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IBM System/360 Model 30
Channel Characteristics and Functional Evaluation

This reference publication describes methods used to calculate System/360 Model 30 data handling capabilities that are dependent upon I/O-channel configurations and operations. Also presented are considerations of methods for:

1. Priority attachment of I/O units for maximum throughput,
2. Addressing I/O units,
3. Calculating buffer transfer times,
4. Calculating interference (with the processing unit) caused by channel operations.

Calculations for a System/360 Model 30 with a 1.5-microsecond RW (Read/Write) cycle and with a 2-microsecond RW cycle are discussed separately.

The user of this publication should be thoroughly familiar with I/O programming considerations as described in IBM *System/360 Principles of Operation,* Form A22-6821. Information related to specific I/O devices is contained in separate Systems Reference Library publications. These publications are listed by form number and briefly described in IBM *System/360 Bibliography,* Form A22-6822.

When you are performing loading calculations related to the multiplexor channel operating in multiplex mode, use the IBM *System/360 Model 30 Multiplexor Channel Worksheet,* Form X24-3407. If the IBM 2702 Communications Control is used in your configuration, use the IBM *System/360 Model 30 2702 Worksheet,* Form X24-3406.

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How to Use This Publication

This publication is divided into two principal sections:

- Section I is devoted to discussing the design characteristics of the channels and to advise on programming their control to achieve best performance and compatibility of System/360 models. This section covers the subjects of CPU and channel interferences, how I/O units are connected to the channels, how priority is established between I/O units, how I/O units are addressed, and advice on programming channel control. This information is applicable to any System/360 Model 30 regardless of its RW cycle speed.

- Section II (IIA and IIB) is devoted to calculating: loads on the system; buffer transmission times; and available processing time within any processing cycle time.

The Appendix contains tables that are used in the calculation procedures.

Section I should be read for background information so that you may understand the calculation methods used in Sections IIA and IIB.

Sections IIA and IIB are designed to be used as a tool by a systems designer, to calculate the various nominal load limits and times needed to determine satisfactory operation of a particular system. To use these sections, it is only necessary to refer to and follow the step-by-step procedures given, when once these procedures are understood.

If your System/360 Model 30 has an RW cycle time of 1.5 microseconds, use Section IIA in your calculation. Do *not* use Section IIB, which is devoted to a System/360 Model 30 with a 2-microsecond RW cycle. The reverse is also true. Section IIA, relating to a System/360 Model 30 with a 1.5-microsecond RW cycle, has been essentially duplicated, in Section IIB, for a processing unit with a 2-microsecond RW cycle.

Sections IIA and IIB are divided into four parts:

1. I/O unit and channel loading calculation methods, when units on the multiplexor channel are operating in burst mode only.
2. I/O unit and channel loading calculation methods, when units on the multiplexor channel are operating in multiplex mode.
3. Buffered unit timing considerations are presented separately. Also, in this separate section are data and command chaining times for both the multiplexor and selector channels.
4. Methods for calculating the amounts of interference that I/O device and channel operations have upon the processing unit (i.e., during a given period of time). The remaining amount of processing unit time is then available for program processing.

As previously stated, the four preceding parts of Sections IIA and IIB (and their subsections) are essentially presented twice: once for the system with a 1.5-microsecond RW cycle (Section IIA) and once for a system with a 2-microsecond RW cycle (Section IIB). Therefore, when performing calculations, be sure that you are using the section related to your specific system's RW cycle time. Otherwise, your calculations will be meaningless.

The part fully described in Section IIA but only referred to in Section IIB dealing with calculations for the multiplexor channel operating in multiplex mode is applicable to a System/360 Model 30 with either a 1.5-microsecond or 2-microsecond RW cycle. The difference in procedure, for the system with the 2-microsecond RW cycle, is that a different load limit is used. Use of this load limit is described in the section dealing with multiplex mode calculations.

Among the topics presented in this publication are methods for determining the loading effects imposed upon IBM System/360 Model 30 by input/output devices, multiplexor channel, and selector channel operations. As a concept, a load value of a unit is the percent of the system's work capability that the unit uses in being serviced. For example, main storage in a System/360 Model 30, that has a storage cycle (read/write cycle) time of 1.5 microseconds, can accept data at a *maximum* rate of 667 kilobytes per second. A device sending that much data into main storage would load the system to 100% of its capacity during the data transfer operation. On the other hand, if the system must devote its time entirely to handling a function for an I/O device, no matter how slow that device is, the load caused by the device for that period of time is also 100%. As a warning, however, the nominal load values given in the tables in the appendix for the different I/O units *can not be used* as directly noting the entire load that a unit places on the system.

These values are specifically designed for use in the formulas and procedures in this publication.

Loading calculations may indicate that a device will overrun (lose data) in a specific configuration. However, because of consideration of worst-case situations (implicit in the loading calculations) and because calculations are measured against coincidences of operations that have low probabilities of simultaneous occurrence, a repeat run of the overrun operation, by the system, will probably yield satisfactory results (i.e., overrun will probably not occur upon repetition of the operation).

The reader of this manual should have a thorough understanding of I/O operations as described in IBM *System/360, Principles of Operation,* Form A22-6821. Information related to I/O device operation, cycle timing considerations, and programming considerations can be found in the Systems Reference Library publications dealing with the specific devices. These publications are listed by form number and briefly described in IBM *System/360 Bibliography,* Form A22-6822.

It is conceivable that, in rare instances, certain I/O-channel configurations (performing particular combinations of operations) might exceed the system's capability to handle the I/O data transfers called for. In most configurations, interactions of I/O and channel operations will not exceed the data handling capabilities of the system. Therefore, consideration of possible data overloading is applicable mainly to systems that use a number of high-speed I/O devices that may be run concurrently in certain applications.

Mutual Interference of Channels and CPU

Recall that two types of input/output channels – multiplexor and selector – are available for System/360 Model 30. The main purpose of the multiplexor channel is to provide for operation of lower speed I/O devices in multiplex mode. In the multiplex mode, information is transferred in groups of bytes between the processing unit and several I/O devices concurrently. For example, multiplexing service for two serial unbuffered card readers could proceed as follows:

1. One byte of data is sent from the control unit of the first card reader to the processing unit.
2. Next, one byte of data is sent from the control unit of the second card reader to the processing unit.

Steps 1 and 2 are repeated until a complete record is transferred for one of the units. Servicing for the other unit is then completed alone.

While some I/O units always operate in burst mode regardless of the channel, buffered units (except the 2520) attached to the multiplexor channel can operate in burst mode as well as in multiplex mode. This capability is provided by a switch associated with the buffered unit. In burst mode, the transfer is completed on a record basis.

Multiplexing operations are not allowed on the multiplexor channel during the time that a unit attached to the multiplexor channel is operating in burst mode. Therefore, care must be taken by the programmer not to start a burst mode unit while multiplexing units are operating.

Selector channels operate only in burst mode. An I/O control unit obtains control of the channel and transfers an entire record (i.e., multiplexing does not occur) for the associated I/O unit. After the record is transferred, another I/O control unit can obtain control of the selector channel for record transfer.

Overlapping operations of the processing unit and the selector and multiplexor channels frequently occur. For example, the following could be overlapped:

1. CPU (Central Processing Unit) processing of an instruction,
2. An I/O device on a selector channel sending data to the CPU,
3. An I/O device on the multiplexor channel receiving data from the CPU.

The selector channel must access main storage each time it sends a byte of data to the CPU. The multiplexor channel uses main storage *and* the read-only-storage microprogram control each time a byte is transferred. Also, the CPU uses main storage and the read-only-storage microprogram control to process instructions.

Only one of these operations can be in progress during any specific read/write storage cycle. The reason for this is that the same facilities are used by different operations. For example, when the read-only-storage microprogram is used to control a data transfer or chaining operation on the multiplexor channel, the registers (*not* the 16 general purpose or 4 floating point registers) in the CPU are also used for the operation. Program processing uses these same facilities. Hence program processing must be stopped until the multiplexor channel has completed the required operation. The CPU can then continue with processing.

When a chaining operation is called for on a selector channel, the read-only-storage control and the CPU registers must be used. Again, CPU program processing must be stopped until the selector channel chaining operation is completed.

Because the selector channels do not need microprogram control to transfer a data byte to or from main storage, program processing is stopped only for the time required (one read/write cycle) to store or fetch the data byte from main storage. This is not the case when microprogram control is required (as for multiplexor or selector channel chaining). The microprogram for these operations uses registers in the CPU. Hence the information in these CPU registers must be stored when an operation requiring the use of these registers breaks into the operation in progress that is using these same registers. To summarize:

Selector Channels

- The selector channels use separate and independent circuitry and registers to control data transfers to or from an I/O device.
- In selector channel data operations, one RW cycle is needed to transfer a data byte to or from main storage.
- CPU registers and the read-only-storage control are used by selector channels in such operations as chaining.

Multiplexor Channel

- The multiplexor channel uses CPU registers and the read-only-storage control for data-byte transfers as well as for chaining operations.

Program Processing

- The CPU registers and read-only-storage control are used to process instructions.

It may be observed, therefore, that there is cross interference among the CPU, selector channels, and multiplexor channel operations. Because of this, a priority servicing arrangement is set up. The order of priority is:

Highest priority	1. Selector channel share cycles (for data).
	2. Selector channel chaining (microprogram break-in).
	3. Multiplexor channel share microprogram (for data or chaining).
Lowest priority	4. CPU microprogram cycles.

Each of these categories is interruptible by any of the other categories of higher priority. Therefore, the length of time required to complete a particular operation is dependent upon how many break-ins by other operations have occurred (and how much time each break-in requires).

Note, then, that maximum data rates quoted for selector or multiplexor channel operations presume that no other operations are breaking in. For example, the multiplexor channel can handle up to 31,000 bytes per second (23,800 bytes in a CPU with a 2-microsecond RW cycle) in multiplex mode. This figure pertains to the *peak* multiplex mode data transfer rate. If other operations break in, the peak rate is lowered according to the time required by the other operations.

To prevent a channel operation of high priority from excluding all other channel operations of lower priority, the channel priorities are rotated. An example of an operation that might exclude other operations is that of a data transfer from the 2030 to an I/O device (or to another CPU) that has a higher cycle rate than the 2030 storage cycle rate.

The system of rotating priorities operates only with channels and then only when their requests for service occur simultaneously. No problem occurs in all cases in which only one channel requires service. However, when requests for the following occur at the same time:

1. main storage cycle steals (when an RW cycle is required for selector channel transfer of data to or from main storage),
2. chaining microprogram cycles,
3. multiplexor microprogram cycles to transfer data,

then the priority circuits are sequenced. The sequencing proceeds as follows:

1. Selector channel one data cycles have highest priority 50% of the time.
2. Selector channel two data cycles have highest priority 25% of the time.
3. Microprogram cycles for selector channel chaining, or for multiplexor channel operations, have priority 25% of the time.

In item 3, if selector channel chaining microprogram cycles are called for, no multiplexor channel cycles are taken until the completion of the selector channel microprogram cycles.

Control Unit Connection to Standard I/O Interface

Up to eight control units can be connected to a channel in System/360 Model 30. However, connection of control units to the I/O interface can be thought of in one of three ways, depending upon the units involved:

1. A single control unit that controls *one* I/O unit can be connected to the channel. An example is the IBM 1443 Printer. The control unit for the 1443 is contained in the 1443 itself. When the 1443 is connected to a channel, one of the eight I/O interface positions is used.

2. A single control unit that services the requirements of *several* I/O units (one at a time) can be connected to the channel. An example of this arrangement is an IBM 2841 Storage Control Unit and attached direct access storage units. The 2841 is a single control unit that provides for servicing of only one of its attached I/O units at a time. (Up to eight access mechanisms can be attached to the 2841.) Again, the 2841 requires use of one of the eight positions on the I/O interface. Here, however, multiple units are serviced (one at a time) by the control unit.
3. The third situation occurs when *several* control units are contained in one unit that is itself called a control unit. Each of the separate control units services one I/O device. An example is the IBM 2821 Control Unit, which concurrently services IBM 1403 or 1404 Printers, and the IBM 2540 Card Read-Punch. Each of the attached I/O devices has its own control unit contained in the 2821. The 2821 uses only one of the eight positions on the I/O interface.

Note that while not more than eight interface attachments can be made to a channel, the number of I/O units attached can be greater than eight. For example, one interface adapter is used to attach a 2841 control unit which can control up to eight access mechanisms.

Also, note that, as a special case, the IBM 1050 Documentary Console devices do *not* use up one of the eight possible connections to the channel.

Priority Attachment of I/O Units (Multiplexor Channel)

The method used to service a device on the multiplexor channel requires that in order to obtain maximum throughput, devices must be attached to the channel in a certain sequence.

When a device is ready to send or receive a byte of data, then that device raises a request-in line in the interface cable. The channel then sends a select signal over the interface cable. This signal is sent serially to each control unit connection on the interface cable. Each control unit, if it does not require service, allows the select signal to proceed to the next control unit. When the select signal reaches a control unit that requires service, further propagation of the select signal is blocked (i.e., it does not proceed to any other control unit on the cable). The control unit, at which the signal was stopped, then secures temporary use of the interface data and signal paths so that data or status information can be transferred. After the data or status information has been handled, the interface becomes available to the other units. Polling starts again when another request for service is recognized. If simultaneous requests for two units occur, the one closer (electrically) to the channel is serviced first. Therefore, priority of servicing is in the same order as the physical positioning of the control units on the select line of the I/O interface. As already discussed, an I/O interface connection can be used by a single control unit and attached I/O unit, a single control unit controlling multiple I/O units (one at a time), or multiple control units each of which controls one I/O device.

Priority of servicing devices on the channel is determined by the following basic considerations:

1. Buffered units can be delayed without losing data. The information is contained in the buffer until needed and hence operation does not depend upon the speed of operation of the actual device that is buffered. For example, a 1403 print-cycle does not affect the movement of data from main storage to the 1403 buffer. Once the 1403 buffer is loaded, the transfer of data is complete as far as the channel is concerned.
2. Synchronous unbuffered devices, once started, cannot be delayed without loss of data. For example, suppose that a serial unbuffered card reader has started a read cycle. Because the data read from the card is unbuffered, the channel must accept that data as it is read.
3. Asynchronous unbuffered units operate, on demand, for each character cycle. Examples here are the 1442 punch and 1050 documentary console units. These units do not overrun, but they lose speed if not serviced at their maximum speed.

Because synchronous unbuffered devices cannot be delayed, they must be placed first, in order of priority, on the channel. If simultaneous requests occur, from both a buffered and a synchronous unbuffered device, then the select signal is stopped by the unbuffered device before it reaches the buffered device. The unbuffered device can then proceed and not have to wait for a possible buffered device operation to be completed. This is desirable because the synchronous unbuffered device *must* have access to the channel when it has a data byte ready for transfer.

In addition, higher speed synchronous unbuffered devices require priority over slower speed synchronous unbuffered devices. The higher speed unbuffered devices have a shorter time in which they can wait before they *must* transfer a byte of data. Therefore, the higher speed synchronous unbuffered devices should be positioned first, in priority, within the synchronous unbuffered device group.

A further condition must be considered for the buffered device group because there are basically two types of devices in the buffered group:

1. Synchronous
2. Asynchronous

An example of an asynchronous device is the 1403 printer. For the 1403 printer, there is a specific waiting time before printing can begin. If loading of the buffer is completed after the waiting time, then printing can begin. Asynchronous buffered devices should be placed last in priority within the buffered group.

On the other hand, synchronous buffered devices should be placed first, in order of priority, within the buffered group. An example here is the IBM 2540 Card Read-Punch. In 2540 operations, card feeding is under control of mechanical clutches, whose engaging points are $\frac{1}{3}$ cycle apart. Assume that a card-feed cycle is in progress in the read feed. Toward the end of the cycle, at a predetermined point (i.e., device end), the 2540 reader can receive another command to read so that the contents of its buffer will be sent to the channel. If, for some reason, this buffer transmission is delayed past the next normal clutch point, the clutching mechanism cannot be engaged until the following clutching point ($\frac{1}{3}$ cycle away, in time). In this case, card reading speed drops to $\frac{3}{4}$ of full speed. Therefore, this synchronous buffered device should be placed in a position of higher priority than asynchronous buffered devices.

The IBM 2520 Card Read-Punch is handled somewhat differently than other devices. Card reading in the 2520 is synchronously unbuffered and serial while card punching is buffered. Therefore, if only one 2520 is used, and both reading and punching are performed, then that 2520 must be placed between the serial unbuffered devices and the buffered devices.

If, however, more than one 2520 is used and all 2520's are punching *and* reading, then the unit of highest priority (the card reader, which is unbuffered) should be started first (assume that the punch buffer is already loaded) and *then* the second card punch should be started. This situation is rare, however, because it implies that more than one 2520 is used in a punch-back operation (i.e., punching is being done in the card previously read).

If the 2520 is only reading or only punching, it can be placed in the channel priority arrangement according to the rules for I/O priority already described.

Summary of Priority Attachment

Devices should be connected to the multiplexor channel interface cable in the following order of descending priority, for most efficient operation (for unit identification, consult column labeled key in Table 1, *Appendix*):

1. *Synchronous unbuffered serial devices* (e.g., 2501 and 2702). Within this group, the devices should be placed in descending priority order of their waiting-time intervals (see Table 1, *Appendix*). The devices with shortest waiting time are placed first within this group.
2. *Synchronous buffered units* (e.g., 2540 and 2520). Within this group, devices with the shortest waiting time should be placed first.
3. *Asynchronous buffered units* (e.g., 1443 and 1403). Within this group, devices with the shortest waiting time should be placed first.
4. Burst-mode devices which are time dependent on command chaining (e.g., 2311).
5. Other burst-mode devices.
6. Asynchronous unbuffered devices (e.g., 1050 documentary console).

As a special exception to this priority attachment, the channel-to-channel adapter is placed, by its design, at the highest priority position on the cable even though it is a burst mode device.

The 1050 console does not count as one of the eight possible control unit attachments. However, it can be given either the highest or lowest priority to all other possible device attachments. It is suggested that it be given the lowest priority such that its adapter will not delay the select signal propagation in command chaining some other unit on the cable.

Unit Addressing Method

Before a command can be sent to the control unit of a device, the device must be addressed. The address is derived from a START I/O instruction and consists of 11 bits of information. The channel's address is contained in the three high order bits, and the address of the device is in the eight low order bits, as follows:

	Channel Address	*Device Address*
Bit "position"	0 1 2	3 4 5 6 7 8 9 10

Notice here that up to 256 different addresses can be developed in the eight low-order bits. That is, the addresses in the eight low-order bits can range from:

Binary Value	*Decimal Value*
00000000	0
to	to
11111111	255

Any of the 256 addresses can be used to designate a device on a selector channel. In IBM System/360 Model 30 there can be a maximum of two selector channels (special features). The two selector channel addresses are:

Selector Channel	*Channel Address*
1	001
2	010

Therefore, the 11-bit addresses used with selector channel devices have the following ranges:

Selector Channel One Addresses	*Selector Channel Two Addresses*
001 0000 0000	010 0000 0000
to	to
001 1111 1111	010 1111 1111

Recall that up to eight connections can be made to the standard I/O interface. This restriction, however, does *not* limit, to eight, the number of attached I/O units. For clarification of this subject, refer to the *Control Unit Connection to Standard I/O Interface* section of this publication.

A different situation exists for device addressing on the multiplexor channel. Device addressing on the multiplexor channel is dependent upon how the device and its control unit operate with the channel. For devices that have exclusive use of a control unit, the high-order bit of the unit address is set to a value of zero. Examples of such devices are:

1. *The 1443 printer.* The control unit for the 1443 printer is in the 1443 printer and it is for the 1443's exclusive use.
2. *The 1403 printers and 2540 card read-punch.* Each 1403 printer, attached to a 2821 control unit, has a control unit (for its exclusive use) contained in the 2821. If three 1403 printers are attached to a 2821, then there are three separate control units in the 2821, one for each 1403. If a 2450 is attached to the same 2821, then the 2540 reader and 2540 punch each has its own separate control unit contained in the 2821.

The high order bit of the unit address also has a value of zero for devices that operate simultaneously, but all of which use the same control unit. This situation occurs for a communications multiplexor, which controls a number of terminals that are operating simultaneously.

For these two types of devices (viz., those that have exclusive use of a control unit or those that operate simultaneously with a single control unit) the device addresses range, in a System/360 Model 30 with 8192 positions of main storage, from:

Binary Address	*Decimal Value*
0000 0000	0
to	to
0001 1111	31

The restriction of 32 device addresses (maximum) is caused by the amount of special storage (multiplexor storage) available for channel use in a Model 30 with 8192 positions of main storage.

All other System/360 Model 30 processing units have at least 16384 positions of main storage. These other models have 96 unit addresses available for use by this category of unit on the multiplexor channel. Hence unit addresses (with a high order bit value of zero), in a Model 30 with 16384 or more positions of main storage, range from:

Binary Address	*Decimal Value*
0000 0000	0
to	to
0101 1111	95

The multiplexor channel address (three high order bits of the 11-bit address) is 000. Hence, the valid ranges for the addresses (with high order bit of unit address set to a zero value) are:

Processing Unit Main-Storage Positions	*Multiplexor Channel Valid Addresses*
8192	000 0000 0000 *to* 000 0001 1111
16384 (or more)	000 0000 0000 *to* 000 0101 1111

Consequently, the following addresses are invalid:

Processing Unit Main-Storage Positions	*Multiplexor Channel Invalid Addresses*
8192	000 0010 0000 *to* 000 0111 1111
16384 (or more)	000 0110 0000 *to* 000 0111 1111

Note that System/360 Model 30 processing units with 32,768 or 65,536 positions of main storage can have an optional feature that permits addressing of up to 224 units. This feature, however, excludes use of shared control units and their method of addressing, which we shall now consider.

Certain types of I/O units (such as magnetic tape drives) share a single control unit. For these devices, only one of the I/O units can transmit data at a time. For example, consider two tape drives (A and B) attached to a control unit. If tape drive A is transmitting data, then tape drive B cannot transmit data until tape drive A has completed its operation. Here, only one multiplexor channel subchannel is provided for the control unit that controls the two tape drives. For this situation, the device address must have its high order bit set to a value of one. The next three high order bits designate the shared control unit of the attached devices. The low-order four bits designate the address of devices attached to the shared-control unit. The addresses for shared-control units range from:

Multiplexor Channel Address	*Shared Control-Unit Address*	*Device Address**
000	1000	XXXX
	to	
000	1111	XXXX

*XXXX can range from 0000 to 1111 for each value of the shared control unit address.

Notice that only three bits are used to address the shared control unit. The number of shared control units that can be addressed is then:

Binary Address	*Decimal Value*
000	0
to	to
111	7

We have considered two types of addresses on the multiplexor channel:

1. Those in which the high-order bit of the unit address has a value of zero.
2. Those in which the high-order bit of the unit address has a value of one.

An important point to note is that, in certain cases, the unit using a shared control unit and the unit using a single control unit (i.e., the two types of addresses considered) could conceivably use the same subchannel in the multiplexor channel. That is, to the multiplexor channel, the unit address 0000 0001 is interpreted in the same way as unit address 1001 XXXX (where the X's represent the address of a device attached to a shared control unit).

Now if both of the units, to which these addresses apply, were operating at the same time, they would both use the same UCW (Unit Control Word) in multiplexor storage. Because a subchannel can keep track of only one unit's operation at a time, an attempt to keep track of two operations simultaneously with the same subchannel (UCW) would cause meaningless information to be stored in the special subchannel storage. Therefore, the first eight subchannels are shared on a mutually exclusive basis between the first eight single control-unit addresses and the eight possible shared control-unit addresses.

Hence, if a unit address, listed in a column of the following table, is used on the multiplexor channel, then the corresponding address in the other column cannot be used:

Single Control Unit	*Shared Control Unit*
0000 0000	1000 XXXX
0000 0001	1001 XXXX
0000 0010	1010 XXXX
0000 0011	1011 XXXX
0000 0100	1100 XXXX
0000 0101	1101 XXXX
0000 0110	1110 XXXX
0000 0111	1111 XXXX

These are the only *mutually exclusive* addresses for the multiplexor channel.

At the installation of the system, the customer engineer sets in each I/O device and control unit the bit address desired for a unit, within the limits imposed by the preceding rules.

Programming Considerations

Storage Addressing

All System/360 models have address resolution to a single byte, but for data chaining operations, programming consideration should be given to the one-to-eight range of bytes obtained per storage access cycle by the various models. If the larger byte widths used by certain models and the possibility of using faster I/O devices are kept in mind when writing programs for lower capacity models, better performance will be obtained when the programs are run on larger models. For example, a tape operation at a 30 kilobyte data rate may data chain on arbitrary byte boundaries on a System/360 Model 30 with one selector channel, but the same tape operation cannot be performed at arbitrary byte boundaries at 120 kilobytes on a System/360 Model 50.

Time Dependent Command Chaining

Operation of direct access devices (such as a disk storage unit) depends upon execution of a sequence of chained CCW's. Between certain operations, such as the search for a record identification key and the reading of data on a direct access device, the control unit has a fixed time interval during which a new command must be received. If activity on another channel (or channels) delays execution of CCW chaining past this time interval, then the channel program is terminated and an I/O interruption condition occurs.

More significantly, if another unit on another channel is chaining, its chaining may occur at the same time as that for the disk-storage unit. Hence chaining on other units, when the disk unit is chaining, may cause overrun and the operation may have to be repeated. Also, interference with the disk unit's chaining is more severe when writing (on the disk) than when reading (from the disk) because the time allowed for writing is much less than the time for reading.

Overrun

Overrun (data loss) occurs when a channel does not accept or transfer data within required time limits during a read, read backward, or write operation. 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 slowed down (i.e., a buffered device) and no data lost, or, as in the case of a tape drive read operation, the device may continue transferring until the end of the record is reached.

An overrun causes an I/O interruption condition, either immediately or later. An I/O interruption condition causes an I/O interrupt whenever the channel is not masked against I/O interruptions. When the overrun condition is recognized, the operation may be restarted. Calculations for possible overrun, in this publication, are based on worst case conditions occurring together. Hence, if on rerun these conditions do not occur together, then the operation may well be successful.

Burst Versus Multiplex Mode Channel Operations

A burst mode device attached to the multiplexor channel (such as a tape drive) prohibits CPU instruction processing from initial selection to channel end. For a buffered unit, CPU instruction processing is stopped for the time it takes to either load (or unload) the buffer from (or to) the channel (whether the buffer is operated in either burst or multiplex mode).

After channel end occurs for a burst mode operation on the multiplexor channel, the CPU can start processing instructions again. If the unit is command chaining, however, CPU instruction processing is stopped again as soon as device-end occurs. Hence, from channel-end to device-end the multiplexor channel is not busy to a START I/O instruction. If commands are chained on the selector channels, the channels are busy to further START I/O's even between channel-end and device-end. They are busy for the full chain of commands.

It is important to realize that, while CPU *instruction processing* is stopped during a buffer transmission in multiplex mode, CCW operations already started may break into the data transfer operation between the buffer and the channel. For example, suppose that a START I/O instruction has initiated the sequence of events that results in a card-read operation (in multiplex mode) from a serial unbuffered card reader on the multiplexor channel. Assume that command chaining is used, such that a new CCW will be used to start a second card-read cycle (after the first card is read). For this operation, CPU instruction processing is not stopped for the entire data transfer from either card (the unit is *unbuffered*).

Now, while the first card is being read, a START I/O instruction initiates the sequence of events that results in sending a print record from main storage (in multiplex mode) to the buffer of a printer on the multiplexor channel.

Further assume that data transfer to the print buffer has started just prior to the time that device-end occurs in the card reader for the first card. Because the unbuffered card reader is a higher priority device than the printer, data transfer to the print buffer is interrupted. Device-end status is then sent to the channel (for the card reader) and the CCW for the next card read operation is processed. Note, however, that another *instruction* cannot be processed by the CPU until the data transfer to the printer is completed. The printer buffer transfer occurs at high speed and locks out CPU instruction processing.

Overlapping of buffered and unbuffered units can be achieved when operating in burst mode. This type of operation, however, either excludes or requires careful use of command chaining. For example, a magnetic tape drive (unbuffered) can be started and several CCW's chained during the time (approximately 98 milliseconds) between channel-end and device-end for an IBM 1403 Model 2 Printer. If this time is always available to the CPU (i.e., no other operation is blocking use of the channel between channel-end and device end, for the printer) then the printer and the tape drive could be chained. Also, a START I/O could be given for the tape drive at each channel-end from the printer. Better control could be retained, however, if the printer were not chained.

On a selector channel, a difference exists in that once a unit is started and is being command chained, the channel is busy to further instructions until the end of the chain. Hence, if a 1403 and a tape drive are attached to the same channel, the 1403 should not be chained if overlap is desired with the tape drive.

Use of Immediate Commands

All calculations in this manual, in regard to chaining, assume that no two chaining operations occur together (sequentially) for the same unit. For example the chain consisting of:

Read
NO OP
Read

is not included, since on device-end from the first read the channel chains to the NO OP. The unit is reselected, commanded, and then ended by device-end immediately. This device-end immediately causes a second chain to the last read command.

Such chaining causes an excessive load on lower priority units on the multiplexor channel and should be avoided. As a rule the NO OP CCW should be used only at the end of a chain.

Section IIA. Calculating Channel Load Limits (for an IBM System/360 Model 30 with a 1.5-Microsecond RW Cycle)

Load limits define a maximum channel load capacity. The load limit values are upper limits in that any configuration that has a load that is less than the corresponding load limit value will operate without data overrun (i.e., without loss of data). However, an exception to this statement exists for the case of a *bufered* unit's data load value that exceeds the calculated load limit. Here, the effect is to extend the time for transferring data to or from the buffer. The time extension is calculated by using the ratio of the load value of the buffered unit to the calculated load limit. (Refer to the *How to Calculate Buffer Transmission Times (Chaining Times Are Listed Here)* section). Hence, in this case, data overrun does not occur.

The implication of the loading limits given in the tables (or calculated by the appropriate formula) is that no unit should be run on a channel if operation of that unit causes the determined load limit to be exceeded. Loss of data may result (data overrun). In fact, it is advisable to plan I/O configurations and I/O-channel operations so that the peak load figure is not reached. This practice allows for some latitude in expansion of operations (i.e., those that might not be considered at initial installation).

