REFERENCE

NBS TECHNICAL NOTE 843

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

A Technical Guide to Computer-Communications Interface Standards

QC
100
.U5753
no. 843
1974

NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards[1] was established by an act of Congress March 3, 1901. The Bureau's overall goal is to strengthen and advance the Nation's science and technology and facilitate their effective application for public benefit. To this end, the Bureau conducts research and provides: (1) a basis for the Nation's physical measurement system, (2) scientific and technological services for industry and government, (3) a technical basis for equity in trade, and (4) technical services to promote public safety. The Bureau consists of the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, the Institute for Computer Sciences and Technology, and the Office for Information Programs.

THE INSTITUTE FOR BASIC STANDARDS provides the central basis within the United States of a complete and consistent system of physical measurement; coordinates that system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. The Institute consists of a Center for Radiation Research, an Office of Measurement Services and the following divisions:

Applied Mathematics — Electricity — Mechanics — Heat — Optical Physics — Nuclear Sciences[2] — Applied Radiation[2] — Quantum Electronics[3] — Electromagnetics[3] — Time and Frequency[3] — Laboratory Astrophysics[3] — Cryogenics[3].

THE INSTITUTE FOR MATERIALS RESEARCH conducts materials research leading to improved methods of measurement, standards, and data on the properties of well-characterized materials needed by industry, commerce, educational institutions, and Government; provides advisory and research services to other Government agencies; and develops, produces, and distributes standard reference materials. The Institute consists of the Office of Standard Reference Materials and the following divisions:

Analytical Chemistry — Polymers — Metallurgy — Inorganic Materials — Reactor Radiation — Physical Chemistry.

THE INSTITUTE FOR APPLIED TECHNOLOGY provides technical services to promote the use of available technology and to facilitate technological innovation in industry and Government; cooperates with public and private organizations leading to the development of technological standards (including mandatory safety standards), codes and methods of test; and provides technical advice and services to Government agencies upon request. The Institute consists of a Center for Building Technology and the following divisions and offices:

Engineering and Product Standards — Weights and Measures — Invention and Innovation — Product Evaluation Technology — Electronic Technology — Technical Analysis — Measurement Engineering — Structures, Materials, and Life Safety[4] — Building Environment[4] — Technical Evaluation and Application[4] — Fire Technology.

THE INSTITUTE FOR COMPUTER SCIENCES AND TECHNOLOGY conducts research and provides technical services designed to aid Government agencies in improving cost effectiveness in the conduct of their programs through the selection, acquisition, and effective utilization of automatic data processing equipment; and serves as the principal focus within the executive branch for the development of Federal standards for automatic data processing equipment, techniques, and computer languages. The Institute consists of the following divisions:

Computer Services — Systems and Software — Computer Systems Engineering — Information Technology.

THE OFFICE FOR INFORMATION PROGRAMS promotes optimum dissemination and accessibility of scientific information generated within NBS and other agencies of the Federal Government; promotes the development of the National Standard Reference Data System and a system of information analysis centers dealing with the broader aspects of the National Measurement System; provides appropriate services to ensure that the NBS staff has optimum accessibility to the scientific information of the world. The Office consists of the following organizational units:

Office of Standard Reference Data — Office of Information Activities — Office of Technical Publications — Library — Office of International Relations.

---

[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Part of the Center for Radiation Research.
[3] Located at Boulder, Colorado 80302.
[4] Part of the Center for Building Technology.

NOV 1 1974 not acc - Ref.
QC100
U5753
.843
1974

A Technical Guide to Computer-Communications Interface Standards

Albrecht J. Neumann, Brian G. Lucas,
Justin C. Walker, and Dennis W. Fife

Systems and Software Division
Institute for Computer Sciences and Technology
U.S. National Bureau of Standards
Washington, D.C. 20234

t. Technical note no. 843

Sponsored by:
Joint Technical Support Activity
Defense Communications Agency
Washington, D.C. 20305

U.S. DEPARTMENT OF COMMERCE, Frederick B. Dent, *Secretary*
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, *Director*

Issued August 1974

Library of Congress Catalog Card Number: 74-600131

National Bureau of Standards Technical Note 843
Nat. Bur. Stand. (U.S.), Tech. Note 843, 111 pages (Aug. 1974)
CODEN: NBTNAE

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON: 1974

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
(Order by SD Catalog No. C13.46:843). Price $1.50

ACKNOWLEDGMENT

The authors are indebted to George Clark, Jack Little, and Ray Moore of the Computer Systems Engineering Division, NBS, who contributed their expertise as experienced participants in data communications standards to a constructive review of this report.

CONTENTS

FIGURES

TABLES

A TECHNICAL GUIDE TO COMPUTER-COMMUNICATIONS INTERFACE STANDARDS

Albrecht J. Neumann,
Brian G. Lucas, Justin C. Walker, Dennis W. Fife

A technical summary and guide is given for existing and forthcoming Federal and national standards on data communications pertinent to computer networking. Selected international standards and industry practices are included for completeness. Prepared to assist the application of standards within the World Wide Military Command and Control System, this handbook should be useful to all ADP system designers interested in uniform data terminal interfaces, character sets and codes, keyboard arrangements, and communications line disciplines for effective message exchange between computers.

Key words: ADP standards; communications disciplines; computer networks; data communications.

1. INTRODUCTION

1.1 Purpose

Remote data acquisition and computer access through communications networks has become a central aspect of computer utilization in a wide variety of applications. The World Wide Military Command and Control System (WWMCCS) presents a significant example where terminal-to-computer and computer-to-computer communications are increasingly important in computer service to individual bases, commands, and national military authorities. Designers of information systems and data processing operations have necessarily become involved with data communications factors in configuring systems, software, and operational procedures. Understanding and utilization of the available standards affecting computer-communications can significantly simplify design and procurement problems, contribute to operational dependability, and extend the useful life of networking arrangements. The purpose of this report is to provide a technical summary and guide to existing or forthcoming Federal and national standards. Selected international standards and industry practices (akin to defacto standards) are included where advisable for completeness. Having the essential technical considerations at hand in one volume should enable ADP system designers to assess the adequacy of available standards and to consistently employ them wherever they are sufficient for operational requirements.

1.2 Scope

This guide is directed at data processing equipment and operations factors that are fundamental to effective information interchange through modern data communications networks. It does not address electronic communications equipment or techniques per se, such as switches, modems, concentrators, or transmission media, which are the province of common carriers and telecommunications engineers.

This report is further limited to standards directly involved in message transfer between data sources and sinks, including terminal standards, terminal-modem interfaces, and link control. This excludes many control and information handling functions more closely associated with data processing procedures and system requirements, such as message formats, log-on sequences, and computer system responses to control characters. These have received little investigation toward wide standardization, and are intended for coverage in a subsequent report.

Also, as a technical guide, this report is not meant as an ultimate authority on any standard. Complete references are provided so that the source material can be readily pursued for additional detail.

1.3 Sources of Standards

The standards covered in this guide are Federal Information Processing Standards, American National Standards, selected international and industry standards.

Federal Information Processing Standards (FIPS) are developed and published by the National Bureau of Standards [1-1] with approval of the Secretary of Commerce. NBS frequently is guided by the consultation of Government agencies represented by individual members of FIPS Task Groups. FIPS are developed to meet uniform Federal requirements and, with certain exceptions, are mandatory for implementation by all agencies of the Federal Government. To the extent practicable, they are consistent with national and international standards. NBS is responsible for recommending Federal automatic data processing standards, and works cooperatively with the Office of the Manager of the National Communication System in regard to data communications standards [1-2].

American National Standards are developed under auspices of the American National Standards Institute (ANSI), and represent cooperative effort by producer,consumer, and general interest groups to establish voluntary standards. ADP standards are the responsibility of a committee/sub-committee organization designated as X3, with secretarial support given by the Computer and Business Equipment Manufacturers Association (CBEMA). (See references [1-2] and [1-3] for detailed organizational description and history).

International standards are published by the International Standards Organization (ISO), of which ANSI is a member body. Technical Committee 97 (ISO/TC 97) and its subcommittees are responsible for computer and information processing standards. Also, the publication of the International Telecommunications Union (ITU) and the International Telegraph and Telephone Consultative Committee (CCITT), although oriented to international telecommunications, are sources of relevant technical material in computer networking.

Industry standards of national or international significance may stem from a variety of associations and working groups of manufacturers and producers. In the United States, the Electronic Industries Association (EIA) has done significant work. The European Computer Manufacturers Association (ECMA) provides another example of industry cooperation toward mutual standardization.

1.4 Overview

The perspective of this guide is that computer-communications system design is facilitated by a uniform definition of the necessary physical and logical interfaces among equipment and software components. One physical interface that has been standardized for networking is readily identified. This is the interconnection of DTE (data terminal equipment of any variety, including computers) and DCE (data communications equipment, i.e. modems or analogous devices driving the transmission facility). The DTE-DCE circuit interfaces are described in Section 2 which follows. Logical interfaces or "protocols" are less readily pinpointed, since individual functions of the interface realization may be distributed among equipment and software components having no direct physical connections. All logical interfaces are dependent then on consistent information interchange throughout the system, which begins between the terminals. Thus data codes and the format of codes in data transmission are described in Section 3. Besides uniform interpretation of encoded data, it is equally vital that messages, packets, or any formatted collections of related characters be accurately recovered from the transmission facility and transfered in orderly fashion among terminals on the network. This requires a control discipline for the transmission link, the logical path interconnecting terminals through the transmission facility. Section 4 summarizes standard link control disciplines and the pertinent data flow and message interchanges.

Higher level protocols for information network (or system) control and application processing functions involve further considerations in message formats and interchanges as well as computer software functions. These are beyond the scope of this volume, but would be discussed in a subsequent report from the viewpoint of potential basis for future standards.

1.5 References

1-1. National Bureau of Standards, Federal Information Processing Standards Index, FIPS PUB 12-1, 1 July 1972.

1-2. National Bureau of Standards, Objectives and Requirements of the Federal Information Processing Standards Program, FIPS PUB 23, 15 February 1973.

1-3. Marjorie F. Hill, The World of EDP Standards, Technical Memo 4, Control Data Corporation, September 1972.

2. DTE-DCE INTERFACES

The standard interface between data terminal equipment (DTE) and data communications equipment (DCE) is, in the commercial sector, based on two standards: the interface between the data terminal equipment and the modem [RS-232-C], and the interface between the DTE and the automatic calling equipment [RS-366]. Figure 2-1 delineates these two major interfaces.

For military systems the interfaces are specified as part of the Equipment Technical Design Standards for Digital End Instruments and Ancillary Devices [MIL-STD-188-347]. Also relevant in this connection are MIL-STD-188-C, which deals with Tactical System Standards, and MIL-STD-188-100 which deals with standards common to long haul and tactical communications systems.

2.1 DTE-Modem Interface [EIA RS-232-C]

The standard interface between data terminal equipment and data sets or modems is characterized by serial, binary data interchange. Detail is provided in reference RS-232-C. A summary of the technological constraints and of interface functions is provided in this section. Data must be serialized by the data terminal equipment, so that the data communications equipment may be independent of the character length and codes used by the data terminal equipment. No restrictions on bit sequence arrangements provided by the DTE must be made by the DCE.

The interface standard RS-232-C defines electrical signal characteristics, mechanical interface characteristics, functional description of interface circuits and standard interfaces for selected communication systems configurations. The standard also contains explanations and recommendations as well as a glossary of terms.

2.1.1 Electrical Interface.

The electrical interface is characterized by positive and negative voltage swings at the interface: a negative signal signifying the marking condition and a positive signal signifying the space condition. Broad voltage limits are specified for both positive and negative polarities (3 volts to 25 volts). The region between negative 3 and positive 3 volts is defined as transition region, in which signals are not defined. Further details as to equivalent circuit configuration, circuit parameter tolerances and other detail are given in document RS-232-C.

2.1.2 Mechanical Interface.

The mechanical interface is located at a pluggable connector signal interface point. The female connector is associated with the DTE, the male counterpart with the DCE. An extension cable is provided with the DTE, and is optional with the DCE. The connector provides 25 circuits, and pin number assignment for circuits are part of the standard. [RS-232-C, CCITT V-24, ISO 2110]. Although the standard specifies that pin assignments listed in the standard shall be used, it also specifies that "pin assignments for circuits not specifically defined ... are to be made by mutual agreement. Preference should be given to the use of unassigned pins, but in the event that additional pins are required, extreme caution should be taken in their selection."

2.1.3 Functional Description of Interchange Circuits.

The Standard provides for 25 circuits, 21 of which are summarized in figure 2-2. The four unassigned circuits are spares.

There are four general categories: Ground or common return, Data circuits, Control circuits, and Timing circuits. Functions assigned to the various circuits are described in the following:

2.1.3.1 Ground Circuits - Two distinct ground circuits are provided:

PROTECTIVE GROUND

This circuit is electrically bonded to the equipment frame. It may be further connected to external grounds as required by applicable regulations.

SIGNAL GROUND

This conductor establishes the common ground reference potential for all interchange circuits except for the Protective Ground circuit.

2.1.3.2 Data Circuits - Two circuits carry data: TRANSMITTED DATA provide for data flow from the DTE to the DCE, RECEIVED DATA provide for data flow from the DCE to the DTE.

TRANSMITTED DATA

This circuit carries data from the local DTE to the local DCE and from there to the distant communications and processing equipment. When no data are transmitted, this circuit is held in the marking or OFF condition.[1] Data cannot be transmitted unless all of the following circuits are in the ON conditions (when implemented): REQUEST TO SEND, CLEAR TO SEND, DATA SET READY, DATA TERMINAL READY.

RECEIVED DATA

This circuit carries data from the receiving DCE in response to

1 Note: In this standard MARKING and OFF conditions correspond to a negative signal voltage, while SPACING and ON refer to a positive voltage, with respect to ground.

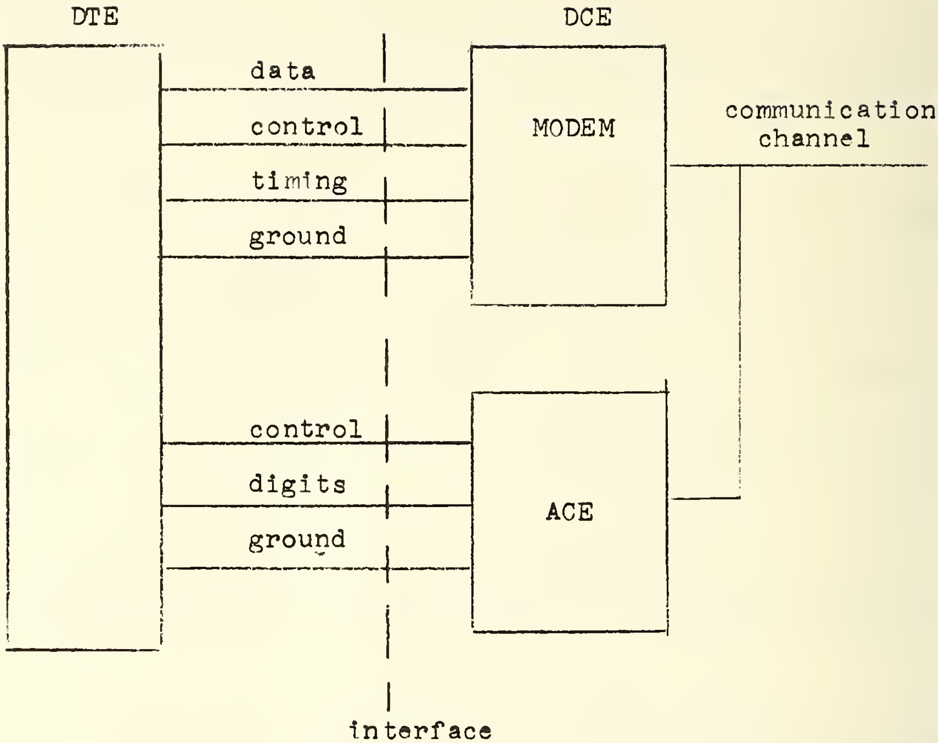


Figure 2-1. DTE - DCE Interface, Non-Military

Pin Numbers	Interchange Circuit	C.C.I.T.T. Equivalent	Description	Gnd	Data		Control		Timing	
					From DCE	To DCE	From DCE	To DCE	From DCE	To DCE
1	AA	101	Protective Ground	X						
7	AB	102	Signal Ground/Common Return	X						
2	BA	103	Transmitted Data			X				
3	BB	104	Received Data		X					
4	CA	105	Request to Send					X		
5	CB	106	Clear to Send				X			
6	CC	107	Data Set Ready				X			
20	CD	108.2	Data Terminal Ready					X		
22	CE	125	Ring Indicator				X			
8	CF	109	Received Line Signal Detector				X			
21	CG	110	Signal Quality Detector				X			
23	CH	111	Data Signal Rate Selector (DTE)					X		
23	CI	112	Data Signal Rate Selector (DCE)				X			
24	DA	113	Transmitter Signal Element Timing (DTE)							X
15	DB	114	Transmitter Signal Element Timing (DCE)						X	
17	DD	115	Receiver Signal Element Timing (DCE)						X	
14	SBA	118	Secondary Transmitted Data			X				
16	SBB	119	Secondary Received Data		X					
19	SCA	120	Secondary Request to Send					X		
13	SCB	121	Secondary Clear to Send				X			
12	SCF	122	Secondary Rec'd Line Signal Detector				X			

Note: Pins 0, 10, 11, 13, and 18 are unassigned.
Pins 9, 10 are reserved for data set testing.
Source: RS-232-C.

Figure 2-2. Interchange Circuits [RS-232-C]

Request to Send	One way only	Two way alternate	Two way simultaneous
ON	maintain DCE in transmit mode	DCE transmit ON receive OFF	maintain DCE in transmit mode
OFF	maintain DCE in non-transmit mode	DCE receive ON transmit OFF	maintain DCE in non-transmit mode
ON-OFF transition	DCE: Complete transmission;non-transmit or receive		
OFF-ON transition	DCE: Transmit,reply clear to send		

Figure 2-3. Control Circuit Actions [RS-232-C]

the remote DCE and DTE. This circuit is held in the OFF condition when the circuit RECEIVED LINE SIGNAL DETECTOR is in the OFF condition.

2.1.3.3 Control Circuits - The following control circuits are provided:

REQUEST TO SEND

This circuit is used to condition the local DCE for data transmission. On a two way alternate channel this means control of the direction of data transmission of the local DCE. Figure 2-3 summarizes these actions. The ON condition maintains the DCE in the transmit mode, and in the case of two way alternate mode inhibits the receive mode. The OFF condition maintains the DCE in the nontransmit mode, and in the case of the two way alternate mode enables the receive mode. The OFF-to-ON transition puts the DCE into the transmit mode, and generates the CLEAR TO SEND SIGNAL. The ON-to-OFF transition puts the DCE into the non-transmit or receive mode.

CLEAR TO SEND

Signals on this circuit are generated by the DCE and indicate to the DTE that the DCE is ready to transmit data. The ON condition, together with the ON conditions on all of the circuits: REQUEST TO SEND, DATA SET READY, and DATE TERMINAL READY, (when implemented) indicate to the DTE that signals can be transmitted on the TRANSMITTED DATA circuit. The OFF condition indicates to the DTE that it should not transmit data. The ON condition on the CLEAR TO SEND circuit is a response to the simultaneous ON conditions on circuits DATA SET READY, and REQUEST TO SEND.

DATA SET READY

Signals on this circuit indicate the status of the local DCE. The ON condition indicates that the local DCE is connected to a communications channel (off-hook in switched service), and that the local DCE is not in test, alternate voice or dial mode, and that the local DCE has completed any timing functions required by the switching system. It also indicates that the local DCE has completed call establishment, and the transmission of a discrete answer tone, the duration of which is controlled only by the local data set, if these functions are implemented.

DATA TERMINAL READY

Signals on this circuit go to the DCE and control switching of the DCE to the communications channel. The ON condition prepares the DCE to be connected to the communications channel and maintains the connection established by external means, i.e. manual call origination, manual answering, or automatic call origination. The OFF condition causes the DCE to be removed from the communications channel, following completion of any in-process transmission.

RING INDICATOR

The ON condition received from the DCE indicates to the DTE that a ringing signal is being received on the communications channel, from the distant DCE. ON and OFF conditions correspond to the ring and no-ring signals.

RECEIVED LINE SIGNAL DETECTOR

The ON condition on this circuit indicates that the DCE is receiving a signal suitable for demodulation. Criteria for suitability are established by the DCE manufacturer.

SIGNAL QUALITY DETECTOR

An ON condition received from DCE indicates to the DTE that there is no reason to believe that an error has occurred. The OFF condition indicates that there is a high probability of error. This signal may be used to call for automatic retransmission of a previously transmitted signal.

DATA SIGNAL RATE SELECTOR

Signals on this circuit originate at the DTE or DCE to select one of two signalling rates available in a dual rate synchronous DCE, or one of two ranges available in a dual range asynchronous DCE. The ON condition selects the higher rate or range. One circuit is available for this function. The signal source may be either in the DTE or the DCE.

2.1.3.4 Timing Signals - Three circuits provide for timing information flow between DTE and DCE.

TRANSMITTER SIGNAL ELEMENT TIMING

Two circuits provide timing signals, originating either from the DCE or the DTE, indicating signal element center, (DTE source) or signal element transitions (DCE source) on the TRANSMITTED DATA circuit. Only one of these circuits is employed in any particular implementation.

RECEIVER SIGNAL ELEMENT TIMING (DCE SOURCE)

Signals on this circuit provide received signal element timing information from the DCE to the DTE. The ON to OFF transition on this circuit nominally indicates the center of each signal element on the circuit RECEIVED DATA.

2.1.4 Secondary Channel Operation

If a secondary channel is available the following circuits are used: SECONDARY TRANSMITTED DATA, SECONDARY RECEIVED DATA, SECONDARY REQUEST TO SEND, SECONDARY CLEAR TO SEND, SECONDARY RECEIVED LINES SIGNAL DETECTOR.

These circuits function similarly to the primary circuits described above, and permit a secondary channel capability for low speed supervisory communications.

2.1.5 Standard Interfaces for Selected System Configurations.

For various modes of operation a total of 14 interface types have been established in RS-232-C. Figures 2-4, and 2-5 summarize these configurations.

The standard provides that driver circuits must be provided for every interchange circuit included in the standard interface. Terminating circuits are not required for all interchange circuits, but the equipment designer is tagged with responsibility for possible degradation of service. Additional interchange circuits may be included in multipurpose equipment, but dummy loads for unused circuits must be provided, and open circuits must be considered on the terminating end for special circuits not in the standard.

2.2 DTE - ACE Interface [EIA RS-366]

This interface is also defined in terms of the electrical and mechanical interface characteristics, as well as by functional descriptions of the interface circuits. Furthermore four specific interface configurations are defined for four classes of automatic calling equipment, which are characterized by the division of labor between the DTE and the ACE. These interfaces are summarized in figure 2-6.

2.2.1 Electrical Interface Characteristics.

The electrical characteristics prescribed by RS-366 conform to the DTE-Modem interface standard RS-232-C.

2.2.2 Mechanical Interface Characteristics.

The mechanical characteristics specified by RS-366 are similar to those in the DTE-Modem standard RS-232-C. A 25 pin connector is used. Ten circuits are unassigned. Seven circuits are used for control, and four circuits are used to transmit binary digits equivalent to the call numbers.

2.2.3 Functional Description of Interchange Control Circuits.

2.2.3.1 Control Circuits - The following control circuits are provided:

CALL REQUEST

Signals on this circuit are generated by the DTE to request the ACE to originate a call. The ON condition indicates a request to originate a call. This condition must be maintained until the CALL ORIGINATION CIRCUIT is turned on.

