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## I/O CHANNEL INTERFACE

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**SUBCATEGORY: INTERFACE**

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U.S. DEPARTMENT OF COMMERCE, Philip M. Klutznick, *Secretary*  
Luther H. Hodges, *Deputy Secretary*  
Jordan J. Baruch, *Assistant Secretary* for Science and Technology  
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

## Foreword

Federal Information Processing Standards Publications of the National Bureau of Standards are adopted and promulgated under the provisions of Public Law 89-306, and Part 6 of Title 15 Code of Federal Regulations. The standards are required for implementation by Federal agencies in the acquisition, development and use of automated information systems and in the interchange of data between and among agencies and with the public. The use of such standards which are adopted after extensive review by Federal agencies, industry and the public is intended to reduce Government Costs and improve the effectiveness of Government Services.

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Ernest Ambler, *Director*

## Abstract

This standard defines the functional, electrical, and mechanical interface specifications for connecting computer peripheral equipment as a part of automatic data processing (ADP) systems. This standard, together with a companion standard for power control, defines the hardware characteristics for the I/O channel level interface. In order to achieve full plug-to-plug interchangeability of peripheral components, device class specific operational specifications standards are also required for each class of peripheral device. These operational specifications standards will be proposed as Federal Information Processing Standards to accompany this standard as they are developed.

The Government's intent in employing this I/O Channel Interface standard is to reduce the cost of satisfying the Government's data processing requirements through increasing its available alternative sources of supply for computer system components at the time of initial system acquisition, as well as in system replacement and augmentation and in system component replacement.

This standard is also expected to lead to improved reutilization of system components. When acquiring ADP systems and system components, Federal agencies shall cite this standard in specifying the interface for connecting computer peripheral equipment as a part of ADP systems.

Key words: Automatic data processing (ADP); Channel level power control interface; Computer peripherals; Computers; Federal Information Processing Standard; Input/Output; Interfaces.

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ANNOUNCING THE STANDARD FOR

**I/O CHANNEL INTERFACE**

Federal Information Processing Standards Publications are issued by the National Bureau of Standards pursuant to the Federal Property and Administrative Services Act of 1949, as amended, Public Law 89-306 (79 Stat. 1127), Executive Order 11717 (38 FR 12315, dated May 11, 1973) and Part 6 of Title 15 Code of Federal Regulations (CFR).

Name of Standard. I/O Channel Interface (FIPS PUB 60-1).

Category of Standard. Hardware Standard, Interface.

Explanation. This standard defines the functional, electrical, and mechanical interface specifications for connecting computer peripheral equipment as a part of automatic data processing (ADP) systems. This standard, together with a companion standard for power control, defines the hardware characteristics for the I/O channel level interface. In order to achieve full plug-to-plug interchangeability of peripheral components, device class specific operational specifications standards are also required for each class of peripheral device. These operational specifications standards will be proposed as Federal Information Processing Standards to accompany this standard as they are developed.

The Government's intent in employing this I/O Channel Interface standard is to reduce the cost of satisfying the Government's data processing requirements through increasing its available alternative sources of supply for computer system components at the time of initial system acquisition, as well as in system replacement and augmentation and in system component replacement.

This standard is also expected to lead to improved reutilization of system components. When acquiring ADP systems and system components, Federal agencies shall cite this standard in specifying the interface for connecting computer peripheral equipment as a part of ADP systems.

Approving Authority. Secretary of Commerce.

Maintenance Agency. Department of Commerce, National Bureau of Standards (Institute for Computer Sciences and Technology).

Cross Index. American National Standards Institute document X3T9/600, Rev. 2, Draft Proposed American National Standard for I/O Channel Interface.

Applicability. This standard is applicable to the acquisition of all ADP systems and peripheral equipment for those systems except those minicomputer, microcomputer, and other small scale systems which are specifically excluded by the National Bureau of Standards (NBS). A list of such currently excluded systems and the current criteria for exclusion will be developed and maintained by NBS and will be periodically distributed to all Federal agencies and be publicly available upon request.

This standard is applicable to the acquisition of (1) all new and replacement ADP systems, (2) computer peripheral equipment acquired to replace existing peripheral equipment of or to augment ADP systems that employ interfaces conforming with this standard, and (3) peripheral equipment acquired to replace existing peripheral equipment of or to augment ADP systems that do not conform to this standard, but for which the hardware and software necessary to conform to this standard are commercially available.

Specifically, this standard shall be employed in the interconnection of computer peripheral equipment as a part of ADP systems for the following types of peripherals: (1) magnetic tape equipment employing open reel-to-reel magnetic tape storage devices, specifically excluding magnetic tape cassette and tape cartridge storage devices, (2) magnetic disk storage equipment employing disk drives each having a capacity greater than 7 megabytes per storage module, specifically excluding flexible disk and disk cartridge devices having a smaller storage capacity per device, and (3) peripheral equipment employing all peripheral device types for which accompanying operational specifications standards have been issued as Federal Information Processing Standards.

Verification of the correct operation of all interfaces that are required to conform to this standard shall, through demonstration or other means acceptable to the Government, be provided prior to the acceptance of all applicable ADP equipment.

**Specifications.** This standard incorporates by reference the technical specifications of ANSI document number X3T9/600, Rev. 2. Copies of the technical specifications section of the standard will be available from the National Technical Information Service as described in the *Where to Obtain Copies* section below.

**Implementation.** The provisions of this standard are effective June 23, 1980. All applicable equipment ordered on or after the effective date, or procurement actions for which solicitation documents have not been issued by that date, must conform to the provisions of this standard unless a waiver has been granted in accordance with the procedure described elsewhere in this standard.

This standard shall be reviewed by NBS within three years after its effective date, taking into account technological trends and other factors, to determine whether the standard should be affirmed, revised, or withdrawn.

**Waivers.** Heads of agencies desiring a waiver from the requirements stated in this standard, so as to acquire ADP equipment that does not conform to this standard, shall submit a request for such a waiver to the Secretary of Commerce for review and approval. Approval will be granted if, in the judgment of the Secretary based on all available information, including that provided in the waiver request, a major adverse economic or operational impact would occur through conformance with this standard.

A request for waiver shall include: (1) a description of the existing or planned ADP system for which the waiver is being requested, (2) a description of the system configuration, identifying those items for which the waiver is being requested, and including a description of planned expansion of the system configuration at any time during its life cycle, and (3) a justification for the waiver, including a description and discussion of the major adverse economic or operational impact that would result through conformance to this standard as compared to the alternative for which the waiver is requested.

The request for waiver shall be submitted to the Secretary of Commerce, Washington, D.C. 20230, and labeled as a Request for Waiver to a Federal Information Processing Standard. Waiver requests will normally be processed within 45 days of receipt by the Secretary. No action shall be taken to issue solicitation documents or to order equipment for which this standard is applicable and which does not conform to this standard prior to receipt of a waiver approval response from the Secretary.

**Where to Obtain Copies.** Either paper or microfiche copies of this Federal Information Processing Standard, including the technical specifications, may be purchased from the National Technical Information Service (NTIS) by ordering Federal Information Processing Standard Publication 60-1 (NBS-FIPS-PUB-60-1), I/O Channel Interface. Ordering information, including prices and delivery alternatives, may be obtained by contacting the National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, Virginia 22161, Telephone: (703) 557-4650.

**TECHNICAL SPECIFICATIONS**  
**FOR**  
**I/O CHANNEL INTERFACE**



**Draft Proposed**  
**American National Standard**  
SPECIFICATIONS FOR  
**I/O CHANNEL INTERFACE**

**Abstract**

The functional, electrical, and mechanical specifications are defined for attaching devices through their control units to the I/O channel of a computing system. This interface is the communication link between the I/O channel of a CPU and the various I/O control units. This will facilitate, for user and supplier, the specification for interconnect. General purpose computers are considered to be the most significant of this Standard. Mini-computers and special purpose units will be addressed through a separate American National Standard.

Full "plug-to-plug interchangeability" is possible if no changes in hardware or software components in the system are required when interchanging devices with their respective control units. This Standard provides functional, electrical, and mechanical specifications. To obtain full interchangeability, an operational specification and power control specification (not part of this Standard) must be defined for each type of device. The operational specifications define the command codes, data formats, program requirements, etc., for a specific device.

**Foreword**

(This Foreword is not a part of the Standard, Specifications for I/O Channel Interface.

This Standard provides the specifications for the functional, electrical and mechanical characteristics of the interface of the I/O channel for a general purpose computer system. The I/O interface (channel to control unit) is the communication link between an I/O channel in the CPU (Central Processing Unit) and the various I/O control units. The information formats and control signal sequencing provide a uniform means for attaching and controlling a wide range of control units. This Standard will provide a common basis for compatibility of equipments to be attached to computer systems and will facilitate, for users and suppliers, the specification for interconnection.

Information, in the form of data, status and sense information, control signals, and I/O device addresses, is transmitted over the time-and-function-shared lines of this interface. All transmissions of information are interlocked with corresponding response signals.

The design of this interface provides the following important features:

1. A degree of consistency of input/output programming over a wide range of control units.
2. Ready physical connection to general purpose computer channels of control units designed by any manufacturer to operate with this interface.
3. Ability to physically accommodate future control units designed to meet the parameters of this interface.

4. An interlocked interface operation that is, in most cases, time-independent; this feature increases the range of control units that may be attached.
5. An operation applicable to both multiplex and burst mode operations as well as many control operations and channel-to-channel transmission.
6. Up to eight control units serviced per set of lines.

This Standard provides a functional description of these lines together with the electrical and mechanical considerations. It does not define the interface between control units and I/O devices. Refer to the main body of this Standard for interface sequence definitions. The flow diagrams in Appendix A and the sequence charts in Appendix B are provided for illustrative purposes and should not be considered as an instrument for obtaining precise definitions of interface sequences.

This Standard is open-ended to permit future extensions to the I/O interface. Features which are defined in section 2.9, "Features", of the Standard may be added. If operations of the basic I/O interface are affected, this is delineated in the specification for the feature.

The electrical and mechanical specifications for the I/O interface are defined in chapters 3 and 4, "Electrical" and "Mechanical Specifications", of this Standard. Mechanical adapters may be used in a control unit to convert an otherwise non-standard connection provided the electrical specifications are met.

To obtain complete "plug-to-plug interchangeability" an operational specification and power control specification (not part of this Standard) must be defined. The operational specification would include parameters such as command codes, command sequences, status codes, channel program requirements, etc. required to support a specific device. The power control specification would include the definitions and descriptions of the power control interface lines and would also include the emergency power off operations and procedures.

Subcommittee X3T9 on I/O Interface, which developed this Standard, had the following members:

D. L. Shoemaker, *Chairman*

D. L. Anderson	D. H. Lee
J. M. Bakshi	M. H. Lohrenz
R. Bender	D. C. Loughry
J. Biddle	H. T. Meyer
W. H. Bridge	W. J. McClain
G. E. Clark	D. L. Nelson
R. Derby	K. S. Oakes
R. E. Douglas	R. Patel
J. R. Eastling	J. Rapoza
T. E. Gardner	N. J. Ream
J. W. Greenleaf	K. Spiro
R. L. Hendrickson	H. W. Swanson
M. Kirby	W. Topercer
C. Klueber	G. E. Williams
D. E. Knoblock	R. A. Whitcomb
P. Lannan	



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## CHAPTER 1.

### Introduction

**1.1 Scope.** This American National Standard specifies functional, electrical, and mechanical characteristics of the interface between I/O control units and channels in general purpose computer systems.

**1.2 Definitions.**

**Channel Program**—A sequence of CCW's which control the operation of a subchannel.

**Channel Command Word (CCW)**—A CCW specifies the information necessary for the channel, control unit, and addressed device to initiate an I/O operation. Information in the CCW includes the operation to be performed, the address and length of the relevant data, and a set of flags indicating what is to be done at the termination of the operation.

**Subchannel**—The channel facilities required for sustaining a single I/O operation. These facilities include registers which contain address, command, count, and status information relating to the I/O operation currently in progress.

## CHAPTER 2.

### Functional Specifications

Sections 2.1 thru 2.8 define the functional requirements for the basic interface. Features, which can be added to the basic interface, are defined in section 2.9.

**2.1 General.** Input/output devices provide external storage and a means of communication between data processing systems or between a system and the external world.

Input/output (I/O) devices are attached to the central processing unit (CPU) by means of channels and control units in various configurations (figure 1).

The channel directs the flow of information between I/O control units and main storage.

The control unit provides the logical capability necessary to operate and control an I/O device and adapts the characteristics of each I/O device to the standard form of control provided by the channel. A control unit may be housed separately or it may be physically and logically integrated with the I/O device.

An I/O device attached to the control unit may be designated to perform only certain limited operations; for example, recording data and moving the recording medium. To accomplish these functions the I/O device needs detailed signal sequences peculiar to that type of I/O device. The control unit decodes the commands received from the channel, interprets them for the I/O device, and provides the signal sequence for executing the operation.

The connection between the channel and the control unit is called the I/O interface. The I/O interface provides an information format and a signal sequence common to all control units. The interface consists of signal lines that connect a number of control units to a channel (figure 1). Except for signals used to establish selection control, all communications to and from the channel occur over a common bus; i.e., any signal provided by the channel is available to all control units (figure 2). At any one time,

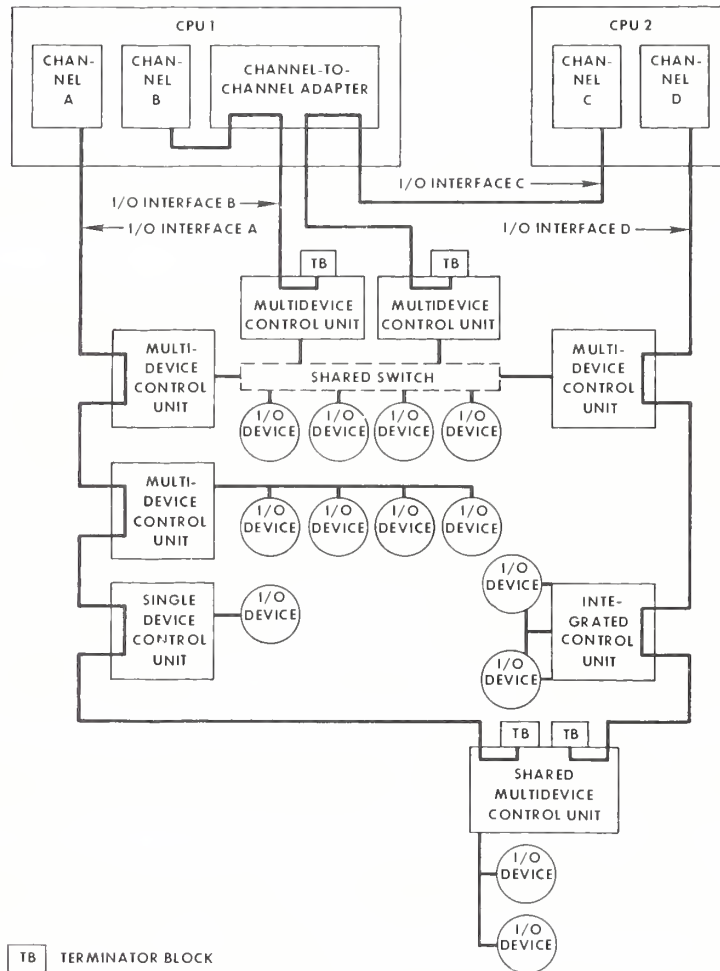


FIGURE 1. Input/Output Interface—Multiple Configurations

however, only one control unit can be logically connected to the channel. Selection of a control unit for communication with the channel is controlled by a signal (passing serially through all control units) that permits, sequentially, each control unit to respond to the signals provided by the channel. A control unit remains logically connected to the interface until it transfers the information it needs or has, or until the channel signals it to disconnect.

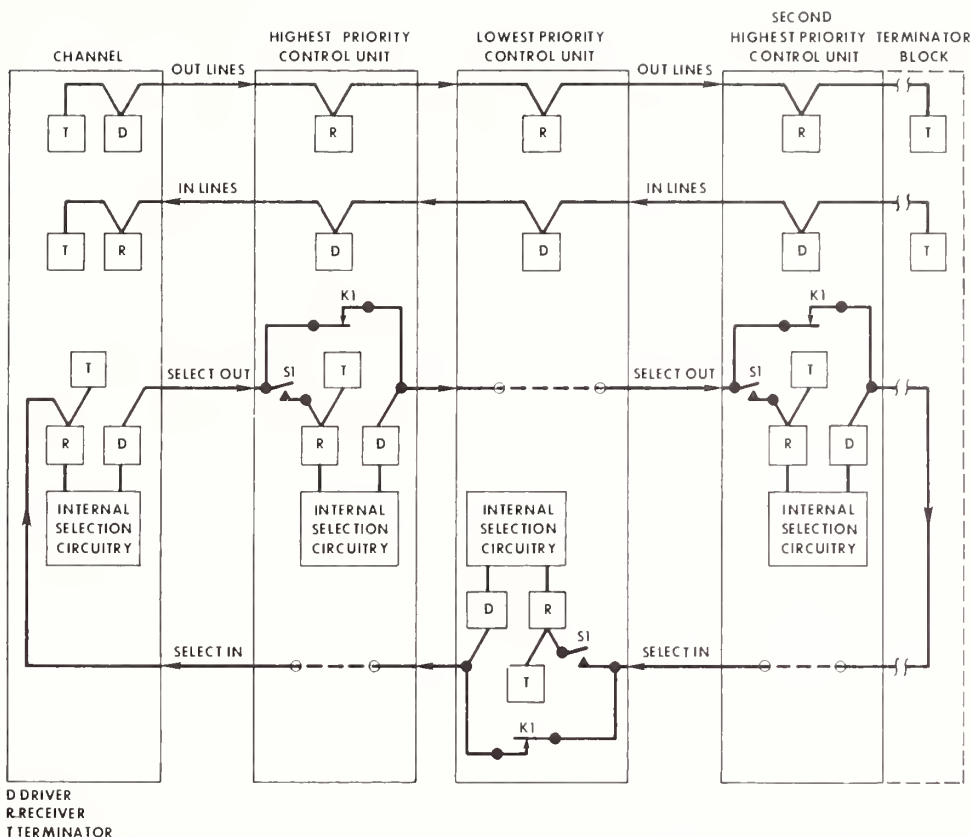


FIGURE 2. Interconnections on the Input/Output Interface

The interface can accommodate up to 256 directly addressable I/O devices (limit set by addressing facilities). The number of control units that can be accommodated is limited only by timing and electrical considerations within the given addressing limitations. (See section 3.1 "Multiple Drivers and Receivers" and section 2.8.3 "System Configuration".)

The multiplexing facilities of the interface permit the possibility of operating any number of the 256 I/O devices concurrently on a single interface; portions of various messages can be transmitted over the interface in an interleaved fashion to or from different I/O devices, or a complete message can be transmitted in a single interface operation. The operation is determined by the particular channel and control unit.

The rise and fall of all signals transmitted over the interface are controlled by interlocked responses. Interlocking removes the dependence of the interface on circuit speed, and makes it applicable to a wide variety of circuits and data rates. Further, interlocking permits connecting control units of different circuit speeds to a single channel.

**2.2 Line Definition.** The I/O interface connects a channel with control units. External cables physically connect all control units in a chain, with the first control unit connected to the channel. (See figures 1 and 2.)

## Input/Output Interface Lines

The I/O interface lines and their uses are:

Name of Line	Abbreviation	Uses
Bus 0 Out Position P	Bus 0 Out P	BUS OUT—Used to transmit information (data, I/O device address, command, control orders) from the channel to the control unit. ('Bus 1' is only available with the bus extension feature.)
Bus 0 Out Position 0	Bus 0 Out 0	
Bus 0 Out Position 1	Bus 0 Out 1	
Bus 0 Out Position 2	Bus 0 Out 2	
Bus 0 Out Position 3	Bus 0 Out 3	
Bus 0 Out Position 4	Bus 0 Out 4	
Bus 0 Out Position 5	Bus 0 Out 5	
Bus 0 Out Position 6	Bus 0 Out 6	
Bus 0 Out Position 7	Bus 0 Out 7	
Bus 1 Out Position P	Bus 1 Out P	
Bus 1 Out Position 0	Bus 1 Out 0	
Bus 1 Out Position 1	Bus 1 Out 1	
Bus 1 Out Position 2	Bus 1 Out 2	
Bus 1 Out Position 3	Bus 1 Out 3	
Bus 1 Out Position 4	Bus 1 Out 4	
Bus 1 Out Position 5	Bus 1 Out 5	
Bus 1 Out Position 6	Bus 1 Out 6	
Bus 1 Out Position 7	Bus 1 Out 7	
Bus 0 In Position P	Bus 0 In P	BUS IN—Used to transmit information (data, selected I/O device identification, status information, sense data) from the control unit to the channel. ('Bus 1' is only available with the bus extension feature.)
Bus 0 In Position 0	Bus 0 In 0	
Bus 0 In Position 1	Bus 0 In 1	
Bus 0 In Position 2	Bus 0 In 2	
Bus 0 In Position 3	Bus 0 In 3	
Bus 0 In Position 4	Bus 0 In 4	
Bus 0 In Position 5	Bus 0 In 5	
Bus 0 In Position 6	Bus 0 In 6	
Bus 0 In Position 7	Bus 0 In 7	
Bus 1 In Position P	Bus 1 In P	
Bus 1 In Position 0	Bus 1 In 0	
Bus 1 In Position 1	Bus 1 In 1	
Bus 1 In Position 2	Bus 1 In 2	
Bus 1 In Position 3	Bus 1 In 3	
Bus 1 In Position 4	Bus 1 In 4	
Bus 1 In Position 5	Bus 1 In 5	
Bus 1 In Position 6	Bus 1 In 6	
Bus 1 In Position 7	Bus 1 In 7	
Mark 0 In	Mk 0 In	MARK—Used to indicate the bus(es) being used. (Except for 'Mark 0 In', these lines are only used with the bus extension feature.)
Mark 0 Out	Mk 0 Out	
Mark 1 In	Mk 1 In	
Mark 1 Out	Mk 1 Out	
Mark In Parity	Mk In P	
Mark Out Parity	Mk Out P	
Address Out	Adr Out	TAGS—Used for interlocking and controlling information on the buses and for special sequences. ('Disconnect In' is only used with the I/O error alert feature. 'Data In' and 'Data Out' are only used with the high-speed transfer feature.)
Address In	Adr In	
Command Out	Cmd Out	
Status In	Sta In	
Service Out	Srv Out	
Service In	Srv In	
Data In	Dat In	
Data Out	Dat Out	
Disconnect In	Dis In	



Operational Out	Opl Out	SELECTION CONTROLS—Used for the scanning of, or the selection of, attached I/O devices.
Operational In	Opl In	
Hold Out	Hld Out	
Select Out	Sel Out	
Select In	Sel In	
Suppress Out	Sup Out	
Request In	Req In	
Metering Out	Mtr Out	METERING CONTROLS—Used for the conditioning of usage meters located in the various attached units.
Metering In	Mtr In	
Clock Out	Clk Out	

Note: The validity of information on the buses and the timing of the signals on the tag lines is specified at the channel cable connectors.

**2.2.1 Buses.** Each bus is a set of nine lines consisting of eight information lines and one parity line. Information on the buses is arranged so that bit position 7 of a bus always carries the low-order bit within an eight-bit byte. The highest-order bit is in position 0 and intervening bits are in descending order from position 1 to position 6.

When a byte transmitted over the interface consists of less than eight information bits, the bits must be placed in the highest-numbered contiguous bit positions of the bus. Any unused lines of the bus must include the low-numbered positions (position 0 and adjacent positions). Unused lines must present logical zeros to the receiving end. The parity bit of any byte must appear in the parity position (P). The byte must always have odd parity (figure 3).

Bus Line	BCD (Position Value)	Packed Numeric (Position Value)		Unpacked Numeric (Position Value)	EBCDIC (Bit Positions)	ASCII (Bit Positions)	Binary (Position Value)	
<i>P</i>	<i>P</i>	<i>P</i>		<i>P</i>	<i>P</i>	<i>P</i>	<i>P</i>	
<i>0</i>	0	8	} Digit x	{ 0	0	(zero vaue)	128	
<i>1</i>	0	4			1		7	64
<i>2</i>	B	2			2		6	32
<i>3</i>	A	1			3		5	16
<i>4</i>	8	8	} Digit x + 1	{ 8	4	4	8	
<i>5</i>	4	4			5	3	4	
<i>6</i>	2	2			6	2	2	
<i>7</i>	1	1			7	1	1	

X = Higher order digit  
X + 1 = Lower order digit  
0 = Logical Zero

FIGURE 3. Organization of Information on Bus

**2.2.1.1 Bus Out.** 'Bus out' is used to transmit addresses, commands, control orders, and data to the control units. The type of information transmitted over 'bus out' is indicated by the outbound tag lines:

1. When 'address out' is up during the channel-initiated selection sequence, 'bus out' specifies the address of the I/O device with which the channel wants to communicate.
2. When 'command out' is up in response to 'address in' during the channel-initiated selection sequence, 'bus out' specifies a command.