Two approaches for describing selector and multiplexor channel load limitations are presented in this publication. One approach is applicable to the case in which the multiplexor channel is operating in burst mode. The other pertains to the case in which the multiplexor channel is operating in multiplex mode.

Figure 1 indicates limiting load factors by referring to appropriate formulas in text and applies to multiplexor channel burst mode operations only. It indicates how these burst mode operations are affected by multiplexor channel chaining and selector channel operations.

SELECTOR CHANNEL OPERATION	MULTIPLEXOR CHANNEL OPERATION 1.		
	No Chaining	Command Chaining	Data Chaining
Neither running	F-I	F-I	F-IV
One or both running but no chaining	F-I	F-I 2.	F-IV
One channel is data chaining and the other selector channel is not chaining*	F-Vb	F-Vb 3.	F-Va
One channel is command chaining and the other selector channel is not chaining	F-VIb	F-VIb 3.	F-VIa
Both channels are either data chaining or command chaining*	F-VIIb	F-VIIb 3.	F-VIIa

Notes:

1. For buffered units, use formula F-1 in all cases. The no chaining row must not be used for channels with attached magnetic tape or direct access devices because command chaining is required for these units.
2. For the 2311 and 2302, when writing without TIC, the maximum load on either or both selector channels (i.e., both channels taken together) is 23.4.
3. Magnetic tape and direct access storage devices will not operate properly if they are attached and run on the multiplexor channel when a selector channel is also operating.

* If a channel is both data chaining and command chaining, consider only the command chaining.

F "F" means formula. For example, F-VIb means "see formula F-VIb in the text."

When a load value is determined, then that load value can be converted to a data rate by dividing the load value by the factor 0.2222 (i.e., $\frac{\text{Load Value}}{0.2222}$).

The resulting data rate is in kilobytes per second.

• Figure 1. Multiplexor Channel Load Limit Calculations (Burst Mode Only) Used for Evaluation of a System with a 1.5-Microsecond RW Cycle Only.

On the multiplexor channel, buffer transmission time is lengthened by both chaining and data transfers that are performed on the selector channels. Further consideration of the buffered units is taken up in the *How to Calculate Buffer Transmission Times (Chaining Times Are Listed Here)* section.

Figure 2 indicates limiting load factors by referring to the appropriate formulas in text or by stating the limiting load factors outright. Figure 2 applies to the consideration of how the two selector channels interact with one another. Hence, information in Figure 2 is used to determine the load limit that cannot be exceeded on the selector channels if either chaining or no chaining is being performed. If the load limit is exceeded, data overrun may result.

The load values used for the different I/O units are indicated as data load values. (See Table 1 in *Appendix*). The peak data rate (in kilobytes per second) for a unit (or for a channel load limit, depending upon the value referenced) can be found by dividing the appropriate load value by the factor 0.2222.

Channel-to-channel adapter considerations are handled in a separate section.

Consideration of determining the loading of the multiplexor channel, by units operating in multiplex mode, is facilitated by use of Table 1 in *Appendix* and the channel loading worksheet (Form X24-3407).

Note that in certain instances, it is necessary to consider the effects of the load of a unit on a channel when chaining also occurs. Consider, for example, the case in which a selector channel is data chaining a unit. Because data chaining is involved, use the *data chaining* load value for the unit (see Table 1 in *Appendix*). It is this load value that is compared to the calculated channel limit load value for this particular case.

A somewhat different situation occurs when using a load value for a unit on the multiplexor channel. Here, if chaining of *any* type is done on either selector channel, or if the unit on the multiplexor channel is data chained, use the *data chaining* value for the unit on the multiplexor channel. This value is then used to compare to the load limit calculated for the channel.

In certain calculations, even though a unit is data chained, the unit's no-chaining lòad value is sometimes used. These situations are pointed out in text and made use of in the examples sections.

When the multiplexor channel is operated in burst mode only, the data load values used for units on the multiplexor channel are the data load values given in Table 1 in *Appendix*.

OTHER SELECTOR CHANNEL OPERATION	SELECTOR CHANNEL 3		SELECTOR CHANNEL 3	
	Not chaining or only command chaining	Data chaining 2.	Not chaining or only command chaining	Data chaining 2.
Not running	Rated speed	7.72 (no TIC) 5.9 (with TIC)	Rated speed	7.72 (no TIC) 5.9 (with TIC)
Running but not chaining	Rated speed 1.	No TIC: 7.72 - .234L* With TIC: 5.9 - .179L*	Rated speed 1.	No TIC: 7.72 - .234L* With TIC: 5.9 - .179L*
Data chaining	Rated speed 1.	4.0 (no TIC) 3.02 (with TIC)	Rated speed 1.	3.31 (no TIC) 2.55 (with TIC)
Command chaining	Rated speed 1.	F-II	Rated speed 1.	F-III

Notes:

1. If 2311 or 2302 is run concurrently with another device (on the other selector channel) that is chaining, the operation may have to be repeated due to overrun. The load on the other selector channel should not exceed 47.0.
2. Data chaining of a buffered unit effectively adds only the chaining time to the buffer transfer time. Therefore, use formula F-I for the buffered unit if that unit is also data chaining.
3. The 2314 may be operated only on selector channel one. Other direct access storage units should also be attached to selector channel one when the 2314 is attached.

L* means load on the other selector channel.
F means formula. For example, F-II means "see formula F-II in the text."

Convert load value to peak data rate by dividing by 0.2222 (i.e., $\frac{\text{Load Value}}{0.2222}$). The resulting data rate is in kilobytes per second.

• Figure 2. Selector Channel Maximum Load Values (with Chaining and with Interference of the Other Selector Channel). Used for Evaluation of a System with a 1.5-Microsecond RW Cycle Only.

How to Calculate Channel Load Limits When the Multiplexor Channel is Operating In Burst Mode Only

Use this section to evaluate selector channel operations whether or not the multiplexor channel is operating in burst mode. If the multiplexor channel is operating in burst mode, use this section for its evaluation. If the multiplexor channel is operating in multiplex mode, use the *Calculating the Multiplexor Channel Load when Operating in Multiplex Mode* section after the selector channel's evaluation has been made by use of this section.

The symbol L (or L_1 or L_2) is used in the following descriptions to designate the data load of an I/O unit. L values are found in the column headed data load in Table 1 of *Appendix.*

With No Chaining on Any Channel

Any units that can be attached to either selector channel will run one at a time or concurrently (one unit on each selector channel) at their rated speeds. Data chaining and in some cases command chaining, limits the speed at which data can be handled.

If the multiplexor channel is also to run concurrently (*in burst mode*) with the selector channels, then the maximum burst mode rate allowed on the multiplexor channel is determined by:

(F—I)

$$L_m = \frac{148.3 - L_1 - L_2}{2.5}$$

where

L_1 = data load on selector channel one (see *Appendix*)

L_2 = data load on selector channel two (see *Appendix*)

L_m = maximum burst rate load allowed for the multiplexor channel

Formula (F—I) assumes no chaining of any kind on either selector channel. There may be command chaining (*not* data chaining) for the multiplexor channel unit. However, the multiplexor channel unit cannot be time-dependent on the command chaining (as is the case for a disk storage unit.)

L_m cannot exceed 33.0 if both selector channels are running. If only one selector channel is running, L_m cannot exceed 42.4. If neither selector channel is running, the maximum burst rate load for the multiplexor channel is 59.4.

With Chaining on the Selector Channels

When chaining is done on either or both selector channels, the relative effect on each other's maximum data rate load is:

1. If a selector channel is running without data chaining (it may, however, be command chaining), its data rate is not affected by chaining or data handling on the other selector channel.
2. If a selector channel is data chaining, however, its rate of data handling is definitely affected by the operation being performed on the other selector channel:
   a. If only one selector channel is running, that channel is limited to a 7.72 data rate load if it is also data chaining.

   b. If the other selector channel is running but it is not data or command chaining, the maximum data rate load for the selector channel that is data chaining is:

   7.72 − .234L (if a TIC is not used)

   or

   5.9 − .179 L (if a TIC is used).

   where

   L = data load on the other selector channel (see *Appendix*)

   c. If both selector channels are data chaining, the maximum load for selector channel one is 4.0 (with no TIC) or 3.02 (with a TIC). The maximum load for selector channel two is 3.31 (with no TIC) or 2.55 (with a TIC).

   d. If a selector channel is data chaining and the other selector channel is command chaining:

   (1) If selector channel one is the channel that is data chaining, its maximum load is:

(F—II)

$$\frac{222.2}{40.0 + 19.2\left(\frac{1000}{1000 - 6.75L}\right)}$$

Where L is the data load on the other selector channel (see *Appendix*).

Note: If a TIC is used on selector channel one, replace the factor 19.2 by 28.2. If a TIC is used on selector channel two, replace the factor 40.0 by 49.0.

   (2) If selector channel two is the one that is data chaining, its maximum load is:

(F—III)

$$\frac{222.2}{44.3 + 19.2\left(\frac{1000}{1000 - 6.75L}\right)}$$

Again, L is the data load on the other selector channel (see *Appendix*).

Note: If a TIC is used on selector channel two, replace the 19.2 factor by 28.2 If a TIC is used on selector channel one, replace 44.3 by 53.3.

With Chaining on the Multiplexor Channel

1. Whether or not the selector channels are running, the maximum burst mode rate of a device on the multiplexor channel is not affected by command chaining on the multiplexor channel, if that device is not time dependent upon the command chaining. If data chaining is being done on the multiplexor channel and the selector channels are not running, the maximum multiplexor channel burst mode is:
   - 9.9 without a TIC.
   - 7.78 with a TIC.
2. If either or both selector channels are running concurrently (but not chaining) with the multiplexor channel, the maximum multiplexor channel burst mode load, if data chaining is also done on the multiplexor channel is:

(F—IV) $$L_m = 9.9\left[\frac{1000 - 6.75(L_1 + L_2)}{1000}\right]$$

   Note: If a TIC is used, replace the 9.9 factor by 7.78.

   where

   L_m = maximum burst rate load on the multiplexor channel.

   L_1 = data load on selector channel one (see *Appendix*).

   L_2 = data load on selector channel two (see *Appendix*).

3. If data chaining (but no command chaining) is done on one of the selector channels and the other selector channel is not running, then the maximum multiplexor channel burst mode load *with data chaining* is:
   - 4.23 (with no TIC on the multiplexor channel)
   - 3.8 (with a TIC on the multiplexor channel)

   If one selector channel is data chaining and the other selector channel is running without any chaining, then the maximum multiplexor channel burst mode load *with data chaining* is:

(F—Va) $$L_m = \frac{222.2 - 1.5L}{52.5 + T_1 + T_2}$$

   where

   L = data load on the selector channel that is not chaining (see *Appendix*).

   $T_1 = 6$ (if a TIC is used on the multiplexor channel).

   $T_1 = 0$ (if a TIC *is not* used on the multiplexor channel).

   $T_2 = 9$ (if a TIC is used on the selector channel that is chaining).

   $T_2 = 0$ (if a TIC *is not* used on the selector channel that is chaining).

   The maximum multiplexor burst mode load when either no chaining or command chaining only (no data chaining) is being performed on the multiplexor channel is:

(F—Vb) $$L_m = \frac{222.2 - 1.5L}{33.75 + T_2}$$

   where

   L = data load on the selector channel that is not chaining (see *Appendix*).

   $T_2 = 9$ (if a TIC is used on the selector channel that is chaining).

   $T_2 = 0$ (if a TIC *is not* used on the selector channel that is chaining).

4. If one selector channel is command chaining (whether or not it is also data chaining) and the other selector channel is not running, then the maximum multiplexor channel burst mode load *with data chaining* is:
   - 2.78 (*no* TIC in multiplexor operation)
   - 2.58 (with a TIC in multiplexor operation)

   If the other selector channel is running but not chaining, then the maximum multiplexor channel burst mode load *with data chaining* is:

(F—VIa) $$L_m = \frac{222.2 - 1.5L}{80.0 + T_1 + T_2}$$

   where

   L = data load on the selector channel that is not chaining (see *Appendix*).

   $T_1 = 6$ (if a TIC is used on the multiplexor channel).

   $T_1 = 0$ (if a TIC *is not* used on the multiplexor channel).

   $T_2 = 9$ (if a TIC is used on the selector channel that is chaining).

   $T_2 = 0$ (if a TIC *is not* used on the selector channel that is chaining).

   If the multiplexor channel is either command chaining (with devices that are not time dependent upon the command chaining) or not chaining (i.e., it is definitely not data chaining) then its maximum burst mode load is:

(F—VIb) $$L_m = \frac{222.2 - 1.5L}{61.5 + T_2}$$

   L and T_2 in formula (F—VIb) have the same meanings and values as shown for the appropriate conditions under formula (F—VIa).

5. When data chaining or command chaining (or both data chaining and command chaining) are being done concurrently on both selector channels, the

following formulas apply for the maximum multiplexor channel burst mode load with data chaining. If both command and data chaining are being done on a selector channel, ignore the data chaining and use only the formula for command chaining.

a. The selector channel chaining values to be used in formula (F–VIIa) are determined by:

- Command chaining value =

$$(56.25 + T_2)\left(\frac{1000}{1000 - 6.75L_1}\right)$$

- Data chaining value $= (28.5 + T_2)\left(\frac{1000}{1000 - 6.75L_1}\right)$

b. The multiplexor channel data chaining value to be used in formula (F–VIIa) is determined by:

- Data chaining value $= (22.5 + T_1)\left(\frac{1000}{1000 - 6.75L_2}\right)$

For the chaining value formulas in (a) and (b):

L_1 = data load on the other selector channel (i.e., not the channel for which the chaining value is being determined). Note here that L_1 refers to the *data load* value of the unit on the other selector channel and *not* to its chaining value (see *Appendix*).

L_2 = the calculated total load for both selector channels. Again, this value is obtained by adding the data load value of the unit on selector channel one to the data load value of the unit on selector channel two. L_2 does *not* include calculated selector channel chaining values (see *Appendix*).

T_1 or $T_2 = 0$ (if a TIC is not used).

Otherwise

$T_1 = 6$ (for a TIC on the multiplexor channel).

$T_2 = 9$ (for a TIC on a selector channel).

By using the chaining values calculated in (a) and (b), the multiplexor channel maximum burst mode load with data chaining is:

(F—VIIa)

$$L_m = \frac{222.2}{C_1 + C_2 + C_3}$$

where

C_1 = the chaining value for selector channel one.

C_2 = the chaining value for selector channel two.

C_3 = the data chaining value for the multiplexor channel.

If the multiplexor channel is not chaining or only command chaining (with devices that are not time dependent upon the command chaining), formula (F–VIIb) is used. F–VIIb is the same as F–VIIa except that the value of C_3 is:

$$C_3 = (3.75)\left(\frac{1000}{1000 - 6.75L_2}\right)$$

(L_2 is the same as already defined in 5b.)

The maximum burst load on the multiplexor channel is then:

(F—VIIb)

$$L_m = \frac{222.2}{C_1 + C_2 + C_3}$$

With the Channel-to-Channel Adapter Feature

The channel-to-channel adapter is unique in its loading aspect in that it adjusts its speed to the varying demands of the other channels and to the two processing units to which it is attached. In general, this adapter tends to impose a maximum load on a channel with which it is used. It adjusts its speed to the demands of the other channels according to their priority assignments and relative loads.

The formula (F–I) for multiplexor channel burst mode operation without chaining still applies:

(F—I)

$$L_m = \frac{148.3 - L_1 - L_2}{2.5}$$

where

L_1 = data load on selector channel one (see *Appendix*).

L_2 = data load on selector channel two (see *Appendix*).

L_m = maximum burst load allowed for the multiplexor channel.

However, the following maximum load limits are used:

1. L_m cannot exceed 12.9 when *reading* and 10.2 when *writing,* when the channel-to-channel adapter is running on either of the selector channels. Here, reading refers to movement of data from a channel unit to the CPU; writing refers to movement of data from the CPU to a unit.
2. If the channel-to-channel adapter is attached to selector channel one, the maximum load for selector channel two is 37.0 (assuming that the multiplexor channel is running), or 74.0 (assuming the multiplexor channel is not running).
3. If the channel-to-channel adapter is on selector channel two, the maximum load limit on selector channel one is 74.0 (whether or not the multiplexor channel is running).

4. If the multiplexor channel is not running and the channel-to-channel adapter is on one of the selector channels, then that channel's load limit is obtained from formula (F—I). However, there is a load limit on the other selector channel. Hence, if the channel-to-channel adapter is on selector channel one, then the load limit for selector channel two is:

   74.0

   If the channel-to-channel adapter is on selector channel two, then the load limit for selector channel one is:

   74.0

To obtain a load value for a selector channel to which the channel-to-channel adapter is connected, use formula (F—I). To do this, insert the data load values, for the units on the other two channels, in formula (F—I). Then solve for the remaining factor. Note, however, the limitations imposed on the other channels by the preceding steps (1) through (4). To convert the load value to kilobytes per second, divide the calculated load value by 0.2222.

The resulting value can be up to 667kb (kilobytes) per second if the channel-to-channel adapter is connected to a selector channel, and no other units are operative on the other two channels. However, the value generated by the formula is a maximum. The actual rate depends upon the speed of response from the second system's channel that is attached to the channel-to-channel adapter. The second system's channel is also limited by units running on other channels of the second system and by the storage cycle rate of the second system.

In general, the channel-to-channel adapter can run only as fast as the slower of the two channels to which it connects.

The channel-to-channel adapter can be attached to the multiplexor channel, on System/360 Model 30, only when no selector channel is installed on the system. The channel-to-channel adapter *must* be attached to both selector channels for a channel-to-channel *wrap* (i. e., for interconnection of two channels on the same system).

The channel-to-channel adapter operates with the multiplexor channel in burst mode only. The maximum rate on the multiplexor channel is 267kb per second. However, if the channel on the other system, to which the channel-to-channel adapter is attached, operates at a lower rate, the 267kb rate will not be attained.

Figure 3 shows the various load limits on the selector channels on which the channel-to-channel adapter is *not* attached. For each entry in this figure, the farthest column on the left shows the selector channel on which the channel-to-channel adapter is assumed to be operating. The next column shows the channel for which the load limits apply. The load limits themselves are entered in these columns headed by the condition on the third channel (the remaining one of the three channels).

For example, if selector channel one has the channel-to-channel adapter, go to the first entry of the first column. To the right of this entry are two rows. The first row is labeled selector channel two (in second column). Now look across the chart to the value 37.0. This value means that, if the channel-to-channel adapter is on selector channel one, the load limit for selector channel two is 37.0 if the multiplexor channel is also running.

Step-by-Step Procedure for Determining Possible Overrun when the Multiplexor Channel Is Operating in Burst Mode Only

1. First determine the configuration involved and obtain the applicable data load and data chaining load values for the units involved (see Table 1 in *Appendix).*

2. If a channel-to-channel adapter is attached to a selector channel do the following (if a buffered unit is used, treat it according to step 4.):

   a. Determine the load on the channel to which the channel-to-channel adapter is connected. Use

CHANNEL-TO-CHANNEL ADAPTER ON:		MULTIPLEXOR CHANNEL		SELECTOR CHANNEL ONE		SELECTOR CHANNEL TWO	
		Running	Not Running	Running	Not Running	Running	Not Running
Selector Channel One	Selector Channel Two	37.0	74.0				
	Multiplexor Channel					12.9 (read 10.2 (write)	12.9 (read 10.2 (write)
Selector Channel Two	Selector Channel One	74.0	74.0				
	Multiplexor Channel			12.9 (read) 10.2 (write)	12.9 (read) 10.2 (write)		

The load on the selector channel that is using the channel-to-channel adapter is given by the formula:

$L_1+L_2+2.5L_m=148.3$ (where L_1=load on selector channel one,
L_2=load on selector channel two,
L_m=load on the multiplexor channel)

with the loads on the other channels not exceeding the limits given in this figure.

Conversion of load value to peak data rate is obtained by dividing load value by 0.2222 (i.e., $\frac{\text{Load}}{0.2222}$).
The resulting data rate is in kilobytes per second.

•Figure 3. Load Limits of Other Channels When Channel-to-Channel Adapter Is Used on a Selector Channel. Used for Evaluation of a System with a 1.5-Microsecond RW Cycle Only.

formula (F—I). (Refer to the *With Channel-to-Channel Adapter Feature* section.)

b. Determine if the units on the other channels are overloading their respective channels (see Figure 3). For this step use the no chaining data loads of the units involved (see *Appendix*). Do *not* use their data chaining loads whether or not data chaining is involved.

c. Next consider the data chaining. If the data chained unit is on the multiplexor channel, use Figure 1 to calculate the allowed load. If the data chained unit is on a selector channel, use Figure 2 to calculate the allowed load. For these calculations, use the channel-to-channel adapter load, calculated in step (a), for the selector channel to which the channel-to-channel adapter is attached.

Use the data chaining load of the unit (see *Appendix*) to compare to the calculated load limit of the channel on which the data chaining is performed. If the data chaining load (see *Appendix*) of the unit exceeds the calculated limit for the channel, then the data chaining will overload the channel.

3. If a channel-to-channel adapter is not used, do the following (If a buffered unit is used, treat it according to step 4.):

   a. Refer to Figure 2 for each selector channel in turn. If a unit on a selector channel is data chained, use the data chaining column in Figure 2. Then find the entry, in Figure 2, that corresponds to the appropriate condition on the other selector channel (i.e., the condition indicated in the leftmost column of Figure 2). The entry referenced indicates the calculation to be made, the formula to be used, or directly, what the load limit is. If the data chaining load of the unit (see *Appendix*) is greater than this limit, the channel to which it is attached is overloaded (i.e., data overrun can occur if the unit is data chained).

   b. If a selector channel unit is not data chained, use the *No Chaining or Only Command Chaining* column in Figure 2. Units that are permissibly attached run at their rated speeds for this situation.

c. Next consider the unit on the multiplexor channel (refer to Figure 1). Use the appropriate column according to whether the unit is data chained or command chained or not chained. If the unit is both command chained and data chained, use the data chaining column. Then find the entry that corresponds to the statement in the leftmost column, which refers to the operations on the selector channels. Use the formula obtained from Figure 1. This formula is used to calculate a limit for the unit being investigated. Compare the value calculated to the unit's data load value (see *Appendix*). If the data load value of the unit (see *Appendix*) exceeds the calculated value, overrun can occur.

4. If one or more units are buffered, the procedure is essentially the same as for (2) and (3). However, the following notes apply:

   a. Buffered units adjust their speeds of data transmission (to or from the buffer) according to the concurrent demands of units operating on the other channels. The main problem, then, is not one of overloading, but of determining the time taken to transfer the data to or from the buffer.

   b. On the selector channels, the buffer data transfer times are extended only by the actual time of a data chaining operation for that buffered unit (if the buffer is indeed data chained).

   c. The load limit allowed to the multiplexor channel may be less than the listed data load value (see *Appendix*) for a buffered unit. In this case, the time of data transfer for the buffer is extended. The extension is calculated by multiplying the calculated minimum transfer time for the buffered unit by a ratio. The ratio is formed by dividing the data load value (see *Appendix*) for the buffered unit by the calculated load limit of the multiplexor channel. Also, the actual data chaining time, if any, performed with the buffered unit, and the actual command chaining and data chaining times executed on the selector channels must be added. However, this chaining must be performed during the short time required for the data transfer for the buffer. This can only be determined by inspection of the probable concurrence of these operations.

Examples of the Procedure

Example 1

The first step is to determine the configuration and operations involved. In this example:

1. A 2400 series tape drive model 2 (9 track) is reading (data movement from tape to main storage) on selector channel two. The tape drive (density 800) is not chained in any way.

2. A 2311 (attached to a 2841) is writing (data movement from main storage to 2311) on selector channel one. Command chaining is also being performed for this unit.

3. An IBM 1403 Model 3 printer (attached to a 2821) is operating on the multiplexor channel. The 1403 is not chained in any way.

The data load factors for this configuration are obtained from Table 1 in *Appendix*. Using the appropriate data load factors, construct a table for ease of reference:

Channel	*Unit*	*Chaining*	*Operation*	*Data Load*
Selector 2	2400-2	None	Reading	18.8
Selector 1	2311	Command	Writing	36.1
Multiplexor	1403-3	None	Writing	27.8

Before considering the multiplexor channel, determine the effects that the selector channels have on each other. Hence, refer to Figure 2 and look first at the label *Selector Channel Two*. Under this label, find two columns. Because selector channel two is not chaining, use the *Not Chaining or only Command Chaining* column. We are, however, considering command chaining on selector channel one. Hence, use the last row in the *Not Chaining or only Command Chaining* column because that row corresponds to *Command Chaining* on the other selector channel (in this case, selector channel one). The referenced entry is then *Rated Speed*[1]. This entry means that the magnetic tape unit (2400 series) can be run at its rated speed without overrun (i.e., loss of data). *Note 1* does not apply because we are *not* considering a 2311 or 2302 on selector channel *two*.

Now consider the 2311 on selector channel one. Looking at the *Selector Channel One* label (Figure 2), use the *Not Chaining or only Command Chaining* column because the 2311 is command chaining. Also use the *Running But Not Chaining* row because the tape drive on selector channel two is running but it is not chained. The entry then referenced is *Rated Speed*[1]. *Note 1* states that a 2311 run concurrently with a device on the other selector channel, may overrun if that other device is chaining or if it has a data load value greater than 47.0.

The tape drive is not chaining and its data load value is 18.8, which is less than 47.0. Therefore, *Note 1* does not restrict the operation. Hence the 2311 can be run at its rated speed without overrun.

Now turn to the 1403-3 on the multiplexor channel. The 1430-3 is operating in burst mode. Refer to Figure 1. *Note 1* in this figure states that for all buffered units use formula F—I. Formula F—I is:

$$L_m = \frac{148.3 - L_1 - L_2}{2.5}$$

L_2 is the data load of the unit on selector channel two. This value, for the tape drive, is 18.8. L_1 is the data load for the unit on selector channel one. This value, for the 2311, is 36.1. Inserting these values in formula F—I, we obtain:

$$L_m = \frac{148.3 - 36.1 - 18.8}{2.5} = 37.56$$

This value (37.56) is the maximum calculated load limit at which the multiplexor channel unit can run. However, in the *How to Calculate Channel Load Limits When the Multiplexor Channel is Operating in Burst Mode Only* section, under Formula F—I, we find a restriction. This restriction is that L_m cannot exceed 33.0 if both selector channels are running. This is the case in our example. However, the data load value for the 1403 model 3 printer (on the multiplexor channel) was found to be 27.8. Because 27.8 is less than 33.0, data will be transferred at maximum buffer speed for the 1403 model 3 (except for the momentary delay for the possible concurrent chaining on the selector channel).

We conclude that overloading cannot occur for the configuration in this example and that the printer buffer will be filled in time to permit maximum print speed.

The time for the 1403 model 3 buffer transmission can be found by using the appropriate formula in the *How to Calculate Buffer Transmission Times (Chaining Times Are Listed Here)* section. The formula is

$$T = Rr$$

For the 1403 printer, $r = 8.0$ microseconds. For this example, assume that a full line is to be printed on the 1403. For the 1403 a full line of print is 132 characters. Hence, $R = 132$. Therefore:

$T = 132 \times 8.0 = 1056$ microseconds $= 1.056$ milliseconds.

Note that T is the *buffer transfer time* and it is *not* the time required to print the line on the 1403 printer.

For greater accuracy, the chaining times on the selector channel should be added.

Example 2

The configuration and operations for this example are:

1. A 2400 series tape drive model 1 (9 track) is reading on selector channel one. The tape drive is data chained and its density is 800.
2. A 2400 series tape drive model 1 (9-track) is writing on selector channel two. This tape drive is not chained in any way and its density is 800.
3. A 2540 and 1403 model 3 are attached to a 2821 on the multiplexor channel. The 2540 card reader is reading 80-column card records. The 2540 card punch is punching 80-column card records. The 1403-3 is printing 132 characters per line of print. Neither the 2540 nor the 1403 is chained in any way.

Again, we obtain the appropriate load values from Table 1 in *Appendix* and summarize in table form:

Channel	*Unit*	*Chaining*	*Operation*	*Data Load*
Selector 1	2400-1	Data (No TIC)	Reading	4.9*
Selector 1	2400-1	None	Reading	9.4**
Selector 2	2400-1	None	Writing	6.7
Multiplexor	2540-Punch	None	Writing	18.5
Multiplexor	2540-Reader	None	Reading	18.5
Multiplexor	1403-3	None	Writing	27.8

Notes:

*The 4.9 value (data chaining load) is used to compare to the calculated selector channel one load limit.

**The 9.4 (no chaining data load) is used in formula F—I.

Refer to Figure 2 to determine the effects that the selector channels have on each other. Selector channel one is data chaining and selector channel two is running but not chaining. Also, a TIC is not being performed on selector channel one. The entry for selector channel one is then:

$$7.72 - .234L \text{ (No TIC)}$$

Here L is the load on the other selector channel, or 6.7. Therefore, the limit for selector channel one is:

$$7.72 - (.234)(6.7) = 6.15$$

The data chaining load value (4.9) for the tape drive on selector channel one is less than the 6.15 value. Therefore, selector channel one can operate without overrun.

Selector channel two is not chaining. Therefore, the rated speed of the tape drive on selector channel two can be assumed for the load value of selector channel two. Hence the tape drive on selector channel two can be run at its maximum rate (data load value of 6.7).

Having determined that the units on the selector channels can be run satisfactorily, we consider the multiplexor channel. The first thing to notice is that only one device at a time can be operated on the multiplexor channel because we are considering burst mode operation only. Referring to Figure 1, we notice that for buffered units we must use formula (F—I) for all cases. Formula (F—I) is:

$$L_m = \frac{148.3 - L_1 - L_2}{2.5}$$

The L_1 and L_2 values used in formula (F—I) are the data loads of units on the selector channels. The data load value for the tape drive on selector channel one is then 9.4. (The load value used here is not the data chaining value of 4.9.) The data load for the tape drive on selector channel two is 6.7. Solving for L_m:

$$L_m = \frac{148.3 - 9.4 - 6.7}{2.5} = 52.9$$

In the *How to Calculate Channel Load Limits When the Multiplexor Channel Is Operating in Burst Mode Only* section a restriction is placed on L_m. This restriction states that if both selector channels are running, then L_m cannot exceed 33.0. However, this value (33.0) is greater than the load imposed by any one of the buffered units (2540 or 1403). Recall that only one of the buffered units can be run at any given time (burst mode operation).

