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Systems

**IBM 4341 Processor
Channel Characteristics**



Preface

This manual describes how to check the effects of loads imposed on the IBM 4341 Processor channels. It is intended for programmers and systems analysts who wish to verify that a proposed configuration of input/output (I/O) devices can work satisfactorily with the 4341 Processor.

The sections present general 4341 channel organization and implementation, a description of subchannels and unit control words, the procedure for channel interference determination, concurrent I/O capabilities, block-multiplexer and byte-multiplexer channel loading, specific device considerations, and channel evaluation tables.

Before using this manual, you should have a thorough understanding of input/output operations for the 4341 as described in:

- *IBM 4341 Processor Functional Characteristics and Processor Complex Configurator*, Order No. GA24-3672
- *IBM System/370 Principles of Operation*, GA22-7000
- *IBM 4300 Processors Principles of Operation for ECPS:VSE Mode*, GA22-7070

When testing for data overrun on the byte-multiplexer channel, two special worksheets are required:

- *IBM 4341 Byte-Multiplexer Channel Preliminary Worksheet*, GX24-3746
- *IBM 4341 Processor Channel Load Sum Worksheet*, GX24-3670

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IBM 4341 Processor Channel Characteristics

This publication describes the calculations required to optimize channel operation on the IBM 4341 Processor. Detailed formulas, along with timing charts for input/output devices, enable users to determine maximum channel throughput with data overrun avoidance for actual 4341 configurations.

General Channel Information

The channels of the 4341 Processor transfer data between main storage and I/O devices under control of a channel program that is executed independently of the processor program. The 4341 is free to resume the processor program after initiating an I/O operation.

The 4341 channels can run concurrently within the data-rate and channel-programming conventions specified in this manual.

A major feature of the channels is the common I/O interface connection between a variety of I/O devices and System/360, System/370, and 4300 Processor input/output control units.

At the end of an I/O operation, the channel signals an I/O interruption request to the processor. If not disallowed, an I/O interruption occurs that places the I/O new program status word (PSW) in control of the processor. When I/O interruptions are disallowed, interruption requests are queued (stacked). Until honored, an I/O interruption condition is called a *pending I/O interruption*.

At the end of an I/O interruption, a channel has information about the success or lack of success of the operation. The information (status) is available to the processor program.

Each 4341 channel can perform these functions:

- Accept an I/O instruction from the processor.
- Address the device specified by an I/O instruction.
- Fetch the channel program from main storage.
- Decode the channel command words that make up the channel program.
- Test each channel command word (CCW) for validity.
- Execute CCW functions.
- Place control signals on the I/O interface.
- Accept control-response signals from the I/O interface.
- Transfer data between an I/O device and main storage.
- Check parity of bytes transferred.
- Count the number of bytes transferred.
- Accept status information from I/O devices.
- Maintain channel-status information.
- Signal interruption requests to the processor.
- Sequence interruption requests from I/O devices.
- Send status information to location 40 hexadecimal when an interruption occurs.
- Send status information to location 40 hexadecimal upon processor request.

Channel Control

The 4341 channels provide a common input/output interface that permits the attachment of control units. The control units are governed by six channel commands and seven processor instructions. The instructions are:

- Start I/O
- Start I/O Fast Release
- Test Channel
- Test I/O
- Halt I/O
- Halt Device
- Clear I/O

All I/O instructions set the PSW condition code. Under certain conditions, all except Test Channel cause a channel status word to be stored. A Test Channel instruction calls for information about the addressed channel; a Test I/O instruction calls for information about a channel and a particular device. Halt I/O terminates any operation on the addressed channel, subchannel, or device. Halt Device terminates an I/O operation on a particular device on a channel without interfering with other I/O operations in progress on the channel. Only Start I/O and Start I/O Fast Release make use of channel command words.

A Start I/O instruction initiates execution of one or more I/O operations, and specifies a channel, subchannel, control unit, and I/O device. The channel fetches the channel address word (CAW) from location 48 hexadecimal. The CAW contains the protection key and the address of the first channel command word for the operation. Beginning with the first CCW specified by the CAW, the channel fetches and executes one or more CCWs.

Note: *In the 4341., Start I/O Fast Release is decoded and executed as a Start I/O instruction. Throughout this manual, references to Start I/O also apply to Start I/O Fast Release.*

The Clear I/O instruction causes the current operation being executed by the addressed device to be terminated with both byte-multiplexer and block-multiplexer channels. In selector channel mode, the instruction is executed as a Test I/O.

Six channel commands are used:

- Read
- Write
- Read Backward
- Control
- Sense
- Transfer-in-Channel (TIC)

The first three are self-explanatory.

Control commands specify such operations as advance paper in a printer, set tape density, and rewind tape.

A Sense command brings information from a control unit into main storage. This information can concern unusual conditions detected during the latest I/O operation and detailed status about the device.

A Transfer-in-Channel (TIC) command specifies the location in main storage from which the next CCW in the channel program is to be fetched. A TIC cannot specify another TIC. Also, the CAW cannot address a TIC.

Each CCW specifies the channel operations to be performed and, for data-transfer operations, specifies contiguous locations in main storage to be used. One or more CCWs make up a channel program that directs a channel operation.

Command retry is a channel and control-unit procedure that causes a command to be retried without requiring an I/O interruption.

Retry is initiated by the control unit. When the command being executed encounters a retrievable error, the control unit presents unit check and status modifier (retry status) along with channel end, or channel end and device end, to the channel. If conditions permit, a normal device reselection occurs to reissue the previous command. If retry is not possible, any chaining is terminated, and an I/O interruption follows.

Channel Registers

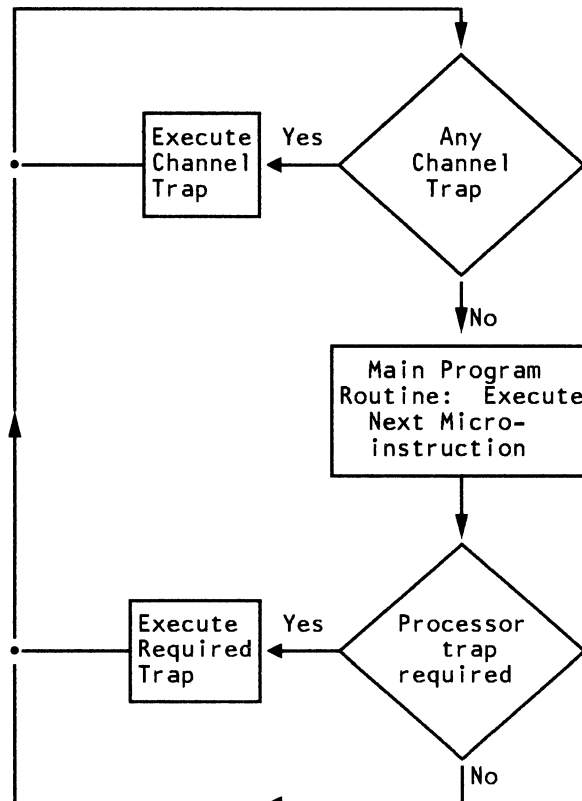
For each I/O device selected, the 4341 channels maintain the following channel-control information:

- Protection key
- Data address
- Identity of operation specified by command code
- CCW flags
- Byte count
- Channel status
- Address of next CCW

On byte- and block-multiplexer channels, the listed information must be maintained for each subchannel in operation. Storage for this information is provided by special channel storage that is not directly addressable. Each subchannel has provision in a special area of storage for channel-register information. When a particular subchannel is selected by a Start I/O instruction and a channel program is initiated, the channel storage locations for the subchannel are loaded with the information necessary for each operation of the subchannel.

At the completion of each activity in a subchannel, its particular area in storage contains updated information, and the multiplexer channel is available for operation of another subchannel.

Figure 1 shows the sharing of facilities by the channels and the processor.



A trap is an interruption of the current activity to allow another activity of a higher priority to take precedence.

Figure 1. Sharing of Processor and Channel Facilities

Chaining

A single CCW may specify contiguous locations in main storage for a data-transfer operation, or successive CCWs may be chained together to specify a set of noncontiguous storage areas. The presence of a flag bit in a CCW causes chaining to the next CCW.

In data chaining, the address and count information in a new CCW is used; the command code field is ignored.

Entire CCWs, including their command code fields, can also be chained together for a sequence of channel operations. Such coupling, called *command chaining*, is specified by a different flag bit in a CCW.

Data chaining has no effect on a device, as long as the channel has sufficient time to perform both data chaining and data transfer for the device.

In this manual, when a device is said to data-chain, the channel program for the device specifies data chaining.

Fetching Channel Command Words

The channel must fetch a new CCW whenever a CCW specifies data chaining, command chaining, or transfer in channel (TIC). The extra control activity caused by these operations takes time and diminishes a channel's ability to do other work.

A data-chaining fetch usually occurs while a channel also has a data-transfer load from the same device. The time required to fetch the new CCW necessarily limits the time available for successive data transfers through the channel. An absence of data chaining ordinarily permits a channel to operate with a faster I/O device. Similarly, when a channel is not transferring data, a data-chaining operation has a lesser impact on channel facilities.

Data Chaining in Gaps

For direct-access storage devices, such as an IBM 3330 Direct Access Storage or an IBM 2314 Direct Access Storage Facility, formatting Write commands causes the control unit to create gaps between count, key, and data fields on the recording track. Read, Write, and Search commands that address more than one of the fields can specify data chaining to define separate areas in main storage for the fields.

The gaps on a track have significance to channel-programming considerations for direct-access storage devices. The channel does not transfer data during the time a gap is created or passes under the read-write head. This time is sufficient for a 4341 Processor to perform a command-chaining or data-chaining operation.

Command chaining ordinarily occurs only during gap time, but data chaining can occur during gap time or while data is being transferred. A data-chaining operation occurring during gap time has less impact on channel facilities than when data transfers also occur. If a channel program for a direct-access storage device calls for data chaining only during gap time, the device's overall load on channel facilities is significantly less.

When a direct-access device is said to data-chain in a gap, the reference is to a gap *other than* a gap following a data field. The latter causes a device-end indication. Command chaining is used in such a gap if the transfer or more information is desired. Device end occurring in the absence of a CCW specifying command terminates the operation. When command chaining continues the operation, the status information available at the end of the operation relates to the last operation in the chain.

During a read operation, an attempt to data-chain in a gap following a data field causes an incorrect length indication in the channel status byte.

Late Command Chaining

Operation of direct-access devices, such as disk storage, requires command chaining. Between certain operations, such as the search for a record identification key and the reading of a data field on a direct access-storage device, the control unit has a fixed time interval during which it must receive and execute a new command. If activity on other channel(s) causes too much delay in initiation of the operation specified by the new command, the channel program is terminated and an I/O interruption occurs. If, however, the device has command retry capabilities, the command is retried.

Storage Addressing

During data chaining, the beginning and ending byte addresses and the minimum number of bytes transferred are factors in the maximum data rates that different System/360 and System/370 models and 4300 Processors channels can sustain. When writing channel programs for larger systems, consider the storage width and the possibility of adding faster I/O devices.

Channel Implementation

The 4341 Processor has two basic types of channels. A byte-multiplexer channel and two block-multiplexer channels are standard. Three additional block-multiplexer channels are available as an option. Within this option, a second byte channel may be selected on channel 4.

The 4341 channels are integrated. They share with the processor the use of control storage, the processor storage data flow, and the arithmetic logic unit. Each channel can attach as many as eight control units and can address up to 256 I/O devices, except for the byte-multiplexer channels (channel 0 and 4) which can attach up to seven control units and has addresses OF0-OFF reserved. Control units are connected to all channels through the standard I/O interface.

Byte-Multiplexer Channel

The byte-multiplexer channels have a single data path that can be fully utilized by one I/O device (burst mode) or shared by many I/O devices (multiplex mode). Burst mode is defined as operation in which the device and the channel remain connected for a relatively long period of time in terms of system operation. Multiplex mode is defined as byte-interleaved operation in which the channel and any one device remain connected for a relatively short period of time, typically long enough to transfer one byte or a small number of bytes. Multiplexing, however, refers to the channel and device capability of disconnecting and reconnecting during an operation. The byte-multiplexer channel operates either in burst mode or in multiplex mode with multiplexing capability between bytes or groups of bytes.

Some control units are designed to operate on the byte-multiplexer channel in burst mode or in multiplex mode. Other control units allow the mode to be set at the installation.

When multiple I/O devices concurrently share byte-multiplexer channel facilities, the operations are in multiplex mode. Each device is selected, one at a time, for transfer of a byte or a few bytes to or from main storage. Bytes from multiple devices are interleaved and routed to or from desired locations in main storage. Thus, the byte-multiplexer channel data path is used by one device for transfer of one or a few bytes of data, and then another device uses the same data path. The sharing of the data path makes each device appear to the programmer as if it has a data path of its own. A device's share of the data path is called a *subchannel*.

Block-Multiplexer Channels

Two block-multiplexer channels are standard on the 4341 Processor. Block-multiplexer channel operation is described in the *IBM 4300 Processors Principles of Operation for ECPS:VSE Mode*, Order No. GA22-7070, and *IBM System/370 Principles of Operation*, GA22-7000.

The block-multiplexer channels can operate in either *block-multiplex* mode or *selector* mode. The mode of operation is determined by the block-multiplex mode bit of the control registers, as well as how the the I/O device is described to the system.

The block-multiplexer channel in block-multiplex mode allows concurrent operation of many I/O devices. This mode is intended for relatively high-speed burst operations. A single block-multiplexer channel can support interleaved, concurrent execution of multiple high-speed channel programs. The block-multiplexer channel in this mode can be shared by multiple high-speed I/O devices operating concurrently just as the byte-multiplexer channel can be shared by multiple low-speed devices. Like the byte-multiplexer channel, the block-multiplexer channel has multiple subchannels, each has an associated UCW in control storage and can support one I/O operation.

A block-multiplexer channel functions differently in selector mode in the way that it handles command-chained channel programs. A block-multiplexer channel operating in selector mode and executing a command-chained channel program is busy during the entire time the channel program is in operation, whether or not data transfer is occurring. A block-multiplexer channel in block-multiplex mode executing a command-chained channel program can disconnect from the operational program during certain nondata transfer operations. That is, a block-multiplexer channel in block-multiplex mode can be freed during nonproductive activity (for example, during disk seeking and most record positioning) to allow more data to be transferred per unit of channel busy time.

The selector and block-multiplex modes monitor the interface for an expected tag sequence. If an erroneous tag is activated (by a control unit) in addition to the normal interface sequence, the channel may not indicate a check. The channel may ignore the erroneous tag and proceed as if it did not exist.

Channel-Available Interruption

The 4341 Processor implements the channel-available interruption on channels 1 through 5 when they are operating as block-multiplexer channels.

The channel-available-interruption condition is meaningful only for the block-multiplexer. In selector mode, the channel always terminates a channel-busy condition with an interruption or an interruption-pending condition.

Channel Priority

All channels share one trap level for all functions, such as data transfer, chaining, status handling, and UCW fetching and storing.

The priority for handling channel trap requests is channel 1, 2, 3, 4, 5, and 0. To prevent high priority channels with constant trap requests from locking out low priority channels, each channel, except channel 0, has a trap request inhibit latch. When a channel's inhibit latch is on or when a channel is in a trap, the trap priority controls do not consider a pending trap request for that channel. When a channel trap is taken, the inhibit latch for that channel is set on, or all inhibit latches are reset off. That is: the inhibit latch for the trapping channels is set if any trap requests are pending for lower priority channels; otherwise, all inhibit latches are reset.

Function of Traps

Traps are requested by the channel hardware to indicate to the microcode that certain events have occurred or that certain conditions exist. Examples: the last command issued to the channel hardware has been completed, a device has connected to the I/O interface because of a polling sequence, or there is data in the data buffer to be transferred to storage.

The channel-trap microcode: fetches and stores the UCWs; transfers data between storage and the channel data buffers; fetches CCWs for SIO, command chaining, and data chaining; handles status and interface check conditions detected by the hardware; etc.

Channel Data Buffer

When the channel operation is set up, hardware controls the data transfer. Each channel has 256 bytes of channel data buffer. Depending on the data length and address boundary, hardware controls the transfer of data to processor storage:

- in 64-byte blocks
- in a partial block to line up to a 64-byte address boundary
- in a partial block to complete a data transfer
- in a partial block for very short records
- in a partial block for byte-multiplex operation.

Subchannels and Unit Control Words

Subchannels

The channel facilities required to sustain a single I/O operation are called a *subchannel*. Subchannels can be either unshared or shared. An unshared subchannel has the facilities to operate only one I/O device. A shared subchannel provides facilities to operate one of an attached set of I/O devices.

