) to be installed on each base. If less than three bases are used, enter the number of lines for the unused base as 0 (zero).

2. From Figure F-2, enter the internal priority number P(A), P(B), P(C) for each base according to the base type and the number of lines installed. For any base that is not used, enter the priority number as 0 (zero).

3. For base A, find the time WT(A).

   a. From Figure F-3, find those entries that relate to the types and speeds of lines to be installed on that base.

   b. Choose the entry that has the shortest wait time and enter that time in the calculation format as WT(A).

4. Repeat step 3 for the remaining bases.

5. For each base, complete the calculation format as shown in the example (Figure F-4) in order to determine the "effective" number of lines Ne for each base and the "effective" wait time WTe.

6. The base having the smallest effective wait time WTe is the critical base.

How to Determine Wait Time, Device Load, and Previous Load

Wait Time: Use the WT ( )* of the critical base.

Device Load: This is given by the following formula:

$$\text{Device load} = \frac{8.75\ \text{XNe}(\ )}{\text{WT}(\ )^*}$$

where Ne( ) and WT( )* are, respectively, the effective number of lines and the wait time of the critical base.

Previous Load: This is the lesser of the following items 1 and 2:

1. The device load just calculated.

2. The result of the following calculation:

$$\left(\frac{\text{Sum of X values}}{\text{WT}(\ )^*} + \text{Sum of Y values}\right) \ \text{X}\ 100$$

   where X and Y are factors relating to each lower-priority device on the byte-multiplexer channel (Figure F-5).

Priority Load: A priority-load factor is not needed because the 2703 is the lowest priority class-1 device to appear on the byte-multiplexer channel load sum worksheet.

---

* Use the time WT( ), not the effective time WTe( ), of the critical base.

Action	Base A		Base B		Base C	
ENTER DATA	Number of lines on base A =	.... *N(A)*	Number of lines on base B =	.... *N(B)*	Number of lines on base C =	.... *N(C)*
	Internal priority number for base A (see Figure E-2) = ... *P(A)*		Internal priority number for base B (see Figure E-2) = ... *P(B)*		Internal priority number for base C (see Figure E-2) = ... *P(C)*	
	Wait time for base A (see Figure E-3) = ... *WT(A)*		Wait time for base B (see Figure E-3) = ... *WT(B)*		Wait time for base C (see Figure E-3) = ... *WT(C)*	
CALCULATE	$N(A,B) = \frac{P(B)}{P(A)} \times N(A)$ or $N(A,B) = 2 \times N(B)$ (whichever is smaller)	.... *N(A,B)*	$N(B,C) = \frac{P(C)}{P(B)} \times N(B)$ or $N(B,C) = 2 \times N(C)$ (whichever is smaller)	.... *N(B,C)*	$N(C,A) = \frac{P(A)}{P(C)} \times N(C)$ or $N(C,A) = 2 \times N(A)$ (whichever is smaller)	.... *N(C,A)*
	$N(A,C) = \frac{P(C)}{P(A)} \times N(A)$ or $N(A,C) = 2 \times N(C)$ (whichever is smaller)	.... *N(A,C)*	$N(B,A) = \frac{P(A)}{P(B)} \times N(B)$ or $N(B,A) = 2 \times N(A)$ (whichever is smaller)	.... *N(B,A)*	$N(C,B) = \frac{P(B)}{P(C)} \times N(C)$ or $N(C,B) = 2 \times N(B)$ (whichever is smaller)	.... *N(C,B)*
	$Ne(A) = N(A) + N(A,B) + N(A,C) =$	.... *Ne(A)*	$Ne(B) = N(B) + N(B,C) + N(B,A) =$	.... *Ne(B)*	$Ne(C) = N(C) + N(C,A) + N(C,B) =$	.... *Ne(C)*
	$WTe(A) = \frac{WT(A)}{Ne(A)} =$	.... *WTe(A)*	$WTe(B) = \frac{WT(B)}{Ne(B)} =$	.... *WTe(B)*	$WTe(C) = \frac{WT(C)}{Ne(C)} =$	.... *WTe(C)*

Figure F-1: 2703 calculation format

Type of base	Number of lines	Internal priority number
Start-Stop Base Type I	16	1
	32	2
	48	3
	64	4
	80	5
	88	6
Start-Stop Base Type II	8	1
	16	3
	24	4
Synchronous Base Type 1A	4	1
	8	3
	12	4
	16	5
	20	7
	24	8
Synchronous Base Type 1B	4	2
	8	4
	12	6
	16	8
Synchronous Base Type 2A	4	3
	8	5
	12	8

Figure F-2: Internal priority numbers as functions of
2703 base types and number of lines installed per base

Type of line control	Bit rate (bps)	Data rate (cps)	Wait time (ms)
IBM Terminal Control Type I	75	8.3	108.50
	134.5	14.8	59.50
	600	66.7	13.30
IBM Terminal Control Type II	600	60	13.30
Synchronous Terminal Control, Synchronous Base Type 1A, 24 lines, eight-bit code			
Without autopolling	600	75	51.00
	1200	150	24.00
	2000	250	15.00
	2400	300	12.00
With autopolling	600	75	24.00
	1200	150	12.00
	2000	250	6.00
	2400	300	6.00
Synchronous Terminal Control, Synchronous Base Type 1B, 16 lines, eight-bit code			
Without autopolling	600	75	53.00
	1200	150	24.50
	2000	250	14.30
	2400	300	12.20
With autopolling	600	75	26.50
	1200	150	12.20
	2000	250	6.10
	2400	300	6.10
Synchronous Terminal Control, Synchronous Base Type 1B, 16 lines, six-bit code			
Without autopolling	600	100	38.70
	1200	200	16.40
	2000	333	10.20
	2400	400	8.20
With autopolling	600	100	18.30
	1200	200	8.20
	2000	333	4.10
	2400	400	4.10
Synchronous Terminal Control, Synchronous Base Type 2A, 12 lines, eight-bit code			
Without autopolling	4800	600	6.20
With autopolling	4800	600	3.10
Telegraph Terminal Control Type I	45.5	6.0	131.00
	56.9	7.5	105.00
	74.2	10	80.90
Telegraph Terminal Control Type II	110	100	81.80