The formula for calculating the buffer transfer time is found in the *How to Calculate Buffer Transmission Times (Chaining Times are Listed Here)* section of this publication. This formula is:

$$T = Rr$$

The buffer transfer times are then:

1. For the 2540 reader:
   r = 12 microseconds
   R = 80 bytes (80 card columns)

   T = (12)(80) = 960 microseconds, or 0.96 milliseconds.
2. For the 2540 punch:
   r = 12 microseconds
   R = 80 bytes (80 card columns)

   T = (12)(80) = 960 microseconds or 0.96 milliseconds.
3. For the 1403 model 3 printer:
   r = 8 microseconds
   R = 132 bytes (132 print positions)

   T = (8)(132) = 1056 microseconds or 1.056 milliseconds.

Example 3

The configuration and operations for this example are:

1. A 2400 series tape drive model 3 (9 track) is reading on selector channel one. The tape drive is not chained in any way and its density is 800.
2. A channel-to-channel adapter is connected to selector channel two. No chaining is involved here.
3. A 2400 series tape drive model 1 (9 track) is reading on the multiplexor channel. The tape drive is data chained and its density is 800.

To summarize (see *Appendix*):

Channel	*Unit*	*Chaining*	*Operation*	*Data Load*
Selector 1	2400-3	None	Reading	28.5
Selector 2	Chan.-to-Chan. Adp.	None	Reading or Writing	To be Determined
Multiplexor	2400-1	Data	Reading	9.4*
Multiplexor	2400-1	Data	Reading	4.9**

Notes:

*The 9.4 value (no chaining data load) is used when data chaining is not considered.

**The 4.9 value (data chaining load) is used for the data chaining.

First, calculate the load at which selector channel two will operate. The figure calculated here is a limit for the channel-to-channel adapter. Whether or not selector channel two will operate at this speed depends both on this calculated limit and the speed at which the other channel (to which the channel-to-channel adapter is connected) will run. The actual load is the smaller of the two (i.e., the limit calculated or the limit available on the other channel to which the channel-to-channel adapter is connected). For this example, assume that the channel-to-channel adapter will operate at the limit calculated for selector channel two.

The limit for selector channel two is calculated by using formula (F—I):

$$L_m = \frac{148.3 - L_1 - L_2}{2.5}$$

Here, we are solving for L_2. From our configuration, $L_m = 9.4$ and $L_1 = 28.5$. Substituting in formula (F—I):

$$9.4 = \frac{148.3 - 28.5 - L_2}{2.5}$$

Therefore, $L_2 = 96.3$, which is the load limit of selector channel two. Therefore, this is the load impressed upon selector channel two by the channel-to-channel adapter. (This was our assumption.) To convert this load value to kilobytes per second, divide by 0.2222. That is:

$$\frac{96.3}{.2222} = 433 \text{ kb/second}$$

To determine if the other two channels are overloaded refer to Figure 3. Look at the leftmost column in the figure. We choose the *Selector Channel Two* row of that column because the channel-to-channel adapter is attached to selector channel two. Now find the *Selector Channel One* column in the *Selector Channel Two* row. Now move across the same row to the *Multiplexor Channel* column. We use the *Running* section of this column because the multiplexor channel is running. The entry selected is then 60.8. However, the load on selector channel one for the configuration in this example is 28.5. Because 28.5 is less than 60.8 (from Figure 3), then selector channel one is not overloaded.

Next look at the *Multiplexor Channel* entry (second column from left) in the *Selector Channel Two* row in Figure 3. Look across to the *Running* part of the *Selector Channel One* column. The entry found is 12.9 for reading, which is being done on the multiplexor channel. However, the tape unit on the multiplexor channel has a data load of 9.4, which is less than the 12.9 value. Therefore, the multiplexor channel is not overloaded.

The next question is, "Can the tape unit on the multiplexor channel be data chained, as we have set up in our configuration?" Referring to Figure 1 we use the *Data Chaining* column and the *One or Both Running But No Chaining* row. The entry found is F—IV. Formula (F—IV) is:

$$L_m = 9.9\left[\frac{1000 - 6.75(L_1 + L_2)}{1000}\right] \quad \text{(No TIC)}$$

In our example, $L_1 = 28.5$, and calculation has shown that $L_2 = 96.3$.

Substituting in F—IV:

$$L_m = 9.9\left[\frac{1000 - 6.75(28.5 + 96.3)}{1000}\right]$$

Therefore, $L_m = 1.56$, which is the load limit for data chaining on the multiplexor channel in this example. This limit is less than the data chaining load value (4.9) for the tape drive on the multiplexor channel. Therefore, the tape drive cannot be data chained, but, as previously determined, it can be run without data chaining.

Note that the tape drive on the multiplexor channel could be command chained (in this example) because the tape drive is not time-dependent upon command chaining.

Calculating the Multiplexor Channel Load When Operating in Multipex Mode

Features and Assumptions that Affect the Method of Calculation

Concurrent operation of I/O devices on a multiplexor channel involves many variables:

1. Devices vary in their data transfer rates.
2. Devices have buffers varying in capacity from 1 byte to 132 bytes.
3. Devices vary in the number and type of CCW's needed for their operation.
4. Combinations of devices on the selector channels vary in the interference they cause, and
5. The large number of I/O devices available for use on a multiplexor channel may be combined in many different configurations.

The problem of determining whether a particular multiplexor channel configuration will run simultaneously in a satisfactory manner has been reduced to an arithmetic procedure using a worksheet form and the factors provided in the tables in this manual.

The evaluation procedures specified in the *Step-by-Step Procedure for Evaluating the Multiplexor Channel Load in Multiplex Mode* section of this manual minimize the need for judgments, on the part of the user, by providing a clear-cut decision path specified in a step-by-step procedure.

To understand the factors and the significance of their use in the evaluation procedure, consider these facts:

1. Multiplex mode devices vary in the length of time they can wait for channel facilities after requesting service.
2. This length of time is related to their priority on the multiplexor channel.
3. This length of time is related to the impact a high priority device has on a lower priority device.
4. This impact will be expressed as a mathematical function of the waiting time.

Multiplex Mode Device Waiting Time

After a multiplex-mode device requests channel service, it has a fixed length of time that it can wait for service. If the channel provides service within this length of time, the device operates satisfactorily. If, however, the channel does not service the device within the device's waiting time, the device must continue waiting (device not susceptible to overrun) or lose data and subsequently cause an I/O interruption condition (device susceptible to overrun).

Device waiting times must be considered in evaluating an I/O configuration for simultaneous operation. Some devices must transfer data within their waiting time or an overrun occurs. Other devices can wait past their waiting time for the channel to transfer data without occasioning overrun. For example, when an IBM 1403 Printer on an overloaded multiplexor channel fails to receive data within its waiting time, it merely waits until service is provided by the multiplexor channel. The delay does not cause an interruption condition; nor is a new START I/O instruction required to select the 1403. The only effect is a lessening of performance. If an IBM 1442 Card Read-Punch read operation does not receive data service within its waiting time, however, overrun occurs. Multiplex-mode device waiting time factors are specified in the tables in this manual. For further details, refer to the *Priority Attachement of I/O Units (Multiplexor Channel)* section.

Priority Loads

The multiplexor channel sustains concurrent operations in the multiplex mode by servicing one device at a time. The operating devices compete for service, and the multiplexor channel services them in the order of their priority.

Devices on the selector channels or higher priority devices on the multiplexor channel may force a lower priority multiplex-mode device to wait for channel service. The former is called a *priority device* and the latter is called a *waiting device.*

When a higher priority device forces a lower priority device to wait for channel service, the load placed on I/O facilities by the priority device is called an interference load. The device generating an interference load may be on a selector channel or on the multiplexor channel.

When more than one priority device forces a multiplex mode device to wait, each of the priority devices generates an interference load. All interference loads must be considered in determining whether or not the waiting device will receive channel service before its waiting time is exceeded.

The evaluation procedure for concurrent operation of multiplex mode devices assumes that a waiting device has made its request for channel service at the worst possible time, when the priority devices cause maximum loads on channel facilities during the waiting device's waiting time.

The channel ordinarily works its way through the interference loads, and the waiting device is unaffected by the wait. If, however, heavy interference loads force the waiting device to wait past its particular waiting time, it will be subject to overrun, or it will continue waiting for service. A priority device, then, is a device that interferes with a waiting device's attempt to obtain channel service.

To evaluate the effect an interference load will have on a particular waiting device, it is necessary to consider the length of time the waiting device can wait for channel service.

The effective interference caused by a priority device is called a priority load. It has three factors:

1. The control load caused by execution of CCW's, including chaining and Transfer in Channel operations,
2. The priority device's data transfer load, and
3. The waiting time of the device being evaluated.

Thus, a priority load depends on a priority device's channel program, on the priority device's data transfer rate, and on the waiting time of the waiting device.

Note that because a priority load is a function of waiting 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 waiting time.

This relationship between a priority device's load on channel facilities and various waiting times is shown in Figure 4. The abscissa relates to device waiting times. The short waiting time shown results in a heavy priority load; the longer waiting time falls in a part of the curve showing much less priority load. The overall impact of a priority device on a waiting device is more intense for a waiting device with a short waiting time than it is to a device with a long waiting time. The latter device can wait for the lessening in the priority load on channel facilities and still obtain service within its waiting time.

Two factors, A and B, are tabulated in Table 1 (*Appendix*) to represent average load curve values for priority devices. They are used in a function which defines hyperbolic curves of average load vs time based on device/channel time relationships and channel programming considerations.

To define an average load curve which appropriately relates a priority device's impact over a wide range of

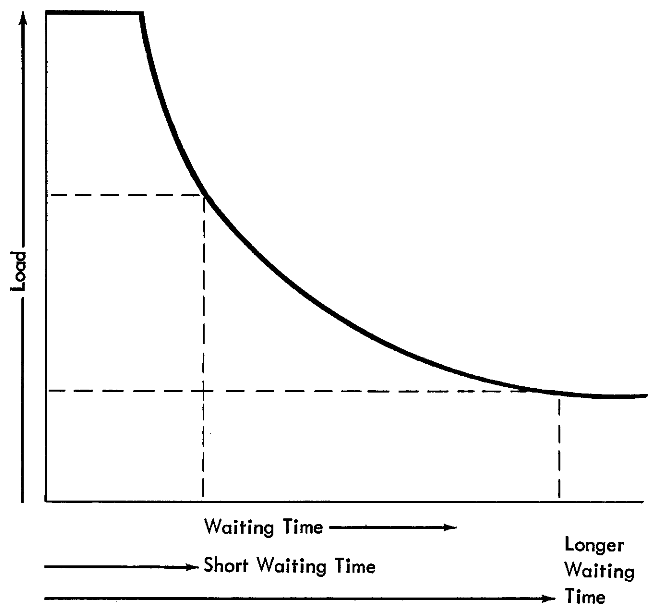

Figure 4. Priority Load Curve

waiting times, it is necesary to provide more than one set of A and B factors for many devices. In this case, each set of A and B factors represents a part of the average load curve. The associated time factor defines the beginning of the ranges of waiting times which apply to a part of the curve.

The time factor(s) define ranges of waiting times like this:

Time	*Ranges of Waiting Times*
.200	.200 to 3.11
3.11	3.11 to 100.
100.	100 up

If a waiting device has a waiting time factor of 6.5, this is in the above range 3.11 to 100. Therefore, the values of A and B associated with the 3.11 time factor are used.

The time factor is used in the evaluation procedure only to identify the associated set of A and B values for subsequent use.

The A and B and waiting time factors, for the various multiplex mode devices, have been computed for use in a formula that yields the priority load occurring for a particular priority device when associated with a particular waiting device.

The sum of the B factor and the quotient obtained by dividing the A factor by the W (waiting time) factor is the priority load. The arithmetic looks like this:

$$A/W + B = \text{Priority Load}$$

The tables in this publication provide the A, B, and waiting time factors for use in the formula.

Previous Loads

A waiting multiplex 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 is called a *previous load* and it must be added to the priority load caused by priority devices. The device with lowest priority on the channel has no previous load; a zero value is used in the addition. Previous load factors are also provided in the tables.

Channel Programming Assumptions

Selector and multiplexor channel programming considerations are implicit in the priority load function. That is, the priority load function is dependent on how an I/O device is programmed. The factors used in the priority load function formula provide for:

1. A maximum of useful channel programming.
2. Command chaining of card readers, printers, etc., on a multiplexor channel, but not on a selector channel.
3. Data chaining of communication lines, and as specified in Table 1 (*Appendix*), for magnetic tape units and Direct Access Storage Devices (DASD).
4. Immediate commands, only when essential to correct operation, such as set mode for seven-track tape.
5. NO OP commands, only as necessary to provide the NO OP/TIC switch function for program controlled scheduling, with a TIC setting assumed.
6. TIC commands, only if they afford advantage to noncontiguous channel programs. For example, the supervisor program may use the TIC to DASD program to add, say, a set file mask order to any channel program for a direct access storage device.

The operation of a system programmed in violations of these rules is:

1. Unsatisfactory, to the extent the rules were disregarded, and
2. Satisfactory, to the extent a device involved did not require the maximum amount of channel service available to it, as determined in the final step of the evaluation procedure for the device. But operation is satisfactory only insofar as the following lower priority devices also did not require the maximum channel service available to them, and could absorb the impact of the additional interference caused by the device violating the rules.

The rules are appropriate for practical channel programming and the results of the evaluation procedures in this manual depend upon their observance.

In general, extra data chaining and transfer in channel (TIC) operations, that occur in worst case moments, are most likely to cause a device, or a lower priority device, to overrun or lose performance.

Step-by-Step Procedure for Evaluating the Multiplexor Channel Load in Multiplex Mode

Use the *How to Calculate Channel Load Limits When the Multiplexor Channel Is Operating in Burst Móde Only* section to evaluate the selector channels before attempting to determine multiplexor channel multiplex mode loading. Before attempting evaluations of multiplexor channel configurations having IBM 2702 Transmission Control Unit equipment, first read the section of this manual devoted to this device.

Specific spaces on the worksheet are used for making the entries mentioned below, as indicated in Figure 5. The numbers in Figure 5 relate to the following numbered steps.

The following procedure assumes prior definition and evaluation for the appropriate system (i.e., one with a 1.5-microsecond or a 2-microsecond RW cycle), of the selector channel configuration (see the appropriate *How to Calculate Load Limits When the Multiplexor Channel Is Operating in Burst Mode Only* section for selector channel evaluation):

1. Enter system identification and data (Figure 5).
2. Enter identification of the device in each selector channel group of devices that has the heaviest device load. These are the selector channel priority devices that may impact waiting devices. Where one or more devices in a selector channel group have similar device loads, but different priority load functions, it may be necessary to repeat the multiplexor channel evaluation procedure with these other devices entered as priority devices.
3. Enter the Time, A, B sets from Table 1 (*Appendix*) for the devices entered in Step 2.
4. Arrange the multiplex mode devices proposed for simultaneous operation into the three priority categories: 1, 2, and 3 specified in Table 1.

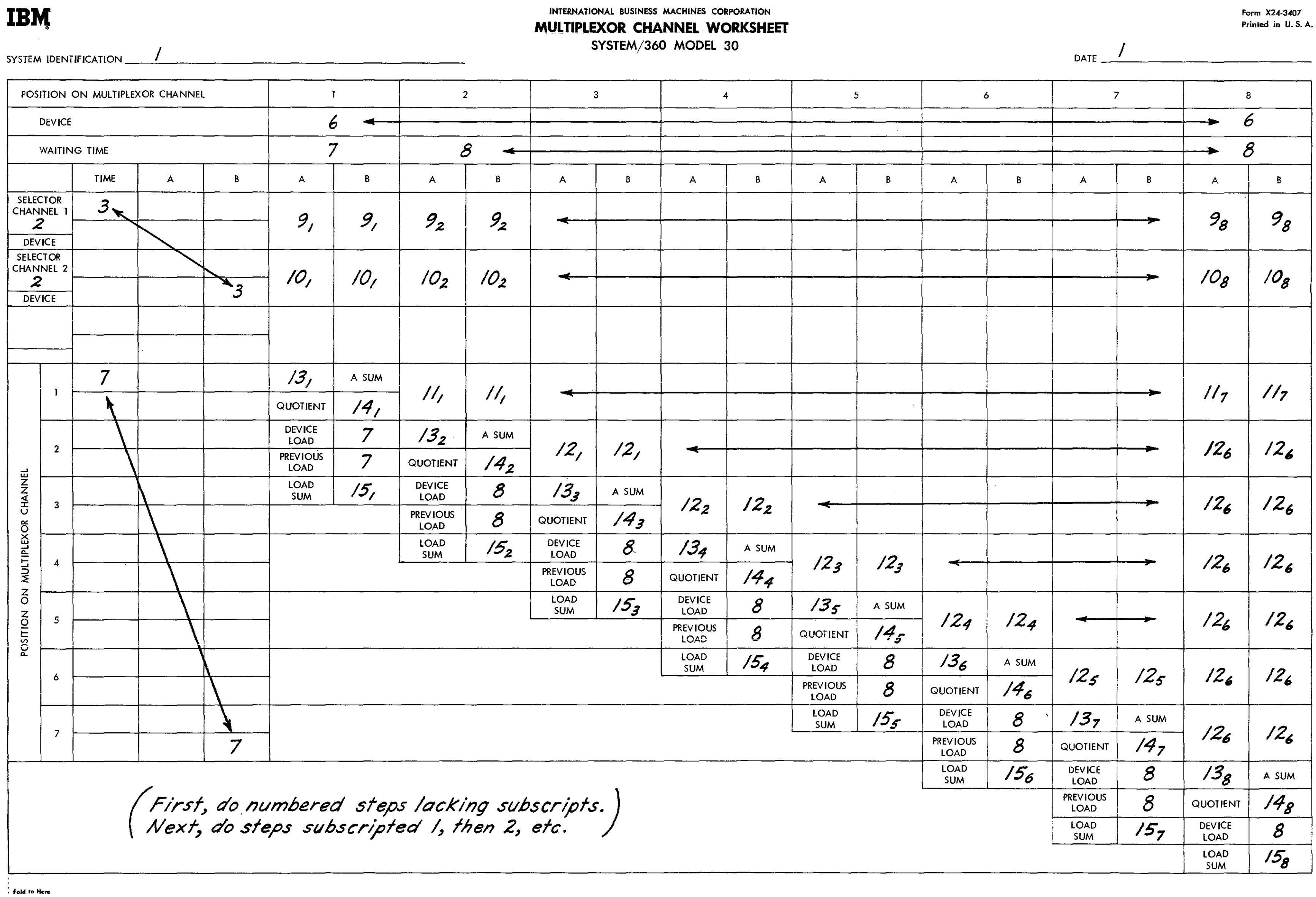

Figure 5. Entry Sequence for Procedure Steps

5. Assign priority to devices within each category in the order of their increasing waiting time factors, which also appear in Table 1.
6. Enter the devices in the priority sequence established in Steps 4 and 5.
7. Enter the Waiting Time, Time, A, B, Previous Load, and Device Load factors from Table 1 for the first device entered in Step 6.
8. Repeat Step 7 for each remaining device entered in Step 6, but for the lowest priority device, the previous load is zero.
9. Compare the Waiting Time of the waiting device being evaluated to the Time factor(s) of the first selector channel priority device; the largest Time factor that is less than the Waiting Time identifies the priority device's A and B factors to be entered. Where a priority device has only one set of A and B factors, it is, of course, entered.
10. Repeat Step 9 for the other selector channel priority device entered in Step 2.
11. (This step is performed when evaluating devices with second or lower priority.) Repeat Step 9 for multiplexor channel priority devices instead of selector channel priority devices.
12. If Step 11 has been performed, repeat it for each of any remaining multiplex mode priority devices. (This Step 12 is effective when evaluating waiting devices with third or lower priority.)
13. Add the selected A factors and enter the sum.
14. Divide the sum of the A factors by the Waiting Time of the waiting device and enter the quotient.
15. Add the B values entered in Step 9, the quotient entered in Step 14, and the Device Load and Previous Load entered in Step 7, and enter the load sum.
16. The load sum must be less than or equal to 100 for satisfactory operation of the waiting device (equal to or less than 75 for a CPU with a 2-microsecond RW cycle). If an IBM 2702 Transmission Control Unit has a load sum greater than 100 (or greater than 75 for a CPU with a 2-microsecond RW cycle), further evaluation is required. Consult the *Procedure for a More Critical Analysis of the 2702* section of this manual.
17. Evaluate the waiting device with second priority by performing for it Steps 9 through 16 (Step 12 is not performed).
18. Perform Steps 9 through 16 for all remaining waiting devices.

Synchronization Tendency of Buffer Servicing and Its Effect in Minimizing Channel Load

When evaluation of a multiplex mode configuration shows loss of performance for several buffered devices, additional analysis may show that some of them can be expected to have infrequent, trifling reduction in performance, and that others will have loss in performance somewhat more often. This is because of the tendency of multiple buffered devices to synchronize, to a greater or lesser extent, their use of channel facilities. The analysis enables an estimate to be made of how often a buffered device can be expected to have loss in performance.

By estimating the delays involved in servicing the devices' buffers and relating the delays to the devices' requests for channel service, it may be discovered that some of the buffered priority devices do not interfere with buffered waiting devices to the extent premised in the evaluation procedure. The procedure assumes a random relationship between the operations of the various I/O devices that may not apply to buffered devices.

For example, if both of two card readers in operation request channel service at the same time, the higher priority device will, of course, force the other device to wait. And having once waited, the second card reader will next request channel service after the first device has already made its next request for channel service. The two new requests will not coincide unless the first card reader has been similarly delayed by some other device.

This synchronization effect tends to organize buffered devices' requests for channel service into a sequence that enables the channel to service them on a rotating basis, and a loss of performance premised on random channel service requests may be significantly reduced.

The analysis of the synchronization effect is done by laying out the operating cycles of the buffered devices, one below another, on a millisecond scale. The devices that operate satisfactorily are drawn with a zero starting point. A new starting point is established on the millisecond scale for each device found to incur delay. The resulting synchronization pattern may be studied to see which buffered device priority loads may be ignored in computing new Load Sums.

Operation cycle times are specified in Systems Reference Library manuals for the devices. An existing printed form is convenient for use in laying out operating cycles. This is the IBM *650 Sequence Timing Chart*, Form X24-6337.

Multiplexor channel capabilities for maintaining performance of multiple buffered I/O devices may be calculated through simulation with greater accuracy when the number of characters in a line of print, forms layout, programming requirements, etc., are known for a particular application. On the other hand, an application known to be CPU-limited will cause reduced input/output performance, even though the channels are capable of operating the I/O devices simultaneously at their rated speeds.

An Example of a Multiplexor Channel Loading Calculation (Multiplex Mode)

This example is for a System/360 Model 30 with a 1.5-millisecond RW cycle. Assume the following configuration for an IBM System/360 Model 30:

1. Selector Channel 1 has four tape drives attached:
   a. Two 2401-1's (density 800)
   b. One 2402-3 (density 800)
   c. One 2403-3 (density 800)

No chaining of any type is used for these tape drives.

2. Selector Channel 2 has three 2311's attached to a 2841. The 2311's are command-chained.
3. Attached to the multiplexor channel are:
   a. A 2501-B2.
   b. A 2702, 6 lines used by 1031's, 9 lines used by 1051's.
   c. A second 2702, 31 lines used by 1051's.
   d. A 2520-B2.
   e. A 2821 with one attached 1403-3.
   f. A 2821 with three attached 1403-3's.
   g. A 1052 Printer Keyboard.

The first step in evaluating the system load is to consider the two selector channels separately from the multiplexor channel. Use the procedure described in the *How to Calculate Channel Load Limits When the Multiplexor Channel Is Operating in Burst Mode Only* section. Figure 2, in that section, indicates that the magnetic tapes on selector channel one will operate, without overrun, at their rated speed. A footnote in Figure 2 indicates that if a 2311 is run on selector channel two, the data load values of the devices on selector channel one cannot be greater than 47.0 (for a CPU with a 1.5-microsecond RW cycle).

The data load factors for the tape drives are obtained from Table 1 in *Appendix*.

2401-1	9.4 (Reading) 6.7 (Writing)
2402-3 or 2403-3	28.5 (Reading) 20.0 (Writing)

None of these values exceed 47.0. Therefore, any of the tape drives on selector channel one will run concurrently with a 2311 on selector channel two without overrun. Note also that none of the tape drives are chained in any way, and hence, in this respect, the footnote (in Figure 2) applying to the 2311 is satisfied. We conclude that this configuration, on the selector channels, is satisfactory.

Next we consider the multiplexor channel and use the procedure outlined in the *Step-by-Step Procedure for Evaluating the Multiplexor Channel Load in Multiplex Mode* section. Appropriate calculations are made and a multiplexor channel worksheet is filled out. Use Figure 6 to see how the step-by-step evaluation procedure applies to this example.

The worksheet (Figure 6) shows that, for every case, the load sum is less than 100 except for the second 1403-3. This means that each unit will run concurrently with the other units without overrun or slowdown except for the second 1403-3. Note that only two 1403's are shown on the worksheet in Figure 6. The reasons for this are explained in the following paragraphs.

It is important to note that this evaluation considers that *all* units are to run concurrently. Hence, assuming this concurrence of operation, then the second 1403-3 (in Figure 6) will slow down by some slight amount in printing its first line. Actually, its cycle time will increase by a number of milliseconds equal to 6.3% of its wait time (15.7 milliseconds). The 6.3% is obtained by subtracting 100 from the calculated load sum of 106.3 (for the second printer).

Because the 1403 is an asynchronous buffered unit, it will adjust its cycle of service requests such that subsequent requests will not conflict with the requests of the other 1403. (Refer to the *Synchronization Tendency of Buffer Servicing and Its Effect in Minimizing Channel Load* section.) Therefore, the two 1403 printers will tend not to be concurrent, and consequently one can be removed from the worksheet. This effectively means that several buffered units can run concurrently as long as their servicing times are not overlapped. The cycle time of the 1403-3 is 54.5 ms and its service time (see first printer on worksheet) is 94% of 15.7 ms, or 14.8 ms (less than $\frac{1}{3}$ of 54.5). Therefore, three 1403-3 printers could be run concurrently without an overlap of their service times. Also, they would tend to arrange their servicing in this way if they were kept running at full speed.

This example considers four 1403-3 printers. Hence, one printer would always tend to conflict with the others. At least two of these printers should be entered

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MULTIPLEXOR CHANNEL WORKSHEET

SYSTEM/360 MODEL 30

Form X24-3407
Printed in U. S. A.

SYSTEM IDENTIFICATION *Example Configuration*

DATE *4/1/65*

POSITION ON MULTIPLEXOR CHANNEL				1		2		3		4		5		6		7		8	
DEVICE				2501-B2		2702 (1030)		2702 (1050)		2520-B2		1403-3		1403-3		1052			
WAITING TIME				.915		.944		1.97		9.0		15.7		15.7		70.0			
	TIME	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
SELECTOR CHANNEL 1 2402-3 READING	.100	5.03	—		19.3		19.3		19.3		19.3		19.3		19.3		19.3		
DEVICE	.262	—	19.3																
SELECTOR CHANNEL 2 2311	.202	12.0	—	3.85	24.1	3.85	24.1	3.85	24.1	3.85	24.1	3.85	24.1	3.85	24.1	3.85	24.1		
DEVICE	.338	3.85	24.1																
POSITION ON MULTIPLEXOR CHANNEL 1	.104	10.4	6.6	3.85	A SUM	10.4	6.6	10.4	6.6	10.4	6.6	10.4	6.6	10.4	6.6	7.0	—		
	38.5	7.0	0	QUOTIENT	4.2														
2	.200	6.04	13.7	DEVICE LOAD	11.0	14.25	A SUM	6.04	13.7	68.4	5.1	68.4	5.1	68.4	5.1	68.4	5.1		
	7.24	68.4	5.06	PREVIOUS LOAD	10.5	QUOTIENT	15.1												
3	.200	6.52	6.84	LOAD SUM	69.1	DEVICE LOAD	4.9	20.29	A SUM	6.52	6.8	6.52	6.8	6.52	6.8	151.0	2.14		
	30.8	151.0	2.14			PREVIOUS LOAD	10.8	QUOTIENT	10.3										
4	.096	—	100.			LOAD SUM	80.8	DEVICE LOAD	2.4	89.17	A SUM	216.	—	216.	—	216.	—		
	2.16	216	—					PREVIOUS LOAD	5.2	QUOTIENT	9.9								
5	.100	—	100.					LOAD SUM	81.6	DEVICE LOAD	24.0	305.17	A SUM	192.0	—	192.0	—		
	1.92	192.0	—							PREVIOUS LOAD	1.1	QUOTIENT	19.4						
6	.100	—	100.							LOAD SUM	96.9	DEVICE LOAD	12.2	497.17	A SUM	192.0			
	1.92	192.0	—									PREVIOUS LOAD	.6	QUOTIENT	31.6				
7												LOAD SUM	94.1	DEVICE LOAD	12.2	830.25	A SUM		
														PREVIOUS LOAD	.6	QUOTIENT	11.8		
														LOAD SUM	106.3	DEVICE LOAD	.05		A SUM
																PREVIOUS LOAD	—	QUOTIENT	
																LOAD SUM	62.5	DEVICE LOAD	
																		LOAD SUM	

Fold to Here

Figure 6. Example Multiplexor Channel Worksheet

on the worksheet, as has been done in this example. The conclusion is that at least one of these four printers would be subjected to a small slow-down of about 6% of 15.7 ms or about .9 ms. That is, for any specific time, the other three printers would not have overlapped waiting times.

The configuration in this example assumes four tape drives on selector channel one and three 2311's on selector channel two. However, because only one unit at a time, on a selector channel, can transmit data, the worksheet should contain only the information for the unit with the largest data load for each channel. The rule is to list only those units, on the worksheet, that might run concurrently and to use only those (of the possible units) which have the greatest data load when they are exclusive of one another. This rule was applied (see Figure 6) to the first 2702 which controls a mixture of 1031 and 1051 terminals. The 1031 is a faster terminal than the 1051. Hence the information for the 1031 was used in Figure 6. The result would have been similar, then, if all 15 terminals had been 1031's.