3. When 'service out' is up in response to 'service in' (or 'data out' is up in response to 'data in') during the execution of a write or control command, the nature of the information on 'bus out' depends on the type of operation. For example, during a write operation it contains data to be recorded by the I/O device. During a control operation, it can specify an order code or a second-level address within the control unit or I/O device.

The period during which information in 'bus out' is valid is controlled by the tag lines. During transmission of the I/O device address, information on the bus must be valid from the rise of 'address out' until the rise of 'operational in', 'select in', or in the case of the control-unit-busy sequence, until 'status in' drops. When the channel is transmitting any other type of information, the information on 'bus out' is valid from the rise of the signal on the associated outbound tag line until the fall of the signal on the responding inbound tag line.

Some skew on 'bus out' must be accommodated by the channel. (Except as noted in section 2.2.2.3 "Address Out", the channel must delay raising of the signal on the outbound tag lines by a time duration that ensures that the information on 'bus out' will precede the signal on the outbound tag line by not less than 100 nanoseconds. The delay is measured at the channel cable connectors and under the worst-case skew conditions.) Therefore, the channel must provide a delay that accommodates skew caused by its own circuitry and, in addition, must provide a delay of at least 100 nanoseconds. This delay compensates for skew caused by the cable and, for most control units, will also be sufficient to accommodate the skew caused by the interface receivers. When a control unit can cause more skew, the control unit must provide the additional delay to compensate for it. (See section 2.8.1 "Interface Time-Out Considerations".)

**2.2.1.2 Bus In.** 'Bus in' is used to transmit addresses, status, sense information, and data to the channel. A control unit can place and maintain information on 'bus in' only when its 'operational in' is up, except in the case of the control-unit-busy sequence.

The type of information transmitted over 'bus in' is indicated by the inbound tag lines:

1. When 'address in' is up, 'bus in' specifies the address of the currently selected I/O device.
2. When 'status in' is up, 'bus in' contains a byte of information that describes the status of the I/O device or control unit.
3. When 'service in' (or 'data in') is up during execution of a read or sense command, the nature of the information contained on 'bus in' depends on the type of operation. During a read operation, it may contain a bit of data from the record medium. During a sense operation, the bus contains a set of bits describing the detailed status of the I/O device and the conditions under which the last operation was terminated.

The period during which information on 'bus in' is valid is controlled by the tag lines. Information on the bus must be valid within 100 nanoseconds after the rise of the associated inbound tag and must remain valid until the rise of the responding outbound tag, or, in a control-unit-busy sequence, until 'select out' drops. The 100 nanoseconds delay between the rise of the inbound tag and the time the signal becomes valid on 'bus in' places the responsibility on the channel for deskewing 'bus in'. The channel must provide a delay in the inbound tag lines to accommodate skew caused by the channel circuitry (including its receivers) and, in addition, must provide a delay of at least 100 nanoseconds. This delay compensates for skew caused by the cable, and for most control units, the skew caused by the drivers. This delay provides sufficient time to deskew the information so that the inbound tag can be raised by the control unit at the same time information is placed on the bus. When a control unit and cable can cause more skew than can be accommodated by a 100 nanosecond delay, the control unit must provide the additional delay to eliminate this greater skew.

## 2.2.2 Selection Controls and Tag Lines.

**2.2.2.1 Operational Out.** 'Operational out' is a line from the channel to all attached control units and is used for interlocking purposes. Except for 'suppress out', all lines from the channel are significant only when 'operational out' is up. Whenever 'operational out' is down, all inbound lines from the control unit must drop and any operation currently in process over the interface must be reset. Under these conditions, all control unit-generated interface signals must be down within 1.5 microseconds after the fall of 'operational out' at the control unit. (See sections 2.5.11 "Selective Reset" and 2.5.12 "System Reset".)

**2.2.2.2 Request In.** 'Request in' is a line from all attached I/O control units to the channel and indicates that the control unit is ready to present status information or data and is therefore requesting a selection sequence. (See section 2.3.3 "Control Unit-Initiated Sequence".) 'Request in' should be dropped when 'operational in' rises, unless additional selection sequences are required, or when the control unit is no longer ready to present the status information or data, or when the selection requirement is satisfied by another path. 'Request in' must never fall later than 250 nanoseconds after the fall of 'operational in' if the sequence satisfies the service requirements of the control unit.

'Request in' must not remain up when 'suppress out' is up if the request for status presentation is suppressible (see section 2.5.7 "Suppress Status"). Under this condition, 'request in' must fall at the control unit within 1.5 microseconds after the rise of 'suppress out' at the control unit.

'Request in' can be signaled by more than one control unit at a time.

**2.2.2.3 Address Out.** 'Address out' is a tag line from the channel to all attached control units. It provides two functions:

1. **I/O Device Selection.** 'Address out' is used to signal all the control units to decode the I/O device address on 'bus out'. The control unit, when recognizing the address, must respond by raising its 'operational in' line when its incoming 'select out' (see section 2.2.2.4 "Select Out, Hold Out, and Select In") rises with 'address out' still up (except in the case of control-unit-busy). The rise of 'address out' follows the placing of the I/O device address on 'bus out' by at least 250 nanoseconds. 'Address out' must have been down for at least 250 nanoseconds before its rise for device selection. If 'address out' falls before 'select out' rises, this control unit selection is canceled.

'Address out' can rise only when 'select out' ('hold out'), 'select in', 'status in', and 'operational in' are down at the channel (except as otherwise noted below in 2). Ultimate use of the address on 'bus out' at the control unit is timed by the next rise of 'select out' at the addressed control unit.

Once 'address out' and 'select out' ('hold out') are up, 'address out' must stay up until either 'select in' or 'operational in' rises, or until 'status in' falls, in the case of the control-unit-busy sequence. During I/O device selection, 'address out' cannot be up concurrently with any other outbound tag line.

2. **Disconnect Operation.** If 'hold out' is down and 'address out' rises or 'address out' is up and 'hold out' falls, the presently connected control unit must drop its 'operational in', thus disconnecting from the interface. 'Address out' remains up until 'operational in' drops. 'Operational in' must drop within 6 microseconds after receiving the disconnect indication. Mechanical motion in process continues to a normal stopping point. Status information is generated and presented to the channel as defined in section 2.5.10 "Interface Disconnect".

**2.2.2.4 Select Out, Hold Out, and Select In.** Control unit selection is controlled by 'select out', 'select in', and 'hold out'. 'Select out' and 'select in' form a loop from the channel through each control

unit to the cable terminator block ('select out'), again through each control unit back to the channel ('select in'). Control unit selection circuitry may be attached to either 'select out' or 'select in'. A selection priority is established because the rise of 'select out' is effective only to the first control unit on the line, and if selection is not required, is in turn propagated by each control unit to the next control unit on the line. This priority is in a descending sequence from the channel through each control unit with selection circuitry attached to 'select out' followed, in descending order back to the channel, by the remaining control units with selection circuitry attached to 'select in'. (See figure 2.)

Note: For purposes of clarity, this document assumes that the selection circuitry of all control units is attached to 'select out'.

Each control unit must ensure that the process of electrically bypassing 'select out' before power changes does not interfere with the propagation of 'select out'. Each control unit must therefore ensure that 'select out' discontinuities, which may occur when another control unit on the interface is powered up or down, do not affect the propagation of 'select out'. This should be accomplished by the use of a special latch circuit. The latch is turned on by the AND of 'select out' and 'hold out', and is reset by the fall of 'hold out'. The circuit is in series with the remaining selection circuitry in the control unit and provides a constant 'select out' within the control unit, and therefore to the following control unit, regardless of variations in the input 'select out' signal. (See figure 4.)

Throughout the following description, 'select out' assumes the proper operation of the latch; i.e., the rise of 'select out' at the control unit presumes that 'hold out' is up and the fall of 'select out' is a result of the fall of 'hold out'.

'Select out' is a line from the channel to the control unit that has highest priority, and from any control unit to the control unit next lower in priority. This line, together with 'select in', provides a loop for scanning the attached control units. A control unit can raise its 'operational in' only at the rise of its incoming 'select out'. If a control unit does not require selection, it must propagate the signal to the next control unit. Once a control unit propagates 'select out', it cannot raise its 'operational in' or respond with a control-unit-busy sequence until the next rise of the incoming 'select out'.

When an operation is being initiated by the channel, 'select out' is raised no sooner than 400 nanoseconds after the rise of 'address out' which indicates the address of the device being selected.

The channel must keep 'select out' up until either 'select in' or 'address in', or 'address in' and 'operation in', or 'status in' rises.

When 'select in' rises, 'select out' must drop and may not rise again until after 'select in' falls.

A control unit becomes selected only when it raises its 'operational in'. 'Select out' must drop so that 'operational in' may drop. However, after the drop of 'select out', the control unit must keep 'operational in' up until the current signal sequence is completed. A rise of the incoming 'select out' in a control unit signals that the control unit can become selected to the channel by raising 'operational in'. If a control unit raises 'operational in', it must suppress the propagation of 'select out' to the next control unit. If the control unit does not require selection, it must propagate 'select out' to the next control unit within 1.8 microseconds. (See section 2.8.1 "Interface Time-Out Considerations".)

When 'status in' rises in response to 'select out' during a channel initiated selection sequence (indicating control-unit-busy), 'select out' must be dropped and must not rise until 'address out' has dropped.

'Hold out' is a line from the channel to all attached control units and is used in conjunction with 'select out' to provide synchronization of control unit selection.

'Hold out' is also used to minimize the propagation of the fall of 'select out' by purging the 'select out' signal from the 'select out' signal path. Therefore, once 'hold out' drops, it must not rise for at least 4 microseconds in general system configurations. The minimum downtime of this signal may be optionally adjusted at installation time to a minimum of 2 microseconds to handle high-speed channel configurations. In all cases, the channel must be capable of providing the 4-microsecond timing for general system configuration. (See section 2.8.3 "System Configuration".)

In order to prevent overlapping interface sequences, one of the following procedures must be accomplished:

1. 'Select out' is not raised until all in-tags and 'operational in' are in a down state, or:
2. In-tags are not considered valid until 1.5 microseconds after the fall of 'operational in'.

'Select in' is a line that extends the 'select out' signal from the jumper in the terminator block to the channel (see figure 2). It provides a return path (to the channel) for the 'select out' signal.

**2.2.2.5 Operational In.** 'Operational in' is a line from all attached control units to the channel, and is used to signal to the channel that an I/O device has been selected (except for the control-unit-busy sequence). It must stay up for the duration of the selection. The selected I/O device is identified by the address byte transmitted over 'bus in'.

The rise of 'operational in' indicates that control unit is selected and is communicating with the channel. 'Operational in' can rise only when the incoming 'select out' to the control unit is up and the outgoing 'select out' is down; i.e., the control unit may raise 'operational in' (except for the control-unit-busy sequence) only in response to the rise of 'select out' and must block 'select out' from emanating to the next control unit. 'Operational in' can drop only after 'select out' drops.

When 'operational in' is raised for a particular signal sequence, it must stay up until all required information is transmitted between the channel and the control unit. If 'select out' is down, 'operational in' must drop after the rise of the outbound tag associated with the transfer of the last byte of information. With the exception of 'request in' or 'metering in', all inbound signals must be down within 1.5 microseconds of the fall of 'operational in' at the control unit.

**2.2.2.6 Address In.** 'Address in' is a tag line from all attached control units to the channel and is used to signal the channel when the address of the currently selected I/O device has been placed on 'bus in'. The channel responds to 'address in' by 'command out'.

The rise of 'address in' indicates that the address of the currently selected I/O device is available on 'bus in'. 'Address in' must stay up until the rise of 'command out'. 'Address in' must fall so that 'command out' may fall. 'Address in' cannot be up concurrently with any other inbound tag line.

**2.2.2.7 Command Out.** 'Command out' is a tag line from the channel to all attached control units and is used to signal the selected I/O device in response to a signal on 'address in', 'status in', or 'service in'. A signal on 'command out' as a response to 'address in' during the initial-selection sequence indicates to the selected I/O device that the channel has placed a command byte on 'bus out'. (The command byte has a fixed format. See section 1.4 "Commands".) The rise of 'command out' indicates that information on 'bus in' is no longer required to be valid. 'Command out' must stay up until the fall of the associated 'address in', 'status in', or 'service in'. It cannot be up concurrently with any other outbound tag line, except possibly during an interface-disconnect sequence in which case 'address out' may be up. (See section 2.5.10 "Interface Disconnect".)

'Command out' in response to 'address in' means *proceed* during a control unit-initiated sequence. In the case of a channel-initiated selection sequence, 'command out' indicates that 'bus out' defines the operational command to be performed. 'Command out' in response to 'service in' always means *stop* (see section 2.5.2 "Stop"). 'Command out' in response to 'status in' means *stack* (see section 2.5.3 "Stack Status").

When 'command out' is raised to indicate *proceed*, *stack*, or *stop*, 'bus out' must have a byte of all zeros, but need not necessarily have correct parity. 'Bus out' is not to be checked for parity or decoded by the control unit under these circumstances.

**2.2.2.8 Status In.** 'Status in' is a tag line from all attached control units to the channel and is used to signal the channel when the selected control unit has placed status information on 'bus in'. The status byte has a fixed format and contains bits describing the current status at the control unit (see section 2.6.1 "Status Byte"). The channel responds with 'service out' to accept status or 'command out' to stack status.

The rise of 'status in' indicates that a byte of status information is available on 'bus in'. 'Status in' cannot be up concurrently with any other inbound tag line. 'Status in' must stay up until the rise of either 'command out', 'service out', or 'address out', or in the control-unit-busy sequence, until 'select out' falls. It must fall so that the responding out-tag may fall. During the control-unit-busy sequence, status information on 'bus in' must be valid until 'select out' ('hold out') falls.

**2.2.2.9 Service Out.** 'Service out' is a tag line from the channel to all attached control units and is used to signal the selected I/O device in recognition of a signal on 'service in' or 'status in'. A signal on 'service out' indicates to the selected I/O device that the channel has accepted the information on 'bus in' or has provided on 'bus out' the data requested by 'service in'.

When 'service out' is sent in response to 'service in' during a read or sense operation, or to 'status in', the service out signal must rise after the channel accepts the information on 'bus in'. In these cases, the rise of 'service out' indicates that the information is no longer required to be valid on 'bus in', and is not associated with any information on 'bus out'. When 'service out' is sent in response to 'service in' during a write or control operation, the rise of 'service out' indicates that the channel has provided the requested information on 'bus out'. In this case the signal must rise after the information is placed on the bus. 'Service out' must stay up until the fall of the associated 'service in' or 'status in'. 'Service out' cannot be up concurrently with any other out-tag except during an interface-disconnect sequence (when 'address out' may be up).

A 'service out' response to 'status in' while 'suppress out' is up indicates to the control unit that the operation is being chained and that this status is accepted by the channel. (See 2.5.9 "Command Chaining").

**2.2.2.10 Service In.** 'Service in' is a tag line from all attached control units to the channel and is used to signal to the channel when the selected I/O device wants to transmit or receive a byte of information. The nature of the information associated with 'service in' depends on the operation and the I/O device. The channel must respond to 'service in' by 'service out', 'command out', or, during an interface disconnect, by 'address out'.

During read, read-backward, and sense operations, 'service in' rises when information is available on 'bus in'. During write and control operations, 'service in' rises when information is required on 'bus out'. 'Service in' cannot be up concurrently with any other inbound tag line. 'Service in' must stay up until the rise of either 'service out', 'command out', or 'address out'.

When, in the case of cyclic I/O devices, the channel does not respond in time to the preceding 'service in', an overrun condition occurs. This condition must be recognized by the I/O device. In any case, 'service in' must not drop if an out-tag has not risen, nor may it rise if 'service out' has not dropped.

An overrun condition causes both the 'unit check' status indicator and the 'overrun' sense indicator to be set. Data transfer stops after an 'overrun' condition. For I/O devices that may overrun, the critical signal timing involved must be part of the operation I/O device specifications.

**2.2.2.11 Suppress Out.** 'Suppress out' is a line from the channel to all attached control units and is used both alone and in conjunction with the out-tag lines to provide the following special functions: suppress data, suppress status, command chaining, and selective reset. Each of these functions is described in subsequent sections.

**2.2.3 Metering Controls.** 'Clock out', 'metering in', and 'metering out' are used to condition usage meters in the channel and control unit.

**2.2.3.1 Clock Out.** 'Clock out' is a line from the channel to all attached control units and is used to provide the CPU interlock control necessary for changing the enable/disable states of the control units (refer to the Operational Specifications for the control unit). 'Clock out' must be down to permit changing states. 'Clock out' is lowered whenever the channel can tolerate a change of state at the control unit (such as during a stop, halt, or wait state). In addition, the control unit's transition between the enabled and disabled state requires the same prevailing conditions as for the offline/online transition. (See section 2.8.4 "Offline/Online".)

The down state of 'clock out' must be at least 1 microsecond in duration.

**2.2.3.2 Metering In.** 'Metering in' is a line from all attached control units and is used to condition the CPU meter for operation. The 'metering in' signal originates from each I/O device, control unit, or both, and is generated by the device from the time of acceptance of a command until the generation of 'device end' for that command. 'Metering in' may be raised concurrently with 'operational in' for any interface signaling sequence that does not involve 'device end', such as test I/O or a control unit-initiated status presentation. If raised, the duration of the signal must not exceed that of 'operation in'. 'Metering in' may be signaled by more than one control unit at a time.

'Metering in' is not raised:

1. Between the generation and acceptance of 'device end'.
2. Between the generation of 'device end' and the acceptance of the next command during chaining.
3. While a device is waiting for initiation of an automatic start. For example, transmission control units do not necessarily activate 'metering in' during the idle portion of prepare commands.

**2.2.3.3 Metering Out.** 'Metering out' is a line from the channel to all attached control units and is used to condition all other meters in assignable units and I/O units. 'Metering out' is raised whenever 'metering in' is raised or whenever the CPU is in a run mode (not in a stop, halt, or wait state).

**2.2.4 Reserved Lines.** Some of the signal lines in the I/O interface are reserved. (See section 3.5.5 "Interface Connector Pin Assignments".)

The 40 assigned and 8 reserved transmission lines in cables (1) and (2), with the exception of 'select out' ('select in' if low priority), must be carried thru all control units from the IN cable connector to the OUT cable connector. All control units using 'bus 1' must carry through all 48 signal transmission lines in cables (1), (2), and (3). (See section 3.5.5 "Interface Connector Pin Assignments", and figure 12.)

2.2.5 Signal Interlock Summary. The following rules for direct-current interlocking of signals must be used in the design of channels and control units using this I/O interface:

1. Except for 'address out', no more than one out-tag may be up at any given time during the interface-disconnect sequence.
2. No more than one in-tag may be up at any given time.
3. An in-tag may rise only when all out-tags are down, except for the control-unit-busy sequence.
4. An in-tag may fall only after the rise of a responding out-tag, except for 'status in' in the control-unit-busy sequence.
5. 'Service out' and 'command out' may rise only in response to the up level of an in-tag.
6. 'Address out' for a channel-initiated selection sequence may rise only when 'select in' and 'select out' are down at the channel.
7. Once 'address out' and 'select out' have risen for a channel-initiated selection sequence, 'address out' must stay up until after the rise of 'select in' or 'operational in' or the fall of 'status in'.
8. Once 'address out' has risen for the interface-disconnect control sequence, it must not drop until 'operational in' drops.
9. None of the out lines, except 'suppress out', have meaning when 'operational out' is down.
10. 'Select out' can rise only if 'operational in' and 'select in' are down.
11. 'Operational in' cannot fall until either:
  - a. 'Select out' falls and an out-tag response is sent for the last in-tag of any given signal sequence, or
  - b. 'Operational out' falls, or
  - c. An interface-disconnect sequence is given.
12. 'Operational in' cannot rise unless 'operational out' is up and must drop if 'operational out' drops.

**Note:** Designers should carefully consider the effects of interface signal transition times. Although transition time should not generally be a problem, some cases may exist, due to wide variation in circuit tolerance or physically integrated channel control units, where transition time must be considered.

The general design rule is that the unit originating the signal (channel or control unit) must fully recognize internally the transition of the signal from one state to the other before any result of the transition can be returned from the receiving unit.

Interlocks for the basic interface may be altered when features are installed. If so these are delineated in the feature specifications. (See section 2.9 "Features".)

**2.3 Operation.** This section describes the detailed signal sequence for a complete I/O operation. These sequences include: initial selection, data transfers, and ending procedures. For further reference see Flow Diagrams 1-8 in Appendix A and Sequence Charts 1-4 in Appendix B.



**2.3.1 Initial-Selection Sequence.** To initiate an I/O operation, the channel places the address of the desired I/O device on 'bus out' and raises 'address out'. Each control unit connected to the channel attempts to decode the address on the bus; however, only one control unit should be assigned to a given I/O address. To be acceptable, the address must have correct parity.

The channel then issues 'select out'; and when the incoming 'select out' appears at the addressed control unit, the control unit blocks its propagation and raises the 'operational in' line. When 'operational in' rises, the channel responds by dropping 'address out'. After 'address out' falls and the I/O device address is on 'bus in', 'address in' may rise. For a byte multiplex operation (see section 2.3.4.1 "Byte Multiplex Mode"), 'hold out' with 'select out' may drop any time after this point. After the channel checks the address, it responds by placing the command on 'bus out' and signaling on the 'command out' line. The selected control unit processes the command and drops 'address in', which allows 'command out' to fall. After 'command out' drops, the control unit places the status information on 'bus in' and raises 'status in'.

If the channel accepts this status condition, it responds with 'service out'. 'Service out' allows 'status in' to fall, completing the initial-selection sequence. A 'command out' response from the channel also allows 'status in' to fall. (See section 2.5.3 "Stack Status".)

If the I/O device is operating during this channel-initiated selection sequence the control unit presents 'busy' status. When the control unit has, for the addressed device, status information outstanding from a previous operation or an externally initiated status condition, it presents the 'busy' status (except to the all-zero command) along with the other status conditions in the status byte. (See section 2.6.2 "Unit Status Conditions".)

If the command is rejected by the control unit, for example, as a result of the detection of an invalid command, the control unit presents the 'unit check' status condition. No operation is initiated at the control unit and no ending status is generated.

An immediate-type command or command-immediate is a command whose execution meets the following requirements:

1. Execution requires no more information than that in the command byte; that is, no data or information bytes are transferred.
2. Channel-end time coincides with initial-status time; and on a normal operation, 'channel end' instead of zero status will be in the initial-status byte.

**Note:** A channel response of 'command out' to 'status in' cannot prevent the execution of an immediate command.

**2.3.2 Control-Unit-Busy Sequence.** If an I/O device is addressed and the control unit to which it is attached is busy or has status pending for an I/O device other than the one addressed, the control unit responds with a status byte indicating the 'busy' condition. (See section 2.6.6 "Busy".) The control unit can present this status byte in either of two ways, depending on the design of the control unit; it can present status information as in the initial-selection sequence or it can respond with the shorter control-unit-busy sequence.

**Note:** The control-unit-busy sequence must not be used in response to an initial-selection sequence addressed to a device for which chaining has just been indicated.

The control-unit-busy sequence begins when the channel places the I/O device address on 'bus out' and raises 'address out'. 'Select out' is then raised. Each control unit attempts to decode the address on

'bus out'. When 'select out' rises at the addressed control unit, the control unit blocks the propagation of 'select out', places the 'busy' status byte on 'bus in' and raises 'status in'. 'Operational in' is not raised.

After accepting the status byte, the channel drops 'select out'. The control unit responds by dropping 'status in' and disconnecting from the interface. The channel must keep 'address out' up until 'status in' drops, thus completing the control-unit-busy sequence.

**2.3.3 Control Unit-Initiated Sequence.** When any control unit requires service, it raises 'request in' to the channel. The next time 'select out' rises at any control unit requiring service and no I/O selection is being attempted by the channel ('address out' down), the control unit places the address of the I/O device on 'bus in', and signals both 'address in' and 'operational in'. When the channel recognizes the address, 'command out' is sent to the control unit, indicating *proceed*. After 'address in' drops, the channel responds by dropping 'command out'.

If the service request is for data, the sequence proceeds as described in section 2.3.4 "Data Transfer". The control unit-initiated selection for data transfer occurs in byte multiplex mode.

If the service request is to present status information, the sequence proceeds as defined for the status cycle in the ending procedure. (See section 2.3.5 "Ending Procedure and Asynchronous Status".)