The initiation of multiple I/O operations requires that the subchannels have channel storage to record the addresses, count, status, and control information associated with the I/O operation. In the 4341., the storage for a single set of such information is called a *unit control word* (UCW). The UCW storage is provided by moving the high address boundary of user storage. The number of required UCWs is determined by the number of I/O devices described to the system. A maximum of 1,024 UCWs are available.

When an I/O operation is initiated, the UCW specified by the I/O unit address is modified (if the subchannel is not already busy) according to the operation to be performed. Each channel has one local-storage area for use in processing a single UCW. Therefore, when a UCW is set up in that area during execution of an I/O operation, requests from other units on that channel are prevented.

Unit Control Words (UCWs)

A UCW is either shared or unshared according to the type of subchannel it contains. The subchannel type is determined by the control and device(s) that use the subchannel and the UCW. An unshared UCW is reserved for a specified device. Examples are:

1. A single control unit that controls one I/O unit and requires one unshared UCW. For example, the 1443 Printer or the 3211 Printer each requires an unshared UCW.
2. A single unit that contains several control units and requires an unshared UCW for each unit. For example, the 2821 Control Unit that handles functions for a 1403 Printer and the reader and punch sections of a 2540 Read/Punch requires three unshared UCWs.
3. A single control unit that services the requirements of several devices at once and requires an unshared UCW for each device. For example, the 3830 Storage Control requires an unshared UCW for each device.

A shared UCW is reserved for a specified control unit and is shared by the devices attached to that control unit. For example, each 3272 Control Unit requires an exclusive UCW, but all 3277 Displays serviced by that control unit share the UCW assigned to the 3272.

UCW Pool

From 128 to 1,024 subchannels (UCWs) can be configured. If more than 128 UCWs are required, additional groups of 32 UCWs are allocated, up to the maximum of 1,024.

Each of the minimum allocation of 128 UCWs occupies 64 bytes of processor storage (for a total of 8,192 bytes). Additional UCWs (in groups of 32, up to a maximum of 1,024) may be assigned (by trained service personnel), with the user-storage reduction described in the following section.

System Storage Requirements

A portion of processor storage is required for systems functions and reduces the amount of processor storage available for user programming. The size of the reduction depends upon the processor configuration.

Each group of 32 additional UCWs reduces the usable processor storage by 2,048 bytes. For example, 128 UCWs require 8K of storage, and 1,024 UCWs require 64K of storage. For each increase in the number of UCWs, the additional UCW storage requirement limits the high address boundary.

Sixteen UCWs (000 through 00F) are reserved for natively attached I/O and for internal functions. Each channel has a shared UCW through which all unassigned I/O devices can present asynchronous interruptions. Each device attached to a channel must have a UCW associated with its address.

Channel UCW Directory

Each channel has a channel directory. Each directory has 256 entries, one for each possible device address (00-FF) on the channel.

Each directory entry contains the reference number of its associated UCW.

Each entry also contains the following status and attribute bits:

ASSIGNED	indicates that this entry was assigned to an I/O device by the user.
SHARED	indicates a shared UCW.
SEL	indicates a device that must operate in selector mode.
DATA STREAM	indicates a control unit or device attached to a control unit that can operate in data streaming mode.

UCW Assignment

UCWs for natively attached I/O devices (such as the 3278-2A) are preassigned. The logical addresses for these devices are assigned by the user. All other I/O devices must be described to the processor by the service representative at the user's request.

The device addresses for a channel that are not used by a described device are assigned to a *channel shared UCW*. A device that has not been described to the system can submit status via the channel shared UCW, but I/O instructions issued to that device result in a *not operational* condition (condition code 3). This information is kept in the UCW directory tables for automatic assignment of UCWs by the processor.

All UCW assignments are written onto the system diskette and become effective after subsequent initial microcode load (IML) operations. Note, however, that UCW reassignments for natively attached equipment become effective immediately (without a re-IML).

Figure 2 shows the special control-unit and devices requirements to be entered to describe them to the systems for UCW assignments.

Device Considerations

The system is generally able to provide better throughput if devices are assigned an unshared UCW and allowed to multiplex; however, this is not always the case. Some shared control units are capable of sustaining only one operation at a time. A shared UCW is quite satisfactory for this type of control unit. Assigning a UCW for each device is wasteful of UCWs. Some

Type of MPX Channel		Devices
Byte	Block	
-	LS	Direct Access Storage Units 2314*-2312,2313,2318,2319
-		2835*-2305
-	LS	2841*-2311
-		3540
-		3830*-3330,3333,3340,3344,3350
-	D	3880*-3330,3340,3344,3350,3370,3375,3380
		Magnetic Tape I/O
-	LS	2403,2404
-	LS	2415
-	LS	2803*-2401,2402,2420
-	LS	2804*-2401,2402
-	LS	3411
-	LS	3411*-3410
-	LS	3803*-3420
		Punched Card I/O and Printers
		1442
		1443
		2501,2520
		2821*-1403,2540
		3203
		3811*-3211
		3505,3525
		3800
-	LD	Data Security Devices 3848
		Displays and Console Printers
	L	2250
S	LS	2840*-2250
-	S	3258*-3251,3255
S	S	3272*-3277,3284,3286,3287,3288
S**	S**	3274*-3277,3278,3284,3286,3287,3288,3289
		3791*-3277,3284,3286,3287,3288,3793
		Magnetic Character and Optical Readers
	L	1255
		1287,1288
	L	1419
		3881,3886
		3890
-		3895
		Communication/Data Acquisition/Process Control
	LS	2701
-		2715*-2791,2793
-		3704
-		3705
		Paper Tape I/O
		2822*-2671
-		2826*-1017,1018
		Mass Storage System
		3850/51
		Auxiliary Processor
-		3838
		Audio Response
-		7770

Key:

D Control Unit/Device capable of operating in data streaming mode.

L Device requires the block multiplexer channel to work in selector mode.

S Device requires a shared UCW.

* Control unit

** 3274 Model 1A should use an unshared UCW for its single address.

- Not applicable.

none: Device requires an unshared UCW and the channel working in multiplexer mode.

Figure 2. UCW Assignment Chart

control units rely on the characteristics of the selector mode. These control units must have the multiplexing ability of the block-multiplex mode inhibited.

Devices that share a control unit and operate in selector mode can share a common UCW on the channel. The SEL mode bit must be on in the directory entry.

Devices capable of running in block-multiplexer mode can use an *unshared* UCW for each actual device attached, or one *shared* UCW for all devices attached to the control unit. Normally, UCWs for the block-multiplexer channel are unshared, with SEL mode off.

Some devices, such as the IBM 3272 Control Unit, require one exclusive UCW for each control unit on the channel. Each 3277 attached to that control unit shares that control unit's UCW. The SHARED bit must be on in the directory entry for that UCW.

Magnetic tape devices use a shared UCW and operate in selector mode.

Channel-to-channel adapters are treated as control units and require one UCW for each interface attached to the processor.

The use of data streaming mode is independent of whether a UCW is shared or unshared, or whether operation is in selector or block-multiplexer mode. The use of data streaming mode is still determined by device type.

Channel Interference with Processor

Because the processor and the channels share main storage and control storage, execution of processor instructions is slowed by activities on the channels. This is referred to as channel interference with processor or channel/processor interference. For simplicity, channel interference with processor is referred to as interference in this section.

This section defines how to calculate this amount of interference for I/O operations. To calculate interference time requires a knowledge of the particular systems I/O configurations and of the I/O programming involved. To calculate this time involves:

1. Calculation of the total interference time caused by the individual activities on the channel.
2. Calculation of the total interference percentage with the processor by relating the total interference time to a particular time span that is pertinent to the operation; for example, the time taken to execute all or part of an I/O operation, or even an entire program. The choice of a particular span of time is up to you.

Calculation of Total Channel/Processor Interference Time

The channel activities that can cause channel/processor interference and the duration of those activities are listed in Figures 3 and 4. To calculate total duration of interference:

1. From the figures, list the channel activities and their associated interference times that can occur in the time span chosen.
2. Record the number of times each channel activity (step 1) occurs in this time span.
3. For each channel activity (step 1), multiply the interference time (step 1) by the number of times that the activity occurs (step 2). This product is the duration of interference caused by that activity.
4. Add together the individual duration of interference times (step 3) to obtain the total interference duration.

Channel Activity	Channel Mode		
	Byte Multiplex	Block Multiplex	Selector Channel
Data Transfer			
Byte Mode/Byte	20.8		
Multi-Byte Mode/Connection	20.8		
Burst Mode/64 Bytes	3.7	3.7	3.7
CCW Execution			
Command Chaining with:			
CE and DE Together*	26.0	5.2	5.2
CE and DE Separated*	40.6	19.8	7.3
Data Chaining*	8.8	4.3	4.3
TIC	2.1	2.1	2.1
I/O Operations Concluding with:			
CE and DE Together**	37.3	35.3	30.7
CE and DE Separated**	73.5	76.9	71.8
PCI Processing	28.7	39.9	39.9
IDAW Fetch	2.3	2.3	2.3

* Add time for one IDAW fetch if IDA bit is ON in the new CCW.
 ** Includes creation time and I/O interruption time.

Figure 3. Processor Interference Times in Microseconds (System/370 Mode)

Channel Activity	Channel Mode		
	Byte Multiplex	Block Multiplex	Selector Channel
Data Transfer			
Byte Mode/Byte	22.8		
Multi-Byte Mode/Connection	22.8		
Burst Mode/64 Bytes	3.7	3.7	3.7
CCW Execution			
Command Chaining with:			
CE and DE Together*	29.9	7.2	7.2
CE and DE Separated*	44.5	23.7	9.3
Data Chaining*	12.7	6.3	6.3
TIC	4.1	4.1	4.1
I/O Operations Concluding with:			
CE and DE Together**	37.3	35.3	30.7
CE and DE Separated**	73.5	76.9	71.8
PCI Processing	28.7	39.9	39.9

* Add time for one IDAW fetch if IDA bit is ON in the new CCW.
 ** Includes creation time and I/O interruption time.

Figure 4. Processor interference Times in Microseconds (ECPS:VSE Mode)

Figure 5 gives an example calculation of total interference time that is caused by a tape-to-printer operation during which:

Channel Activity	Processor Inter-Ference Factors	Number of Bytes or Occurrences	Duration of Interference with Processor
Reading tape in selector mode: Data transfer in burst mode	3.7 usec/byte	1000 bytes/64 = 16	59.2 usec
CCW execution by data chaining	4.3 usec	9	38.7 usec
Concluding of I/O operation with CE and DE together	30.7 usec	1	30.7 usec
Writing to printer on byte multiplexer channel: Data transfers (in byte mode)	20.8 usec/byte	1000 bytes	20,800 usec
Execution of a CCW by command chaining with CE and DE separated	40.6 usec	9	365.4 usec
Concluding of I/O operation with CE and DE separated	73.5 usec	1	73.5 usec
Total duration of interference			21,367.5 usec = 21.4 ms

Figure 5. Duration of Channel Interference with Processor – (Example Calculation for a Tape-to-Printer Operation in System/370 Mode)

1. A 1,000-byte record is read from tape (selector mode on a block-multiplexer channel) by ten data-chained CCWs.
2. The 1,000 bytes are then sent to the printer (byte mode on a byte-multiplexer channel) by ten command-chained CCWs.
3. The example time span is assumed to be the duration of the complete operation.

The duration of interference time does not depend on the data rate of the device but on the characteristics of the 4341 channels and on the amount of data being transferred.

Calculation of Total Channel/Processor Interference Percentage

The previous calculations describe how to obtain the actual duration of interference in microseconds over a particular time span. This time figure, divided by the time span used for calculations, yields a percentage of interference.

The significance of the derived percentage of interference depends on the choice of time span. For example, the percentage of interference due to the tape-to-print operation in Figure 5 over a period of one minute is as follows:

$$[21.4 \text{ ms} \div (1 \times 60 \text{ seconds} \times 1000 \text{ bytes})] \times 100 = 0.036\%$$

$$\text{Conversely, the processor available time is} \\ 100\% - 0.036 = 99.964\%.$$

The percentage interference figure is the percentage by which the processing of processor instructions is slowed. If the interference is too great for the device being operated (see "Program Overrun"), queues develop for those

buffered devices that need service on the byte-multiplexer channel. This results in loss of performance on those devices.

Program Overrun

Program overrun is a particular effect of channel interference with the processor (see previous section). Program overrun results from a program being slowed 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 IBM 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 not stacked correctly and the channel program stops.

Assessing Program Overrun

To investigate the possibility of program overrun:

1. Establish the available program time, that is, the time during which the program must perform 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 instructions (see "Instruction Timings" in *IBM 4341 Processor Functional Characteristics*, GA24-3672). When establishing this time, take all program activity into account, including 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 processor interference time that can be caused by simultaneous activities on all channels during time A. The calculation of total channel/processor interference time is described previously in this section. Call this time I (interference time).
4. Calculate $P + I$ (processing time) + I (interference time) and compare the result to A (available time). 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 additional channel activities are: (1) a 3330 Disk Storage Device transferring data on one of the channels in burst mode at the rate of 806 kilobytes per second, and (2) a 1442 Card Read Punch using one-byte transfers and punching EBCDIC characters.

For this example, assume that the interference with the processor caused by these two operations during the available time A is the worst that can occur in this application or that 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 interference that is caused by the 3330 data transfer within the time span A. At 806 kilobytes per second, the number of bytes transferred in time A (9.50 milliseconds) is:

$$\text{Number of bytes} = (806,000 \times 9.50) \div 1000 = 7,657 \text{ bytes}$$

By using the duration of interference on a channel in burst mode to be 3.7 $\mu\text{s}/\text{byte}$ (from Figure 3), the total interference in time A caused by transferring 7,657 bytes is:

$$7,657 \text{ bytes} \div 64 = 120 \text{ 64-byte transfers}$$

$$120 \times 3.7 \mu\text{s per 64 bytes} = 444.0 \mu\text{s of interference time}$$

- b. Calculate the duration of interference caused by the 1442 within the time span A. This is assumed to be the execution of one command-chained CCW, and two one-byte data transfers (see Figure 4).

Execution of a CCW with command chaining:

$$26.0 \mu\text{s} \times 1 = 26.0 \mu\text{s Data transfer in byte mode:}$$

$$20.8 \mu\text{s} \times 2 = 41.6 \mu\text{s}$$

$$\text{Total: } 67.6 \mu\text{s}$$

- c. Calculate the total interference time I from steps a and b

$$444.0 \mu\text{s (Step a)} + 67.6 \mu\text{s (Step b)} = 511.6 \mu\text{s}$$

$$\text{or } 0.512 \text{ ms total interference time}$$

4. Calculate P + I and compare the result with A.

$$P(8.00 \text{ ms}) + I(0.512 \text{ ms}) = 8.512 \text{ ms}$$

$$\text{or } P + I = 8.512 \text{ ms}$$

Because A (9.50 ms) is larger than P + I (8.512 ms), no program overrun can occur.

Concurrent Input/Output Capabilities

Each I/O device in operation places a load on its channel facilities. The magnitude of a load depends on a device's channel programming and its data-transfer rate. In this manual, numeric factors are used to relate the loads caused by operation of I/O devices to the channel's abilities to sustain concurrent operation of the devices.

One or more numeric factors are specified for each I/O device and channel available with a 4341 Processor. The numeric factors are given in tables in the Appendix and are used in arithmetic procedures for determining whether the operations of specific 4341 input/output configurations are satisfactory.

Several procedures are provided for evaluating a configuration of I/O devices for concurrent operation on 4341 channels. For most configurations, using the basic procedures suffices in determining whether operation is satisfactory. Use detailed procedures only for configurations that appear to exceed 4341 input/output capabilities.

Worst-Case Loads

The evaluation factors and procedures allow for a worst-case situation, when the most demanding devices in the configuration make their heaviest demands on 4341 I/O capabilities at the same time. Such a situation may not occur frequently, but this is the situation that the evaluation procedures test. If a particular configuration fails this test, one or more devices can be expected to incur overrun or loss of performance.

Overrun

Overrun occurs when a channel does not accept or transfer data within the required time limit. This data loss may occur when the total channel activity initiated by the program exceeds channel capabilities. Depending on the device, the operation may be halted, or data transfer may continue until the end of the block is reached.

An overrun may cause a unit-check indication to be presented to the channel and stored in the CSW. Chaining, if any, is suppressed, and an I/O interruption condition is generated at the end of the operation. Certain control units, however, can initiate a command-retry sequence without storing a CSW or requiring an I/O interruption.

Loss of Performance

Overrun occurs only on unbuffered I/O devices. When buffer service is not provided within required time limits, the device merely waits for channel service. This means a loss of performance.

