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PRELIMINARY

Bell System Data Communications
TECHNICAL REFERENCE

DATAPHONE® SWITCHED DIGITAL SERVICE CHANNEL INTERFACE SPECIFICATIONS

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ENGINEERING MANAGER – DATA NETWORK SERVICES

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NOTICE

If further information is required, please contact:

Engineering Manager - Data Network Services
American Telephone and Telegraph Company
295 North Maple Avenue
Basking Ridge, New Jersey 07920

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1. SWITCHED DIGITAL DATA SYSTEM - GENERAL

This document describes the Bell System Switched Digital Data System (SDDS), which is utilized to provide DATAPHONE® Switched Digital Service, and the interface between the channel termination equipment of the SDDS, contained in a Channel Service Unit (550A - type CSU), and the customer's data terminal equipment. There are three sections:

- Section 1 - Briefly describes the SDDS, introduces the CSU and covers design objectives, system parameters, testing and maintenance considerations.
- Section 2 - Covers technical details on the channel interface specifications.
- Section 3 - Covers system operation for SDDS, including station addresses, the Not Ready condition and operating procedures.

1.1 Service Provided

The SDDS provides common user, switched, duplex* data transmission service at the synchronous data rate of 56 kilobits per second (kb/s). No alternate voice or voice coordination is provided. Data transfer to and from the customer must be synchronized with the network timing control system.

Multiline hunting is available on an optional basis with DATAPHONE Switched Digital Service. Among a group of SDDS stations in a Switched Digital Serving Area, which are designated by the customer to be in a multiline hunting group, the system hunts for an idle station in an attempt to complete an incoming call. Hunting takes place whenever a station in a multiline hunting group is called, but is

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* Duplex operation, also called full-duplex operation, is the transmission of signals in both directions simultaneously.

busy or signaling that it is not ready to receive calls. The type of multiline hunting provided by the SDDS is called terminal hunting. Terminal hunting is carried out in a prescribed sequence, with the sequence dependent on the station addresses and which station is being called. Stations having CSUs and stations having Data Service Units (501A - type DSUs), which are described in Section 1.2.2, may belong to the same multiline hunting group. Further information on multiline hunting groups and their station addresses is provided in Section 3.1.

1.2 System Description

The SDDS, shown schematically in Figure 1, is functionally discrete from but physically integrated into the existing Bell System network. This concept allows SDDS to share the Bell System's extensive routing flexibility and 24-hour maintenance coverage.

The SDDS will use the hierarchy of digital transmission systems. Cable routes and T1 digital systems are currently deployed in many metropolitan areas. They provide a basic means of distributing service within the network's Switched Digital Serving Areas. In addition, radio and coaxial systems are used to interconnect the various Switched Digital Serving Areas into a nationwide network.

1.2.1 Channel Service Unit (550A - type CSU) Interface

The basic customer interface unit for an SDDS access line* is the 550A-type Channel Service Unit (CSU). This unit, pictured in Figure 2, provides the ability to quickly and decisively test (remotely from a Telephone Company test center) an SDDS access line up to the point of interface with the customer. The CSU is essential for this purpose and contains the minimum amount of hardware required.

A six-wire interface permits the customer to connect his data communication equipment to an SDDS access line. When interfaced with the CSU, the customer's equipment must perform the following functions:

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* Access lines are dedicated duplex SDDS channels between individual stations and their associated switches.

1. Proper coding and decoding of signals
2. Timing recovery
3. Synchronous sampling
4. Formatting
5. Generation and recognition of control signals
6. Call origination
7. Call addressing
8. Call answering
9. Call termination

The specifications for these functions are contained in Sections 2 and 3 of this Technical Reference.

1.2.2 Data Service Unit and Manual Call Controller

At the option of the customer, the Bell System can provide a unit that performs the signal-related functions listed above, and one that permits the call handling functions to be performed manually. The Data Service Unit (501A - type DSU) and Manual Call Controller (821A - type Data Auxiliary Set) are described in the Technical Reference, "DATAPHONE Switched Digital Service Data Service Unit Interface Specifications" (PUB 41452). The DSU includes the functions of the CSU along with the additional circuitry necessary to provide an EIA RS-366 Automatic Calling Interface and an EIA RS-232-C Data Interchange Interface, except for the electrical characteristics of the data and timing circuits, which conform to CCITT Recommendation V.35. The Manual Call Controller (provided as an option) permits an attendant to originate, answer and terminate calls manually and to place the station in the automatic control mode when desired.