**2.3.4 Data Transfer.** Data transfer may be requested by a control unit after a selection sequence. To transmit data to the channel, the control unit places a data byte on 'bus in' and raises 'service in'; the tag and the validity of 'bus in' must be maintained until an outbound tag is raised in response.

To request data from the channel, 'service in' is raised, and the channel places the data on 'bus out' and signals with 'service out'. The channel maintains the validity of 'bus out' until 'service in' falls. After 'service in' falls, the channel responds by dropping 'service out'.

After selection, the control unit remains connected to the channel for the duration of the transfer of information. The information can be a single byte of data, a status report, an initiation of a new command, a string of data bytes, or a complete operation from initiation to reception of the final status report.

The duration of the connection is under control of both the channel and the control unit. To provide a channel with a method of controlling the duration of the connection, a control unit cannot disconnect from the interface before 'select out' ('hold out') falls. However, the control unit may preserve the logical connection after the channel permits the control unit to disconnect-'select out' ('hold out') down-by holding up 'operational in'. In this manner, the control unit can force burst mode. (See section 2.3.4.2 "Burst Mode".)

Depending on the duration of the connection, one of two modes of operation is established: byte multiplex or burst. (These modes are established so that the program can schedule concurrent execution of multiple I/O operations.)

If 'operational in' remains up for longer than the byte multiplexing time-out limit, selection is in burst mode. (See section 2.8.1 "Interface Time-Out Considerations".) If the selection time is less than this time-out limit, the selection is in byte multiplex mode.

**2.3.4.1 Byte Multiplex Mode.** The byte multiplex mode is the normal mode for low-speed I/O devices, however, all I/O devices are designed to operate in burst mode when required by the channel. Channels that are not capable of operating in byte multiplex mode force burst mode by holding up 'select out' ('hold out') until presentation of 'channel end' status conditions. The transfer of one, or more than one, data byte during a single interface sequence, where the time contributed by the control unit is less than 32 microseconds, is considered byte multiplex mode.

**2.3.4.2 Burst Mode.** Burst mode is the normal mode of operation for high-speed I/O devices. These devices force burst mode (by holding up 'operational in') when attached to a channel capable of byte multiplex operation. Medium-speed or buffered I/O devices, which may normally operate in either mode as determined by channel data rate capabilities, are equipped with a manual programmable switch to select the mode of operation. The switch setting is overridden when burst mode is forced by the channel. An interface disconnect executed by the channel overrides the force-burst-mode condition of a control unit. (See section 2.5.10 "Interface Disconnect".)

**2.3.5 Ending Procedure and Asynchronous Status.** The ending procedure may be initiated by either the I/O device or the channel. If the procedure is initiated by the I/O device, the end of operation is completed in one signal sequence, assuming that both 'channel end' and 'device end' status conditions occur together. If the procedure is initiated by the channel, the I/O device may still require time to reach the point where the proper status information is available, in which case a second signal sequence is necessary to complete the ending procedure.

One of three situations may exist at the initiation of the ending procedure (assume selection is already obtained):

1. The channel recognizes the end of an operation before the I/O device reaches its ending point. In this situation, whenever the control unit requires service again, the control unit raises the 'service in' line. The channel responds with 'command out', indicating stop. The control unit drops 'service in' and proceeds to its normal ending point without requesting further service. When the I/O device reaches the point at which it would normally send 'channel end', the control unit places the ending status on 'bus in' and raises 'status in'. The channel responds with 'service out', unless it is necessary to stack the status condition, in which case the channel responds with 'command out'.
2. The channel and the I/O device recognize the end of an operation simultaneously.
3. The I/O device recognizes the end of an operation before the channel reaches the end of an operation.

For situations 2 and 3, status information is available at the control unit. The control unit places the ending status on 'bus in' and raises 'status in'.

If 'device end' does not occur with 'channel end', 'device end' is presented when it is available and an additional status sequence is required.

Some status conditions are unrelated to any previous program-initiated command. One of these conditions is 'attention', which is normally on console or communication devices. Another condition is 'device end', which is generated when the corresponding device goes from the not-ready to the ready state. These status conditions are handled in the same way as any other status information and are subject to the same rules as far as presentation to the channel and stacking are concerned.

**2.3.6 Addressing.** An eight-bit address byte (plus parity) is used over the interface for direct addressing of attached I/O devices. A unique eight-bit I/O device address is assigned to each I/O device at the time a control unit is installed.

**2.3.6.1 Address Assignment.** At the time of installation, control unit and I/O device addresses are assigned as follows:

1. Devices that do not share a control unit with other devices may be assigned any device address in the range 0-255, provided the address is not recognized by any other control unit. Logically,

such devices are not distinguishable from their control unit, and both are identified by the same address.

2. Devices sharing a control unit (magnetic tape units and disk storage units) are assigned addresses within sets of contiguous numbers. The size of a set of contiguous numbers is equal to the maximum number of devices that can share the control unit, or 16, whichever is smaller. Furthermore, the set of addresses starts with an address in which the number of low-order zeros is at least equal to the number of bit positions required to specify the size of the set. The high-order bit positions of an address with a set identify the control unit; the low-order bit positions designate the device on the control unit.
3. Control units designed to accommodate more than 16 devices may be assigned nonsequential sets of addresses. Each set consists of 16 addresses, or the number required to make the total number of assigned addresses equal to the maximum number of devices attachable to the control unit, whichever is smaller. The addressing facilities are added in increments of a set so that the number of device addresses assigned to a control unit does not exceed the number of devices attached by more than 15. For example, if a communication-type control unit has a designed capacity of 56 direct-access paths and if only 40 I/O devices are to be installed at the time of installation, 48 I/O device addresses can be assigned. However, if the full capacity of 56 I/O devices is to be installed, exactly 56 addresses are assigned.

Input/output devices accessible through more than one channel in the same system have a distinct address for each path of communication. For sets of devices connected to two or more control units, the portion of the address identifying the device on the control unit is fixed, and does not depend on the path of communications.

Except for the rules described, the assignment of channel and device addresses is arbitrary. The assignment is made at the time of installation and the addresses normally remain fixed thereafter.

**2.3.6.2 Address Decoding.** Control units must recognize an I/O device address that meets the following conditions:

1. The address has correct parity.
2. The address is assigned to the control unit.

The control unit does not respond to any address outside its assigned set or sets. For example, if a control unit is designed to control devices that have only bits 0000-1001 in the low-order position of the device address, the control unit does not recognize addresses that have 1010-1111 in these bit positions. If no control unit responds to an address ('select out' is propagated through all control units, and back to the channel on 'select in'), the device appears as not operational. Not operational may include (in addition to addresses outside an assigned set):

1. An I/O device address not installed.
2. An I/O device address partitioned out of the system by the program, operator, or customer engineer (offline, disabled, etc.).

The control unit must respond to those addresses in the set for which the corresponding devices are:

1. Ready.
2. Not ready but that can be made ready by means of an ordinary manual intervention. A not-ready device is indicated by the 'unit check' status and 'intervention required' sense indicators.

The control unit may respond to all addresses in the assigned set, regardless of whether the device associated with the address is installed. If a control unit responds to an address for which no device is installed, the 'unit check' status indicator must be turned on (as well as the appropriate sense indicator(s)).

The portion of the address decoder which identifies the control unit (see item 2 under section 2.3.6.1 "Address Assignment") can be set at the time of installation for any bit combination.

Single device address control units must decode all eight bits of the address byte and the decoder can be set to any bit combination at the time of installation. (See item 1 under section 2.3.6.1 "Address Assignment".)

**2.4 Commands.** When 'command out' is up in response to 'address in' during an initial-selection sequence, the information on 'bus out' is the command byte. A channel issues 'command out' to initiate, continue, or terminate an operation in an I/O device.

**2.4.1 Command Byte.** The command byte requires decoding by the control unit only during a channel-initiated selection sequence (when the channel addresses the I/O device). At all other times, the byte is zero (parity is unimportant). The low-order bit positions indicate the type of operation; the high-order bit positions indicate a modification code which expands the basic operation at the control unit or I/O device level.

The actual modifier codes and the particular modes set or the controls performed for them must be specified in the Operational Specifications for each control unit, I/O device, or both.

The command byte on the interface is defined as follows:

	Bit Position									
	P	0	1	2	3	4	5	6	7	
Test I/O*	1	0	0	0	0	0	0	0	0	0
Sence	P	M	M	M	M	0	1	0	0	
Read Backward	P	M	M	M	M	1	1	0	0	
Write	P	M	M	M	M	M	M	0	1	
Read	P	M	M	M	M	M	M	1	0	
Control	P	M	M	M	M	M	M	1	1	

M — Modifier bit

P — Parity bit

\* Although test I/O may be a CPU instruction, it appears over the interface as a command. All references to test I/O in this manual refer to the test I/O command.

Sense, control commands with all-zero modifier bits, and the test I/O command are executed on all I/O devices and are decoded as follows:

	Bit Position									
	P	0	1	2	3	4	5	6	7	
Basic Sense	0	0	0	0	0	0	1	0	0	
Test I/O	1	0	0	0	0	0	0	0	0	
No-operation Control	1	0	0	0	0	0	0	1	1	

**2.4.2 Basic Operations.** The I/O operation to be executed over the interface is determined by the eight-bit coded command issued to the I/O device during a channel-initiated selection sequence. The low-order bit positions of this command byte specify the type of operation. (See section 2.4.1 "Command Byte".) The high-order bit positions (modifier code) expand the interpretation of the basic operation at the control unit or I/O device level.

**Note:** The basic operations are expressed by the commands: read, read backward, write, control, sense, and test I/O. This Standard treats test I/O as a command on the I/O interface, although it may originate as either a CPU instruction or a channel-initiated sequence for the purpose of clearing or stacking interruption conditions.

A command with invalid parity is not recognizable and therefore not executable.

**Note:** Special diagnostic commands, which by intent permit errors to occur on the interface or introduce the possibility that subsequent commands may be executed erroneously, must be interlocked in such a fashion as to prevent inadvertent use of them.

**2.4.2.1 Read.** The read command initiates execution of data transfer from the control unit to the channel and the data is obtained, for example, from the record source of the particular I/O device in operation.

A read command, with all modifiers set to zero, is a basic read command that is also used as an initial-program-loading (IPL) read command. This command, in order to perform the initial-program-loading read as specified for that particular I/O device as stated in the appropriate Operational Specification must be:

1. The first command sent to the I/O device following a system reset.
2. Must not be sent sooner than 1 millisecond following the reset.

**2.4.2.2 Read Backward.** The read-backward command initiates an operation in the same manner as the read command, except that the data bytes are transferred to main storage by the channel in reverse order to that for a read command. The control unit may be designed to cause mechanical motion in the I/O device in the opposite direction of that for a read command or may be designed to operate in the device precisely as with a read command.

Unless otherwise noted, any description that applies to read also applies to read backward.

**2.4.2.3 Write.** The sequence of signals over the I/O interface to perform a write operation is the same as for a read operation. For a write operation, however, the data is sent from the channel to the control unit for operations such as recording or comparing by the selected I/O device.

**2.4.2.4 Control.** The control operation proceeds similarly to a write operation, except that the command modifier bits received by the control unit are decoded to determine which of several possible functions is to be performed. The function may be second-level addressing which may require several bytes of data to complete the control operation. When the particular control function can be completed without involving the transfer of data, the 'channel end' status may be presented during the initial-selection sequence.

The timing in the control unit for the bytes transferred during a control operation is normally such that the byte rate for this operation is not required to be faster than the normal read or write rate for the same I/O device. Input/output devices may be excepted from this restriction as determined on an individual basis, as specified in the Operational Specification.

A control command with all-zero modifiers performs no operation at the I/O device, except to satisfy any previously indicated chaining operations and to allow certain I/O devices to wait for conditions of checking (or any synchronizing indications) before releasing the channel. This variation of the control command is a no-operation control.

**2.4.2.5 Sense.** The sense command proceeds exactly as a read command, except that the data is obtained from sense indicators rather than from a record source.

The purpose of the sense command is to describe the actual state of the device and to extract information that concerns unusual conditions detected during the last operation.

The basic sense command (modifier bits set to zero) initiates a sense operation on all I/O devices. The basic sense command must not initiate any operation other than to sense the sense indicators. The basic sense command to an available control unit must be accepted even though the addressed I/O device is in a not-ready state (mechanically unable to execute other operations). (See section 2.7 "Sense Information".) If the control unit detects an error during the sense operation, 'unit check' is sent with the 'channel end' status condition.

The I/O devices that can provide special diagnostic sense information or that can be instructed to perform other special functions by means of sense may define modifier bits for the control of the function. The special sense operation may be initiated by unique combinations of modifier bits or a group of codes may specify the sense function. Any remaining sense command codes may be considered invalid or may cause the same action as the basic sense command, depending on the particular I/O device.

**2.4.2.6 Test I/O.** The test I/O command relieves the addressed I/O device path of pending status information. If no pending status information is encountered along the I/O path being tested, a zero status byte for the selected I/O device is sent to the channel for processing. If status information is available, pending status bits for the selected I/O device are transmitted to the channel.

Note that the 'busy' condition is defined differently with respect to test I/O than for other commands. (See section 2.6.6 "Busy".)

The signal sequence to accomplish test I/O is the same as any other channel-initiated selection process, except that no operation is initiated.

**2.5 Sequence Controls.** The sequence controls described in this section are determined by the sequence of the signals over the interface.

**2.5.1 Proceed.** Whenever 'command out' responds to 'address in' at any time other than during a channel-initiated selection sequence, it means *proceed*.

*Proceed* indicates to the I/O device that the I/O device should continue the normal servicing sequences on the interface.

**2.5.2 Stop.** *Stop* is indicated by 'command out' in response to 'service in' or as a result of an interface disconnect, which occurs before the normal 'channel end' for the operation in process. (See section 2.5.10 "Interface Disconnect".) *Stop* is used to signal the I/O device that the channel is ending the current operation. On receipt of the *stop* signal, the I/O device must proceed to its normal ending point without sending any further 'service in' signals to the channel. The I/O device remains busy until the ending status is available, presented to, and accepted by the channel.

During data operations, 'command out' is transmitted in response to the first 'service in' that is provided after the designated operation is complete. (If 'select out' is down or goes down after this

sequence, 'operational in' must drop on force-burst-mode type operations on I/O devices that cannot meet the time-out requirements as indicated in section 2.8.1 "Interface Time-Out Considerations".) Also, burst mode I/O devices that have relatively long times between stop and ending status and have no time-dependent chaining requirements must drop 'operational in' at this time. (See appropriate Operational Specification.)

**2.5.3 Stack Status.** *Stack status* is indicated by a command out response to 'status in'. The *stack status* signal causes retention of status information at the control unit or I/O device until that status is accepted on a subsequent status cycle with a 'service out'. When *stack status* occurs, the control unit disconnects from the interface after 'select out' is down. 'Command out' remains up until 'operational in' falls. An attempt by the control unit to initiate a selection sequence to present the status again is under control of 'suppress out'. (See section 2.5.7 "Suppress Status".) 'Command out' is not signaled to a zero status byte that has been provided in response to a command other than test I/O.

**2.5.4 Suppress Data.** Operations whose rate of data transfer can be adjusted without overrunning (completely buffered I/O devices, start-stop devices, and the transfer of data for the basic sense command may fall in this category) are subject to suppression of data by 'suppress out' as follows:

1. 'Suppress out' is ignored for the first data byte following any selection sequence unless the data transfer is contiguous with initial selection; that is, no deselection and reselection between initial selection and data transfer.
2. 'Suppress out' must be up either 250 nanoseconds before the rise of 'service in' or at least 250 nanoseconds before 'service out' falls to ensure suppression of subsequent data.
3. When 'suppress out' is up at the control unit and the operation is in burst mode (whether because 'select out' is up or because the control unit is forcing burst mode), the control unit must not raise 'service in' for subsequent suppressible data.

**2.5.5 Accept Data.** Raising 'service out' in response to 'service in' during a read, read-backward, or sense operation indicates that the information placed on 'bus in' has been accepted by the channel.

**2.5.6 Data Ready.** Raising 'service out' in response to 'service in' during a write or control operation indicates that the requested information has been placed on 'bus out' and is ready for acceptance by the control unit.

**2.5.7 Suppress Status.** Whenever the channel is unable to immediately handle interruption-causing status conditions, 'suppress out' may be raised. With this line up, the control unit must not attempt to initiate a selection sequence to present suppressible-type status information. Status is suppressible if stack status is received. Status that contains 'channel end' is not suppressible until stacked, except when interface disconnect is received for that address. Status that contains 'device end' is not suppressible when chaining has been indicated, until it is stacked. Other asynchronous status may be suppressible at the option of the particular control unit without being stacked.

'Suppress out' must be up at least 250 nanoseconds before 'select out' rises at the control unit if suppression of status is to be ensured. 'Suppress out' suppresses only the initiation of the selection of the interface by the control unit. If 'suppress out' rises after a status sequence has been started, the status sequence proceeds normally.

The relationship between 'request in' and 'suppress out' has been described in section 2.2.2.2 "Request In".

**2.5.8 Accept Status.** Raising 'service out' in response to 'status in' indicates that the status placed on 'bus in' has been accepted by the channel.



**2.5.9 Command Chaining.** Command chaining is indicated if 'suppress out' is up when 'service out' is raised in response to 'status in'. Command chaining means that another command for the I/O device in operation will immediately follow the presentation of 'device end', provided no unusual conditions were encountered during execution of the current operation. The exact time at which the next command is presented depends on the channel and on the parameters of the system.

When command chaining is indicated at the time 'device end' is presented, this indication is valid until reselection is made or until 'suppress out' falls (minimum down-level to ensure break-250 nanoseconds). Reselection of any I/O device attached to the control unit resets the chained-command condition in the control unit. Status conditions such as 'unit check', 'unit exception', 'control unit end', or attention will terminate command chaining in the channel.

A multidevice control unit that is to operate on more than one subchannel must not:

1. Reset the chained-command condition on an address other than the one being selected.
2. Present 'control unit end' with a chaining on an address.

Depending on the particular I/O device, the operation, and configuration, the command-chaining indication requires certain functional control that depends on the individual control unit.

If chaining is indicated when 'channel end' is presented ('device end' not generated) from a control unit that is shared by two or more devices but operates on a single subchannel, the I/O device that presents 'channel end' must be the next device from that control unit to present 'device end' status, unless the control unit is addressed in the meantime on the same interface.

If chaining is indicated when 'device end' is presented, the control unit must ensure that the path to the device remains available until the chaining operation is initiated or until chaining is no longer indicated. Furthermore, unless chaining is being canceled by the channel, the immediately following sequence must be a reselection of the device presenting the 'device end'.

If chaining is indicated on an I/O device shared between more than one control unit or channel, the I/O device must remain available until the chaining operation is initiated or until chaining is no longer indicated.

To ensure recognition of command chaining by the control unit, 'suppress out' must be up at least 250 nanoseconds before 'service out' rises in response to 'status in', and must not fall before 'status in'. If command chaining is not to be indicated, 'suppress out' must be down at least 250 nanoseconds before the rise of 'service out' and must not rise before the fall of 'status in'.

**2.5.10 Interface Disconnect.** The control unit recognizes interface disconnect when 'address out' is up and 'select out' ('hold out') is down at least 250 nanoseconds before the completion of any signal sequence. In this case, 'address out' may be up concurrently with another out-tag.

When 'operational in' drops, the channel may drop 'address out' to complete the interface-disconnect sequence. 'Address out' must be down for at least 250 nanoseconds before a new channel-initiated selection sequence may be attempted.

The control unit responds to the interface disconnect by removing all signals (with the possible exception of 'request in' and 'metering in') from the interface. On an input operation, data on 'bus in' need not be valid after the rise of 'address out'. On an output operation, data on 'bus out' must be valid until the fall of either 'service in' or 'operational in'. When the control unit reaches the normal ending point, it attempts to obtain selection on the interface to present any generated status to the channel.

Any abnormal device operation should be indicated by 'unit check' in the status, and the sense information should provide additional details concerning the operation. (See section 2.6.9 "Unit Check".) The control unit does not generate any status solely as a result of an interface disconnect.

The I/O device path remains busy after it receives an interface disconnect, while performing an operation, until the 'device end' status is accepted by the channel. If interface disconnect is received when the I/O device is not busy, no status is generated nor the I/O device made busy.

Note: If 'address out' is up concurrently with another out-tag, the information on 'bus out' must remain valid until the associated in-tag drops or until 'operational in' drops.

**2.5.11 Selective Reset.** Selective reset is indicated whenever 'suppress out' is up and 'operational out' drops. This condition causes 'operational in' to fall, and the particular I/O device in operation and its status to be reset. The operation in process proceeds to a normal stopping point, if applicable, with no further data transfer. The I/O device operating over the interface is the only device that is reset, even on multi-device control units. The particular I/O device path will be in a busy state throughout this procedure.

'Device end' may be returned after the reset. To be effective, 'suppress out' must rise at least 250 nanoseconds before 'operational out' drops and must remain up until at least 250 nanoseconds after 'operational out' rises. 'Operational out' must stay down until 'operational in' falls or for at least 6 microseconds, whichever is greater, for the selective reset to be effective.

The ready or not-ready state of the control unit is generally not changed by a selective reset. When, however, the enable/disable or online/offline switch was changed before the reset but had not become effective due to the required inhibiting conditions, the ready or not-ready state may change if the reset clears those inhibiting conditions.

Selective reset is issued only as a result of a malfunction detected at the channel or a time-out by the channel. The interpretation of the selective reset must be defined in the Operational Specification for the I/O device.

**2.5.12 System Reset.** System reset is indicated whenever 'operational out' and 'suppress out' are down concurrently, and the I/O device is in the online mode. This condition causes 'operational in' to fall, and all control units and their attached I/O devices, along with their status, to be reset. The control units are in a busy state for the duration of their reset procedure. System reset prepares an I/O device for an initial-program-loading sequence.

System reset is performed when the system reset key is pressed, when the power for the system is turned on, when the channel is offline to the I/O interface, and as a part of the initial-program-loading procedure.

The ready or not-ready state of the control unit is generally not changed by a system reset. When, however, the enable/disable or online/offline switch was changed before the reset, but is not yet effective because of required inhibiting conditions, the ready or not-ready state may change if the reset clears those inhibiting conditions. To ensure a proper reset, 'operational out' and 'suppress out' must be down concurrently for at least 6 microseconds.

The interpretation of the system reset must be defined in the Operational Specification for the I/O device.

**2.6 Status Information.** When 'status in' is up, the information that appears on 'bus in' is the status byte. The conditions reported in the status byte are the status conditions.

The status pertains to the device or implied control unit whose address appeared on 'bus in' (with 'address in') during the polling or selection portion of the sequence. In the case of the control-unit-busy sequence when no 'address in' occurs, it is assumed that the status pertains to the addressed device or implied control unit.

Note: The information in this Standard pertains to control units attached to only one channel interface, unless otherwise stated.

2.6.1 Status Byte. The status byte has the following format:

Bit Position	Designation
P	Parity
0	Attention
1	Status Modifier
2	Control Unit End
3	Busy
4	Channel End
5	Device End
6	Unit Check
7	Unit Exception

The status byte is transmitted to the channel in six situations:

1. During the initial-selection sequence.
2. To present the 'channel end' status at the termination of data transfer.
3. To present the 'device end' signal and any associated conditions to the channel. The I/O device remains busy during an operation until the channel accepts the device end status.
4. To present 'control unit end' or 'device end' status which signals that the control unit, or device that was previously busy and then interrogated, is now free.
5. To present any previously stacked status when allowed to do so.
6. To present any externally initiated status ('attention' and 'device end' because of not-ready-to-ready transition).

Once accepted by the channel, any given status byte is reset and is not presented again.

2.6.2 Unit Status Conditions. The following status conditions are detected by the I/O device or control unit and are indicated to the channel over the I/O interface. The timing and causes of these conditions for each type of device are specified in the Operational Specification for the I/O device.

When the device is accessible from more than one channel, status resulting from channel-initiated operations is signaled to the channel that initiated the associated I/O operation. The handling of conditions not associated with I/O operations, such as 'attention' or 'device end' because of transition from the not-ready to the ready state, depends on the type of device and condition, and must be specified in the Operational Specification for the I/O device.

Note: Control units must provide interlocks in their design so that status is not lost, hidden, or included with other status when the result would cause the program to misinterpret the original meaning and intent of the status.

**2.6.3 Attention.** 'Attention' is generated when some asynchronous condition occurs in the I/O device. 'Attention' is not associated with the initiation, execution, or termination of any I/O operation.