Conventions for Satisfactory Channel Programs

Execution of a channel program causes a load on channel and system I/O facilities. Some I/O devices require execution of a chain of commands before transfer of a data block. However, the impact of the load caused by a channel program is not a simple function of the number of commands used. The sequence in which particular types of commands appear in a channel program is also a factor.

Control commands are particularly significant to sequencing considerations because they are executed at electronic speed and cause no motion. The command is executed as an immediate operation and provides device end in the initial status byte. When command chaining is specified in such an

immediate operation, channel facilities are not disengaged from the channel program until the chain ends or a command causing mechanical motion or data transfer is executed. Therefore, when immediate operations with device end in the initial status byte are chained together, fetching and execution of the CCWs can cause a heavy load on channel facilities. This load can cause excessive delay in channel service to one or more devices in the I/O configuration and result in overrun or loss of performance. For example, a chain of No-Op commands can contribute heavily to channel loading. Thus, a programming convenience may cause a severe overrun situation for concurrently operating devices.

Data-Chaining Considerations

A 4341 user can 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 channel-evaluation procedures and tables in this manual provide guidance in gauging the effects of data-chaining operations.

Relationship of Conventions and Evaluation Procedures

The evaluation procedures depend on channel programs having command sequences that provide efficient operation of I/O devices and that avoid placing unnecessary loads on channel facilities. Channel-programming conventions help I/O programmers avoid overrun situations.

Observing channel-programming conventions is fundamental to the selection of an I/O configuration that permits satisfactory concurrent operation of I/O devices. The channel-programming conventions described are integral to the channel-evaluation procedures. An evaluation indicating satisfactory channel performance is not dependable for channel programs written in violation of the conventions.

Scope of Conventions

1. The conventions relate to the sequence in which certain types of commands can be executed, not to their sequence in main storage.
2. The conventions define four classes of commands and the sequence in which they can be used.
3. The command sequences provided by the conventions differ for different types of devices. Sequences are provided for:
 - DASD: 2305, 2311, 2314A, 3330, 3340, 3350
 - Tape unit: series 2400, 2420, 3410, 3420
 - Card units: 1442, 2501, 2520, 2540, 3505, 3525
 - Printers: 1403, 1442, 3211, 3203
 - Communication adapters: 2701, 3704, 3705
4. The conventions relate to all the commands in a chain including the CCW addressed by the CAW and the terminating CCW that does not specify any chaining. This is of particular interest to I/O programmers working on segments of a single channel program. The conventions still apply when one segment is chained to another segment.
5. The conventions relate only to commands addressed by the CAW that specify chaining.
6. The conventions relate only to the avoidance of overrun; they do not define invalid command sequences that are rejected by a channel (such as TIC to TIC), or that are rejected by a control unit. CCW sequences causing command reject are specified in the I/O device manuals.

The channel-programming conventions in this manual are recommended to 4341 users, particularly in a multiprogramming environment where a programmer is not aware of the overall load on channel facilities. Where a programmer controls or has knowledge of all I/O activity, he can establish somewhat less restrictive channel programming conventions that are particularly suited to his application and configuration.

Classes of Commands

The conventions establish four classes of commands. Commands that always cause mechanical motion are in one class. The other three classes encompass commands that are executed at electronic speeds, plus commands that are sometimes executed at electronic speeds. An example of the latter is rewind, which is executed at electronic speeds when tape is already at load point. The three classes of commands having electronic-speed properties differ in the length of time required for their execution.

The conventions for the different devices specify classifications for the specific commands pertinent to each device.

The conventions define the four classifications by the sequence in which they can precede or follow other commands:

Class A Commands: These commands can be chained in any order, without restriction. In general, Class A commands always cause mechanical motion.

Class B Commands: Only one Class B command can be chained between two Class A commands:

-->A-->B-->A = permissible command-chaining sequence
-->A-->B-->B-->A = command-chaining sequence excluded by conventions

A Class B command can be substituted for a Class C or Class D command.

Class C Commands: A Class C command generally appears only once in a channel program, and then only as the first command in a channel program; therefore, a Class C command usually appears only in the location specified by CAW:

CAW-->C-->A-->B = permissible program
CAW-->A-->C-->A = program excluded by conventions

A Class B command can be substituted for a Class C command:

CAW-->B-->A-->B-->A-->B = permissible program

Class D Commands: A Class D command can appear only as the last command in a channel program; it cannot specify any chaining.

CAW-->X-->X-->D = permissible program
CAW-->X-->D-->A = program excluded by conventions

A Class B command can be substituted for a Class D command.

Some devices have conventions that exclude specific sequences of commands not excluded by the classifications previously described. Some devices have conventions that allow a specific command sequence to be substituted for a single command of a specified class. For detailed information, refer to the publications that describe the individual devices.

Command Classifications for I/O Devices

The following rules define classifications for specific commands used with a particular device. The bit pattern for each command code byte is specified to provide positive identification of commands.

Commands not classified in the following text cannot specify any chaining and can be placed only in the location specified by the CAW. Each such command thus constitutes an entire channel program in which it is the only command. The Sense command is used in this manner for all devices.

Note: For diagnostic or device feature-dependent commands, refer to the device-associated manuals.

Direct-Access Storage Devices: These command classifications are valid for all DASD devices.

Class A commands (any order):

Read	}	xxxx xx10	
Write			
Search			xxxx xx01
Erase			
Space Count		0000 1111	
Recalibrate		0001 0011	(Class A, 2311 only)
Orient		0010 1011	
No-Op		0000 0011	(No-Op can be used only when preceded by a 0001 xx01 or 0000 0001 formatting Write.)

Class B commands (not more than one between Class A commands):

TIC	xxxx 1000
Seek	{ 0000 0111
	{ 000x 1011
Set Sector	0010 0011
Read Sector	0010 0010

These command chains have the properties of a single Class B command:

TIC-->Seek	xxxx 1000-->	{ 0000 0111	
		{ 000x 1011	
Seek-->TIC	{ 0000 0111 }	--->xxxx 1000	
	{ 000x 1011 }		
TIC-->Seek-->Set Sector			
xxxx 1000-->	{ 0000 0111-->	0010 0011	
	{ 000x 1011 }		
Seek-->Set Sector-->TIC			
0000 0111 }			
000x 1011 }	-->0010 0011-->	xxxx 1000	

Note that a Read Sector must be preceded by a Read, Write, or Search command and that a Seek must precede a Set Sector.

Class C commands (first CCW in program): These command chains have the properties of a single Class C command:

```
Set File Mask 0001 1111
Seek-->Set File Mask-->TIC-->Set Sector
0000 0111 }
000x 1011 } -->0001 1111-->xxxx 1000 0010 0011
```

Class D commands (last CCW in program):

No-Op	0000 0011	(except when preceded by a formatting Write)
Restore	0001 0111	(No-Op on other than 2311 or 2321)
Release	0001 0011	(two-channel switch use only)

Excluded chains:

```
Search-->TIC-->Write
x011 0001 }
x010 1001 } -->xxxx 1000-->0000 x101
```

Data chaining can propagate through a TIC command for gap-only data chaining (see "Data Chaining in Gaps").

Tape Units:

Class A commands (any order):

Read	xxxx xx10
Write	xxxx xx01
Read Backward	xxxx 1100
Forward Space	0011 x111
Backspace	0010 x111
Write Tape Mark	0001 1111
Erase Gap	0001 0111

Class B commands (not more than one between Class A commands):

TIC	xxxx 1000
-----	-----------

Class C commands (first CCW in program):

Set Mode	xxxx x011
----------	-----------

This command chain has the properties of a single Class C command:

```
Set Mode-->TIC xxxx x011--> xxxx 1000
```

Class D commands (last CCW in program):

Rewind	0000 0111
Rewind and Unload	0000 1111
No-Op	0000 0011
Data Security Erase	1001 0111

Mixed-Mode, Seven-Track Tape Operations: A routine can be used to select a tape unit, set its density mode, and then TIC to a desired channel program:

```
SIO-->Set Mode Class C
TIC sequence
```

The conventions require the CCW addressed by the TIC to be Class A.

If the tape applications involve mixed-mode, seven-track operations, the programmer can make provision for placing the proper Set Mode command in the location addressed by the CAW before SIO is issued, or the programmer can begin each channel program addressed by the TIC with an appropriate Set Mode command. This additional Set Mode command violates the convention for Class C commands and causes an additional load on channel facilities.

Card Units:

Class A commands (any order):

Read xxxx xx10
 Write xxxx xx01

Class B commands (not more than one between Class A commands):

TIC xxxx 1000

Class C commands (first CCW in program):

Control xxxx xx11

Class D commands (last CCW in program):

Control xxxx xx11

Printers:

Class A commands (any order):

Write xxxx xx01

Class B command (not more than one between Class A commands):

TIC xxxx 1000

Class C commands (first CCW in program):

Control xxxx xx11

Class D commands (last CCW in program):

Control 0000 0011

Communication Adapters: Data chaining with or without TIC can be used for these adapters.

Class A commands (any order):

Write	}	xxxx xx01
Dial		
Break		
Diagnostic write		
Read	}	xxxx xx10
Prepare		
Inhibit		
Search		
Diagnostic read		

Class B commands:

Not applicable

Class C commands (first CCW in program):

Control* xxxx xx11

Class D commands (last CCW in program):

Control* xxxx xx11

* For a communications network of switch-type terminals, these two control commands are Class A:

Disable	0010 1111
Enable	0010 0111

Evaluating Heavily Loaded Channels

When evaluating the performance of a system susceptible to channel overload conditions, consider the relative ease of restarting an interrupted I/O operation. For example, an overrun on a communication line coupling two processors is handled more readily than a read overrun on a card read-punch. Preferential priority can be given to devices that require manual intervention in response to an overrun condition.

Some circumstances may warrant placing devices with heavy load factors on the same block-multiplexer channel, rather than on separate block-multiplexer channels, to reduce the channel load on the system.

Evaluations should not ignore the characteristics of IBM Programming Systems packages:

- Operating System/360
- Disk Operating System

These programs attempt to execute any start I/O instruction for which the channel and device are available.

Block-Multiplexer Channel Loading

Overrun Evaluation Consideration

When more than one channel is running concurrently, the channels compete for the processor's resources. If any channel is delayed in its bid for the shared resources because the resources are being used by other channels, the channel being delayed may overrun. Block-multiplexer channel operations resulting in overrun cause degradation of the total system because of the time required for error-recovery procedures. Using data chaining with TIC increases the time that a channel needs the shared resources; this can, in turn, reduce the maximum data rate that can be sustained on the channel and can diminish the capabilities of lower-priority channels.

If the program causes data chaining to occur only during gap time, the data chaining does not reduce the maximum data rate that can be sustained on that channel.

Late Command Chaining

In systems that have disk-storage and/or fixed-head storage facilities operating on the lower-priority channels, simultaneous chaining can cause late command chaining on the lower priority channel.

When late command chaining occurs on the facilities with retry capabilities, the channel and control unit cooperate to reissue the late command to repeat the operation after one revolution of the disk. In this case, because it occurs infrequently, system performance is not likely to be affected significantly. Without retry facilities, the channel program ends and an I/O interruption condition occurs. This can cause significant performance degradation.

Testing for Overrun

To determine the maximum individual block-multiplexer channel capabilities with various configurations and operating conditions, refer to Appendix C and D. Check to ensure that no device operating under the conditions specified exceeds the maximum data rate specified.

Byte-Multiplexer Channel Loading

The byte-multiplexer channel should not be required to handle a burst-mode I/O device that is subject to data overrun. Burst-mode devices (tapes or disk drives) should be attached on a block-multiplexer channel. However, the operation of non-overrunnable buffered I/O devices, such as printers, and card readers and punches, is supported in burst mode. Other devices attached to the byte-multiplexer channel are locked out during this period. This can cause overrun when the ability to wait for channel service is exceeded.

Byte-Mode Considerations

Concurrent operation of I/O devices on a byte-multiplexer channel is governed by several variables:

1. Devices vary in data-transfer rates.
2. Devices have buffers varying in capacity.
3. Devices vary in the number and type of CCWs needed for their operation.
4. Combinations of devices on the block-multiplexer channels vary in the interference they cause.
5. The large number of I/O devices available for use on a byte-multiplexer channel can be combined in many different ways.
6. Devices in a particular configuration can be physically connected in many different priority sequences.

Worksheet and factor tables can be used to determine whether a byte-multiplexer channel configuration can run concurrently in a satisfactory manner.

Device Load

A numeric factor, called a *device load*, for each byte-mode device represents its load on channel facilities. The factors are listed in Appendix A for channel 0, and in Appendix B when channel 4 is selected as a second byte-multiplexer channel.

The values given in Appendix A and B need to be modified if any block-multiplexer channel is active. The D1 factor is used in the following formula to modify the device load:

$$\text{Device Load (modified)} = \text{Device Load} + (D1 \times n)$$

where n = number of active block-multiplexer channels.

Appendix A and B lists other factors for use in considering the impact of higher-priority devices on lower-priority devices.

Device Wait Time

After requesting channel service, a byte-mode device has a fixed time that it can wait for service. If service is provided within this time, the device operates satisfactorily. If, however, the channel does not service the device within the device's wait time, either of two things occurs: if the device is not susceptible to overrun, it continues waiting; if it is, it loses data and causes an I/O interrupt condition. For example, if a 1403 Printer on a overloaded byte-multiplexer channel fails to receive data, it waits until service is provided by the channel. The delay does not cause an interrupt condition, nor is a new start I/O instruction required for selecting the 1403. The only effect is a slight reduction in performance. If, however, a 1442 Card Read Punch read operation does not receive data service within its wait time, an overrun occurs.

Wait time factors for byte-mode devices are listed in Appendix A and B.

Device Priority on Byte-Multiplexer Channel

The priority of devices on a byte-multiplexer channel is established 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 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 line 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 can 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; for example, 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 because of synchronization lag.

Class 3: Devices that do not require synchronized channel service; for example, the IBM 2660 Display Station with a 2848 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 Appendix A and B.

When devices that operate only in burst mode, such as magnetic-tape or disk-storage devices, are attached to the byte-multiplexer channel, they should have lower priority than 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.

The control unit determines whether a device operates on the byte-multiplexer channel in burst mode or in byte mode.

Some devices, such as the IBM 2821 Control Unit, can 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. Such devices are assigned priority on the byte-multiplexer channel according to the mode of operation selected.

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 can be obtained by operating the devices in burst mode.

The support processor and the integrated consoles are connected through the byte-multiplexer channel and have the lowest priority. Other byte-multiplexer channel activity may cause interference with these devices.

Interference from Priority Devices

The byte-multiplexer channel sustains concurrent operations in byte mode by servicing one device at a time.

The operating devices compete for service, and the byte-multiplexer channel services them in the order of their priority.

Devices on the block-multiplexer channels or higher-priority devices on the byte-multiplexer channel can force lower-priority, byte-mode devices to wait for channel service. The former are called *priority devices*, and the latter *waiting devices*.

When a priority device forces a waiting device to wait for channel service, the priority device is said to interfere with the lower-priority device.

When there is more than one priority device, each of the priority devices may generate interference. All such interference must be considered in determining whether the waiting device is to receive channel service before its wait time is exceeded.

The test procedures for concurrent operation of byte-mode devices assume that a waiting device has made its request for channel service at the worst possible time; that is, when the priority devices cause maximum interference during the waiting device's wait time.

The channel ordinarily works its way through the interference, and the waiting device is unaffected by the wait. If, however, heavy interference forces the waiting device to wait past its particular wait time, it is subject to overrun.

Priority Loads

To evaluate the effect of priority-device interference on a waiting device, a numeric priority load is computed.

Three factors determine a priority load:

1. The control load caused by execution of CCWs including chaining and transfer-in-channel operations.
2. The priority device's data-transfer load.
3. The wait time of the device being evaluated.

Note that because a priority load is a function of wait time, a fixed priority load cannot be established for a priority device; the priority load caused by a priority device must be computed as a function of a particular waiting device's wait time.

Ranges of Wait Times

The relationship between the interference generated by a priority device (expressed as *priority load*) and various wait times is shown in Figure 6. The abscissa relates to device wait times. The short wait time shown results in a heavy priority load; the longer wait time falls in a part of the curve showing much less priority load. This curve shows that the impact of a priority device on a waiting device is more intense for a waiting device with a short wait time than it is for a device with a long wait time.