Interchange Circuit		Interface Type													
		A	B	C	D	E	F	G	H	I	J	K	L	M	Z
AA	Protective Ground	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AB	Signal Ground	x	x	x	x	x	x	x	x	x	x	x	x	x	x
BA	Transmitted Data	x	x		x	x	x		x		x		x	x	o
BB	Received Data			x	x	x		x		x		x	x	x	o
CA	Request to Send		x		x		x				x		x		o
CB	Clear to Send	x	x		x	x	x		x		x		x	x	o
CC	Data Set Ready	x	x	x	x	x	x	x	x	x	x	x	x	x	o
CD	Data Terminal Ready	s	s	s	s	s	s	s	s	s	s	s	s	s	o
CE	Ring Indicator	s	s	s	s	s	s	s	s	s	s	s	s	s	o
CF	Received Line Signal Detector			x	x	x		x		x		x	x	x	o
CG	Signal Quality Detector														o
CH/CI	Data Signalling Rate Selector (DTE) /(DCE)														o
DA/DB	Transmitter Sig. Element Timing (DTE) /(DCE)	t	t		t	t	t		t		t	t	t	t	o
DD	Receiver Signal Element Timing (DCE)			t	t	t		t		t		t	t	t	o
SBA	Secondary Transmitted Data							x		x	x	x	x	x	o
SBB	Secondary Received Data						x		x		x	x	x	x	o
SCA	Secondary Request to Send							x			x	x	x		o
SCB	Secondary Clear to Send							x		x	x	x	x	x	o
SCF	Secondary Received Line Signal Detector						x		x		x	x	x	x	o

Legend: o - To be specified by the supplier
— - optional
s - Additional Interchange Circuits required for Switched Service
t - Additional Interchange Circuits required for Synchronous Channel
x - Basic Interchange Circuits, All Systems

Figure 2-4. Standard Interface Types [RS-232-C]

Data Transmission Configuration	Interface Type
Transmit Only	A
Transmit Only*	B
Receive Only	C
Half Duplex	D
Duplex*	D
Duplex	E
Primary Channel Transmit Only * / Secondary Channel Receive Only	F
Primary Channel Transmit Only / Secondary Channel Receive Only	H
Primary Channel Receive Only / Secondary Channel Transmit Only*	G
Primary Channel Receive Only / Secondary Channel Transmit Only	I
Primary Channel Transmit Only* / Half Duplex Secondary Channel	J
Primary Channel Receive Only / Half Duplex Secondary Channel	K
Half Duplex Primary Channel / Half Duplex Secondary Channel	L
Duplex Primary Channel* / Duplex Secondary Channel*	L
Duplex Primary Channel / Duplex Secondary Channel	M
Special (Circuits specified by Supplier)	Z

Note: Data Transmission Configurations identified with an asterisk (*) indicate the inclusion of Circuit CA (Request to Send) in a One Way Only (Transmit) or Duplex Configuration where it might ordinarily not be expected, but where it might be used to indicate a non-transmit mode to the data communication equipment to permit it to remove a line signal or to send synchronizing or timing signals as required.

Figure 2-5. Interface Types for Data Transmission Configurations [RS 232-C]

	DATA TERMINAL EQUIPMENT	DATA COMMUNICATIONS EQUIPMENT
Type I	CALL request	ACE store one or more complete numbers, select in sequence plus modem
Type II	Select numbers stored in ACE by single digit control	ACE store one or more complete numbers, select by DTE establish call(s) plus modem
Type III	Store numbers pass to ACE	ACE receive numbers from DTE establish call(s) plus modem
Type IV	Call request or select numbers stored in ACE by single digit control	Combination ACE and modem in one unit. DTE-ACE interface, type I or II separate cable DTE-modem interface, separate cable
Type V	multiline ACE, to be defined	

Figure 2-6. Standard Automatic Call Equipment Interfaces [RS-366]

POWER INDICATION

Signals on this circuit are generated by the ACE. The ON condition indicates that power is available in the ACE.

DATA LINE OCCUPIED

Signals on this line are generated by the ACE. The ON condition shows that the communications channel is used for automatic calling, data communication, voice communication or for testing.

CALL ORIGINATION STATUS

The ON condition on this circuit, which is generated by the ACE during call origination, shows that control has been transferred from the CALL REQUEST circuit in the ACE, to DATA TERMINAL READY in the associated DTE-modem interface.

ABANDON CALL AND RETRY

These signals are generated by the ACE and indicate to the DTE that the probability of a successful call is low, and provides a suggestion to the DTE, to abandon the call and retry at a later time. The OFF condition indicates that probability of call completion is high.

PRESENT NEXT DIGIT (PND) AND DIGIT PRESENT (DPR)

Signals are generated by the ACE and the DTE respectively, to control the presentation of digit representations on the four digit signal circuits. An ON condition on PND indicates that the ACE is ready to accept the next digit. The OFF to ON transition on DPR indicates that the DTE has completed the next digit representation.

2.2.3.2 Data Signals - Four data signal circuits provide indications of the low order, second order, third order and high order bits of the encoded called number. Parallel binary signals are generated by the DTE. Information presented on these circuits may either be transmitted, i.e. representing digits of the called number, or used locally as control signal. The sixteen possible codes represent the digits 0 to 9, the asterisk, the pound sign, and an end of number code (EON). This code is sent by the DTE to the ACE, and receipt of this code transfers the data channel to the modem, without waiting for an answer signal from the called modem.

2.3 Signal Quality at the Interface Between DTE and DCE

In order to provide reliable communications across the interface certain minimum standards of signal quality must be maintained.

Standardization in this area is concerned with specification of distortion of the signal as well as with test methods to measure the distortion. Separate documents deal with synchronous DCE and start-stop (non-synchronous) DCE interfaces.

2.3.1 Synchronous DCE Interface (RS-334)

Data and timing signals may be measured either at the transmitting terminal or at the receiving terminal of either the DTE or the DCE. Distortion of timing signals, data signals, and of the relationship between timing and data signals is specified. This is summarized in figure 2-7. Characteristics measured for timing signals are the degree of peak individual distortion, the duty cycle and the frequency deviation. For data signals the degree of isochronous distortion is specified. The relationship between timing and data signals is characterized by the ON-OFF or the OFF-ON timing signal transitions as they relate to data signal transitions.

2.3.2 Non Synchronous DCE Interface

Two standards are of concern here [RS-363 and RS-404]. While the standard for the synchronous interface lists quality criteria, specific quantities and tolerances which must be observed, neither of the non-synchronous standards prescribe quantities to be measured. Document RS-363 is arranged as a guide to define signal quality from the transmitting DTE and acceptable to the receiving DTE. Standard statements are provided into which agreed upon limits may be inserted. A standard work sheet is included to assist in preparation of a system specification.

Two system characteristics should be stated: the Modulation Rate (nominal modulation rate) and the Start-Stop character interval (nominal character interval).

2.3.2.1 Signal Quality from the Transmitting DTE - This is characterized by distortion and character interval characteristics.

(a) Distortion - Three types are considered here: the degree of synchronous start-stop distortion (in per cent), the degree of gross start-stop distortion, (in per cent), and the signal element duration.

(b) Character Interval - In continuous start-stop operation transmitted data signals may have a minimum average character interval which is shorter than the nominal character interval, and an occasional character having a minimum character interval. The following characteristics are therefore to be specified:

Minimum average character interval, measured between successive start transitions, averaged over a specified number of characters,

	INTERFACE AT TRANSMITTER		INTERFACE AT RECEIVER
TIMING SIGNALS	DTE or DCE source Degree of Peak Individual Distortion (per cent) Duty cycle (per cent) Frequency Deviation (per cent)		DCE source Degree of Peak Individual Distortion (per cent) Duty Cycle (per cent)
DATA SIGNALS	Not significant for timing not specified Significant for timing Degree of Isochronous distortion		Degree of Isochronous Distortion
RELATIONSHIP BETWEEN TIMING AND DATA SIGNALS	Timing source		Timing source DCE
	DTE	DCE	
	ON-OFF timing to any data signal transition	OFF-ON timing to any data signal transition	ON-OFF transition of received timing signal to any transition on received data circuit

Figure 2-7. Signal Quality Criteria, Synchronous DCE Interface [RS-334]

Minimum character interval,

Signal continuity, specified in break length as per cent of unit interval.

Contact bounce.

2.3.2.2 Signal Quality Acceptable to the Receiving DTE - Signal Quality acceptable to the receiving DTE is characterized by the receiving margin, the character interval and a minimum duration start element.

(a) Receiving Margin - In a start-stop system, this is expressed as the degree of start-stop distortion not exceeding a certain stated percentage (the net margin) provided that no signal element has a duration of less than a specified percentage of the unit interval.

In synchronous operation, modulation rate within specified percentage limits of nominal rate, rate of change of modulation rate, degree of isochronous distortion, and minimum signal element duration are specified.

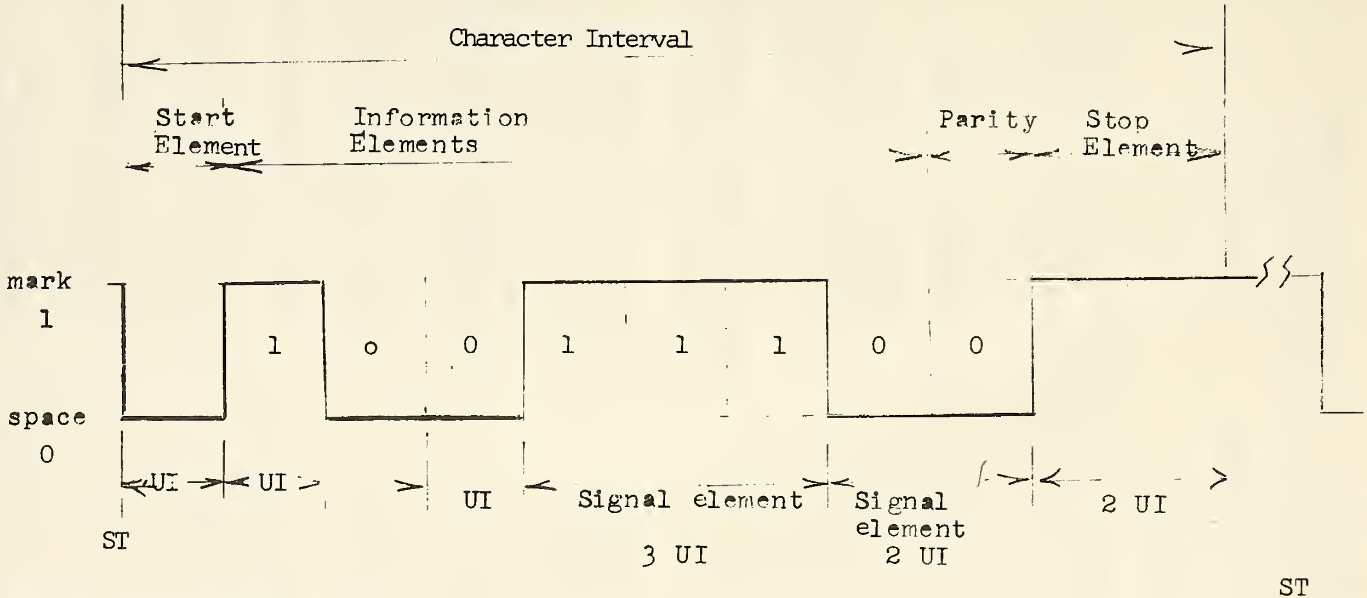
(b) Character interval - In continuous start-stop operation, the minimum average character interval, the minimum character interval, and the minimum duration start element are specified.

Also specified are measurements of interface driver and interface terminator characteristics.

2.3.2.3 Signal Nomenclature - Character format for start-stop operation is precisely defined. Figure 2-8 shows an ideal signal, representing the number "9" in the USA Standard Code for Information Interchange. It has even parity, a one unit start element, and a two unit stop element. The code is transmitted with the low order bit first and is followed by the parity bit.

2.3.2.4 Performance Categories - In addition to the performance criteria listed in RS-363 and described on the previous pages, a later standard published in 1973 [RS-404] specifies a number of different sets of performance requirements based on practical realities of different operating conditions leading to differing ways of implementing equipment. A number of performance categories are therefore defined for transmitting and receiving DTE's. It is intended that any receiving category may be specified with any transmitting category. The actual selection depends on such factors as channel error rate acceptable, and economic considerations of the system.

Five categories are defined for transmitting DTE: Three categories of these cover DTE with electronic timing signal generation, while two cover equipment deriving signal timing from the power line frequency.



Note: Start transition ST
Unit interval UI

Figure 2-8. Start-Stop Signal Nomenclature

Similarly five categories are defined for receiving DTE. Again three of these cover equipment with all-electronic timing signal generation, while two cover power line frequency timing.

Worst case bounds are shown for the criteria listed above, for the various categories.

2.4 Standard Signalling Rates

Industry and Government have standardized signalling rates [RS-269-A, X3.1, FIPS PUB 22] for use on nominal 4 KHz voice bandwidth circuits. These rates are based on data equipment manufacturers and communications supplier preferences.

The standard signalling rates are specified as 600 times N bits per second, where N may be any positive integer from 1 through 16.

Preferred standard signalling rates are 600, 1200, 2400, 4800, 7200 and 9600 bits per second. In order to accomodate established practice an interim standard rate of 2000 bits per second is also recognized in RS-269-A, and ANSI X 3.1 . FIPS 22 specifically excludes 2000 bits per second as standard rate.

For applications requiring synchronous operation below 600 bits per second, standard rates have been established at 75, 150, and 300 bits per second.

Standard parallel signalling rates for equipments designed with up to eight parallel data bits per character are 75 times N character per second, where N may be any positive integer from 1 through 16.

Where error control or similar devices, which change the signalling rates by a fixed ratio are inserted between the DTE and DCE equipments, the 600 x N standard rates apply at the communications side of the interface between error control and DCE.

The Department of Defense has standardized signalling rates for both voice circuits and wide band circuits.

For nominal 3 kHz and nominal 4 kHz channels the following rates apply, according to MIL-STD-188-100:

(a) 25×2^{-m} Bds or b/s

(b) 50.0 Bds or b/s

(c) 75×2^{m} Bds or b/s, up to and including 9600 Bds or b/s, where m is a positive integer 0, 1, 2, ... 7.

Above 9600 Bds or b/s the modulation rates (expressed in Bds) and the data signaling rates (expressed in b/s) are based on 8000 x N as follows:

Standard Rates	Recognized Rates Based on Current Inventory
16 kBds or kb/s	50 kBds or kb/s*
32 kBds or kb/s	288 kBds or kb/s
48 kBds or kb/s**	576 kBds or kb/s
56 kBds or kb/s	1152 kBds or kb/s
64 kBds or kb/s	1536 kBds or kb/s
1344 kBds or kb/s	2048 kBds or kb/s
1544 kBds or kb/s	2304 kBds or kb/s
6312 kBds or kb/s***	
6336 kBds or kb/s***	

*This rate is not based on 8000 x N.

**48 kBds or kb/s is an internationally preferred rate for information over 48 kHz group bandwidth channels. It is also recognized as a current military rate for TDM/PCM transmission.

***The selection of this rate will depend on CCITT recommendations.

2.5 Military Subsystem Interface Standards [MIL-STD-188-347]

Military systems are subdivided according to figure 2-9. The introduction of security transmitting and receiving equipment adds another level of complexity compared to the commercial interface standards. Terminals or data end instruments connect with the digital communications system at the EI (End Instrument) interface. Digital communications control equipment connect with the data transmission channel at the DCCE (Digital Communication Control Equipment) interface.

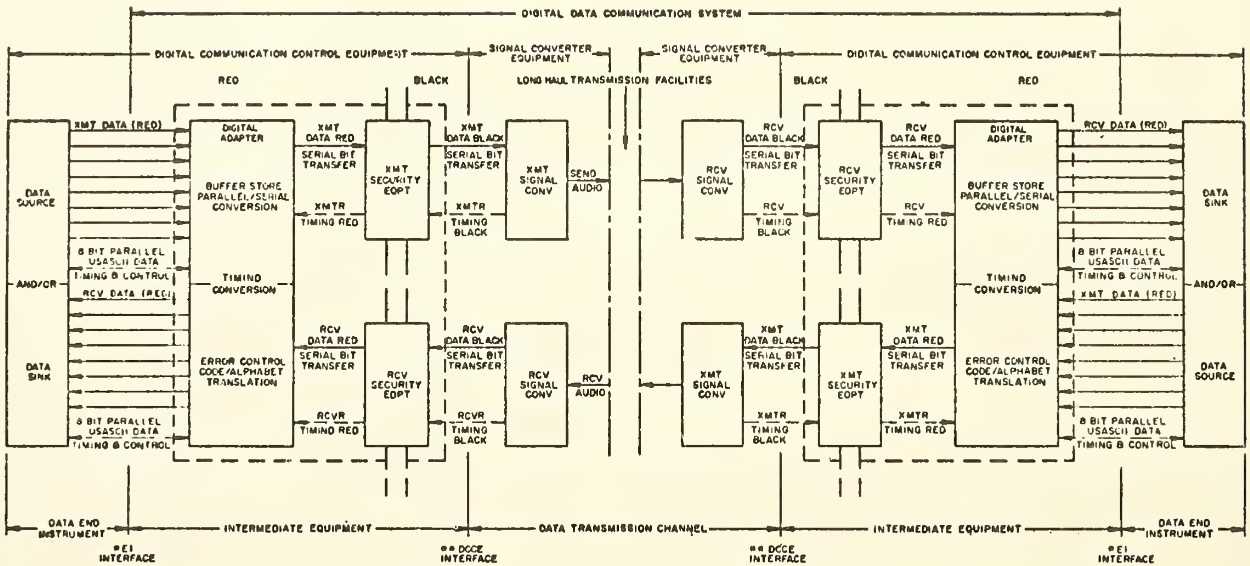
2.5.1 Digital End Instrument Interface.

The low level interface as described in MIL-STD-188-100 is the standard method of station equipment interfacing. Signals may be serial (bit sequential), or parallel, (character or word sequential).

The low level MIL-188 interface differs from the EIA RS-232 interface in several respects:

(a) Data and clock signal polarities are of opposite polarities.

(b) Long signal rise and fall times are specified, i.e. rounded wave shapes. Square waves [RS 232-C] contain higher harmonics, which



* EI END INSTRUMENT (DATA SOURCE AND/OR DATA SINK)

** DCCE DIGITAL COMMUNICATION CONTROL EQUIPMENT (EQUIPMENT COMPRISING THE INTERMEDIATE EQUIPMENT AND THE DATA END INSTRUMENT)

Figure 2-9, Typical Digital Communication Control Equipment Interfaces. [MIL STD 188-347] makes lines more susceptible to inductive tapping.

(c) Low impedance sources permit numerous devices to receive from a given transmitter.

(d) No specific mechanical or electrical connector characteristics are mentioned.

2.6 Conclusions

Standardization of the DTE - DCE interface is of importance to the development of reliable, efficient and cost-effective computer-communications systems. Despite the fact that standards have been developed, both in the commercial sector and by the military, many problems still remain. Considering the electrical interface, differences exist between military and commercial standards. MIL-188-C specifies the mark condition as a positive voltage swing, while RS-232-C defines the mark condition as a negative interchange voltage. For many applications MIL-188-C is superior; as an example RS-232-C will not operate over more than 50 feet of cable between DTE and DCE, as a result of the high driver impedance. Also the high impedance of both driver and receiver makes the circuit susceptible to pick-up of extraneous signals. The high voltages generate cross-talk in adjacent circuits, make shielding difficult, and create possible security problems. For these reasons RS-232-C has not been adopted by the American National Standards Institute.

The existence of standard interface specifications does not insure plug-to-plug interoperability of devices in all cases. Products of many data communications and computer peripheral manufacturers require specially engineered interfaces. Often interface requirements vary from manufacturer to manufacturer, and they vary often within one product line. EIA standards were originally designed around the Bell System 103 data set. Today this modem represents only a small part of the total interface equipment universe. Expanding requirements have added additional functions beyond those specified in the standards. Careful analysis of requirements in each individual DCE application is required, applicability of existing standards must be determined, and the additional requirements must be determined and interface engineering efforts are required to provide needed capabilities.

2.7 Standards

1. ANSI X 3.1-1969
Synchronous Signaling Rates for Data Transmission
August 1969
American National Standards Institute
Same as FIPS 22

2. ANSI X 3.24-1968
Signal Quality at Interface Between Data Processing Terminal Equipment and Synchronous Data Communication Equipment for Serial Data Transmission
September 1968
Same as EIA RS-334

3. EIA RS-232-C
Interface Between Data Terminal Equipment and Data Communication Equipment Employing Serial Binary Data Interchange
August 1969
Electronic Industries Association

4. EIA RS-269-A
Synchronous Signaling Rates for Data Transmission
February 1969
Electronic Industries Association

5. EIA RS-334
Signal Quality at Interface Between Data Processing Terminal Equipment and Synchronous Data Communication Equipment for Serial Data Transmission
March 1967
Electronic Industries Association

6. EIA RS-363
Standard for Specifying Signal Quality for Transmissing and Receiving Data Processing Terminal Equipments Using Serial Data Transmission at the Interface with Non-Synchronous Data Communication Equipment
May 1969
Electronic Industries Association

7. EIA RS-366
Interface Between Data Terminal Equipment and Automatic Calling Equipment for Data Communication
August 1969
Electronic Industries Association

8. EIA RS-404
Standard for Start-Stop Signal Quality Between Data Terminal Equipment and Non-Synchronous Data Communication Equipment
March 1973
Electronic Industries Association

9. FIPS 22
Synchronous Signaling Rates Between Data Terminal and Data Communication Equipment
1972 November 1
U. S. Department of Commerce
National Bureau of Standards

10. ISO 2110-1972(E)
Data Communication-Data Terminal and Data Communication Equipment - Interchange Circuits-Assignment of Connector Pin Numbers
First Edition - 1972-02-15
International Organization for Standardization

11. MIL-STD-188-C
Military Standard, Military Communication System Technical Standards, November 1969, Department of Defense, Washington, D. C. 20301

12. MIL-STD-188-100, Military Standard, Common Long Haul and Tactical Communication System Technical Standards, November 1972, Department of Defense, Washington, D. C. 20301

13. MIL-STD-188-347, Military Standard, Standards for Long Haul Communications, Equipment Technical Design Standards for Digital and Instruments and Ancillary Devices

3. USER TERMINAL STANDARDS

3.1 International Standards for Character Codes

The definition of a standard character set is basic to all standards dealing with communications using typewriter-like terminals. The development of an international standard in this area was an important achievement. (For a history of this development, see [3-1].) The international standard for character sets is ISO R646-1967. It is a 7-bit code which has become the basis for a family of related international standards. CCITT V.3 (Working Alphabet No. 5) is entirely consistent with ISO R646. ISO R646 is currently being considered for revision, but these revisions are not likely to involve major changes to the 7-bit coded character set.

3.2 National Standards for Character Codes

ISO R646 is the basis for the related U. S. standard for character sets, ANSI X3.4 which is known as the American Standard Code for Information Interchange (ASCII). ISO R646 and ASCII are compatible, i.e., they do not differ in the assignment of those characters which are mandatory under R646. However, R646 reserves some positions in the code table for national use, i.e., the character assigned to that bit pattern may differ in the codes of each nation. For the U. S., X3.4 makes a standard assignment to these national use positions. ASCII has undergone several revisions, the major ones are known as ASCII-63, ASCII-67, and the current version, ASCII-68. ASCII is currently under revision, the major changes proposed deal with the meanings of certain control characters; the implications will be discussed later.

On 1968 March 11, the President of the United States approved X3.4-1967 as the first Federal Information Processing Standard (FIPS-1). The Federal version of ASCII differs slightly from the current ANSI version X3.4-1968) in the interpretation of the LF character; this will be covered later. MIL-STD-188-100 (1972 November 15) prescribes the use of FIPS-1 in military systems.

The standards relating to the 7-bit character code are given in Table 3-1.

3.3 Implementation of the 7-bit code

3.3.1 Representation on physical media

Table 3-2 gives the standards defining the representation of the 7-bit character code on various physical media.

The perforated tape standard calls for eight tracks, seven of which are used to record the 7-bit character and the eighth to record an even parity bit.

The 9-track magnetic tape standard calls for seven of the tracks to record the 7-bit character, one track to record zero (reserved for use in an eight bit environment) and one track for odd parity.

The Hollerith punched card standards deal with 12-row standard punched cards. Of the 4096 possible combinations of punches possible in a column, only 256 (128 in the 7-bit standard) combinations are used to represent an 8-bit code.