1.2.3 Office Channel Unit (OCU)

The DSU (or CSU working in conjunction with customer-provided equipment) transmits data over cable pairs to an SDDS office. In the office, this local loop is terminated by an Office Channel Unit (OCU). The functions of the OCU are to:

1. Transmit regenerated outgoing loop signals to the station;

2. Reshape, retime and regenerate incoming loop signals;

3. Assemble the data into a format suitable for multiplexing and switching;

4. Transmit and detect control signals with bipolar violations (see Section 2).

1.2.4 Time-Division Multiplexing

The SDDS uses synchronous time-division multiplexing to pack the data for efficient transmission between SDDS offices. The same structure is used to demultiplex the streams, with each of the equipment pieces performing the reverse of the function it performs in the multiplexing process. Since this is a duplex system (it has independent paths for both directions of transmission), multiplexing and demultiplexing take place simultaneously.

1.2.5 Network Synchronization

A timing control network is employed in the SDDS to ensure that data signals are synchronous. This means that sampling takes place at the same frequency throughout the network.

The synchronous timing control for the network is derived from a single master supply. The timing is distributed to each digital equipment location through a tree-like timing network. This network is an important part of the Switched Digital Data System. The timing supplies provide timing for the data multiplexers, Office Channel Units and other office terminals. Timing is transmitted to the station by means of the bipolar bit stream, which has a sufficient number of pulses to permit timing recovery.

The timing system is designed so that phase jitter and phase hits do not propagate through the network. If branches of the timing tree become severed, the individual timing supplies continue without interruption.

1.3 Design Objectives and System Parameters

The Switched Digital Data System (SDDS) is intended to provide an excellent communications medium for the transfer and switching of digital data between customer terminals. This leads to a set of design objectives which are aimed at the primary concerns that a data customer has about the communication system which he uses.

Overall performance will depend on the characteristics of the data terminal equipment provided and maintained by the customer as well as the characteristics of the SDDS. The quantitative objectives listed below apply to the SDDS exclusively.

1.3.1 Design Objectives

The following are Preliminary Design Objectives only and are not to be construed as performance guarantees. The objectives are subject to change as experience with the SDDS dictates.

1.3.1.1 Quality

The objective is to provide an average performance exceeding 99.5 percent error-free seconds. Quality is the fraction of one-second intervals that are error-free during transmission of customer data.

1.3.1.2 Access Availability

The objective is to provide at least 99.98 percent access availability, which translates to an average annual downtime of 105 minutes. Access availability is the ability of the system to provide a Proceed to Select* signal to the station in response to a Call Request* signal from the station, and to present an incoming call to the station. It should be noted that this average is that value which would be observed over a period of several years. Some of the causes of downtime are failures which occur infrequently but which may have long outages associated with them when

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* The Call Request and Proceed to Select signals are analogous to going off-hook and receiving dial tone in telephone service.

they do occur. While these infrequent long outages represent small contributions to the long-term average, they may significantly affect the downtime seen in a shorter period of time (even as long as a year).

1.3.1.3 "Dial Tone" Delay

The objective is that at least 99 percent of the call attempts should experience a "dial tone" delay less than 3 seconds. "Dial tone" delay is defined as the time between a Call Request* signal and a Proceed to Select* signal at the originating station.

1.3.1.4 Call Setup Time

The objective is that the network average call setup time not exceed 3 seconds. The call setup time is defined as the time between transmission of the End of Address signal and establishment of a data connection (excluding customer delays in answering).

1.3.1.5 Call Teardown Time

The objective is that the call teardown time be less than 100 milliseconds. Call teardown time is defined as the time between a Clear Request** signal and a Clear Confirmation** signal at the station originating the Clear Request signal.

1.3.2 System Parameters

The objectives for DATAPHONE Switched Digital Service are given in Section 1.3.1. However, it is felt that two

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* The Call Request and Proceed to Select signals are analogous to going off-hook and receiving dial tone in telephone service.