Figure F-3: Wait times of 2703 base types according to type and speed of lines installed

These entries relate to a 2703 having the following bases and lines:

Base A: Start-Stop Base Type I, with 88 lines, having IBM Terminal Control Type I and working at 134.5 bits per second.

Base B: Start-Stop Base Type II, with 24 lines, having IBM Terminal Control Type II and working at 600 bits per second.

Base C: Synchronous Base Type IA, with 24 lines, having synchronous terminal control, autopolling, and working at 2400 bits per second.

The example shows WTe(C) to be the smallest effective wait time (0.111) and, hence, base C to be the critical base.

Action	Base A		Base B		Base C	
ENTER DATA	Number of lines on base A =	88 N(A)	Number of lines on base B =	24 N(B)	Number of lines on base C =	24 N(C)
	Internal priority number for base A (see Figure E-2) = 6 P(A)		Internal priority number for base B (see Figure E-2) = 4 P(B)		Internal priority number for base C (see Figure E-2) = 8 P(C)	
	Wait time for base A (see Figure E-3) = 59·50 WT(A)		Wait time for base B (see Figure E-3) = 13·30 WT(B)		Wait time for base C (see Figure E-3) = 6·00 WT(C)	
CALCULATE	$N(A,B) = \frac{P(B)}{P(A)} \times N(A)$ or N(A,B) = 2 x N(B) (whichever is smaller)	48 N(A,B)	$N(B,C) = \frac{P(C)}{P(B)} \times N(B)$ or N(B,C) = 2 x N(C) (whichever is smaller)	48 N(B,C)	$N(C,A) = \frac{P(A)}{P(C)} \times N(C)$ or N(C,A) = 2 x N(A) (whichever is smaller)	18 N(C,A)
	$N(A,C) = \frac{P(C)}{P(A)} \times N(A)$ or N(A,C) = 2 x N(C) (whichever is smaller)	48 N(A,C)	$N(B,A) = \frac{P(A)}{P(B)} \times N(B)$ or N(B,A) = 2 x N(A) (whichever is smaller)	36 N(B,A)	$N(C,B) = \frac{P(B)}{P(C)} \times N(C)$ or N(C,B) = 2 x N(B) (whichever is smaller)	12 N(C,B)
	Ne(A) = N(A) + N(A,B) + N(A,C) =	184 Ne(A)	Ne(B) = N(B) + N(B,C) + N(B,A) =	108 Ne(B)	Ne(C) = N(C) + N(C,A) + N(C,B) =	54 Ne(C)
	$WTe(A) = \frac{WT(A)}{Ne(A)} =$	0.323 WTe(A)	$WTe(B) = \frac{WT(B)}{Ne(B)} =$	0·123 WTe(B)	$WTe(C) = \frac{WT(C)}{Ne(C)} =$	0·111 WTe(C)

Figure F-4: Example calculations to determine critical base, effective number of lines, and 2703 wait time

Input/output device	Operating mode	X	Y
1017 Paper Tape Reader or 1018 Paper Tape Punch	1-byte	0.	0.009
1403 Printer	1-byte	9.5	0
	4-byte	2.97	0
1443 Printer	1-byte	9.48	0
	2-byte	5.82	0
	4-byte	3.99	0
2260 Display Station	Read 1 byte	0	0.169
	Write 1 byte	0	0.176
2520 Card Punch Model B2 or B3	EBCDIC 1-byte	5.84	0
	Col.bin. 2-byte	5.84	0
2540 Card Read Punch punching	EBCDIC 1-byte	6.56	0
	2-byte	3.25	0
	Col.bin. 1-byte	12.64	0
	2-byte	6.56	0
2540 Card Read Punch reading	EBCDIC 1-byte	5.52	0
	2-byte	3.16	0
	Col.bin. 1-byte	11.04	0
	2-byte	6.32	0
3211 Printer	1-byte	8.84	0
	6-byte	1.94	0
3277-1 Display	1-byte	27.36	0
3277-2 Display	1-byte	109.44	0
3284-1 Printer	1-byte	27.36	0
3286-1 Printer	1-byte	27.36	0
3288-1 Printer	1-byte	27.36	0
3284-2 Printer	1-byte	109.44	0
3286-2 Printer	1-byte	109.44	0
3288-2 Printer	1-byte	109.44	0
3505 Card Reader Model B1 or B2	EBCDIC 1-byte	4.32	0
	Card Im. 2-byte	5.04	0
3525 Card Punch Model P1 or P2	EBCDIC 1-byte	4.56	0
	Card Im. 2-byte	5.36	0
3886 Optical Character Reader Model 1 or 2	1-byte	8.10	0
3890 Document Processor	4-byte	28.8	0

Figure F-5: X and Y values used to calculate previous load for 2703

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Channel Characteristics
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