3.3.2 Representation during data transmission

The standards which apply to the 7-bit code in data communications contexts are given in table 3-3.

In serial-by-bit communications as prescribed by ANSI X3.15 and FIPS PUB 16 the bit sequencing is low order bit first. The character structure for serial communications is specified by ANSI X3.16 and FIPS PUB 17. For synchronous communication the character structure consists of eight bits, the seven bits of the character and an odd parity bit. For asychronous communication the character structure consists of ten elements, a start element, followed by the seven bits of the character, followed by an even parity bit and ending with a stop element of the opposite sense as the start element.

In parallel-by-bit communication the character structure, specified by ANSI X3.25 and FIPS PUB 18, consists of eight channels, one for each bit of the 7-bit character and one parity bit. If there is a separate timing channel, the parity sense should be even, otherwise it should be odd.

	Current	Proposed Revision
ISO	ISO R646	
CCITT	V.3	
ANSI	X3.4- (ASCII)	X3L2/1355
Federal	FIPS-1	
Military	MIL-STD-188-100	
ECMA	6	

Table 3-1. Standards for character codes.

	Perforated Tape	9-Track Magnetic Tape	Hollerith Punched Cards 7-bit	8-bit
ISO	ISO/R1113	ISO/R962	ISO/R1679	R2021
ANSI	X3.6	X3.22		X3.26
Federal	FIPS-2	FIPS-3	FIPS-14	
Military	- - -	all in MIL-STD-188-100 - - -		
ECMA	10	12	20	25

Table 3-2. Standards for
representation of characters on physical media.

	Serial-by-bit Bit sequence	Character structure and parity	Parallel-by-bit Character structure and parity
ISO		ISO/R1177	
CCITT	V.4	V.4	
ANSI	X3.15	X3.16	X3.25
Federal	FIPS-16	FIPS-17	FIPS-18
Military	- - -	all in MIL-STD-188-100 - - -	

Table 3-3. Standards for
representation of characters during data transmission.

3.4 Structure of the 7-bit Code

For definitional purposes, the ASCII code is presented in a tabular form with 16 rows and 8 columns, as shown in figure 3-1. --Note: The position of a character in the code table is given by the notation 'column/row'. -- By definition, the characters in the code table are partitioned into several subsets:

1) a set of 32 control characters allocated to columsn 0 and 1;
2) the space character (SP) in position 2/0 (may be regarded as a control character or a non-printing graphic character);

3) a set of 94 graphic characters allocated to columns 2 through 7;
4) the delete character (DEL) in position 7/15.

The structure of the table as shown in figure 3-2 will be the basis of a later discussion on code expansion and extension.

3.4.2 Control Characters

A control character is defined as a character whose occurrence in a particular context initiates, modifies, or stops an action that affect the recording, processing, transmission or interpretation of data. The 32 ASCII control characters have been classified into communication controls, information separators, format effectors, device controls, code extension controls and other controls.

3.4.2.1 Communication controls - The ten communication controls are SOH, STX, ETX, EOT, ENQ, ACK, DLE, NAK, SYN, ETB. Their use is intended to control or facilitate transmission of information over communication links. Standards relating to their use will be discussed in the following chapter.

3.4.2.2 Information separators - The information separators are File Separator (FS), Group Separator (GS), Record Separator (RS), and Unit Separator (US). (The SP character may also be considered an information separator and it has been placed in the code table such that all five characters are contiguous.) These characters form a hierarchy and are used to separate and qualify information in a logical sense.

3.4.2.3 Format effectors - The format effectors are BS, HT, LF, VT, FF, CR. These characters control the layout or positioning of information in printing or display devices. They can be further classified into horizontal format effectors BS, HT, CR and vertical format effectors LF, VT, FF. Each of the format effectors will be discussed in detail as they are often a source of problems in information interchange and terminal compatibility. Also, the meaning of some of these characters may undergo a change under the proposed revisions to ASCII. (The quoted material that follows is from X3.4-1968.)

(a) Backspace (BS) - The backspace character "...controls the movement of the printing position one printing space backward on the same printing line. (Applicable also to display devices.)"

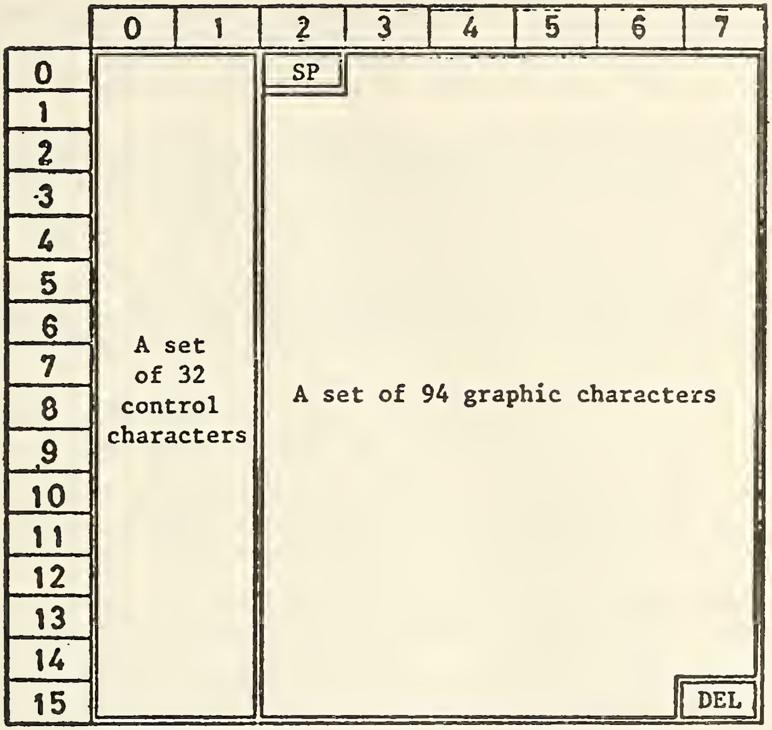
The definition is stated in terms of printing devices and overprinting is thus implied. The relevant international standard (ISO R646) is more direct in its specification that overprinting must occur for the printing of diacritical signs:

"In the 7 bit character set, some printing symbols may be designed to permit their use for the composition of accented letters when necessary for general interchange of information. A sequence of

Bits b_7 b_6 b_5 →					0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
b_4 ↓	b_3 ↓	b_2 ↓	b_1 ↓	COLUMN → ROW ↓	0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	DLE	SP	0	@	P	`	p
0	0	0	1	1	SOH	DC1	!	1	A	Q	a	q
0	0	1	0	2	STX	DC2	"	2	B	R	b	r
0	0	1	1	3	ETX	DC3	#	3	C	S	c	s
0	1	0	0	4	EOT	DC4	$	4	D	T	d	t
0	1	0	1	5	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	6	ACK	SYN	&	6	F	V	f	v
0	1	1	1	7	BEL	ETB	'	7	G	W	g	w
1	0	0	0	8	BS	CAN	(	8	H	X	h	x
1	0	0	1	9	HT	EM	)	9	I	Y	i	y
1	0	1	0	10	LF	SUB	*	:	J	Z	j	z
1	0	1	1	11	VT	ESC	+	;	K	[	k	{
1	1	0	0	12	FF	FS	,	<	L	\	l	¦
1	1	0	1	13	CR	GS	–	=	M	]	m	}
1	1	1	0	14	SO	RS	.	>	N	^	n	~
1	1	1	1	15	SI	US	/	?	O	_	o	DEL

Source: ANSI X3.4-1968

Figure 3-1. ASCII Code Table



Source: ISO 2022-1973

Figure 3-2. Structure of the 7-bit Code Table.

three characters, comprising a letter, 'backspace' and one of these symbols, is needed for this composition, and the symbol is then regarded as a diacritical sign."

The correct interpretation of the BS character may be difficult on non-serial (line-at-a-time) printers. There is also a trend by designers of CRT terminals to use the BS character to perform the editing function 'delete previous character'. This interpretation of 'move the printing position one printing space backward and erase the character in that position' is not in accordance with the ANSI X3.4 standard. [3-2].

(b) Horizontal Tabulation (HT) - The HT character "...controls the movement of the printing position to the next in a series of predetermined positions along the [same] printing line. (Applicable also to display devices and the skip function on punched cards.)"

Note that ASCII does not include any means of setting or clearing the tabulation stops. In some terminal equipment, tab setting and clearing has been implemented by means of 'private escape sequences' (see paragraph 3.6.3.3(c)).

The use of the HT character can result in significant savings in transmission and printing time but can pose an interchange problem.

(c) Carriage Return (CR) - This character "...controls the movement of the printing position to the first printing position on the same printing line. Applicable also to display devices.)"

The CR character should not cause the printing position to be moved to the next line. This is contrary to the action of a normal typewriter carriage (or carrier) return. In an attempt to avoid confusion, the committee responsible for maintenance of the ASCII standard is considering a name (and mnemonic) change to Horizontal Return (HR) or simply Return (RT). One of these two names is likely to be used in the next version of ASCII.

(d) Line Feed (LF) - "A format effector which controls the movement of the printing position to the next printing line."

Note that the printing position on the next line is left unspecified. In most cases, the implementation is such that the horizontal position is not affected. However, the ASCII definition continues:

> "Where appropriate, this character may have the meaning 'New Line' (NL), a format effector which controls the movement of the printing point to the first printing position on the next printing line. Use of this convention requires agreement between sender and recipient of data."

The Federal standard specifically omits that portion of X3.4 which defines the New Line option.

The proposed ASCII revision changes the principal control function of position 0/10 to New Line (NL) and Line Feed (LF) is assigned the secondary function. This was done in response to the trend towards a single control character to perform the new line function.

(e) Vertical Tabulation (VT) - "A format effector which controls the movement of the printing position to the next in a series of predetermined printing lines."

Note that, as with BS, the setting and clearing of vertical tabulation stops is not defined in ASCII. Some terminals use escape sequences to implement these functions.

The present standard does not dictate any horizontal movement when executing a VT function. However, the proposed revision defines VT similar to NL; i.e., the active position is advanced to the first character position on the next predetermined line. Again similar to NL, the (current) definition in which horizontal motion is undefined is made a secondary control function under the proposed changes, contingent upon agreement between the interchanging parties.

(f) Form Feed (FF) - "A format effector which controls the movement of the printing position to the first predetermined printing line on the next form or page."

Again, in the current standard, horizontal motion is left unspecified. The proposed revision specifies movement to the first character position of a predetermined line of the next form or page.

3.4.2.4 Use of the format effectors - The possible horizontal movement resulting from the vertical effectors LF, VT and FF is left undefined in the present ASCII standard. In the case of LF, X3.4-1968 allows the option of implementing the 'New Line' function with the horizontal position moved to the first print position. The related Federal standard does not allow this option. In the proposed revisions to ASCII, the vertical format effectors all move the print position to the first position on a line in addition to the vertical movement. The LF character is replaced by the NL character in the proposed revision.

One of the functions of terminal control software (or terminal drivers) is to map 'canonical' character strings into strings of characters to which the terminal is able to properly react. For example, some simple terminals (e.g., the Teletype Model 33) do not implement the format effectors BS, HT, VT and FF. In order to preserve the proper layout of information, the terminal driver must map these characters into the format effectors which the terminal does implement properly, i.e., CR, LF and SP. This mapping requires that the terminal driver maintain context information such as 'position in line' and 'position in page'. If tab stops are to be simulated by the driver software, additional tables must be maintained. All of the format effectors can be simulated if some minimum subset of them is implemented in the terminal. Two popular subsets are the aforementioned Model 33 Teletype subset, [CR, LF, SP], and the typewriter subset, [BS, NL, SP].

Additionally, a terminal driver must cater to the timing idiosyncrasies of a terminal. Usually this involves sending 'pad' characters to the terminal after a format effector which causes mechanical motion has been sent. For example, on terminals where CR produces mechanical motion a number of pad characters must be sent to allow for the travel time of the carriage. In general, for a given terminal, the minimum number of pad characters required depends on the amount of travel, i.e., the length of the previous line, and the character rate. The calculation of the optimal number of pad characters can involve a significant amount of processing in the terminal driver.

3.4.2.5 Device Controls - The device controls are DC1, DC2, DC3, and DC4. They are intended for control of ancillary devices which may be associated with the data processing or telecommunications systems, in particular, to switch such devices "on" or "off". If only a single control is needed to turn off or "stop" a device, DC4 is the preferred assignment.

The device controls have been used in keyboard terminals to control a paper tape reader and punch with the following assignment:

DC1 - (X-ON) 'Reader On'
DC2 - (TAPE) 'Punch On'
DC3 - (X-OFF) 'Reader Off'
DC4 - ($\overline{\text{TAPE}}$) 'Punch Off'

These assignments have become a de facto standard for terminals with attached paper tape readers and punches or cassette tapes.

3.4.2.6 Code Extension Controls - The code extension controls are SI, SO, and ESC. The use of these characters will be covered in the section on code extension. (The DLE character is used for code extension for communication control and will be discussed with the other communication controls.)

3.4.2.7 Other Controls - The following control characters do not fall into any of the previous classes: NUL, BEL, CAN, EM, SUB, DEL. (Strictly speaking, DEL is not considered to be a control character.).

(a) Null (NUL) - The NUL character is used to accomplish media-fill or time-fill. It may be inserted into or removed from a character stream without affecting the information content; but it may affect layout or control of equipment.

(b) Bell (BEL) - The BEL character is used to call for attention. It may control alarm or attention devices.

(c) Cancel (CAN) - The CAN character is used to indicate that the data it accompanies is in error. The exact meaning of this character must be defined for each application.

(d) End of Medium (EM) - This control character may be used to indicate the physical end of a medium, or the end of the used, or wanted, portion of data recorded on a medium. The position of this character does not necessarily correspond to the physical end of the medium.

(e) Substitute (SUB) - A character that may be substituted for a character that is determined to be invalid or in error. The exact use of this character is left undefined.

(f) Delete (DEL) - The DEL character was intended to be used to erase or obliterate an erroneous or unwanted character in punched tape by overpunching. In addition, current standards have DEL characters serving the same purpose as NUL character, i.e., media-fill or time-fill.

3.4.2.8 Graphic Representation of the Control Characters - For those cases where a graphical representation of a normally non-printing character is desired, such as in the use of monitoring devices or diagnostic printers or display devices, or in system documentation, a standard set of graphics has been designed. As shown in figure 3-3, there are two alternative sets of representations:

1) a pictorial representation,
2) an alphanumeric representation.

The standards which implement figure 3-3 are given in table 3-4.

ISO	ISO 2047
ANSI	X3.32
Federal	
Military	MIL-STD-188-100
ECMA	17

Table 3-4. Standards for graphical representation of control characters.

3.4.3 The Graphic Characters

A graphic character is a character, other than a control character, that has a visual representation, e.g., that may be printed or displayed. The character standards do not specify a type style for printing or display and allow distinctive styling for specific purposes.

Character	Pictorial Representation	Alphanumeric Representation
NUL		NU
SOH		SH
STX		SX
ETX		EX
EOT		ET
ENQ		EQ
ACK		AK
BEL		BL
BS		BS
HT		HT
LF		LF
VT		VT
FF		FF
CR		CR
SO		SO
SI		SI
DLE		DL
DC1		D1
DC2		D2
DC3		D3
DC4		D4
NAK		NK
SYN		SY
ETB		EB
CAN		CN
EM		EM
SUB		SB
ESC		EC
FS		FS
GS		GS
RS		RS
US		US
SP		SP
DEL		DT

Source: ANSI X3.32-1973

Figure 3-3. Standard Graphical Representation of Control Characters.

3.5 Subsets of the 7-bit Code

If the capabilities of the full 7-bit coded character set are not required, several standards exist for subsetting the 7-bit code. Both 6-bit and 4-bit subsets have often been used. The standards that exist for the purpose of defining subsets or defining the subsetting process are given in table 3-5.

ISO	ISO 646, ISO/R 963
ANSI	
Federal	FIPS-15
Military	MIL-STD-188-100
ECMA	14

Table 3-5. Standards that specify subsets of the 7-bit character code.

3.6 Code Extension and Expansion

The present 7-bit ASCII standard provides for 128 positions in the code table and specifies a character for each position. However, it is recognized that some applications may require more than 128 characters or a character not currently in the standard. Efforts have been underway for several years to develop a standard method of meeting these needs by augmenting ASCII [3-3]. This augmentation takes one of two forms: code extension or code expansion.

Remaining in a seven bit environment, use of the control characters ESC, SI and SO allows for <u>extension</u> of the code to additional single control characters or additional sets of control characters and graphic characters.

<u>Expansion</u> to an eight bit environment has also been a subject of standardization efforts. Additional impetus for this effort stems from the widespread use of processing machines which manipulate characters codes as 8-bit bytes and the standardized interchange media which support this mode of operation, such as:

1) the punched card standard which allows 256 code combinations,
2) 9-track magnetic tape supporting 8-bit bytes (plus parity), and
3) transparent text data communication control procedures which support arbitrary bit patterns in units of 8-bits.

An attempt has been made to make code extension and code expansion compatible. When expanding to an 8-bit code table with 256 positions, the leftmost 128 are filled with the 7-bit code table as shown in figure 3-4. Thus, when in an 8-bit environment, characters of the 7-bit code must have a high order bit of zero.

The standards which apply to code extension and expansion are given in table 3-6. Note that nearly all are drafts or proposals.

3.6.1 Definitions

The following definitions will be used in the ensuing discussions of code extension and expansion:

(a) Environment - The characteristic that identifies the number of bits used to represent a character in a data processing or data communications system or in part of such a system.

(b) To announce - To specify what code extension facilities will be used in the data which follows.

(c) To designate - To identify a set of characters that are to be represented, in some cases immediately and in others on the occurrence of a further control function, in a prescribed manner.

(d) To invoke - To cause a designated set of characters to be represented by the prescribed bit combinations whenever those bit combinations occur, until an appropriate code extension function occurs.

(e) To represent - To use a prescribed bit combination with the meaning of a character in a set of characters that has been designated and invoked.

3.6.2 Additional Sets of Characters

To extend the 7-bit character code beyond the 128 characters provided in the standard, additional characters are added in the form of:

1) additional single control characters,
2) additional sets of 32 control characters,
3) additional sets of 94 graphic characters,
4) additional sets of more than 94 graphic characters each represented by more than one byte,
5) an entire code structure requiring different interpretation than the 7-bit standard or 8-bit expanded code.

Excluding options 4) and 5) above from discussion for the present, at any given time there can be invoked:

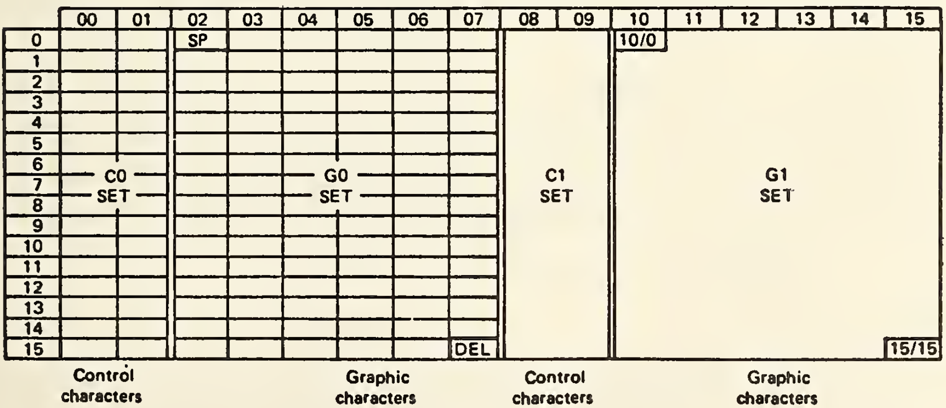
1) two sets of 32 control characters known as the C0 and C1 set;
2) two sets of 94 graphic characters known as the G0 and G1 set;
3) the SP and DEL characters, and if in an 8-bit environment, the characters in positions 10/0 and 15/15;
4) an arbitrary number of additional single controls.

	Extension and Expansion	Escape sequence Registration
ISO	ISO 2022	DIS2375*
ANSI	X3L2/1199* (X3.41 if approved)	X3L2/1100*
Federal		
Military		
ECMA	35	

*draft or proposed

Table 3-6. Standards relating to code extension and expansion.

The remainder of this section will present an explanation of code extension. The material presented is based on ISO 2022, the ANSI version is essentially the same.



Source: ISO 2022-1973

Figure 3-4. 8-bit Code Table.

	X	Y
0	CI	CD
1	PU	CIN
2	PD	CIF
3	PR	SU
4	PL	SD
5		NP
6		PP
7	PM	PFN
8	PH	PFF
9	PT	
10	CSC	
11	CLC	
12	LI	
13	LD	
14	ESO	
15	ESI	

CD - Character Delete
CI - Character Insert
CIF - Character Insert oFf
CIN - Character Insert oN
CLC - Clear Line from Cursor
CSC - Clear Screen from Cursor
ESI - Extended Shift In
ESO - Extended Shift Out
LD - Line Delete
LI - Line Insert
NP - Next Page
PD - Pointer (cursor) Down
PFF - Protect Format oFf
PFN - Protect Format oN
PH - Pointer (cursor) Home
PL - Pointer (cursor) Left
PM - Pointer (cursor) Margin (return)
PP - Previous Page
PR - Pointer (cursor) Right
PT - Pointer (cursor) Tab
PU - Pointer (cursor) Up
SD - Scroll Down
SU - Scroll Up

NOTE:
X, Y are columns 8, 9 when used as the C1 control set in an 8-bit code,
columns 4, 5 when used as the C1 control set in a 7-bit code and are preceded by an ESC character.

Source: ISO 2022

Figure 3-5. A Proposed Set of Extended Control Characters.

Usually, the control set C0 and the graphic set G0 are initialized to the ASCII controls and graphics, respectively. Control set C1 and graphic set G1 may be initialized to some set of controls and graphics by mutual agreement between the parties interchanging information. However, a standard default for C1 and G1 does not, at present, exist. A proposed control set to act as a default for C1 is given in figure 3-5. It contains controls that have been specially designed for CRT displays.

3.6.3 Escape Sequences

Escape sequences provide a standard method of implementing the code extension capabilities. An escape sequence is defined as a sequence of characters starting with an ESC, followed by zero or more 'intermediate' characters, and ending with a 'final' character.

The rules for forming escape sequences are as follows (refer to the ASCII code table in figure 3-1):

1) The control characters in columns 0 and 1, as well as the DEL (7/15) character, are illegal in escape sequences.
2) The characters in column 2 are considered intermediate characters. Any of these 16 characters will be denoted (I).
3) The characters in columns 3 through 7 of the code table, excluding position 7/15, are considered final characters. Any of these 79 characters will be denoted (F). These final characters are further partitioned into the Fp and Ft sets. The Ft set is again partitioned into Fe and Fs sets.
4) In an eight bit environment characters in columns 8 through 15 are not allowed in escape sequences.

Figure 3-6 summarizes the allowable characters in escape sequences.

Escape sequences are used to:

1) announce the code extension facilities used in the data which follows,
2) designate and, in most cases, invoke sets of characters or special code tables,
3) represent individual control characters.

The general scheme for the use of escape sequences is given in table 3-7.

3.6.3.1 Announcement - Escape sequences of the form

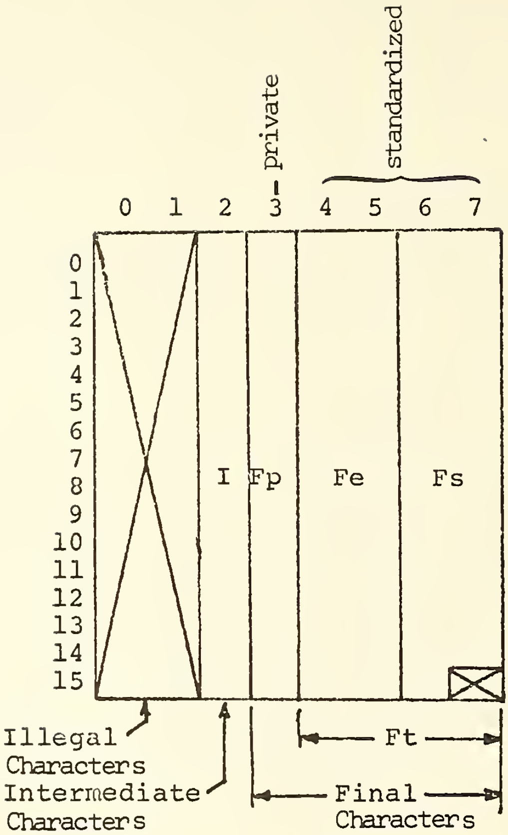
ESC 2/0 (F)

are used to announce what code extension facilities will be used in the data which follows. At the present time only four such sequences are included in the proposed standard:

ESC 2/0 4/1 - data which follows is in 7-bit code with a graphic set G0 only; it may be in a 7-bit or 8-bit environment.