** Either station may originate the Clear Request signal. It is analogous to going on-hook during a call in telephone service. The Clear Confirmation signal from the network indicates that the call has been disconnected and that the system is ready to process new call attempts from the station.

parameters of the SDDS, which are not specified, are also useful in aiding the customer in appropriately implementing software, administrative procedures, etc. These parameters, propagation delay and network blocking, are discussed in this section.

1.3.2.1 Propagation Delay

Propagation delay, the one-way time delay encountered when transmitting data between two stations, is not specified for the SDDS. Normal network reconfigurations, tolerances and alternate routing during heavy traffic periods would make such a specification impractical. However, preliminary estimates, assuming the use of only terrestrial circuits, indicate that the propagation delay between stations in a mature SDDS network should seldom exceed 50 msec. A typical propagation delay between cities that are 1000 airline miles apart is expected to be approximately 15 msec.

1.3.2.2 Network Blocking

The SDDS network* has been engineered to assure that the necessary switching equipment and trunk facilities, which are shared by many customers, will be available for use when a customer places a call. During very busy periods, however, message traffic congestion can occur, and can occasionally prevent a call attempt from being successful. When this happens, the originating station will receive the appropriate call progress code, as described in Section 3.3.1.5. It will then be necessary for the customer to terminate the first call attempt and to originate a second call attempt.

The probability that a call attempt between any two stations will succeed is not specified for the SDDS. Normal network reconfigurations, occasional unusually high traffic peaks and alternate routing during heavy traffic periods would make such a specification impractical. Preliminary estimates, however, indicate that no more than one percent

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* The term "network" includes all parts of the SDDS except the access lines, which are dedicated full-duplex SDDS channels between the individual stations and their associated switches.

of the SDDS calls should require a second attempt due to message traffic congestion.

1.4 Testing and Maintenance Considerations

Testing and maintenance features are an integral part of the SDDS. Test centers can conduct tests with any access line, thus permitting rapid isolation and correction of trouble conditions. The Telephone Company will be aware of most trouble conditions that occur in the SDDS, and repair will be undertaken prior to reports from customers. If the customer suspects an undetected trouble condition in his access line, he should call the number for trouble reporting that is furnished when the channel is installed. A customer reporting procedure that provides indications of specific problems (e.g., no signal, first bit in error, etc.) on the communications channel is a great aid in expediting repairs. It is expected that the reporting customer will assist in analysis of the trouble. It is also expected that the customer will check his terminal equipment for proper operation prior to calling the Telephone Company.

To aid the customer in testing, a 7-digit address called a Digital Test Number will be provided for customer use in testing between his station and the network on a loopback basis. Calls placed to this number will be answered automatically by a Digital Test Line located at the switching center, thus permitting any customer to check out his own call originating procedures and interfaces. After the call is answered, the Digital Test Line will provide a loopback, so that all data transmitted by the calling station will be looped back to the calling station. This permits the customer to monitor the data transmission accuracy of the entire (two-way) connection between his station and the Digital Test Line. When testing is completed, the call should be terminated by the calling station in the same manner as for calls to another customer station.

In the event of trouble the Telephone Company will test the access line. Such tests require the brief removal of customer data. These tests should be infrequent and short, but it is essential to good service that the SDDS user be willing to release his access line when testing is required. Of course, the Telephone Company will not intentionally disturb the channel without first receiving permission from the user to test.

1.4.1 Remote Testing

Most tests of an access line will not require a visit to the user's premises. Remote tests of the access line are under the control of Telephone Company personnel at a test center. They can remotely loop back the access line at the user's premises permitting the Telephone Company to evaluate the access line operation.

1.4.2 Trouble Conditions

When there is a failure in the higher order digital facilities, a call in progress may be disconnected; the failure will be detected automatically, and restoration activities will be initiated. A failure on the local cable pair that carries signals from the OCU to the customer's location is not detected automatically by the SDDS. However, the customer's equipment can detect local loop failure by the absence or distortion of digital signals. If a call is in progress, and there is a failure on the cable pair that is carrying signals to the OCU, the call will be disconnected, and the station will be unable to originate or answer calls. If calls are being disconnected erroneously, or if difficulties are encountered in originating or answering calls, the user should report this to the Telephone Company.