The 'attention' condition cannot be indicated to the channel while an operation is in progress at the I/O device or control unit. Otherwise, the handling and presentation of the condition to the channel depends on the type of I/O device. An I/O device shared between more than one channel path must present the 'attention' status to all channel paths as defined in the individual Operational Specification. Presentation of 'attention' causes command chaining to be suppressed. 'Attention' can occur with 'device end'. Depending on the I/O device application, 'attention' may or may not be presented until command chaining is no longer indicated.

**2.6.4 Status Modifier.** 'Status modifier' is used by control units in three situations:

1. Control units that cannot provide current status in response to test I/O present the 'status modifier' bit alone during the initial-selection procedure.
2. Busy control units present the 'status modifier' bit with the 'busy' bit during the initial-selection procedure to differentiate between a busy control unit and a busy device.
3. Control units designed to recognize special ending conditions (search equal on a disk) present the 'status modifier' bit with 'device end' when the special condition occurs.

In the first case, provision is made for certain types of control units that are not capable of providing current status on a demand basis as required by test I/O. Presentation of the 'status modifier' bit in response to test I/O indicates that the control unit cannot execute the command, and any existing status remains unchanged and unavailable to a test I/O. This type of control unit provides status only on a control unit-initiated selection sequence. In the second case, provision is made for indicating that a busy condition pertains to a control unit and not necessarily to the addressed I/O device. This condition occurs when the control unit is required to perform a function that does not involve the I/O interface (backspace file on magnetic tape). The condition may also occur when the control unit has status pending for an I/O device other than the one addressed. In the third case, provision is made for control units designed to recognize special ending or synchronizing conditions. If the special condition occurs, the 'status modifier' bit with the 'device end' bit is presented during the device end status cycle. Presence of 'status modifier' and 'device end' indicates that the normal sequence of commands must be modified.

**2.6.5 Control Unit End.** The 'control unit end' condition is provided only by channel-shared control units or control units shared by I/O devices, and only when one or both of the following conditions occurs:

1. The control unit was interrogated while it was in the busy state. Interrogated in the busy state means that a previous channel-initiated selection sequence was issued to a device on the control unit and the control unit responded with 'busy' and 'status modifier' in the unit status byte. (See section 2.6.4 "Status Modifier".)
2. The control unit detected an unusual condition while busy, but after 'channel end' was accepted by the channel. Indication of the unusual condition accompanies 'control unit end'.

If the control unit remains busy executing an operation after signaling 'channel end' but is not interrogated and does not detect an unusual condition, 'control unit end' is not generated. When the busy state of the control unit is temporary, 'control unit end' can be included with 'busy' and 'status modifier' in response to interrogation, even though the control unit is not free. The busy condition may be considered temporary if its duration is less than approximately 2 milliseconds.

The I/O device address associated with 'control unit end' is determined as follows:

1. The address of the selected device is used if 'control unit end' is to be presented with 'channel end' and/or 'device end'.
2. If 'control unit end' is generated without 'channel end' or 'device end' and the status is presented during a control unit-initiated selection sequence, the I/O device address to be used when presenting this status can be any legitimate address associated with the control unit. (A legitimate address is any address the control unit is capable of recognizing, regardless of whether or not the I/O device is actually attached.)
3. If 'control unit end' is to be presented during a channel-initiated selection sequence, the I/O device address is the same as the address issued with 'address out'. This channel-initiated selection sequence may be either a normal full-length selection sequence or the control-unit-busy-sequence.

The 'control unit end' condition can be signaled with 'channel end', 'device end' or between the two. When 'control unit end' is signaled by an I/O interruption in the absence of any other status conditions, the interruption may be identified by any address assigned to the control unit. A pending 'control unit end' causes the control unit to appear not available for initiation of new operations. 'Control unit end' causes command chaining to be suppressed.

**2.6.6 Busy.** 'Busy' can occur only during a channel-initiated selection sequence and indicates that the I/O device or control unit cannot execute the command because a previously initiated operation is being executed or because status conditions exist (or in the case of switched control units, because the path is unavailable). An operation is being executed from the time initial status is accepted until 'device end' is accepted. Status conditions for the addressed I/O device, if any, accompany the 'busy' indication. If the 'busy' condition applies to a control unit function, 'busy' is accompanied by 'status modifier'. 'Busy' is indicated to test I/O only if a previously initiated operation is still being executed and no end status is available. The 'busy' condition causes command chaining to be suppressed.

**2.6.7 Channel End.** 'Channel end' is caused by the completion of the portion of an I/O operation involving transfer, if any, of data or control information between the I/O device and the channel. Each I/O operation causes only one 'channel end' signal to be generated. The 'channel end' condition is generated only when the command is accepted, i.e., the initial status byte for the operation contained either all zeros or 'channel end' without 'busy'. During an I/O operation, the exact time that 'channel end' is generated depends on the operation and the type of device. For operations such as writing, some I/O devices generate the 'channel end' condition when the block has been written. On other I/O devices that later verify the writing, 'channel end' may or may not be delayed until verification is performed, depending on the I/O device. On devices such as those equipped with buffers, the 'channel end' condition occurs on completion of data transfer between the channel and the buffer. During control operations, 'channel end' is usually generated after the control information is transferred to the control unit; although for short operations, the 'channel end' may be delayed until completion of the operation. Operations that do not cause data to be transferred can provide the 'channel end' condition during the initial-selection sequence.

**2.6.8 Device End.** 'Device end' is caused by the completion of an I/O operation at the I/O device or by manually changing the device from the not-ready to the ready state. Each I/O operation causes only one 'device end' condition. The 'device end' condition is not generated unless the command is accepted. The 'device end' condition associated with an I/O operation is generated either simultaneously with the 'channel end' condition or later. For data transfer operations on some devices, the operation is complete at the time 'channel end' is generated, and both 'device end' and 'channel end' occur together. On buffered I/O devices, the 'device end' condition occurs only when both the mechanical and the I/O interface

data transfer portions (if any) of the operation are complete. For control operations, the 'device end' condition is generated at the completion of the operation at the device. The operation may be completed at the time 'channel end' is generated or later. When command chaining is being performed, the channel normally only makes available to the program the 'device end' of the last operation of the chain. A 'device end' signal received by the channel in the absence of any unusual conditions causes the channel to initiate the next command-chain I/O operation, if any. If an unusual condition is detected during such an initiation, the chain is terminated without 'device end' being indicated to the program. If a device is addressed while in a busy state, a 'device end' must be signaled to the path that initiates the command when the I/O device becomes not busy. Any unit whose state changes from not-ready to ready normally causes a 'device end' condition to be generated. A device is considered to be not ready when operator intervention is required to make the device available. A not-ready condition can occur, for example, because of any of the following actions:

1. An unloaded condition on magnetic tape.
2. Card equipment out of cards or stacker full.
3. Printer out of paper.
4. Error conditions that need operator intervention.
5. The unit has changed from the enabled to the disabled state.

An I/O device shared between more than one channel path and which has a 'device end' generated because of the device going from a not-ready to a ready state must present a 'device end' to all attached channels as defined in the individual Operational Specification for the I/O device. This is required to alert all channels of the ready state of the device.

**2.6.9 Unit Check.** 'Unit check' indicates that the I/O device or control unit has detected an unusual condition that is detailed by the information available to a sense command. 'Unit check' may indicate that a programming or an equipment error has been detected, that a not ready state of the device has affected the execution of the command or instruction, or that an exceptional condition other than the one identified by 'unit exception' has occurred. The 'unit check' bit provides a summary indication of the conditions identified by sense data. (See also section 2.9.3 "Command Retry".) An error condition causes the 'unit check' indication only when it occurs during execution of a command or during some activity associated with an I/O operation. Unless the error condition pertains to the activity initiated by a command and is of significance to the program, the condition does not cause the program to be alerted after 'device end' has been cleared; a malfunction may, however, cause the device to become not ready. 'Unit check' is indicated when the existence of the not-ready state precludes a satisfactory execution of the command, or when the command, by its nature, tests the state of the device. When no interruption condition is pending for the addressed device at the control unit, the control unit signals 'unit check' when test I/O or the no-operation control command is issued to a not-ready device. In the case of no operation, the command is rejected and 'channel end' and 'device end' do not accompany 'unit check'.

Unless the command is designed to cause 'unit check', such as rewind and unload on magnetic tape, 'unit check' is not indicated if the command is properly executed even though the device has become not ready during, or as a result of, the operation. Similarly, 'unit check' is not indicated if the command can be executed with the device not ready. A console could, for example, accept and execute the alarm-control command when the printer is not ready. Selection of a device in the not-ready state does not cause a 'unit check' indication when the sense command is issued, and whenever an interruption condition is pending for the addressed device at the control unit. If, during the initiation sequence, the device detects that the command cannot be executed, 'unit check' is presented to the channel and it appears without 'channel end', 'control unit end', or 'device end'. Such unit status indicates that no action has

been taken at the device in response to the command. If the condition that precludes proper execution of the operation occurs after execution has been started, 'unit check' is accompanied by 'channel end', 'control unit end', or 'device end', depending on when the condition was detected. Errors detected after 'device end' is cleared may be indicated by signaling 'unit check' with 'attention' or 'unit check' with 'control unit end'. When 'unit check' appears with 'channel end' and without 'device end', a shared control unit must preserve the sense data and an available device path until after the 'device end' is accepted. Errors, such as invalid command code or invalid command code parity, do not cause 'unit check' when the device is working or contains a pending interruption condition at the time of selection. Under these circumstances, the device responds by providing the 'busy' bit and indicating the pending interruption condition, if any. The command code validity is not indicated. Termination of an operation with the 'unit check' indication causes command chaining to be suppressed.

**Note:** If a device becomes not ready on completion of a command, the ending interruption condition can be cleared by test I/O without generation of 'unit check' because of the not-ready state. Any subsequent test I/O issued to the device causes a 'unit check' indication.

**2.6.10 Unit Exception.** 'Unit exception' means that the I/O device detected an unusual condition such as end of file. 'Unit exception' has only one meaning for any particular command and type of I/O device. A sense operation is not required as a response to the acceptance of a 'unit exception' condition. A 'unit exception' condition can be generated only when the I/O device is executing an I/O operation, or when the device is involved with some activity associated with an I/O operation and the condition is of immediate significance. If a device detects a 'unit exception' condition during the initial-selection sequence, 'unit exception' is presented to the channel and it appears without 'channel end', 'control unit end', or 'device end'.

Such unit status indicates that no action has been taken at the device in response to the command. If the condition that precludes normal execution of the operation occurs after the execution is started, 'unit exception' is accompanied by 'channel end', 'control unit end', or 'device end' depending on when the condition is detected. Any unusual condition associated with an operation, but detected after 'device end' is cleared, is indicated by signaling 'unit exception' with 'attention'. The 'unit exception' causes command chaining to be suppressed.

**2.7 Sense Information.** Data transfer during a sense operation provides information concerning unusual conditions detected in the last operation and concerning the actual state of the I/O device. Information provided by the basic sense operation is more detailed than that supplied by the unit status byte, and may describe reasons for the 'unit check' indication. It may also indicate, for example, that the I/O device is in the not-ready state, that a tape drive is in the file-protected state, or that magnetic tape is positioned beyond the end-of-tape marker.

All sense information significant to the use of the I/O device normally is provided in the first two bytes. Any bit positions that follow those used for programming information contain diagnostic information, which may extend to as many bytes as needed. The amount and the meaning of the status information are peculiar to the type of device, and must be specified in the Operational Specification for the I/O device. A device that normally operates in multiplex mode, and transfers a single byte during data transfer, should transmit the maximum number of bytes of sense data possible during the 32-microsecond multiplex time-out limitation.

The sense information that pertains to the last I/O operation or other unit action at a device may be reset anytime after the completion of a sense command addressed to that device. Except for the test I/O and no-operation commands, any other command addressed to the device's control unit may be allowed to reset the sense information provided the 'busy' bit is not included in the initial status byte. The sense information may also be changed as a result of asynchronous actions such as when 'attention' or not-ready to ready 'device end' status is generated.

Sense information that results from more than one action at the unit must not be ORed when this condition would cause the program to misinterpret the original meaning and intent of the sense information. Note that when a group of sense indicators is shared with different devices the residual control unit sense data that pertains to the last command addressed to the control unit may be reset if the device addressed is different from the device that generated the sense data. A command code with invalid parity causes the sense information to be replaced only if 'unit check' is turned on as a result of the invalid parity.

**2.7.1 Sense Byte.** For most I/O devices, the first six bits of the first sense data byte (sense byte 0) are common to all I/O devices that have this type of information. The six bits are independent of each other and are designated as follows:

Bit	Description
0	Command Reject
1	Intervention Required
2	Bus-Out Check
3	Equipment Check
4	Data Check
5	Overrun

## 2.7.2 Sense Conditions.

**2.7.2.1 Command Reject.** The device detected a programming error. A command was received which the device is not designed to execute (read backward issued to a direct-access storage device), or which the device cannot execute because of its present state (a write issued to a file-protected tape unit). In the former case, the program may have required use of an uninstalled optional feature or may have specified invalid control data. 'Command reject' is also indicated when an invalid sequence of commands is recognized (write to a direct-access storage device without previously designating the data block). See the individual I/O device specifications for those commands or sequence of commands which cause 'command reject' to be indicated.

**2.7.2.2 Intervention Required.** 'Intervention required' is generated when the last operation could not be executed because of a condition that requires intervention at the I/O device. This bit indicates conditions such as an empty hopper in a card punch, or a printer that is out of paper. 'Intervention required' is also turned on when the addressed device is in the not-ready state, in test mode, or not provided on the control unit.

**2.7.2.3 Bus-out Check.** 'Bus-out check' results when the I/O device or the control unit receives a data byte or a command byte with invalid parity over the I/O interface.

During writing, 'bus-out check' indicates that a parity error was detected and incorrect data may have been recorded at the I/O device. However, the condition does not cause the operation to be terminated prematurely, unless the operation is such that an error precludes meaningful continuation of the operation. No operation is initiated if the command code has a parity error.

**2.7.2.4 Equipment Check.** The 'equipment check' sense bit indicates detection of an equipment malfunction logically between the I/O interface and the input/output medium. On output operations, this malfunction may have caused invalid data to be recorded. Detection of 'equipment check' stops data transmission and terminates the operation prematurely when the error prevents any meaningful continuation of the operation.



**2.7.2.5 Data Check.** 'Data check' indicates that invalid data has been detected or is probable on the recording medium. This invalidity can be accurately detected only by reading the recording medium. The control unit forces correct parity on data sent to the channel. On writing, the 'data check' condition indicates that incorrect data may have been recorded at the I/O device. Data errors on reading and writing cause the operation to be terminated prematurely only when the errors prevent meaningful continuation of the operation (loss of synchronization).

**2.7.2.6 Overrun.** 'Overrun' results when the channel fails to respond on time to a request for service from the I/O device. 'Overrun' can occur when data is transferred to or from a nonbuffered control unit that operates with a moving medium, and the total activity initiated by the program exceeds the capability of the channel. On an output operation, 'overrun' indicates that data recorded at the device may be invalid. In these cases, data overrun normally stops data transfer and the operation terminates as in stop. The 'overrun' bit is also turned on when the device receives the new command too late during command chaining.

## 2.8 General System Consideration.

**2.8.1 Interface Time-Out Considerations.** Signaling over the I/O interface is specified to be direct-current interlocked and is therefore not time-dependent. Since the signaling is not time-dependent, a certain category of machine malfunctions may cause "hangup" of the channel and, unless detected and canceled, results in "hangup" of the system. The timing considerations involved in determining malfunction cases are described in the following paragraphs.

All references to particular time considerations, in this section, represent the maximum permissible time in worst-case situations. All control units must be designed for minimum signal-sequence-response times within the limitations of the circuit family used and the sequencing method required for particular I/O devices. A maximum worst-case interface signal sequence of 32 microseconds, because of the control unit, is specified. This means that from the time 'select out' rises at a particular control unit for any signal sequence until the sequence is completed ('operational in' drops at the control unit), no more than 32 microseconds, because of the control unit circuitry or the sequencing method used, is required by the control unit.

This applies to all byte multiplex sequences and to all selection sequences. An initial-selection sequence is defined as beginning with the rise of 'select out' at the particular control unit to the fall of 'status in' for initial status. However, a particular interface signal sequence may take longer because of other factors:

1. Delays introduced by the channel.
2. Delay because of the need for a burst mode I/O device to capture the interface before reaching the specified record area of the recording medium (not greater than 500 milliseconds).

In addition to excessive delay that may occur within a particular signal sequence, excessive delay may exist between data cycles during burst mode operation. The maximum allowable delays between data cycles in burst mode is 500 milliseconds. The channel should not indicate a malfunction unless a delay of interface activity exceeds approximately 30 seconds. Absence of activity on the interface may be because of other conditions (reading a long gap on magnetic tape created by successive erase commands).

**2.8.2 Propagation of Select Out.** During an initial-selection or scan sequence, if the control unit does not require service or selection, 'select out' must be propagated by the unit within 600 nanoseconds to meet performance requirements. In no case may propagation time exceed 1.8 microseconds per control

unit. This time, measured at the external cable connectors, extends from the rise of the incoming 'select out' to the rise of the outgoing 'select out'.

### 2.8.3 System Configuration.

**2.8.3.1 Number of Units.** In the general system configuration, as many as eight control units can be directly connected to a single channel I/O interface.

**2.8.3.2 Internal Cabling.** Except for 'select out' and 'select in', the maximum allowable internal resistance (including all contact resistance) contributed by a channel or control unit for every signal line, is specified as 1.0 ohm. The combined 'select out' and 'select in' maximum resistance specified for the control unit is 1.5 ohms.

The maximum resistance case for 'select out'/'select in' in a control unit usually occurs when the control unit be relatively close to the channel. However, the maximum allowable cable length is limited is measured between the incoming and the outgoing pins on the external connectors. For channels, the measurement is made between the external connector pin and the corresponding channel driver or receiver. With the exception of the 'select out'/'select in' line, the maximum signal delay measured between the external pins is specified as 15 nanoseconds. The maximum skew between any two signal lines is specified as 1 nanosecond. The delay for the bus lines must not exceed the delay for the tag lines.

The Operational Specification for each control unit and channel must define, for each possible interface implementation, the value of its internal resistance for the signal lines and for the 'select out'/'select in' line-pair.

**2.8.3.3 External Cabling.** The cable length available for the interconnection of channel and control units is primarily limited by the resistance to the interface lines which is contributed by the channel and the control units. For specific control units, the signal delays due to cable length require that the control unit be relatively close to the channel. However, the maximum allowable cable length is limited by total series resistance between drivers and receivers, if signal cable delay requirements are met for each attached control unit.

The maximum external connector-to-connector cable length for unrestricted general systems configurations is determined by the combined internal resistance specification for 'select out'/'select in'. The maximum line resistance for the total 'select out'/'select in' loop must not be greater than 52.5 ohms for worst-case conditions. In installations where 'select out' is redriven at the end of the cable, the maximum cable length is determined by the 1.0 ohm internal control unit and resistance specifications for the signal lines other than 'select out' and 'select in'. In this case, the maximum cable length can be calculated by using the 33 ohm driver-to-receiver maximum line resistance specification for worst-case conditions.

**2.8.4 Offline/Online.** A control unit in an offline mode must not interfere in the operation between the channel and other control units on the same interface. The control unit in the offline mode must provide the following:

1. Logical bypass for 'select out'.
2. Gate off all other line drivers from interfering with activity on the interface.

The control unit transition to or from an offline/online condition must not cause machine malfunction. The minimum following conditions must exist concurrently before the online-to-offline transition can occur:

1. The online/offline switch is set to OFFLINE.

2. No active communication on the interface because of this control unit, such as 'operational in', or 'status in', etc.
3. No stacked or pending status is on this unit. (Stacked status is that which has been presented to the channel but which has not been accepted. Pending status is that which is forthcoming or which has been generated but not presented.)
4. No command chaining is indicated for this unit.

The preceding conditions ensure that no machine malfunctions can occur because of an operator throwing the switch from ONLINE to OFFLINE.

## 2.8.5 Power Effects.

**2.8.5.1 Steady State.** The power-off state of any control unit must not affect any operations of other control units on the interface. The control unit whose power is off must provide an electrical bypass for 'select out', and all of its interface driver and receiver circuits must be prevented from interfering with the interface signals. The incoming 'select out' signal terminator at the receiver must be disconnected when the signal is electrically bypassed. When power is down on all units, 'select out' must be propagated back to the channel.

**2.8.5.2 Transient and Spurious Signals.** Each control unit must be designed so that, if proper procedures are followed, the process of individually powering up or down does not cause its interface driver or receiver circuits to generate noise on the interface signal lines.

**2.8.5.3 Transient and Select-Out Pulse Splitting.** Each control unit must ensure that the process of electrically bypassing 'select out' before power changes does not interfere with 'select out' propagation, except for possible short discontinuities (less than 1.8 microseconds) because of contact bounce coincident with signal delay through parallel logic circuits. Also, each control unit must ensure that 'select out' discontinuities, which may occur when another control unit on the interface is powering up or down, do not affect the propagation of 'select out'. This should be accomplished by the use of a special latch circuit. The latch is turned on by the AND of 'select out' and 'hold out' and is reset by the fall of 'hold out'. The circuit is in series with the remaining selection logic in the control unit and causes a constant 'select out' signal within the control unit and, therefore, to all following control units, regardless of variations in the input 'select out' signal (figure 4).

**2.8.5.4 Power Off/On Sequence Requirements.** The combination of proper procedures and circuitry must provide the following sequence of events for power off:

1. Logically disconnect the unit from the interface. When the unit becomes logically disconnected, an indicator (I/O interface disabled) comes on. (The control unit can become logically disconnected when it and all connected devices have completed all operations, no status is pending, or stacked, and chaining is not indicated.) This ensures that no unfinished operations exist that can cause indication of machine malfunction when power is turned off. Note that when a control unit is logically disconnected from the interface, all its drivers except 'select out' are logically gated off. A logical disconnect may be accomplished as a result of going offline by use of the online/offline or the metering disable/enable switch.
2. Close 'select out' bypass circuit (mechanical contact, K1, figure 4). The normal logical electronic bypass of 'select out' is still active when the control unit is logically disconnected.
3. Open the connection from the line to the 'select out' receiver terminator (mechanical contact, S1, figure 4).

4. Clamp interface driver gates to ground by means of a mechanical contact (S2, figure 4), if gated drivers are used to avoid transient signals on the interface lines.
5. Turn off power.

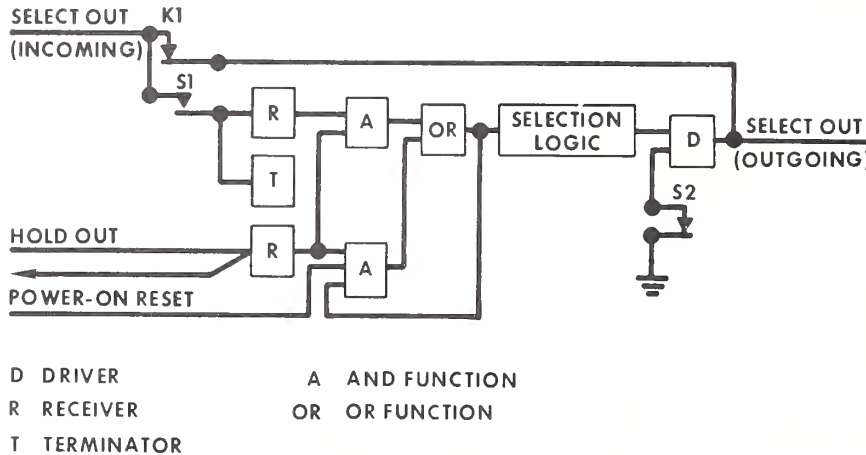


FIGURE 4. Representative Select Out/Hold Out Special Latch

For power on, the sequence is reversed:

1. Turn power on. During the power-on sequence, a power-on reset pulse must automatically reset the control unit circuitry, including reset of the special 'select out' latch, regardless of 'hold out'.
2. Unclamp driver gates. (Open mechanical contact, S2.)
3. Connect 'select out' receiver terminator (S1).
4. Open 'select out' bypass circuit (K1).
5. Logically connect the unit to the interface (panel indicator turns off).

If some method, such as automatic power sequencing rather than gated interface driver circuits, is used to eliminate transients on the signal lines, the steps in the sequence that refer to driver gates may be eliminated.

**Note:** The 'select out' bypass function (relay transfer) of a power-off or power-on sequence must be completed in any one control unit attached to a channel before the 'select out' bypass function (relay transfer) is started in another control unit. Therefore, the 'select out' bypass function should be completely automatic. In any case, the 'select out' bypass function must not be interrupted, but must be completed once it is started.

## 2.9 Features.

**2.9.1 Bus Extension Feature.** This feature extends the interface by adding an extra bus to allow information transfer of either one or two bytes in parallel. The present bus is designated 'bus 0', while the additional bus is designated 'bus 1'. If control units of different widths are attached on one interface, the control units using the wide bus must terminate the bus not used by other control units.