ESC 2/0 4/2 - data which follows is in 7-bit code with graphic sets G0 and G1, graphic sets are invoked by SI, SO respectively; it may be in a 7-bit or 8-bit environment.

ESC 2/0 4/3 - data which follows is in 8-bit code in an 8-bit environment; SI, SO are not used.



Note: Row and Columns are those of the 7-bit ASCII code table. (See figure 3-1)

Figure 3-6. Legal Characters in Escape Sequences.

ESCAPE SEQUENCE		PRIVATE	DESIGNATE	INVOKE	REPRESENT	USE	NUMBER OF POSSIBLE SEQUENCES	
ESC (F)	ESC (Fp)	X			X	single additional controls	16	79
	ESC (Fe)				7	C1 controls	32	
	ESC (Fs)				X	single additional controls	31	
ESC (I) (F)	ESC 2/0 (F)	P				announcers	79	1264
	ESC 2/1 (F)	P	X	X		C0 set	79	
	ESC 2/2 (F)	P	X	X		C1 set	79	
	ESC 2/3 (F)	P			X	single additional controls	79	
	ESC 2/4 (F)	P	X	8		multiple byte G0 set	79	
	ESC 2/5 (F)	P	X	X		specially interpreted code	79	
	ESC 2/6 (F) ESC 2/7 (F)	P				reserved for future standardization	158	
	ESC 2/8 (F) ESC 2/12 (F)	P	X	8		G0 set	158	
	ESC 2/9 (F) ESC 2/13 (F)	P	X	8		G1 set	158	
	ESC 2/10 (F) ESC 2/11 (F) ESC 2/14 (F) ESC 2/15 (F)	P				reserved for future graphics standardization	316	

KEY: X - always
7 - in a 7-bit code only
8 - in an 8-bit code only
P - when (F)=(Fp)

Table 3-7. Use of escape sequences.

ESC 2/0 4/4 - graphic sets G0 and G1 are used as either a 7-bit code when in a 7-bit environment (SI and SO will be used) or an 8-bit code when in an 8-bit environment (SI and SO will not be used).

3.6.3.2 Designation and Invocation - Most of the remaining three character escape sequences of the form

ESC (I) (F)

are used to designate and at the same time (usually) invoke a character set. Invocation, in the case of graphic sets in a 7-bit code, is by use of the SI and SO characters.

A particular escape sequence designates and invokes a particular set of characters. The assignment of escape sequences to character sets is done by means of escape sequence registration. The draft proposed standards which apply were given in table 3-6. Registration of character sets, particularly graphic sets, is taking place within European standardization groups but such activity is considered premature by U. S. standardization groups.

The designation and invocation of each type of character set has a unique form of escape sequence.

(a) C0 control set - Escape sequences of the form

ESC 2/1 (F)

designate and invoke a set of 32 control characters as the C0 set. Of the 79 possible sequences, 16 are private (those ending with Fp) and 63 have standardized meaning.

Since many data transmission, printing, and display devices are code sensitive to the characters in columns 0 and 1, an implementor is warned not to designate and invoke a C0 set with controls not compatible with the communication controls, format effectors, code extension controls, etc.

(b) C1 control set - Escape sequences of the form

ESC 2/2 (F)

designate and invoke a set of 32 control characters as the C1 set. As with the C0 set, there are 16 private sets and 63 standard sets possible.

(c) G0 graphic set - Escape sequences of the forms

ESC 2/8 (F) and
ESC 2/12 (F)

designate a set of 94 graphic characters as the G0 set. There are 32 possible private sequences and 126 possible standardized sequences. In an 8-bit code, designation and invocation occur simultaneously; in a 7-bit code, invocation is effected by the SI character.

(d) G1 graphic set - Escape sequences of the forms
ESC 2/9 (F) and
ESC 2/13 (F)

designate a set of 94 graphic characters as the G1 set. As with the G0 set, there are 32 private sets and 126 standard sets possible. In an 8-bit code, designation and invocation occur simultaneously; in a 7-bit code, invocation is effected by the SO character.

(e) Multiple byte G0 set - Escape sequences of the form

ESC 2/4 (F)

designate a set of graphic characters, containing more than 94 characters, as the G0 set. In an 8-bit code, designation and invocation occur simultaneously; in a 7-bit code, invocation is effected by the SI character. Each character in the multiple byte set will be represented by a sequence of bytes form code table positions 2/1 through 7/14.

(f) Specially interpreted codes - Escape sequences of the form

ESC 2/5 (F)

designate and invoke a code whose characteristics are not compatible with the structure of the standard 7-bit or 8-bit codes and therefore requires special interpretation. The final character in the escape sequence indicates the broad category of the code:

Final in column	Category
3	a private code of any number of bits
4	codes of less than 7 bits
5	7 bit codes
6	8 bit codes
7	codes of greater than 8 bits

An example of an 8-bit code requiring special interpretation is EBCDIC, since the control characters are not in the same columns as the 8-bit expanded standard code.

Entry into the special code occurs immediately after the final character in the escape sequence. A method of returning to the standard code depends on the characteristics of the special code and therefore is left undefined.

3.6.3.3 Representation - All of the two character escape sequences in the form

ESC (F)

and the three character escape sequences of the form

ESC 2/3 (F)

are used to represent control characters. These control characters either lie outside the code table or are in the current C1 set.

(a) Controls in the C1 set - Escape sequences of the form

ESC (Fe)

are used to represent one of the 32 possible control characters in the C1 set when in a 7-bit code. In an eight bit code, the same control characters are represented by code table positions 8/0 through 9/15, and the escape sequence representation should not be used.

(b) Additional standardized single controls - Escape sequences of the forms

ESC (Fs)
ESC 2/3 (Ft)

are used to represent additional control characters which lie outside the code table and whose meaning is standardized. There are 94 possible sequences yielding 94 additional standard controls. Efforts to determine what control functions will be represented by each such sequence are now under way in various standardization groups; however, a standard is not expected in the near future.

(c) Additional private single controls - Escape sequences of the forms

ESC (Fp)
ESC 2/3 (Fp)

are used to represent additional control characters which lie outside the code table and have no standardized meaning, but are intended for private use as required. There are 32 possible sequences yielding 32 control functions.

Although private use escape sequences do not have standardized meanings, de facto conventions have evolved for some of the two character private escape sequences. Implementations of these de facto conventions, shown in table 3-8, exist on many popular terminals.

ESC 3/1	HTS	Horizontal Tab Set
ESC 3/2	HTC	Horizontal Tab Clear
ESC 3/3	HN	Highlight oN (red ribbon)
ESC 3/4	HF	Highlight oFf (black ribbon)
ESC 3/5	VTS	Vertical Tab Set
ESC 3/6	VTC	Vertical Tab Clear
ESC 3/7	RLF	Reverse Line Feed
ESC 3/8	HLR	Half Line Reverse feed
ESC 3/9	HLF	Half Line Forward feed
ESC 3/10	LCF	Local Copy oFf (full duplex)
ESC 3/11	LCN	Local Copy oN (half duplex)

Table 3-8. De facto conventions for two character private escape sequences.

3.6.4 Summary of Code Extension Rules

Table 3-9 summarizes the rules for code extension in a 7-bit code. The resulting code may be used in either a 7-bit or an 8-bit environment. Code extension in an 8-bit code is summarized in table 3-10. An 8-bit environment is required to support an 8-bit code.

3.7 Keyboards

There are a variety of keyboard standards, which have evolved historically from wire telegraphy devices. They have played an important role in military communications and several standards are defined in MIL-STD-1280. Similarly, in the civilian sector there has been standardization activity by the American National Standards Institute and the International Standards Organization.

3.7.1 Military Keyboards

Keyboards are classified according to the type of machine application, and the kind of textual traffic for which an arrangement is best suited. Type I arrangement refers to keyboards that produce an encoded electrical output for control of another device, such as another teletypewriter or a computer. Type II arrangements refer to keyboards that directly control their associated devices, as for instance typewriters. Class 1 refers to arrangements best suited for alphabet oriented traffic, such as inter-office correspondence. Class 2 refers to keyboards best suited for traffic with high content of numerics.

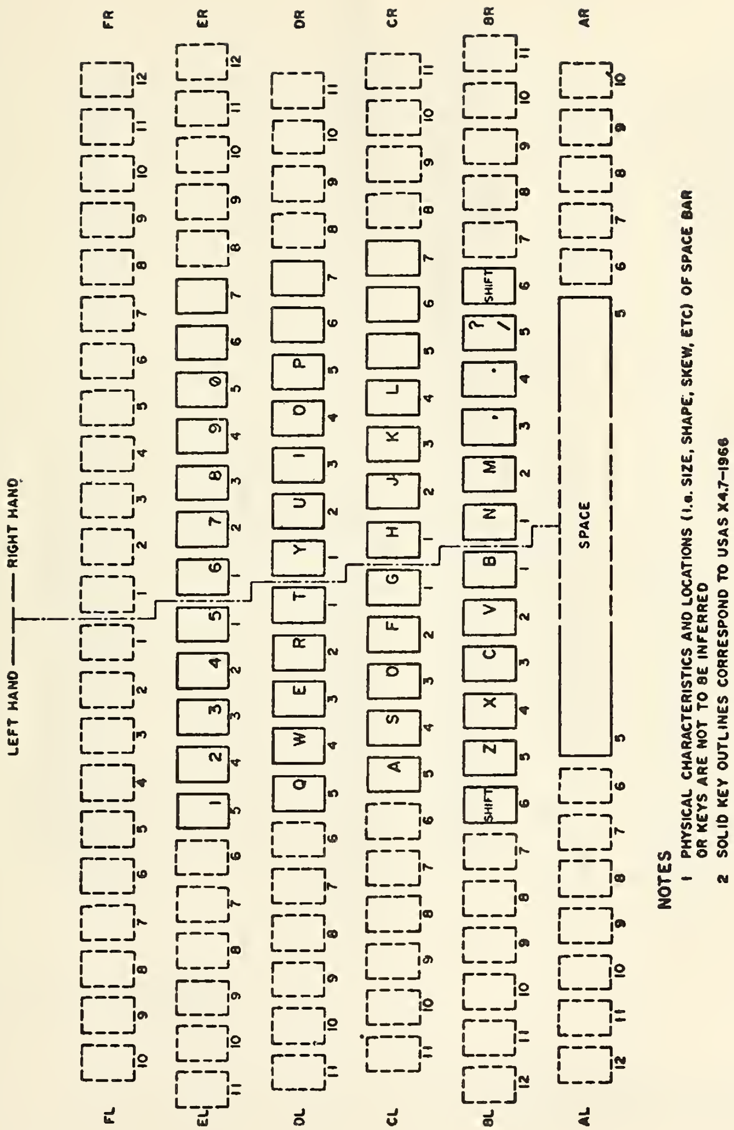
3.7.1.1 Keyboard Arrangement Notational System - Figure 3-7 shows the standard military notational system, that permits designation of key positions. Rows are labelled from the bottom up starting with A. Left hand key keys are designated AL, BL, etc. Similarly right hand keys are labelled AR, BR, etc. A dividing line separates the left hand and right hand sides of the keyboard, and keys are numbered from the inside out, starting with 1, either in the left hand or right hand directions.

CHARACTER SET	DESIGNATE	INVOKE	REPRESENT
single additional controls	not required		ESC (Fp) ESC (Fs) ESC 2/3 (F)
C0 controls	ESC 2/1 (F)		code positions 0/0 through 1/15
C1 controls	ESC 2/2 (F)		ESC (Fe)
G0 graphics	ESC 2/8 (F) ESC 2/12 (F)	SI	code positions 2/1 through 7/14
G1 graphics	ESC 2/9 (F) ESC 2/13 (F)	SO	code positions 2/1 through 7/14
multiple byte graphics	ESC 2/4 (F)	SI	multiples of code positions 2/1 - 7/14
specially interpreted codes	ESC 2/5 (F)		code dependent

Table 3-9. Code extension in a 7-bit code.

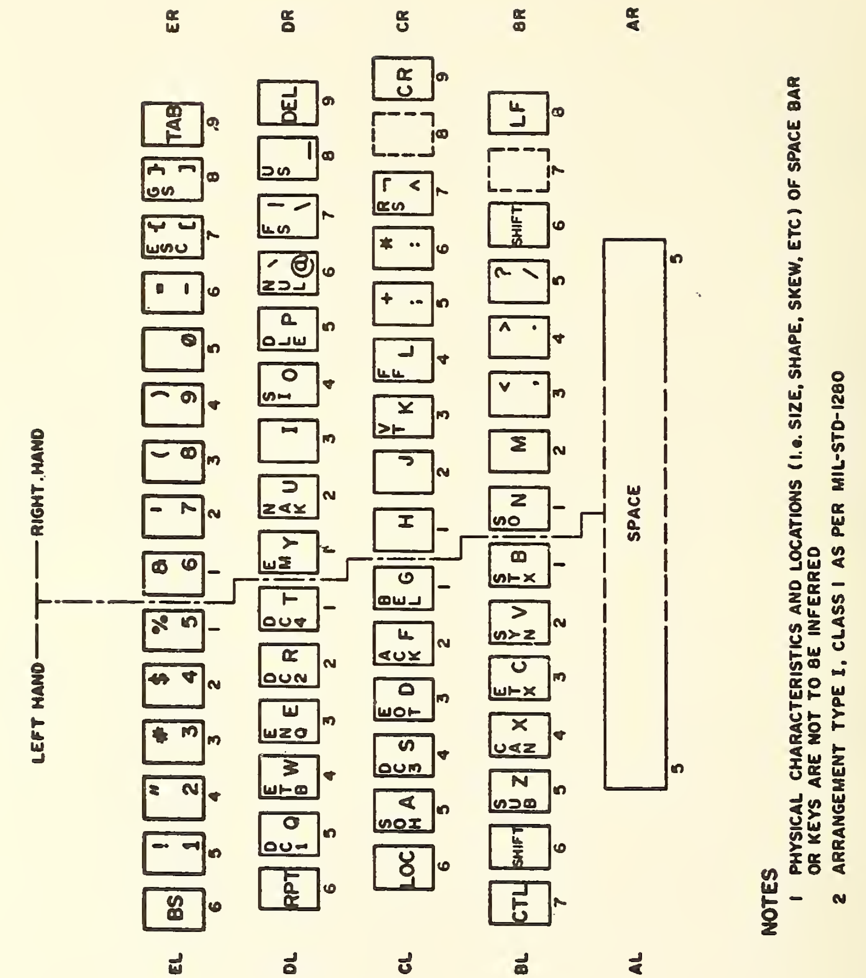
CHARACTER SET	DESIGNATE	INVOKE	REPRESENT
single additional controls	not required		ESC (Fp) ESC (Fs) ESC 2/3 (F)
C0 controls	ESC 2/1 (F)		code positions 0/0 through 1/15
C1 controls	ESC 2/2 (F)		code positions 8/0 through 9/15
G0 graphics	ESC 2/8 (F) ESC 2/12 (F)		code positions 2/1 through 7/14
G1 graphics	ESC 2/9 (F) ESC 2/13 (F)		code positions 10/1 through 15/14
multiple byte graphics	ESC 2/4 (F)		multiples of code positions 2/1 - 7/14
specially interpreted codes	ESC 2/5 (F)		code dependent

Table 3-10. Code extension in an 8-bit code.



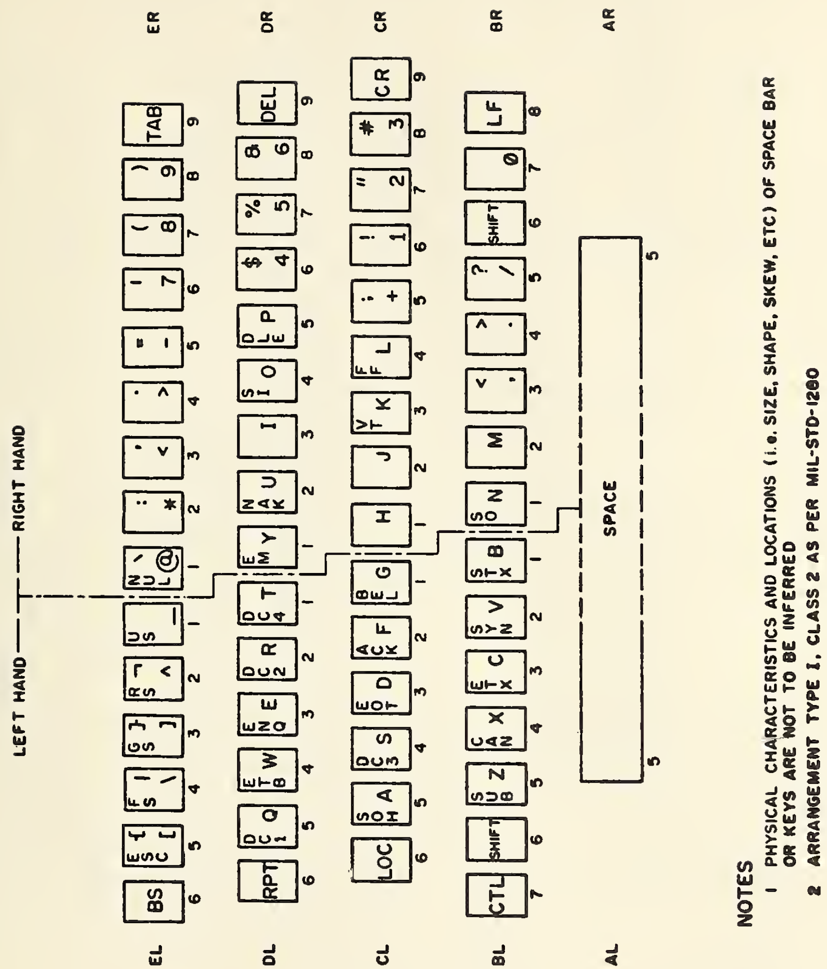
Source: MIL - STD-1280

Figure 3-7. Keyboard Arrangement Notational System



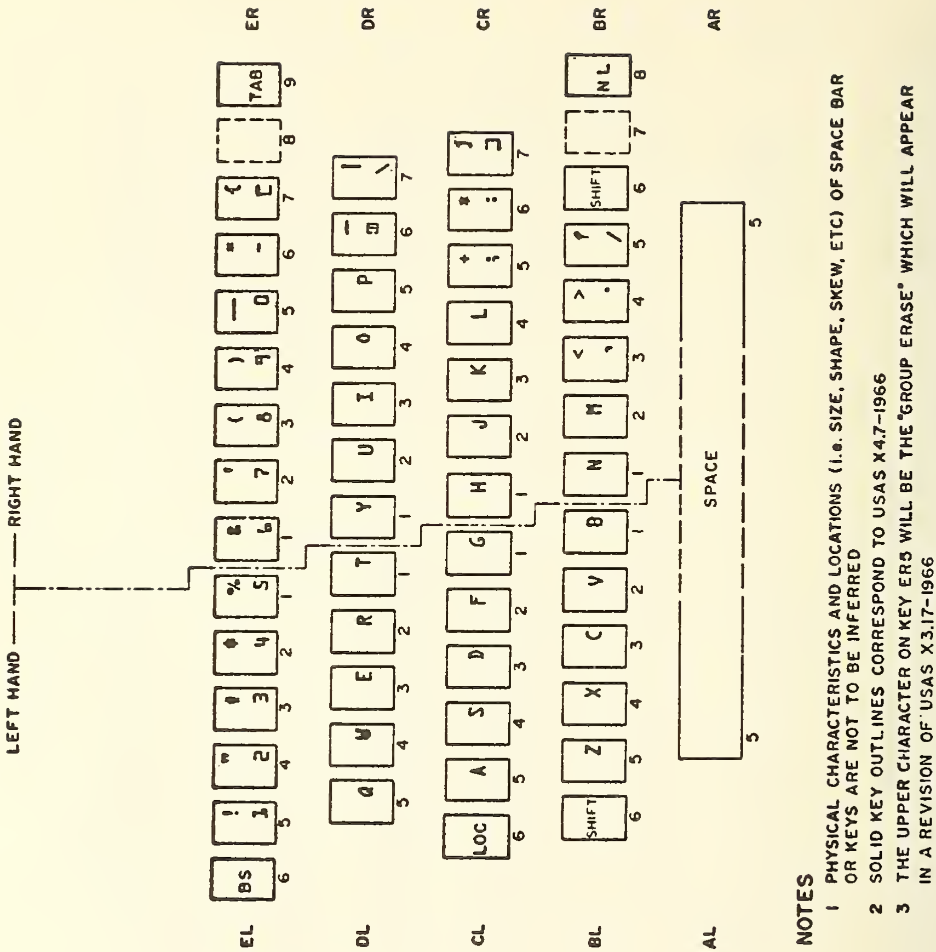
Source: MIL - STD-1280

Figure 3-8. Type I, Class 1 Standard Keyboard Arrangement.



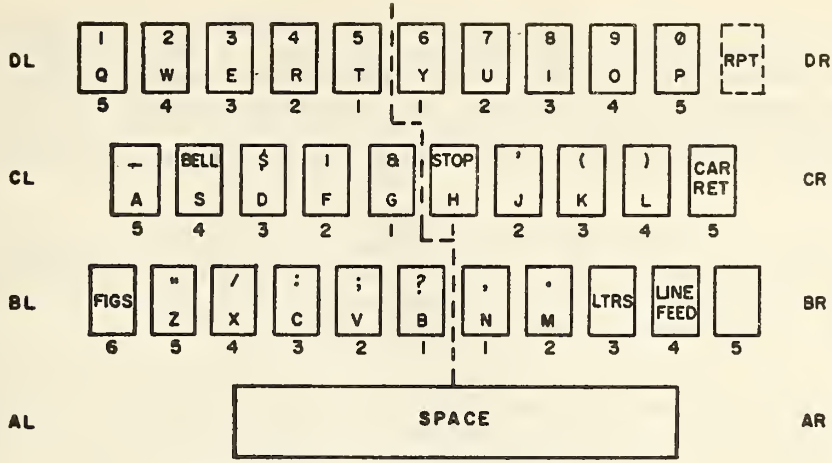
Source: MIL - STD-1280

Figure 3-9. Type I, Class 2 Standard Keyboard Arrangement.



Source: MIL - STD-1280

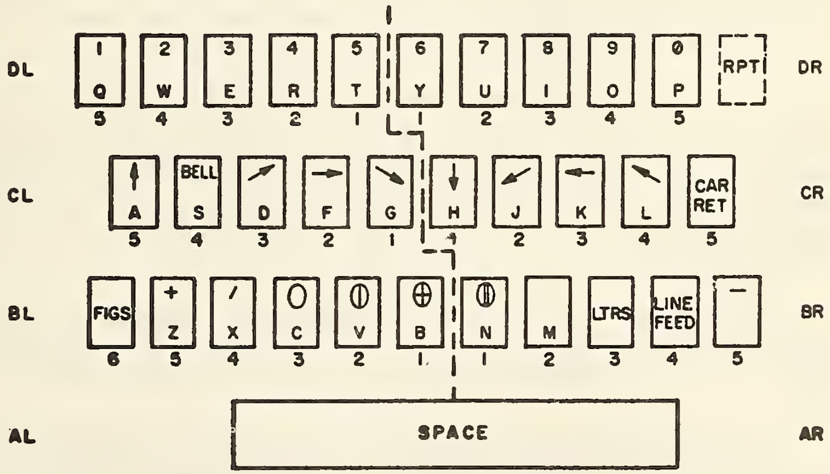
Figure 3-10. Type II, Class 1 Standard Keyboard Arrangement



NOTE: Upper Case H May Be STOP or #

Source: MIL-STD-188-C

Figure 3-11. Three Row Communication Keyboard (Interim Standard).