If the customer's equipment detects invalid incoming signals (bipolar violations* for example), the isolated bipolar violations can be interpreted as data ones (or zeros for that matter without much impact on errorrate).

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* Bipolar violation sequences are discussed in Section 2.

If the occurrence rate is high, the trouble should be reported to the Telephone Company. The customer's equipment may continue to transmit, but no harm to the network results if the signal to the CSU is removed.

If the received signal from the network is lost entirely, then synchronism with the network is also lost and reliable transmission from the customer's equipment is impossible, since the CSU has no timing source of its own. This trouble should be reported to the Telephone Company, and the Not Ready Sequence should be transmitted into the network. The signal from the customer's equipment may be removed, or it can be continued. If the customer's equipment operates slightly off frequency (e.g. less than 0.1 percent as a result of no incoming signal to lock on to) no interferences to other services should result. However, the far end will see either single bit "slips" if the frequency error does not exceed the tracking range of the OCU timing recovery, or a high error rate in addition to slips if it exceeds that range. Since the system is designed to operate in frequency lock, the effect of frequency offset on error performance has not been characterized.

2. INTERFACE DESIGN CONSIDERATIONS

This section is directed to those who use the channel interface provided by the CSU described in Section 1.2.1. For the DSU interface described in Section 1.2.2, refer to the Technical Reference, "DATAPHONE Switched Digital Service Data Service Unit Interface Specifications" (PUB 41452).

Detailed specifications for transmission using the SDDS are discussed in this section. Included are the encoding and decoding requirements that the customer's equipment must observe in order to operate over an SDDS access line equipped with a CSU. If a customer chooses to use a DSU, these requirements are met by circuitry within the DSU.

In such cases the following material provides background information about the SDDS.

2.1 Transmission Plan

Baseband, bipolar return-to-zero signaling is used for transmission over the local loop, and is described by the following coding rules: A binary 0 is transmitted as zero volts. A binary 1 is transmitted as either a positive or negative pulse, opposite in polarity to the previous 1. This is known as the alternate polarity rule. An example of bipolar signaling is shown in Figure 3.

Through the use of bipolar violations, additional information capacity is achieved to provide a convenient way of transmitting network control information. A bipolar violation occurs when the alternate polarity rule is violated. For example, the rule is violated if the last 1 was transmitted as a positive pulse, and the next 1 is also transmitted as a positive pulse. Using the following notations, Figure 4 shows a typical bipolar sequence containing bipolar violations.

0 - denotes zero volts transmitted

B - denotes ±E volts (polarity determined by alternate polarity rule)

V - denotes ±E volts (polarity in violation of alternate polarity rule)

2.2 Encoding and Decoding Rules

To be compatible with the SDDS, the transmit and receive data signals must use bipolar violations to indicate control information and zero suppression. The Zero Suppression sequence is necessary because long sequences of zeros do not provide the transitions necessary to maintain timing recovery. The encoding and decoding rules that the customer must follow are outlined below. The notation is the same as in Part 2.1 with the following addition.

Unrestricted insertion of violations in the pulse stream would produce an undesirable dc component. A means of solving this problem is to reserve a bit position prior to a violation for application of a binary pulse or no-pulse in such a way that successive violations (V) alternate in polarity. The reserved bit position is designated by the symbol X. The desired polarity alternation of Vs is achieved by assigning a value 0 or B to the X such that the total number of Bs since the last V is odd. However, V-bit polarity alternation is not monitored by the network, and if Vs are widely separated (e.g., several seconds in time) no affect will be observed. At higher violation rates, error performance is degraded and some interference to other services is possible.

If pulses of the same polarity are adjacent, performance can be degraded. Therefore, X and V bits are separated by an 0, resulting in an X0V pattern in each bipolar violation sequence.

2.2.1 Transmitting Sequences Containing Bipolar Violations

1. Idle Sequence - This sequence indicates to the network that the station is Idle and is ready to receive incoming calls. It is analogous to the on-hook condition in telephone service. While a call or call attempt is in progress, continuous transmission of Idle sequences will cause the network to disconnect the call. The Idle sequence is BBBBX0V. (See Figure 5.)