Two factors, called *A* and *B*, relate each device's priority load curve to different wait times. The priority load curve was considered in segments related to different time intervals, and an *A* and a *B* factor were computed for

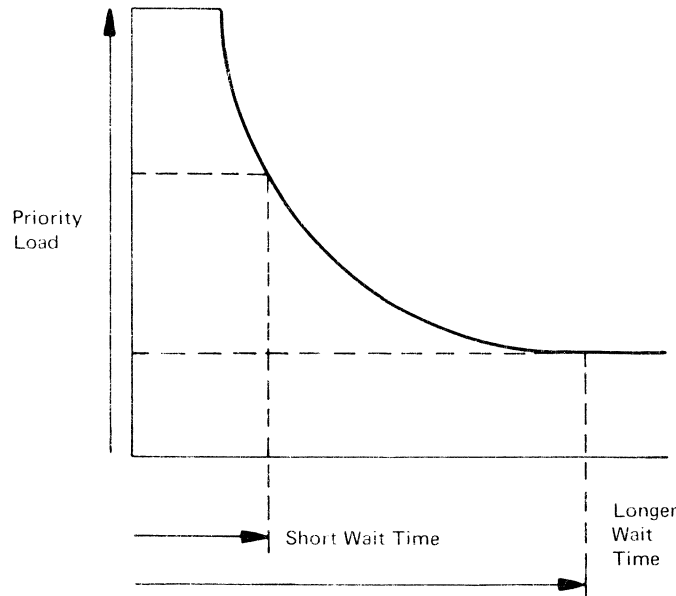


Figure 6. Priority Load Curve

each curve segment. These factors are used to compute the priority load for a waiting device having a wait time that falls within the range of the interval established for the curve segment.

The values of the A and B factors in Appendix A and B need to be *modified* if any block-multiplexer channel is active. The A1, A2, and B1 factors are used to modify the given time (T), A, and B factors by the formula:

$$A \text{ (modified)} = A + (A1 \times n) - (A2 \times n^2)$$

$$B \text{ (modified)} = B + (B1 \times n)$$

$$T \text{ (modified)} = \frac{\text{(difference of modified A values for previous and present lines)}}{\text{(difference of modified B values for previous and present lines)}}$$

n = number of active block-multiplexer channels.

Multiple A and B Factors: The appendixes list the A and B factors for each 4341 Class 1 input/output device.

Some devices have only one set of A and B factors. Other devices have more than one set. Each set has an associated priority time factor that represents the beginning of the time interval over which the A and B factors are effective.

Priority Time Factors: The priority time factors in Appendix A or B are used in the evaluation procedure to identify the A and B factors to be used.

Each waiting device is evaluated on a byte-multiplexer channel worksheet; its wait time is used to select a set of A and B factors for each priority device.

Each set of A and B factors in Appendix A or B has a priority time factor next to it that specifies the beginning of a time interval significant to that set of A and B factors. The range extends from the priority time factor specified for that set to the priority time factor specified for the next set, if any. The end of the last interval is assumed to be unbounded. For example, a device may have three sets of A and B values that describe the priority load function over three contiguous intervals. Figure 7 shows the priority time factors and A and B factors as they appear in Appendix A or B for an IBM 1442 Card Read Punch Model N1 reading EBCDIC.

The time intervals are defined by these priority time factors:

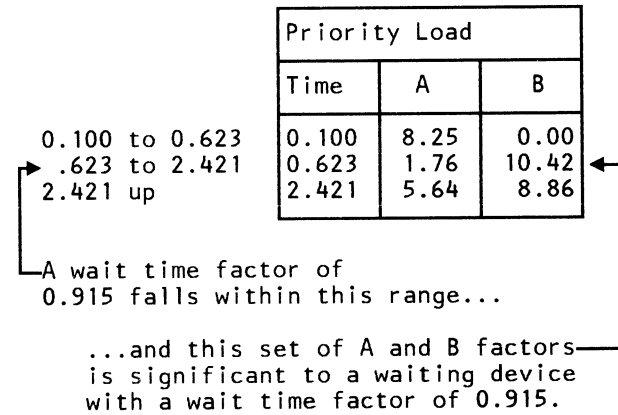


Figure 7. Use of Priority Time Factors

Priority Load Formula

The A and B factors and wait-time factors in Appendix A and B are used in a formula that yields the priority load that occurs when a priority device interferes with a waiting device.

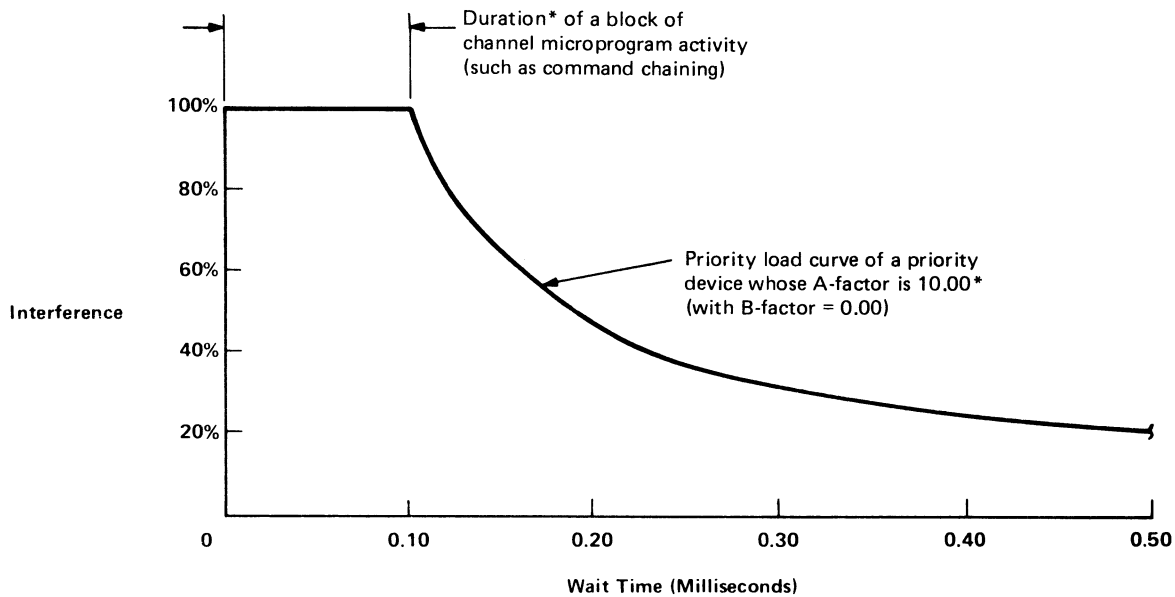
The sum of the B factor and the quotient obtained by dividing the A factor by the wait-time factor of the waiting device is the priority load. The arithmetic looks like this:

$$(A \div \text{wait time}) + B = \text{priority load}$$

A-Factor Interference: A-factor interference is caused by channel microprogram 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 microprogram 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 activity lasting 0.10 millisecond is therefore: $0.10 \times 100 = 10.00$.)

Figure 8 shows how A-factor interference varies with the wait time of the waiting device.

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 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.



* 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 $0.10 \times 100 = 10.00$. Thus, for a waiting device having a wait time of 0.2 millisecond, the interference is obtained directly as a percentage:

$$\frac{\text{A-Factor}}{\text{Wait Time}} = \frac{10.00}{0.2} = 50\%$$

Figure 8. Example of Priority Device Causing Interference by Command Chaining (A-factor Interference)

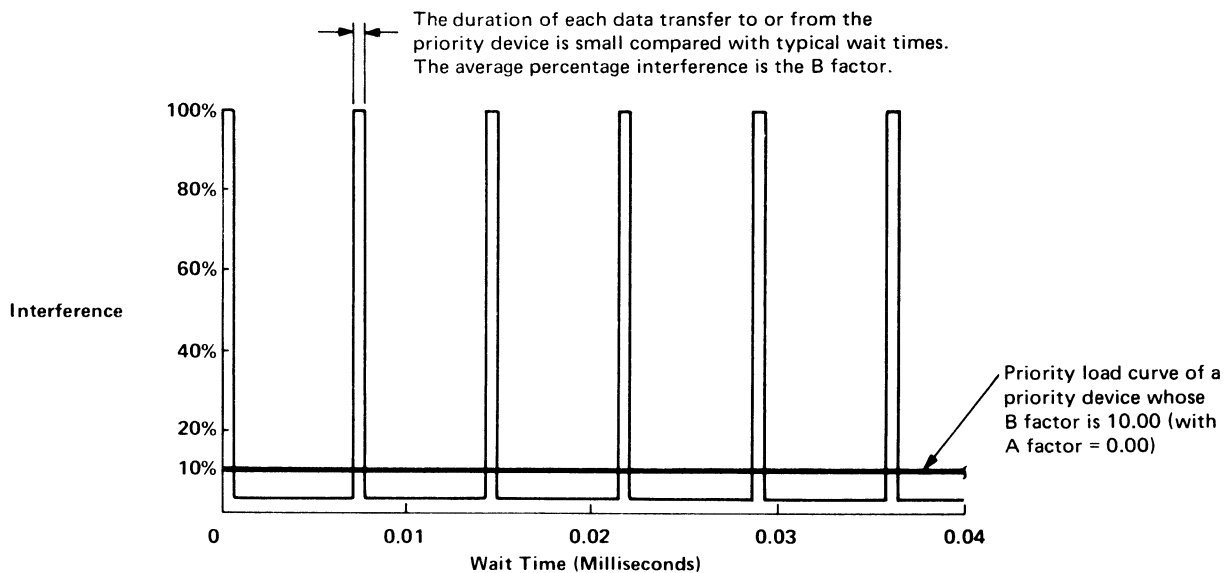


Figure 9. Example of Priority Load Curve of a Priority Device Causing Interference by Transferring Data (B-Factor Interference)

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 8 and 9. Usually, the A and B factors are *both* nonzero, and the total priority load of a priority device is given by:

$$\text{Priority Load} = \left[\frac{A}{\text{Wait time}} + B \right] \%$$

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 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 10 also shows how to choose the appropriate A and B factors according to the wait time of a waiting device. (The A and B factors for integrated adapters vary, depending upon the channel command. The figures given in the appendixes are representative of worst case interference for a typical channel command sequence.)

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
2520 Card Read Punch Model B1 Read/Punch EBCDIC	0.10	0.00	100.00
	2.15	214.00	0.00
	24.78	10.85	8.23

0.10 ms to 2.15 ms
2.15 ms to 24.78 ms
24.78 ms and longer

Example 1

When considering the priority load of a 2520 Card Read Punch Model B1, (that is reading or punching EBCDIC) upon a waiting device that has a wait time of 1.00 ms, use the following priority load factors:

A = 0.00 and B = 100.00 (because 1.00 ms is the range 0.10 ms to 2.15 ms)

Example 2

Similarly, for a waiting device that has a wait time of 10.00 ms, use the following priority load factors:

A = 214.77 and B = 0.00 (because 10.00 ms is in the range 2.15 ms to 24.78 ms)

Figure 10. Examples Showing How to Choose Priority Load Factors

Previous Load

A waiting byte-mode device may be forced to wait for channel facilities, not only by devices with higher priority, but also by a device with lower priority that is in operation when the waiting device requests channel facilities. This interference is called a *previous load* and must be added to the priority load caused by priority devices. Previous load factors are calculated for each device by using the formula:

$$\text{Previous Load} = [13.0 + (2.5 \times n)] \div \text{WT}$$

n = number of active block-multiplexer channels.

WT = wait time of the device.

Load Sum

Several load factors relating to byte-mode operations have been described:

- Device load (contributed by waiting device)
- Priority load (contributed by each priority device)
- Previous load (contributed by a lower-priority device)

These loads added together form a load sum for each waiting device. The load sum represents the total load on system channel facilities under a worst-case condition when:

1. All priority devices are causing maximum priority loads.
2. Any lower-priority device, already in operation, is making maximum demands on channel facilities (previous load).
3. The waiting device places its maximum device load on channel facilities.

A step-by-step procedure for computing load sums is given in "Byte-Mode Evaluation Procedure."

Byte-Mode Channel Load Limit

A numeric factor of 100 is considered the byte-mode channel load limit. If a load sum exceeds 100, overrun is indicated during worst-case situations.

Byte-Mode Evaluation Procedure

The following step-by-step procedure is used with a *IBM 4341 Processor Byte-Multiplexer Channel Preliminary Worksheet (GX24-3746)*, shown in Figure 11, and a *IBM 4341 Processor Channel Load Sum Worksheet (GX24-3670)*, shown in Figure 12.

Most of the steps call for an entry to be made on a worksheet. Each circled number shown on the worksheets in Figures 13 and 14 refer to the numbered step in the following procedures. For example, a circled number 1 is shown at the top of the worksheet in each of the two spaces that receive the entries called for by step 1. As an additional aid for where entries are made on a worksheet, see Figures 15 and 16 which show worksheets that have been completed for a configuration specified in "Worksheet Example."



4341 Byte-Multiplexer Channel Preliminary Worksheet

GX24-3746.1 U/M 050
File No. 4300-01
Printed in U.S.A.

System Identification: _____ Date: _____
Block-Multiplexer Channels N values: N_d _____, N_p _____

Device	Wait Time	Device Load	D1	Original Factors						Modified Factors						
				Time	A	B	A1	A2	B1	Device Load	Previous Load	Time	A	B		
				1										1		
				2										2		
				3										3		
				1										1		
				2										2		
				3										3		
				1										1		
				2										2		
				3										3		
				1										1		
				2										2		
				3										3		
				1										1		
				2										2		
				3										3		
				1										1		
				2										2		
				3										3		
				1										1		
				2										2		
				3										3		
				1										1		
				2										2		
				3										3		
				1										1		
				2										2		
				3										3		

Instructions for using this worksheet are given in
IBM 4341 Processor Channel Characteristics,
Order No. GA24-3671.

Figure 11. Sample 4341 Processor Byte-Multiplexer Channel Preliminary Worksheet



4341 Byte-Multiplexer Channel Preliminary Worksheet

GX24-3746-1 U/M 050
 File No. 4300-01
 Printed in U.S.A.

Date:

Block-Multiplexer Channels N values: N_d , N_p

System Identification:

Device	Wait Time	Device Load	D1	Original Factors					Modified Factors						
				Time	A	B	A1	A2	B1	Time	A	B	Previous Load	Device Load	
③	④			1						1					
				2						2					
				3						3					
				1						1					
				2						2					
				3						3					
				1						1					
				2						2					
				3						3					
③	④			1						1					
				2						2					
				3						3					
				1						1					
				2						2					
				3						3					
				1						1					
				2						2					
				3						3					
③	④			1						1					
				2						2					
				3						3					
				1						1					
				2						2					
				3						3					
				1						1					
				2						2					
				3						3					

Instructions for using this worksheet are given in
 IBM 4341 Processor Channel Characteristics.
 Order No. GA24-3671.

Figure 13. Example of Preliminary Worksheet Entries

Preliminary Worksheet Example

This procedure uses the *IBM 4341 Processor Byte-Multiplexer Channel Preliminary Worksheet (GX24-3746)*.

1. Enter the system identification and the date.
2. This item contains instructions for the calculation of the values N_d , N_p and M_p for the byte-multiplexer channel preliminary and Load Sum worksheets. In these calculations, N_d is the value used to calculate device load, N_p is the value used to calculate previous load and the A and B factors, and M_p is the value used to calculate previous and prior load on the Load Sum worksheet.

These values are shown on the following charts:

N_d = The number of active block-multiplexer channels, plus 1.0 if the other byte-multiplexer channel is active, plus .4 for each channel that is data chaining out of a file gap.

N_p = The number of active block-multiplexer channels with high data rate, plus .4 for each block-multiplexer channel with high data rate that is data chained when not in a file gap, plus 1.4 if the other byte-multiplexer channel is also active, plus .6 if the other byte-multiplexer channel is active and data chaining.

$$M_p = \frac{18}{18 - \sum \text{EDR}}$$

Where \sum EDR (Effective Data Rate) is the sum of the maximum EDR in megabytes per second of each block-multiplexer channel that is not included in N_p .

The EDR for each device on a block-multiplexer channel is equal to the Device Data Rate (DDR) if it is not being data chained, or:

$$\frac{(1 + 256) \times \text{DDR}}{\text{CNT}} \quad \text{- if the device is being data-chained when not in a file gap}$$

Where CNT is equal to the smallest CCW count being used when data chaining.