Source: MIL-STD-188-C

Figure 3-12. Three Row Weather Keyboard (Interim Standard)

3.7.1.2 Keyboards for High Alphabet Content Text - Figure 3-8 shows the standard arrangement for the Type I, Class 1 arrangement. The standard provides for several optional arrangements. Partial set implementations are permitted, and certain characters may be implemented in the shift and unshifted mode (like the comma and period) in key positions BR3 and BR4. Further detail is provided in document MIL-STD 1280.

3.7.1.3 Keyboards for High Numeric Content Text - Figure 3-9 shows the standard arrangement for the Type I Class 2 arrangement. Options allowed are similar to those in paragraph 3.7.1.2. Further detail is provided in document MIL-STD 1280.

3.7.1.4 Three Row Keyboards - Two keyboards have been designated interim standards for communications purposes (Figures 3-11, 3-12). Actuation of the FIGURES or LETTERS key causes subsequent characters to represent upper or lower case symbols, as shown in the diagram. Figure 3-11 shows the standard communications keyboard, and figure 3-12 shows the specialized keyboard for weather communications, providing alphanumeric capability and special weather symbols, such as wind direction and cloud cover.

3.7.2 Commercial Keyboard Standards

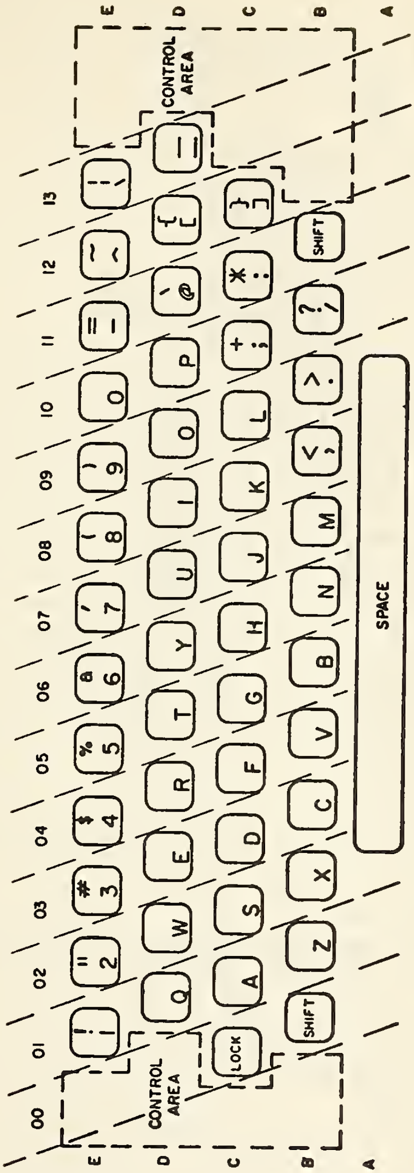
Typewriter keyboard arrangements have been standardized in ANSI X4.7-1973, which is a revision of a 1966 standard. Assignment of the ASCII characters and the ASCSOCR are made in ANSI X4.14-1971. The US Standard X4.6 defines the ten key numeric keyboard used in adding and calculating machines.

3.7.2.1 Keyboard Arrangements - Two major keyboard types are defined by X4.14-71. Figure 3-13 shows the layout for logical bit pairing. Figure 3-14 shows the arrangement for typewriter pairing keyboards. All keyboards provide lower case letters in the unshifted mode and upper case letters in the shifted mode. Those keys not showing alphabetic characters provide graphic characters as shown in upper and lower graphics.

The keyboard shown in figure 3-13 observes logical bit pairing rules, i.e., the code relationship between upper and lower shift characters consists in change of one bit 5 or bit 6 in the ASCII code table only.

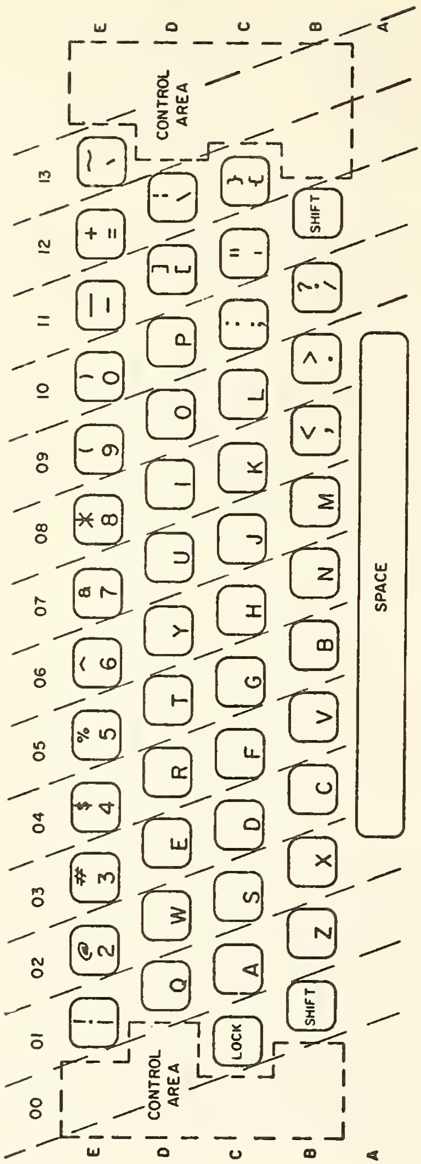
The keyboard shown in figure 3-14 resembles, as closely as possible the electric typewriter keyboard as shown in Standard X4.7-1966.

3.7.2.2 Control Keys - Actuation of the control key will cause keys with control character assignments to generate the ASCII control codes, regardless of the state of the SHIFT or SHIFT LOCK key.



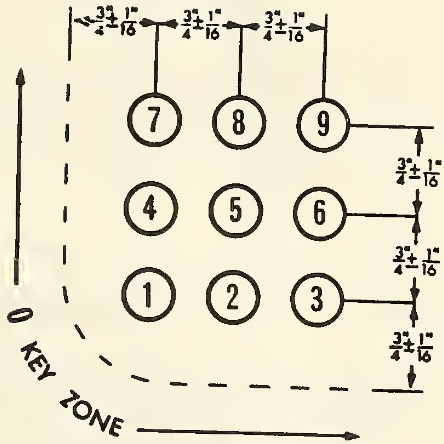
Source: ANSI X4.14-1971

Figure 3-13. Logical Bit Pairing Keyboard Arrangement



Source: ANSI X4.14-1971

Figure 3-14. Typewriter Pairing Keyboard Arrangement



Source: ANSI X4.6-1966

Figure 3-15. Physical Arrangement of Numerical Keys

Table 3-11 shows the control code assignments for bit paired keyboards. As an example, depression of the control key and of key C generate the ETX character.

NUL	@	DLE	P
SOH	A	DC1	Q
STX	B	DC2	R
ETX	C	DC3	S
EOT	D	DC4	T
ENQ	E	NAK	U
ACK	F	SYN	V
BEL	G	ETB	W
BS	H	CAN	X
HT	I	EM	Y
LF	J	SUB	Z
VT	K	ESC	[
FF	L	FS	\
CR	M	GS	]
SO	N	RS	^
SI	O	US	_

Table 3-11. Control code assignments.

3.7.2.3 Numeric Only Keyboard [USAS X4.6-1966] - This standard provides for a ten key numeric keyboard which is used on calculating devices, and which often appears on consoles in conjunction with an alphanumeric and control keyboard. The arrangement is shown in figure 3-15.

3.8 References

3-1 Bemer, R. W.,
A View of the History of the ISO Character Code,
Honeywell Computer Journal,
Vol. 6 No. 4 (1972), pp274-286.

3-2 Bemer, R. W.,
Letter to the Editor,
Datamation,
Vol. 19 No. 9 (1973), p25.

3-3 Fitzsimons, T. F.,
ASCII Extension and Expansion and their Impact on Data Communications,
Proceedings of the Second Symposium on Problems in the Optimization of Data Communications Systems,
IEEE Cat. No. 71 C 59-C (1971), pp73-79.

Standards

1. ANSI X3.4-1968
American Standard Code for Information Interchange
American National Standards Institute

2. ANSI X3.6-1965
Perforated Tape Code for Information Interchange
American National Standards Institute

3. ANSI X3.15-1966
Bit Sequencing of the U.S.A. Standard Code for Information Interchange in Serial-by-Bit Data Transmission
American National Standards Institute

4. ANSI X3.16-1966
Character Structure and Character Parity Sense in Serial-by-Bit Data Communication in the U.S.A. Standard Code for Information Interchange
American National Standards Institute

5. ANSI X3.22-1967
Recorded Magnetic Tape for Information Interchange (800 CPI, NRZI)
American National Standards Institute

6. ANSI X3.25-1968
Character Structure and Character Parity Sense for Parallel-by-Bit Data Communication in the U.S.A. Standard Code for Information Interchange
American National Standards Institute

7. ANSI X3.26-1969
Hollerith Punched Card Code
American National Standards Institute

8. ANSI X3.32-1973
Graphic Representation of the Control Characters of American National Standard Code for Information Interchange

9. ANSI X4.6-1966
U.S.A. Standard, 10 Key Keyboard for Adding and Calculating Machines
United States of America Standards Institute

10. ANSI X4.7-1973
American National Standard for Typewriter Keyboard Arrangement
American National Standards Institute, Inc.

11. ANSI X4.14-1971
American National Standard, Alphanumeric Keyboard Arrangements Accommodating the Character Sets of ASCII and ASCSOCR
American National Standards Institute, Inc.

12. CCITT V.3
International alphabet number 5 for transmission of data and messages
CCITT - ITU

13. CCITT V.4
General structure of signals of the 7 unit code for data and message transmission
CCITT - ITU

14. FIPS PUB 1
Code for Information Interchange
National Bureau of Standards

15. FIPS PUB 2
Perforated Tape Code for Information Interchange
National Bureau of Standards

16. FIPS PUB 3
Recorded Magnetic Tape for Information Interchange (800 CPI, NRZI)
National Bureau of Standards

17. FIPS PUB 14
Hollerith Punched Card Code
National Bureau of Standards

18. FIPS PUB 15
Subsets of the Standard Code for Information Interchange
National Bureau of Standards

19. FIPS PUB 16
Bit Sequencing of the Code for Information Interchange in Serial-by-Bit Data Transmission
National Bureau of Standards

20. FIPS PUB 17
Character Structure and Character Parity Sense for Serial-by-Bit Data Communication in the Code for Information Interchange
National Bureau of Standards

21. FIPS PUB 18
Character Structure and Character Parity Sense for Parallel-by-Bit Data Communication in the Code for Information Interchange
National Bureau of Standards

22. ISO 646-1973
7-bit Coded Character Set for Information Processing Interchange
International Organization for Standardization

23. ISO/R 962-1969 (under revision)
Implementation of the 7-bit Coded Character Set on 9-track 12.7mm (1.2 in) Magnetic Tape
International Organization for Standardization

24. ISO/R 963-1969
Guide for the Definition of 4-bit Character Sets derived from the ISO 7-bit Coded Character Set for Information Processing Interchange
International Organization for Standardization

25. ISO/R 1113-1969
Representation of 6 and 7-bit Coded Character Sets on Punched Tape
International Organization for Standardization

26. ISO/R 1177-1970
Character Structure for Start/Stop and Synchronous Transmission
International Organization for Standardization

27. ISO/R 1679-1970
Representation of ISO 7-bit Coded Character Set on 12-row Punched Cards
International Organization for Standardization

28. ISO/R 2021-1971
Representation of ISO 8-bit Coded Character Set on 12-row Punched Cards
International Organization for Standardization

29. ISO 2022-1973
Code Extension Procedures for the ISO 7-bit Code
International Organization for Standardization

30. ISO DR2047
Graphical Representation for Control Characters of the ISO 7-bit Coded Character Set
International Organization for Standardization

31. ISO DIS2375
Procedures for the Registration of Escape Sequences in Data Processing
International Organization for Standardization

32. MIL-STD-188 C
Military Standard, Military Communication System Technical Standards, November 1969, Department of Defense, Washington, D. C. 20301

33. MIL-STD-188-100, Military Standard, Common Long Haul and Tactical Communication System Technical Standards, November 1972, Department of Defense, Washington, D. C. 20301

34. MIL-STD-1280
Keyboard Arrangements
January 1969
U. S. Army Electronics Command
Fort Monmouth, New Jersey 07703

4. LINK CONTROL PROCEDURES

This chapter describes existing, proposed, and de facto standards relating to use of a link in a network for data communication. There are two distinct modes of link discipline, the character-oriented and the bit-oriented. Three character oriented disciplines are described, ANSI X3.28, IBM's Binary Synchronous Communication Procedure (BSC) (also used by Honeywell) and the procedures used in the ARPANET. Only the former will be described in any detail as it is the national standard. The bit-oriented procedures are new, and draft proposals are currently being developed in ANSI and ISO.

The chapter begins with a description of link configurations in general, and a brief tutorial on link control. Further discussion of this subject is available in the open literature (see [4-1]; this reference has been used in the preparation of this report.). Following that is a discussion of each type of discipline, which includes the type of link configurations supported, nature of link control, error detection, and error recovery.

4.1 Links: Configuration and Control

This section describes the generic structure of a link and the functional capabilities required for data communication. The contents of this section represent a state-of-the-art summary.

4.1.1 Configuration

The term link (as used here) is an abstract one: it specifies only the functional capability to transport data from one terminal to another. A general model of a link must include the capability for both bidirectional and unidirectional communications without restriction to a specific control discipline. The discussion here will be brief. For a more detailed treatment, see [4.1].

Consider two (of possibly more) terminals on a link. Each one can potentially initiate traffic on the link and this traffic may be either in response to traffic from another terminal or not (spontaneous traffic). Thus in the most general case there are two types of traffic on the link proceeding in each of two directions. The fact that traffic can move in two directions requires that the link implement certain control functions to assure orderly transmission of data.

Thus our model must involve two components, one to separate the two kinds of traffic (response and spontaneous) and one to assure bidirectionality. To achieve bidirectionality, the model utilizes two sublinks, one for each direction. A terminal on the link consists of a receiver (R), a transmitter (T), a process responsible for generating messages for transmission (S: source), and a process responsible for handling received messages (D: destination). The model is depicted in figure 4-1.

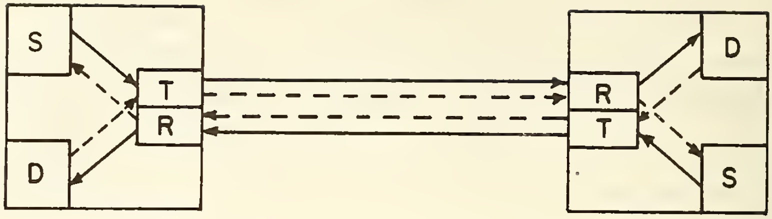


Figure 4-1. The Model Link

In operation, each sublink carries both spontaneous and response traffic in a single direction. The receiver routes the former to D, the latter to S. The transmitter collects the former from S and the latter from D and sends them over its sublink. Note that specific instances of a link may implement only a part of the general model (e.g., half-duplex links; see below). Description of a link involves several attributes, its directionality, its topology, and whether or not the link is switched. These are dealt with now. The terms master and slave are used in the context of control. The former designates a terminal which has control of the link during a given transmission. The latter applies to the remaining terminals when they are also involved in the transmission. Generally, master and slave status is assigned on a temporary basis; it may change from one transmission to the next. Unless otherwise specified, it is the master who has responsibility for link control and error recovery operations during the transmission.

One-way Only: A link of this class handles traffic in one direction only. The direction (source to destination) is fixed once for all. In particular, there must be exactly one terminal on the link which can initiate transmission (and which will receive none). The remaining terminals operate in receive mode only. In this class, master status is permanently assigned, and slave status devolves on those other terminals involved in a given transmission.

Two-way: This class of link permits bidirectional traffic; within this class are subclasses based on whether traffic in both directions can occur at the same time (simultaneous) or not (alternate). This applies both to the terminals on the link and the sublinks, in that, e.g., the (physical) link may support simultaneous traffic while a terminal on the link may not (figure 4-2). Note that a two-way alternate link may be implemented using a two-way simultaneous circuit.

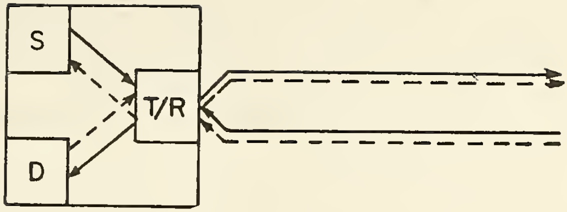


Figure 4-2. Two-way Alternate Terminal, Two-way Simultaneous Sublink(s).

Alternative terminology for these classes is: simplex for one-way only; full-duplex for two-way simultaneous; and half-duplex for two-way alternate. Note, however that for keyboard-type terminals, full-duplex may also mean "remote echo" of typed characters, while half-duplex may mean "local echo", thus introducing an ambiguity into the subject.

The topology of a link specifies the terminals connected to it and their interconnection. Currently, there are two broad classifications of link topology, point-to-point and multipoint. A point-to-point link is one containing exactly two terminals, while a multipoint link generally contains more than two (see switched links, below). In the latter case there is generally only one master at a time. However, there may be multiple slaves active at a given time. Multipoint links are further classified according to the type of control exerted in the link. In any such link there is a control station, designated once for all, which has the responsibility for maintaining the integrity of the link (similar to the master, but the designation is permanent). The remaining terminals on the link are called tributaries. A multipoint link is centralized if its control station must participate actively in all transmissions, and is non-centralized otherwise.

Finally, a link is switched if a circuit switch is used to establish connections between the terminals, and non-switched if the connections are permanent (dedicated).

Note that these classifications,

one-way only/two-way
point-to-point/multipoint
switched/non-switched

are independent in that any one of the eight possible classes may occur. For example, a link may be both switched and point-to-point.

4.1.2 Link Control

Use of a link to transmit data involves not only the transmission of data but the transmission of "control" information which is used by the terminals on the link to correctly handle individual "messages", synchronize operations, and detect and recover from errors.

Specifically, this control information should implement at least the following functional requirements:

transmission initiation
transmission control
identification of sender and receiver
error checking
error recovery
transmission termination

The requirement for transmission initiation includes the capability for one terminal to invite or require one or more others to participate in a transmission and possibly to set up conventions to govern the transmission itself.

Terminal identification is a requirement in any multipoint link, due to the multiplicity of terminals available. In addition, such a feature is valuable when the link is switched so that the connection made may be verified.

The error checking provided in the procedures discussed below is limited to redundancy checking (horizontal, longitudinal, or cyclic); however more sophisticated techniques are known (e.g., Hamming codes) which allow at least some corrective capability. The price to be paid, however, is usually a high overhead. As checking is limited, so error recovery is limited. The general approach in the systems discussed below is to require retransmission of messages detected in error, leaving unspecified other supplementary techniques.

Termination requirements generally include a function to turn off the link (disconnect) and one to abort transmission. Depending on the type of procedure in force, there may also be a requirement to reverse direction after a transmission (exchange master and slave status).

Transmission control has two aspects, framing and control, as follows.

Framing: The current state-of-the-art of data transmission requires explicit "framing" of data to be transmitted into blocks (or messages) of fixed maximum length. An information message may be shorter than one block or may require several blocks. In the first case, logically independent data streams may be sent together as one message. There are two reasons for requiring a maximum length for messages. First, terminals generally have a finite supply of buffers. Second, the error checking mechanisms employed (beyond parity) impose a constraint on the length of the block in order to achieve an acceptably low undetected error rate. Generally, framing consists of additional "framing" data which is transmitted with the "information" data. This is used by a receiving terminal to mark the beginning and end of the message, and may also provide additional information relating to the handling of the message.

Control: In addition, other information is passed on the link which is used to control the overall activity of the link and to maintain its integrity. Such information includes messages from one terminal to another which may acknowledge the correct receipt of a previous message, reject a previous message, request the receiving terminal to receive or transmit a message, respond with its status, and so on.

Thus, link control involves sending along with data, control information which takes up bandwidth, and hence detracts from the efficiency of the link. For a more detailed discussion of link efficiency, see e.g., [4-2]. There, the efficiency of certain links is computed, using a proposed standard measure of efficiency, the so-called TRIB (Transmission Rate of Information Bits, ANSI X3S35/80).

Terminology: Some special terminology occurs in the following discussion of control procedures, which is explained here. Basic mode procedures are a set of procedures standardized by ISO (R1745), and ECMA (ECMA 16) using character-oriented disciplines based on the control characters in ISO R646 (see Ch. 3). ANSI X3.28 defines similar, but incompatible procedures, based on the control characters in X3.4 (Ch. 3). Conversational mode procedures are those which permit the sender and receiver roles of a link to be interchanged without using the normal protocols to exchange master and slave status. Code independent procedures are those which permit the information data to have any form. Byte independent procedures are those which do not place a restriction on the length of transmitted data to be a multiple of a given unit (e.g., of an 8 bit byte). The term "transparent" is often applied to procedures which are code or byte independent. Depending on the procedure, some bit patterns may be interpreted as control information, so that these patterns should somehow be prohibited from occurring in the data itself. For example, the basic mode procedures of X3.28 use certain "control characters" for framing, so these cannot appear within data to be transmitted. On the other hand, the information field provided by ADCCP (4.3.1) is inherently both code and byte independent. Since control information is positional, the occurrence of meaningful control bit patterns (there is only one) is avoided in data by "bit stuffing". To achieve the same result with character-oriented procedures would require "character stuffing", as is done in ANSI X3.28E, ISO R2111, or ECMA 24. The name X3.28E will be used to refer to a proposed revision to X3.28, namely ANSI X3S3.4/437 (1973).

4.2 Character-Oriented Procedures

This section describes the procedures which treat the bit stream as a sequence of characters. Table 4-1 lists the standards for various aspects of link control from the different standards organizations. IBM's Binary Synchronous Communication procedures (used by Honeywell and others) is a defacto standard. The "level 1" protocol of the ARPANET is included for completeness, although it is not a standard at this time. (Not included are the packet switching procedures which are at a "higher level" than the link control considered here). The standards on character codes and related matters have been covered in Ch. 3.

	ANSI	FIPS	ISO	ECMA
BASIC MODE	X3.28		R1745	ECMA-16 ECMA-37
CODE INDEPENDENT			R 2111	ECMA-24
CONVERSATIONAL			R 2629	ECMA-29
ERROR DETECTION	X3.28		R 1115	
ERROR RECOVERY			R 1745	ECMA-26
ABORT/ INTERRUPT				ECMA-27
MULTIPLE SELECT				ECMA-28

Table 4-1. Applicable Standards

4.2.1 ANSI X3.28-1971

This standard utilizes the ten communication control characters (hereinafter, control characters) of the ASCII character set to define link control and specify procedures for establishing, using, and terminating a link connection. Seven classes of establishment/termination procedures and five classes of message transfer procedures are specified. Thus there are some 30 possible systems which are standardized by X3.28 (see table 4-3). In the same way, X3.28E standardizes over 80 systems. X3.28 has not become a Federal Information Processing Standard because of the above and since it does not treat two-way simultaneous (conversational) or transparent mode transmission. These capabilities were deemed necessary in the Federal environment. However, X3.28E does provide these extended procedures.

A problem with X3.28 is that, rather than giving a coherent solution to the problem of link control (even in the limited, "basic" mode), the standard is essentially a list of approved alternative solutions. They are individually ad-hoc, and are generally not consistent with one another. For example, the use and meaning of certain control characters may change from one category of procedure to another. A case in point is the DEOT sequence (see table 4-2) which in some procedures means "disconnect the link" and in others just terminates a particular transmission without breaking the connection (subcategory 2.3, below).

4.2.1.1 Link Configuration Categories - In X3.28, link configuration is included in the definition of the procedures for establishing and terminating a connection on the link. As described in Sec. 5 of X3.28, the following configurations are standard.