The data lines of the additional bus are defined (eight data + parity) similar to 'bus 0'. In addition to the data lines, 'mark in' and 'mark out' lines are defined for each bus cable, including the 'bus 0' cable, to indicate the presence of information on that bus. 'Mark in' and 'mark out' parity lines are also defined in the 'bus 1' cable to permit a validity check of the mark lines.

The number of mark lines active when 'address out', 'address in', 'command out', or 'status in' are up indicates the number of bytes used for these functions. For output operations the control unit must raise the 'mark in' lines before raising 'service in' or 'data in' to indicate the number of bytes required. The channel must then indicate by the 'mark out' lines the number of bytes provided on 'bus out' when 'service out' or 'data out' is raised. The bus width indicated during the early bus width indication (see section 2.9.1.3 "Early Data Bus Width Indication") must be the maximum used by the control unit for that operation. Transfers involving less than the maximum indicated bus width are permitted when the length of the block of information being transferred is not an integral multiple of the maximum transfer width. The partial transfer thus required is permitted as the last transfer of the block.

All information transferred, including that transferred by a read-backward command, must be gated so that the first byte is on 'bus 0' and the second byte is on 'bus 1'.

**2.9.1.1 Mark Out Lines.** During sequences involving the transfer of information from the channel to the control unit, the 'mark out' lines must be valid for the same period of time as the information on 'bus out' and will indicate the number of bytes provided by the channel on 'bus out'.

For sequences involving the transfer of information from the control unit to the channel, the 'mark out' lines indicate the number of bytes that the channel is accepting. The 'mark out' lines must be valid from the rise of the outbound tag line until the resulting fall of the inbound tag line.

A channel capable of extended bus operation must assure that the number of 'mark out' lines up, including 'mark out parity', is odd when addressing the unit with 'address out' up. Additionally, if the unit with which the channel is communicating is operating with extended bus capabilities, the channel must maintain odd mark line parity whenever 'service out', 'data out' or 'command out' is up.

**2.9.1.2 Mark In Lines.** During sequences involving the transfer of information from the control unit to the channel, the 'mark in' lines must be valid for the same period of time as the information on 'bus in' and will indicate the number of bytes provided by the control unit on 'bus in'.

For sequences involving the transfer of information from the channel to the control unit, the 'mark in' lines indicate the number of bytes required by the control unit for that sequence and must be valid from the rise of the inbound tag line until the rise of the corresponding outbound tag line. The number of 'mark in' lines up, including 'mark in parity', must be odd whenever a control unit is operating with extended bus capabilities and 'service in', 'data in', 'address in' or 'status in' is up. Control units operating with the one-byte interface need not activate any 'mark in' lines, except for command retry indication. (See section 2.9.3 "Command Retry Feature".)

**2.9.1.3 Early Data Bus Width Indication.** The control unit indicates to the channel the bus width to be used for an operation by raising the 'mark in' lines during initial selection. These 'mark in' lines are defined as being valid from the rise of 'operational in' to the fall of 'address out'.

**2.9.2 I/O Error Alert Features.** A new line, 'disconnect in', provides control units with the ability to alert the system of a malfunction that is preventing the control unit from signaling properly over the I/O interface. An example of this condition may be a microcoded control unit communicating with the channel at the time a memory storage error is detected. Such a control unit may be unable to complete an interface sequence properly.

'Disconnect in' can be raised by a control unit only when it is connected to the channel (i.e., it has 'operational in' up). When 'disconnect in' is used during a polling sequence, the control unit must assure that the sequence has progressed at least to the point where 'address in' has been raised with the unit address on 'bus in' before raising 'disconnect in'. The channel, in response to 'disconnect in', performs a selective reset. 'Disconnect in' must not fall before the reset nor remain up longer than 100 nanoseconds after the fall of 'operational in'.

**2.9.3 Command Retry Feature.** Command retry is a channel-control unit procedure that can cause a command to be retried without requiring an I/O interruption. It is initiated by the control unit with a unique combination of status bits. A control unit may request the retry of a command in order to recover from a transient error or because the state of the control unit or device prevented the execution of the command when it was previously issued.

A channel, upon accepting a request for command retry repeats the execution of the channel program, beginning at the last command executed.

**2.9.3.1 I/O Interface Sequence.** When the command being executed encounters a condition requiring retry, the control unit indicates it by raising 'mark 0 in' and 'status in' while presenting 'unit check' and 'status modifier' (retry status) together with 'channel end' (meaning the control unit or the device is not yet ready to retry the command), or with 'channel end' and 'device end' (meaning the control unit and device are prepared for immediate retry of the command). 'Device end', if not presented with 'channel end', is presented later, when the control unit is ready to retry the command.

The channel acknowledges the occurrence of command retry by accepting the status byte containing retry status and indicating chaining. If 'device end' accompanies 'channel end', 'mark 0 in', and retry status, the channel immediately initiates a normal, chained initial-selection sequence, reissuing the previous command. If only 'channel end' and 'mark 0 in' accompany the retry status, the retry is not immediately performed.

Rather, when the 'device end' or 'device end' with 'status modifier' is presented to the channel, it is accepted with chaining indicated and a normal reselection occurs to reissue the previous command or, in the case of 'device end' with 'status modifier', the Channel Command Word following the previous command. A channel indicates refusal to perform a command retry by accepting the status byte containing retry status without indicating chaining or by stacking the status byte. The stacked byte is treated as any stacked status.

**2.9.4 High-Speed Transfer Feature.** This feature permits data transfer to take place at almost twice the present data rates. This extension may also be used by some control units to permit the placement of a control unit at a greater distance from the channel than is presently possible.

**2.9.4.1 Data In.** 'Data in' is a tag line from all attached control units to the channel and is used to signal to the channel that the selected control unit requires the transmission of a byte of information. The nature of the information depends on the operation and the I/O device. 'Data in' may be alternated with 'service in' to transfer data at a higher rate than is possible if 'service in' alone is used. The channel must respond to 'data in' with 'data out' or 'command out'. During read, read-backward, and sense operations, 'data in' rises when data is available on 'bus in'. During write and control operations 'data in' rises when data is required on 'bus out'. When 'data in' is alternated with 'service in', 'data in' may rise when 'service out' is raised in response to 'service in'. However, 'data in' is not considered valid until 'service in' is dropped. Similarly, 'service in' may rise when 'data out' is raised in response to 'data in'; however, 'service in' is not considered valid until 'data in' is dropped. The conditions that apply to 'service in' concerning overrun also apply to 'data in'.

**2.9.4.2 Data Out.** 'Data out' is a tag line from the channel to all attached control units and is used in response to a signal on 'data in'. A signal on 'data out' indicates that the channel has accepted the information on 'bus in' or has provided on 'bus out' the data requested by 'data in'. When 'data out' is sent in response to 'data in' during a read, read-backward, or sense operation, the 'data out' signal must rise after the channel accepts the information on 'bus in'. In these cases, the rise of 'data out' indicates that the information is no longer required to be valid on 'bus in' and is not associated with any information on 'bus out'. When 'data out' is sent in response to 'data in' on a write or control operation, the rise of 'data out' indicates that the channel has provided the requested information on 'bus out'. 'Data out' must remain up until the fall of 'data in'.

**2.9.4.3 In/Out Tag Exceptions.** In contrast to the normal interlock conventions, (see section 2.2.5 "Signal Interlock Summary") with this feature installed, 'service in' and 'data in' tags may be up concurrently. Likewise, 'service out' and 'data out' tags may be up concurrently.

## CHAPTER 3.

### Electrical Specifications

**3.1 Multiple Drivers and Receivers.** Up to ten receivers must be able to be driven by one driver. The driver must be located at one of the extreme ends. Up to ten drivers must be able to be 'dot' ORed to drive one receiver. The receiver must be located at one of the extreme ends. There will be no more than one driver and/or receiver per line per control unit. This limitation also applies to the channel.

**Note:** An end-of-line driver or receiver may be placed beyond the terminator. In this case, the distance between the end-of-line driver or receiver and the terminator must be less than six inches. Receivers must be spaced at least three feet apart. No minimum requirement is set for the spacing between drivers. No minimum requirement is set for the spacing between a terminator and driver or receiver if the terminator is placed on the outermost end of the line. The maximum stub length from the line to a driver or receiver on the circuit card is six inches.

### 3.2 General Electrical Requirements.

**3.2.1 Voltage Levels.** There are two logical levels. A dc line voltage of + 2.25 volts or more denotes a logical one state, and a dc voltage of + 0.15 volt or less denotes a logical zero state. These voltages are relative to the driver ground.

**3.2.2. Cable.** All lines must have a characteristic impedance of  $92 \pm 10$  ohms and, with the exception of 'select out', must be terminated at each extreme end in their characteristic impedance by a terminating network. (For 'select out'/'select in', see section 3.5 "Electrical Specifications for Select Out Circuitry".) Cable length may be limited by special conditions but is never to exceed a maximum line resistance of 33 ohms. The 33 ohm line resistance includes all contact resistance, internal cable resistance and interunit cable resistance.

**3.2.3 Terminating Networks.** The terminating network must present an impedance of 95 ohms  $\pm$  2.5 percent between the signal line and ground, and must be capable of dissipating 390 milliwatts.

**3.2.4 Ground Shift and Noise.** The maximum noise (measured at the receiver input) coupled onto any signal line must not exceed 400 millivolts. The maximum allowed ground shift, between an active

driver and any receiver of the same interface line, is 150 millivolts. Therefore, the maximum shift, (coupled noise plus ground shift) allowed on any line is 550 millivolts.

The logical levels defined in section 3.2.1 "Voltage Levels" under section 3.2 "General Electrical Requirements" and the receiver threshold levels specified in section 3.3.1 "Receivers" under section 3.3 "Interface Circuit Requirements" allow for this 550 millivolt shift. That is, a negative noise pulse of 400 millivolts coupled with a positive receiver ground shift of 150 millivolts occurring during a one state (2.25 volts minimum) guarantees a receiver input of 1.7 volts or more. (See diagram A.)

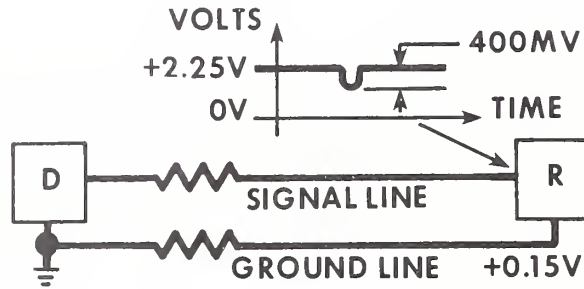


DIAGRAM A. *Negative Noise*

Also, a positive, noise pulse of 400 millivolts coupled with a negative receiver ground shift of 150 millivolts occurring during a zero state (0.15 volt maximum) guarantees a receiver input of 0.7 volt or less. (See diagram B.)

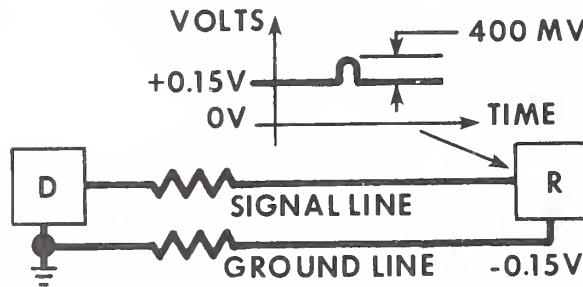


DIAGRAM B. *Positive Noise*

**Note:** The noise measurements are made at the input to the receiver. A combination of the dc level and ac noise must not exceed 0.7 volt for the down level and must not be less than 1.7 volts for the up level.

### 3.3 Interface Circuit Requirements.

**3.3.1 Receivers.** An input voltage (relative to receiver circuit ground) of 1.7 volts or more is interpreted as a logical one; an input of 0.70 volt or less is interpreted as a logical zero. An open-circuited input is interpreted as a logical zero.

1. A dc input of 7.0 volts with power on in the receiver.
2. A dc input of 6.0 volts with power off in the receiver.
3. A dc input of - 0.15 volt with power on or off.



The receiver input must not require a positive current (see diagram C) larger than +0.42 milliampere at an input voltage of +3.11 volts.

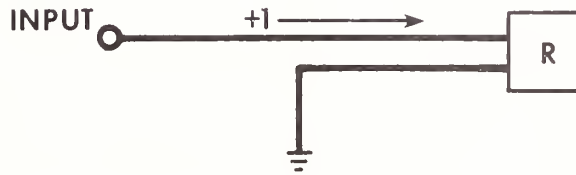


DIAGRAM C. Receiver

Negative receiver input current at +0.15 volt must not exceed -0.24 milliampere. In addition, receiver input impedance must be larger than 4.0 kilohms and less than 20 kilohms.

Receivers must be designed to ensure that no spurious noise is generated on the line during a normal power-up or power-down sequence.

### 3.3.2 Drivers. In the logical zero state:

1. The output voltage must not exceed 0.15 volt at a load of +240 microamperes. (See diagram D for conventional current polarity definition.)

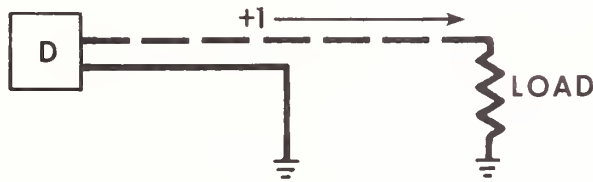


DIAGRAM D. Current Polarity

In the logical one state:

1. The output voltage must be 3.11 volts or more at a load of +59.3 milliamperes (two terminators, ten receivers).
2. The output voltage must not exceed 5.85 volts at a load of +30 microamperes (one receiver, no terminator).
3. The output voltage must not exceed 7.0 volts at a load of +123.0 milliamperes during an over-voltage internal to the drivers.

Drivers must be designed to ensure that no spurious noise is generated on the line during a normal power-up or power-down sequence. For the driver, this may be accomplished by one of the following methods:

1. Sequencing the power supplies.
2. Building noise suppression into the circuit.
3. Providing an externally controlled gate. (See diagram E.)

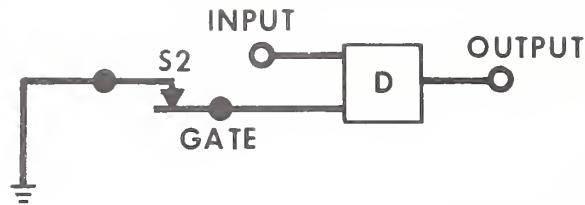


DIAGRAM E. *Driver Gate*

For normal power-down sequence:

1. Logically ensure that the driver is in the zero state.
2. Close contact S2. (See diagram E.)
3. Turn power off.

For a normal power-up sequence:

1. Ensure that contact S is closed.
2. Turn on power.
3. Logically ensure that the input level will cause the driver output to be in the zero state.
4. Open contact S.

3.3.3 **Fault Conditions.** A grounded signal line must not damage drivers, receivers, or terminators. With one driver transmitting a logical one, loss of power in any single circuit driver, receiver, or terminator on the line must not cause damage to other components. With both terminators connected, line operations must not be affected by power off in any drivers or receivers on the line.

3.4 **Typical Circuits.** Figures 5 through 7 show representative circuits used to drive, receive, and terminate the lines between the channel and attached control units.

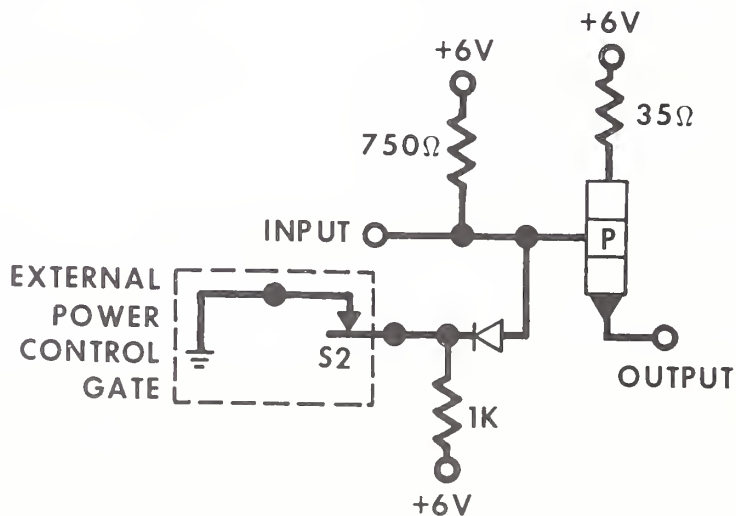


FIGURE 5. *Line Drivers*

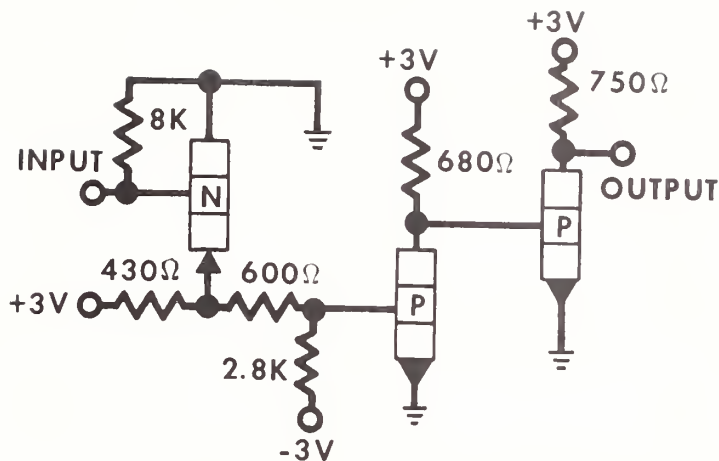


FIGURE 6. Line Receivers

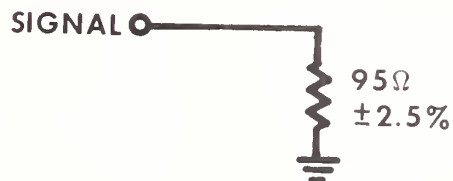


FIGURE 7. Line Terminator

### 3.5 Electrical Specifications for Select Out Circuitry.

**3.5.1 General.** The 'select out' line has a single-driver to single-receiver configuration, with only the receiver end of the line terminated in the characteristic impedance. A dc line voltage of 1.85 volts or more denotes a logical one state, and a dc line voltage of 0.15 volt or less denotes a logical zero state. These voltages are relative to the driver ground.

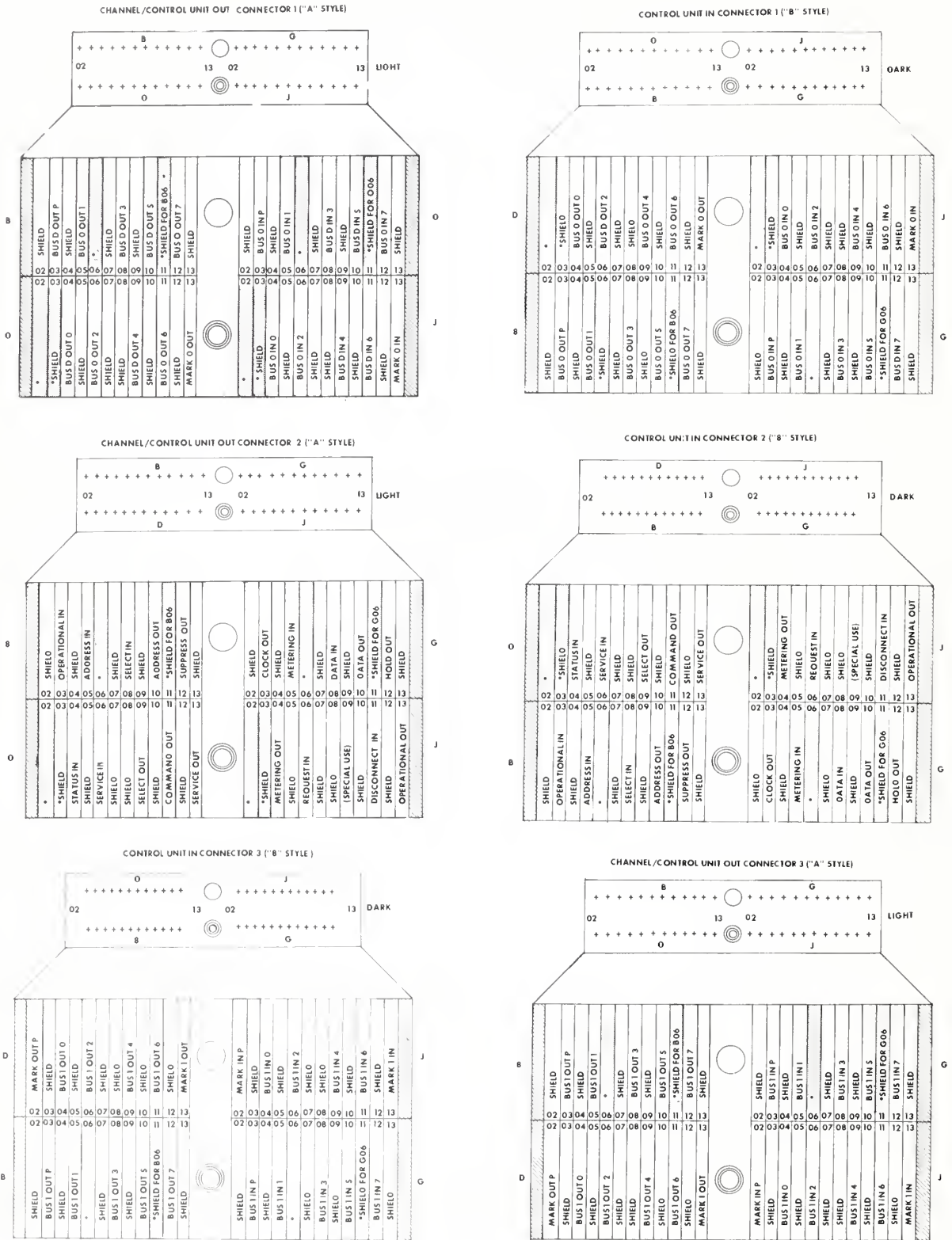
**Note:** Because of the nature of the 'select out'/'select in' line, negative noise tolerance has been neglected.

All electrical requirements specified in section 3.2 "General Electrical Requirements" that are not redefined in this section are also applicable to 'select out'.

**3.5.2 Receiver.** The 'select out' receiver must satisfy all requirements given in Section 3.3.1 "Receivers".

**3.5.3 Driver.** The 'select out' driver must be capable of withstanding a short-circuit-to-ground output condition, while in either the logical one or zero state, without damage to the driver circuit. For the logical zero state:

1. The output voltage of a 'select out' driver must not exceed 0.15 volt at a load of 1 milliampere.



\*Reserved for future use  
 Note: Shading indicates those signals passed only with 48-position cable

FIGURE 8. I/O Interface Connector Pin Assignment

For a logical one state:

1. Output voltage of a channel driver or the driver of a control unit contained within a channel frame must exceed 3.9 volts at a load of 41 milliamperes.
2. The output voltage of a control unit driver not contained within a channel frame must exceed 3.7 volts at a load of 41 milliamperes.

The output voltage of a 'select out' driver should not exceed:

1. 5.8 volts at a load of 0.3 milliampere.
2. 7.0 volts at a load of 72 milliamperes during an overvoltage internal to the driver.

**3.5.4 Terminator.** A 95 ohm  $\pm$  2.5 percent, 390 milliwatt terminator to ground must be placed at each receiver for each line segment along the 'select out'/'select in' path, including the receiver end of 'select in' located in the channel.

The driver end of each segment of 'select out'/'select in' must not be terminated, including the driver end of 'select out' located in the channel. Also, the jumpered 'select out' or 'select in' and the bypassed 'select out' or 'select in' path is not terminated.

**3.5.5 Interface Connector Pin Assignments.** Pin assignments for the I/O interface are shown in figure 8. They are shown as viewed from the connector side of the channel and control unit tailgates. Two interface cables (three cables for the optional two-byte interface) connect the channel to the first of a group of control units. Signal are assigned corresponding pin numbers on the channel and control unit connectors. (See chapter 4 "Mechanical Specifications".)

## CHAPTER 4.

### Mechanical Specifications

#### 4.1 Cabling.

**4.1.1 Cable Halves.** A screwdriver is required to join the cable halves. The connecting screw is spring-loaded to prevent damage to mating block contacts. Blocks should be aligned to ensure proper parallel contact mating. After the blocks are keyed, push the screw forward to engage the insert; then tighten securely.

**4.1.2 Mounting.** In normal applications, the blocks are mounted in the horizontal plane to provide a smoother bend into the coaxial cables (see figure 9). Vertical mounting produces unusual bending configurations, requiring careful routing and strain relieving of the external cables.