The starting values for the preliminary and Load Sum worksheets are obtained from results derived from the following chart. To calculate N_d ,

N_p , and M_p , refer to the following chart and steps a through i:

Sample chart completed for one byte-multiplexer channel on channel 0, and a block-multiplexer channel on channel 4:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Channel	Active	Chain Data	Byte Mpx	Max EDR	nd	np	Used EDR
0	0	0	0	0	0	0	0
1	1	0	0	H	1.0	1.0	0
2	1	1	0	H	1.4	1.4	0
3	1	0	0	H	1.0	1.0	0
4	1	0	0	.333	1.0	0	.333
5	1	1	0	1.800	1.4	0	1.800
					5.8	3.4	2.133

$$M_p = \frac{18}{18 - 2.133} = 1.12 \quad (N_d) (N_p) (\Sigma EDR)$$

Blank form for calculations:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Channel	Active	Chain Data	Byte Mpx	Max EDR	nd	np	Used EDR
0							
1							
2							
3							
4							
5							

$$M_p = \frac{18}{18 - \Sigma EDR} = \quad (N_d) (N_p) (\Sigma EDR)$$

Only channel zero, and optionally channel four, can be configured as byte-multiplexer channels. First enter '0' in all seven columns of the chart for the byte-multiplexer channel being evaluated.

To arrive at columns 1 through 4 for the remainder of the channels:

- Column 1 - Enter a '1' in the 'Active' column for each active channel, and a '0' in the 'Active' column for each inactive channel. If a zero appears in the 'Active' column, enter '0' in all remaining columns for that channel.
- Column 2 - Enter a '1' in the 'Chain Data' column for each active channel that is data chaining when it is not in a file gap; otherwise enter '0'.

- c. Column 3 - Enter a '1' in the 'Byte-MPX' column for the other byte-multiplexer channel (channel 0 or 4) if it is being configured as a byte-multiplexer channel; otherwise enter '0'.
- d. Column 4 - Enter a '0' in the 'Max EDR' column for the other byte-multiplexer channel if it is configured as a byte-multiplexer channel.

The maximum EDR for a channel is determined by calculating an EDR for each device and selecting the maximum value.

Enter an 'H' if the effective data rate (EDR) is high, and will not be used to calculate load; otherwise enter the maximum EDR for each channel.

The EDR for a particular device is determined by the following:

$$\text{If not data chaining or if data chaining in a file gap.} \quad \text{EDR} = \frac{\text{Device Data Rate}}{\text{DDR}}$$

$$\text{If data chaining, when not in a file gap.} \quad \text{EDR} = \frac{(1 + 256) \times \text{DDR}}{\text{CNT}}$$

- e. Columns 5 and 6 - To calculate a final value for N_d and N_p , fill in the nd and np columns for each channel using the following chart:

Col 1 Col 2 Col 3 Col 4 = Col 5 Col 6

Active	Chain Date	Byte Mpx	Max EDR	nd	np
1	0	0	H	1.0	1.0
1	1	0	H	1.4	1.4
1	0	0	L	1.0	0.0
1	1	0	L	1.4	0.0
1	0	1	0	1.0	1.4
1	1	1	0	1.4	2.0

- f. Column 7 - If the np value in column 6 is '0', enter the maximum EDR from column 4 in the 'Used EDR' column 7; otherwise enter '0'.
- g. Sum the 'nd', 'np', and 'Used EDR' columns to obtain the N_d , N_p , and Σ EDR values.
- h. Calculate:

$$M_p = \frac{18}{18 - \Sigma \text{ EDR}}$$

The following table may be used as a guide to help determine whether to enter 'H' in the maximum EDR column.

Find the column for the byte-multiplexer channel being evaluated. If the accumulative EDR for any number of active block-multiplexer channels exceeds the value given in the table, enter 'H' for those channels; otherwise enter the maximum EDR value.

Note: For accumulative EDR close to the value in the table, it might be necessary to use both methods and then choose the one resulting in the lower Load Sum. M_p represents the interference of the block-multiplexer channels on the byte-multiplexer channel resulting from the EDR. However, this interference can never exceed the amount associated with np, which represents the maximum possible interference.

For instance, assume there are a total of three active block-multiplexer channels with respective EDRs of 2.5, 0.4, and 2.0 Mb/second, and the optional byte-multiplexer channel is configured. When channel 0 is evaluated, the accumulative EDR for the first and third block-multiplexer channel exceeds 3.9 Mb/second. 'H' is entered for those channels. However, the accumulative EDR for all three block-multiplexer channels does not exceed 5.3 Mb/second, so 0.4 is entered for the second block-multiplexer channel.

ACCUMULATIVE EDR FOR PREVIOUS/PRIORITY LOAD CONSIDERATIONS (all values in Mb/sec)			
Active Block Multiplexer Channels	Standard Byte MPX Channel	Optional Byte MPX Channels	
	Channel 0	Channel 0	Channel 4
1	2.7	2.2	2.8
2	4.7	3.9	4.8
3	6.2	5.3	6.4
4	7.4	6.5	7.6
5	8.4	---	---

If the device being calculated is a 3704 or 3705 operating in the Emulation programming mode, go to "IBM 3704/3705 Calculations" to calculate the values for the Load Sum worksheet for those devices.

- i. Enter N_d and N_p on the preliminary worksheet, and M_p on the Load Sum worksheet.
3. Arrange the byte-mode devices proposed for simultaneous operation in sequence by priority class (1, 2, and 3).
Class 1 devices that have an inseparable class 2 component should be included with the class 1 devices. Examples of such devices: 1442 and 2520-B1.
Enter the class 1 devices on the worksheet in any order.
Although class 2 and 3 devices can be delayed in some worst-case situations, they are not subject to overrun and need not be include in the overrun evaluation.
4. For each device entered in step 2 that is not a 3705, enter the Wait Time, Device Load, and D1 values, and the sets of Time, A, A1, A2, B, and B1 values. These values are obtained from Appendix A or B, depending on the multiplexer channel selected, 0 or 4.

If the device is one of the following Class 2 or Class 3 devices, no information is given in Appendix A or B because these devices do not overrun.

1017	1018	1403	1442-N2	1443
2250	2520-B2,B3	2540	2671	2715
3203	3211	3250	3277	3278
3284	3286	3287	3288	3289
3505	3525	3540	3791	3800
3881	3886	3890	3895	

The following steps can be performed without referring to the tables. All the needed information is now recorded on the preliminary worksheet.

5. Compute the modified factors for each device by using the following formulas:

$$\text{Device Load (modified)} = \text{Device Load (original)} + (D1 \times N_d)$$

Previous Load (modified), except 3705 =

IF there is a slow device on byte-multiplexer channel 0

THEN use $[13.0 + (1.75 \times N_p)] \div \text{Wait time}$

ELSE use $[10.0 + (1.75 \times N_p)] \div \text{Wait time}$

Previous Load (modified), except 3705 =

IF there is a slow device on byte-multiplexer channel 4,

AND it is not the slowest, or last, device,

THEN use $[10.0 + (1.75 \times N_p)] \div \text{Wait time}$

ELSE use $[7.0 + (1.75 \times N_p)] \div \text{Wait time}$

Notes:

1. *The slowest, or last, device on channel 4 has a fixed previous value of 0.*
2. *Slow devices are shown in Table C-2.*

$$\text{Previous Load (modified), 3705} = \text{Device Load (modified)}$$

$$A_L \text{ (modified)} = A_L \text{ (original)} + (A1_L \times N_p) - (A2_L \times N_p^2)$$

$$B_L \text{ (modified)} = B_L \text{ (original)} + (B1_L \times N_p)$$

$$\text{Time}_1 \text{ (modified)} = \text{Time}_1 \text{ (original)}$$

$$\text{Time}_2 \text{ (modified)} = [A_1 \text{ (modified)} - A_2 \text{ (modified)}] \div [B_2 \text{ (modified)} - B_1 \text{ (modified)}]$$

$$\text{Time}_3 \text{ (modified)} = [A_2 \text{ (modified)} - A_3 \text{ (modified)}] \div [B_3 \text{ (modified)} - B_2 \text{ (modified)}]$$

where:

N_d, N_p = effective number of other active channels.

WT = wait time of selected device.

L = line number 1, 2, or 3 (preliminary worksheet).

6. Proceed to the "Channel Load Sum Worksheet Procedure."

Channel Load Sum Worksheet Procedure

This procedure uses the *IBM 4341 Processor Channel Load Sum Worksheet (GX24-3670)*.

1. Enter the system identification and date; enter the M_p value if not previously entered.
2. Arrange the devices entered on the preliminary worksheet according to increasing wait time. Devices with the smallest wait times are listed first (receive highest priority).
3. Copy the modified factors from the preliminary worksheet to the appropriate areas of this worksheet for each device.
4. For the second and each other waiting device on the byte-multiplexer channel, compare its wait time to the time factors given for each of the byte-multiplexer channel devices with higher priority. Enter the appropriate set of A and B factors (that is, the set that is on the same line with the largest time factor that is less than the wait time).
5. For each byte-multiplexer channel waiting device, add the selected A factors, and enter the A sum and B sum.
6. Divide the A sum by the wait-time factor for the device, and enter the quotient.
7. For each byte-multiplexer channel waiting device, add the B sum, the quotient found in step 6, the previous load, and enter this sum as the subtotal.
8. Calculate M_p times the subtotal for each byte-multiplexer channel waiting device, and add this value and the device load and enter this sum as the Load Sum. The load sum must be less than, or equal to, 100 for satisfactory operation of the waiting device.

Worksheet Example

Channel 1	3330 Disk Storage, no data chaining
Channel 2	
Channel 3	2420 Magnetic Tape Unit Model 7
Channel 4	320 Kb/sec, no data chaining
Byte-MPX	2501 Card Reader Model B2
Channel	EBCDIC; 1288 Optical Page Reader, reading formatted alphameric

The completed worksheets (Figures 15 and 16) for the given configuration show satisfactory operation for all byte-mode devices. No load sum exceeds 100.



4341 Byte-Multiplexer Channel Preliminary Worksheet

GX24-3746-1 U/M 050
 File No. 4300 01
 Printed in U.S.A.

System Identification: _____ Block-Multiplexer Channels N values: N_d 4 N_p 4 Date: _____

Device	Wait Time	Original Factors						Modified Factors								
		Device Load	D1	Time	A	B	A1	A2	B1	Device Load	Previous Load	Time	A	B		
2501-B2 READING EBCDIC	.915	21.27	4.94	1	.100	13.79	0	1.750	0	0	41.03	21.86	1	.100	20.79	0
				2	.442	6.61	16.25	.945	.040	2.881			2	.351	11.03	27.77
				3									3			
1288 UNFORMATTED ALPHAMERIC	1.00	9.09	2.40	1	.100	23.77	7.44	4.139	.076	1.543	18.69	20.00	1	.100	41.54	13.61
				2									2			
				3									3			
				1									1			
				2									2			
				3									3			
				1									1			
				2									2			
				3									3			
				1									1			
				2									2			
				3									3			

Instructions for using this worksheet are given in
 IBM 4341 Processor Channel Characteristics.
 Order No. GA24-3671.

Figure 15. Example of Preliminary Worksheet with a 2501-B2 and a 1288



4341 Processor Channel Load Sum Worksheet

GX24 4670-1 U/M:050
File No. 4340-01
Printed in U.S.A.

System Identification:

Waiting Devices (Priority Positions on Byte-Multiplexer Channel)

Priority Devices	1		2		3		4		5		6		7		8	
	Device No. 2501-B2		Device No. 1288		Device No.		Device No.		Device No.		Device No.		Device No.		Device No.	
	Name	Name	Name	Name	Name	Name	Name	Name	Name	Name	Name	Name	Name	Name	Name	Name
	Wait Time	91.5	Wait Time	1.00	Wait Time		Wait Time		Wait Time		Wait Time		Wait Time		Wait Time	
		A		A		A		A		A		A		A		A
		B		B		B		B		B		B		B		B
1	Priority Load															
	Time	.100	20.79	0												
		A		A		A		A		A		A		A		A
		B		B		B		B		B		B		B		B
		0		0		0		0		0		0		0		0
		(A Sum)		(B Sum)		(A Sum)		(B Sum)		(A Sum)		(B Sum)		(A Sum)		(B Sum)
		.351	11.03	27.77												
		Wait Time														
		11.03		27.77												
		Previous Load*														
		21.86		27.77												
		(A Sum)		(B Sum)												
		Subtotal**	21.86	11.03												
		Wait Time														
		21.86		20.00												
		(A Sum)		(B Sum)												
		41.03		58.80												
		Subtotal**	58.80													
		Wait Time														
		62.89		58.80												
		(A Sum)		(B Sum)												
		Subtotal**	18.69	77.49												
		Wait Time														
		18.69		77.49												
		(A Sum)		(B Sum)												
		Subtotal**														
		Wait Time														
		M _p x Subtotal														
		Device Load														
		Subtotal***														
		M _p x Subtotal														
		Device Load														
		Subtotal***														
		M _p x Subtotal														
		Device Load														
		Subtotal***														
		M _p x Subtotal														
		Device Load														
		Subtotal***														

Devices at Priority Positions on Byte-Multiplexer Channel

Instructions for using this worksheet are given in IBM 4341 Processor Channel Characteristics, Order No. GA24.3671.

* Previous Load = 0 for Channel 4 if the device being evaluated is the lowest priority device.
 ** Subtotal = B Sum + A Sum
 *** Load Sum = (M_p x Subtotal) + Device Load

Figure 16. Example of Final Worksheet with a 2501-B2 and a 1288

IBM 3704/3705 Calculations

This step calculates the values for 3704/3705 devices only. This series of steps provide the information to derive the necessary factors for the Load Sum Worksheet for 3704 and 3705 devices.

The set of numbers in parentheses in the Example Column are provided as examples of values that would be derived if the user has a 3705II on byte-multiplexer channel 0, with a type 2 scanner, and the device has two lines at 9.6 kilobits per second, and one line at 19.2 kilobits per second.

1. Enter the required data to calculate Wait Time values: Example
Column
 - a. Check the appropriate device. 3704___3705I___3705II___ (3705II)
 - b. Check the appropriate scanner No. 1 ___ 2 ___ 3 ___ (2)

(If you have checked scanners 2 and 3, use scanner 2 only.
For multiple scanners of the same type, use the most heavily
loaded scanner for these calculations.)
 - c. Check cycle time in microseconds . 1.2 ___ 1.0 ___ .9 ___ (1.0)

(If you have checked 3704 or 3705I, check
the value of 1.2).
2. If scanner 3 is checked, enter the buffer
length if known, otherwise enter the value 4. BFL ___ (4)
3. If scanner 3 is checked, enter the channel
transfer length if known, otherwise enter the value 4. CTL ___ (4)
4. Enter the number of low speed lines (those
less than 19,200 bits per second.) NL ___ (2)
5. Enter the speed of the fastest low speed line in
kilobits per second. LM ___ (9.6)
6. Calculate the total low speed kilobits per second:
$$LT = \sum_{n_i} I$$

(where n_i is the number of lines at speed I,
and I is line speed in kilobits per second,
and I is less than 19,200 bits per second.) LT ___ (19.2)
7. Enter the number of high speed lines (those equal to
or greater than 19,200 bits per second). NH ___ (1)
8. Enter the speed of the fastest high-speed line in
kilobits per second. HM ___ (19.2)
9. Calculate the total high speed kilobits per second
$$HT = \sum_{n_i} I$$

(where n_i is the number of lines at speed I, and I
is line speed in kilobits per second, and I is equal
to or greater than 19,200 bits per second.) HT ___ (19.2)

If the above NH = 0, continue to step A1, otherwise go to step A2.

Step A1. This step calculates the Wait Time factor when no high speed lines are involved. Refer to Table D-2 for the required values.

From Table D-2, and using the scanner selection, cycle time specification, and buffer load values values from step 1 (previous page), determine the TA, TB, TC and TD values for the following lines:

TA _____

TB _____

TC _____

TD _____

Calculate TE =

Low maximum (LM)+[TC value x Low total (LT)] = TE = _____

Calculate TF =

10 - [TD value x Low total (LT)] = TF = _____

Calculate Wait Time =

(TA ÷ TE) - (TB ÷ TF) = Wait Time = _____

Note: *If the device is a 3704, multiply the Wait Time by 0.9.*

Proceed to Step B1.

Step A3. This step calculates a value of Low Wait Time for a combination of both High Speed and Low Speed lines.

Example
Column

Calculate IA:

$$IA = .575 \times LM \div (BFL + 1)$$

$$IA = \underline{\hspace{1cm}} (1.10)$$

Calculate IB:

$$IB = TKB \div (16 \times BFL)$$

$$IB = \underline{\hspace{1cm}} (.600)$$

Calculate IC:

$$IC = HT \div (16 \times BFL)$$

$$IC = \underline{\hspace{1cm}} (.300)$$

Calculate ID:

$$ID = IB + IC + IA$$

$$ID = \underline{\hspace{1cm}} (2.00)$$

Calculate IE:

$$IE = \sqrt{ID^2 - (4 \times IB \times IC)}$$

$$IE = \underline{\hspace{1cm}} (1.81)$$

To calculate the Critical Time (CL) for Low Speed Lines:

$$CL = (ID - IE) \div (2 \times IB \times IC)$$

$$CL = \underline{\hspace{1cm}} (.528)$$

To calculate Low WT:

$$\text{Low WT} = CL - (TB \div TF)$$

$$\text{Low WT} = \underline{\hspace{1cm}} (.445)$$

For this step final result Wait time, enter the value of High Wait Time calculated in step A2, or this step's calculated Low Wait Time, whichever is the lower value.