The procedure of this example would be the same if a System/360 Model 30 with a 2-microsecond RW cycle were considered. However, the load sums would have been compared to a factor of 75 (instead of to 100, as in this example). Also, the selector channel evaluation would have required use of the *How to Calculate Channel Load Limits When the Multiplexor Channel Is Operating in Burst Mode Only* subsection in *Section IIB. Calculating Channel Load Limits (for an IBM System/360 Model 30 with a 2-Microsecond RW Cycle).*

Advice on Worksheet Entries for IBM 2821 Control Unit Devices

Each device attached to the IBM 2821 Control Unit is evaluated as if it had its own separate control unit. Each device has its own channel service requirements with regard to waiting time, etc.

In burst mode, no attached device may have a device load greater than the selector channel load limit or multiplexor channel burst mode load limit.

Each 2821 device desired to operate in multiplex mode, simultaneously with other multiplexor channel devices, must be evaluated in a separate column on the multiplexor channel worksheet. This may cause the worksheet evaluation procedure for some configurations to spill over onto scratch paper.

The priority sequence for a subgroup of 2821 devices is:

1. IBM 2540 Card Reader (Highest Priority).
2. IBM 2540 Card Punch.
3. Printer(s).
   a. Printer Control No. 1
   b. Printer Control No. 2
   c. Printer Control No. 3 (Lowest Priority).

Advice on Worksheet Entries for IBM 2702 Communication Control Unit

This control unit connects a variety of communication terminals to a multiplexor channel. A 2702 may attach 1 to 15 or 1 to 31 terminal lines.

The 2702 uses delay lines for storage of data and control information. The information circulates in the delay line and may be accessed for transfer to or from the multiplexor channel or to or from a terminal.

When priority devices force a 2702 to wait for channel service, additional delay may occur in the 2702 due to any time required for synchronization with the delay line. Such additional delay exists only for the 2702 and does not affect other devices on the multiplexor channel.

Each delay line has a characteristic reflecting the length of time it takes a bit of information to go once around the delay line. A 2702 with capacity for 15 terminal lines has a delay line revolution time of .480 milliseconds, and a 31-line 2702 has a delay line revolution time of .992 milliseconds. The longer delay line can hold more information.

The number of communciation lines attached to a 2702 has a direct bearing on the speed with which they must receive channel service. Maximum waiting time exists when only one communciation line is used. Each additional line in operation reduces the length of time a 2702 can wait for channel service.

In addition, the data transfer speed of a terminal affects 2702 waiting time. Multiple high speed line configurations cannot wait as long for channel service as can the same number of lower speed lines.

Therefore, different waiting time factors are specified for the different types of terminal controls and numbers of lines available. Terminal controls are listed in Table 1 (see *Appendix*). The different waiting time and device load, previous load, CPU interference, and priority load factors are specified for different numbers of lines, from one to the maximum permitted.

To reference factor values from Table 1, for entry on a multiplexor channel evaluation worksheet, look up the highest speed line attached and use the values specified for the number of lines proposed for simultaneous operation.

Procedure for Relieving Load of 2702 on Waiting Devices

Where a priority 2702 has lines with different speeds attached, the sets of Time, A, B factor values in Table 1 may be used first. If their use does not cause any load sum for a waiting device to exceed 100, satisfactory operation is indicated. If the values contribute to any load sum in excess of 100, a more accurate second set of Time, A, B values may be computed for a 2702 with a mix of line speeds. These are substituted for highest-speed values, and new load sums are formed for waiting devices. Any new load sum that is less than or equal to 100 indicates satisfactory operation (less than or equal to 75 for a CPU with a 2-microsecond RW cycle).

Each new set of Time, A, B values is computed as specified below.

1. Select from Table 3 (see *Appendix*) a "b" factor for each type of terminal. Multiply each "b" value by the number of terminal lines having that "b" factor, and add all of the products. The sum of the products is the new B value.
2. Subtract the new B value form the B factor specified in segment 1 of Table 3. The difference is an intermediate value used in step 4.

   Note that the single set of Time, A, B values in segment 1 are the same as the first (uppermost) set already entered for the priority 2702 on the multiplexor channel worksheet. This first set does not change.
3. Find the time factor for the number of lines attached in segment 2 of Table 3. This is the new time value.
4. Multiply the new time value by the remainder found in step 2. The product is an intermediate value used in step 5.
5. Add the A value in segment 1 (Table 3) to the product found in step 4. The sum is the new A value.
6. Substitute the Time, A, B values found in steps 3, 5, and 1 in place of the second set of Time, A, B values previously entered on the multiplexor channel worksheet for the priority 2702.

Repeat steps 1-6 for any remaining 2702 priority devices and compute new load sums.

Because of the variables involved, the factor values specified in Table 1 have been computed for ease of use and have a conservative bias. When the load sum found for a 2702 exceeds 100, additional analysis, not ordinarily required, is in order (exceeds 75, for a CPU with a 2-microsecond RW cycle).

To this end, a performance analysis procedure, unique to the 2702, is provided in the next section of this manual. The procedure uses a special worksheet for analysis of the situation, with resolution to a single delay line cycle.

When the performance analysis indicates satisfactory operation of the 2702, attention may be returned to the multiplexor channel worksheet for evaluation of the next waiting device. If, however, the analysis still indicates overrun, some of the communication lines may have to be connected to another 2702 in order to eliminate overrun.

In a system with a large number of lines, construction of a probabilistic model may lead to the conclusion that the frequency of overrun is sufficiently low to be acceptable in a particular application area.

Procedure for a More Critical Analysis of the 2702

Whenever the multiplexor channel evaluation worksheet procedure finds a load sum greater than 100 for a 2702 (greater than 75 for a CPU with a 2-microsecond RW cycle), a more sophisticated performance analysis may indicate satisfactory operation. A special worksheet and special tables, unique to the 2702, are used.

The analysis assumes that all attached communication lines will request service during a single delay line revolution and that a scanning sequence will occur that gives service, last of all, to the highest speed communication line. The analysis reveals whether, considering priority loads, the number of delay line revolutions available is sufficient for the total delay line revolution requirements of all the communication lines.

It is seldom necessary to test all communication lines' requirements for delay line revolutions. After a communication line tests satisfactorily, a projection is made of both the minimum and the maximum number of revolutions needed to service the remaining communication lines. When a projected maximum is less than the waiting time factor for the highest speed remaining line, satisfactory operation is indicated and no further analysis is required. Similarly, if a projected minimum is greater than the waiting time, overrun is indicated, and the analysis is complete.

The projections are made as the 2702 worksheet procedure progresses. Figure 7 illustrates the relationship of the two projections to the waiting time of the highest speed line. Satisfactory operation is indicated whenever an upper curve crosses the waiting time line.

To determine the number of delay line cycles required by a particular communication line, tables of factor values are provided in this manual for use with the 2702 worksheet, Form X24-3406.

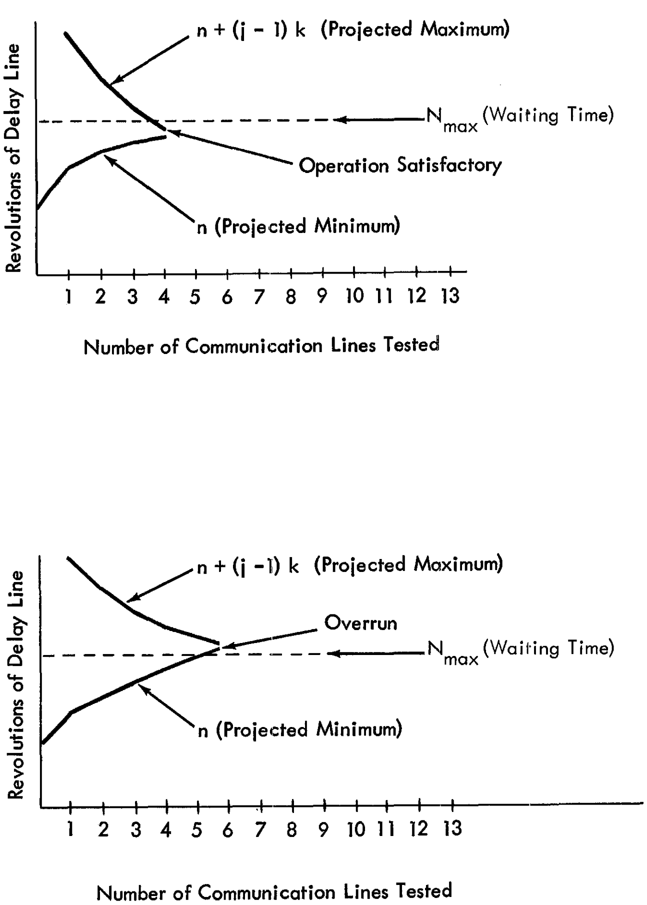

Figure 7. Projection of Delay Line Revolution

The factors are used to compute a load sum occurring during the servicing of each communication line. The load sum consists of priority load functions caused by selector channel priority devices and by multiplexor channel priority devices, plus a device load factor and a previous load factor for the terminal being tested. The various factors are entered on the 2702 worksheet and used to compute a load sum which is compared to the load limit specified on the worksheet for that particular revolution (first, second, etc.).

If the load sum is greater than the specified load limit, the communication line under consideration requires an additional delay line revolution. The projected minimum time for service is increased one revolution and tested. If overrun is not indicated, the next column of the 2702 worksheet is used to compute a new load sum which is compared, etc.

If, however, the first load sum mentioned in the previous paragraph was not greater than the specified load limit, adequate service is indicated for the communication line under consideration, and if it was serviced in one revolution, or if it is the last communication line to be considered, satisfactory operation of the 2702 is indicated. But if the communication line serviced was not the last one and was not serviced in a single revolution, it is necessary to see if the remaining communication lines can be serviced within the number of revolutions remaining to them. A new projection of the maximum time for service is made.

In this analysis, no remaining communication line will take more revolutions than the communication line for which satisfactory service was just indicated, so if the number of revolutions it required is multiplied by the number of remaining lines, the results may be compared to the remaining number of revolutions available. A low or equal comparison indicates satisfactory operation and the analysis is complete. A high comparison indicates a need to test the next communication line. This is done by transferring some of the values on the worksheet in use to a fresh 2702 worksheet and testing the next communication line for satisfactory operation. A load sum is computed and compared with the load limit. Comparison results have the same significance already described.

Figure 8. IBM 2702 Worksheet

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IBM 2702 WORKSHEET

SYSTEM/360 MODEL 30

Form X24-3406
Printed in U. S. A.

SYSTEM IDENTIFICATION ____________ DATE ____________

NUMBER OF LINES = 1,24	REVOLUTION		j = 1		j = 2		j = 3		j = 4		j = 5		j = 6		j = 7		j = 8	
LINE NUMBER = 2,25	t_1 = 7,26		t_2 = 9 9		t_2 = 9'		t_2 = Overlay		t_2 =		t_2 =		t_2 =		t_2 =		t_2 =	
SUBTRACT: K = 3,25	n = 1,28		n = 1,28, 29		n = 19, 20, 21		n = 9		n =		n =		n =		n =		n =	
n_{max} = 4	A_1	B_1	A_2	B_2	A_2	B_2	A_2	B_2	A_2	B_2	A_2	B_2	A_2	B_2	A_2	B_2	A_2	B_2
SELECTOR CHANNEL 1																		
SELECTOR CHANNEL 2																		
DEVICE 1																		
DEVICE 2																		
DEVICE 3																		
DEVICE 4 6	8,27	8,27	10	10	10'	10'												
DEVICE 5																		
DEVICE 6																		
DEVICE 7																		
DEVICE 8																		
DEVICE 9																		
DEVICE 10																		
SUM A's AND B's	11	11	13	13	13'	13'												
MULTIPLY: t_i X SUM B_i	X	12	X	14	X	14'	X		X		X		X		X		X	
A REMAINDER			15		15'													
B REMAINDER			16		16'													
DEVICE LOAD			5															
PREVIOUS LOAD			5															
LOAD SUM			17		17' etc.													
LOAD LIMIT: 15 Line 2702	19	18	46.4		94.4		142.4		190.4		238.4		286.4		334.4		382.4	
LOAD LIMIT: 31 Line 2702	22		97.6		196.8		296.0		395.2		494.4		593.6		692.8		792.0	

MAXIMUM NUMBER OF REVOLUTIONS TO COMPLETE SERVICE: n + (j - 1) k = 22, 23 24 Operation Satisfactory

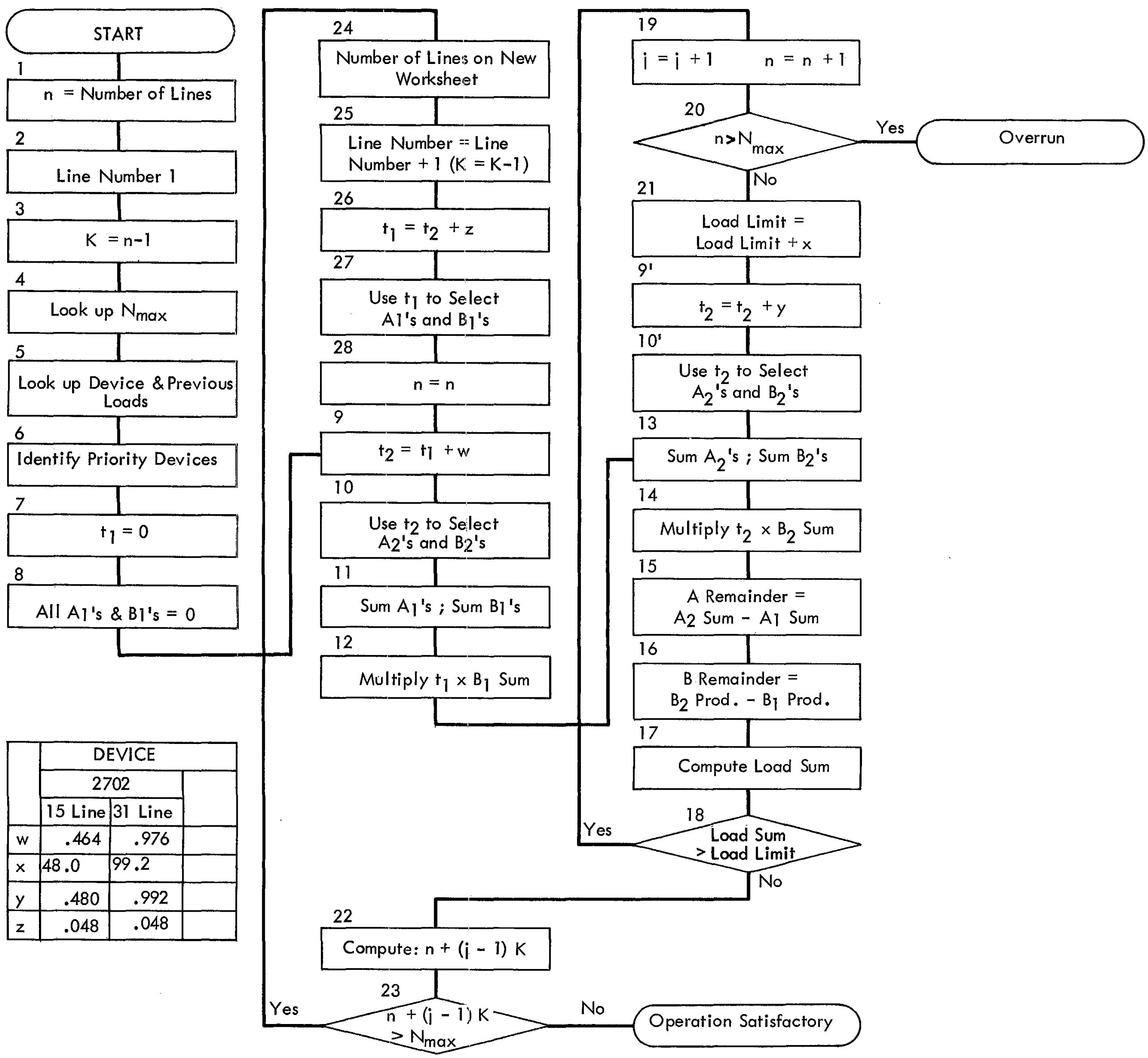
Fold to Here

The 2702 worksheet is used with a step-by-step procedure. Each step has a number that is used in Figure 8 to show the spaces that receive entries as a result of the step.

The procedure is shown in flow chart form in Figure 9. Figure 9 is keyed to the numbered steps in the procedure.

This is the procedure for using the 2702 performance analysis worksheet:

1. Enter the number of communication lines proposed for attachment into the *number of lines space* and also into the first and second *n* spaces.
2. Enter 1 in the *line number* space.
3. Subtract the step 2 entry from the step 1 entry and enter the remainder in the *K* space.
4. Consult Table 2 *(Appendix)* and find the smallest N_{max} value among the terminals proposed for attachment. Enter the value found in the N_{max} space.
5. From the same table used in step 4, enter device load and previous load values shown for the terminal selected in step 4.
6. Enter identification of selector channel and multiplexor channel priority devices in the leftmost column, in the order of their priority (copy from old multiplexor channel worksheet).
7. Enter a t_1 value of zero.



	DEVICE		
	2702		
	15 Line	31 Line	
w	.464	.976	
x	48.0	99.2	
y	.480	.992	
z	.048	.048	

Figure 9. Flowchart for IBM 2702 Performance Analysis Worksheet

8. The A_1 and B_1 spaces have zero values.
9. Enter a t_2 value.

   when $j = 1$ (see Figure 8), the t_2 value is:
   $t_1 + .464$ for a 15-line 2702
   $t_1 + .976$ for a 31-line 2702

   When $j > 1$, the t_2 value is:
   previous $t_2 + .480$ for a 15-line 2702
   previous $t_2 + .992$ for a 31-line 2702
10. Use the t_2 value just entered to select A_2 and B_2 values from the left-hand column of the multiplexor channel worksheet. The selected A's and B's are copied from the multiplexor channel worksheet into the A_2 and B_2 spaces on the 2702 worksheet.

    Note: The second set of Time, A, B values used for a priority 2702 with a mix of communication line speeds may be:

    a. As specified in Table 1 *(Appendix)* for the highest speed line, or
    b. As computed with the procedure given in the *Advice on Worksheet Entries for* IBM *2702 Communication Control Unit* section of this publication.
11. This step is performed only once per worksheet: Enter the A_1 sum and B_1 sum. (When Line Number = 1, the A_1 sum and B_1 sum have zero values.)
12. This step is performed only once per worksheet: Multiply the B_1 sum by the t_1 value and enter the product.
13. Enter the A_2 sum and B_2 sum.
14. Multiply the B_2 sum by the t_2 value and enter the product.
15. Subtract the A_1 sum from the A_2 sum and enter the A remainder.
16. Subtract the B_1 product from the B_2 product and enter the B remainder.
17. Add A remainder, B remainder, device load, previous load, and enter the load sum.
18. The load sum is compared to the appropriate load limit. If not greater, adequate communication line service is indicated; go to step 22. If greater, the communication line needs another delay line revolution; go to step 19.
19. Add 1 to the last entered n value, and enter the sum in the next n space.
20. If the new n value is greater than the N_{max} value, no additional delay line revolution is available for the communication line. This indicates overrun.
21. If the new n is not greater than N_{max}, go to step 9 and repeat the performance analysis for the fresh delay line revolution. When j is greater than 8, the analysis spills over to another worksheet, and each new load limit is computed by adding a load limit increment to the old load limit.

    Load Limit Increment:
    48.0 for 15-line 2702
    99.2 for 31-line 2702
22. The step 18 load sum was not greater than the load limit, thereby indicating adequate channel service for the communication line under test. If this is the last communication line, or if it was serviced by the first delay line revolution ($j = 1$), satisfactory operation of the 2702 is indicated. But if the communication line serviced was not the last one and was not serviced by the first revolution (j greater than 1), add its n value to the product of its revolution number minus one ($j - 1$) times K, and enter the sum in the space at the bottom of the worksheet, where $n + (j - 1)K$ is printed.
23. If the value just entered is not greater than the N_{max}, satisfactory operation of the 2702 is indicated. If greater, get a fresh 2702 worksheet.
24. The number of lines entry for the fresh worksheet stays the same as it was on the old worksheet.
25. The new line number entered is 1 greater than the old line number. The subtraction, of course, gives a new K value entry 1 less than the old.
26. Enter a new t_1 value:

    For a 2702, add .048 to old t_2
27. The new t_1 is used to select priority device A and B values from the multiplexor channel worksheet for entry into the A_1 and B_1 spaces.
28. The old n value is entered into the n spaces under t_1 and $j = 1$.
29. Go to step 9.

Summary of Channel Control Capabilities

Channel control capabilities for a System/360 Model 30 with a 1.5-microsecond storage cycle are summarized in Figure 9.1.

Multiplexor Channel Mode	Selector Channel	Multiplexor Channel Capability
Burst (no data chaining)	Not operating	2841's (any configuration), 2400 series magnetic tape (Models 1 through 5), all models of the 2415, or 7340's at 170,000 bytes/second.
Burst (no data chaining)	Operating (command chaining -- required for 2841's, 2314's and magnetic tape units).	No overrunable continuous burst mode devices (tape or disk) may be operated.
Interleaved (with no chaining)	Not operating	Aggregate data rate approaching 30,000 bytes/second.
Interleaved (with chaining)	Not operating	Approximately 6,000 bytes/second with unbuffered devcies.*
Interleaved (with chaining)	Operating at maximum load	Approximately 1,500 bytes/second with unbuffered devices.*

Selector Channel Mode	Multiplexor Channel	Number of Selector Channels Operating	Selector Channel Capability**
Command chaining (required for 2841, 2314, and magnetic tape)	Operating	1	2314's, 2841's (any configuration), 2400 series tape (including 2415's), and 7340's at 170,000 bytes/second.
Command chaining (required for 2841, 2314, and magnetic tape)	Operating	2	When 2314 is operating, then 2400 series magnetic tape (Models 1 through 5) and all models of the 2415 will operate on selector channel two. When 2314 is not operating, all models of the 2400 series tape units (including the 2415), the 2841, and the 7340 may operate at 170,000 bytes/second on either or both selector channels.

Notes:

* When operating with buffered devices, and without chaining, the multiplexor channel is capable of higher rates.

** No chaining of overrunnable, continuous-burst-mode, unbuffered devices. One exception: DASDs may be chained between count, key, or data fields.

Figure 9.1 Summary of Channel Control Capabilities for a 1.5-Microsecond Storage Cycle System.

How to Calculate Buffer Transmission Times (Chaining Times Are Listed Here)

When data is sent to a buffer (or received from a buffer) the following formula is used to calculate the time required (in microseconds) for the data transfer in multiplex mode:

(F—VIII) $T \text{ (in microseconds)} = [31.5 + r(N - 1)]\frac{R}{N}$

where

N = the number of bytes sent or received by the buffer for each servicing by the channel.

r = the time to send each successive byte after the first one of the group. Note that the r and N values for the different buffered units are:

- 1403 Printers
  r = 8.0 microseconds
  N = 4
- 2540 Reader
  r = 19.5 microseconds
  N = 2
- 2540 Punch
  r = 24.5 microseconds
  N = 2
- 1443-N1 or 1445-N1 Printer
  r = 16.2 microseconds
  N = 2, or N = 4 (depending upon mode of operation)

  Note: For the 1443 or 1445 only, replace the term 31.5 (in formula F—VIII) by 47.7.
- 2520 Punch
  r = 20.0 microseconds
  N = 2

R = the total number of bytes transferred. R could be either an entire record from a buffer (i.e., 80 bytes from the buffer for the 2540 reader) or less than the capacity of the buffer if transfer is halted by the channel prior to when the capacity is reached.

Note, however, that unbuffered units can also be running on the multiplexor channel in multiplex mode. Recall that the unbuffered units are attached to the channel in a higher priority location than the buffered units. Hence, an unbuffered unit, when it is ready for a data transfer, obtains use of the channel before the buffered unit (in simultaneous requests for service). Therefore, when buffered and unbuffered units are both operating (in multiplex mode), the unbuffered unit channel times must be added to the buffer times calculated from formula (F—VIII).

An approximate total time is obtained by multiplying formula (F—VIII) by:

$$\frac{1}{1 - .142L}$$

Here, L is the total data load of all the units of higher priority (on the multiplexor channel) that are running concurrently with the buffer transmission (or reception). For the 2702, use a data load value of .43 (15 line version) or .22 (31 line version). If the selector channels are also transmitting data during the buffer data transfers and the buffer is running in *either* burst or multiplex mode, then multiply formula (F—VIII by):

$$\frac{1000}{1000 - 6.75L}$$

where L is the total data load of both selector channels.

If the selector channels are chaining, during the buffer transmission or reception time, then these chaining times should be added. Also, any data chaining time that is used with the buffer operation should be added. This situation, however, adds an undue complexity to precise calculation for the amount of additional accuracy it gives.

For a closer approximation, then, add chaining times for each selector channel and the time for the buffer unit chaining.

Hence, in the user's judgment, if chaining is likely to occur during the buffer operation, the following basic chaining times may be added:

1. Selector channel chaining
   - Command chaining
     38.25 microseconds (no TIC)
     47.25 microseconds (with a TIC)
   - Data chaining
     28.5 microseconds (no TIC)
     37.5 microseconds (with a TIC)
2. Multiplexor channel chaining
   - Data chaining
     18.75 microseconds (no TIC)
     24.75 microseconds (with a TIC)
   - Command chaining
     108.25 microseconds (no TIC)
     114.25 microseconds (with a TIC)

The preceding considerations apply to the buffer only when operating in multiplex mode on the multiplexor channel.

If the buffer is operating in burst mode on any channel, the formula for the time of data transfer is:

(F—IX) $T = Rr$ microseconds

where R is the number of bytes transmitted and r is as follows:

Unit	r
1403	8
2540 Reader	12
2540 Punch	12
1443-N1	16.2
1445-N1	16.2

Formula F–IX is used to calculate the time for a buffered unit's transfer in burst mode. Suppose, however, that the load limit available on the channel is less than the load required by a buffered unit. The extended time for the buffer transfer is then calculated as follows:

1. Divide the data load value for the buffered unit (data load value from Table 1 in *Appendix*) by the load limit allowed on the channel.
2. Calculate the buffered unit's minimum transfer time by use of formula F–IX.
3. Multiply the factor obtained in step 1 by the time obtained in step 2. The result is the time for the buffered unit's transfer within the load available on the channel (burst mode only).

How to Calculate Channel Interference with CPU Processing Time

Interference with the microprogram control of the processing unit occurs, to some degree, whenever a channel services an I/O unit. The type and amount of interference differs according to the channel (multiplexor or selector) causing the interference.

Each time a selector channel sends a byte of data to an I/O unit (or receives a byte of data from an I/O unit), the processing unit program is stopped. The program is stopped only for the amount of time required to store or readout the byte of data from main storage. This time is 1.5-microseconds (for a model 30 processing unit that has a 1.5-microsecond RW cycle). Therefore, for every transfer of a byte of data on a selector channel, there is an interference of 1.5 microseconds with the processing unit.

When a selector channel is command chaining or data chaining, then that channel uses the microprogram controls of the processing unit. Here, the full chaining time, plus any selection time to an I/O unit (during command chaining), interferes with the processing unit program. That is, the processing unit program is stopped for the total chaining and selection times involved.

The multiplexor channel interferes with the processing unit program to a greater degree than do the selector channels. This is because the multiplexor channel uses the microprogram controls for both chaining and data handling operations.

The multiplexor channel operates in either burst or multiplex mode, depending upon the I/O unit involved in the operation. When the multiplexor channel operates in burst mode, it is interlocked with the I/O unit from the time of selecting that unit to the receipt of channel end from the unit. Because it is using the microprogram control of the processing unit, the multiplexor channel causes 100% interference with the processing unit during this entire time (i.e., from selection to channel end).

When operating in multiplex mode, the amount of processing unit interference caused by the multiplexor channel depends upon the frequency of requests for service from the I/O units being multiplexed. When the total number of bytes multiplexed (from or to the I/O units) is less than 16,000 bytes per second, each request for service interferes with processing unit microprogram operations for 62.3 microseconds. This time period is required to:

1. Store the contents of the processing unit registers into local storage.
2. Service the request.
3. Restore the processing unit registers so that the processing unit program that was interrupted can continue.

Each byte of data, handled by the multiplexor channel, causes this amount (62.3 microseconds) of interference with the processing unit. If the number of bytes multiplexed exceeds 16,000 bytes per second for any period, then 100% interference is caused (in the worst case) with the processing unit for that period of time.

Buffered units operating in multiplex mode on the multiplexor channel cause the channel to run at top speed. During the buffer transfer data, there is 100% interference with the processing unit, regardless of the other units that may be multiplexed with the buffered unit. Hence, the problem here is to calculate the time taken by the buffer's data transfer. We can then take this time and determine how much processing unit interference is caused. The formula used for this calculation is in the *How to Calculate Buffer Transmission Times (Chaining Times Are Listed Here)* section of this publication. The result obtained may also be calculated by multiplying the number of bytes transferred, to or from the buffer, by the buffered unit's processing unit interference factor given in Table 1 of *Appendix* (i.e., the multiplexor channel interference factor for the unit).

Having calculated the buffer time, the next question is, "How much is the buffer's time extended by the multiplexed units (of higher priority than the buffered unit) and by selector channel operations?" The extension can be calculated by the appropriate formulas given in *How to Calculate Buffer Transmission Times (Chaining Times Are Listed Here)* section.

In general, for unbuffered units being multiplexed, multiply the number of bytes transmitted over the multiplexor channel (during the time being investigated for processing unit interference) by 62.3. The result is the time in microseconds that the multiplexor channel takes from the processing unit program. If the total byte rate exceeds 16,000 bytes per second, the product obtained may indicate processing unit interference for the entire period of time considered. If calculation shows this to be the case, then consider that there is only 100% of interference (i.e., ignore the excess time taken). If this is so, it means that there is 100% of interference with the processing unit.