2. Not Ready Sequence - This sequence indicates to the network that the station is Not Ready to answer incoming calls. A station placing a call to a station that is in the Not Ready mode (transmitting Not Ready sequences) will receive the Not Ready call progress code described in Section 3.3.1.5. While a call or call attempt is in progress, continuous transmission of Not Ready sequences will cause the network to disconnect the call. The Not Ready sequence is BB0BX0V. (See Figure 6.)

3. Data Mode Zero Suppression Sequence - This sequence is necessary because long sequences of zeros do not provide the transitions necessary to maintain timing recovery. Any sequence of 7 consecutive zeros must be encoded as 0000X0V. "Any sequence of 7 consecutive zeros" may be interpreted in either of two ways.

   a. A count is kept of the number of consecutive zeros. When that number has reached 7 bits the zeros are encoded in the Data Mode Zero Suppression sequence, as shown below:

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Binary ...1111000000000000000001...
Bipolar...BBBB0000X0V0000X0V00B...
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b. Each set of 7 consecutive bits is considered as a unit. When any such unit contains all zeros, it is encoded in the Data Mode Zero Suppression sequence, as shown below:

```
         ...Unit 1   Unit 2   Unit 3...
Binary - ...1111000  0000000  0000001...
Bipolar- ...BBBB000  0000X0V  000000B...
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Under either of these rules, no more than 12 consecutive zeros can be transmitted. (See Figure 7.) Also, as discussed in Section 2.6.2.14, the minimum average pulse density will be at least 1 in 7.

4. <u>Data Mode Extension (DME) Sequence</u>

The Data Mode Extension (DME) sequence is BBB0X0V. (See Figure 8.) During a call between two SDDS stations, this sequence may be transmitted by either station, and it will be delivered, unchanged, to the other station. The DME sequence does not affect the state of the call in progress, and is provided for end-to-end signaling between stations, especially where customer terminal equipment operates in the half-duplex mode, as discussed below.

During an SDDS call, a station having a DSU with the Terminal Controlled Carrier option (see PUB 41452) will transmit the DME sequence to the other station continuously whenever the customer terminal equipment has its Request to Send (CA) circuit at the Data Interchange Interface in the off condition. The minimum number of DME sequences transmitted in this situation is three. Also, during an SDDS call, whenever a station having a DSU receives three successive DME sequences, it will cause the Received Line Signal Detector (CF) circuit at the Data Interchange Interface to turn off. The CF circuit will remain off until bits that are not part of a DME sequence are again received from the distant station. A delay of approximately 14 bits is inserted by a DSU after it receives the last DME sequence before it turns on the CF circuit. (This avoids most "false starts" when transmission errors occur.) Thus, it can be seen that DME sequences can be used between SDDS stations to indicate the "nontransmit" mode without disconnecting the call. This is similar to the procedure commonly used in half duplex analog data transmission systems for indicating the nontransmit mode, wherein the analog carrier is turned off when a station is in the nontransmit mode. However, since SDDS is a duplex system, the presence or absence of DME characters in one direction does not affect the SDDS capability to allow the customer to use the transmission channel in the opposite direction.

Within the SDDS network, the transmission delay for DME sequences can be up to 6 bits longer than the transmission delay for data bits. For this reason, the network may insert up to 6 bits* following the last customer data bit transmitted prior to the first bit of a DME sequence. Also, up to 6 data bits, which are transmitted by the customer immediately following a set of one or more DME sequences, may be replaced by bits in the final DME sequence. These exchanges are illustrated below. The additional transmission delay for the DME sequence in this example is 4 bits.

Bits Transmitted: ...B000BBB0X0V0B00B0B...

Bits Received: ...B000BBB0BBB0X0VB0B...

2.2.2 Receiving Sequences Containing Bipolar Violations

1. Idle Sequence - This sequence is transmitted to a station from the network while the network is prepared for the station to originate a call. Its presence also indicates to the station that any call that had been in progress has been disconnected. The Idle sequence is BBBBX0V. (See Figure 5.)

2. Control State Active (CSA) Sequence - The network transmits this sequence to a station during a call origination by the station when the network is