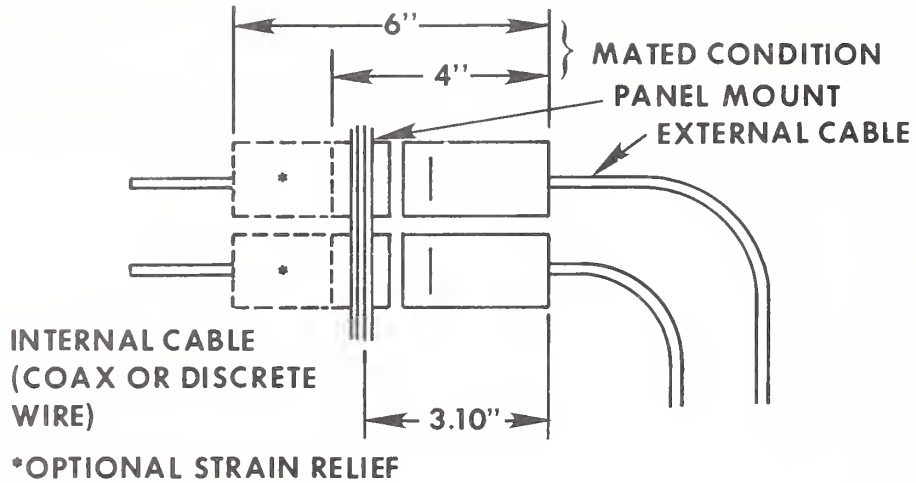


FIGURE 9. Typical Mounted Cable Halves

Figure 10 shows an exploded view of the panel mounting.

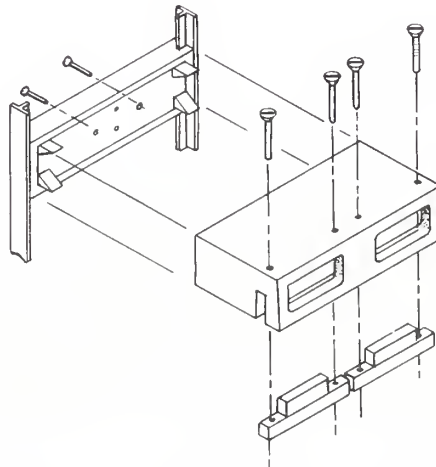


FIGURE 10. Typical Panel Mount with Optional Strain Relief

**4.1.3 Offline Utilization.** This cable connector has the unique feature of being able to mate cable-half to cable-half for offline utilization or for the physical bypassing of machine units (see figure 11).

When mating cable halves, it is only necessary to use the screw on the "B -" style connector. This allows the "A -" style connector's screw to fall within the empty insert location in the "B -" style block and makes for easier connection. Typical connections are shown in figures 11 and 12.

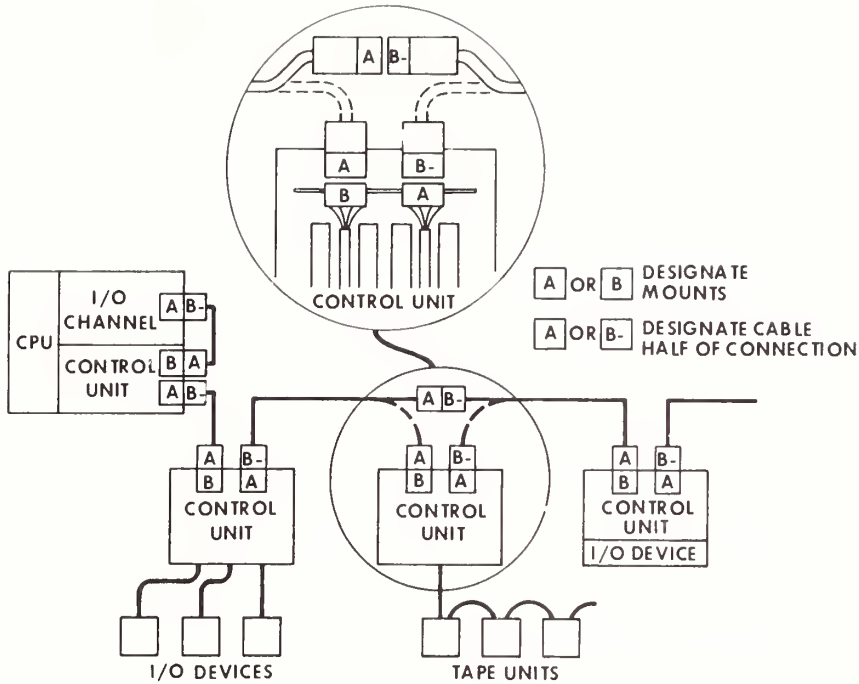


FIGURE 11. Offline Utilization

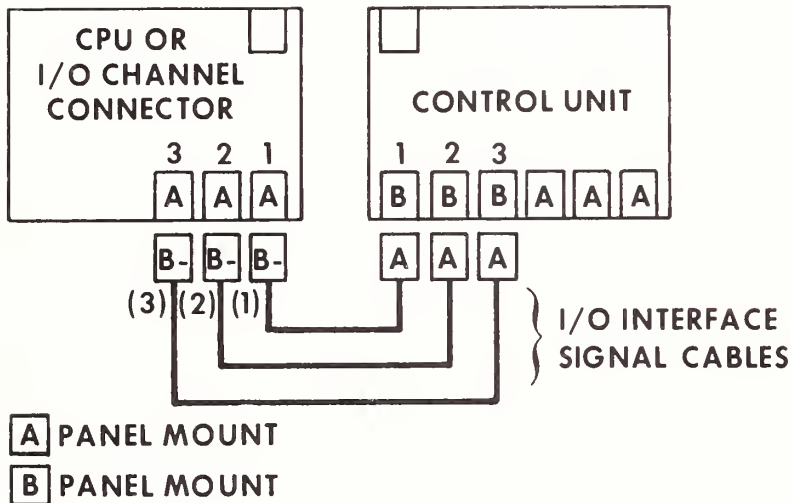


FIGURE 12. Typical Connection

4.2 Connectors.

4.2.1 Connector Block. Three styles of connector blocks are available: "A", "B", and "B -". The "A" and "B" designations are used to identify proper mating arrangements since the physical hardware is identical. The two styles are differentiated by the color coding of the blocks: the "A" style is a light color and the "B" style is a dark color (see figure 13). The "B -" style block is the same as the "B" style but does not have a threaded insert.

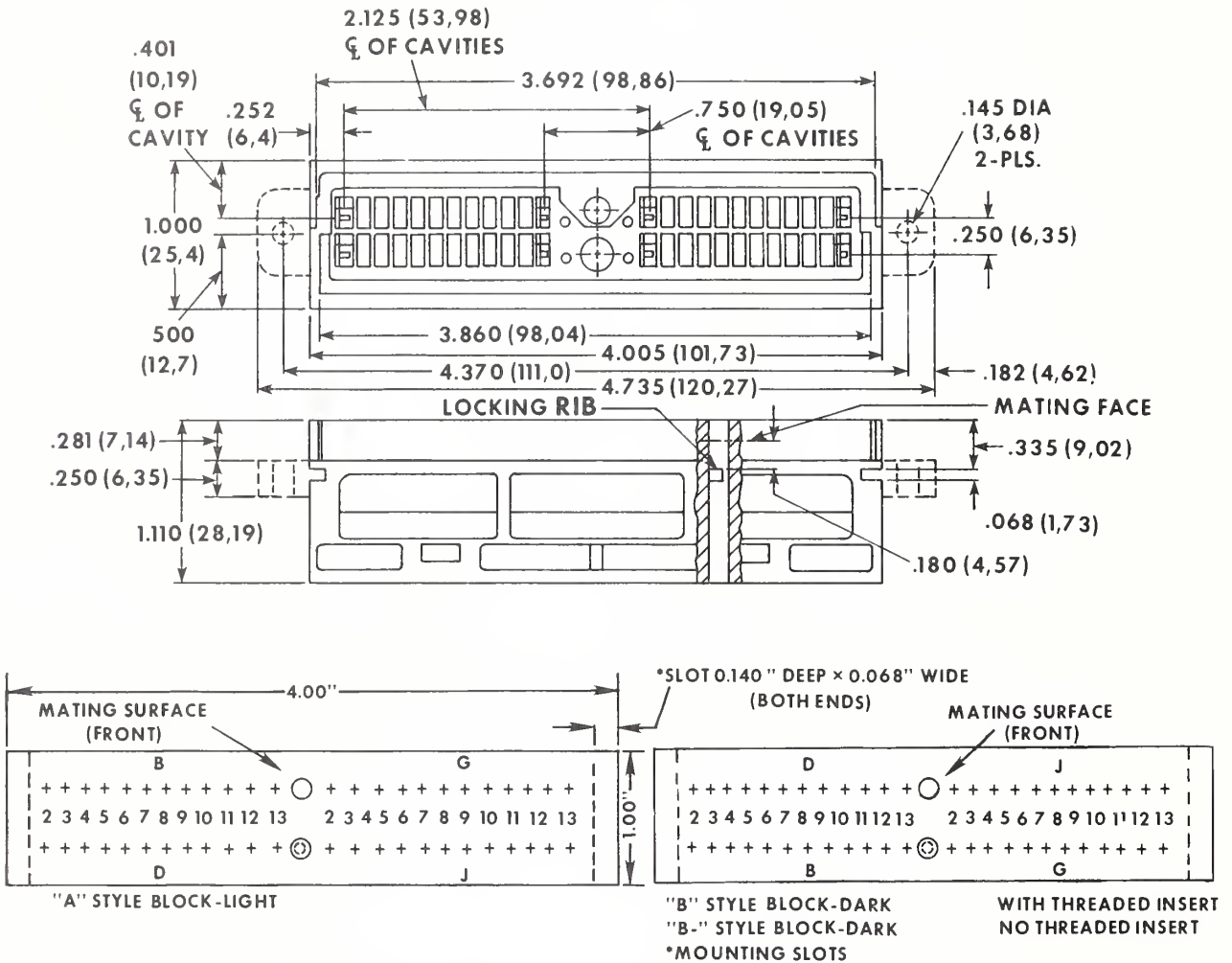


FIGURE 13. Connectors Blocks and Contact Location

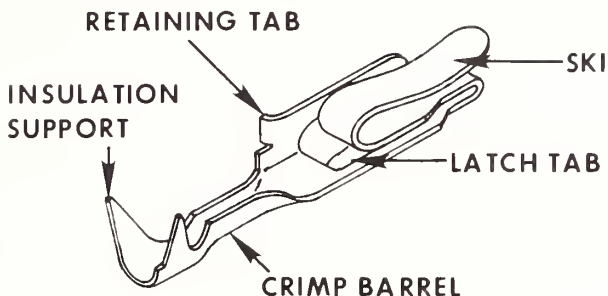
When mating connectors, care should be taken to prevent accidental mismatching of two "A" or two "B" style connectors since letter positions would then be transposed. Connectors of the same color must never be mated. Both the "A" and the "B" style blocks are used for panel mounts. The "A" style may also be used for a cable end. The "B-" style is used only as a cable end (refer to section 4.1.3 "Offline Utilization").

**4.2.2 Capacity.** Forty-eight (48) individual positions (contacts) are provided for in the connector blocks. Application of the connector is limited only by the number of coaxial wires (shielded wires or twisted pairs) used and the method used to ground the shields of the coaxial wires.

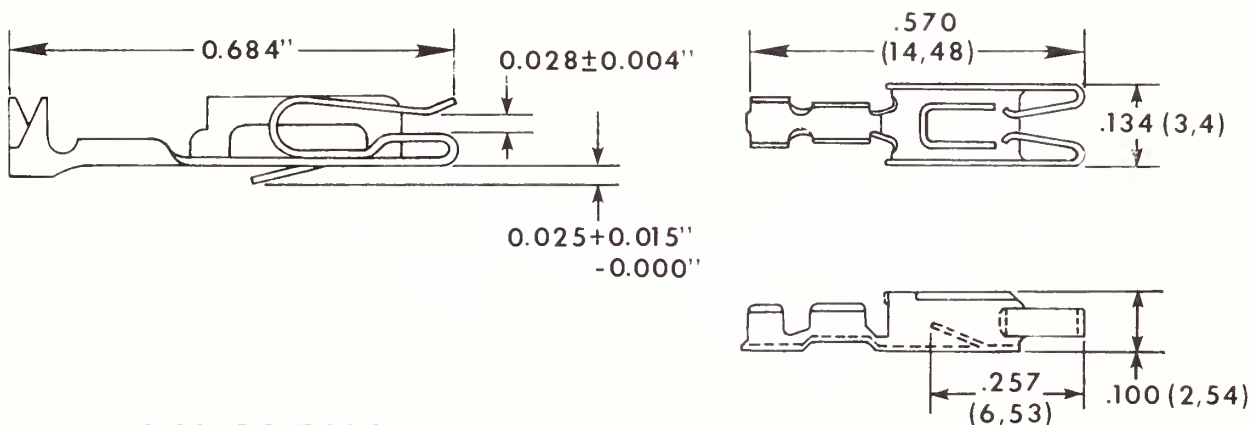
**4.2.3 Contacts.** The contact is a hermaphroditic, gold-plated phosphor bronze, dual-mating surface contact or equivalent (see figure 14).



**A. PART IDENTIFICATION**



**B. DIMENSIONS**



**C. MATING CONFIGURATION**

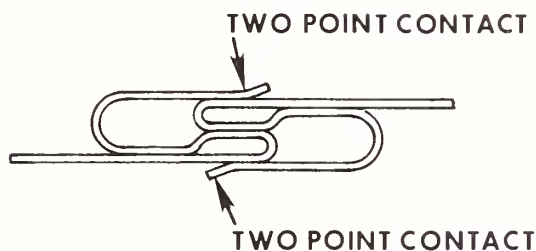


FIGURE 14. Typical Contacts

**4.2.3.1 Voltage Ratings.** The maximum voltage rating of this connector is 24 volts ac or dc.

**4.2.3.2 Current Rating.** The maximum continuous current rating of each contact is 6 amperes. The contacts are not intended for interrupting current.

**4.2.3.3 Resistance.** The termination-to-termination resistance (includes 2 crimps and mated contacts) will not exceed:

1. 0.020 ohms when installed on #22 AWG and larger wire.

2. 0.030 ohms when installed on #24-#26 AWG wire.
3. 0.040 ohms when installed on #28-#32 AWG wire.

4.2.3.4 Insulation Resistance. The contact-to-contact insulation resistance is 100 megohms (minimum) measured at a test potential of 100 volts dc, after exposure of one hour at a temperature of 38 degrees Centigrade and 85-90 percent relative humidity.

4.2.3.5 Grounding. All surfaces of the connectors are nonconductive plastic; therefore, no grounding is necessary.

4.3 Terminators. The I/O interface line termination is provided by the assemblies shown in figure 15. There is one tag and one bus assembly required, the difference being the handling (turn-around) of the 'select out' line.

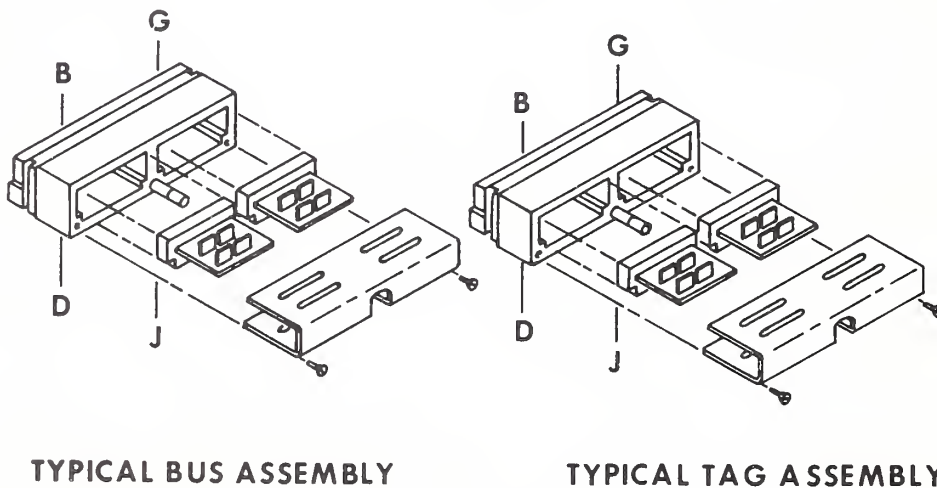


FIGURE 15. Terminator Assemblies

## APPENDIX A.

### FLOW DIAGRAMS

(This Appendix is not a part of the Standard, Specifications for I/O Channel Interface but is included for information purposes only.)

**Note:** The terms "Byte Multiplexer Channel", "Block Multiplexer Channel", and "Selector Channel" are used to describe possible implementations of this standard.

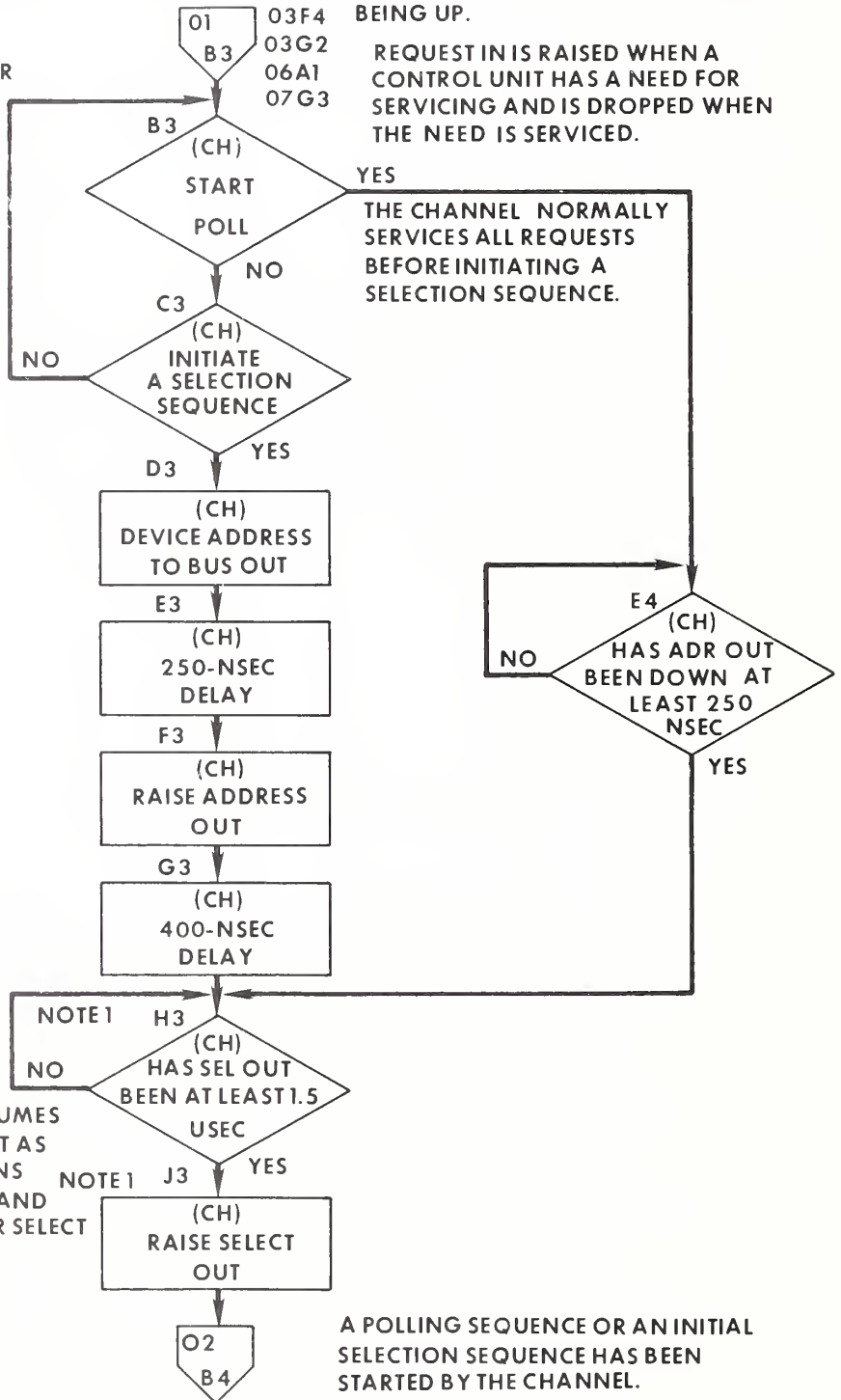
AT DECISION BLOCKS INVOLVING SIGNAL LINES, THE QUESTION TO BE RESOLVED IS --- IS THE LINE LOGICALLY UP.

THE PRESENCE OF CH (CHANNEL) OR CU (CONTROL UNIT) IN A BLOCK, SPECIFIES RESPONSIBILITY FOR THE ACTION TAKEN OR DECISION MADE.

THE START-POLL DECISION IS USUALLY MADE ON THE BASIS OF REQUEST IN BEING UP.

REQUEST IN IS RAISED WHEN A CONTROL UNIT HAS A NEED FOR SERVICING AND IS DROPPED WHEN THE NEED IS SERVICED.

THE CHANNEL NORMALLY SERVICES ALL REQUESTS BEFORE INITIATING A SELECTION SEQUENCE.



NOTE 1

ALL MENTION OF SELECT OUT ASSUMES PROPER OPERATION OF HOLD OUT AS WELL. THUS, SELECT OUT UP MEANS SELECT OUT AND HOLD OUT UP, AND SELECT OUT DOWN MEANS EITHER SELECT OUT OR HOLD OUT DOWN.

A POLLING SEQUENCE OR AN INITIAL SELECTION SEQUENCE HAS BEEN STARTED BY THE CHANNEL.