To handle this apparent overload, the channel operates at its fastest rate. What happens here is that the processing unit registers are stored in local storage only at the beginning of the period of time in which the multiplexor channel is operating at its fastest rate. The processing unit registers are not restored for each service request. At the end of this operation (i.e., when the multiplexor channel rate is lowered below 16,000 bytes per second) the processing-unit registers are restored from local storage and program processing continues. Note that the faster the multiplexor channel operates, the less frequently the operations of storing and restoring of the processing unit registers occur.

In summation of the preceding considerations, the following procedure is used to calculate interference of the processing unit by the channels. That is, in order to determine how much processing unit time is available for program processing (during some period, T, of the processing cycle), subtract the following items from T, when applicable:

1. For each unit running on a selector channel during time T, subtract 1.5n where

   n = number of bytes transmitted during time T.

2. For any device operating in burst mode on the multiplexor channel, subtract from time T the entire time of the unit's cycle (from the selection of the unit to channel end for that unit). If this period does not wholly fall within time T, then only subtract the portion that does.

   The time from selection to channel end for a unit is dependent upon the unit and hence must be determined from that unit's cycle time.

3. For any group of units being multiplexed during time T, subtract the product of 62.3 times the number of bytes transferred.

4. For any buffer transmission being executed during time T, multiply the multiplexor interference value for that unit (see *Appendix*) by the number of bytes in the buffer transfer. Then subtract this product from time T.

   A refinement of this calculation can be made when the buffer's data transfer is multiplexed with unbuffered units. The effect of this is to extend the buffer time by the factor:

   $$\frac{1}{1 - .142L}$$

   where L is the total load of the other, higher priority, unbuffered multiplexed units. Use the data load values for the units (i.e., from Table 1 in *Appendix*). For the 2702, use a data load of .43 (15-line version) or .22 (31-line version).

   Concurrent action on the selector channels further extends the buffer time by the factor (refer to the *How to Calculate Buffer Transmission Times (Chaining Times Are Listed Here)* section):

   $$\frac{1000}{1000 - 6.75L}$$

   Here L is the sum of the data loads of the units on the selector channel.

   Although in most cases it makes little difference, a finer correction for interference can be made here by not counting the bytes transmitted from the higher priority devices during the time that a data transfer to or from a buffer is being made.

5. Finally, consideration must be given to START I/O, selection, end sequences, and chaining times. The number of times that these items occur can only be determined by inspection. For each item, the following table indicates the amount of interference time to subtract from time T:

Operation	*Selector Channel Time (in microseconds)*	*Multiplexor Channel Time (in microseconds)*
Start I/O	42.75**	42.75**
Selection	0	45.75 + 1.5n
Data Chaining	28.5*	18.75*
Command Chaining	38.25* + 1.5n	108.75* + 1.5n
End Sequences	0	69.75

*If a TIC is used, add the following:

1. For a selector channel – 9 microseconds
2. For the multiplexor channel – 6 microseconds

n = priority of order of a unit (1-8). For the unit of highest priority, n = 1.

**This time is really processing unit time, which is interruptible by the channels.

After the preceding amounts have ben subtracted from time T, the remaining time is the amount that can be used by the processing unit program.

An Example of Calculating Interference with CPU Processing

Suppose that, during time T, the following functions are performed by the channels:

1. A 2401 Model 1 tape drive, on selector channel one, is reading three data blocks of 1000 bytes each. No chaining, of any type, is being performed.
2. A 2401 Model 1 tape drive, on selector channel two, is writing three data blocks of 1000 bytes each. Every 100 bytes is data-chained. Nine data-chaining operations, therefore, are required for each 1000 bytes.
3. On the multiplexor channel:
   a. A 2501 Model B2 card reader reads two cards (80 columns each). The operation for the second card is command-chained.
   b. A 2520 Model B2 card punch punches one card (80 columns).
   c. A 1403 Model 3 printer prints two lines, each containing 132 characters. The operation for the second line is command-chained.

The tape drive on selector channel one requires about 137 milliseconds to read its data. The tape drive on selector channel two requires about 138 milliseconds for its write operation. During this time, the two lines of print, for the 1403 printer, take approximately 109 milliseconds and the two cards are read by the 2501 in about 120 milliseconds. The 2520 takes 120 milliseconds to punch the one card.

Let us assume, then, that we wish to determine the processing unit interference during the 138-millisecond period required for the tape drive writing operation (on selector channel two).

We use the following procedure:

1. During the period of time in question, 3000 bytes of data were read from the tape drive on selector channel one. Also, 3000 bytes of data were written on the tape drive on selector channel two. At an interference of 1.5 microseconds per byte, the total number of bytes transferred on the two selector channels (i.e., 6000 bytes) requires 9 milliseconds of interference to the processing unit.
2. We note that no unit is operating in burst mode on the multiplexor channel.
3. The 2501-B2 card reader reads 160 bytes of data (in reading the two cards). At 62.3 microseconds per byte this amounts to 9.97 milliseconds of processing unit interference.

   The 2520-B2 card punch punches 80 columns, or bytes of data, but is buffered. To calculate the interference for this unit requires the same procedure as for the 1403. The calculation is shown later.
4. The 1403 printer is buffered. The procedure here is that first we shall calculate the buffer time and its extension due to the higher priority multiplexed units. The buffer time of the 1403 can be calculated from the formula given in the *How to Calculate Buffer Transmission Times (Chaining Times Are Listed Here)* section of this publication. The buffer transfer time thus calculated for the 1403 printer is 1.83 milliseconds. The transfer, however, is extended by the factor:

$$\frac{1}{1-.142L}$$

Here, L is the sum of all the data load values of the higher priority multiplexed units (i.e., refer to Table 1 in *Appendix*). This value for the 2501-B2 is .47. The extended buffer time is then:

$$1.83 \text{ ms}\left(\frac{1}{1-.142\times.47}\right) = 1.96 \text{ milliseconds}$$

The buffer transfer time, for the 1403 printer, will be extended further by selector channel data handling. This extension can be obtained by using the factor:

$$\frac{1000}{1000-6.75L}$$

Here, L is the sum of the data loads of the tape drives on the selector channels:

Unit		Load Value
2401-1 (reading)		9.4
2401-1 (writing)		6.7
	Total	16.1

Hence,

$$\frac{1000}{1000-6.75\times16.1} = \frac{1000}{891.3}$$

The further extended time is then:

$$1.96\left(\frac{1000}{891.3}\right) = 2.2 \text{ ms}$$

If we wished to refine the calculation further, we could consider how many bytes of data could, at most, be handled by the channel from the higher priority units during this extended buffer time. The resulting time, multiplied by 62.3, could then be subtracted from the total interference because the above extension of buffer time considers this overlay problem. Usually such refinement exceeds the need of accuracy in calculating the programming time.

During a period, then, of 2.2 milliseconds, how many bytes could the other unit handle (namely, the 2501)? Note that the minimum time between bytes for this unit is:

Unit	*Time*
2501-B2	.473 milliseconds

This time (in microseconds) is obtained by dividing 222.2 by the data load of the unit (from Table 1 in *Appendix*).

Divide this number into 2.2. (Any fractional quotient is rounded off to the next whole number.) Then, multiply the quotient by 62.3 microseconds. We can subtract this product from the processing unit interference.

In our example we have:

Unit	*Bytes*
2501-B2	$5 = \frac{2.2}{.473}$ (Rounded off)

Hence:

$$5 \times 62.3 = .312 \text{ milliseconds}$$

This is the amount by which the processing unit interference can be reduced. It should be noted, however, that this subtraction (a reduction of the interference caused to the processing unit) can be done only if data is being transmitted to or from the multiplexed unbuffered units during the buffer data transfer. This can only be determined by inspecting the coincidence of operations of the different units.

Because two lines are printed in period T, we must double the preceding figure. This results in 4.4 ms of interference and .624 ms of interference reduction.

The calculation of the interference due to the 2520-B2 is done in exactly the same manner as for the 1403. This unit is buffered and the procedure is the same for all buffered units.

The calculation of CPU interference for the 2520, then, will give:

Buffer time = 2.06 milliseconds
Extension due to 2501-B2 = 2.21 milliseconds
Extension due to Selector Channels = 2.48 milliseconds
Reduction of Interference = .374 milliseconds.

5. Our last consideration is the special operations, such as selection, chaining, etc. Hence, for this operation:

Operation	*Multiplexor Channel*	*Selector Channel*
Start I/O	3 times	6 times
Selection	3 times	0 times
Data Chaining	0 times	27 times
Command Chaining	2 times	0 times
End Sequences	3 times	0 times

Multiplying each of these operations by its respective time, we obtain:

Operation	*Multiplexor Channel*	*Selector Channel*
Start I/O	.128 ms	.257 ms
Selection	.146 ms*	. . .
Data Chaining	. . .	.770 ms
Command Chaining	.224 ms*	. . .
End Sequences	.209 ms	. . .
Totals	.707 ms	1.027 ms

Grand Total = .707 + 1.027 = 1.73 ms (of interference)

*This includes polling time of 1.5n. (Refer to the *How to Calculate Channel Interference with CPU Processing Time* section.)

The interferences can now be added (from the 5 preceding steps):

Step	*Interference (in milliseconds)*
1	9.0
2	0.0
3	9.97
4	4.4
4	2.48
5	1.7
	27.55
Minus correction from step 4:	(−)1.00
Total	26.55 ms (of interference)

Because the total period of time considered is 138 milliseconds, the amount of time available for use by the processing unit is:

$$138 - 26.55 = 111.5 \text{ milliseconds}$$

Section IIB. Calculating Channel Load Limits (for an IBM System/360 Model 30 with a 2-Microsecond RW Cycle)

Load limits define a maximum channel load capacity. The load limit values are upper limits in that any configuration that has a load that is less than the corresponding load limit value will operate without data overrun (i.e., without loss of data). However, an exception to this statement exists for the case of a *buffered* unit's data load value that exceeds the calculated load limit. Here, the effect is to extend the time for transferring data to or from the buffer. The time extension is calculated by using the ratio of the load value of the buffered unit to the calculated load limit (refer to the section on *How to Calculate Buffer Transmission Times (Chaining Times Are Listed Here)*. Hence, in this case, data overrun does not occur.

The implication of the loading limits given in the tables (or calculated by the appropriate formula) is that no unit should be run on a channel if operation of that unit causes the determined load limit to be exceeded. Loss of data may result (data overrun). In fact, it is advisable to plan I/O configurations and I/O-channel operations so that the peak load figure is not reached. This practice allows for some latitude in expansion of operations (i.e., those that might not be considered at initial installation).

Two approaches for describing selector and multiplexor channel load limitations are presented in this publication. One approach is applicable to the case in which the multiplexor channel is operating in burst mode. The other pertains to the case in which the multiplexor channel is operating in multiplex mode.

Figure 10 indicates limiting load factors by referring to appropriate formulas in text and applies to multiplexor channel burst mode operations only. It indicates how these burst mode operations are affected by multiplexor channel-chaining and selector-channel operations. On the multiplexor channel, buffer transmission

SELECTOR CHANNEL OPERATION	MULTIPLEXOR CHANNEL OPERATION 1.		
	No Chaining	Command Chaining	Data Chaining
Neither running	F-I	F-I	F-IV
One or both running but no chaining	F-I	F-I 2.	F-IV
One channel is data chaining and the other selector channel is not chaining*	F-Vb	F-Vb 3.	F-Va
One channel is command chaining and the other selector channel is not chaining	F-VIb	F-VIb 3.	F-VIa
Both selector channels are either data chaining or command chaining*	F-VIIb	F-VIIb 3.	F-VIIa

Notes:

1. For buffered units, use formula F-I in all cases.
2. For the 2311 and 2302, when writing without TIC, then the selector channels should not be running on a system with a 2-microsecond RW cycle.
3. If the 2311 and 2302 are used on the multiplexor channel while chaining is performed on the selector channels, the operation may have to be repeated due to overrun.

* If a channel is both data and command chaining, consider only the command chaining.

F means formula. For example, F-VIb means "see formula F-VIb in the text."

When a load value is determined, then that load value can be converted to a data rate by dividing it by the factor 0.2222 (i.e., $\frac{\text{Load Value}}{0.2222}$). The resulting data rate is in kilobytes per second.

Figure 10. Multiplexor Channel Load Limit Calculations (Burst Mode Only) Used for Evaluation of a System with a 2-Microsecond RW Cycle Only.

time is lengthened by both chaining and data transfers that are performed on the selector channels. Further consideration of the buffered units is taken up in the section on *How to Calculate Buffer Transmission Times (Chaining Times Are Listed Here).*

Figure 11 indicates limiting load factors by referring to the appropriate formulas in text or by stating the limiting load factors outright. Figure 11 applies to the consideration of how the two selector channels interact with one another. Hence, information in Figure 11 is used to determine the load limit that cannot be exceeded on the selector channels if either chaining or no chaining is being performed. If the load limit is exceeded, data overrun may result.

The load values used for the different I/O units are indicated as data load values (see Table 1 in *Appendix*). The peak data rate (in kilobytes per second) for a unit (or for a channel load limit, depending upon the value referenced) can be found by dividing the appropriate load value by the factor 0.2222.

Channel-to-channel adapter considerations are handled in a separate section.

Consideration of determining the loading of the multiplexor channel, by units operating in multiplex mode, is facilitated by use of Table 1 in *Appendix* and the multiplexor channel loading worksheet (Form X24-3407).

Note: In certain instances, it is necessary to consider the effects of the load of a unit on a channel when chaining also occurs. Consider, for example, the case in which a selector channel is data chaining a unit. Because data chaining is involved, use the *data chaining* load value for the unit (see Table 1 in *Appendix*). It is this load value that is compared to the calculated channel limit load value for this particular case.

A somewhat different situation occurs when using a load value for a unit on the multiplexor channel. Here, if chaining of *any* type is done on either selector channel, or if the unit on the multiplexor channel is data-chained, use the *data-chaining* value for the unit on the multiplexor channel. This value is then used to compare to the load limit calculated for the channel.

In certain calculations, even though a unit is data chained, the unit's *no-chaining* load value is sometimes used. These situations are pointed out in text and made use of in the examples sections.

When the multiplexor channel is operated in burst mode only, the data load values used for units on the multiplexor channel are the data load values given in Table 1 in *Appendix*.

OTHER SELECTOR CHANNEL OPERATION	SELECTOR CHANNEL ONE		SELECTOR CHANNEL TWO	
	Not chaining or only command chaining	Data chaining 2.	Not chaining or only command chaining	Data chaining 2.
Not running	Rated speed	5.79 (no TIC) 4.42 (with TIC)	Rated speed	5.79 (no TIC) 4.42 (with TIC)
Running but not chaining	Rated speed 1.	No TIC: 5.79 - .234L* With TIC: 4.42 - .179L*	Rated speed 1.	No TIC: 5.79 - .234L* With TIC: 4.42 - .179L*
Data chaining	Rated speed 1.	3.0 (no TIC) 2.27 (with TIC)	Rated speed 1.	2.48 (no TIC) 1.91 (with TIC)
Command chaining	Rated speed 1.	F-II	Rated speed 1.	F-III

Notes:

1. If 2311 or 2302 is run concurrently with another device (on the other selector channel) that is chaining, the operation may have to be repeated due to overrun. The load on the other selector channel should not exceed 17.5.
2. Data chaining of a buffered unit effectively adds only the chaining time to the buffer transfer time. Therefore, use formula F-I for the buffered unit if that unit is also being data chained.

L* means load on other channel.

F means formula. For example, F-II means "see formula F-II in the text."

Convert load value to data rate by dividing the load value by 0.2222 (i.e., $\frac{\text{Load Value}}{0.2222}$). The resulting data rate is in kilobytes per second.

Figure 11. Selector Channel Maximum Load Values (with Chaining and with Interference of the Other Selector Channel). Used for Evaluation of a System with a 2-Microsecond RW Cycle Only.

How to Calculate Channel Load Limits When the Multiplexor Channel Is Operating in Burst Mode Only

Use this section to evaluate selector channel operations whether or not the multiplexor channel is operating in burst mode. If the multiplexor channel is operating in burst mode, use this section for its evaluation. If the multiplexor channel is operating in multiplex mode, use the *Calculating the Multiplexor Channel Load When Operating in Multiplex Mode* section after the selector channels' evaluation has been made by use of this section.

The symbol L (or L_1 or L_2) is used in the following descriptions to designate the *data load* of an I/O unit. L values are found in the column headed "data load" in Table 1 of *Appendix.*

With No Chaining on Any Channels

So far as data transmission goes, any units that can be attached to either selector channel will run one at a time or concurrently (one unit on each selector channel) at their rated speeds. Data chaining, and in some cases command chaining, limits the speed at which data can be handled.

If the multiplexor channel is also to run concurrently (*in burst mode*) with the selector channels, then the maximum burst mode rate allowed on the multiplexor channel is determined by:

(F—I) $$L_m = \frac{111.1 - L_1 - L_2}{2.5}$$

where

L_1 = data load on selector channel one (see *Appendix*).

L_2 = data load on selector channel two (see *Appendix*).

L_m = maximum burst rate load allowed for the multiplexor channel.

Formula (F—I) assumes no chaining of any kind on either selector channel. There may be command-chaining (*not* data-chaining) for the multiplexor channel unit. However, the multiplexor channel unit cannot be time dependent on the command-chaining (as is the case for a disk-storage unit).

L_m cannot exceed 24.7 if both selector channels are running. If only one selector channel is running, L_m cannot exceed 31.8. If neither selector channel is running, the maximum burst rate load for the multiplexor channel is 44.4.

With Chaining on Selector Channels

When chaining is done on either or both selector channels, the relative effect on each other's maximum data rate load is:

1. If a selector channel is running without data chaining (it may, however, be command-chaining), its data rate is not affected by chaining or data handling on the other selector channel.
2. If a selector channel is data-chaining, however, its rate of data handling is definitely affected by the operation being performed on the other selector channel:
   a. If only one selector channel is running, that channel is limited to a 5.79 data rate load if it is also data-chaining.
   b. If the other selector channel is running but it is not data or command chaining, the maximum data rate load for the selector channel that is data-chaining is:

      5.79 − .234L (if a TIC is not used)

      or

      4.42 − .179L (if a TIC is used).

   where

   L = data load on the other selector channel (see *Appendix,* Table 1).

   c. If both selector channels are data-chaining, the maximum load for selector channel one is 3.0 (with no TIC) or 2.27 (with a TIC). The maximum load for selector channel two is 2.48 (with no TIC) or 1.91 (with a TIC).
   d. If a selector channel is data-chaining and the other selector channel is command-chaining:
      (1) If channel one is the channel that is data chaining, its maximum load is:

(F—II) $$\frac{222.2}{48.3 + 25.6\left(\frac{1000}{1000 - 9L}\right)}$$

where L is the data load on the other selector channel (Table 1 in *Appendix).*

Note: If a TIC is used on selector channel one, replace the factor 25.6 by 37.6. If a TIC is used on selector channel two, replace the factor 48.3 by 60.3.

(2) If selector channel two is the one that is data chaining, its maximum load is:

(F—III) $$\frac{222.2}{54.1 + 25.6\left(\frac{1000}{1000 - 9L}\right)}$$

Again, L is the data load on the other selector channel (Table 1 in *Appendix*).

Note: If a TIC is used on selector channel two, replace the 25.6 by 37.6.

If a TIC is used on selector channel one, replace 54.1 by 66.1.

With Chaining on the Multiplexor Channel

1. Whether or not the selector channels are running, the maximum burst mode rate of the multiplexor channel is not affected by command chaining on the multiplexor channel. Note that the maximum burst rate of the multiplexor *channel* is the rate referenced. However, the maximum rate of a particular *I/O device* on the multiplexor channel may not be attained if that device is time dependent on the command-chaining (such as a disk storage device). If data-chaining is being done on the multiplexor channel and the selector channels are *not* running, the maximum multiplexor channel burst mode is:
   - 7.42 without a TIC.
   - 5.83 with a TIC.
2. If either or both selector channels are running concurrently (but not chaining) with the multiplexor channel, the maximum multiplexor channel burst mode load, if data-chaining is also done on the multiplexor channel, is:

(F—IV) $$L_m = 7.42\left[\frac{1000 - 9(L_1 + L_2)}{1000}\right]$$

   Note: If a TIC is used, replace the factor 7.42 by 5.83.

   where

   L_m = maximum burst rate load on the multiplexor channel.

   L_1 = data load on selector channel one (Table 1 in *Appendix*).

   L_2 = data load on selector channel two (Table 1 in *Appendix*).

3. If data-chaining (but no command-chaining) is done on one of the selector channels and the other selector channel is not running, then the maximum multiplexor channel burst mode load *with data chaining* is:
   - 3.17 (with no TIC on the multiplexor channel).
   - 2.84 (with a TIC on the multiplexor channel).

   If one selector channel is data-chaining and the other selector channel is running without any chaining, then the maximum multiplexor channel burst mode load *with data-chaining* is:

(F—Va) $$L_m = \frac{222.2 - 2L}{70.0 + T_1 + T_2}$$

   where

   L = data load on the selector channel that is not chaining (see Table 1 in *Appendix*).

   T_1 = 8 (if a TIC is used on the multiplexor channel).

   T_1 = 0 (if a TIC is *not* used on the multiplexor channel).

   T_2 = 12 (if a TIC is used on the selector channel that is chaining).

   T_2 = 0 (if a TIC is *not* used on the selector channel that is chaining).

   The maximum multiplexor burst mode load when either no chaining or command chaining only *(no data chaining)* is being performed on the multiplexor channel is:

(F—Vb) $$L_m = \frac{222.2 - 2L}{45.0 + T_2}$$

   where

   L = data load on the selector channel that is not chaining (see Table 1 in *Appendix*).

   T_2 = 12 (if a TIC is used on the selector channel that is chaining).

   T_2 = 0 (if a TIC *is not* used on the selector channel that is chaining).

4. If one selector channel is command-chaining (whether or not it is also data-chaining) and the other selector channel is not running, then the maximum multiplexor channel burst mode load *with data chaining* is:
   - 2.08 (*no* TIC in multiplexor operation)
   - 1.97 (with a TIC in multiplexor operation).

   If the other selector channel is running but not chaining, then the maximum multiplexor channel burst mode load *with data chaining* is:

(F—VIa) $$L_m = \frac{222.2 - 2L}{102 + T_1 + T_2}$$

   where

   L = data load on the selector channel that is not chaining (see Table 1 in *Appendix*).

   T_1 = 8 (if a TIC is used on the multiplexor channel).

   T_1 = 0 (if a TIC is *not* used on the multiplexor channel).

   T_2 = 12 (if a TIC is used on the selector channel that is chaining).

   T_2 = 0 (if a TIC is *not* used on the selector channel that is chaining).

If the multiplexor channel is either command chaining (with devices that are not time dependent upon the command chaining) or not chaining (i.e., it is definitely not data chaining) then its maximum burst mode load is:

(F—VIb) $$L_m = \frac{222.2 - 2L}{77 + T_2}$$

L and T_2 in formula (F—VIb) have the same meanings and values as shown for the appropriate conditions under formula (F—VIa).

5. When data chaining or command chaining (or both data chaining and command chaining) are being done concurrently on both selector channels, the following formulas apply for the maximum multiplexor channel burst mode load with data chaining. If both command and data chaining are being done on a selector channel, ignore the data chaining and use only the formula for command chaining.
   a. The selector channel-chaining values to be used in formula (F—VIIa) are to determined by:
      - Command-chaining value $= (70.0 + T_2)\left(\frac{1000}{1000 - 9L_1}\right)$
      - Data-chaining value $= (30.0 + T_1)\left(\frac{1000}{1000 - 9L_1}\right)$
   b. The multiplexor channel data chaining value to be used in formula (F—VIIa) is determined by:
      - Data-chaining value $= (30.0 + T_1)\left(\frac{1000}{1000 - 9L_2}\right)$

   For the chaining value formulas in (a) and (b):

   L_1 = data load on the other selector channel (i.e., not the channel for which the chaining value is being determined). Note here that L_1 refers to the *data load* value of the unit on the other selector channel and *not* to its chaining value (see Table 1 in *Appendix*).

   L_2 = the calculated total load for both selector channels. Again, this value is obtained by adding the data load value of the unit on selector channel one to the data load value of the unit on selector channel two. L_2 does *not* include calculated selector channel-chaining values (see Table 1 in *Appendix*).

   T_1 or $T_2 = 0$ (if a TIC is not used)

   Otherwise

   $T_1 = 8$ (for a TIC on the multiplexor channel)
   $T_2 = 12$ (for a TIC on a selector channel).

   By using the chaining values calculated in (a) and (b), the multiplexor channel maximum burst mode load with data chaining is:

(F—VIIa) $$L_m = \frac{222.2}{C_1 + C_2 + C_3}$$

where

C_1 = the chaining value for selector channel one.

C_2 = the chaining value for selector channel two.

C_3 = the data chaining value for the multiplexor channel.

If the multiplexor channel is not chaining or only command chaining (with devices that are not time dependent upon the command chaining) then (F—VIIb) is used. F—VIIb is the same as F—VIIa except that the value of C_3 is:

$$C_3 = (5.0)\left(\frac{1000}{1000 - 9L_2}\right)$$

(L_2 is the same as already defined in 5b.)

The maximum burst load on the multiplexor channel is then:

(F—VIIb) $$L_m = \frac{222.2}{C_1 + C_2 + C_3}$$

With Channel-to-Channel Adapter Feature

The channel-to-channel adapter is unique in its loading aspect in that it adjusts its speed to the varying demands of the other channels and to the two processing units to which it is attached. In general, this adapter tends to impose a maximum load on a channel with which it is used. It adjusts its speed to the demands of the other channels according to their priority assignments and relative loads.

The formula (F—I) for multiplexor channel burst mode operation without chaining still applies:

(F—I) $$L_m = \frac{111.1 - L_1 - L_2}{2.5}$$

where

L_1 = data load on selector channel one (see Table 1 in *Appendix*).

L_2 = data load on selector channel two (see Table 1 in *Appendix*).

L_m = maximum burst load allowed for the multiplexor channel.

However, the following maximum load limits are used:

1. L_m cannot exceed 9.68 when *reading* and 7.65 when *writing*, when the channel-to-channel adapter is running on either of the selector channels. Here, reading refers to movement of data from a channel unit

to the CPU; writing refers to movement of data from the CPU to a unit.

2. If the channel-to-channel adapter is attached to selector channel one, the maximum load for selector channel two is 24.6 (assuming that the multiplexor channel is running) or 35.7 (assuming the multiplexor channel is not running).
3. If the channel-to-channel adapter is on selector channel two, the maximum load limit on selector channel one is 45.5 (assuming that the multiplexor channel is running).
4. If the multiplexor channel is not running and the channel-to-channel adapter is on one of the selector channels, then that channel's load limit is obtained from formula (F—I). However, there is a load limit on the other selector channel. Hence, if the channel-to-channel adapter is on selector channel one, then the load limit for selector channel two is:

   35.7

   If the channel-to-channel adapter is on selector channel two, then the load limit for selector channel one is:

   45.5

To obtain a load value for a selector channel to which the channel-to-channel adapter is connected, use formula (F—I). To do this, insert the data load values for the units on the other two channels in formula (F—I). Then solve for the remaining factor. Note, however, the limitations imposed on the other channels by the preceding steps (1) through (4). To convert the load value to kilobytes per second, divide the calculated load value by 0.2222.

The resulting value can be up to 500kb (kilobytes) per second if the channel-to-channel adapter is connected to a selector channel and no other units are operative on the other two channels. However, the value generated by the formula is a maximum. The actual rate is dependent upon the speed of response from the second system's channel that is attached to the channel-to-channel adapter. The second system's channel is also limited by units running on other channels of the second system and by the storage cycle rate of the second system.

In general, the channel-to-channel adapter can only run as fast as the slower of the two channels to which it connects.

The channel-to-channel adapter can be attached to the multiplexor channel, on System/360 Model 30, only when no selector channel is installed on the system. The channel-to-channel adapter *must* be attached to both selector channels for a channel-to-channel *wrap* (i. e., for interconnection of two channels on the same system).

The channel-to-channel adapter operates with the multiplexor channel only in burst mode. The maximum rate on the multiplexor channel is 200kb per second. However, if the channel on the other system, to which the channel-to-channel adapter is attached, operates at a lower rate, the 200kb rate will not be attained.

Figure 12 shows the various load limits on the selector channel to which the channel-to-channel adapter is not attached. For each entry in this figure, the farthest column on the left shows the selector channel on which the channel-to-channel adapter is assumed to be operating. The next column shows the channel for which the load limits apply. The load limits themselves are entered in the columns headed by the condition on the third channel (the remaining one of the three channels).

For example, if selector channel one has the channel-to-channel adapter, go to the first entry of the first column. To the right of this entry are two rows. The first row is labeled selector channel two (in second column). Now look across the chart to the value 24.6. This value means that, if the channel-to-channel adapter is on selector channel one, the load limit for selector channel two is 24.6 if the multiplexor channel is also running.

CHANNEL-TO-CHANNEL ADAPTER ON:		MULTIPLEXOR CHANNEL		SELECTOR CHANNEL ONE		SELECTOR CHANNEL TWO	
		Running	Not Running	Running	Not Running	Running	Not Running
Selector Channel One	Selector Channel Two	24.6	35.7				
	Multiplexor Channel					9.68 (read) 7.65 (write)	9.68 (read) 7.65 (write)
Selector Channel Two	Selector Channel One	45.5	45.5				
	Multiplexor Channel			9.68 (read) 7.65 (write)	9.68 (read) 7.65 (write)		

The load on the selector channel that is using the channel-to-channel adapter is given by the formula:

$L_1+L_2+2.5L_m = 111.1$ (where L_1 = load on selector channel one,
L_2 = load on selector channel two,
L_m = load on the multiplexor channel)

with the loads on the other channels not exceeding the limits given in this figure.

Conversion of load value to peak data rate is obtained by dividing load value by 0.2222 (i.e., $\frac{\text{Load}}{0.2222}$).
The resulting data rate is in kilobytes per second.

• Figure 12. Load Limits of Other Channels When Channel-to-Channel Adapter Is Used on a Selector Channel. Used for Evaluation of a System with a 2-Microsecond RW Cycle Only.