Subcategory			
1.1	One-way only	Multipoint (Centralized)	Non-switched
2.1	Two-way alternate	Point-to-point	Switched
2.2	"	"	Switched
2.3	"	"	Non-switched
2.4	"	Multipoint (Centralized)	Non-switched
2.5	"	Multipoint (Centralized, Fast Select)	"
2.6	"	Multipoint (Noncentralized)	"

Subcategory 1.1: This subcategory provides for one-way only transmission in a centralized, multipoint, non-switched link. Transmission is always initiated by the master (always the control station), with no replies from the tributaries, which essentially have permanent slave status. (Since the link is non-switched, procedures for establishing or verifying terminal identification are not specified).

Subcategory 2.1: This subcategory provides for two-way traffic alternating between two terminals in a (circuit-) switched network. The calling station is master initially. Master and slave status may be interchanged on command from the current master. An example of this is a computer system linked to multiple Remote Job Entry (RJE) stations.

Subcategory 2.2: This subcategory provides for a link as in 2.1, but with an identification procedure included, to assure proper connection through the switched network.

Subcategory 2.3: This subcategory provides for two terminals on a non-switched, two-way alternate, link, each of which may contend for master status. An example is a dedicated link between two computers.

Subcategory 2.4: This subcategory provides for a non-switched, centralized multipoint, two-way alternate link. The control station may assume the master role itself, or it may assign the master role to a tributary thereby becoming the slave for the following transmission. In this subcategory the designated control station must participate (as master or slave) in all transmissions.

Subcategory 2.5: This subcategory is essentially the same as 2.4, but with a "fast select" procedure; see Establishment and Termination procedures below.

Subcategory 2.6: This subcategory is similar to subcategory 2.4 except that the system is non-centralized. In particular, the current master may transmit to other tributaries as slaves without going through the control station. As in 2.4, the control station must monitor all transmissions.

4.2.1.2 Framing - Data communication under X3.28 consists of the transmission of character streams from one terminal to another. The primary purpose of the procedures described below is to facilitate the sending of "information messages" (or messages, for short) which are strings of characters, and must contain no control characters (table 4-2) other than those described here. In particular, X3.28 prohibits the so-called transparent mode of transmission in that any bit-pattern which can be interpreted as a control character will be so treated. However, the new X3.28E provides explicitly for transparent operation (Subcategory D1; this revision is not treated here in any detail, because of its provisional status). The method used is essentially that used in IBM's BSC and the ARPANET procedures (4.2.2 and 4.2.3 below).

Messages in X3.28 are otherwise unspecified as to content or length. However, for purposes of efficiency or convenience, the implementor may, depending on the procedure chosen, split a message into "blocks", each one of which is transmitted separately, with reassembly at the receiving terminal. A message or block may be further divided into two sections, transmitted together, called the header and the text. No specification of form or content for either section is provided in the standard. Again, X3.28E provides additional capability in that blocking may be "message independent", e.g., more than one message or partial message may exist in one block.

The message is "framed" by certain control characters as indicated below and in figure 4-3. Every block begins with an SOH (if a header is present) or an STX otherwise. If the message is multi-block, the blocks other than the last are terminated by an ETB. The last block of a message (including the one-block message) is terminated by an ETX.

SOH	<HEADING>	STX	<TEXT>	ETX	BCC

(a) One-block Message

SOH	<HEADING>	STX	<TEXT>	ETB	BCC
SOH	<HEADING>	STX	<TEXT>	ETX	BCC

(b) Multi-block Message

Figure 4-3. Message Formats

Note that the standard does not dictate the means by which blocks are correctly reassembled into a message. In general, decisions on blocking are left to the implementor. The only constraint made by the standard is that of the individual subcategories to support no blocking, message associated, or message independent blocking (X3.28E).

4.2.1.3 Control Procedures - Table 4-2 lists the control characters to be used for link control, as well as the character sequences extending the basic set. There are several classes of messages, as dictated by the control characters framing the message. The actual interpretation of the characters is discussed with the procedures specific to each category. The following discussion conforms more to the treatment in ISO R1745 than that of X3.28, although the information content is that of the latter. The treatment gives two discussions of procedures, one verbal and one in terms of state graphs. The latter is the more rigorous.

Character	Meaning
SOH	Start of heading
STX	Start of text
ETX	End of text
EOT	End of transmission
ETB	End of block
ENQ	Enquire (request for response)
ACK	Positive acknowledge
NAK	Negative acknowledge
SYN	Synchronous idle
DLE	Data link escape
DEOT	Mandatory disconnect (DLE,EOT)
ACK0	Alternate Acknowledge 0 (DLE,0)
ACK1	Alternate Acknowledge 1 (DLE,1)

Table 4-2. ASCII Communications control characters

The link supports three kinds of messages, forward and backward supervisory, and information. The forward supervisory message is initiated by the master station; its main purpose is to transmit control information rather than data. The backward supervisory message is initiated by a slave in response to a transmission from a master station. The information message carries otherwise unstructured data and is initiated by the master station. In general, it is expected that between any two (noncontiguous) blocks there will be (at least) two SYN characters transmitted to maintain synchronization of the two stations.

The control procedures in X3.28 are divided into two classes, establishment and termination, and message transfer. These are briefly given in matrix form in table 4-3. The "definition" of a data link requires one procedure subcategory from each class, subject to the constraints indicated in table 4-3.

To facilitate presentation of these procedures, figure 4-4 depicts the general case of data transmission, broken down into phases. (This discussion is based on ISO R1745, and is represented only implicitly in X3.28). Phases 1 and 5, not shown here, are circuit connect and disconnect respectively (applicable only to circuit-switched networks). They are not governed by the standard although they appear in the state diagrams of the X3.28 document. Phase 2 is establishment, phase 3 is message transfer, and phase 4 is termination. The discussion of establishment and termination procedures below is in terms of the link subcategories above.

Establishment and Termination Subcategories: Phases 2 and 4 of transmission, described by procedure subcategory, are concerned with selection, polling, contention, line turn-around, and link disconnect. Note that these subcategories are the same as those discussed previously, for the purposes of the standard. In general, any message transfer subcategory (used in phase 3) may be used with the subcategories described here. The two exceptions are in 1.1, where only A1 and A2 can be used; and 2.5, where A1 or A2 must be used if multiple selection is used.

Subcategory 1.1: One-way only
centralized multipoint
non-switched

Phase 2: Establishment is via selection. A prefix (short sequence of characters; format and content are to be agreed upon for implementation; outside the scope of the standard), to address one or more tributary terminals, is sent, followed by ENQ. No other control characters sent.

Phase 4: Termination occurs when the master sends EOT, which releases the slave terminals for the next transmission.

Establish & Terminate \ Message Transfer	A1	A2	A3	B1	B2
1.1	✓	✓	NA	NA	NA
2.1	✓	✓	✓	✓	✓
2.2	✓	✓	✓	✓	✓
2.3	✓	✓	✓	✓	✓
2.4	✓	✓	✓	✓	✓
2.5	✓	✓	NA*	NA*	NA*
2.6	✓	✓	✓	✓	✓

✓ : Applicable

NA : Not Applicable

NA*: Not Applicable in Certain Cases

Table 4-3. Control procedure matrix

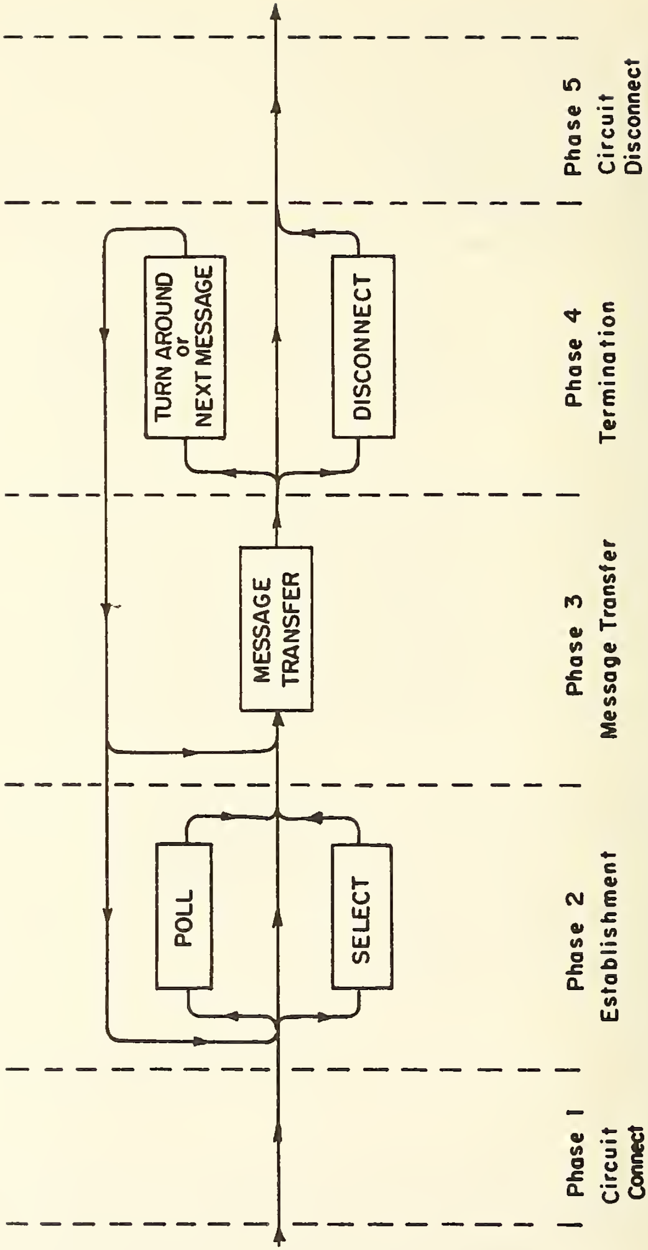


Figure 4-4. Phases of Transmission

Subcategory 2.1: Two-way alternate
point-to-point
switched

Phase 2: This subcategory involves no establishment procedure. The master terminal enters phase 3 or 4 directly.

Phase 4: The master may issue either an EOT to terminate transmission and exchange status with the slave; or a DEOT in which case both master and slave execute a local disconnect.

Note: The master may issue a DEOT at any time to abort transmission.

Subcategory 2.2: Two-way alternate
point-to-point
switched

This subcategory is the same as 2.1, with the addition of an optional identification procedure to assure proper connection in the switched network.

Phase 2: A prefix for identification is issued by the master, followed by ENQ. The receiving (slave) station responds affirmatively by means of ACK or ACK0 (see B2) if ready to receive. Otherwise, it responds negatively with a NAK. In the first case, the master enters phase 3; in the second, it enters phase 4.

Phase 4: The master may issue a DEOT for mandatory disconnect, or it may terminate transmission and exchange status with the slave by issuing an EOT.

Subcategory 2.3: Two-way alternate
point-to-point
non-switched

This subcategory is similar to 2.1, but since the connection between the terminals is dedicated, a contention scheme is provided to gain master status.

Phase 2: Each of the two terminals on the link may contend for master status by issuing a single ENQ with no prefix. The problem of lockout is not treated in the standard, but is discussed in B2.3 of the Appendix B. Once a terminal has received an ENQ, it responds either affirmatively (ready to receive) and takes the slave status by sending an ACK or ACK0 (see B2), or it responds negatively by sending a NAK. In either case, an optional prefix is allowed. In the first case, the successful bidding terminal assumes master status and enters phase 3. In the second case, it rebids with an ENQ.

Phase 4: The issuing of an EOT or DEOT by the master has the effect of resetting the status of the link to that prior to phase 2. DEOT is included to facilitate the use of terminal equipment and is otherwise equivalent to EOT.

Subcategory 2.4: Two-way alternate
centralized multipoint
non-switched

Phase 2: The control station is initially designated master. It may either poll or select by using an appropriate prefix followed by ENQ. In response to polling, a tributary merely assumes master status without responding if it is ready to send; it issues an EOT if not ready to send. In response to selection, the tributary issues an ACK or ACK0 (see B2) if ready to receive; otherwise, it issues a NAK. With an affirmative response for both polling and selection, the master enters phase 3. If the response is negative, the master must issue an EOT if polling and must reenter phase 2; if selecting, it may enter phase 4 or reenter phase 2 to reselect the same tributary.

Phase 4: To terminate transmission, the current master issues an EOT. This resets the link to its status prior to phase 2 and the control station "regains control".

Subcategory 2.5: Two-way alternate
centralized multipoint
non-switched

This subcategory duplicates 2.4, and adds a "fast select" option.

Phase 2: The selection prefix may be sent by the master with an immediate entry into phase 3 without issuing an ENQ or waiting for a response.

Phase 4: As in 2.4.

Subcategory 2.6: Two-way alternate
noncentralized multipoint
non-switched

Phase 2: The control station is initially master. It may poll or select by sending the appropriate prefix followed by ENQ. No response occurs if the polled tributary is ready to send. The polled tributary assumes master status and enters phase 2 to select a tributary. In the contrary case it enters phase 4. If a selected tributary is ready to receive, it sends an ACK or ACK0 (see B2), at which point the current master enters phase 3. If not, it issues a NAK, at which point the master either reenters phase 2 to reselect the same tributary or enters phase 4.

Phase 4: The issuance of an EOT by the current master terminates transmission and resets the link to its status prior to entering phase 2.

Message Transfer Subcategories: These procedures cover the transmission of information messages (i.e., phase 3 transmissions) as described under framing (4.2.1.2) and the valid responses to them.

Subcategory A1: Message oriented, no blocking
no replies
no error checking

This subcategory covers the transmission of unblocked messages without replies from the receiving stations and with no (required) error checking. The master station may initiate phase 3 transmission with an

SOH or STX depending on whether there is or is no heading, and the message is terminated by the corresponding ETX. The master may repeat this process until all messages have been sent. At this point, the master should enter phase 4 of the appropriate subcategory.

Subcategory A2: Message oriented, no blocking
no replies
error checking

This subcategory duplicates subcategory A1 but with an error checking requirement in the form of a Block Check Character (BCC, see Error Detection, 4.2.1.4, below) to be sent immediately following each ETX transmitted.

Subcategory A3: Message oriented, no blocking
replies
no error checking

This subcategory covers systems where the master station sends one or more messages to a single slave. A reply is required from the slave following each message. If the reply is affirmative, another message may be sent (to the same slave); if negative, immediate retransmission is not required.

The master initiates a message with either an SOH or STX and terminates with an ETX. No BCC is transmitted. The slave, on receiving the ETX, must reply with an ACK or NAK following an optional prefix. If an invalid reply or no reply occurs, the master may retry a specified number of times. Note that detecting a "no reply" condition implies the use of a timer, which is not covered by the standard.

Subcategory B1: Message oriented blocking
single acknowledgement
error checking

This subcategory allows messages to be subdivided into blocks which are transmitted separately. Blocks are (apparently) transmitted in sequence, and all blocks comprising a message must be sent before a block from another message may be sent. After sending a block, the master must await reply before sending the next block. If the reply is negative, the previous block must be retransmitted immediately (i.e., before any other block).

The master begins each transmission block with either an SOH or STX. The transmission is terminated by either an ETX or ETB, followed immediately by a BCC. The ETB is to be used if the block does not terminate the message. If the block terminates the message, or the message consists of only one block, the ETX is used. Upon receipt of the ETX and BCC, the slave must reply, either with an ACK or NAK, with an optional prefix. When the master receives an ACK, it may transmit another block or it may enter phase 4. The latter can occur only if the previous block was terminated by (ETX) (BCC). If the master detects a NAK, the previous block must be retransmitted. A sequence of retries may occur before error recovery is required. The number of retries is by agreement. If the master detects an invalid reply or no reply (by use of a timer), the reply-request sequence must be sent. This consists of an optional prefix, followed by ENQ. The slave is required to repeat its last reply when this sequence is received, and a sequence of retries is allowed before the master initiates error recovery.

The standard suggests a numbering scheme to eliminate the problem of lost or duplicated blocks, but does not require one. Blocks may be lost or duplicated in the process of retransmission or error recovery; without a numbering scheme this situation is difficult to detect.

Subcategory B2: Message oriented blocking
alternating acknowledgements
error checking

This subcategory duplicates B1, except that the single acknowledgement (ACK) is replaced by alternating acknowledgements ACK0 and ACK1. These are used for replies by the slave as follows. ACK1 replies to the first block received, ACK0 replies to the second, and thereafter the two are used alternately. The need for a negative acknowledgement (using NAK) does not affect the sequence of ACK's. Thus, the sequence ACK1, ACK0, NAK, ACK1,... is valid while ACK1, ACK0, NAK, ACK0,...is not. The master responds to an ACKn out of sequence as if a NAK had been sent, i.e., by retransmitting the last block.

4.2.1.4 Error Detection - In some procedures (A2,B1,B2) X3.28 provides for error detection beyond character parity (see Ch. 3) by means of longitudinal redundancy checking (LRC: exclusive OR of each bit position) to provide a block-check character (BCC). This character is transmitted immediately following the ETB or ETX of an information message. As indicated in fig. 4-3, the characters following the first SOH or STX (including STX if SOH is used) and including the ETB or ETX, are included in the computation of BCC. Any internal SYN's are excluded.

X3.28E provides for more sophisticated error checking in the form of cyclic redundancy checking (CRC; see 4.2.2.4, Error Detection) for the subcategory providing transparent operation. Either the CCITT V41 polynomial or IBM's CRC-16 polynomial may be used in computing the CRC.

4.2.1.5 Error Recovery - No provision is made for error recovery beyond an implementation-dependent retry count. This subject is treated in more detail in X3.28E where various timers are prescribed.

4.2.1.6 Related Standards - Two other standards groups have standards relating to the ANSI link control procedures, ISO and ECMA. As noted earlier, they are similar to, but incompatible with, X3.28. As far as the Basic Mode procedures are concerned, there is little or no conceptual difference between the three (see table 4-1). However, both ISO and ECMA have gone beyond ANSI in extending the Basic Mode to include conversational and transparent mode procedures and in providing additional error detection and recovery capabilities. Again, once it is adopted, X3.28E will provide these additional features. Table 4-1 lists the relevant standards.

4.2.2 IBM Binary Synchronous Communications Protocol

This protocol (hereinafter referred to as BSC) is similar in concept to ANSI X3.28-1971. It was developed by IBM prior to the adoption of X3.28 and has become a de facto standard in the industry. For complete details on BSC, see [4-5]. X3.28 was developed around BSC, and by and large corresponds to the latter. However, there are a few points of difference between them. For example, in BSC any point-to-point link functions by contention, while in X3.28, a point-to-point link on a switched network assumes that the calling station is initially master (subcategory 2.1 in 4.2.1.1). On the other hand, BSC supports transparent mode operation and implements (mandatorily) several control functions not present in X3.28, e.g., ITB and RVI (see table 4-4). BSC supports transmission in three different code sets, EBCDID, ASCII, and IBM's Six-bit Transcode.

4.2.2.1 Link Configurations - BSC defines only two configurations. One is multipoint and essentially duplicates the link configuration of X3.28 subcategory 2.4. As there, the link is centralized, with the central control station participating in all transmissions on the link: every message or response sent on the link is routed through the control station. The link is two-way alternate.

The other configuration is point-to-point, and has no exact duplicate in X3.28. The link may be switched or non-switched, the distinction not being made by the protocols. In either case, the link functions by contention: either of the two stations on the link may bid for master status by sending the appropriate control sequence. (Cf. X3.28 categories 2.2 and 2.3 in 4.2.1.1).

4.2.2.2 Framing - As in X3.28, the basic unit of transmission is the message. The format for messages is essentially the same here, and the control characters are similar in name, but are implemented differently. The only difference at a conceptual level is that of an "intermediate block". In BSC, a block, bracketed by SOH or STX and ETB or ETX, can be divided internally into intermediate blocks, each but the last being terminated by ITB (see table 4-4). The effect of this character is to force computation of the block check character, which follows ITB immediately, and to restart block check. The entire block is responded to normally, except that an error in one intermediate block puts the whole block in error (see 4.2.2.4).

Character	Meaning
SYN	Synchronous Idle
SOH	Start of Header
STX	Start of Text
ETB	End of Transmission Block
ETX	End of Text
EOT	End of Transmission
ENQ	Enquiry
ACK0	Affirmative Acknowledgement 0
ACK1	Affirmative Acknowledgement 1
NAK	Negative Acknowledgement
DLE	Data Link Escape
ITB	Intermediate Transmission Block
WACK	Affirmative Acknowledgement, Wait
RVI	Reverse Interrupt
TTD	Temporary Text Delay

Table 4-4. BSC communications control characters from the EBCDIC character set.

4.2.2.3 Control Procedures - As with X3.28, the control procedures are allied with link configurations. In each case below, message transfer consists of sending the message, framed as indicated above and returning to a neutral state on the link.

For point-to-point links, contention is used to gain control. Each station bids for control with the "message" ENQ. Deadlock is avoided by assigning a priority to the two stations, with the higher priority gaining control in case of conflict. When one station bids successfully, the other acknowledges positively (with ACK0, if ready, or with WACK, if not ready temporarily) or negatively (with NAK), according to its current status. Message transfer begins once the ACK0 is received. At the end of the transmission, the link returns to neutral state and rebidding may occur.

Multipoint link operation is similar to that in category 2.4 of X3.28. The control station is initially master, and initiates operation by polling or selection. A polled tributary responds with a message (to the control station, now in slave mode) if it is ready to transmit. If temporarily not ready, it responds with a TTD, and if not ready, with an EOT (not a NAK). A selected station responds as a point-to-point operation, i.e., with an ACK, WACK or NAK, according to its status. At the end of message transmission, the link returns to neutral, with the control station regaining master status, to initiate another polling or selection sequence.

BSC also supports a limited version of "conversational" mode operation, and transparent mode operation. The former permits line turnaround by transmitting a message in place of a positive acknowledgement to a block ending with ETX (or DLE, ETX). Transparent mode operation proceeds by prefixing each meaningful control character within the text of a message with a DLE, and "doubling" DLE's. These features, not present in X3.28 are being implemented in X3.28E.

4.2.2.4 Error Detection - BSC provides a variety of error checking depending on the character set being used (EBCDIC, ASCII, or Six-bit code), and whether the link is capable of operating in transparent mode. A 12-bit Cyclic Redundancy Check (CRC) is used with the Six-bit code in any case. For ASCII, a 16-bit CRC, Longitudinal Redundancy Check (LRC), and Character Parity are available. CRC is used here only when transparent mode is available. Parity is used when not in transparent mode, and LRC when transparent mode is not implemented. For EBCDIC, only the 16-bit CRC is used. In any case, the CRC or LRC is sent as a Block Check Character (sequence) following the appropriate ETX, ETB, or ITB.

In addition, BSC incorporates a set of timers to assure continuity of operation. There is one for transmission which allows the insertion of SYN characters at regular intervals, one to assure that a tributary does not remain in control mode too long without transmitting, one to disconnect (used in a switched link, to prohibit long intervals of inactivity), and one to control waiting following receipt of a WACK or TTD. Again, most of these features are present in X3.28E.

4.2.2.5 Error Recovery - No recovery procedures are mentioned in the manual.

4.2.3 ARPANET Link Control

Link control procedures in the ARPANET [4-7] are not yet standardized. ANSI has recently convened a subcommittee (X3S37) with an ambitious program to study techniques for link control in computer networks, but no substantive work is currently available. In the ARPANET, messages are passed between Hosts via IMPs and between neighboring IMPs for network control. These messages are nominally streams of characters (8-bit bytes) in the ASCII format, but the use and meaning of the control characters differs from that in X3.28. Full details of the control procedures and message formats are available elsewhere (see [4-3], [4-7]), and are only briefly summarized here.

4.2.3.1 Link Configuration - There is essentially one configuration, as described in 4.1, in the ARPANET, namely a two-way, simultaneous, non-switched, point-to-point link.

4.2.3.2 Framing - All traffic on a link is framed the same way, as depicted in figure 4-5. As indicated, two SYN characters are the minimum inter-message interval. The message is enclosed by a DLE, STX and DLE, ETX pair, and its contents are "transparent", in that any bit pattern is permissible. DLE characters in the text are "doubled" by the transmitting hardware and one DLE character is again removed by the receiving hardware.