If the 3704 device had been checked in step A1, multiply this page final value by 0.9.

$$\text{Wait Time} = \underline{\hspace{1cm}} (.445)$$

Step B1. From steps 1 through 6 of the "Preliminary Worksheet Example," enter the values for N_d , N_p and M_p .

Example
Column

$N_d = \underline{\hspace{1cm}} (4)$
 $N_p = \underline{\hspace{1cm}} (4)$
 $M_p = \underline{\hspace{1cm}} (1)$

Use the CTL value and the table below to derive the device factor (DF).

	CTL=4	CTL=8	CTL=16	CTL=32
Channel 0	8.1	8.7	9.9	12.3
Channel 4	5.2	5.8	7.0	9.4

DF = (8.1)

Calculate bursts per transfer =

$$BFL \div CTL$$

MB = (1)

To calculate service time (TS).

$$TS = DF + (1.4 \times N_p)$$

TS = (13.7)

To calculate Device Load:

$$DL = [(DF + (2.4 \times N_d)) + [M_p \times (NB - 1) \times TS]] \div WT$$

DL = (39.8)

For channel 0, if there are no slow devices, then:

$$PL = [10 + (1.75 \times N_p)] \div WT$$

otherwise

$$PL = [13 + (1.75 \times N_p)] \div WT$$

For channel 4, if there are no slow devices, then:

$$PL = [7 + (1.75 \times N_p)] \div WT$$

otherwise

$$PL = [10 + (1.75 \times N_p)] \div WT$$

PL = (44.9)

Proceed to Step B2.

Step B2. If no lower priority over-runnable devices than the 3704/3705 exist on the channel, priority Load factors need not be calculated; proceed directly to the Load Sum Worksheet. Otherwise, calculate the Load Factor values below.

Example
Column

To calculate TSN:

$$TSN = TS \times NB$$

$$TSM = \underline{\hspace{2cm}} \quad (13.7)$$

Calculate and enter the priority Load Factor on the Load Sum Worksheet as follows:

$$Time_1 = 0.100$$

$$B_1 = 100.000$$

$$A_1 = 0.000$$

$$Time_2 = 0.2 \times TSN$$

$$Time_2 = \underline{\hspace{2cm}} \quad (.274)$$

$$B_2 = (10 \times TSN) \div [(0.1 \times TSN) + TB]$$

$$B_2 = \underline{\hspace{2cm}} \quad (62.27)$$

$$A_2 = Time_2 \times (100 - B_2)$$

$$A_2 = \underline{\hspace{2cm}} \quad (10.34)$$

$$Time_3 = (NH + NL) \times [(0.01 \times TSN) + (0.1 \times TB)]$$

$$Time_3 = \underline{\hspace{2cm}} \quad (.660)$$

$$B_3 = [(LT + HT) \times TSN] \div (8 \times BFL)$$

$$B_3 = \underline{\hspace{2cm}} \quad (16.44)$$

$$A_3 = A_2 + [Time_3 \times (B_2 - B_3)]$$

$$A_3 = \underline{\hspace{2cm}} \quad (40.59)$$

Proceed to the "Channel Load Sum Worksheet Procedure;" enter the Device Load, Previous Load and Priority Load factor values.

Appendix A. Evaluation Factors for Channel 0

	Key	Nominal Data Rate (kb/sec)	Cycle Time (ms)	Wait Time (ms)	Device Load	D1	Priority Load								
							Time	A	B	A1	A2	B1			
1255 Magnetic Character Reader															
Model 1, 21	1M	.33	120	.680	14.28	3.529	.100	23.76	.00	3.500	.000	.000			
							1.616	6.49	10.69	1.101	.029	2.059			
							34.073	258.65	3.29	3.141	.029	.62			
Model 2, 3, 22, 23	1M	.50	80	.680	14.28	3.529	.100	23.76	.00	3.500	.000	.000			
							1.616	6.49	10.69	1.101	.029	2.059			
							34.073	202.66	4.93	3.132	.029	.936			

	Key	Nominal Data Rate (kb/sec)	Cycle Time (ms)	Wait Time (ms)	Device Load	D1	Priority Load								
							Time	A	B	A1	A2	B1			
1287 Optical Reader:															
1428/ASCSDRC Font	1M	2.50	Var	.40	24.67	6.00	.100	33.83	.00	4.900	.000	.000			
							1.601	6.05	17.35	.880	.049	2.996			
1428/ASCSDRC Font with Blank Detection	1M	2.50	Var	.13	75.91	18.46	.100	33.83	.00	4.900	.000	.000			
							.536	3.18	57.14	.200	.151	10.769			
1428 Imprinting	1M	.5	Var	2.00	4.93	1.20	.100	32.34	4.40	4.415	.039	.794			
7B1/ASCSDRC Imprintin	1M	.40	Var	2.50	3.95	.96	.100	32.63	3.55	4.510	.031	.640			
Handwritten/Gothic	1M	.33	Var	1.50	6.58	1.60	.100	31.96	5.54	4.290	.049	1.000			
Handwritten Verify	1M	.20	Var	5.00	1.97	.48	.100	33.22	1.80	4.702	.016	.324			
Mode (1287-5)															
Mark Read 10 Position	1M	1.00	Var	2.00	4.93	1.20	.100	32.32	4.46	4.409	.039	.804			
Mark Read 12 Position	1M	.87	Var	2.30	4.29	1.04	.100	32.52	3.89	4.472	.034	.701			
Alphameric Modes (1287-3,4 only)	1M	1.00	Var	1.00	9.87	2.40	.100	31.14	7.96	4.024	.071	1.436			
Roll Form	1M	2.50	Var	.40	24.67	6.00	.100	11.75	.00	1.750	.000	.000			
							.307	6.05	18.57	.880	.050	3.500			
Roll Form with Blank Separate Mark Line Command	1M	2.50	Var	.40	24.67	6.00	.100	23.50	.00	3.500	.000	.000			
							.940	6.05	18.57	.880	.050	3.500			
Roll Form with Blank Detection	1M	2.50	Var	.20	49.34	12.00	.100	11.75	.00	1.750	.000	.000			
							.191	4.67	37.14	.360	.100	7.000			
Roll Form with Blank Detection and Mark Line Command	1M	2.50	Var	.20	49.34	12.00	.100	23.50	.00	3.500	.000	.000			
							.507	4.67	37.14	.360	.100	7.000			

Key:
 1 Device subject to overrun; highest priority required.
 2 Device requires synchronized channel service; not subject to overrun; second highest priority required.
 3 Device does not require synchronized channel service; not subject to overrun; lowest priority.
 M Byte mode on byte multiplexer channel.
 E Evaluate punching and reading separately by using the wait times, device loads, and previous loads for the independent operations.
 Var Variable.

Table A-1. Channel Evaluation Factors—1255 and 1287

	Key	Nominal Data Rate (kb/sec)	Cycle Time (ms)	Wait Time (ms)	Device Load	D1	Priority Load								
							Time	A	B	A1	A2	B1			
1288 Optical Page Rdr:															
Formatted Alphameric	1M	1.00	Var	1.00	9.09	2.40	23.77	7.44	4.139	.076	1.543				
Unformatted Alphameric	1M	1.00	Var	1.00	9.09	2.40	23.77	7.44	4.139	.076	1.543				
Handwritten/Gothic	1M	.33	Var	1.50	6.06	1.60	24.44	4.83	4.406	.049	1.002				
Mark Read 1	1M	.71	Var	1.40	6.49	1.71	24.26	5.50	4.337	.056	1.141				
Mark read 2	1M	.46	Var	2.20	4.13	1.09	24.77	3.54	4.538	.03	.734				
Mark read 3	1M	.33	Var	3.00	3.03	.80	25.01	2.61	4.633	.027	.541				
Mark read 4	1M	.26	Var	3.80	2.39	.63	25.15	2.06	4.689	.021	.428				
Mark read 5	1M	.22	Var	4.60	1.98	.52	25.24	1.71	4.725	.017	.354				
Mark read 6	1M	.18	Var	5.40	1.68	.44	25.30	1.46	4.751	.015	.302				
Mark read 7	1M	.16	Var	6.20	1.47	.39	25.35	1.27	4.770	.013	.264				
Mark read 8	1M	.14	Var	7.00	1.30	.34	25.39	1.13	4.785	.011	.234				
Mark read 9	1M	.13	Var	7.80	1.16	.31	25.42	1.01	4.797	.010	.210				
Mark read 10	1M	.12	Var	8.60	1.06	.28	25.44	.92	4.806	.009	.190				
Mark read 11	1M	.11	Var	9.40	.97	.26	25.46	.84	4.814	.009	.174				
Mark read 12	1M	.10	Var	10.20	.89	.24	25.48	.77	4.821	.008	.161				

	Key	Nominal Data Rate (kb/sec)	Cycle Time (ms)	Wait Time (ms)	Device Load	D1	Priority Load								
							Time	A	B	A1	A2	B1			
1419 Magnetic Character Reader:															
Single Address Adapter	1M	1.25	32.2	.655	22.84	5.647	23.76	.00	3.500	.000	.000				
1,600 Documents/Min.							6.02	17.10	.921	.046	3.294				
Single Address Adapter With Batch Numbering Feature	1M	1.25	32.3	.655	22.84	5.647	47.32	.00	7.000	.000	.000				
Dual Address Adapter without Expanded Capability Feature							6.02	17.10	.921	.046	3.294				
Dual Address Adapter With Expanded Capability Feature:															
- Relative to other Devices in System	1M	1.25	32.2	.655	22.84	5.647	46.14	.00	4.550	.000	.000				
- Relative to other 1419s in System	1M	1.25	32.3	.655	22.84	5.647	6.02	17.10	.921	.046	3.294				

Key:

- 1 Device subject to overrun; highest priority required.
- 2 Device requires synchronized channel service; not subject to overrun; second highest priority required.
- 3 Device does not require synchronized channel service; not subject to overrun; lowest priority.
- M Byte mode on byte multiplexer channel.
- E Evaluate punching and reading separately by using the wait times, device loads, and previous loads for the independent operations.
- Var Variable.

Table A-2. Channel Evaluation Factors—1288 and 1419

	Key	Nominal Data Rate (kb/sec)	Cycle Time (ms)	Wait Time (ms)	Device Load	D1	Priority Load					
							Time	A	B	A1	A2	B1
1442 Card Reader Model N1: Reading EBCDIC	1M	.53	150	.800	25.76	6.000	.100	12.894	.000	1.750	.000	.000
							.334	6.319	19.662	.849	.049	3.500
							2.479	27.206	11.236	4.685	.028	2.000
							.100	12.894	.000	1.750	.000	.000
Reading Card Image	1M	1.07	150	.800	29.84	6.000	.238	7.241	23.737	7.735	.049	3.500
							2.495	32.623	13.564	4.620	.028	2.000
							.100	27.830	1.222	4.431	.010	.224
							.000	.000	.000	.000	.000	.000
Punching EBCDIC	1M	.12	656	11.000	1.83	.436	.000	.000	.000	.000	.000	.000
							.000	.000	.000	.000	.000	.000
							.100	32.429	1.605	4.403	.010	.224
							.000	.000	.000	.000	.000	.000
Punching Card Image	1M	.24	656	11.000	2.27	.436	.000	.000	.000	.000	.000	.000
							.000	.000	.000	.000	.000	.000
							.000	.000	.000	.000	.000	.000
							.000	.000	.000	.000	.000	.000

	Key	Nominal Data Rate (kb/sec)	Cycle Time (ms)	Wait Time (ms)	Device Load	D1	Priority Load					
							Time	A	B	A1	A2	B1
2501 Card Reader Model B1: Reading EBCDIC	1M	.80	100	.915	21.27	4.94	.100	13.79	.00	1.750	.000	.000
							.442	6.61	16.25	.945	.040	2.881
							.100	13.79	.00	1.750	.000	.000
							.309	7.69	19.72	.848	.040	2.881
Model B2: Reading EBCDIC	1M	1.33	60	.915	21.27	4.94	.100	13.79	.00	1.750	.000	.000
							.442	6.61	16.25	.945	.040	2.881
							.100	13.79	.00	1.750	.000	.000
							.309	7.69	19.72	.848	.040	2.881
Reading Card Image	1M	2.67	60	.915	24.74	4.94	.100	13.79	.00	1.750	.000	.000
							.442	6.61	16.25	.945	.040	2.881
							.100	13.79	.00	1.750	.000	.000
							.309	7.69	19.72	.848	.040	2.881

Key:
1 Device subject to overrun; highest priority required.
2 Device requires synchronized channel service; not subject to overrun; second highest priority required.
3 Device does not require synchronized channel service; not subject to overrun; lowest priority.
M Byte mode on byte multiplexer channel.
E Evaluate punching and reading separately by using the wait times, device loads, and previous loads for the independent operations.
Var Variable.

Table A-3. Channel Evaluation Factors—1442 and 2501 B1 and B2

	Key	Nominal Data Rate (kb/sec)	Cycle Time (ms)	Wait Time (ms)	Device Load	D1	Priority Load					
							A		B	A1	A2	B1
							Time					
2520 Card Read/Punch: Reading EBCDIC	1M	.67	120	1.020	20.27	4.71	.100	27.38	.00	3.500	.000	.000
							1.411	6.74	14.63	.990	.036	2.593
							42.739	394.21	5.56	70.808	.013	.962
Reading Card Image	1M	1.33	120	1.020	23.58	4.71	.100	27.38	.00	3.500	.000	.000
							1.098	7.88	17.75	.903	.036	2.593
							42.756	480.89	6.68	70.776	.013	.962
Punching EBCDIC	2M	.67	120	9.000	45.03	6.53	.100	.00	100.00	.000	.000	.000
							4.052	391.55	3.38	54.829	.288	.490
Punching Column Binary	2M	1.33	120	9.000	87.62	12.76	.100	.00	100.00	.000	.000	.000
							7.886	736.76	6.57	99.712	1.098	.957
Reading And Punching EBCDIC	1,2M	1.33	120	.000	.00	.67	.100	.00	100.00	.000	.000	.000
							4.107	410.73	.00	59.500	.000	.000
							27.618	6.74	14.63	.990	.036	2.593
							42.739	257.68	8.76	50.422	.016	1.438
Reading and Punching Card Image	1,2M	2.67	120	.000	.00	1.33	.100	.00	100.00	.000	.000	.000
							7.941	794.08	.00	115.500	.000	.000
							42.756	235.09	13.07	33.885	.027	1.905

Key:

- 1 Device subject to overrun; highest priority required.
- 2 Device requires synchronized channel service; not subject to overrun; second highest priority required.
- 3 Device does not require synchronized channel service; not subject to overrun; lowest priority.
- M Byte mode on byte multiplexer channel.
- E Evaluate punching and reading separately by using the wait times, device loads, and previous loads for the independent operations.
- Var Variable.