Step-by-Step Procedure for Determining Possible Overrun When the Multiplexor Channel Is Operating in Burst Mode Only

1. First determine the configuration involved and obtain the applicable data load and data chaining load values for the units involved (see Table 1 in *Appendix*).

2. If the channel-to-channel adapter is attached to a selector channel, do the following (if a buffered unit is used, treat it according to step 4.):
   a. Determine the load on the channel to which the channel-to-channel adapter is connected. Use formula F—I. (Refer to the *With the Channel to Channel Adapter Feature* section.)
   b. Determine if the units on the other channels are overloading their respective channels (see Figure 12). For this step use the no chaining data loads of the units involved. Do *not* use their data chaining loads whether or not data chaining is involved.
   c. Next consider the data chaining. If the data chained unit is on the multiplexor channel, use Figure 10 to calculate the allowed load. If the data chained unit is on a selector channel, use Figure 11 to calculate the allowed load. For these calculations, use the channel-to-channel adapter load, calculated in step (a), for the selector channel to which the channel-to-channel adapter is attached.

   Use the data chaining load of the unit (see Table 1 in *Appendix*) to compare to the calculated load limit of the channel on which the data chaining is performed. If the data chaining load of the unit exceeds the calculated limit for the channel, then the data chaining will overload the channel.

3. If a channel-to-channel adapter is not used, do the following (if a buffered unit is used, treat it according to step 4.):
   a. Refer to Figure 11 for each selector channel in turn. If a unit on a selector channel is data

chained, use the data-chaining column in Figure 11. Then find the entry, in Figure 11, that corresponds to the appropriate condition on the other selector channel (i.e., the condition indicated in the leftmost column of Figure 11). The entry referenced indicates the calculation to be made, the formula to be used, or directly, what the load limit is. If the data chaining load of the unit (see Table 1 in *Appendix*) is greater than this limit, the channel to which it is attached is overloaded (i.e., data overrun can occur if the unit is data chained).

b. If a selector channel unit is not data-chained, use the *no chaining or only command chaining* column in Figure 11. Units that are permissibly attached run at their rated speeds for this situation.

c. Next consider the unit on the multiplexor channel (refer to Figure 10). Use the appropriate column according to whether the unit is data chained or command-chained or not chained. If the unit is both command-chained and data chained, use the data chaining column. Then find the entry that corresponds to the statement, in the left-most column, which refers to the operations on the selector channels. Use the formula obtained from Figure 10. This formula is used to calculate a limit for the unit being investigated. Compare the value calculated to the unit's data load value (see Table 1 in *Appendix*). If the data load value of the unit exceeds the calculated value, overrun can occur.

4. If one or more units are buffered, the procedure is essentially the same as for (2) and (3). However, the following notes apply:

   a. Buffered units adjust their speeds of data transmission (to or from the buffer) according to the concurrent demands of units operating on the other channels. The main problem, then, is not one of overloading, but of determining the time taken to transfer the data to or from the buffer.

   b. On the selector channels, the buffer data transfer times are extended only by the actual time of a data chaining operation for that buffered unit (if the buffer is indeed data-chained).

   c. The load limit allowed to the multiplexor channel may be less than the listed data load value (see Table 1 in *Appendix)* for a buffered unit. In this case, the time of data transfer for the buffer is extended. The extension is calculated by multiplying the calculated minimum transfer time for the buffered unit by a ratio. The ratio is formed by dividing the data load value (from Table 1) for the buffered unit by the calculated load limit of the multiplexor channel.

   Also, the actual data chaining time, if any, performed with the buffered unit, and the actual command chaining and data chaining times executed on the selector channels must be added. However, this chaining must be performed during the short time required for the data transfer for the buffer. This can only be determined by inspection of the probable concurrence of these operations.

Examples of the Procedure

Example 1

The first step is to determine the configuration and operations involved. In this example:

1. A 2400 series tape drive model 1 (9 track) is reading (data movement from tape to main storage) on selector channel two. The tape drive is not chained in any way and its density is 800.
2. A 2311 (attached to a 2841) is writing (data movement from main storage to 2311) on selector channel one. Command chaining is also being performed for this unit.
3. An IBM 1403 Model 3 Printer (attached to a 2821) is operating on the multiplexor channel. The 1403 is not chained in any way.

The data load values for this configuration are obtained from Table 1 in *Appendix.* Using the appropriate data load values, construct a table for ease of reference:

Channel	*Unit*	*Chaining*	*Operation*	*Data Load*
Selector 2	2400-1	None	Reading	9.4
Selector 1	2311	Command	Writing	36.1
Multiplexor	1403-3	None	Writing	27.8

Before considering the multiplexor channel, determine the effects that the selector channels have on each other. Hence, refer to Figure 11 and look first at the label *Selector Channel Two.* Under this label, find two columns. Because selector channel two is not chaining, use the *Not Chaining or Only Command Chaining* column. We are, however, considering command chaining on selector channel one. Hence use the last row in the *Not Chaining or Only Command Chaining* column because that row corresponds to *Command Chaining* on the other selector channel (in this case, selector channel one). The referenced entry is then

Rated Speed[1]. This entry means that the magnetic tape unit (2400 series) can be run at its rated speed without overrun (i.e., loss of data). *Note 1* does not apply because we are *not* considering a 2311 or 2302 on selector channel *two*.

Now consider the 2311 on selector channel one. Looking at the *Selector Channel One* label (Figure 11), use the *Not Chaining or Only Command Chaining* column because the 2311 is command chaining. Also use the *Running, But Not Chaining* row because the tape drive on selector channel two is running but it is not chained. The entry then referenced is *Rated Speed*[1]. *Note 1* states that a 2311, run concurrently with a device on the other selector channel, may overrun if that other device is chaining or if it has a data load value greater than 17.5. The tape drive is not chaining and its data load value is 9.4, which is less than 17.5. Therefore, *Note 1* does not restrict the operation. Hence the 2311 can be run at its rated speed without overrun.

Now turn to the 1403-3 on the multiplexor channel. The 1403-3 is operating in burst mode. Refer to Figure 10. *Note 1* in this figure states that for all buffered units use formula (F—I). Formula F—I is:

$$L_m = \frac{111.1 - L_1 - L_2}{2.5}$$

L_2 is the data load of the unit on selector channel two. This value, for the tape drive, is 9.4. L_1 is the data load for the unit on selector channel one. This value, for the 2311, is 36.1. Inserting these values in formula (F—I), we obtain:

$$L_m = \frac{111.1 - 36.1 - 9.4}{2.5} = 26.24$$

This value (26.24) is the maximum calculated load limit at which the multiplexor channel unit can run. However, in the section *How to Calculate Channel Load Limits When the Multiplexor Channel Is Operating in Burst Mode Only,* under formula (F—I), we find a restriction. This restriction is that L_m cannot exceed 24.7 if both selector channels are running. This is the case in our example. However, the data-load value for the 1403 Model 3 printer (on the multiplexor channel) was found to be 27.8. Because 27.8 is greater than 24.7, data will be transferred at less than maximum buffer speed for the 1403 Model 3. Also, should the chaining for the 2311 coincide with the buffer operation, the chaining time must be added.

We conclude that overloading cannot occur for the configuration in this example but that the 1403-3 buffer time will be extended. Note that this extension will not cause a slow-down of the printer.

The time for the 1403 Model 3 buffer transmission (at maximum speed) can be found by using the appropriate formula in the *How to Calculate Buffer Transmission Times (Chaining Times Are Listed Here)* section. The formula is:

$$T = Rr$$

For the 1403 printer, r = 8.0 microseconds. For this example, assume that a full line is to be printed on the 1403. For the 1403, a full line of print is 132 characters. Hence, R = 132. Therefore:

$$T = 132 \times 8.0 = 1056 \text{ microseconds} = 1.056 \text{ milliseconds.}$$

Note that T is the *buffer transfer* time and it is *not* the time required to print the line on the 1403 printer.

For greater accuracy, the chaining time on the selector channel should be added.

In this example, however, the buffer is not operating at maximum speed because of the load imposed upon the system by the other operations. The time to load the 1403 buffer is extended. This extension can be found by using a ratio of the 1403-3 load value (27.8) to the actual load limit available to the multiplexor channel (24.7).

The ratio is:

$$\frac{27.8}{24.7} = 1.13$$

Now multiply this ratio by the maximum speed transfer time for the 1403 buffer:

$$(1.13)\ (1.056 \text{ ms}) = 1.193 \text{ milliseconds}$$

The transfer to the 1403 buffer then requires an increase of

$$1.193 - 1.056 = .137 \text{ milliseconds}$$

more time for this configuration than it would if operated at maximum speed. The cycle time of the printer (54.5 milliseconds, see Table 1) is increased by .137 milliseconds to 54.637 milliseconds.

Example 2

The configuration and operations for this example are:

1. A 2400 series tape drive model 1 (9 track) is reading on selector channel one. The tape drive is data chained and its density is 800.
2. A 2400 series tape drive model 1 (9 track) is writing on selector channel two. This tape drive is not chained in any way and its density is 800.
3. A 2540 and 1403 model 3 are attached to a 2821 on the multiplexor channel. The 2540 card reader is reading 80-column card records. The 2540 card punch is punching 80-column card records. The 1403-3 is printing 132 characters per line of print. Neither the 2540 nor the 1403 is chained in any way.

Again, we obtain the appropriate load values from Table 1 in *Appendix* and summarize in table form:

Channel	*Unit*	*Chaining*	*Operation*	*Data Load*
Selector 1	2400-1	Data (no TIC)	Reading	4.9*
Selector 1	2400-1	None	Reading	9.4**
Selector 2	2400-1	None	Writing	6.7
Multiplexor	2540-Punch	None	Writing	18.5
Multiplexor	2540-Reader	None	Reading	18.5
Multiplexor	1403-3	None	Writing	27.8

Notes:

*The 4.9 value (data-chaining load) is used to compare to the calculated selector channel one load unit.

**The 9.4 value (no chaining data load) is used in formula (F–I).

Refer to Figure 11 to determine the effects that the selector channels have on each other. Selector channel one is data-chaining and selector channel two is running but not chaining. Also, a TIC is not being performed on selector channel one. The entry for selector channel one is then:

$$5.79 - .234L \text{ (No TIC)}$$

Here, L is the load on the other selector channel, or 6.7. Therefore, the limit for selector channel one is:

$$5.79 - (.234)(6.7) = 4.22$$

The data chaining load value (4.9) for the tape drive on selector channel one is greater than the 4.22 value. Therefore, selector channel one cannot data chain the tape drive without overrun. However, note in Figure 11 that the tape drive on selector channel one can be operated at its rated speed without chaining or with command chaining only.

Selector channel two is not chaining. Therefore, the rated speed of the tape drive on selector channel two can be assumed for the load value of selector channel two. Hence the tape drive on selector channel two can be run at its maximum rate (data load value of 6.7).

Having determined that the units on the selector channels can be run, but that the tape drive on selector channel one cannot be data chained, we consider next the multiplexor channel. The first thing to notice is that only one buffered device at a time can be operated on the multiplexor channel because we are considering burst mode operation only. Referring to Figure 10, we notice that for buffered units we must use formula (F–I) for all cases. Formula F–I is:

$$L_m = \frac{111.1 - L_1 - L_2}{2.5}$$

The L_1 and L_2 values used in formula F–I are the data loads of units on the selector channels. The load value for the tape drive on selector channel one is 9.4. (The load value used here is *not* the data-chaining value of 4.9.) The load for the tape drive on selector channel two is 6.7.

Solving for L_m:

$$L_m = \frac{111.1 - 9.4 - 6.7}{2.5} = 38.0$$

In the *How to Calculate Channel Load Limits When the Multiplexor Channel Is Operating in Burst Mode Only* section, a restriction is placed on L_m. This restriction states that if both selector channels are running, then L_m cannot exceed 24.7. This value is greater than the load imposed by either the 2540 reader buffer or the 2540 punch buffer. However, the load value (27.8) for the 1403 exceeds the limit 24.7. This merely causes the load time of the 1403 buffer to be extended.

The formula for calculating the buffer transfer times is found in the *How to Calculate Buffer Transmission Times (Chaining Times Are Listed Here)* section of this publication. This formula is:

$$T = Rr$$

The buffer transfer times are then:

1. For the 2540 reader:
   r = 12 microseconds
   R = 80 bytes (80 card columns)
   T = (12)(80) = 960 microseconds or 0.96 milliseconds.
2. For the 2540 punch:
   r = 12 microseconds
   R = 80 bytes (80 card columns)
   T = (12)(80) = 960 microseconds or 0.96 milliseconds.
3. For the 1403 model 3 printer:
   r = 8 microseconds
   R = 132 bytes (132 print positions)
   T = (8)(132) = 1056 microseconds or 1.056 milliseconds.

However, the loading of the 1403 buffer is extended because of the 24.7 load factor allowed to the multiplexor channel in this configuration. To find the time extension for the 1403 buffer loading, divide the 1403 data load value by the calculated load value of the multiplexor channel:

$$\frac{27.8}{24.7} = 1.13$$

Multiply this ratio by the 1403 buffer load time:

$$(1.13)(1.056) = 1.193 \text{ milliseconds}$$

This is the time required to load the 1403 buffer in this configuration. The cycle time of the 1403 is extended, by this increase of .137 milliseconds, to 54.637 milliseconds.

Example 3

The configuration and operations for this example are:

1. A 2400 series tape drive model 3 (9 track) is reading on selector channel one. The tape drive is not chained in any way and its density is 800.
2. A channel-to-channel adapter is connected to selector channel two. No chaining is involved here.
3. A 2400 series tape drive model 1 (9 track) is reading on the multiplexor channel. The tape drive is data-chained.

To summarize (see Table 1 in *Appendix*):

Channel	*Unit*	*Chaining*	*Operation*	*Data Load*
Selector 1	2400-3	None	Reading	28.5
Selector 2	Chan.-to-Chan. Adp.	None	Reading or Writing	To be determined
Multiplexor	2400-1	None	Reading	9.4**
Multiplexor	2400-1	Data	Reading	4.9*

Notes:

*The 4.9 value (data-chaining load) is used for the data chaining.

**The 9.4 value (no chaining load) is used when data chaining is not considered.

First, calculate the load at which selector channel two will operate. The figure calculated here is a limit for the channel-to-channel adapter. Whether or not selector channel two will operate at this speed depends both on this calculated limit and the speed at which the other channel (to which the channel-to-channel adapter is connected) will run. The actual load is the smaller of the two (i.e., the limit calculated or the limit available on the other channel to which the channel-to-channel adapter is connected). For this example, assume that the channel-to-channel adapter will operate at the limit calculated for selector channel two.

The limit for selector channel two is calculated by using formula (F—I):

$$L_m = \frac{111.1 - L_1 - L_2}{2.5}$$

Here, we are solving for L_2. From our configuration, $L_m = 9.4$ and $L_1 = 28.5$. Substituting in formula (F—I):

$$9.4 = \frac{111.1 - 28.5 - L_2}{2.5}$$

Therefore, $L_2 = 59.1$, which is the load limit of selector channel two. Therefore, this is the load impressed upon selector channel two by the channel-to-channel adapter. (This was our assumption.) To convert this load value to kilobytes per second, divide by 0.2222. That is:

$$\frac{59.1}{.2222} = 266 \text{ kb/second}$$

To determine if the other two channels are overloaded refer to Figure 12. Look at the leftmost column in the figure. We choose the *Selector Channel Two* row of that column because the channel-to-channel adapter is attached to selector channel two. Now find the *Selector Channel One* column in the *Selector Channel Two* row. Now move across the same row to the *Multiplexor Channel* column. We use the *Running* section of this column because the multiplexor channel is running. The entry selected is then 45.5. However, the load on selector channel one for the configuration in this example is 28.5. Because 28.5 is less than 45.5 (from Figure 12), then selector channel one is not overloaded.

Next look at the *Multiplexor Channel* entry (second column from left) in the *Selector Channel Two* row in Figure 12. Look across to the *Running* part of the *Selector Channel One* column. The entry found is 9.68 for reading, which is being done on the multiplexor channel. However, the tape unit on the multiplexor channel has a load of 9.4, which is less than the 9.68 value. Therefore, the multiplexor channel is not overloaded.

The next question is, "Can the tape unit on the multiplexor channel be data chained, as we have set up in our configuration?" Referring to Figure 10, we use the *Data Chaining* column and the *One or Both Running But No Chaining* row. The entry found is F—IV. Formula (F—IV) is:

$$L_m = 7.42 \left[\frac{1000 - 9(L_1 + L_2)}{1000}\right] \quad \text{(No TIC)}$$

In our example, $L_1 = 28.5$, and calculation has shown that $L_2 = 59.1$.

Substituting in F—IV:

$$L_m = 7.42 \left[\frac{1000 - 9(28.5 + 59.1)}{1000}\right]$$

Therefore, $L_m = 1.57$, which is the load limit for data chaining on the multiplexor channel in this example. This limit is less than the data-chaining load value (4.9) for the tape drive on the multiplexor channel. Therefore, the tape drive cannot be data-chained, but, as previously determined, it can be run without data chaining.

Note that the tape drive on the multiplexor channel could be command chained (in this example) because the tape drive is not time dependent upon command chaining.

Procedure for Evaluating the Multiplexor Channel Loading (Multiplex Mode) for an IBM System/360 Model 30 with a 2-Microsecond RW Cycle

The information already presented in the *Calculating the Multiplexor Channel Load When Operating in Multiplex Mode* for a system with a 1.5-microsecond RW cycle is applicable to a system with a 2-microsecond RW cycle, with the following exceptions:

1. The selector channel's evaluation, that must be made before the multiplexor channel evaluation is attempted, is done by using the *When the Multiplexor Channel Is Operating in Burst Mode Only* subsection of *Section II-B.*
2. The load limit compared to, in the multiplexor channel evaluation, is 75 for a system with a 2-microsecond RW cycle (rather than the 100 value used for the system with a 1.5-microsecond RW cycle).

Hence, with the two exceptions just noted, the following section and its subsections apply to both the system with a 1.5-microsecond RW cycle and to the system with a 2-microsecond RW cycle: *Calculating the Multiplexor Channel Load When Operating in Multiplex Mode.* Also, the load values shown for the 15- and 31-line 2702's, at the bottom of the 2702 worksheet (see Figure 8) must be multiplied by .75 when calculating for a Model 30 with a 2-microsecond RW cycle.

How to Calculate Buffer Transmission Times (Chaining Times Are Listed Here)

When data is sent to a buffer (or received from a buffer) the following formula is used to calculate the time required (in microseconds) for the data transfer in multiplex mode:

(F—VIII) $$T \text{ (in microseconds)} = [42.0 + r(N-1)]\frac{R}{N}$$

where

N = the number of bytes sent or received by the buffer for each servicing by the channel.

r = the time to send each successive byte after the first one of the group. Note that the r and N values for the different buffered units are:

- 1403 Printers
  r = 8.0 microseconds
  N = 4
- 2540 Reader
  r = 19.5 microseconds
  N = 2
- 2540 Punch
  r = 24.5 microseconds
  N = 2
- 1443-N1 or 1445-N1 Printer
  r = 16.2 microseconds
  N = 2, or N = 4 (depending upon mode of operation)
  Note: For the 1443 or 1445 only, replace the term 42.0 (in formula F—VIII) by 58.2.
- 2520 Punch
  r = 20.0 microseconds
  N = 2

R = the total number of bytes transferred. R could be either an entire record from a buffer (i.e., 80 bytes from the buffer for the 2540 reader) or less than the capacity of the buffer if transfer is halted by the channel prior to when the capacity of the buffer is reached.

Note, however, that unbuffered units can also be running on the multiplexor channel (in multiplex mode). Recall that the unbuffered units are attached to the channel in a higher priority location than the buffered units. Hence, an unbuffered unit, when it is ready for a data transfer, obtains use of the channel before the buffered unit (in simultaneous requests for service). Therefore, when buffered and unbuffered units are both operating (in multiplex mode), unbuffered unit channel times must be added to the buffer times calculated from formula (F—VIII).

An approximate total time is obtained by multiplying formula (F—VIII) by:

$$\frac{1}{1-.189L}$$

Here, L is the total data load of all the units of higher priority that are running concurrently with the buffer transmission (or reception) on the multiplexor channel. For the 2702, use a data load of .43 (15-line version) or .22 (31-line version). If the selector channels are also transmitting data during the buffer data transfers and the buffer is running in *either* burst or multiplex mode, then multiply formula (F—VIII) by:

$$\frac{1000}{1000-9L}$$

where L is the total data load of both selector channels.

If the selector channels are chaining, during the buffer transmission or reception time, then these chaining times should be added. Also, any data-chaining time that is used with the buffer operation should be added. This situation, however, adds an undue complexity to precise calculation for the amount of additional accuracy it gives.

For a closer approximation, then, add chaining times for each selector channel and the time for the buffer unit chaining.

Hence, in the user's judgment, if chaining is likely to occur during the buffer operation, the following basic chaining times may be added:

1. Selector channel chaining
   - Command chaining
     51.0 microseconds (no TIC)
     63.0 microseconds (with a TIC)
   - Data chaining
     38.0 microseconds (no TIC)
     54. 0 microseconds (with a TIC)
2. Multiplexor channel chaining
   - Data chaining
     25.0 microseconds (no TIC)
     33.0 microseconds (with a TIC)
   - Command chaining
     145 microseconds (no TIC)
     153 microseconds (with a TIC)

The preceding considerations apply to the buffer only when operating in multiplex mode on the multiplexor channel.

If the buffer is operating in burst mode on any channel, the formula for the time of data transfer is:

(F—IX) $T = Rr$

Where R is the number of bytes transmitted, and r is as follows:

Device	*r*
1403	8
2540 Reader	12
2540 Punch	12
1443-N1	16.2
1445-N1	16.2

Formula (F–IX) is used to calculate the time for a buffered unit's transfer in burst mode. Suppose, however, that the load limit available on the channel is less than the load required by a buffered unit. The extended time for the buffer transfer is then calculated as follows:

1. Divide the data load value for the buffered unit (data load value from Table 1 in *Appendix)* by the load limit allowed on the channel.
2. Calculate the buffered unit's minimum transfer time by use of formula (F–IX).
3. Multiply the factor obtained in step 1 by the time obtained in step 2. The result is the time for the buffered unit's transfer within the load available on the multiplexor channel (burst mode only).

How to Calculate Channel Interference with CPU Processing Time

Interference with the microprogram control of the processing unit occurs, to some degree, whenever a channel services an I/O unit. The type and amount of interference differs according to the channel (multiplexor or selector) causing the interference.

Each time a selector channel sends a byte of data to an I/O unit (or receives a byte of data from an I/O unit), the processing unit program is stopped. The program is stopped only for the amount of time required to store or read out the byte of data from main storage. This time is 2 microseconds (for a model 30 processing unit that has a 2-microsecond RW cycle). Therefore, for every transfer of a byte of data on a selector channel, there is an interference of 2.0 microseconds with the processing unit.

When a selector channel is command-chaining or data-chaining, then that channel uses the microprogram controls of the processing unit. Here, the full chaining time, plus any selection time to an I/O unit (during command chaining), interferes with the processing unit program. That is, the processing unit program is stopped for the total chaining and selection times involved.

The multiplexor channel interferes with the processing unit program to a greater degree than do the selector channels. This is because the multiplexor channel uses the microprogram controls for both chaining and data handling operations.

The multiplexor channel operates in either burst or multiplex mode, depending upon the I/O unit involved in the operation. When the multiplexor channel operates in burst mode, it is interlocked with the I/O unit from the time of selecting that unit to the receipt of channel end from the unit. Because it is using the microprogram control of the processing unit, the multiplexor channel causes 100% interference with the processing unit during this entire time (i.e., from selection to channel end).

When operating in multiplex mode, the amount of processing unit interference caused by the multiplexor channel depends upon the frequency of requests for service from the I/O units being multiplexed. When the total number of bytes multiplexed (from or to the I/O units) is less than 12,000 bytes per second, each request for service interferes with processing-unit microprogram operations for 83.0 microseconds. This time period is required to:

1. Store the contents of the processing unit registers into local storage.
2. Service the request.
3. Restore the processing unit registers so that the processing unit program that was interrupted can continue.

Each byte of data, handled by the multiplexor channel, causes this amount (83.0 microseconds) of interference with the processing unit. If the number of bytes multiplexed exceeds 12,000 bytes per second for any period, then 100% interference is caused with the processing unit for that period of time.

Buffered units operating in multiplex mode on the multiplexor channel cause the channel to run at top speed. During the buffer transfer of data, there is 100% interference with the processing unit, regardless of the other units that may be multiplexed with the buffered unit. Hence, the problem here is to calculate the time taken by the buffer's data transfer. We can then take this time and determine how much processing unit interference is caused.

The formula used for this calculation is in the *How to Calculate Buffer Transmission Times (Chaining Times Are Listed Here)* section of this publication. Note that the CPU Interference values in Table 1 (*Appendix*) are given for the 1.5-microsecond system only. Do not use these figures for the 2-microsecond system.

Having calculated the buffer time, the next question is "How much is the buffer's time extended by the multiplexed units (of higher priority than the buffered unit) and by selector channel operations?" The extension can be calculated by the appropriate formulas given in the *How to Calculate Buffer Transmission Times (Chaining Times Are Listed Here)* section.

In general, for unbuffered units being multiplexed, multiply the number of bytes transmitted over the multiplexor channel (during the time being investigated for processing unit interference) by 83.0. The result is the time in microseconds that the multiplexor channel takes from the processing unit program.

If the total byte rate exceeds 12,000 bytes per second, the product obtained may indicate processing unit interference for the entire period of time considered. If this is so, it means that there is 100% of interference with the processing unit. To handle this apparent overload, the channel must operate at its fastest rate. What happens here is that the processing unit registers are stored in local storage only at the beginning of the period of time in which the multiplexor channel is operating at its fastest rate. The processing unit registers are not restored for each service request. Hence, there is no overlapping with the processing unit program. At the end of this operation (i.e., when the multiplexor channel rate is lowered below 12,000 bytes per second) the processing unit registers are restored from local storage and program processing continues. Note that the faster the multiplexor channel operates, the less frequently the operations of storing and restoring of the processing unit registers occurs.

In summation of the preceding considerations, the following procedure is used to calculate interference of the processing unit by the channels. That is, in order to determine how much processing unit time is available for program processing (during some period, T, of the data processing cycle), subtract the following items from T, when applicable:

1. For each unit running on a selector channel during time T, subtract 2n where,

   n = number of bytes transmitted during time T.

2. For any device operating in burst mode on the multiplexor channel, subtract from time T the entire time of the unit's cycle (from the selection of the unit to channel end for that unit). If this period does not wholly fall within time T, then only subtract the portion that does. The time from selection to channel end for a unit depends upon the unit and hence must be determined from that unit's cycle time.

3. For any group of units being multiplexed during time T, subtract the product of 83.0 times the number of bytes transferred.

4. For any buffer transmission being executed during time T, multiply the load value for that unit (from Table 1 in *Appendix*) by the number of bytes in the buffer transfer. Then subtract this product from time T.

   A refinement of this calculation can be made when the buffer's data transfer is multiplexed with unbuffered units. The effect of this is to extend the buffer time by the factor:

   $$\frac{1}{1-.189L}$$

   where L is the total load of the other, higher priority, multiplexed units. Use the data load values for the units (i.e., from Table 1 in *Appendix*). For the 2702, use a data load of .43 (15-line version) or .22 (31-line version).

   Concurrent action on the selector channels further extends the buffer time by the factor (refer to the *How to Calculate Buffer Transmission Times (Chaining Times Are Listed Here* section):

   $$\frac{1000}{1000-9L}$$

   Here, L is the sum of the data loads of the units on the selector channels.

   Although in most cases it makes little difference, a finer correction for interference can be made here by not counting the bytes transmitted from the higher priority devices during the time that a data transfer to or from a buffer is being made.

5. Finally, consideration must be given to START I/O, selection, end sequences, and chaining times. The number of times that these items occurs can only be determined by inspection. For each item, the following table indicates the amount of interference time to subtract from time T:

Operation	*Selector Channel Time (in microseconds)*	*Multiplexor Channel Time (in microseconds)*
Start I/O	57.0*	57.0*
Selection	0	61.0 + 1.5n
Data Chaining	38.0**	25.0**
Command Chaining	51.0** + 1.5n	145** + 1.5n
End Sequences	0	93.0

*This time is really processing-unit time, which is interruptible by the channels.

**If a TIC is used, add the following:
1. For a selector channel — 12 microseconds
2. For the multiplexor channel — 8 microseconds

n = priority of order of a unit (1-8). For the unit of highest priority, n = 1.

After the preceding amounts have been subtracted from time T, the remaining time is the amount that can be used by the processing unit program.

An Example of Calculating Interference with CPU Processing

Suppose that, during time T, the following functions are performed by the channels:

1. A 2401 Model 1 tape drive, on selector channel one, is reading three data blocks of 1000 bytes each. No chaining, of any type, is being performed.
2. A 2401 Model 1 tape drive, on selector channel two, is writing three data blocks of 1000 bytes each. Every 100 bytes is data-chained. Nine data-chaining operations, therefore, are required for each 1000 bytes.
3. On the multiplexor channel:
   a. A 2501 Model B2 card reader reads two cards (80 columns each). The operation for the second card is command-chained.

b. A 2520 Model B2 card punch punches one card (80 columns).

c. A 1403 Model 3 printer prints two lines, each containing 132 characters. The operation for the second line is command-chained.

The tape drive on selector channel one requires about 137 milliseconds to read its data. The tape drive on selector channel two requires about 138 milliseconds for its write operation. During this time, the two lines of print, for the 1403 printer, take approximately 109 milliseconds and the two cards are read by the 2501 in about 120 milliseconds. The 2520 takes about 120 milliseconds to punch the one card.

Let us assume, then, that we wish to determine the processing unit interference during the 138 millisecond period required for the tape-drive writing operation (on selector channel two).

We use the following procedure:

1. During the period of time in question, 3000 bytes of data were read from the tape drive on selector channel one. Also, 3000 bytes of data were written on the tape drive on selector channel two. At an interference of 2.0 microseconds per byte, the total number of bytes transferred on the two selector channels (i.e., 6000 bytes) requires 12 milliseconds of interference to the processing unit.
2. We note that no unit is operating in burst mode on the multiplexor channel.
3. The 2501-B2 card-reader reads 160 bytes of data (in reading the two cards). At 83 microseconds of interference per byte, this amounts to 13.28 milliseconds of processing unit interference.