FLOW DIAGRAM 1. Initiation of Polling or Selection

NOTE 1

ALL MENTION OF SELECT OUT ASSUMES PROPER OPERATION OF HOLD OUT AS WELL. THUS, SELECT OUT UP MEANS SELECT OUT AND HOLD OUT UP, AND SELECT OUT DOWN MEANS EITHER SELECT OUT OR HOLD OUT DOWN

NOTE 2

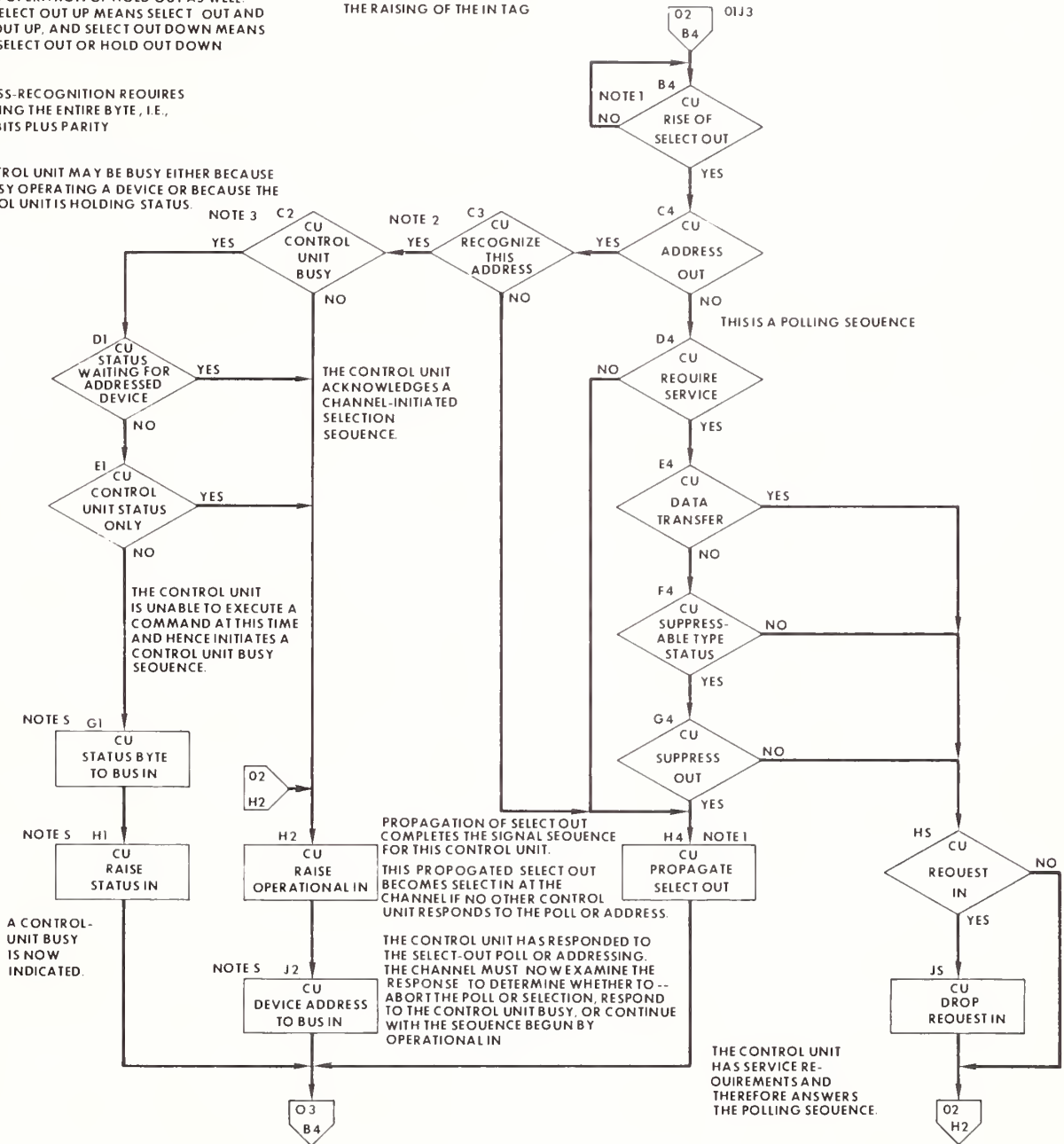
ADDRESS-RECOGNITION REQUIRES DECODING THE ENTIRE BYTE, I.E., EIGHT BITS PLUS PARITY

NOTE 3

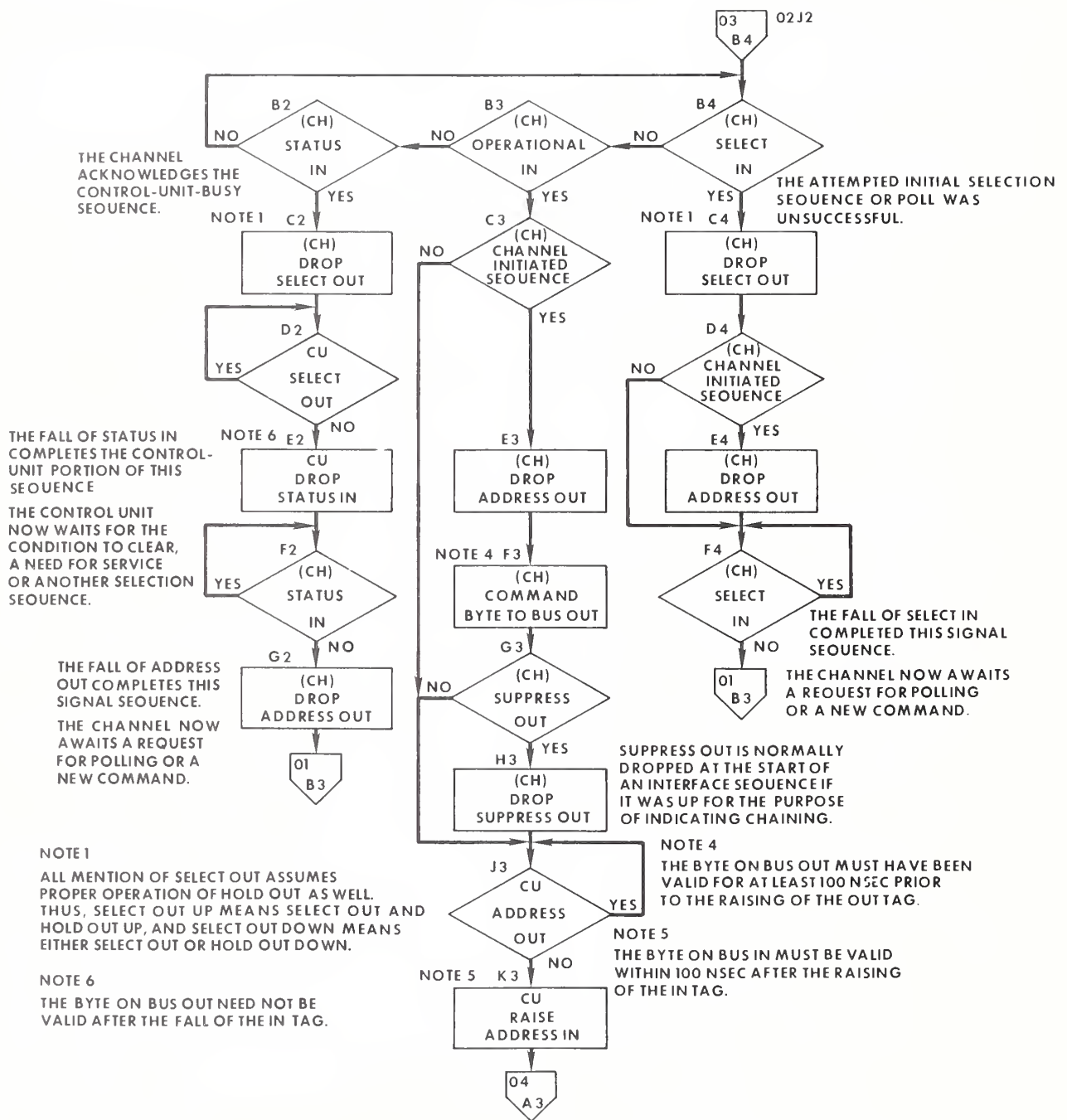
A CONTROL UNIT MAY BE BUSY EITHER BECAUSE IT IS BUSY OPERATING A DEVICE OR BECAUSE THE CONTROL UNIT IS HOLDING STATUS.

NOTE 5

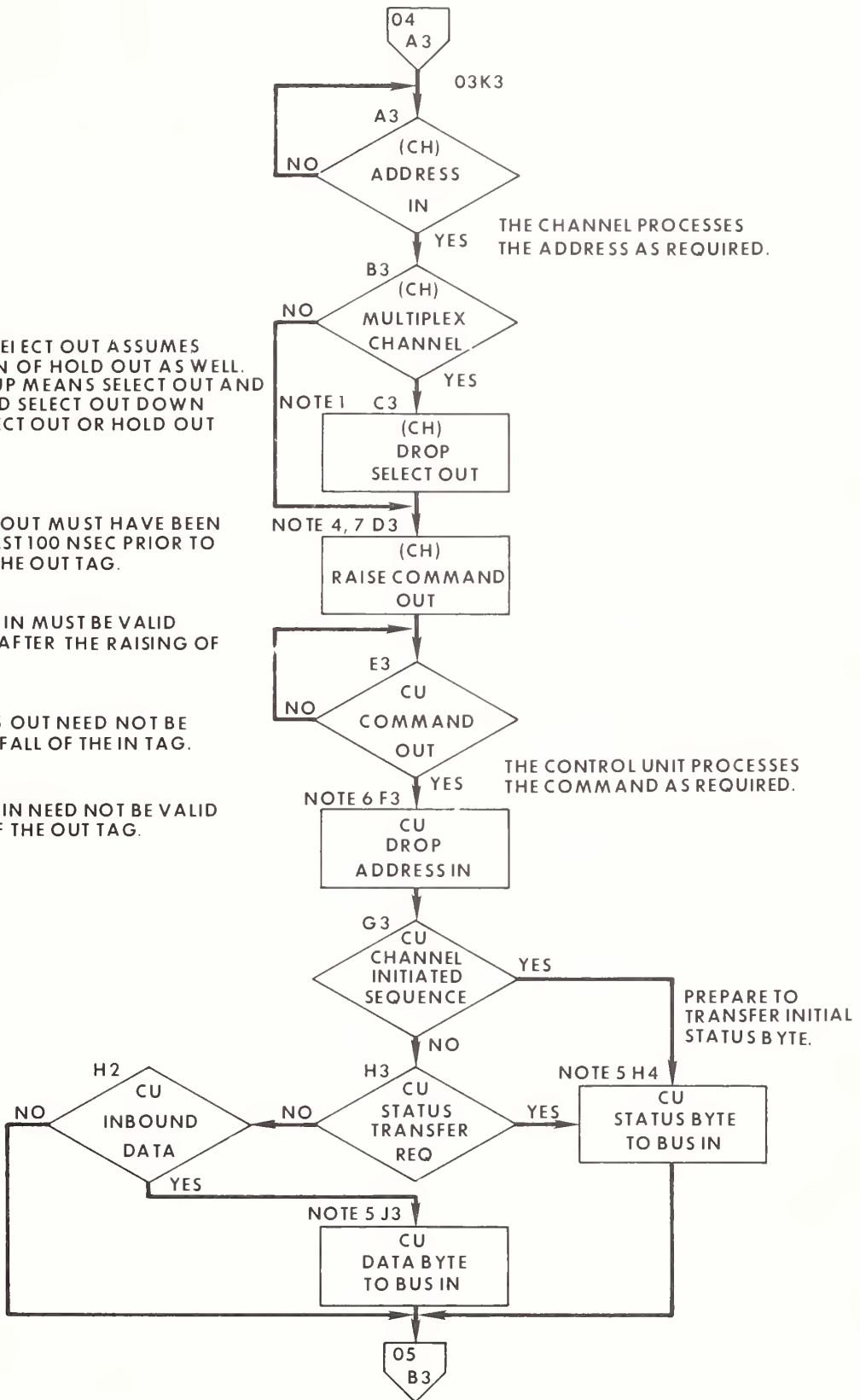
THE BYTE ON BUS IN MUST BE VALID WITHIN 100 NSEC AFTER THE RAISING OF THE IN TAG



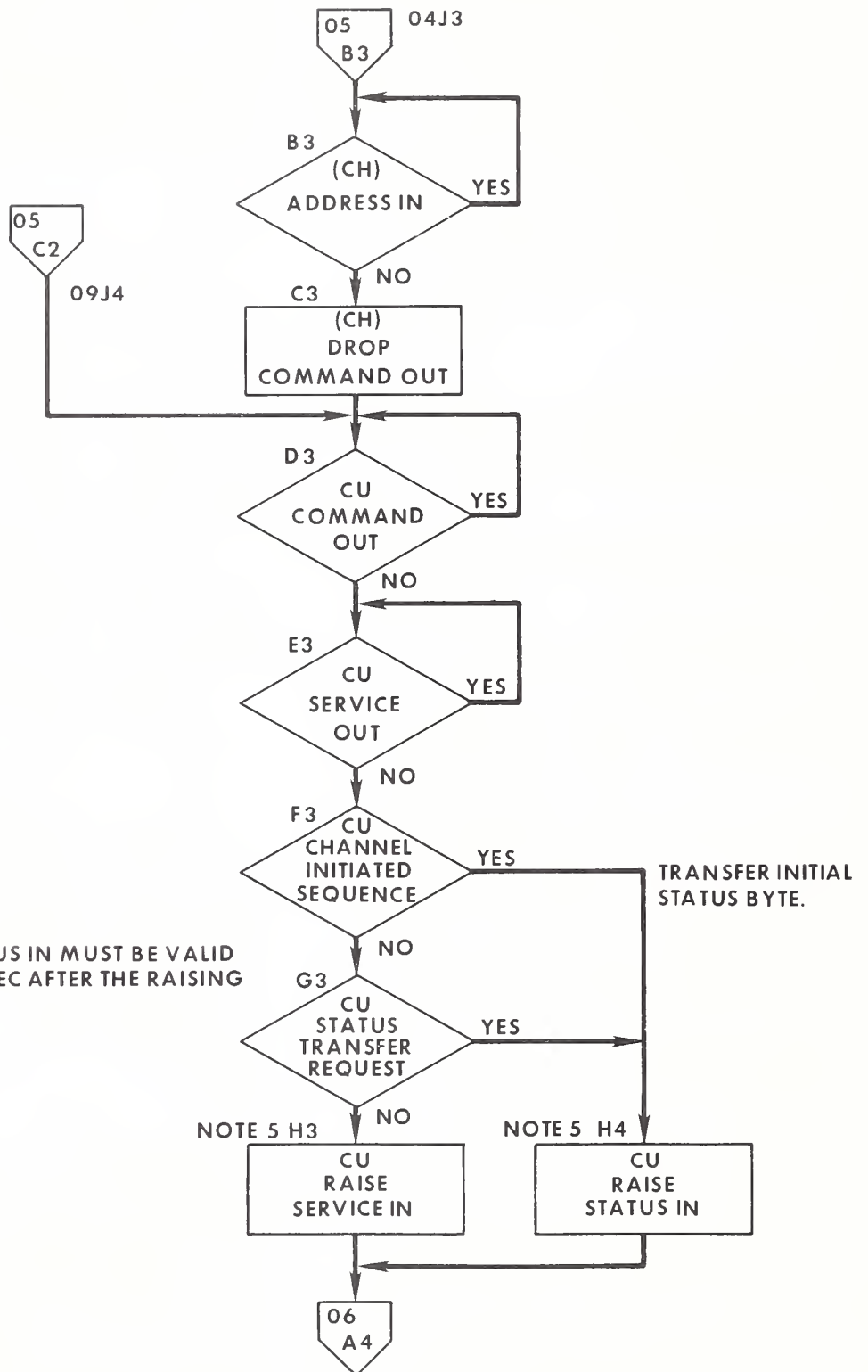
FLOW DIAGRAM 2. Control Unit Response to Select Out (Part 1 of 2)



FLOW DIAGRAM 2. Control Unit Response to Select Out (Part 2 of 2)

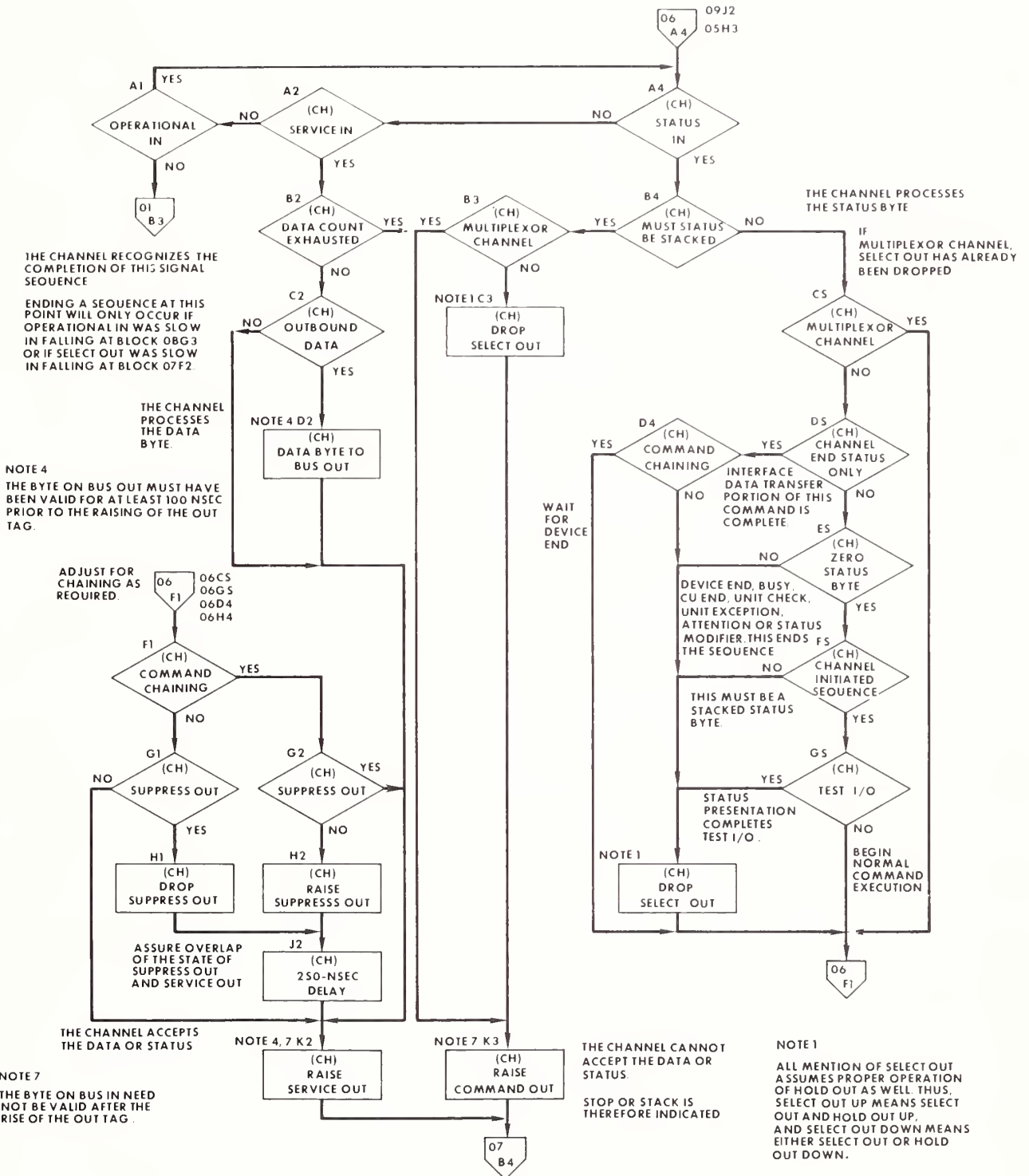


FLOW DIAGRAM 3. Command Transfer

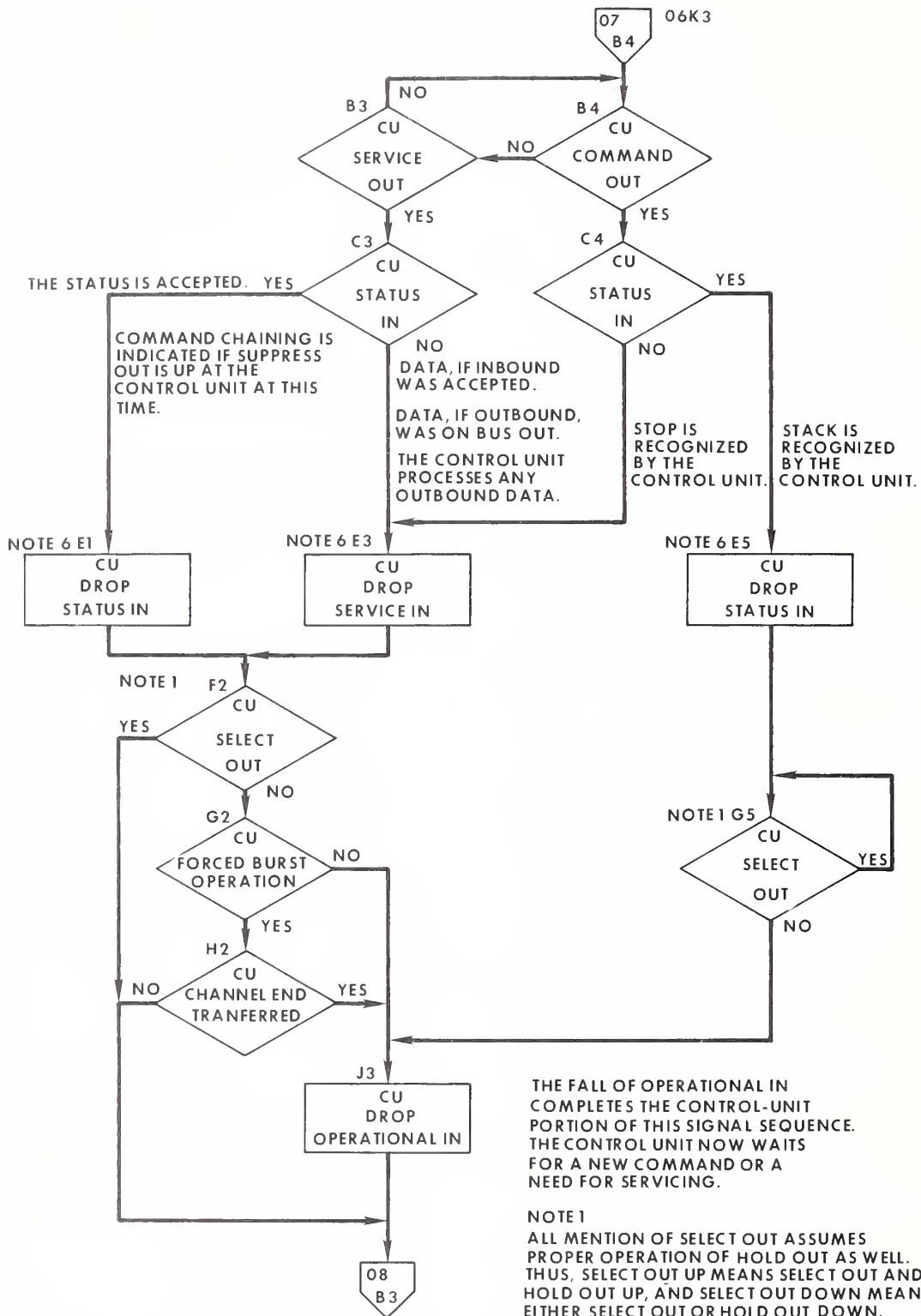


FLOW DIAGRAM 4. Status/Data Presentation

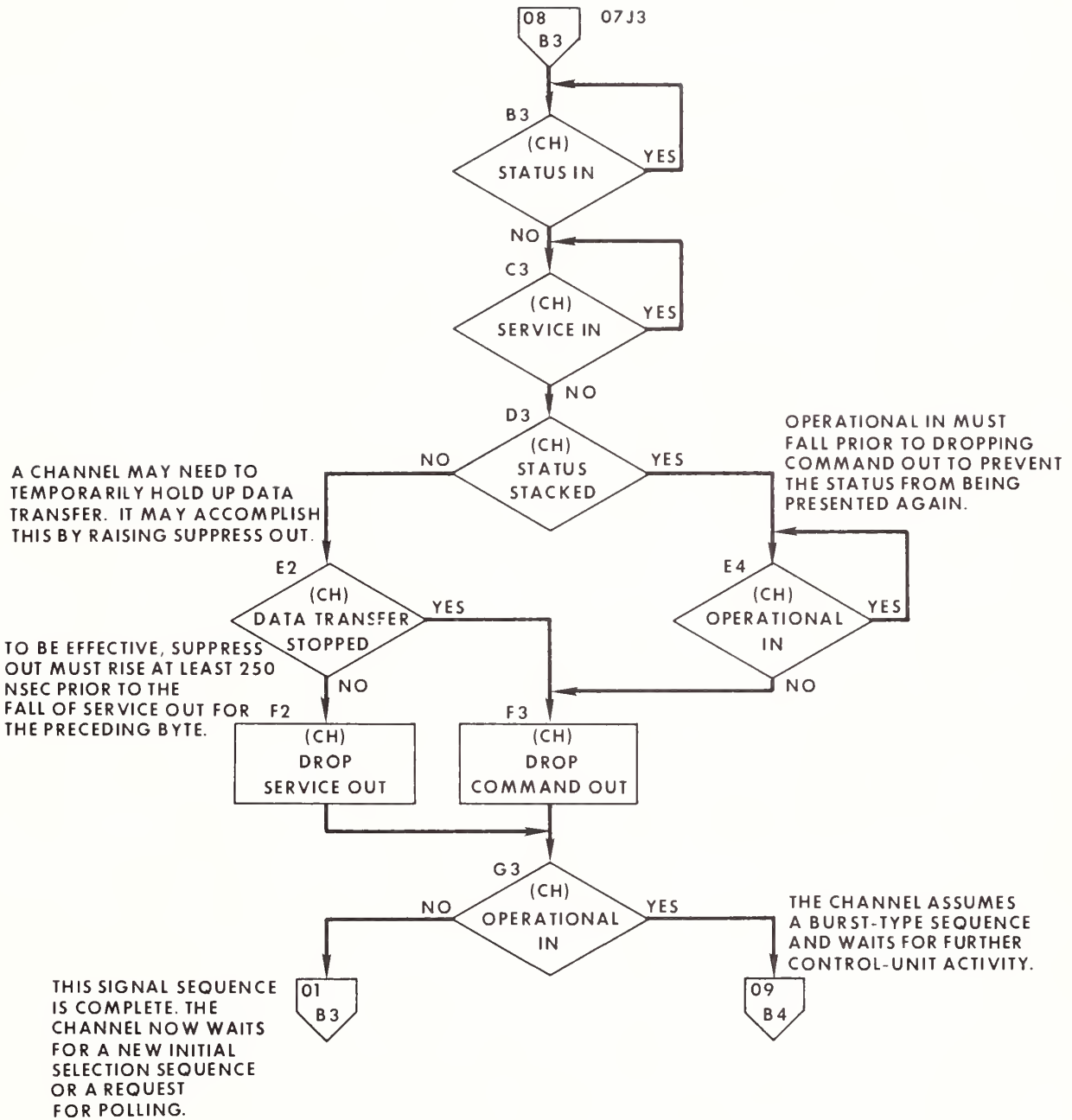




FLOW DIAGRAM 5. Response to Status/Data Presentation



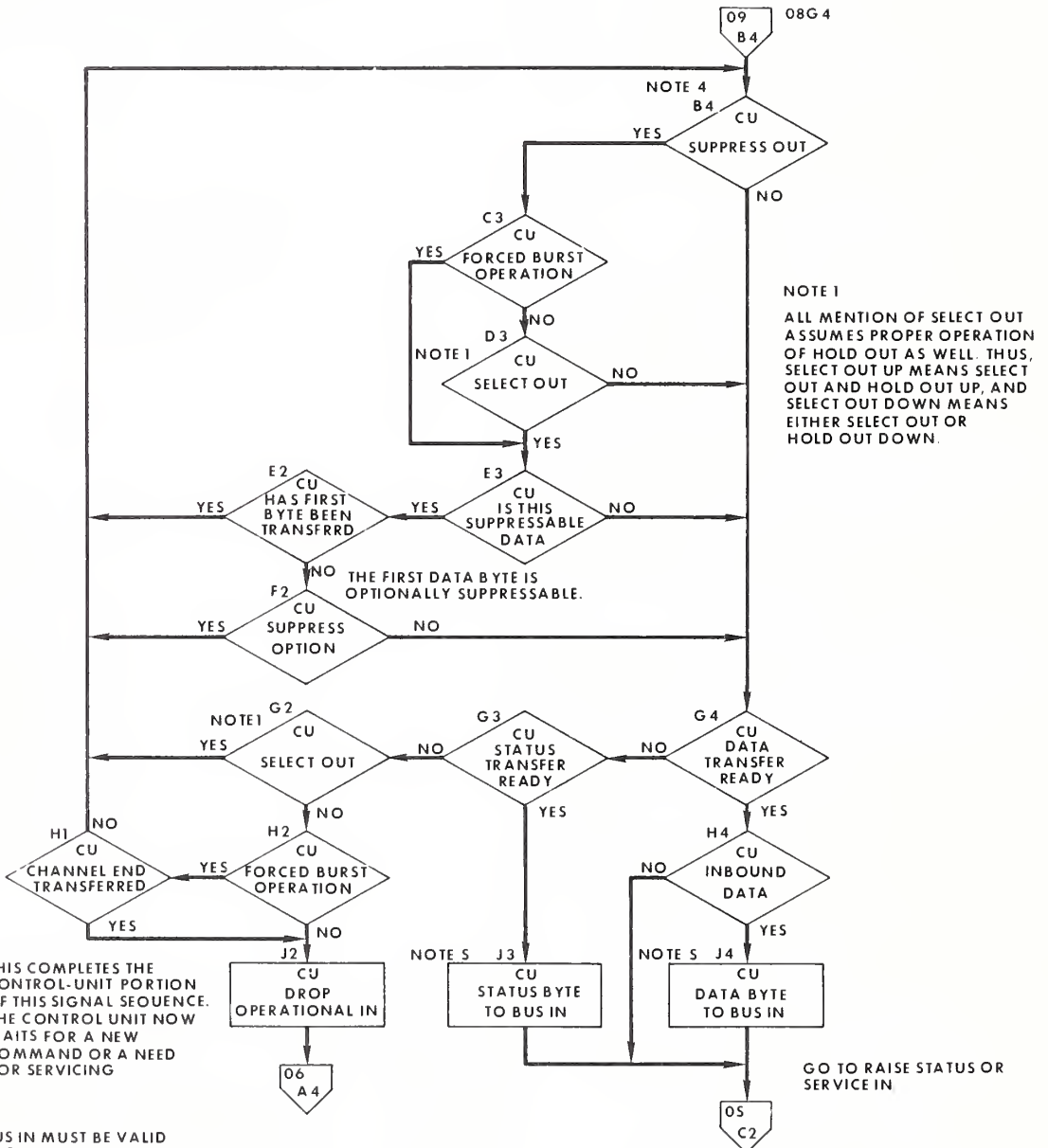
FLOW DIAGRAM 6. Response to Stack/Stop Accept