Table A-4. Channel Evaluation Factors—2520

	Bit Rate (bps)	Data Rate (cps)	Wait Time (ms)	Device Load	D1	Priority Load						
						Time	A	B	A1	A2	B1	
2701 Data Adapter Unit: IBM Terminal Control I	134.5	14.80	63.200	.14	.04	.100	15.59	.10	3.144	.001	.021	
	600.0	56.70	14.200	.64	.17	.100	15.54	.44	3.122	.003	.093	
IBM Terminal Control II	600.0	60.00	14.200	.64	.17	.100	15.55	.40	3.124	.003	.084	
IBM Terminal Control III	1200.0	120.00	8.300	1.09	.29	.100	15.48	.79	3.099	.005	.168	
	2400.0	240.00	4.200	2.15	.57	.100	15.36	1.58	3.048	.011	.336	
IBM Telegraph Adapter	75.0	8.33	113.300	.08	.02	.100	15.60	.05	3.146	.000	.012	
Telegraph Adapter Type I	45.5	6.00	141.300	.06	.02	.100	15.60	.04	3.147	.000	.008	
	56.9	7.50	113.200	.08	.02	.100	15.60	.05	3.147	.000	.010	
	74.2	10.00	86.900	.10	.03	.100	15.60	.07	3.146	.000	.014	
Type II	110.0	10.00	85.800	.11	.03	.100	15.60	.07	3.146	.000	.014	
World Trade TTY	50.0	6.60	128.700	.07	.02	.100	15.60	.04	3.147	.000	.009	
	75.0	10.00	85.800	.11	.03	.100	15.60	.07	3.146	.000	.014	
Synchronous Data Adapter Type I	1200.0	150.00	5.800	1.56	.41	.100	15.45	.99	3.086	.007	.210	
	2000.0	250.00	3.500	2.58	.69	.100	15.35	1.65	3.043	.011	.350	
	2400.0	300.00	2.900	3.12	.83	.100	15.30	1.98	3.022	.013	.420	
	19200.0	2400.00	.360	25.10	6.67	.100	13.14	15.83	2.127	.106	3.360	
	40800.0	5100.00	.170	53.16	14.12	.100	10.36	33.65	.976	.225	7.140	
Type II Eight-Bit Code (No Autopolling)	600.0	75.00	25.800	.36	.09	.100	15.66	.49	3.118	.003	.105	
	1200.0	150.00	12.900	.71	.19	.100	15.58	.99	3.086	.007	.210	
	2000.0	250.00	7.700	1.19	.31	.100	15.47	1.65	3.043	.011	.350	
	2400.0	300.00	6.400	1.43	.38	.100	15.42	1.98	3.022	.013	.420	
	4800.0	600.00	3.200	2.86	.75	.100	15.11	3.96	2.893	.026	.840	
	19200.0	2400.00	.810	11.31	2.96	.100	13.24	15.83	2.123	.106	3.360	
	40800.0	5100.00	.380	24.12	6.32	.100	10.44	33.65	.967	.225	7.140	
	50000.0	6250.00	.310	29.56	7.74	.100	9.25	41.24	.474	.276	8.750	
	230400.0			100%								
Six-Bit Code (No Autopolling)	600.0	100.00	19.200	.48	.13	.100	15.63	.66	3.107	.004	.140	
	1200.0	200.00	9.600	.95	.25	.100	15.53	1.32	3.064	.009	.280	
	2000.0	333.00	5.700	1.61	.42	.100	15.39	2.20	3.007	.015	.466	
	2400.0	400.00	4.800	1.91	.50	.100	15.32	2.64	2.979	.018	.560	
	19200.0	3200.00	.600	15.27	4.00	.100	12.41	21.11	1.780	.141	4.480	
40800.0	6800.00	.280	32.73	8.57	.100	8.67	44.87	.239	.300	9.520		
50000.0	8333.00	.230	39.85	10.43	.100	7.08	54.98	.417	.367	11.666		
230400.0			100%									
Eight-Bit Code (With Autopolling)	600.0	75.00	14.200	.65	.17	.100	15.66	.49	3.118	.003	.105	
	1200.0	150.00	7.100	1.29	.34	.100	15.58	.99	3.086	.007	.210	
	2000.0	250.00	4.200	2.18	.57	.100	15.47	1.65	3.043	.011	.350	
	2400.0	300.00	3.500	2.62	.69	.100	15.42	1.98	3.022	.013	.420	
4800.0	600.00	1.800	5.09	1.33	.100	15.11	3.96	2.893	.026	.840		
Six-Bit Code (With Autopolling)	600.0	100.00	10.800	.85	.22	.100	15.63	.66	3.107	.004	.140	
	1200.0	200.00	5.400	1.70	.44	.100	15.53	1.32	3.064	.009	.280	
	2000.0	333.00	3.200	2.86	.75	.100	15.39	2.20	3.007	.015	.466	
	2400.0	400.00	2.700	3.39	.89	.100	15.32	2.64	2.979	.018	.560	

Table A-5. Channel Evaluation Factors—2701

	Data Rate (cps)	Wait Time (ms)	Device Load	D1	Priority Load							
					Time	A	B	A1	A2	B1		
7770 Audio Response Unit:												
8 Lines	12	9.02	1.04	.266	.100	9.631	6.70	1.516	.020	1.136		
16 Lines	12	4.49	2.09	.534	.100	9.631	6.70	1.516	.020	1.136		
24 Lines	12	2.99	3.14	.804	.100	9.631	6.70	1.516	.020	1.136		
32 Lines	12	1.48	6.36	1.625	.100	9.631	6.70	1.516	.020	1.136		
40 Lines	12	1.48	6.36	1.625	.100	9.631	6.70	1.516	.020	1.136		
48 Lines	12	1.48	6.36	1.625	.100	9.631	6.70	1.516	.020	1.136		

Key:

- 1 Device subject to overrun; highest priority required.
- 2 Device requires synchronized channel service; not subject to overrun; second highest priority required.
- 3 Device does not require synchronized channel service; not subject to overrun; lowest priority.
- M Byte mode on byte multiplexer channel.
- E Evaluate punching and reading separately by using the wait times, device loads, and previous loads for the independent operations.
- Var Variable.

Table A-6. Channel Evaluation Factors—7770

Appendix B. Evaluation Factors for Byte Multiplexer Channel 4

	Key	Nominal Data Rate (kb/sec)	Cycle Time (ms)	Wait Time (ms)	Device Load	D1	Priority Load							
							T Time	A	B	A1	A2	B1		
1255 Magnetic Character Reader														
Model 1, 21	1M	.33	120	.680	11.10	3.529	.100	17.46	.00	3.500	.000	.000	.000	.000
							1.697	4.72	7.51	1.190	.029	.029	2.059	.624
							34.051	181.52	2.32	3.230	.029	.029	.624	
Model 2, 3, 22, 23	1M	.50	80	.680	11.10	3.529	.100	17.46	.00	3.500	.000	.000	.000	.000
							1.697	4.72	7.51	1.190	.029	.029	2.059	.624
							34.051	142.10	3.47	3.221	.029	.029	.936	

	Key	Nominal Data Rate (kb/sec)	Cycle Time (ms)	Wait Time (ms)	Device Load	D1	Priority Load							
							T Time	A	B	A1	A2	B1		
1287 Optical Reader:														
1428/ASCSORC Font	1M	2.50	Var	.40	19.82	6.00	.100	25.95	.00	4.900	.000	.000	.000	.000
1428/ASCSORC Font with Blank Detection	1M	2.50	Var	.13	60.99	18.46	1.628	4.74	13.03	1.016	.049	.049	3.025	.000
1428 Imprinting	1M	.5	Var	2.00	3.96	1.20	.100	25.95	.00	4.900	.000	.000	.000	.000
7BI/ASCSORC Imprintin	1M	.40	Var	2.50	3.17	.96	.540	3.17	42.22	.218	.151	.151	10.769	.796
Handwritten/Gothic	1M	.33	Var	1.50	5.29	1.60	.100	25.26	2.65	4.532	.031	.031	.641	.003
Handwritten Verify	1M	.20	Var	5.00	1.59	.48	.100	24.88	4.14	4.437	.049	.049	1.003	.325
Mode (1287-5)	1M	1.00	Var	2.00	3.96	1.20	.100	25.09	3.33	4.528	.039	.039	.806	.000
Mark Read 10 Position	1M	.87	Var	2.30	3.45	1.04	.100	25.20	2.90	4.576	.034	.034	.703	.000
Mark Read 12 Position	1M	1.00	Var	1.00	7.93	2.40	.100	24.41	5.95	4.234	.071	.071	1.442	.000
Alphameric Modes (1287-3,4 only)	1M	2.50	Var	.40	19.82	6.00	.100	8.78	.00	1.750	.000	.000	.000	.000
Roll Form	1M	2.50	Var	.40	19.82	6.00	.295	4.74	13.72	1.020	.050	.050	3.500	.000
Roll Form with Separate Mark Line Command	1M	2.50	Var	.40	39.64	12.00	.100	17.56	.00	3.500	.000	.000	.000	.000
Roll Form with Blank Detection	1M	2.50	Var	.20	39.64	12.00	.935	4.74	13.72	1.020	.050	.050	3.500	.000
Roll Form with Blank Detection and Mark Line Command	1M	2.50	Var	.20	39.64	12.00	.100	8.78	.00	1.750	.00	.00	.000	.000
							.175	3.98	27.44	.630	.100	.100	7.000	.000
							.100	17.56	.00	3.500	.000	.000	.000	.000
							.495	3.98	27.44	.630	.100	.100	7.000	.000

Key:
 1 Device subject to overrun; highest priority required.
 2 Device requires synchronized channel service; not subject to overrun; second highest priority required.
 3 Device does not require synchronized channel service; not subject to overrun; lowest priority.
 M Byte mode on byte multiplexer channel.
 E Evaluate punching and reading separately by using the wait times, device loads, and previous loads for the independent operations.
 Var Variable.

Table B-1. Channel Evaluation Factors—1255 and 1287

	Key	Nominal Data Rate (kb/sec)	Cycle Time (ms)	Wait Time (ms)	Device Load	D1	Priority Load				
							Time	A	B	A1	A2
1288 Optical Page Rdr:	1M	1.00	Var	1.00	6.93	2.40	16.35	5.04	4.386	.076	1.551
Formatted Alphameric	1M	1.00	Var	1.00	6.9	2.40	16.35	5.04	4.386	.076	1.551
Unformatted Alphameric	1M	.33	Var	1.50	4.62	1.60	16.65	3.27	4.567	.049	1.006
Handwritten/Gothic	1M	.71	Var	1.40	4.95	1.71	16.58	3.72	4.520	.056	1.146
Mark read 1	1M	.46	Var	2.20	3.15	1.09	16.80	2.39	4.656	.03	.736
Mark read 2	1M	.33	Var	3.00	2.31	.80	16.91	1.76	4.720	.027	.542
Mark read 3	1M	.26	Var	3.80	1.82	.63	16.98	1.39	4.758	.021	.429
Mark read 4	1M	.22	Var	4.60	1.51	.52	17.02	1.15	4.782	.017	.355
Mark read 5	1M	.18	Var	5.40	1.28	.44	17.05	.98	4.800	.015	.303
Mark read 6	1M	.16	Var	6.20	1.12	.39	17.07	.86	4.813	.013	.264
Mark read 7	1M	.14	Var	7.00	.99	.34	17.09	.76	4.823	.011	.234
Mark read 8	1M	.13	Var	7.80	.89	.31	17.10	.68	4.830	.010	.210
Mark read 9	1M	.12	Var	8.60	.81	.28	17.11	.62	4.837	.009	.190
Mark read 10	1M	.11	Var	9.40	.74	.26	17.12	.57	4.842	.009	.174
Mark read 11	1M	.11	Var	10.20	.68	.24	17.13	.52	4.847	.008	.161
Mark read 12	1M	.10	Var								

	Key	Nominal Data Rate (kb/sec)	Cycle Time (ms)	Wait Time (ms)	Device Load	D1	Priority Load				
							Time	A	B	A1	A2
1419 Magnetic Character Reader:	1M	1.25	32.2	.655	17.75	5.647	17.46	.00	3.500	.000	.000
Single Address Adapter	1M	1.25	32.3	.655	17.75	5.647	4.49	12.01	1.064	.046	3.294
1,600 Documents/Min.											
Single Address Adapter With Batch Numbering Feature	1M	1.25	32.3	.655	17.75	5.647	34.72	.00	7.000	.000	.000
Dual Address Adapter without Expanded Capability Feature	1M	1.25	32.3	.655	17.75	5.647	4.49	12.01	1.064	.046	3.294
Dual Address Adapter With Expanded Capability Feature:	1M	1.25	32.2	.655	17.75	5.647	37.86	.00	4.550	.000	.000
- Relative to other Devices in System							4.49	12.01	1.064	.046	3.294
- Relative to other 1419s in System	1M	1.25	32.3	.655	17.75	5.647	44.11	12.01	4.508	.231	3.294
	1M	1.25	32.3	.655	17.75	5.647	4.49	12.01	1.064	.046	3.294

Key:

- 1 Device subject to overrun; highest priority required.
- 2 Device requires synchronized channel service; not subject to overrun; second highest priority required.
- 3 Device does not require synchronized channel service; not subject to overrun; lowest priority.
- M Byte mode on byte multiplexer channel.
- E Evaluate punching and reading separately by using the wait times, device loads, and previous loads for the independent operations.
- Var Variable.

Table B-2. Channel Evaluation Factors—1288 and 1419

	Key	Nominal Data Rate (kb/sec)	Cycle Time (ms)	Wait Time (ms)	Device Load	D1	Priority Load					
							T:Time	A	B	A1	A2	B1
1442 Card Reader Model N1: Reading EBCDIC	1M	.53	150	.800	20.28	6.000	.100	9.834	.000	1.750	.000	.000
							.350	4.869	14.184	1.003	.049	3.500
							2.457	19.803	8.105	4.773	.028	2.000
Reading Card Image	1M	1.07	150	.800	24.36	6.000	.100	9.834	.000	1.750	.000	.000
							.212	5.970	18.259	.889	.049	3.500
							2.473	25.322	10.434	4.708	.028	2.000
Punching EBCDIC	1M	.12	656	11.000	2.46	.436	.100	20.787	.891	4.462	.010	.224
							.000	.000	.000	.000	.000	.000
							.000	.000	.000	.000	.000	.000
Punching Card Image	1M	.24	656	11.000	1.89	.436	.100	25.430	1.274	4.434	.010	.224
							.000	.000	.000	.000	.000	.000
							.000	.000	.000	.000	.000	.000

	Key	Nominal Data Rate (kb/sec)	Cycle Time (ms)	Wait Time (ms)	Device Load	D1	Priority Load					
							T:Time	A	B	A1	A2	B1
2501 Card Reader Model B1: Reading EBCDIC	1M	.80	100	.915	16.85	4.94	.100	10.73	.00	1.750	.000	.000
							.479	5.07	11.83	1.069	.040	2.881
							.100	10.73	.00	1.750	.000	.000
Reading Card Image	1M	1.60	100	.915	20.32	4.94	.290	6.30	15.30	.972	.040	2.881
							.100	10.73	.00	1.750	.000	.000
							.479	5.07	11.83	1.069	.040	2.881
Model B2: Reading EBCDIC	1M	1.33	60	.915	16.85	4.94	.100	10.73	.00	1.750	.000	.000
							.479	5.07	11.83	1.069	.040	2.881
Reading Card Image	1M	2.67	60	.915	20.32	4.94	.100	10.73	.00	1.750	.000	.000
							.290	6.30	15.30	.972	.040	2.881

Key:
1 Device subject to overrun, highest priority required.
2 Device requires synchronized channel service; not subject to overrun; second highest priority required.
3 Device does not require synchronized channel service; not subject to overrun; lowest priority.
M Byte mode on byte multiplexer channel.
E Evaluate punching and reading separately by using the wait times, device loads, and previous loads for the independent operations.
Var Variable.

Table B-3. Channel Evaluation Factors—1442 and 2501 B1 and B2

	Key	Nominal Data Rate (kb/sec)	Cycle Time (ms)	Wait Time (ms)	Device Load	D1	Priority Load					
							Time	A	B	A1	A2	B1
2520 Card Read/Punch: Reading EBCDIC	1M	.67	120	1.020	16.06	4.71	.100	21.26	.00	3.500	.000	.000
Reading Card Image	1M	1.33	120	1.020	19.37	4.71	1.513	5.14	10.65	1.102	.036	2.593
Punching EBCDIC	2M	.67	120	9.000	34.92	6.53	42.718	21.26	.00	3.500	.000	.000
Punching Column Binary	2M	1.33	120	9.000	67.97	12.76	1.078	6.41	13.77	1.014	.036	2.593
Reading And Punching EBCDIC	1,2M	1.33	120	.000	.00	.67	42.734	373.30	5.19	70.807	.013	.962
Reading and Punching Card Image	1,2M	2.67	120	.000	.00	1.33	.100	.00	100.00	.000	.000	.000
							3.143	306.06	2.62	55.720	.288	.490
							6.117	580.55	5.10	103.095	1.098	.957
							.100	.00	100.00	.000	.000	.000
							3.187	318.71	.00	59.500	.000	.000
							29.442	5.14	10.65	1.102	.036	2.593
							42.718	180.69	6.54	50.484	.016	1.438
							.100	.00	100.00	.000	.000	.000
							6.162	616.16	.00	115.500	.000	.000
							42.734	182.70	10.14	33.967	.027	1.905

Key:

- 1 Device subject to overrun; highest priority required.
- 2 Device requires synchronized channel service; not subject to overrun; second highest priority required.
- 3 Device does not require synchronized channel service; not subject to overrun; lowest priority.
- M Byte mode on byte multiplexer channel.
- E Evaluate punching and reading separately by using the wait times, device loads, and previous loads for the independent operations.

Var Variable.