   The 2520-B2 card punch punches 80 columns, or bytes of data, but is buffered. To calculate the interference for this unit will require the same procedure as for the 1403. The calculation is shown later.
4. The 1403 printer is buffered. The procedure here is that first we shall calculate the buffer time and its extension due to the higher priority multiplexed units. The buffer time of the 1403 can be calculated from the formula given in the *How to Calculate Buffer Transmission Times (Chaining Times Are Listed Here)* section of this publication. The buffer transfer time thus calculated for the 1403 printer is 2.18 milliseconds. The transfer, however, is extended by the factor:

$$\frac{1}{1-.189L}$$

Here, L is the sum of all the data load values of the higher priority multiplexed units (i.e., refer to Table 1 in *Appendix*). This value is .47 for the 2501-B2. The extended buffer time is then:

$$2.18 \text{ ms}\left(\frac{1}{1-.189\times.47}\right)=2.4 \text{ ms}$$

The buffer transfer time, for the 1403 printer, will be extended further by selector channel data handling. This extension can be obtained by using the factor:

$$\frac{1000}{1000-9L}$$

Here, L is the sum of the data loads of the tape drives on the selector channels:

Unit		*Load Value*
2401-1 (reading)		9.4
2401-1 (writing)		6.7
	Total	16.1

Hence,

$$\frac{1000}{1000-9\times16.1}=\frac{1000}{855.1}$$

The further extended time is then:

$$2.4\left(\frac{1000}{855.1}\right)=2.8 \text{ ms}$$

If we wished to refine the calculation further, we could consider how many bytes of data could, at most, be handled by the channel from the higher priority units during this extended buffer time. The resulting time, multiplied by 83, could then be subtracted from the total interference because the preceding extension of buffer time considers this overlay problem. Usually such refinement exceeds the need of accuracy in calculating the programming time.

During a period, then, of 2.8 milliseconds how many bytes could the other unit handle (namely the 2501)? Note that the minimum time between bytes for this unit is:

Unit	*Time*
2501-B2	.473 ms

This time (in microseconds) is obtained by dividing 222.2 by the data load of the unit (from Table 1 in *Appendix*).

Divide this number into 2.8. (Any fractional quotient is rounded off to the next whole number.) Then, multiply the quotient by 83 microseconds. We can subtract this product from the processing unit interference.

In our example, then, we have:

Unit	*Bytes*
2501-B2	$6=\frac{2.8}{.473}$ (Rounded off)

Hence:

6×83 microseconds $=.498$ milliseconds

This is the amount by which the processing unit interference can be reduced. It should be noted, however, that the subtraction (a reduction of the interference caused to the processing unit) can be done only if data is being transmitted to or from the multiplexed unbuffered units during the buffer data transfer. This can only be determined by inspecting the coincidence of operations of the different units.

Because two lines are printed in period T, we must double the preceding figures. This results in 5.6 ms of interference and .996 ms of interference reduction.

The calculation of the interference due to the 2520-B2 is done in exactly the same manner as for the 1403. This unit is buffered and the procedure is the same for all buffered units.

The calculation of CPU interference for the 2520, then, will give:

Buffer time = 2.48 milliseconds
Extension due to 2501-B2 = 2.73 milliseconds
Extension due to Selector Channels = 3.19 milliseconds
Reduction of Interference = .581 ms.

5. Our last consideration is the special operation, such as selection, chaining, etc. Hence, for this operation:

Operation	*Multiplexor Channel*	*Selector Channel*
Start I/O	3 times	6 times
Selection	3 times	0
Data Chaining	0	27 times
Command Chaining	2 times	0
End Sequences	3 times	0

Multiplying each of these operations by its respective time, we obtain:

Operation	*Multiplexor Channel*	*Selector Channel*
Start I/O	.171 ms	.342 ms
Selection	.192* ms	. . .
Data Chaining	. . .	1.026 ms
Command Chaining	.296* ms	. . .
End Sequences	.279 ms	. . .
Totals	.938 ms	1.368 ms

Grand Total = .938 + 1.368 = 2.3 ms (of interference)

*This includes polling time of 1.5n (refer to the *How to Calculate Channel Interference with CPU Processing Time* section).

The interference can now be added (from the 5 preceding steps):

Step	*Interference (in milliseconds)*
1	12.0
2	0.0
3	13.28
4	3.19
4	5.6
5	2.3
	36.37
Minus corrections from step 4:	−1.58
Interference total of:	34.79

Because the total period of time considered is 138 milliseconds, the amount of time available for use by the processing unit is:

$$138 - 34.79 = 103.2 \text{ milliseconds}$$

Input-Output Device	Key	Nominal Data Rate (kb/sec)	Gap or Cycle Time (in ms)	Data Load	Selector Channel Load Function Time (in ms)	Selector Channel Load Function A	Selector Channel Load Function B	Waiting Time (in ms)	Multiplexor Channel Device Load	Multiplexor Channel Previous Load	Multiplexor Channel CPU Interference (in us)	Multiplexor Channel Load Function Time (in ms)	Multiplexor Channel Load Function A	Multiplexor Channel Load Function B
Console														
1052 Printer-Keyboard	3M	.0148	Var	—	—	—	—	70.0	.047	—	—	—	—	—
Punched Card I/O and Printers														
1442-N1 Card Read Punch Reading (400 CPM) EBCD	1M	.533	150	0.56	.100 2.80	— 0.59	0.38 0.17	.800	11.6	12.0	62.3	.096 1.30 2.80	9.60 — 34.2	— 7.90 3.50
Card Image	1M	1.067	150	1.11	.100 2.80	— 1.17	0.75 0.33	.800	19.5	12.0	62.3	.096 .265 2.80 80.0	9.60 — 24.8 600.	— 16.1 7.20 —
Punching (91 CPM) EBCD	3M	.121	656.3	.0356	.100	—	.024	11.0	0.75	0.87	62.3	.096 20.4	9.60 —	— 0.51
Card Image	3M	.243	656.3	.0712	.100	—	.048	11.0	1.25	0.87	62.3	.096 10.4	9.6 —	— 1.03
1442-N2 Card Punch Punching (91 CPM) EBCD	3M	.121	656.3	.0356	.100	—	.024	11.0	0.75	0.87	62.3	.096 20.4	9.60 —	— 0.51
Card Image	3M	.243	656.3	.0712	.100	—	.048	11.0	1.25	0.87	62.3	.096 10.4	9.60 —	— 1.03
1443-N1 (or 1445-N1*) Printer 13 Char Set (600 LPM)	3M	1.44	100	13.7	.100 2.33	— 21.7	9.3 —	18.5	18.8	0.56	24.1	.100 3.47	— 347.	100. —
39 Char Set (300 LPM)	3M	.72	200	13.7	.100 2.33	21.7	9.3 —	18.5	18.8	0.56	24.1	.100 3.47	— 347.	100. —
52 Char Set (240 LPM) (Standard)	3M	.58	250	13.7	.100 2.33	— 21.7	9.3 —	18.5	18.8	0.56	24.1	.100 3.47	— 347.	100. —
63 Char Set (200 LPM)	3M	.48	300	13.7	.100 2.33	— 21.7	9.3 —	18.5	18.8	0.56	24.1	.100 3.47	— 347.	100. —
Byte-Burst Switch set for Burst Mode all char sets	3B	same	same	13.7	.100 2.33	— 21.7	9.3 —	18.5	—	—	16.2	—	—	—
2501 Card Reader Model B1 (600 CPM) EBCD	1M	.80	100	0.48	.100 38.4	— 12.3	0.32 —	.915	11.0	10.5	62.3	.104 38.5	10.4 7.00	6.60 —
Card Image	1M	1.60	100	0.95	.100 38.4	— 24.6	0.64 —	.915	18.4	10.5	62.3	.104 38.5	10.4 13.7	13.2 —
2501 Card Reader Model B2 (1000 CPM) EBCD	1M	1.33	60	0.47	.100 38.4	— 12.3	0.32 —	.915	11.0	10.5	62.3	.104 38.5	10.4 7.0	6.60 —
Card Image	1M	2.67	60	0.95	.100 38.4	— 24.6	0.64 —	.915	18.4	10.5	62.3	.104 38.5	10.4 13.7	13.2 —
2520 Card Read-Punch Model B1 Reading EBCD	1M	0.67	120	0.42	.100 43.4	— 12.1	0.28 —	1.02	9.6	9.4	62.3	.096 1.87 48.2	9.6 — 284.	— 5.8 —
Card Image	1M	1.33	120	0.84	.100 43.4	— 24.2	0.56 —	1.02	16.0	9.4	62.3	.096 1.87 48.2	9.6 — 573.	— 11.6 —

Key:
- 1- May be overrun.
- 2- Will not overrun; synchronous mechanical operation.
- 3- Will not overrun; asynchronous mechanical operation.
- -B Burst mode operation on Multiplexor Channel.
- -M Multiplex mode operation on Multiplexor Channel.

*All entries are the same for 1445 except nominal data rate and cycle time.

Table 1, Part 1. IBM System/360 Model 30 Channel Loading and CPU Interference Table

Input-Output Device	Key	Nominal Data Rate (kb/sec)	Gap or Cycle Time (in ms)	Data Load	Selector Channel Load Function: Time (in ms)	Selector Channel Load Function: A	Selector Channel Load Function: B	Waiting Time (in ms)	Multiplexor Channel: Device Load	Multiplexor Channel: Previous Load	Multiplexor Channel: CPU Interference (in us)	Multiplexor Channel Load Function: Time (in ms)	Multiplexor Channel Load Function: A	Multiplexor Channel Load Function: B
Punching EBCD	2M	0.67	120	22.2	.100 .800	— 80.0	100. —	9.0	24.0	1.07	25.8	.096 2.16	— 216.	100. —
Card Image	2M	1.33	120	22.2	.100 1.60	— 160.	100. —	9.0	46.9	1.07	25.8 -	.096 4.22	— 422.	100. —
Read-Punch EBCD	1M	1.33	120	Read 0.42 Punch 22.2	.100 .841 32.4	— 84.1 75.0	100. — 0.28	Read 1.02 Punch 9.0	Read 9.6 Punch 24.0	Read 9.4 Punch 1.07	Read 62.3 Punch 25.8	.100 2.16 27.7 76.8	— 216. — 499.	100. — 6.50 —
Card Image	1M	2.67	120	Read 0.84 Punch 22.2	.100 1.64 33.8	— 164. 146.	100. — 0.56	Read 1.02 Punch 9.0	Read 16.0 Punch 46.9	Read 9.4 Punch 1.07	Read 62.3 Punch 25.8	.100 4.22 26.8 78.5	— 422. — 1020.	100. — 13.0 —
Model B2 (500 CPM) Punch EBCD	2M	0.67	120	22.2	.100 .800	— 80.0	100. —	9.0	24.0	1.07	25.8	.096 2.16	— 216.	100. —
Card Image	2M	1.33	120	22.2	.100 1.60	— 160.	100. —	9.0	46.9	1.07	25.8	.096 4.22	— 422.	100. —
Model B3 (300 CPM) Punch EBCD	2M	0.40	200	22.2	.100 .800	— 80.0	100. —	15.0	14.4	0.64	25.8	.096 2.16	— 216.	100. —
Card Image	2M	0.80	200	22.2	.100 1.60	— 160.	100. —	15.0	28.1	0.64	25.8	.096 4.22	— 422.	100. —
2540 Card Read-Punch Reader Std. (1000 CPM) MPX Mode EBCD	2M	1.33	60	18.5	.100 .960	— 12.0	12.5 —	6.5	32.9	1.57	25.5	.100 2.14	— 214.	100. —
Card Image	2M	2.67	60	18.5	.100 1.92	— 24.0	12.5 —	6.5	64.2	1.57	25.5	.100 4.18	— 418.	100. —
Burst Mode	2B	same	60	18.5	same	same	same	6.5	16.2	—	12.0	—	—	—
Reader 51 Col MPX Mode EBCD	2M	1.07	75	18.5	.100 .612	— 2.65	12.5 —	8.0	17.8	1.28	25.5	.100 1.42	— 142.	100. —
Card Image	2M	2.13	75	18.5	.100 1.22	— 15.3	12.5 —	8.0	33.7	1.28	25.5	.100 2.70	— 270.	100. —
Burst Mode	2B	same	same	18.5	same	same	same	8.0	8.85	—	12.0	—	—	—
Punch (300 CPM) MPX Mode EBCD	2M	0.40	200	18.5	.100 .960	— 12.0	12.5 —	14.0	16.7	0.73	28.0	.100 2.34	— 234.	100. —
Card Image	2M	0.80	200	18.5	.100 1.92	— 24.0	12.5 —	14.0	32.7	0.73	28.0	.100 4.58	— 458.	100. —
Burst Mode	2B	same	same	18.5	same	same	same	14.0	7.54	—	12.0	—	—	—
Punch Feed Read (300 CPM)	2M	0.80	200	18.5	.960 12.9	96.0 189.	— —	14.0	31.3	0.73	—	2.34 13.7	234. 357.	— —
1403 Model 2 (600 LPM) (Includes Univ Char Set except cycle time)	3M	1.32	100	27.8	.100 1.06	— 19.8	18.8 —	15.7	12.2	0.65	13.9	.100 1.92	— 192.	100. —
Burst Mode	3B	1.32	100	27.8	same	same	same	15.7	6.75	—	8.0	—	—	—
1403 Model 3 (1100 LPM) Model N1 (Includes Univ Char Set except cycle time)	3M	2.42	54.5	27.8	.100 1.06	— 19.8	18.8 —	15.7	12.2	0.65	13.9	.100 1.92	— 192.	100. —
Burst Mode	3B	2.42	54.5	27.8	same	same	same	15.7	6.75	—	8.0	—	—	—

Key:
- 1- May be overrun.
- 2- Will not overrun; synchronous mechanical operation.
- 3- Will not overrun; asynchronous mechanical operation.
- -B Burst mode operation on Multiplexor Channel.
- -M Multiplex mode operation on Multiplexor Channel.

Table 1, Part 2. IBM System/360 Model 30 Channel Loading and CPU Interference Table

Input-Output Device			Key	Nominal Data Rate (kb/sec)	Gap or Cycle Time (in ms)	Data Load	Data Chain-ing Load	Priority Load								
								No Data Chain			Data Chaining					
											Count=20			Count=100		
								Time (in ms)	A	B	Time (in ms)	A	B	Time (in ms)	A	B
Magnetic Tape																
READING																
MDL	Den-sity	Byte Conv														
1	200	No	1B	7.5	20.0	2.4	1.2	.100 3.16	5.03	1.59	.100 1.37	5.03 .795	3.09	.100 1.37	5.03 2.44	1.89
		Yes	1B	5.6	20.0	2.4	1.2	.100 4.22	5.03	1.19	.100 1.82	5.03 -.62	2.70	.100 1.82	5.03 1.58	1.49
	556	No	1B	20.8	20.0	6.5	3.3	.100 1.14	5.03	4.42	.100 .493	5.03 .795	8.60	.100 .493	5.03 2.44	5.26
		Yes	1B	15.6	20.0	6.5	3.3	.100 1.52	5.03	3.3	.100 .660	5.03 -.62	7.51	.100 .660	5.03 1.58	4.15
	800	No *	1B	30.0	16.0	9.4	4.9	.100 .791	5.03	6.36	.100 .342	5.03 .795	12.4	.100 .342	5.03 2.44	7.58
		Yes	1B	22.5	20.0	9.4	4.9	.100 1.05	5.03	4.77	.100 .457	5.03 -.62	10.8	.100 .457	5.03 1.58	5.98
2	200	No	1B	15.0	10.0	4.7	2.4	.100 1.59	5.03	3.18	.100 .686	5.03 .795	6.18	.100 .686	5.03 2.44	3.78
		Yes	1B	11.3	10.0	4.7	2.4	.100 2.12	5.03	2.38	.100 .915	5.03 -.62	5.40	.100 .915	5.03 1.58	2.98
	556	No	1B	41.7	10.0	13.1	6.8	.100 .57	5.03	8.84						
		Yes	1B	31.3	10.0	13.1	6.8	.100 .762	5.03	6.62						
	800	No *	1B	60.0	8.0	18.8	10.1	.100 .396	5.03	12.7						
		Yes *	1B	45.0	10.0	18.8	10.1	.100 .529	5.03	9.55						
3	200	No *	1B	22.5	6.7	7.1	3.6	.100 1.06	5.03	4.77	.100 .457	5.03 .795	9.30	.100 .457	5.03 2.44	5.67
		Yes	1B	16.9	6.7	7.1	3.6	.100 1.41	5.03	3.57	.100 .608	5.03 -.62	8.10	.100 .608	5.03 1.58	4.48
	556	No	1B	62.5	6.7	19.7	10.5	.100 .379	5.03	13.3						
		Yes	1B	46.9	6.7	19.7	10.5	.100 .505	5.03	9.95						
	800	No *	1B	90.0	5.3	28.5	15.8	.100 .262	5.03	19.3						
		Yes	1B	67.5	6.7	28.5	15.8	.100 .348	5.03	14.5						

* Gap time nine track only.
Loads for seven or nine tracks.

Key:
1- May be overrun.
-B Burst mode operation on Multiplexor Channel.

Table 1, Part 3. IBM System/360 Model 30 Channel Loading and CPU Interference Table

Input-Output Device			Key	Nominal Data Rate (in kb/sec)	Gap or Cycle Time (in ms)	Data Load	Data Chaining Load	Priority Load								
								No Data Chain			Data Chaining					
											Count=20			Count=100		
								Time (in ms)	A	B	Time (in ms)	A	B	Time (in ms)	A	B
Magnetic Tape																
WRITING																
MDL	Den-sity	Byte Conv														
1	200	No	1B	7.5	20.0	1.7	1.7	.100 4.46	5.03 —	— 1.13	.100 1.93	5.03 .785	— 2.19	.100 1.93	5.03 2.44	— 1.34
		Yes	1B	5.6	20.0	1.7	1.7	.100 5.96	5.03 —	— 8.44	.100 2.58	5.03 .095	— 1.91	.100 2.58	5.03 2.31	— 1.06
	556	No	1B	20.8	20.0	4.6	4.6	.100 1.61	5.03 —	— 3.13	.100 .696	5.03 .785	— 6.10	.100 6.96	5.03 2.44	— 3.73
		Yes	1B	15.6	20.0	4.6	4.6	.100 2.15	5.03 —	— 2.35	.100 .928	5.03 .095	— 5.32	.100 .928	5.03 2.31	— 2.94
	800	No *	1B	30.0	20.0	6.7	6.7	.100 1.12	5.03 —	— 4.51	.100 .483	5.03 .785	— 8.80	.100 .483	5.03 2.44	— 5.37
		Yes	1B	22.5	20.0	6.7	6.7	.100 1.49	5.03 —	— 3.38	.100 .644	5.03 .095	— 7.66	.100 .644	5.03 2.31	— 4.23
2	200	No	1B	15.0	10.0	3.3	3.3	.100 2.23	5.03 —	— 2.25	.100 .967	5.03 .785	— 4.39	.100 .967	5.03 2.44	— 2.68
		Yes	1B	11.3	10.0	3.3	3.3	.100 2.98	5.03 —	— 1.69	.100 1.29	5.03 .095	— 3.83	.100 1.29	5.03 2.31	— 2.12
	556	No	1B	41.7	10.0	9.3	9.3	.100 .804	5.03 —	— 6.25	.100 .348	5.03 .785	— 12.2	.100 .348	5.03 2.44	— 7.45
		Yes	1B	31.3	10.0	9.3	9.3	.100 1.07	5.03 —	— 4.69	.100 .464	5.03 .095	— 10.6	.100 .464	5.03 2.31	— 5.88
	800	No *	1B	60.0	8.0	13.3	13.3	.100 .559	5.03 —	— 9.00						
		Yes *	1B	45.5	10.0	13.3	13.3	.100 .748	5.03 —	— 6.74						
3	200	No *	1B	22.5	6.7	5.0	5.0	.100 1.06	5.03 —	— 4.77	.100 .457	5.03 .795	— 9.3	.100 .457	5.03 2.44	— 5.67
		Yes	1B	16.9	6.7	5.0	5.0	.100 1.41	5.03 —	— 3.57	.100 .608	5.03 .62	— 8.1	.100 .608	5.03 1.58	— 4.48
	556	No	1B	62.5	6.7	13.9	13.9	.100 .379	5.03 —	— 13.3						
		Yes	1B	46.9	6.7	13.9	13.9	.100 .505	5.03 —	— 9.95						
	800	No *	1B	90.0	5.3	20.0	20.0	.100 .262	5.43 —	— 19.3						
		Yes	1B	67.5	6.7	20.0	20.0	.100 .348	5.03 —	— 14.5						
Hypertape																
Low Density (1511bpi)			1B	170	3.5	43.4	—	.100	—	29.3						

Key:
1 - May be overrun.
-B Burst mode operation on Multiplexor Channel.

* Gap time nine track only;
Loads for seven or nine track.

Table 1, Part 4. IBM System/360 Model 30 Channel Loading and CPU Interference Table

Input-Output Device	Key	Nominal Data Rate in kb/sec	Gap or Cycle Time (in ms)	Data Load	Data Chaining Load	No Data Chain		
						Time	A	B
Direct Access Storage *			Rotation Time					
2302 Disk	1B	156	34.0	35.7		.202 .338	12.0 3.85	 24.1
2311 Disk	1B	156	25.0	36.1		.202 .338	12.0 3.85	 24.1
2321 Data Cell	1B	54.7	50.0	13.0				
7320 Drum	1B	136	17.5	30.9				
2314 Disk **	1-	312	25.0	73.1		.055 .110	5.5	 50.0

Key: 1- May be overrun.
-B Burst mode operation on Multiplexor Channel.

* When one or more direct access control units are operated concurrently on two selector channels, nearly simultaneous command chaining requests from both channels causes the second request to be delayed until service is completed for the first request. If this second request calls for a WRITE command to record information beginning at the very first possible recording position, overrun may occasionally occur (if the requests occur less than about 10 microseconds apart). The channel program must be repeated when the overrun occurs.

Also, the tendency to overrun (for the direct access control units) increases when:

1. The number of WRITE's in the program increases, or
2. The number of chaining operations on the other selector channel increases. (For example, a second direct access control unit is operating on the other selector channel), or
3. A TIC must also be executed before the WRITE is executed (i.e., the TIC requires additional time).

These same considerations apply to a System/360 Model 30 with a 2-microsecond storage cycle. For the 2-microsecond system, however, the overrun condition occurs more frequently than it does on a 1.5-microsecond storage cycle system.

** The 2314 can operate only with a System/360 Model 30 that has a 1.5-microsecond storage cycle. The 2314 should be attached to selector channel one only. For proper operation of the system, other direct access storage devices should also be attached to selector channel one when the 2314 is so attached.

● Table 1, Part 5. IBM System/360 Model 30 Channel Loading and CPU Interference Table

Input/Output Device	Key	Nominal Data Rate (in cps)	CPU Intf	15 Line Maximum: Waiting Time	15 Line Maximum: Device Load	15 Line Maximum: Prev Load	15 Line Maximum: Time (in ms)	15 Line Maximum: A	15 Line Maximum: B	Nr of Ls	31 Line Maximum: Waiting Time	31 Line Maximum: Device Load	31 Line Maximum: Prev Load	Priority Load: Time (in ms)	Priority Load: A	Priority Load: B
Communication Equipment																
2702 Transmission Ctl-I IBM Term Ctl-I 75 bps	1M	8.3	62.3	116.	.040	.088	.200	7.00	.040	1	116.	.040	.088	.200	7.00	.040
				58.1	.080	.176	.200 .582	6.04 14.0	13.7 .080	2	57.5	.081	.177	.200 1.09	6.52 13.9	6.84 .080
				38.4	.121	.266	.200 1.09	6.04 20.9	13.7 .120	3	38.7	.120	.264	.200 2.12	6.52 20.7	6.84 .120
				28.8	.162	.354	.200 1.61	6.04 27.7	13.7 .160	4	28.8	.162	.355	.200 3.14	6.52 27.5	6.84 .160
				23.0	.202	.443	.200 2.12	6.04 34.6	13.7 .200	5	22.8	.204	.447	.200 4.17	6.52 34.2	6.84 .200
				19.2	.242	.532	.200 2.63	6.04 41.4	13.7 .240	6	18.8	.247	.542	.200 5.19	6.52 40.8	6.84 .240
				16.3	.285	.626	.200 3.14	6.04 48.1	13.7 .280	7	15.9	.293	.643	.200 6.21	6.52 47.3	6.84 .280
				14.4	.323	.709	.200 3.65	6.04 54.8	13.7 .320	8	13.9	.335	.735	.200 7.24	6.52 53.7	6.84 .320
				12.5	.373	.818	.200 4.17	6.04 61.5	13.7 .360	9	12.9	.361	.792	.200 8.26	6.52 60.0	6.84 .360
				11.5	.404	.887	.200 4.68	6.04 68.1	13.7 .400	10	10.9	.427	.936	.200 9.29	6.52 66.3	6.84 .400
				10.5	.441	.967	.200 5.19	6.04 74.7	13.7 .440	11	9.90	.470	1.03	.200 10.3	6.52 72.5	6.84 .440
				9.58	.485	1.06	.200 5.70	6.04 81.3	13.7 .480	12	8.91	.522	1.15	.200 11.3	6.52 78.6	6.84 .480
				8.62	.539	1.18	.200 6.21	6.04 87.8	13.7 .520	13	8.91	.522	1.15	.200 12.4	6.52 84.6	6.84 .520
				8.14	.571	1.25	.200 6.73	6.04 94.2	13.7 .560	14	7.92	.587	1.29	.200 13.4	6.52 90.5	6.84 .560
				7.66	.607	1.33	.200 7.24	6.04 101.	13.7 .600	15	6.93	.671	1.47	.200 14.4	6.52 96.4	6.84 .600
										16	6.93	.671	1.47	.200 15.4	6.52 102.	6.84 .640
										17	5.94	.783	1.72	.200 16.5	6.52 108.	6.84 .680
										18	5.94	.783	1.72	.200 17.5	6.52 113.	6.84 .720
										19	5.94	.783	1.72	.200 18.5	6.52 119.	6.84 .760
										20	4.94	.941	2.06	.200 19.5	6.52 124.	6.84 .800
										21	4.94	.941	2.06	.200 20.6	6.52 130.	6.84 .840
										22	4.94	.941	2.06	.200 21.6	6.52 135.	6.84 .880
										23	4.94	.941	2.06	.200 22.6	6.52 140.	6.84 .920
										24	3.95	1.18	2.58	.200 23.6	6.52 145.	6.84 .960
										25	3.95	1.18	2.58	.200 24.6	6.52 150.	6.84 1.00
										26	3.95	1.18	2.58	.200 25.7	6.52 155.	6.84 1.04
										27	3.95	1.18	2.58	.200 26.7	6.52 160.	6.84 1.08
										28	3.95	1.18	2.58	.200 27.7	6.52 165.	6.84 1.12
										29	3.95	1.18	2.58	.200 28.7	6.52 170.	6.84 1.16
										30	2.96	1.57	3.45	.200 30.0	6.52 174.	6.84 1.20
										31	2.96	1.57	3.45	.200 30.8	6.52 179.	6.84 1.24

Note: Data load factor for 2702:
15 line version = .43
31 line version = .22

Key:
1- May be overrun.
-M Multiplex mode operation on Multiplexor Channel.

Table 1, Part 6. IBM System/360 Model 30 Channel Loading and CPU Interference Table

Input/Output Device	Key	Nominal Data Rate	CPU Intf	15 Line Maximum: Waiting Time	Dev Load	Prev Load	Priority Load: Time (in ms)	A	B	Nr of Ls	31 Line Maximum: Waiting Time	Dev Load	Prev Load	Priority Load: Time (in ms)	A	B
Communication Equipment																
2702 Transmission Ctl IBM Term Ctl-I 135.5 bps	1M	14.8	62.3	66.7	.070	.153	.200	7.00	.069	1	66.4	.070	.154	.200	7.00	.069
				33.1	.140	.308	.200 .582	6.04 13.9	13.7 .138	2	32.7	.142	.312	.200 1.09	6.52 13.8	6.84 .138
				22.1	.211	.462	.200 1.09	6.04 20.8	13.7 .207	3	21.8	.213	.468	.200 2.12	6.52 20.6	6.84 .207
				16.3	.285	.626	.200 1.61	6.04 27.6	13.7 .276	4	15.9	.293	.643	.200 3.14	6.52 27.1	6.84 .276
				12.9	.359	.788	.200 2.12	6.04 34.3	13.7 .345	5	12.9	.361	.792	.200 4.17	6.52 33.6	6.84 .345
				11.0	.422	.925	.200 2.63	6.04 40.9	13.7 .414	6	10.9	.427	.936	.200 5.19	6.52 39.9	6.84 .414
				9.10	.511	1.12	.200 3.14	6.04 47.5	13.7 .483	7	8.91	.522	1.15	.200 6.21	6.52 46.0	6.84 .483
				8.14	.571	1.25	.200 3.65	6.04 54.0	13.7 .552	8	7.92	.587	1.29	.200 7.24	6.52 52.0	6.84 .552
				7.18	.647	1.42	.200 4.17	6.04 60.4	13.7 .621	9	6.93	.671	1.47	.200 8.26	6.52 57.9	6.84 .621
				6.22	.747	1.64	.200 4.68	6.04 66.8	13.7 .690	10	5.94	.783	1.72	.200 9.29	6.52 63.6	6.84 .690
				5.74	.810	1.78	.200 5.19	6.04 73.1	13.7 .759	11	5.94	.783	1.72	.200 10.3	6.52 69.2	6.84 .759
				5.26	.883	.194	.200 5.70	6.04 79.3	13.7 .828	12	4.94	.941	2.06	.200 11.3	6.52 74.6	6.84 .828
				4.78	.972	2.13	.200 6.21	6.04 85.4	13.7 .897	13	4.94	.941	2.06	.200 12.4	6.52 80.0	6.84 .897
				4.30	1.08	2.37	.200 6.73	6.04 91.5	13.7 .966	14	3.95	1.18	2.58	.200 13.4	6.52 85.1	6.84 .966
				4.30	1.08	2.37	.200 7.24	6.04 97.5	13.7 1.04	15	3.95	1.18	2.58	.200 14.4	6.52 90.1	6.84 1.04
										16	3.95	1.18	2.58	.200 15.4	6.52 95.0	6.84 1.10
										17	2.96	1.57	3.45	.200 16.5	6.52 99.7	6.84 1.17
										18	2.96	1.57	3.45	.200 17.5	6.52 104.	6.84 1.24
										19	2.96	1.57	3.45	.200 18.5	6.52 109.	6.84 1.31
										20	2.96	1.57	3.45	.200 19.5	6.52 113.	6.84 1.38
										21	2.96	1.57	3.45	.200 20.6	6.52 117.	6.84 1.45
										22	2.96	1.57	3.45	.200 21.6	6.52 121.	6.84 1.52
										23	1.97	2.36	5.18	.200 22.6	6.52 125.	6.84 1.59
										24	1.97	2.36	5.18	.200 23.6	6.52 129.	6.84 1.66
										25	1.97	2.36	5.18	.200 24.6	6.52 132.	6.84 1.73
										26	1.97	2.36	5.18	.200 25.7	6.52 136.	6.84 1.79
										27	1.97	2.36	5.18	.200 26.7	6.52 139.	6.84 1.86
										28	1.97	2.36	5.18	.200 27.7	6.52 142.	6.84 1.93
										29	1.97	2.36	5.18	.200 28.7	6.52 145.	6.84 2.00
										30	1.97	2.36	5.18	.200 29.8	6.52 148.	6.84 2.07
										31	1.97	2.36	5.18	.200 30.8	6.52 151.	6.84 2.14

Note: Data load factor for 2702
15 line version = .43
31 line version = .22

Key:
1- May be overrun.
-M Multiplex mode operation on Multiplexor Channel.