FLOW DIAGRAM 7. Response to Fall of Status/Service in

NOTE 4

THE BYTE ON BUS OUT MUST HAVE BEEN VALID FOR AT LEAST 100 NSEC PRIOR TO THE RAISING OF THE OUT TAG



FLOW DIAGRAM 8. Burst Mode Waiting Loop

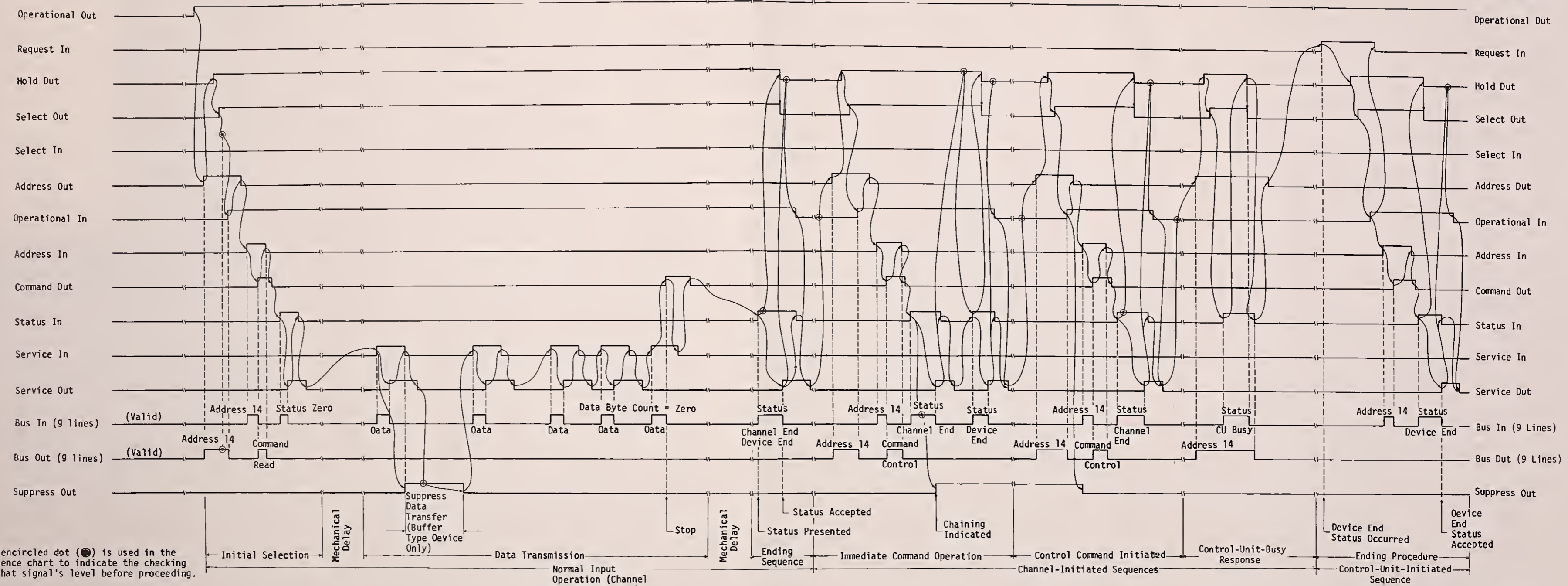
## APPENDIX B.

### SEQUENCE CHARTS

(This Appendix is not a part of the Standard, Specifications for I/O Channel Interface, but is included for information purposes only.)

**Note:** The terms "Byte Multiplexer Channel", "Block Multiplexer Channel", and "Selector Channel" are used to describe possible implementations of this standard.



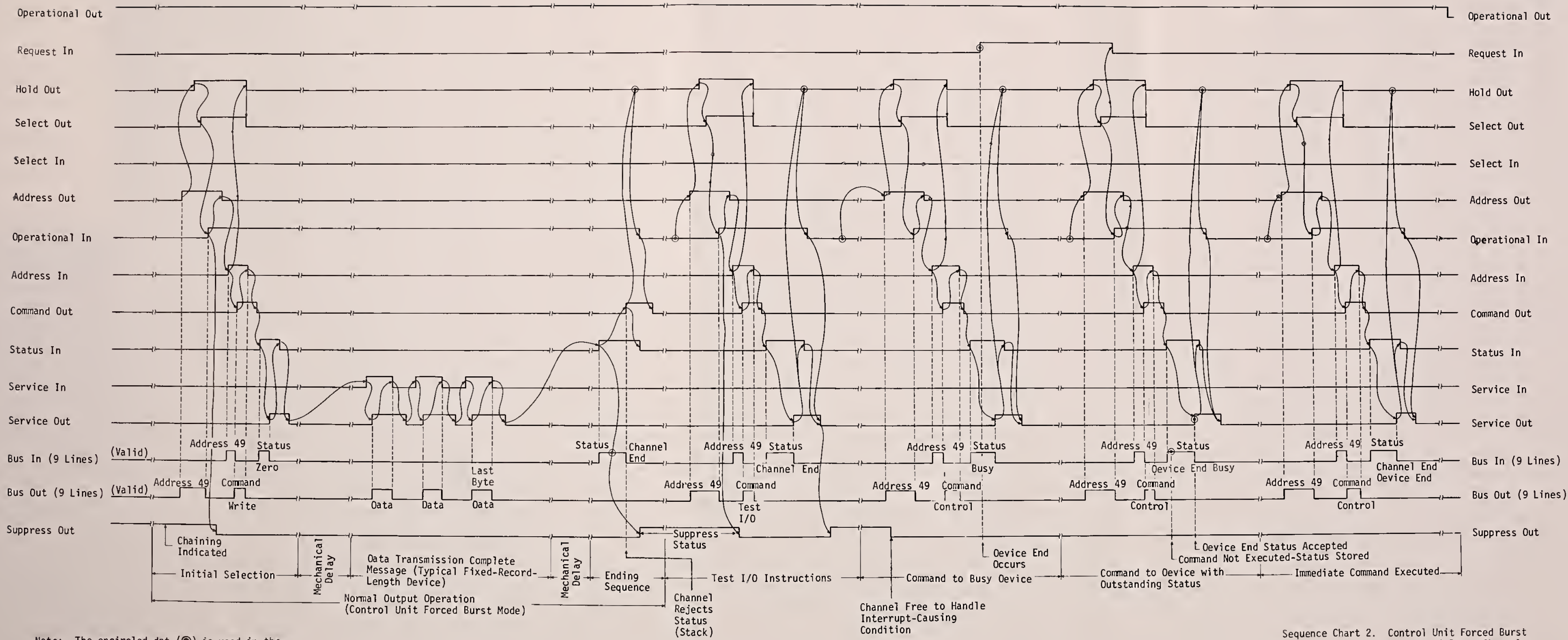


Note: The encircled dot (●) is used in the sequence chart to indicate the checking of that signal's level before proceeding.

Normal Input Operation (Channel Forced Burst Mode Selector Channel)



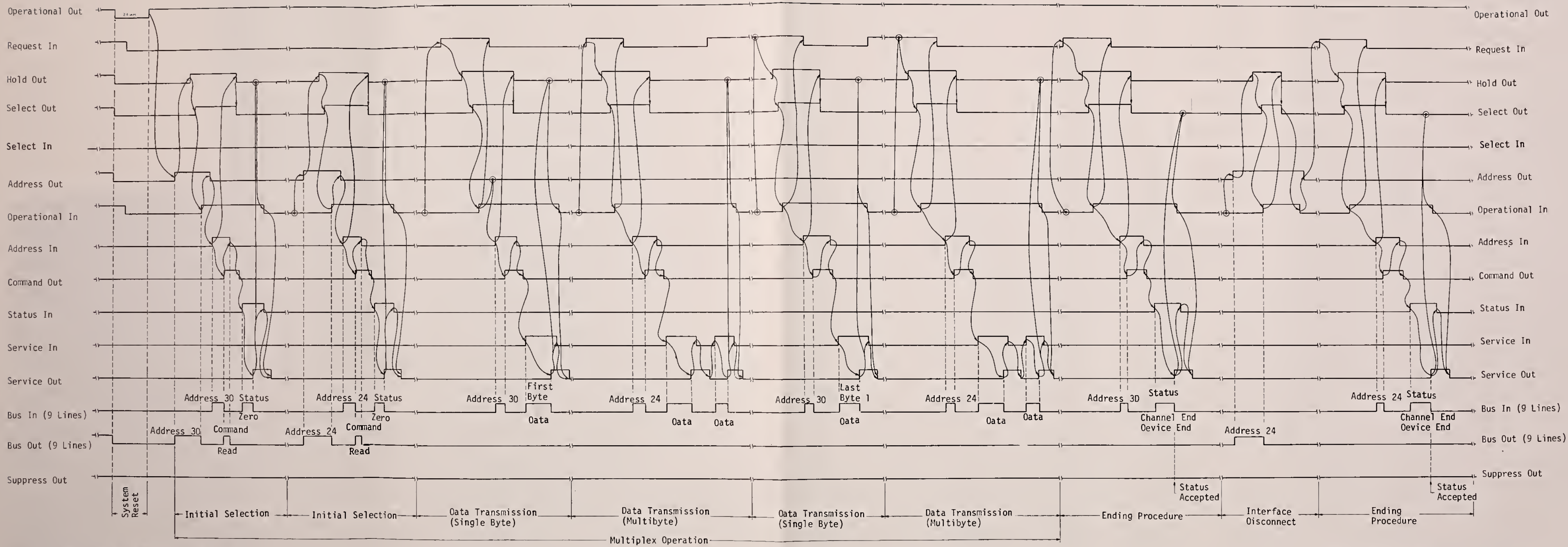




Note: The encircled dot (●) is used in the sequence chart to indicate the checking of that signal's level before proceeding.

Sequence Chart 2. Control Unit Forced Burst Mode-Multiplexer Channel  
Appendix B, Page 2

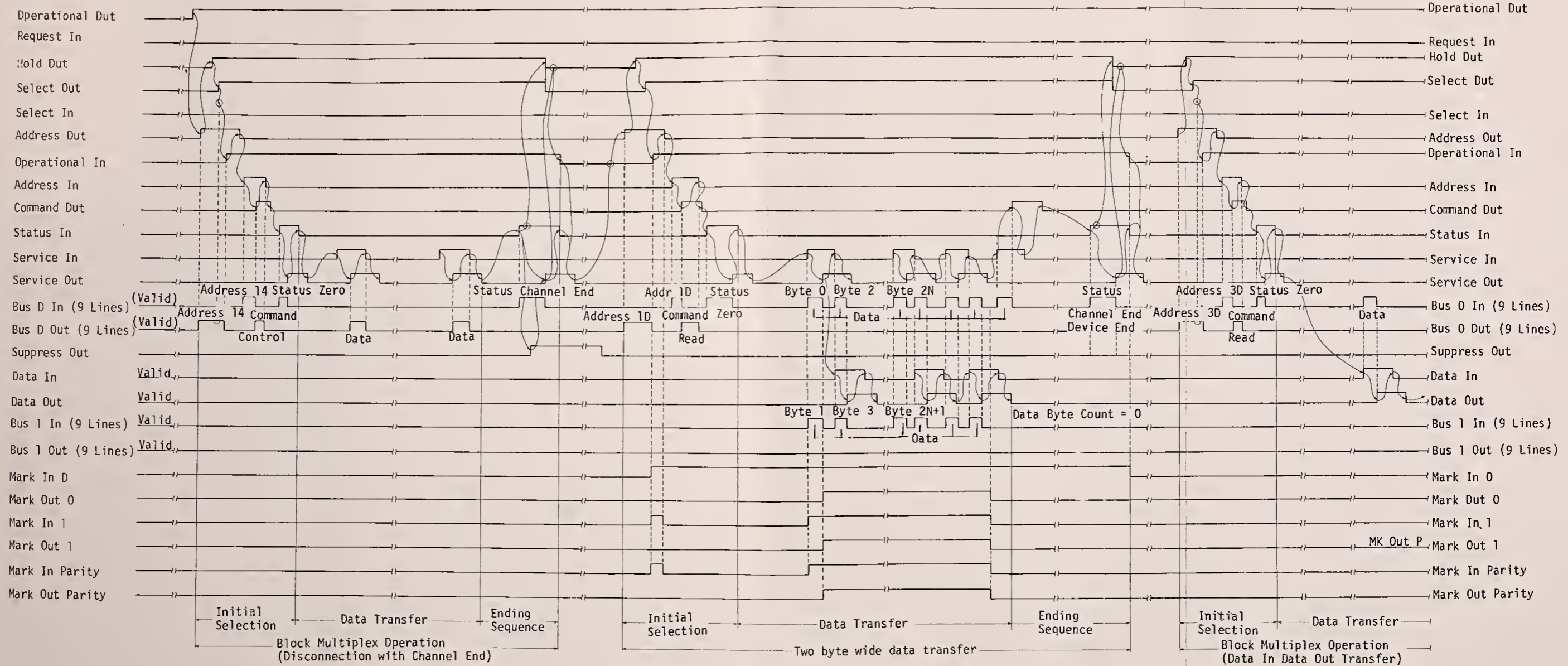




Note: The encircled dot (●) is used in the sequence chart to indicate the checking of that signal's level before proceeding.

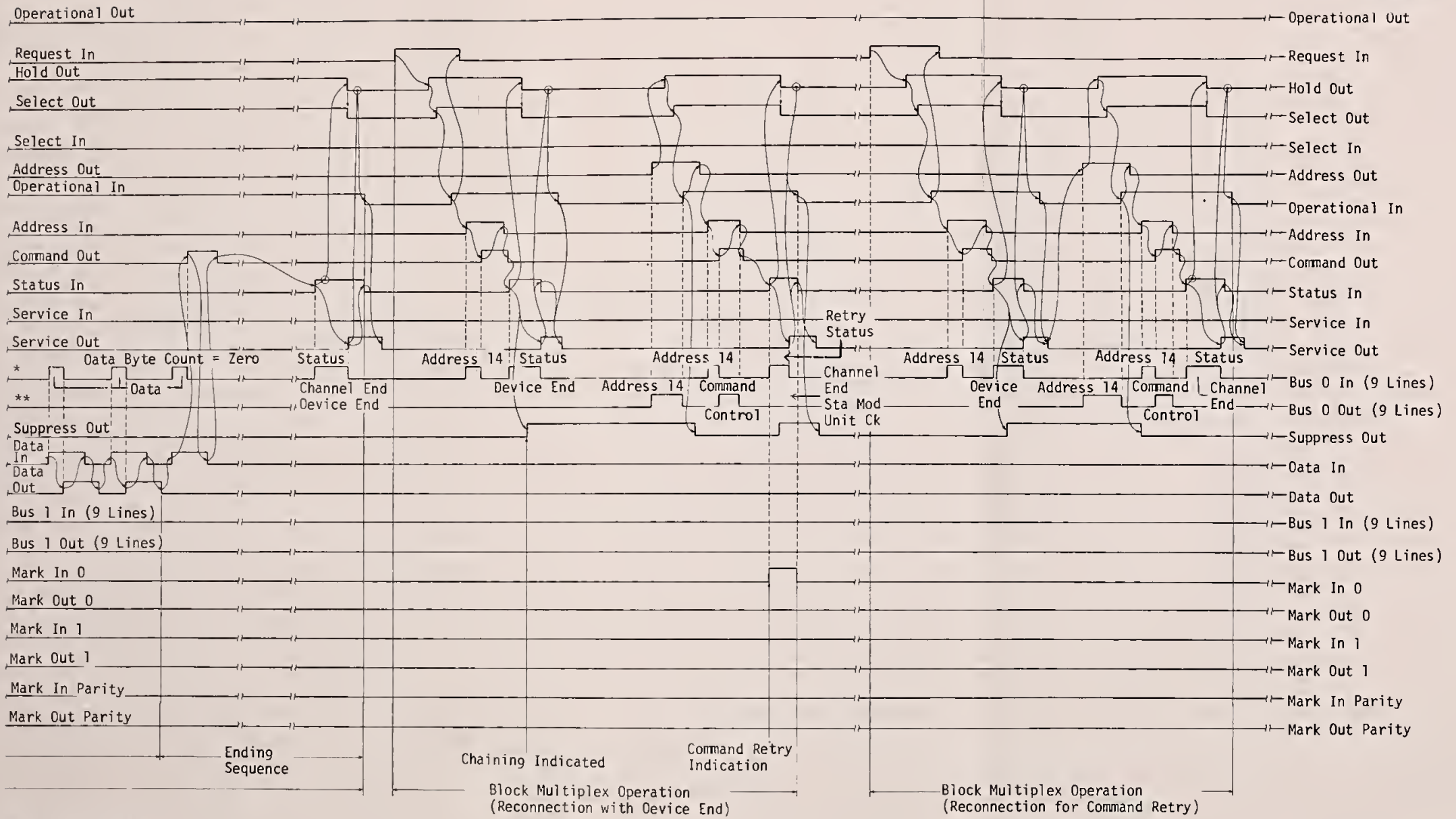
Sequence Chart 3. Multiplexing Operation on Multiplexer Channel  
Appendix B, Page 3





Sequence Chart 4. Block Multiplexer Channel Operation (Part 1 of 2)





\* Bus 0 In (9 Lines)  
 \*\* Bus 0 Out (9 Lines)

Sequence Chart 4. Block Multiplexer Channel Operation (Part 2 of 2)





## APPENDIX C.

### EXPOSITORY REMARKS

The initial ANSI X3 ad hoc committee for I/O Channel Interface Standards originated in November, 1965. In March, 1967 the first meeting was conducted to develop the supporting evidence of justification and need. The ad hoc committee held a series of fifteen meetings that resulted in a set of work guidelines and a set of criteria. Their report, dated December 13, 1968 was presented to X3 in February, 1969.

**C.1 Introduction and Rationale.** The X3T9 Technical Committee on Interface Standards was chartered in May 1969 and considered a wide variety of potential interface points applicable to a common standard definition as used in data processing systems. In the early stages of development, no less than 14 such interface locations were identified. Though not unanimous in its opinion, the technical committee considered a channel level interface as the most tangible area for further development and specification and concluded that from an overall industry-user consideration, the channel level interface offered the highest economic return of all the approaches investigated. Of major consideration was the concept that a channel level interface could permit a specification independent from device functional characteristics. It was recognized that total "plug-to-plug I/O interchangeability" could not be achieved without full specifications for Functional, Electrical, Mechanical, and Operational characteristics.

As a result the standard has been written for a relatively high degree of device independence, but with a goal of achieving the greatest degree of interchangeability possible.

Consideration of the channel level interface took into account three major categories of interest: Users, system manufacturers, and peripheral equipment manufacturers. *Users* are concerned with software costs and thus a standard that permits relative independence from device functional characteristics offers attractive economic and system configuration advantages with minimum impact on the operating system. In addition, a channel level interface would offer greater flexibility in the reconfiguration and reutilization of system components. The *system manufacturer* has similar objectives to the user with the exception that device substitution is not a primary objective; however, device enhancement may be an objective. Device functional independence for the system manufacturer is a major concern. The *peripheral manufacturer* has, as a primary objective, the substitution or replacement of original system I/O devices. The software impact caused by peripheral manufacturers I/O devices is of indirect interest since the peripheral manufacturer does not usually write or maintain the software. In contradiction, the peripheral manufacturer might prefer to include innovations in product designs to enhance the marketability of their product. To a certain extent, the peripheral manufacturer is constrained to provide products that do not impact the overall operating systems.

The Committee has taken into consideration the above objectives and constraints. This standard is the alternative believed to have the widest possible use and acceptance for the channel level interface.

**C.2 Evolution of the Channel Level Interface.** The X3T9 Committee developed a draft group of functional requirements for the channel level interface to evaluate proposed interface standards. Progress on the standard development was necessarily slow due to the complexity of the interface concepts and objectives of meeting a wide variety of goals, some of which were in conflict. It was decided by the Committee to evaluate an existing interface specification in wide use which met 30 of the 32 requirements specified in that document and to propose it as an American National Standard.

**C.3 Channel Level Perspective and Limitations.** The subject of the administration of an interface standard as complex as the channel level standard has been discussed by the X3T9 Technical Committee. The requirement for an administrative body to both interpret the standard itself and verify compatibility with the standard has been accepted in principle. The user of this document is advised that at the present time, ANSI does not provide for the administration of voluntary standards and no such administrative body is available for consultation and evaluation purposes. Methods for performing these technical administrative functions are under consideration.

**C.4 Implementation Aids.** The following list of documents and references may be found useful in design of systems using this standard interface.

1. IBM System/370 Principles of Operation, IBM Publication number GA22-7000.
2. IBM Model 2860 Selector Channel, IBM Publication number SR23-3204.
3. IBM Model 2870 Multiplexer Channel, Field Engineering Theory of Maintenance, IBM Publication number SY27-2300.
4. IBM Model 2880 Block Multiplexer Channel, Theory of Operation (IBM Maintenance Library), IBM Publication number SY27-2305.
5. Katzan, Harry, Jr.  
Computer Organization and the System/370  
Chapter 4, Channel Organization and Input/Output  
Van Nostrand Reinhold





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