Table B-4. Channel Evaluation Factors—2520

	Bit Rate (bps)	Data Rate (cps)	Wait Time (ms)	Device Load	D1	Priority Load					
						Time	A	B	A1	A2	B1
2701 Data Adapter Unit: IBM Terminal Control I	134.5	14.80	63.200	.11	.04	10.29	.07	3.146	.001	.021	
	600.0	66.70	14.200	.48	.17	10.27	.30	3.131	.003	.093	
IBM Terminal Control II	600.0	60.00	14.200	.48	.17	10.27	.27	3.133	.003	.084	
IBM Terminal Control III	1200.0	120.00	8.300	.83	.29	10.24	.53	3.116	.005	.168	
	2400.0	240.00	4.200	1.64	.57	10.19	1.07	3.082	.011	.336	
IBM Telegraph Adapter	75.0	8.33	113.300	.06	.02	10.29	.04	3.148	.000	.012	
Telegraph Adapter Type I	45.5	6.00	141.300	.05	.02	10.29	.03	3.148	.000	.008	
	56.9	7.50	113.200	.06	.02	10.29	.03	3.148	.000	.010	
	74.2	10.00	86.900	.08	.03	10.29	.04	3.147	.000	.014	
Type II	110.0	10.00	85.800	.08	.03	10.29	.04	3.147	.000	.014	
World Trade TTY	50.0	6.60	128.700	.05	.02	10.29	.03	3.148	.000	.009	
	75.0	10.00	85.800	.08	.03	10.29	.04	3.147	.000	.014	
Synchronous Data Adapter Type I	1200.0	150.00	5.800	1.19	.41	10.23	.67	3.107	.007	.210	
	2000.0	250.00	3.500	1.97	.69	10.18	1.11	3.079	.011	.350	
	2400.0	300.00	2.900	2.37	.83	10.16	1.33	3.065	.013	.420	
	19200.0	2400.00	.360	19.10	6.67	9.20	10.65	2.469	.106	3.360	
	40800.0	5100.00	.170	40.46	14.12	7.97	22.63	1.702	.225	7.140	
Type II Eight-Bit Code (No Autopolling)	600.0	75.00	25.800	.27	.09	10.39	.33	3.129	.003	.105	
	1200.0	150.00	12.900	.54	.19	10.35	.67	3.107	.007	.210	
	2000.0	250.00	7.700	.91	.31	10.31	1.11	3.079	.011	.350	
	2400.0	300.00	6.400	1.09	.38	10.29	1.33	3.064	.013	.420	
	4800.0	600.00	3.200	2.19	.75	10.15	2.66	2.979	.026	.840	
	19200.0	2400.00	.810	8.65	2.96	9.31	10.65	2.464	.106	3.360	
	40800.0	5100.00	.380	18.43	6.32	8.06	22.63	1.693	.225	7.140	
	50000.0	6250.00	.310	22.60	7.74	7.53	27.74	1.364	.276	8.750	
				100%							
Six-Bit Code (No Autopolling)	600.0	100.00	19.200	.36	.13	10.38	.44	3.121	.004	.140	
	1200.0	200.00	9.600	.73	.25	10.33	.89	3.093	.009	.280	
	2000.0	333.00	5.700	1.23	.42	10.27	1.48	3.055	.015	.466	
	2400.0	400.00	4.800	1.46	.50	10.24	1.78	3.036	.018	.560	
	19200.0	3200.00	.600	11.67	4.00	8.94	14.20	2.236	.141	4.480	
	40800.0	6800.00	.280	25.02	8.57	7.28	30.18	1.207	.300	9.520	
			30.46	10.43	6.57	36.98	.769	.367	11.666		
			100%								
Eight-Bit Code (With Autopolling)	600.0	75.00	14.200	.49	.17	10.39	.33	3.129	.003	.105	
	1200.0	150.00	7.100	.99	.34	10.35	.67	3.107	.007	.210	
	2000.0	250.00	4.200	1.67	.57	10.31	1.11	3.079	.011	.350	
	2400.0	300.00	3.500	2.00	.69	10.29	1.33	3.064	.013	.420	
Six-Bit Code (With Autopolling)	600.0	100.00	10.800	.65	.22	10.38	.44	3.121	.004	.140	
	1200.0	200.00	5.400	1.30	.44	10.33	.89	3.093	.009	.280	
	2000.0	333.00	3.200	2.19	.75	10.27	1.48	3.055	.015	.466	
	2400.0	400.00	2.700	2.59	.89	10.24	1.78	3.036	.018	.560	

Table B-5. Channel Evaluation Factors—2701

	Data Rate (cps)	Wait Time (ms)	Device Load	D1	Priority Load						
					Time	A	B	A1	A2	B1	
7770 Audio Response Unit:											
8 Lines	12	9.02	.79	.266	.100	6.839	4.65	1.587	.020	1.136	
16 Lines	12	4.49	1.59	.534	.100	6.839	4.65	1.587	.020	1.136	
24 Lines	12	2.99	2.39	.804	.100	6.839	4.65	1.587	.020	1.136	
32 Lines	12	1.48	4.83	1.625	.100	6.839	4.65	1.587	.020	1.136	
40 Lines	12	1.48	4.83	1.625	.100	6.839	4.65	1.587	.020	1.136	
48 Lines	12	1.48	4.83	1.625	.100	6.839	4.65	1.587	.020	1.136	

Key:

- 1 Device subject to overrun; highest priority required.
- 2 Device requires synchronized channel service; not subject to overrun; second highest priority required.
- 3 Device does not require synchronized channel service; not subject to overrun; lowest priority.
- M Byte mode on byte multiplexer channel.
- E Evaluate punching and reading separately by using the wait times, device loads, and previous loads for the independent operations.
- Var Variable.

Table B-6. Channel Evaluation Factors—7770

Appendix C. Device Data Rates

Device and Model	Density	Nominal Speed (Megabytes/Second)	Command Retry on Command Overrun?	Command Retry on Data Overrun?			
2250-3	-	0.526	No	No			
2305-2	-	1.500	Yes	Yes			
2311-1	-	0.156	No	No			
2314-A or B	-	0.312	No	No			
3330	-	0.806	Yes	Yes			
3340	-	0.885	No	No			
3344	-	0.885	No	No			
3350	-	1.198	Yes	Yes			
3370	-	1.859	Yes	Yes			
3375	-	1.859	Yes	Yes			
3380	-	3.000	Yes	Yes			
3848	-	3.000	No **	No **			
2401, 2402, 2403, 2404-1	200 556 800	0.0075 or 0.0056* 0.0208 or 0.0156* 0.0300 or 0.0225*	* Data conversion in effect. **3848 is fully buffered, not subject to overrun.				
2401, 2402, 2403, 2404-2	200 556 800	0.0150 or 0.0113* 0.0417 or 0.0313* 0.0600 or 0.0450*					
2401, 2402, 2403, 2404-3	200 556 800	0.0225 or 0.0169* 0.0625 or 0.0469* 0.0900 or 0.0675*					
2401, 2402, 2403, 2404-4	800 1600	0.0300 0.0600					
2401, 2402, 2403, 2404-5	800 1600	0.0600 0.1200					
2401, 2402, 2403, 2404-6	800 1600	0.0900 0.1800					
Device and Model	Density	Nominal Speed (Megabytes/Second)			Device and Model	Density	Nominal Speed (Megabytes/Second)
2415	200 556 800 1600	0.0038 0.0104 0.0150 0.0300			3420-3	556 800 1600	0.0417 0.0600 0.1200
2420-5	1600	0.1600			3420-4	1600 6250	0.1200 0.4688
2420-7	1600	0.3200			3420-5	556 800 1600	0.0695 0.1000 0.2000
3410-1	200 556 800 1600	0.0025 0.0070 0.0100 0.0200			3420-6	6250 556 800 1600	0.7803 0.1112 0.1600 0.3200
3410-2	200 556 800 1600	0.0050 0.0139 0.0200 0.0400			3420-7	6250 556 800 1600	0.7803 0.1112 0.1600 0.3200
3410-3	200 556 800 1600	0.0100 0.0278 0.0400 0.0800	3420-8	6250	1.2500		

Table C-1. Data Rates by Device

CONTROL UNIT(S)	DEVICE	TAG SPEED	INSTANTANEOUS DATA RATE (Mb/sec)
Direct Access Storage Devices:	3540	slow	Note 1
Punched Card I/O and Printers:	1442	slow	Note 1
	1443	slow	Note 1
	2501	slow	Note 1
	2520	slow	Note 1
2821	1403	slow	0.200
2821	2540	slow	0.166
	3203	fast	0.598
3811	3211	slow	0.288
	3505	fast	EBCDIC: 0.167 / card image 0.350
	3525	fast	EBCDIC: 0.167 / card image 0.350
	3800	fast	0.235
Display and Console Printers:			
3272		fast	0.650
3274-1A		fast	Note 1
3274-1B, 1D		fast	0.650
3791	3793	fast	Note 1
Magnetic Character and Optical Reader:			
	1255	slow	Note 1
	1287	slow	Note 1
	1288	fast	Note 1
	1419	slow	Note 1
	3881	slow	0.115
	3886	fast	0.126
	3890	slow	0.200
	3895	fast	Note 2
Communication/Data Acquisition/Process Control:			
2715	2701	fast	Note 1
2715	2791	slow	Note 2
	2793	slow	Note 2
	3704	fast	Note 2
	3705	fast	Note 1
Paper Tape I/O:			
2822	2671	slow	Note 1
2826	1017	slow	Note 2
2826	1018	slow	Note 2
	3850/51	fast	Channel Speed (1 Mb/sec or 1 Mb/sec)
Audio Response Unit:			
	7770	slow	Note 2
	CHAN-to CHAN ADAPTER	fast	Channel Speed (1 Mb/sec or 1 Mb/sec)

Table C-2. Data Rates by Device

Notes:

1. Negligible for EDR consideration.
2. Not applicable for EDR consideration.

Appendix D. Miscellaneous Tables

SECTION 1	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5
No Data Chaining	3.0 Mb	3.0 Mb	2.0 Mb	2.0 Mb	1.0 Mb
If Data Chaining	Section 2 or 3*	Section 2 or 3*	Section 3	Section 3	Section 3

* Use Section 2 if Extra Channel feature is not installed.
Use Section 3 if Extra Channel feature is installed.

SECTION 2		
Smallest CCW Count	Channel	
	1	2
1	11 Kb	8 Kb
2	22	16
4	44	33
8	87	65
16	168	125
32	313	234
64	553	412
128	894	665
256	1293	960
512	1665	1232
1024	1945	1436
2048	2123	1565
4096	2225	1639
8192	2280	1678
16384	2308	1699
32768	2323	1709
65535	2330	1715

SECTION 3					
Smallest CCW Count	Channel				
	1	2	3	4	5
1	5 Kb	4 Kb	4 Kb	3 Kb	3 Kb
2	11	9	8	7	6
4	22	19	16	14	12
8	43	37	32	28	25
16	83	71	62	55	48
32	155	133	115	102	90
64	273	234	202	180	158
128	440	376	325	289	252
256	633	541	465	414	360
512	810	692	594	528	457
1024	942	804	689	612	528
2048	1026	875	749	665	573
4096	1073	915	783	695	598
8192	1099	937	810	711	612
16384	1112	948	810	720	619
32768	1118	954	815	724	622
65535	1122	956	818	726	624

Table D-1. Data Chaining Rates for Block Multiplexer Channels

	BFL	TA	TB	TC	TD
Scanner 1	4	8.70	.996	.124	.35000
Scanner 2					
CT = 1.2	4	8.70	.996	.136	.04880
CT = 1.0	4	8.70	.830	.136	.04060
CT = 0.9	4	8.70	.747	.136	.03660
Scanner 3					
CT = 1.2	4	8.70	1.420	.136	.01550
	8	15.70	1.870	.122	.00939
	16	29.60	2.780	.115	.00634
	32	57.40	4.610	.112	.00481
	64	113.00	8.260	.110	.00405
	96	169.00	11.900	.110	.00379
	128	224.00	15.600	.110	.00366
	160	280.00	19.200	.109	.00359
	192	336.00	22.800	.109	.00354
	224	391.00	26.500	.109	.00350
CT = 1.0	4	8.70	1.180	.136	.01290
	8	15.70	1.560	.122	.00783
	16	29.60	2.320	.115	.00528
	32	57.40	3.840	.112	.00401
	64	113.00	6.880	.110	.00337
	96	169.00	9.920	.110	.00316
	128	224.00	13.000	.110	.00305
	160	280.00	16.000	.109	.00299
	192	336.00	19.000	.109	.00295
	224	391.00	22.100	.109	.00292
CT = 0.9	4	8.70	1.060	.136	.01160
	8	8.70	1.060	.136	.01160
	16	29.60	2.090	.115	.00475
	32	57.40	3.460	.112	.00361
	64	113.00	6.190	.110	.00303
	96	169.00	8.930	.110	.00284
	128	224.00	11.700	.110	.00275
	160	280.00	14.400	.109	.00269
	192	336.00	17.100	.109	.00265
	224	391.00	19.900	.109	.00262

Table D-2. IBM 3704/3705 Timing Chart

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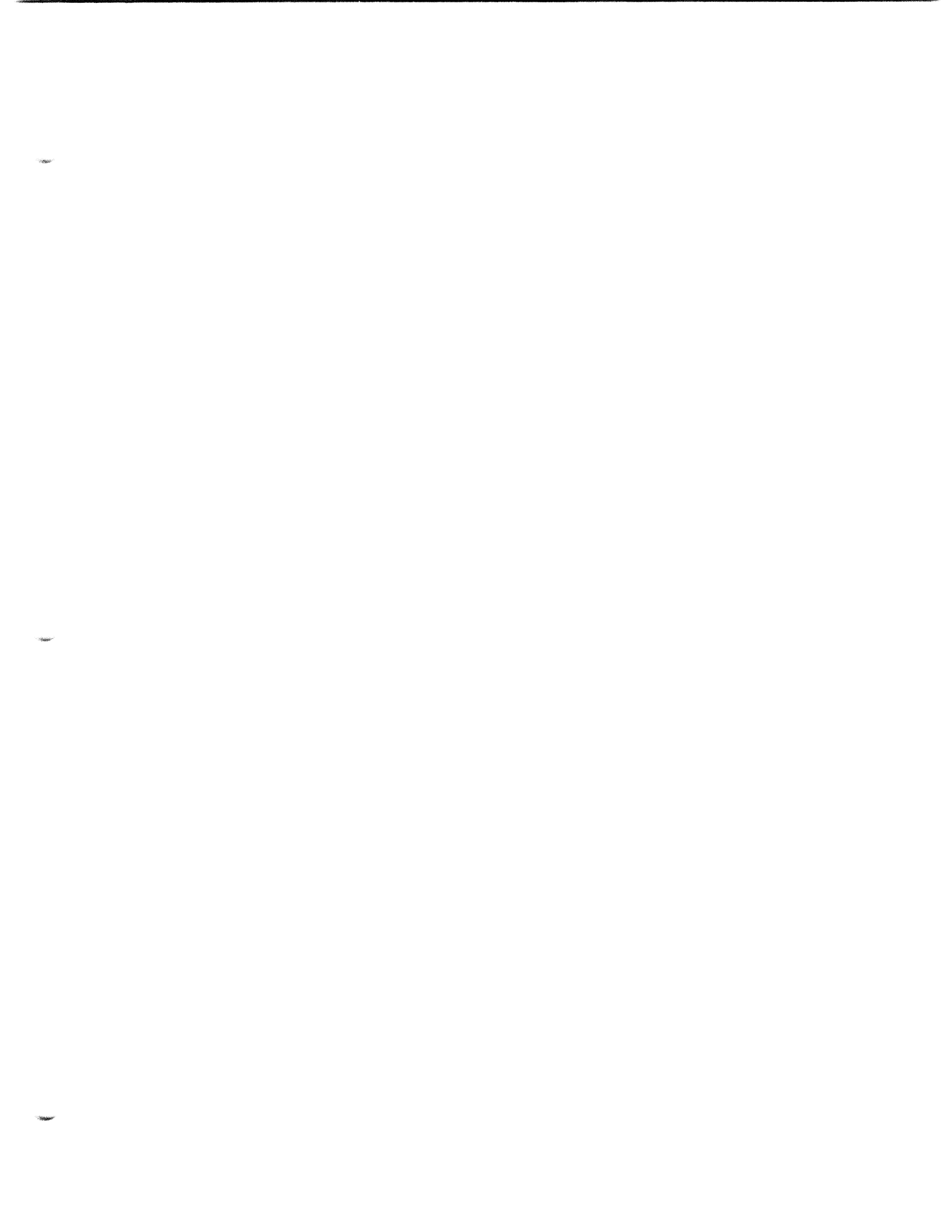
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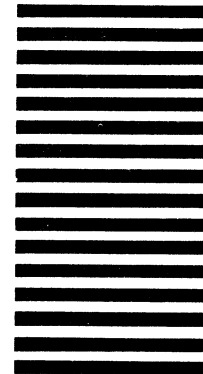
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