Table 1, Part 7. IBM System/360 Model 30 Channel Loading and CPU Interference Table

Input/Output Device	Key	Nominal Data Rate	CPU Intf	15 Line Maximum						Nr of Ls
				Waiting Time	Dev Load	Prev Load	Priority Load			
							Time (in ms)	A	B	
Communication Equipment										
2702 Transmission Ctl IBM Term Ctl-I 600 bps	1M	66.6	62.3	14.4	.323	.709	.200	6.98	.321	1
				7.18	.647	1.42	.200 .582	6.04 13.6	13.7 .642	2
				4.78	.972	2.13	.200 1.09	6.04 19.9	13.7 .963	3
				3.34	1.39	3.05	.200 1.61	6.04 25.9	13.7 1.28	4
				2.86	1.62	3.56	.200 2.12	6.04 31.6	13.7 1.61	5
				2.38	1.95	4.28	.200 2.63	6.04 36.9	13.7 1.92	6
				1.90	2.44	5.36	.200 3.14	6.04 41.9	13.7 2.25	7
				1.42	3.27	7.16	.200 3.65	6.04 46.6	13.7 2.57	8
				1.42	3.27	7.16	.200 4.17	6.04 51.0	13.7 2.89	9
				1.42	3.27	7.16	.200 4.68	6.04 55.0	13.7 3.21	10
				.944	4.93	10.8	.200 5.19	6.04 58.7	13.7 3.53	11
				.944	4.93	10.8	.200 5.70	6.04 62.0	13.7 3.85	12
				.944	4.93	10.8	.200 6.21	6.04 65.1	13.7 4.17	13
				.944	4.93	10.8	.200 6.73	6.04 67.8	13.7 4.49	14
				.944	4.93	10.8	.200 7.24	6.04 70.1	13.7 4.82	15
IBM Term Ctl-II 600 bps	1M	60	62.3	14.4	.323	.709	.200	6.98	.337	1
				7.18	.647	1.42	.200 .582	6.04 13.6	13.7 .674	2
				4.78	.972	2.13	.200 1.09	6.04 19.9	13.7 1.01	3
				3.34	1.39	3.05	.200 1.61	6.04 25.8	13.7 1.35	4
				2.86	1.62	3.56	.200 2.12	6.04 31.4	13.7 1.69	5
				2.38	1.95	4.28	.200 2.63	6.04 36.7	13.7 2.02	6
				1.90	2.44	5.36	.200 3.14	6.04 41.6	13.7 2.36	7
				1.42	3.27	7.16	.200 3.65	6.04 46.1	13.7 2.70	8
				1.42	3.27	7.16	.200 4.17	6.04 50.4	13.7 3.03	9
				1.42	3.27	7.16	.200 4.68	6.04 54.2	13.7 3.37	10
				.944	4.93	10.8	.200 5.19	6.04 57.8	13.7 3.71	11
				.944	4.93	10.8	.200 5.70	6.04 60.9	13.7 4.04	12
				.944	4.93	10.8	.200 6.21	6.04 63.8	13.7 4.38	13
				.944	4.93	10.8	.200 6.73	6.04 66.3	13.7 4.72	14
				.944	4.93	10.8	.200 7.24	6.04 68.4	13.7 5.06	15

Note: Data load factor for 2702:
15 line version = .43
31 line version = .22

Key: I- May be overrun.
-M Multiplex mode operation on Multiplexor Channel.

Table 1, Part 8. IBM System/360 Model 30 Channel Loading and CPU Interference Table

Input/Output Device	Key	Nominal Data Rate	CPU Intf	15 Line Maximum						Nr of Ls	31 Line Maximum					
				Waiting Time	Dev Load	Prev Load	Priority Load				Waiting Time	Dev Load	Prev Load	Priority Load		
							Time (in ms)	A	B					Time (in ms)	A	B
Communication Equipment 2702 Transmission Ctl Telegraph Ctl-I 45 bps	1M	6.0	62.3	159.	.029	.064	.200	7.00	.028	1	159.	.029	.064	.200	7.00	.028
				79.7	.058	.128	.200 .582	6.04 14.0	13.7 .056	2	79.3	.059	.129	.200 1.09	6.52 13.9	6.84 .056
				52.8	.088	.193	.200 1.09	6.04 20.9	13.7 .084	3	52.6	.088	.194	.200 2.12	6.52 20.8	6.84 .084
				39.8	.117	.256	.200 1.61	6.04 27.8	13.7 .112	4	39.7	.117	.257	.200 3.14	6.52 27.6	6.84 .112
				31.7	.147	.322	.200 2.12	6.04 34.7	13.7 .140	5	31.7	.147	.321	.200 4.17	6.52 34.4	6.84 .140
				26.4	.176	.387	.200 2.63	6.04 41.6	13.7 .168	6	25.8	.180	.396	.200 5.19	6.52 41.1	6.84 .168
				22.5	.206	.452	.200 3.14	6.04 48.4	13.7 .196	7	21.8	.213	.468	.200 6.21	6.52 47.8	6.84 .196
				19.7	.236	.519	.200 3.65	6.04 55.2	13.7 .224	8	19.8	.235	.515	.200 7.24	6.52 54.4	6.84 .224
				17.3	.269	.591	.200 4.17	6.04 62.0	13.7 .252	9	16.8	.276	.605	.200 8.26	6.52 60.9	6.84 .252
				15.8	.294	.645	.200 4.68	6.04 68.7	13.7 .280	10	15.9	.293	.643	.200 9.29	6.52 67.4	6.84 .280
				14.4	.323	.709	.200 5.19	6.04 75.4	13.7 .308	11	13.9	.335	.735	.200 10.3	6.52 73.8	6.84 .308
				12.9	.359	.788	.200 5.70	6.04 82.1	13.7 .336	12	12.9	.361	.792	.200 11.3	6.52 80.2	6.84 .336
				12.0	.388	.851	.200 6.21	6.04 88.7	13.7 .364	13	11.9	.391	.858	.200 12.4	6.52 86.5	6.84 .364
				11.0	.422	.925	.200 6.73	6.04 95.4	13.7 .392	14	10.9	.427	.936	.200 13.4	6.52 92.8	6.84 .392
				10.5	.441	.967	.200 7.24	6.04 102.	13.7 .420	15	9.90	.470	1.03	.200 14.4	6.52 98.9	6.84 .420
										16	9.90	.470	1.03	.200 15.4	6.52 105.	6.84 .448
										17	8.91	.522	1.15	.200 16.5	6.52 111.	6.84 .476
										18	7.92	.587	1.29	.200 17.5	6.52 117.	6.84 .504
										19	7.92	.587	1.29	.200 18.5	6.52 123.	6.84 .532
										20	7.92	.587	1.29	.200 19.5	6.52 129.	6.84 .560
										21	6.93	.671	1.47	.200 20.6	6.52 134.	6.84 .588
										22	6.93	.671	1.47	.200 21.6	6.52 141.	6.84 .616
										23	5.94	.783	1.72	.200 22.6	6.52 146.	6.84 .644
										24	5.94	.783	1.72	.200 23.6	6.52 152.	6.84 .672
										25	5.94	.783	1.72	.200 24.6	6.52 158.	6.84 .700
										26	5.94	.783	1.72	.200 25.7	6.52 163.	6.84 .728
										27	4.94	.941	2.06	.200 26.7	6.52 169.	6.84 .756
										28	4.94	.941	2.06	.200 27.7	6.52 174.	6.84 .784
										29	4.94	.941	2.06	.200 28.7	6.52 180.	6.84 .812
										30	4.94	.941	2.06	.200 29.8	6.52 185.	6.84 .840
										31	4.94	.941	2.06	.200 30.8	6.52 190.	6.84 .868

Note: Data load factor for 2702:
15 line version = .43
31 line version = .22

Key:
1- May be overrun.
-M Multiplex mode operation on Multiplexor Channel.

Table 1, Part 9. IBM System/360 Model 30 Channel Loading and CPU Interference Table

Input/Output Device	Key	Nominal Data Rate	CPU Intf	15 Line Maximum Waiting Time	Dev Load	Prev Load	Priority Load Time (in ms)	A	B	Nr of Ls	31 Line Maximum Waiting Time	Dev Load	Prev Load	Priority Load Time (in ms)	A	B
Communication Equipment																
2702 Transmission Ctl Telegraph Ctl-I 57 bps	1M	7.5	62.3	125.	.037	.082	.200	7.00	.035	1	125.	.037	.082	.200	7.00	.035
				62.4	.075	.164	.200	6.04	13.7	2	62.5	.074	.163	.200	6.52	6.84
							.582	14.0	.070					1.09	13.9	.070
				41.3	.113	.247	.200	6.04	13.7	3	41.6	.112	.245	.200	6.52	6.84
							1.09	20.9	.105					2.12	20.8	.105
				31.2	.149	.327	.200	6.04	13.7	4	30.7	.151	.332	.200	6.52	6.84
							1.61	27.8	.140					3.14	27.6	.140
				24.9	.186	.409	.200	6.04	13.7	5	24.8	.188	.412	.200	6.52	6.84
							2.12	34.6	.175					4.17	34.3	.175
				20.6	.225	.495	.200	6.04	13.7	6	20.8	.223	.490	.200	6.52	6.84
							2.63	41.4	.210					5.19	40.9	.210
				17.7	.262	.575	.200	6.04	13.7	7	17.8	.261	.572	.200	6.52	6.84
							3.14	48.2	.245					6.21	47.5	.245
				15.3	.303	.665	.200	6.04	13.7	8	14.9	.313	.686	.200	6.52	6.84
							3.65	55.0	.280					7.24	54.0	.280
				13.4	.346	.760	.200	6.04	13.7	9	13.9	.335	.735	.200	6.52	6.84
							4.17	61.7	.315					8.26	60.4	.315
				12.5	.373	.818	.200	6.04	13.7	10	11.9	.391	.858	.200	6.52	6.84
							4.68	68.4	.350					9.29	66.8	.350
				11.0	.422	.925	.200	6.04	13.7	11	10.9	.427	.936	.200	6.52	6.84
							5.19	75.0	.385					10.3	73.0	.385
				10.1	.462	1.01	.200	6.04	13.7	12	9.90	.470	1.03	.200	6.52	6.84
							5.70	81.6	.420					11.3	79.2	.420
				9.58	.485	1.06	.200	6.04	13.7	13	8.91	.522	1.15	.200	6.52	6.84
							6.21	88.2	.455					12.4	85.4	.455
				8.62	.539	1.18	.200	6.04	13.7	14	8.91	.522	1.15	.200	6.52	6.84
							6.73	94.7	.490					13.4	91.4	.490
				8.14	.571	1.25	.200	6.04	13.7	15	7.92	.587	1.29	.200	6.52	6.84
							7.24	101.	.525					14.4	97.4	.525
										16	6.93	.671	1.47	.200	6.52	6.84
														15.4	103.	.560
										17	6.93	.671	1.47	.200	6.52	6.84
														16.5	109.	.595
										18	6.93	.671	1.47	.200	6.52	6.84
														17.5	115.	.630
										19	5.94	.783	1.72	.200	6.52	6.84
														18.5	121.	.665
										20	5.94	.783	1.72	.200	6.52	6.84
														19.5	126.	.700
										21	5.94	.783	1.72	.200	6.52	6.84
														20.6	132.	.735
										22	4.94	.941	2.06	.200	6.52	6.84
														21.6	137.	.770
										23	4.94	.941	2.06	.200	6.52	6.84
														22.6	143.	.805
										24	4.94	.941	2.06	.200	6.52	6.84
														23.6	148.	.840
										25	4.94	.941	2.06	.200	6.52	6.84
														25.5	153.	.875
										26	3.95	1.18	2.58	.200	6.52	6.84
														25.7	159.	.910
										27	3.95	1.18	2.58	.200	6.52	6.84
														26.7	164.	.945
										28	3.95	1.18	2.58	.200	6.52	6.84
														27.7	169.	.980
										29	3.95	1.18	2.58	.200	6.52	6.84
														28.7	174.	1.02
										30	3.95	1.18	2.58	.200	6.52	6.84
														29.8	179.	1.05
										31	3.95	1.18	2.58	.200	6.52	6.84
														30.8	184.	1.09

Note: Data Load Factor for 2702:
15 Line Version = .43
31 Line Version = .22

Key:
1- May be overrun.
-M Multiplex mode operation on Multiplexor Channel.

Table 1, Part 10. IBM System/360 Model 30 Channel Loading and CPU Interference Table

Input/Output Device	Key	Nominal Data Rate	CPU Intf	15 Line Maximum						Nr of Ls	31 Line Maximum					
				Waiting Time	Dev Load	Prev Load	Priority Load Time (in ms)	Priority Load A	Priority Load B		Waiting Time	Dev Load	Prev Load	Priority Load Time (in ms)	Priority Load A	Priority Load B
Communication Equipment																
2702 Transmission Ctl Telegraph Ctl-I 75 bps	1M	10.0	62.3	96.0	.048	.106	.200	7.00	.047	1	95.2	.049	.107	.200	7.00	.047
				48.0	.097	.213	.200 .582	6.04 13.9	13.7 .094	2	47.6	.098	.214	.200 1.09	6.52 13.9	6.84 .094
				31.7	.147	.322	.200 1.09	6.04 20.8	13.7 .141	3	31.7	.147	.321	.200 2.12	6.52 20.7	6.84 .141
				24.0	.194	.425	.200 1.61	6.04 27.7	13.7 .188	4	23.8	.195	.429	.200 3.14	6.52 27.4	6.84 .188
				19.2	.242	.532	.200 2.12	6.04 34.5	13.7 .235	5	18.8	.247	.542	.200 4.17	6.52 34.0	6.84 .235
				15.8	.294	.645	.200 2.63	6.04 41.3	13.7 .282	6	15.9	.293	.643	.200 5.19	6.52 40.5	6.84 .282
				13.4	.346	.760	.200 3.14	6.04 48.0	13.7 .329	7	12.9	.361	.792	.200 6.21	6.52 47.0	6.84 .329
				12.0	.388	.851	.200 3.65	6.04 54.6	13.7 .376	8	11.9	.391	.858	.200 7.24	6.52 53.3	6.84 .376
				10.5	.441	.967	.200 4.17	6.04 61.2	13.7 .423	9	9.90	.470	1.03	.200 8.26	6.52 59.5	6.84 .423
				9.58	.485	1.06	.200 4.68	6.04 67.8	13.7 .470	10	8.91	.522	1.15	.200 9.29	6.52 65.6	6.84 .470
				8.62	.539	1.18	.200 5.19	6.04 74.3	13.7 .517	11	7.92	.587	1.29	.200 10.3	6.52 71.7	6.84 .517
				7.66	.607	1.33	.200 5.70	6.04 80.8	13.7 .564	12	7.92	.587	1.29	.200 11.3	6.52 77.6	6.84 .564
				7.18	.647	1.42	.200 6.21	6.04 87.2	13.7 .611	13	6.93	.671	1.47	.200 12.4	6.52 83.4	6.84 .611
				6.70	.694	1.52	.200 6.73	6.04 93.6	13.7 .658	14	5.94	.783	1.72	.200 13.4	6.52 89.2	6.84 .658
				6.22	.747	1.64	.200 7.24	6.04 99.9	13.7 .705	15	5.94	.783	1.72	.200 14.4	6.52 94.8	6.84 .705
										16	5.94	.783	1.72	.200 15.4	6.52 100.	6.84 .752
										17	4.94	.941	2.06	.200 16.5	6.52 106.	6.84 .799
										18	4.94	.941	2.06	.200 17.5	6.52 111.	6.84 .846
										19	4.94	.941	2.06	.200 18.5	6.52 116.	6.84 .893
										20	3.95	1.18	2.58	.200 19.5	6.52 122.	6.84 .940
										21	3.95	1.18	2.58	.200 20.6	6.52 127.	6.84 .987
										22	3.95	1.18	2.58	.200 21.6	6.52 132.	6.84 1.03
										23	3.95	1.18	2.58	.200 22.6	6.52 137.	6.84 1.08
										24	3.95	1.18	2.58	.200 23.6	6.52 141.	6.84 1.13
										25	2.96	1.57	3.45	.200 24.6	6.52 146.	6.84 1.18
										26	2.96	1.57	3.45	.200 25.7	6.52 151.	6.84 1.22
										27	2.96	1.57	3.45	.200 26.7	6.52 155.	6.84 1.27
										28	2.96	1.57	3.45	.200 27.7	6.52 160.	6.84 1.32
										29	2.96	1.57	3.45	.200 28.7	6.52 164.	6.84 1.36
										30	2.96	1.57	3.45	.200 29.8	6.52 168.	6.84 1.41
										31	2.96	1.57	3.45	.200 30.8	6.52 172.	6.84 1.46

Note: Data Load Factor for 2702:
15 Line Version = .43
31 Line Version = .22

Key:
1- May be overrun
-M Multiplex mode operation on Multiplexor Channel

Table 1, Part 11. IBM System/360 Model 30 Channel Loading and CPU Interference Table

Input/Output Device	Key	Nominal Data Rate	CPU Intf	15 Line Maximum						Nr of Ls	31 Line Maximum					
				Waiting Time	Dev Load	Prev Load	Priority Load				Waiting Time	Dev Load	Prev Load	Priority Load		
							Time (in ms)	A	B					Time (in ms)	A	B
Communication Equipment 2702 Transmission Ctl Telegraph Ctl-II 110 bps	1M	10.0	62.3	96.9	.048	.105	.200	7.00	.047	1	97.2	.048	.105	.200	7.00	.047
				48.5	.096	.210	.200 .582	6.04 13.9	13.7 .094	2	48.6	.096	.210	.200 1.09	6.52 13.9	6.84 .094
				32.1	.145	.317	.200 1.09	6.04 20.8	13.7 .141	3	31.7	.147	.321	.200 2.12	6.52 20.7	6.84 .141
				24.0	.194	.425	.200 1.61	6.04 27.7	13.7 .188	4	23.8	.195	.429	.200 3.14	6.52 27.4	6.84 .188
				19.2	.242	.532	.200 2.12	6.04 34.5	13.7 .235	5	18.8	.247	.542	.200 4.17	6.52 34.0	6.84 .235
				15.8	.294	.645	.200 2.63	6.04 41.3	13.7 .282	6	15.9	.293	.643	.200 5.19	6.52 40.5	6.84 .282
				13.4	.346	.760	.200 3.14	6.04 48.0	13.7 .329	7	13.9	.335	.735	.200 6.21	6.52 47.0	6.84 .329
				12.0	.388	.851	.200 3.65	6.04 54.6	13.7 .376	8	11.9	.391	.858	.200 7.24	6.52 53.3	6.84 .376
				10.5	.441	.967	.200 4.17	6.04 61.2	13.7 .423	9	9.90	.470	1.03	.200 8.26	6.52 59.5	6.84 .423
				9.58	.485	1.06	.200 4.68	6.04 67.8	13.7 .470	10	8.91	.522	1.15	.200 9.29	6.52 65.6	6.84 .470
				8.62	.539	1.18	.200 5.19	6.04 74.3	13.7 .517	11	7.92	.587	1.29	.200 10.3	6.52 71.7	6.84 .517
				7.66	.607	1.33	.200 5.70	6.04 80.8	13.7 .564	12	7.92	.587	1.29	.200 11.3	6.52 77.6	6.84 .564
				7.18	.647	1.42	.200 6.21	6.04 87.2	13.7 .611	13	6.93	.671	1.47	.200 12.4	6.52 83.4	6.84 .611
				6.70	.694	1.52	.200 6.73	6.04 93.6	13.7 .658	14	6.93	.671	1.47	.200 13.4	6.52 89.7	6.84 .658
				6.22	.747	1.64	.200 7.24	6.04 99.9	13.7 .705	15	5.94	.783	1.72	.200 14.4	6.52 94.8	6.84 .705
										16	5.94	.783	1.72	.200 15.4	6.52 100.	6.84 .752
										17	4.94	.941	2.06	.200 16.5	6.52 106.	6.84 .799
										18	4.94	.941	2.06	.200 17.5	6.52 111.	6.84 .846
										19	4.94	.941	2.06	.200 18.5	6.52 116.	6.84 .893
										20	3.95	1.18	2.58	.200 19.5	6.52 122.	6.84 .940
										21	3.95	1.18	2.58	.200 20.6	6.52 127.	6.84 .987
										22	3.95	1.18	2.58	.200 21.6	6.52 132.	6.84 1.03
										23	3.95	1.18	2.58	.200 22.6	6.52 137.	6.84 1.08
										24	3.95	1.18	2.58	.200 23.6	6.52 141.	6.84 1.13
										25	2.96	1.57	3.45	.200 24.6	6.52 146.	6.84 1.18
										26	2.96	1.57	3.45	.200 25.7	6.52 151.	6.84 1.22
										27	2.96	1.57	3.45	.200 26.7	6.52 155.	6.84 1.27
										28	2.96	1.57	3.45	.200 27.7	6.52 160.	6.84 1.32
										29	2.96	1.57	3.45	.200 28.7	6.52 164.	6.84 1.36
										30	2.96	1.57	3.45	.200 29.8	6.52 168.	6.84 1.41
										31	2.96	1.57	3.45	.200 30.8	6.52 172.	6.84 1.46

Note: Data load factor for 2702:
15 line version = .43
31 line version = .22

Key:
1- May be overrun
-M Multiplex mode operation on Multiplexor Channel

Table 1, Part 12. IBM System/360 Model 30 Channel Loading and CPU Interference Table

Input/Output Device	Key	Nominal Data Rate	CPU Intf	15 Line Maximum: Waiting Time	Dev Load	Prev Load	Priority Load: Time (in ms)	A	B		31 Line Maximum: Waiting Time	Dev Load	Prev Load	Priority Load: Time (in ms)	A	B
Communication Equipment 2702 Transmission Ctl World Trade TTY 50 bps	1M	6.6	62.3	144.	.032	.071	.200	7.00	.039	1	144.	.032	.071	.200	7.00	.039
				72.0	.065	.142	.200 .582	6.04 14.0	13.7 .078	2	71.4	.065	.143	.200 1.09	6.52 13.9	6.84 .078
				48.0	.097	.213	.200 1.09	6.04 20.9	13.7 .117	3	47.6	.098	.214	.200 2.12	6.52 20.8	6.84 .117
				36.0	.129	.283	.200 1.61	6.04 27.7	13.7 .156	4	35.7	.130	.286	.200 3.14	6.52 27.5	6.84 .156
				28.8	.162	.354	.200 2.17	6.04 34.6	13.7 .195	5	28.8	.162	.355	.200 4.17	6.52 34.2	6.84 .195
				24.0	.194	.425	.200 2.63	6.04 41.4	13.7 .234	6	23.8	.195	.429	.200 5.19	6.52 40.8	6.84 .234
				20.1	.231	.506	.200 3.14	6.04 48.1	13.7 .273	7	19.8	.235	.515	.200 6.21	6.52 47.3	6.84 .273
				17.7	.262	.575	.200 3.65	6.04 54.9	13.7 .312	8	17.8	.261	.572	.200 7.24	6.52 53.7	6.84 .312
				15.8	.294	.645	.200 4.17	6.04 61.5	13.7 .351	9	15.9	.293	.643	.200 8.62	6.52 60.1	6.84 .351
				14.4	.323	.709	.200 4.68	6.04 68.2	13.7 .390	10	13.9	.335	.735	.200 9.29	6.52 66.4	6.84 .390
				12.9	.359	.788	.200 5.19	6.04 74.8	13.7 .429	11	12.9	.361	.792	.200 10.3	6.52 72.6	6.84 .429
				12.0	.388	.851	.200 5.70	6.04 81.3	13.7 .468	12	11.9	.391	.858	.200 11.3	6.52 78.7	6.84 .468
				11.2	.422	.925	.200 6.21	6.04 87.8	13.7 .507	13	10.9	.427	.936	.200 12.4	6.52 84.7	6.84 .507
				10.1	.462	1.01	.200 6.73	6.04 94.3	13.7 .546	14	9.90	.470	1.03	.200 13.4	6.52 90.7	6.84 .546
				9.58	.485	1.06	.200 7.24	6.04 101.	13.7 .585	15	8.91	.522	1.15	.200 14.4	6.52 96.6	6.84 .585
										16	8.91	.522	1.15	.200 15.4	6.52 102.	6.84 .624
										17	7.92	.587	1.29	.200 16.5	6.52 108.	6.84 .663
										18	7.92	.587	1.29	.200 17.5	6.52 114.	6.84 .702
										19	6.93	.671	1.47	.200 18.5	6.52 119.	6.84 .741
										20	6.93	.671	1.47	.200 19.5	6.52 125.	6.84 .780
										21	5.94	.783	1.72	.200 20.6	6.52 130.	6.84 .819
										22	5.94	.783	1.72	.200 21.6	6.52 135.	6.84 .858
										23	5.94	.783	1.72	.200 22.6	6.52 141.	6.84 .897
										24	5.94	.783	1.72	.200 23.6	6.52 146.	6.84 .936
										25	4.94	.941	2.06	.200 24.6	6.52 151.	6.84 .975
										26	4.94	.941	2.06	.200 25.7	6.52 156.	6.84 1.01
										27	4.94	.941	2.06	.200 26.7	6.52 161.	6.84 1.05
										28	4.94	.941	2.06	.200 27.7	6.52 166.	6.84 1.09
										29	4.94	.941	2.06	.200 28.7	6.52 170.	6.84 1.13
										30	3.95	1.18	2.58	.200 29.8	6.52 175.	6.84 1.17
										31	3.95	1.18	2.58	.200 30.8	6.52 180.	6.84 1.20

Note: Data load factor for 2702:
15 Line Version = .43
31 Line Version = .22

Key:
1- May be overrun.
-M Multiplex mode operation on Multiplexor Channel

Table 1, Part 13. IBM System/360 Model 30 Channel Loading and CPU Interference Table

Terminal Control	N_{max} 15 Line	31 Line
IBM Type I		
75 bps	242	117
135.5 bps	139	67
600 bps	30	-
IBM Type II		
600 bps	30	-
Telegraph I		
45 bps	332	160
57 bps	260	126
75 bps	200	96
Telegraph Type II		
110 bps	202	98
WTC Telegraph		
50 bps	300	145
75 bps	200	96
	15 Line Max	31 Line Max
Device Load	15.09	7.17
Previous Load	21.98	10.45

Table 2. IBM 2702 Evaluation Factors (System/360 Model 30)

One Line Priority Load Function

Terminal Control	b	15 Line Max Time	A	B	31 Line Max Time	A	B
IBM Type I							
75 bps	0.040	.200	7.00	0.040	.200	7.00	0.40
135.5 bps	0.069	.200	7.00	0.069	.200	7.00	0.69
600 bps	0.321	.200	6.98	0.321			
IBM Type II							
600 bps	0.337	.200	6.98	0.337			
Telegraph Type I							
45 bps	0.028	.200	7.00	0.028	.200	7.00	0.028
57 bps	0.035	.200	7.00	0.035	.200	7.00	0.035
75 bps	0.047	.200	7.00	0.047	.200	7.00	0.047
Telegraph Type II							
110 bps	0.047	.200	7.00	0.047	.200	7.00	0.047
World Trade Telegraph							
50 bps	0.039	.200	7.00	0.039	.200	7.00	0.039
75 bps	0.047	.200	7.00	0.047	.200	7.00	0.047

Segment 1

Multiple Line Priority Load Function

15 Line Max Time	A	B	31 Line Max Time	A	B
.200	6.04	13.7	.200	6.52	6.84

Segment 2

15 Line Max Number of Lines	Time	31 Line Max Number of Lines	Time	Number of Lines	Time
2	0.582	2	1.094	17	16.454
3	1.094	3	2.118	18	17.478
4	1.606	4	3.142	19	18.502
5	2.118	5	4.166	20	19.526
6	2.630	6	5.190	21	20.550
7	3.142	7	6.214	22	21.568
8	3.654	8	7.238	23	22.598
9	4.166	9	8.262	24	23.622
10	4.678	10	9.286	25	24.646
11	5.190	11	10.310	26	25.670
12	5.702	12	11.334	27	26.694
13	6.214	13	12.358	28	27.718
14	6.726	14	13.382	29	28.742
15	7.238	15	14.406	30	29.766
		16	15.430	31	30.790

Table 3. IBM 2702 Priority Load Factors (System/360 Model 30)

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Note: Page numbers shown in parentheses ( ) pertain to information related to a system with a 2-microsecond RW cycle.

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