SYN	SYN	DLE	STX	TEXT	DLE	ETX	BCC	BCC	BCC	SYN	SYN

Figure 4-5. Link Level Message Format

4.2.3.3 Control Procedures - There are three distinct interfaces in the ARPANET which require their own set of procedures. Other, higher level interfaces (such as process to process) are not discussed here. All procedures are based on a "header" which prefixes the message to be transmitted. Since these headers are of fixed length and precede their accompanying text, no termination characters are used. The logical nature of the various "interfaces" in the ARPANET are discussed next. The discussions briefly indicate the characteristics of the message level interfaces as opposed to the electrical ones.

IMP-Host Interface: A message on this link has a header prefixed to it, called a "leader". The leader is 32 bits long and contains information pertaining to the current message, acknowledgments to previous messages and other control information. A message on this link can be from 32 to 8095 bits long.

IMP-IMP Interface: To transmit a message from one Host to another, the source IMP breaks the message into "packets" of up to 1008 bits and prefixes these with 80 bits of "packet header". This header gives control information pertaining to the current message, acknowledgments (to previous packets), requests for status, allocation, etc. Using an equivalent of a multiple numbering scheme, the IMPs implement several "logical channels" to each neighboring IMP. Only one of these is used for routing and network control messages; the rest are used for the packets of messages between hosts.

Very-Distant-Host Interface: This interface connects the IMP to a HOST at a distance too great to permit operation of the normal IMP-Host interface. It operates through modems using packets as in the IMP-IMP interface, and the leader from the HOST-IMP interface. Each packet is up to 63 16-bit words long, and is preceded by a 16 bit control word. The first packet must contain only the 32-bit leader expected in normal IMP-Host communications. Thus a Very-Distant-Host must be aware of packets and provide for their reassembly. In the normal IMP-Host interface, the IMP does the reassembly. The normal bit-count considerations prevail in addition to these.

4.2.3.4 Error Detection - All messages in the ARPANET are suffixed with a 24-bit Cyclic-Redundancy Check (CRC), which encompasses all bytes in the message from the DLE STX to DLE ETX inclusive. The CRC is transmitted following the latter. In addition, Odd/Even bits are provided in the headers of packets to permit detection of duplicate packets (blocks).

4.2.3.5 Error Recovery - No procedures are specified for error recovery other than retransmission. Use of the 24-bit CRC and a "reliable transmission package" (for the VDH) is purported to make undetected errors rather unlikely.

4.3 Bit-Oriented Procedures

The American National Standards Institute is currently developing a proposed standard (X3S3.4/475, Feb. 15, 1973) called Advanced Data Communication Control Procedures (ADCCP) which approaches the same problem as X3.28-1970, but from a different point of view. In ADCCP, all transmissions have a common format, called a <u>frame</u>, in contradistinction to X3.28-1970, where different types of "messages" have different forms (e.g., selection vs. text transfer). The control characters are replaced by a subfield of the ADCCP frame which contains commands or responses to commands. Stations are identified by another subfield of the frame.

A similar proposal (ISO/TC 97.SC 6, #794, High Level Data Link Control, or HDLC) is being developed by ISO. Both are related to IBM's Synchronous Data Link Control (SDLC), which recently has been announced for use in some industry-specific communications systems (banking and point-of-sale).

The description of ADCCP begins with a description of the link configurations supported (4.3.1). Then the framing and structure of a transmission is described (4.3.2), followed by a state-variable description of the terminals on a link (4.3.3). The commands and responses used are defined (4.3.4) with an indication of their effect on the terminals on the link. Error detection and recovery (4.3.5,6) are discussed next, and finally, a discussion of related developments is presented (4.3.7).

4.3.1 Link Configurations.

ADCCP supports two general configurations, depicted in figures 4-6 and 4-7 (see 4.1). These are termed Primary/Primary and Primary/Secondary, respectively, and correspond to the point-to-point and multipoint links as described in 4.1. In ADCCP (as in HDLC and SDLC), a terminal (or station) is permanently designated as being either Primary or Secondary. The terminology of 4.1 does not correspond to these terms in that the Primary station is the control station of the link and has permanent master status. Similarly, the Secondary is a tributary and is in permanent slave status.

The Primary station has the responsibility for link initialization, control and organization of data flow, and control of error recovery procedures at the link level, including retransmission. The Secondary has the responsibility to act only on the commands from the Primary, as described below (4.3.4).

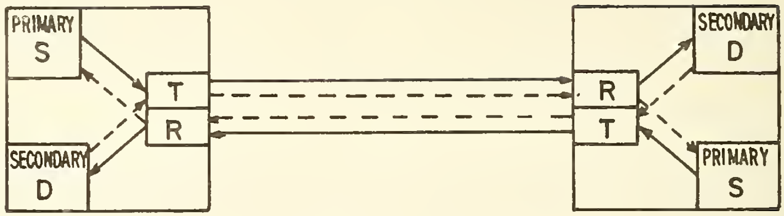


Figure 4-6. Primary/Primary Link

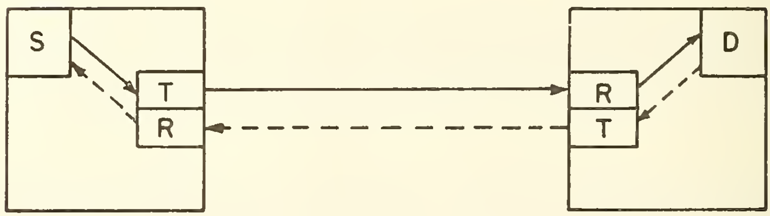


Figure 4-7. Primary/Secondary Link

The Primary/Primary link (figure 4-6), referred to as a balanced point-to-point link, consists in reality of two sublinks, each station comprising both a primary and a secondary component. In terms of 4.1, it may be described as two-way simultaneous, point-to-point, and may be either switched or non-switched.

The Primary/Secondary link (figure 4-7) consists of one primary station and one or more secondary stations. It may be characterized as two-way simultaneous or alternate, multipoint, and may be either switched or non-switched.

For an ADCCP link operating on a switched network, the called station, by convention, initiates transmission. If necessary, this may be done by a Secondary by sending an (unsolicited) status response (see 4.3.3).

Note that all links in X3.28 and X3.28E can be accommodated, and the bewildering array of configurations (especially in X3.28E) have been replaced by just the two in ADCCP. The variety of message formats of X3.28 and X3.28E has been replaced by one (see framing, below) which presumably simplifies the link at both ends. Finally, the internal structure of a terminal has been extensively specified, thereby easing the burden of the implementor and hopefully minimizing the problems associated with modifying or extending the communications system.

4.3.2 Framing

The unit of transmission in ADCCP is a frame, and all transmissions on the link utilize this format. The structure of a frame is shown in figure 4-8.

FLAG	ADDRESS FIELD	CONTROL FIELD	INFORMATION FIELD	FRAME CHECK SEQUENCE	FLAG

Figure 4-8. ADCCP Frame

The fields are as follows.

<u>Flag</u>: An 8-bit sequence, 01111110, which begins and ends a frame. All terminals hunt for the flag in idle state, since this field is used for frame synchronization.

<u>Address Field</u>: An 8-bit sequence identifies a secondary terminal on the link. It may be extended (recursively) to provide for multiple fields. The structure is :

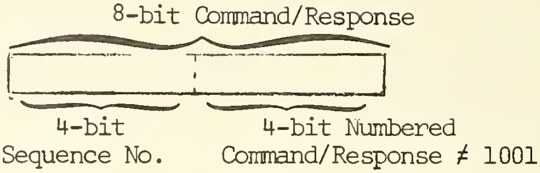
7-bit Address	

Extended: 0=No
1=Yes

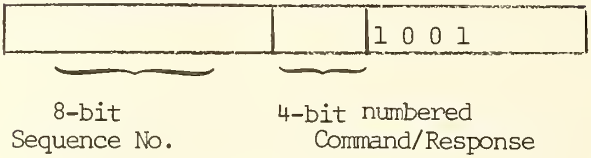
<u>Control Field</u>: An 8-bit field, extendable to allow for larger sequence numbers (see 4.3.3 below). The control field contains the sequence number (if used) and the command (Primary to Secondary) or response (Secondary to Primary) (see 4.3.4). Note that the bit pattern for a command may be the same as that for a response, so that a knowledge of direction is necessary to interpret a frame. The control field is formatted as follows. The first format applies to the "single octet" numbered command/response; the second, to the "double octet" numbered command/response (using the extended sequence number); and the third

to the unnumbered command/response.

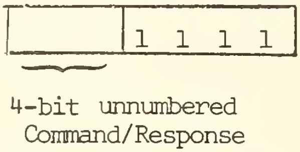
a)



b)



c)



Information Field: A field of length 0 or more bits. The maximum length is unspecified, as is its structure. In particular, it is completely transparent (i.e., code and byte independent), since addressing and commands are positional.

To achieve the transparency mentioned above, a process of bit-stuffing is used to assure that the flag sequence (01111110) does not appear within a frame. This is because a terminal must always check for the flag, either to terminate a frame or to maintain synchronization with other stations. A transmitting station must insert a 0 following five consecutive 1's, and a receiving station must remove it. (The receiving station examines the bit following five consecutive ones; if it is a zero it removes it).

Frame Check Sequence: A 16-bit Cyclic Redundancy Check (CRC) based on the CCITT (V41) polynomial

$$X^{16} + X^{12} + X^{5} + 1$$

This field is computed on the basis of the contents of the address, control, and information fields.

Time-fill between frames is achieved by sending continuous flags or abort sequences (see 4.3.5 below). No provision is made for time-fill during frame transmission.

Address and Control fields are sent low-order bit first, the Frame Check Sequence is sent high-order bit first. Bit-sequencing for the Information field is application-dependent, and is unspecified.

A frame is considered invalid if it is not properly bounded between flags or if it is shorter than the minimum length of 32 bits (exclusive of flags). This allows for an address, control, and frame check sequence with a zero-length information field. Any invalid frame is merely ignored by the receiving station.

4.3.3 State-Variable Description of Terminals

Secondary terminals in an ADCCP link are described by a set of so-called state-variables and parameters which are either integer or boolean valued. Primary terminals have no explicit structure according to the (proposed) standard, but by implication, must have a set of counters and buffers for each secondary on the link. Table 4-5 lists these variables briefly. Each Primary-Secondary unit utilizes a single numbering scheme to coordinate transmission. Each information-containing frame and some others transmitted by the primary is assigned a "sequence number", N, in the range

$$0 \leq N < MOD$$

where MOD is a predefined modulus (in X3S3.4.475, the value is MOD = 16, in the unextended control field). The value of N which follows N = 15 is then N = 0. Note that all values stated below, e.g. N-M, are to be taken modulo MOD.

Variable	Meaning
M	Maximum number of unacknowledged responses that may be stored in Secondary
R	Next expected sequence number
Y	Lowest numbered deferred response in Secondary
Z	Lowest numbered unacknowledged response in Secondary
E	Exception state indicator

Table 4-5. Secondary state-variables and parameters

Parameter: M The parameter, M, defines, for a given secondary, the amount of buffer space available within it for storing unactioned responses (either ones that have been transmitted and not acknowledged, or ones that have been deferred and not requested, or both). Note that this places a burden on the Primary in that this value determines the number of outstanding sequentially numbered commands it may have. For this reason such a command, numbered N, automatically acknowledges a response from the Secondary numbered N-M, and thus frees a buffer in the Secondary. The nominal value of M is in the range

$$0 \leq M < MOD$$

but for efficient operation the value should satisfy

$$M > \text{loop storage factor}$$

the latter being a function of the entire link. Note that this value may vary from Secondary to Secondary on a given link, and that the Primary(s) on the link must know the values for each Secondary.

State-Variable: R This variable gives the sequence number of the next sequentially numbered command expected by the Secondary. Thus, it is incremented by one on receipt of an error-free frame containing such a command. The range of its value is

$$0 \leq R < MOD \ .$$

State-Variable: Y This variable gives the sequence number of the lowest numbered deferred response queued within the Secondary. The range of values is

$$0 \leq Y < MOD$$

and additionally, must satisfy

$$Z \leq Y \leq MOD$$

with Y=R if and only if no deferred responses are presently queued.

State-Variable: Z This variable gives the sequence number of the lowest-numbered unacknowledged affirmative response. Its range of values is

$$R-M \leq Z \leq Y$$

with Y=Z if and only if all responses have been acknowledged.

State-Variable: E This variable is a binary variable which signals the presence of an "Exception State" within the Secondary. The handling of this variable is treated further below in the section on commands and responses. When E=1 (Exception State) there are five possible error conditions described by ADCCP. They are

Frame Check Sequence error
(Short-term Link Level Exception)
Sequence Number error
(Short-term Link Level Exception)
Unspecified temporary error
(Short-term Higher Level Exception)

Format error
(Long-term Link Level Exception)
Unspecified long-term error
(Long-term Higher Level Exception)

4.3.4 Control Procedures

In this section, we briefly describe the individual Primary commands and Secondary responses and indicate their action in terms of the state-variables of the Secondaries. No actual procedures are defined by ADCCP, the presumption being that this is the province of the system designer.

Table 4-6 lists the commands and responses. A single numbering scheme is used to coordinate messages and responses and maintain frame synchronization. A recent proposal by IBM, utilized in SDLC, specifies a "dual" numbering scheme, whereby the Primary and Secondary each maintain (dual) send and receive sequence counters. See 4.3.7.2, below. According to the proposed standard, certain frames are numbered sequentially, using modular arithmetic to increment the counter (see 4.3.2). Other commands and responses are keyed to this sequence.

There are two classes of commands and two of responses. For both cases the distinction is whether or not the sequence numbers are used (see table 4-6). If so, the sequence number of the command or response must be related to the current value of R in a specified way.

Numbered Commands: There are two types of numbered commands, those which use the next available sequence number, and those which use a previous number (which must therefore be in the range

$$R-M \le N \le R$$

modulo MOD).

Commands of the first type are used for transmission of "new" frames. These commands are Sx and Xx. The Sx (SELECT) selects the addressed Secondary and requests that it accept the accompanying information field. The Xx (EXCHANGE) sends a (possibly null) information field in the frame and requests a response from the Secondary containing an information field, if possible. Note that the EXCHANGE command used with a null information field, is equivalent to a "poll" command (present, e.g., in HDLC). Each command has an "immediate" version (X = R) which requires a response, as soon as possible and a "deferred" version (X = D) which instructs the Secondary to queue its response until requested by the Primary. In the case of errors, an appropriate negative response is sent or queued, and if command was a "deferred" one, the Secondary additionally sets its Exception State variable (E).

The other numbered commands use the sequence number, N, to refer to previous frames. The commands are ER, PA, and DR. The ER command

Command/Response	Meaning
Sequentially Numbered Commands	
SR	Select
SD	Delayed Select
XR	Exchange
XD	Delayed Exchange
Other Numbered Commands	
ER	Enquiry
PA	Primary acknowledge
DR	Transmit deferred responses
Unnumbered Commands	
DC	Disconnect
SS	Request status, basic
RS	Reset
Numbered Responses	
AC	Accept
AW	Accept, Wait
AE	Accept enquiry
NF	Not accept, frame check error
NS	Not accept, sequence number error
NL	Not accept, improper format
NT	Not accept, temporary high level exception
NH	Not accept, long term high level exception
Unnumbered Responses	
NN	Not Ready, Send or Receive
TN	Ready Send, Not Ready Receive
NR	Not Ready Send, Ready Receive
TR	Ready, Send or Receive

Source: ANSI X353.4/475 (Seventh Draft) 12/73

Table 4-6. ADCCP Commands and Responses

acknowledges response frames previously transmitted, numbered up to N and requests retransmission of those with larger numbers, if any. The PA command implements a subset of the actions implied by ER. The DR command requests transmission of those deferred responses queued by the Secondary as a result of SD or XD commands.

Unnumbered Commands: These commands (SS, DC, RS) are used to request the status of the addressed Secondary, disconnect the link, or reset the Secondary to its initial state.

Numbered Responses: These responses are used by the Secondary to acknowledge frames transmitted by the Primary, either positively or negatively. There are a sufficient number of each type of acknowledgement to inform the Primary of the secondary status.

Unnumbered Responses: These responses are used by the Secondary to inform the Primary of its status in response to a SS.

Implementation: In implementing an ADCCP link, the configuration must be one of the two specified in 4.3.1 utilizing the format in 4.3.2, and a subset of the above commands and responses. The proposed standard defines a number of classes of procedures by means of the configuration and command/response subset utilized. These classes are summarized in table 4-7.

Primary/Secondary Link
- Deferred Responses, Send and Receive
- Non-deferred Responses, Send and Receive
- Deferred Responses, Receive only
- Deferred Responses, Send only
- Non-deferred Responses, Receive only
- Non-deferred Responses, Send only

Primary/Primary Link
- Deferred Responses, Send and Receive
- Non-deferred Responses, Send and Receive

Table 4-7. Classes of Procedures

Details on the command/response subsets are not presented because the standard is still in draft form. ADCCP is intended to provide a "shopping list" with which to build a communications link. The advantage of the ADCCP approach over that of X3.28 is the common base from which all such systems can grow. The basic design of the terminals and the interpretation of the various fields of the frame must be the same in any "standard" system.

4.3.5 Error Detection

ADCCP provides the 16-bit CRC for detecting errors in transmission. In addition, a Response Timer is specified for the Primary, to detect no response from the Secondary. The sequential numbering scheme also helps detect lost or duplicated frames. An Abort sequence is provided (1111111) which allows a transmitting station to terminate transmission abnormally. The receiving station is expected to ignore an aborted frame.

4.3.6 Error Recovery

No provisions for recovery other than retransmission are made. The negative acknowledgements allow the Primary to decide whether retransmission will correct an error (short-term vs. long-term, and Link level vs. Higher level).

4.3.7 Related Developments

There are several efforts currently underway to develop procedures analogous to ADCCP. ISO is developing its High Level Data Link Control Procedures (HDLC) and IBM has recently announced two systems using their Synchronous Data Link Control Procedures (SDLC), both of which are similar to ADCCP. ISO's HDLC is quite close to the latter, while IBM's SDLC differs from it in a number of respects.

4.3.7.1 High Level Data Link Control (ISO) - This proposal is essentially the same as ADCCP and it is the intent of ANSI to maintain the compatibility of the two proposed standards insofar as it is practicable. According to the most recent drafts, the primary points of difference are in the definitions of some commands and responses and in the prescription of classes of procedures. Specifically, HDLC includes the PR and PD (POLL) commands while ADCCP uses XR and XD (EXCHANGE) to achieve the same results; the ER (ENQUIRY) command, available in both ADCCP and HDLC, has been augmented in the former by the inclusion of the DR (TRANSMIT DEFERRED RESPONSES) command, to simplify some operations. The AI (ACCEPT WITH INFORMATION) command in HDLC has been replaced by the AE (ACCEPT ENQUIRY) command in ADCCP since the AC (ACCEPT) command can accomplish the same results. Finally, ADCCP has gone into some detail in prescribing classes of procedures, whereas HDLC provides none. (In an appendix to HDLC, a "classification" of such classes is presented which is similar in spirit to that in ADCCP; it is not part of the standard.)

4.3.7.2 Synchronous Data Link Control (IBM) - This method of link control, discussed at length in [4-6], is conceptually the same as the other bit-oriented procedures. It utilizes the same frame format as the others and prescribes a uniform set of commands from which to build a communications link. The major points of difference are mainly in the interpretation of the frame fields. Minor differences are the address field, which is not extendable beyond the minimum eight bits, and the frame check sequence, which is computed in a different manner. A recent proposal to ANSI from IBM notes that possible difficulties may arise if this field is computed, as in ADCCP, by setting the field value initially to zero. This remains to be worked out. The major difference between SDLC and the others is in the format of the control field. There are three formats, as follows.

(I)	FI	N_s	P/F	N_r
(S)	FI	S	P/F	N_r
(NS)	FI	M	P/F	M

The FI field, common to all, dictates the interpretation of the remaining fields. It has three values, indicating an information transfer (I), supervisory (S), or non-sequenced (NS) frame. In the first case, the remaining fields are:

N_s: Send Sequence Number
P/F: Poll command (from Primary)
Last Frame flag (from Secondary)
N_r: Receive Sequence Number

A supervisory frame has fields P/F and N_r as above, and also an S field, which is used to inhibit the transmission of information fields in response frames, request retransmission of frames, or acknowledge the receipt of frames (when transmitted by a Primary) and to indicate a wait state, or acknowledge or request retransmission of information frames (when transmitted by a Secondary). A non-sequenced frame, containing no sequence numbers, has a P/F field as above and "modifier" fields, M, which are used to effect control of the link without changing sequence number counts. The precise definition of the M field is given in [4-6] and relates to the specific use to which IBM intends to put SDLC.

The I format above indicates another difference between SDLC and the others, namely the use of "dual" numbering scheme. In this scheme, a Primary-Secondary pair maintains a pair of sequence number counts, one for frames sent and one for frames received. The counts are dual in the sense that the send count for one station should agree with the receive count for the other.

Additional differences are present in the operation of individual links, and are primarily due to the more immediate needs of IBM as compared to the more general audience hopefully to be served by the standards organizations.

4.4 References

4-1 Stutzman, B. W.,
"Data Communication Control Procedures",
Computer Surveys, 4, 4, 12 72, pp. 197-220

4-2 Grubb, D. S.,
"Data Communications System Throughput Performance Using High Speed Terminals on the Dial Telephone Network",
NBS Tech. Note 770, 5/73

4-3 Interface Message Processor,
BBN Report 1822, 4/72

4-4 PWIN Communications Software Programming Specifications,
N341, 3/73

4-5 Binary Synchronous Communications,
IBM Corp., Order No. GA27-3004-2, 10/70

4-6 Donnan, R. A., and J. Ray Kersey,
"Synchronous Data Link Control: A Perspective",
IBM Systems J., 13, 2,1974,
pp. 140-162

4-7 Proceedings of the SJCC, Spring, 1972, pp. 243-298,
AFIPS Press, 1972

Standards

1. ANSI X3.28-1971
Procedures for the use of the Communication Control Characters of American National Standard Code for Information Interchange in Specified Data Communication Links
American National Standards Institute

2. ANSI X3S3.4/437 (project 48) 9/71
Proposed Draft Revision of X3.28
American National Standards Institute

3. ANSI X3S3.4/475 (Seventh Draft) 12/73
Advanced Data Communication Control Procedures
American National Standards Institute

4. ANSI X3S35/80 Dept. X3
American National Standards Institute

5. CCITT V41
Code-independent Error Control Systems,
International Telecommunications Union

6. ISO R1155-1969
The use of Longitudinal Parity to Detect Errors in Information Messages
International Organization for Standardization

7. ISO R1745-1971
Basic Mode Control Procedures for Data Communications Systems
International Organization for Standardization

8. ISO R2111-1972
Data Communication - Basic Mode Control Procedures - Code Independent Information Transfer
International Organization for Standardization

9. ISO R2629-1973
Basic Mode Control Procedures: Conversational Information Transfer
International Organization for Standardization

10. ISO/TC 97/SC 6, N794, 6/73
Proposed Draft on Commands and Responses, High Level Data Link Control Procedures
International Organization for Standardization

11. ISO/TC 97/SC 6, N731,
Proposed Draft on Frame Structure Definition, High Level Data Link Control Procedures
International Organization for Standardization

12. ECMA-16, 1973
Basic Mode Control Features for Data Communication Systems using the ECMA 7-bit Code
European Computer Manufacturer's Association

13. ECMA-24, 1969
Code Independent Information Transfer (Extension of Basic Mode)
European Computer Manufacturer's Association

14. ECMA-26, 1971
Recovery Procedures (Extension of Basic Mode)
European Computer Manufacturer's Association

15. ECMA-27, 1971
Abort and Interrupt Procedures (Extension of Basic Mode)
European Computer Manufacturer's Association

16. ECMA-28, 1971
Multiple Station Selection Procedures (Extension of Basic Mode)
European Computer Manufacturer's Association

17. ECMA-29, 1971
Conversational Information Transfer (Extension of Basic Mode)
European Computer Manufacturer's Association

18. ECMA-37, 1972
Supplementary Transmission Control Functions (Extension of Basic Mode)
European Computer Manufacturer's Association

5. GLOSSARY OF TERMS

ASCII - Abbr: American Standard Code for Information Interchange.

AUXILIARY CHANNEL - A secondary channel whose direction of transmission is independent of the primary channel and is controlled by an appropriate set of secondary control interchange circuits.

BACKWARD CHANNEL - A secondary channel whose direction of transmission is constrained to be always opposite to that of the primary channel. The direction of transmission of the backward channel is restricted by the control interchange circuit that controls the direction of transmission of the primary channel.

BACKWARD SUPERVISION - The use of supervisory sequences from a secondary to a primary station or node.

BAUD - The unit of modulation rate. It corresponds to a rate on one unit interval per second. Example: If the duration of the unit is 20 milliseconds, the modulation rate is 50 bauds.

BINARY DIGIT - In the binary notation, either of the characters 0 or 1.

BIT - Abbreviations for binary digit.

BLOCK - A group of digits transmitted as a unit, over which a coding procedure is usually applied for synchronization or error control purposes.

BYTE - A binary element string operated upon as a unit and usually shorter than a computer word, e.g., six bit, eight bit, or nine bit bytes.

CHARACTER INTERVAL - In start-stop operation the duration of a character expressed as the total number of unit intervals (including information, error checking and control bits and the start and stop elements) required to transmit any given character in any given communications system.

CODE - (1) A set of unambiguous rules specifying the way in which data may be represented, e.g., the set of correspondences in the Standard Code for Information Interchange. (2) In telecommunications, a system of rules and conventions according to which the signals representing data can be formed, transmitted, received and processed. (3) In data processing, to represent data or a computer program in a symbolic form that can be accepted by a data processor.

CODE EXPANSION - In character oriented data link control procedures, the changing of a character code by enlargement of the code table, as from a 7 bit code to an 8 bit code.

CODE EXTENSION - In character oriented data link control procedures, the provision of additional character codes by means of escape sequences, the "shift in", and "shift out" characters.

COMMUNICATION CONTROL CHARACTER - In ASCII a functional character intended to control or facilitate transmission over data networks. There are ten control characters specified in ASCII which form the basis for character oriented communications control procedures.

CONTENTION - A condition on a communications channel when two or more stations try to gain control at the same time.

CONTINUOUS START-STOP OPERATION - The method of operation in a start-stop system in which the signals representing a series of characters follow one another at the nominal character rate, (e.g. in sending steadily from a perforated paper tape as compared to manual keyboard operation). Note: Under these conditions, the character intervals will have their nominal durations.

CONTROL CHARACTER - (1) A character whose occurrence in a particular context initiates, modifies, or stops a control function. (2) In the ASCII code, any of the 32 characters in the first two columns of the Standard Code table.

CONTROL PROCEDURE - The means used to control the orderly communication of information between stations on a data link.

CONTROL STATION - The station on a network which supervises the network control procedures such as polling, selecting and recovery. It is also responsible for establishing order on the line in the event of contention, or any other abnormal situation, arising between any stations on the network.

DATA LINK - An assembly of terminal installations and the interconnecting circuits operating according to a particular method that permits information to be exchanged between terminal installations. Note: The method of operation is defined by particular transmission codes, transmission modes, direction, and control.

DATA TRANSMISSION CHANNEL - The transmission media and intervening equipment involved in the transfer of information between data terminal equipments. A data transmission channel includes the signal conversion equipment. A data transmission channel may support the transfer of information in one direction only, in either direction alternately, or in both directions simultaneously and the channel is accordingly classified. When the data communications equipment has more than one speed capability associated with it, for example 1200 baud transmission in one direction and 150 baud transmission in the opposite direction, a channel is defined for each speed capability.

DEDICATED LINE - A communications channel which is nonswitched, i.e., which is permanently connected between two or more data stations. These communication channels are also referred to as "leased" or "private"; however, since leased and private switched networks do exist, the term "dedicated" is preferred herein to define a nonswitched connection between two or more stations.

DEGREE OF GROSS START-STOP DISTORTION - The degree of start-stop distortion determined using the unit interval which corresponds exactly to the assigned modulation rate of the system.

DEGREE OF DISTORTION (at the digital interface) - A measure of the time displacement of the transitions between signal states from their ideal instants. The degree of distortion is generally expressed as a percentage of the unit interval.

DEGREE OF INDIVIDUAL DISTORTION (of a particular signal transition) - The ratio to the unit interval of the displacement, expressed algebraically, of this transition from its ideal instant (late).

DEGREE OF ISOCHRONOUS DISTORTION - (1) Ratio to the unit interval of the maximum measured difference, irrespective of sign, between the actual and the theoretical intervals separating any two transitions of modulation, these transitions being not necessarily consecutive. (2) Algebraical difference between the highest and lowest value of individual distortion affecting the transitions of an isochronous modulation. (This difference is independent of the choice of the reference ideal instant.) The degree of distortion of an isochronous modulation is usually expressed as a percentage.

DEGREE OF PEAK INDIVIDUAL DISTORTION - The maximum individual distortion, irrespective of sign, of all significant instants occuring during a particular measuring period.

DEGREE OF START-STOP DISTORTION - The ratio to the unit interval of the maximum measured difference, irrespective of sign, between the actual interval and the theoretical interval (the appropriate integral multiple of unit intervals) separating any transition from the start transition preceding it.

DEGREE OF SYNCHRONOUS START-STOP DISTORTION - The degree of start-stop distortion determined using the unit interval which corresponds to the actual mean modulation rate of the signal involved.

DUPLEX CHANNEL (FULL DUPLEX CHANNEL) - A primary or secondary channel capable of operating in both directions simultaneously. The term duplex used to describe a primary channel does not imply anything about the type of secondary channel or the existence of a secondary channel; similarly, the use of the term to describe a secondary channel implies nothing about the type of primary channel present. (Note that a full duplex channel has the same signaling rate capability in both directions.

A system with different rates would be considered to be a one way only primary channel in one direction and a one way only secondary channel in the opposite direction.)

DRIVER - The electronic circuitry or relay contact at the transmitting end (source) of an interchange circuit which transmits binary digital signals to a terminator via an interconnecting cable.

ESCAPE SEQUENCE - In character oriented data link control procedures, a sequence of characters, starting with the "escape character", and followed by specified characters to establish additional character codes, or code sets.

FORWARD SUPERVISION - Use of supervisory sequences sent from the primary to a secondary station or node.

HALF DUPLEX CHANNEL - A primary or secondary channel capable of operating in both directions, but not simultaneously. The direction of transmission is reversible. The term half duplex used to describe a primary channel does not imply anything about the type of secondary channel; similarly, the use of the term to describe a secondary channel implies nothing about the type of primary channel present. (Note that as a result of the definitions, both directions of a half duplex channel have the same signaling rate capability.)

HEADER - The control information prefixed to a message text, e.g., source or destination code, priority, or message type.

HEADING - See HEADER.

IDEAL INSTANT OF A MODULATION - Instants with which the significant instants would coincide under certain ideal conditions.

INTERCHANGE CIRCUIT - A circuit between the data terminal equipment and the data communication equipment for the purpose of exchanging data, control or timing signals.

LEADER - See HEADER.

LINK - (1) Any specified relationship between two nodes in a network. (2) A communications path between two nodes. (3) A data link.

MASTER STATION - Syn: Primary Station.

MODULATION RATE - 1) Reciprocal of the unit interval measured in seconds. This rate is expressed in bauds. (2) The number of unit intervals per second, as long as the modulation rate is maintained without stopping.

MULTI-POINT CONNECTION - A configuration in which more than two terminal installations are connected.

NONSYNCHRONOUS DATA TRANSMISSION CHANNEL - A data channel in which no timing information is transferred between the data terminal equipment and the data communication equipment.

ONE-WAY ONLY OPERATION - A mode of operation of a data link in which data are transmitted in a preassigned direction over one channel.

ONE WAY ONLY (UNIDIRECTIONAL) CHANNEL - A primary or secondary channel capable of operation in only one direction. The direction is fixed and cannot be reversed. The term "one way only" used to describe a primary channel does not imply anything about the type of secondary channel or the existence of a secondary channel; similarly, the use of the term to describe a secondary channel implies nothing about the type of primary channel present.

PACKET - A group of binary digits including data and control elements which is switched and transmitted as a composite whole. The data and control elements and possibly error control information are arranged in a specified format.

POINT-TO-POINT CONNECTION - (1) A network configuration in which a connection is established between two, and only two, terminal installations. The connection may include switching facilities. (2) A circuit connecting two points without the use of any intermediate terminal or computer.

POLLING - The process of inviting another station or node to transmit data.

PRIMARY CHANNEL - The data transmission channel having the highest signaling rate capability of all the channels sharing a common interface connector. A primary channel may support the transfer of information in one direction only, either direction alternately or both directions simultaneously and is then classified as "one way only", "half duplex" or "duplex".

PRIMARY (LINK CONTROLLER) - In bit oriented data link control procedures, that part of the DTE which controls the data link, i.e. performs initialization, controls data flow, and initiates recovery procedures.

PRIMARY STATION - (1) The station which at any given instant has the right to select and to transmit information to a secondary station, and the responsibility to insure information transfer. There should be only one primary station on a data link at one time. (2) A station which has control of a data link at a given instant. The assignment of primary status to a given station is temporary and is governed by standardized control procedures. Primary status is normally conferred upon a station so that it may transmit a message, but a station need not have a message to be nominated primary station.

PROTOCOL - A formal set of conventions governing the format and relative timing of message exchange between two communicating processes.

SECONDARY CHANNEL - The data transmission channel having a lower signaling rate capability than the primary channel in a system in which two channels share a common interface connector. A secondary channel may be either one way only, half duplex or duplex as defined later. Two classes of secondary channels are defined, auxiliary and backward.

SECONDARY (LINK CONTROLLER) - In bit oriented data link control procedures, that part of the DTE which is controlled by a primary, i.e. executes commands from the primary, and responds when appropriate.

SECONDARY STATION - A station that has been selected to receive a transmission from the primary station. The assignment of secondary status is temporary, under control of the primary station, and continues for the duration of a transmission.

SELECTING - A process of inviting another station or node to receive data.

SIGNAL CONVERSION EQUIPMENT - Those portions of the data communication equipment which transform (e.g., modulate, shape, etc.) the data signals exchanged across the interface into signals suitable for transmission through the associated communication media or which transform (e.g., demodulate, slice, regenerate, etc.) the received line signals into data signals suitable for presentation to the data terminal equipment.

SIGNAL ELEMENT - Each of the parts of a digital signal, distinguished from others by its duration, position and sense, or by some of these features only. A signal element has as a minimum a duration of one unit interval. If several unit intervals of the same sense run together, a signal element of duration of more than one unit element may be formed. Signal elements may be start elements, information elements or stop elements.

SIGNIFICANT INSTANTS OF A MODULATION - Instants limiting significant intervals of modulation.

SIGNIFICANT INTERVAL OF A MODULATION - A time interval during which a given significant condition should be maintained, based on the code and the signal to be transmitted.

START ELEMENT - In a character transmitted in a start-stop system, the first element in each character, which serves to prepare the receiving equipment for the reception and registration of the character. The start element is a spacing signal.

START-STOP SYSTEM - A system in which each group of code elements corresponding to a character is preceded by a start element which serves to prepare the receiving equipment for the reception and registration of a character, and is followed by a stop element during which the equipment comes to rest in preparation for the reception of the next character.

START TRANSITION - In a character transmitted in a start-stop system, the mark-to-space transition at the beginning of the start element.

STOP ELEMENT - In a character transmitted in a start-stop system, the last element in each character, to which is assigned a minimum duration, during which the receiving equipment is returned to its rest condition in preparation for the reception of the next character. The stop element is a marking signal.

SYNCHRONOUS DATA TRANSMISSION CHANNEL - A data channel in which timing information is transferred between the data terminal equipment and the data communication equipment. Transmitter signal element timing signals can be provided by either the data terminal equipment or by the data communication equipment. Receiver signal element timing is normally recovered in and provided by the data communication equipment. A synchronous data channel will not accommodate start-stop data signals unless they are transmitted isochronously and timing signals are interchanged at least at the transmitting station.

SYNCHRONOUS SYSTEM - A system in which the sending and receiving data processing terminal equipments are operating continuously at substantially the same frequency, and are maintained in a desired phase relationship by an appropriate means.

TERMINAL - (1) A point in a communications network at which data can either enter or leave. (2) A device that permits data entry into or data exit from a computer system or computer network, e.g., a data capture device, a teletypewriter, a remote job entry device, or a computer. Terminals may accommodate data in human or machine readable form.

TERMINATOR - The electronic circuitry at the receiving end (sink) of an interchange circuit which receives binary digital signals from a driver via an interconnecting cable.

TEXT - (1) A sequence of characters forming part of a transmission which is sent from the data source to the data sink, and contains the information to be conveyed. It may be preceded by a header and followed by an end of text signal. (2) In ASCII and communications, a sequence of characters, treated as an entity if preceded by a start of text and followed by an "end of text" or "end of block" control character.

TRANSPARENCY - A property of a communications medium to pass within specified limits a range of signals having one or more defined proper ties, e.g., a channel may be code transparent, or an equipment may be bit pattern transparent.

TRIBUTARY STATION - A station on a data link that is not a control station.

TWO WAY ALTERNATE OPERATION - A mode of operation of a data link in which data may be transmitted in both directions, one way at a time.

TWO WAY SIMULTANEOUS OPERATION - A mode of operation of a data link in which data may be transmitted simultaneously in both directions over two channels. Note: One of the channels is equipped for transmission in one direction while the other is equipped for transmission in the opposite direction.

UNIT ELEMENT - A signal element of one unit element duration.

UNIT INTERVAL - The longest interval of time such that the nominal durations of the signal elements in a synchronous system or the start and information elements in a start-stop system are whole multiples of this interval. (Note: A unit interval is the shortest nominal signal element.)

UNIT INTERVAL - A unit interval is the duration of the shortest nominal signal element. It is the longest interval of time such that the nominal durations of the signal elements in a synchronous system or the start and information elements in a start-stop system are whole multiples of this interval. The duration of the unit interval (in seconds) is the reciprocal of the modulation rate, expressed in bauds.

☆U.S. GOVERNMENT PRINTING OFFICE: 1974-583-010/9

NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBS TN-843	2. Gov't Accession No.	3. Recipient's Accession No.
4. TITLE AND SUBTITLE A TECHNICAL GUIDE TO COMPUTER-COMMUNICATIONS INTERFACE STANDARDS			5. Publication Date August 1974
			6. Performing Organization Code
7. AUTHOR(S) Albrecht J. Neumann, Brian G. Lucas, Justin C. Walker, Dennis W. Fife			8. Performing Organ. Report No.
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234			10. Project/Task/Work Unit No. 640-1400
			11. Contract/Grant No.
12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)* Joint Technical Support Activity Defense Communications Agency Washington, D. C. 20305			13. Type of Report & Period Covered
			14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

Library of Congress Catalog Card Number: 74-600131

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

A technical summary and guide is given for existing and forthcoming Federal and National standards on data communications pertinent to computer networking. Selected international standards and industry practices are included for completeness. Prepared to assist the application of standards within the World Wide Military Command and Control System, this handbook should be useful to all ADP system designers interested in uniform data terminal interfaces, character sets and codes, keyboard arrangements, and communications line disciplines for effective message exchange between computers.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

ADP standards; communications disciplines; computer networks; data communications.

18. AVAILABILITY	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
[X] Unlimited	UNCLASSIFIED	111
[ ] For Official Distribution. Do Not Release to NTIS		
[X] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13.46:843	20. SECURITY CLASS (THIS PAGE)	22. Price
[ ] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151	UNCLASSIFIED	$1.50

USCOMM-DC 29042-P74

INSTRUCTIONS

FORM NBS-114A: BIBLIOGRAPHIC DATA SHEET (REVERSE SIDE). This Bibliographic Data Sheet is an NBS adaptation of the form prescribed by COSATI guidelines (Appendix F. NBS Manual for Scientific and Technical Communications). Please complete with extreme care. This sheet will provide the basis for the literature citation of the publication, and in most cases it will become an integral part of the final publication itself.

A. Complete item 1 if information is available; otherwise, OTP will complete later. If non-NBS publication, state:"see item 15". (Additional instructions under K below.)

B. Ignore items 2, 3, 6, and 14; these are reserved for possible future use.

C. Complete items 4 and 7. When NBS-114A is resubmitted these items must be as they will actually appear on the published paper.

D. Leave items 5, 21, and 22 blank; OTP will complete.

E. Items 9, 19, and 20 are preprinted; you need add nothing.

F. Complete items 10, 11, and/or 12 when applicable. If no sponsor is involved, in item 12 state: same as item 9.

G. For item 13, enter "Final" or "Interim" and calendar period covered, as appropriate.

H. For item 15, enter other relevant information. (For example, upon receipt of completed Form NBS-266 from author, OTP will enter the complete citation for NBS-authorized papers published in non-NBS media.)

I. Complete items 16 and 17. Guidance is given in Section 4 and Appendix B of the NBS Manual for Scientific and Technical Communications. The abstract must agree with the one of the published paper.

J. For item 18, indicate one of the following: "Unlimited" - for open-literature documents cleared under NBS editorial procedures, or "For official distribution. Do not release to NTIS" - for limited, restricted, or need-to-know material. (See 5.1.4.2.1 of Brady memo dated January 16, 1973 "Reports to Sponsors.")

K. In completing item 1, use the brief designators shown in the right-hand column below. Each designator will be followed by the specific publication number for that item. This number will be the same in both the longer and briefer designators for the same document. For example: NBS Technical Note 548 will be equivalent to NBS TN-548. You would enter NBS TN-548 in item 1 of Form NBS-114A.

NBS Identification

NBS Technical Note	NBS TN-
NBS Monograph	NBS MN-
NBS Handbook	NBS HB-
NBS Special Publication	NBS SP-
NBS Applied Mathematics Series	NBS AMS-
NBS National Standard Reference Data Series	NBS NSRDS-
NBS Building Science Series	NBS BSS-
NBS Federal Information Processing Standards Publication	NBS FIPS-
NBS Voluntary Product Standards	NBS PS-
NBS Consumer Information Series	NBS CIS-
NBS Journal of Research Section A	NBS JRA-
NBS Journal of Research Section B	NBS JRB-
NBS Dimensions	NBS D-
NBS Interagency or Internal Report *	NBS IR-

Since each paper in the two volume NBS Journal of Research is assigned a specific designator, OTP will add appropriate Journal designator for item 1.

*If the outside sponsor assigned his own number, enter his number in item 1, and the NBSIR number in item 8.

NBS TECHNICAL PUBLICATIONS

PERIODICALS

JOURNAL OF RESEARCH reports National Bureau of Standards research and development in physics, mathematics, and chemistry. Comprehensive scientific papers give complete details of the work, including laboratory data, experimental procedures, and theoretical and mathematical analyses. Illustrated with photographs, drawings, and charts. Includes listings of other NBS papers as issued.

Published in two sections, available separately:

• Physics and Chemistry (Section A)

Papers of interest primarily to scientists working in these fields. This section covers a broad range of physical and chemical research, with major emphasis on standards of physical measurement, fundamental constants, and properties of matter. Issued six times a year. Annual subscription: Domestic, $17.00; Foreign, $21.25.

• Mathematical Sciences (Section B)

Studies and compilations designed mainly for the mathematician and theoretical physicist. Topics in mathematical statistics, theory of experiment design, numerical analysis, theoretical physics and chemistry, logical design and programming of computers and computer systems. Short numerical tables. Issued quarterly. Annual subscription: Domestic, $9.00; Foreign, $11.25.

DIMENSIONS/NBS (formerly Technical News Bulletin)—This monthly magazine is published to inform scientists, engineers, businessmen, industry, teachers, students, and consumers of the latest advances in science and technology, with primary emphasis on the work at NBS.

DIMENSIONS/NBS highlights and reviews such issues as energy research, fire protection, building technology, metric conversion, pollution abatement, health and safety, and consumer product performance. In addition, DIMENSIONS/NBS reports the results of Bureau programs in measurement standards and techniques, properties of matter and materials, engineering standards and services, instrumentation, and automatic data processing.

Annual subscription: Domestic, $6.50; Foreign, $8.25.

NONPERIODICALS

Monographs—Major contributions to the technical literature on various subjects related to the Bureau's scientific and technical activities.

Handbooks—Recommended codes of engineering and industrial practice (including safety codes) developed in cooperation with interested industries, professional organizations, and regulatory bodies.

Special Publications—Include proceedings of high-level national and international conferences sponsored by NBS, precision measurement and calibration volumes, NBS annual reports, and other special publications appropriate to this grouping such as wall charts and bibliographies.

Applied Mathematics Series—Mathematical tables, manuals, and studies of special interest to physicists, engineers, chemists, biologists, mathematicians, computer programmers, and others engaged in scientific and technical work.

National Standard Reference Data Series—Provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated. Developed under a world-wide program coordinated by NBS. Program under authority of National Standard Data Act (Public Law 90-396). See also Section 1.2.3.

Building Science Series—Disseminates technical information developed at the Bureau on building materials, components, systems, and whole structures. The series presents research results, test methods, and performance criteria related to the structural and environmental functions and the durability and safety characteristics of building elements and systems.

Technical Notes—Studies or reports which are complete in themselves but restrictive in their treatment of a subject. Analogous to monographs but not so comprehensive in scope or definitive in treatment of the subject area. Often serve as a vehicle for final reports of work performed at NBS under the sponsorship of other government agencies.

Voluntary Product Standards—Developed under procedures published by the Department of Commerce in Part 10, Title 15, of the Code of Federal Regulations. The purpose of the standards is to establish nationally recognized requirements for products, and to provide all concerned interests with a basis for common understanding of the characteristics of the products. The National Bureau of Standards administers the Voluntary Product Standards program as a supplement to the activities of the private sector standardizing organizations.

Federal Information Processing Standards Publications (FIPS PUBS)—Publications in this series collectively constitute the Federal Information Processing Standards Register. The purpose of the Register is to serve as the official source of information in the Federal Government regarding standards issued by NBS pursuant to the Federal Property and Administrative Services Act of 1949 as amended, Public Law 89-306 (79 Stat. 1127), and as implemented by Executive Order 11717 (38 FR 12315, dated May 11, 1973) and Part 6 of Title 15 CFR (Code of Federal Regulations). FIPS PUBS will include approved Federal information processing standards information of general interest, and a complete index of relevant standards publications.

Consumer Information Series—Practical information, based on NBS research and experience, covering areas of interest to the consumer. Easily understandable language and illustrations provide useful background knowledge for shopping in today's technological marketplace.

NBS Interagency Reports—A special series of interim or final reports on work performed by NBS for outside sponsors (both government and non-government). In general, initial distribution is handled by the sponsor; public distribution is by the National Technical Information Service (Springfield, Va. 22151) in paper copy or microfiche form.

Order NBS publications (except Bibliographic Subscription Services) from: Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

BIBLIOGRAPHIC SUBSCRIPTION SERVICES

The following current-awareness and literature-survey bibliographies are issued periodically by the Bureau:

Cryogenic Data Center Current Awareness Service (Publications and Reports of Interest in Cryogenics). A literature survey issued weekly. Annual subscription: Domestic, $20.00; foreign, $25.00.

Liquefied Natural Gas. A literature survey issued quarterly. Annual subscription: $20.00.

Superconducting Devices and Materials. A literature survey issued quarterly. Annual subscription: $20.00. Send subscription orders and remittances for the preceding bibliographic services to the U.S. Department of Commerce, National Technical Information Service, Springfield, Va. 22151.

Electromagnetic Metrology Current Awareness Service (Abstracts of Selected Articles on Measurement Techniques and Standards of Electromagnetic Quantities from D-C to Millimeter-Wave Frequencies). Issued monthly. Annual subscription: $100.00 (Special rates for multi-subscriptions). Send subscription order and remittance to the Electromagnetic Metrology Information Center, Electromagnetics Division, National Bureau of Standards, Boulder, Colo. 80302.

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Washington, D.C. 20234

OFFICIAL BUSINESS

Penalty for Private Use, $300

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE
COM-215

U.S.MAIL