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* The first four bits inserted are the same as the first four bits of the DME sequence. The fifth and sixth bits, if inserted, are both 1s.

ready to receive address digits (see Section 3.3) from the station, and also while the station is waiting for the connection to be completed. The Control State Active sequence is BB0BX0V. (See Figure 6.)

3. Data Mode Zero Suppression Sequence - Data Mode Zero Suppression sequences delivered to stations always encode exactly 6 zeros. This is different from the 7-bit Data Mode Zero Suppression sequences generated at the station. Reception of 000X0V must be decoded as six 0s. It is important to note that a Data Mode Zero Suppression sequence may not be received when one was transmitted and vice versa. For example, if a Data Mode Zero Suppression sequence is transmitted by a station just after it transmits a B and just before it transmits a 0000B sequence, then depending upon the alignment of the bipolar violations from the station and the SDDS network bytes (see Section 2.2.3), the data received at the other station could contain 11 consecutive 0s, with no Data Mode Zero Suppression sequences.

4. Data Mode Extension (DME) Sequence - This sequence, BBB0X0V, is identical to the Data Mode Extension sequence described in Section 2.2.1. (See Figure 8.)

5. Control Mode Extension (CME) Sequence - This sequence is BB00X0V. (See Figure 9.) It is used both as a call alerting code (ringing), and as an identifying prefix for call progress information. (See Sections 3.3.1.5 and 3.4.1).

6. Out-of-Service Sequence - This sequence is an indication of recognized trouble within the SDDS. It is 000BX0V. (See Figure 10.)

2.2.3 System Response to Bipolar Violation Sequences

A single bit transmission error could change a data sequence into a bipolar violation sequence. This would not be particularly serious if, for example, data were changed to the Data Mode Zero Suppression sequence. One or two errors would be the result. However, if data were changed to the Idle sequence or Out-of-Service sequence, for example, it could seriously affect the operation of data terminal equipment, unless spurious occurances of these sequences were ignored by the customer's equipment.

The design of the logic circuitry associated with the encoding and decoding functions in the data communication equipment can reduce the effect of short bursts of errors. For example, the Bell System Data Service Unit requires eight repetitions of the Idle, Out-of-Service, Control State Active (when used as a Proceed to Select signal), or Control Mode Extension (when used as an alerting signal) sequences before reacting to these conditions.

In addition, the OCU groups data into network bytes which are independent of the alignment of bipolar violations from the CSU. Thus, on the occurrence of a bipolar violation sequence from the near end station (either intentionally transmitted by the station or because of one or more errors in a sequence of data bits), the OCU transmits a corresponding network control mode sequence through the network during the next available complete byte interval. The result is that, at the far end CSU, a network generated sequence appears with a random delay with respect to the place of occurrence of the original bipolar violation sequence in the data stream from the near end CSU. The range of this delay is from 0 to 6 bits for 56 kbps. The delayed sequence will then overwrite a number of bits equal to the delay in the following data stream. The received bit pattern of the network generated sequence may be modified from the pattern which appeared at the near end OCU, and it may or may not include a bipolar violation.

Data Mode Zero Suppression codes from the station are the only bipolar violation sequences not realigned by the network. Therefore, the effect is that data bits which are corrupted into a Data Mode Zero Suppression sequence (e.g., 0000B00 into 0000X0V) are simply transmitted through the network as all zeros without misalignment or overwriting of any other bits. A Data Mode Zero Suppression sequence will be generated by the far end OCU if the last 6 data bits of any network byte are all zeros.

In general, most single bit errors from a station toward the network will result in a byte aligned pattern translation causing the effect described previously. Of all of those errors, about half will be received as "XOV" sequences by the far end station.

During data transmission, the Data Mode Zero Suppression and Data Mode Extension (DME) sequences from the data communication equipment at the customer's location are detected at the Telephone Company central office, and are transmitted to the distant central office with a signal format that does not involve bipolar violations. At the distant central office the bipolar violations are inserted in the pulse train that is transmitted to the customer's location in accordance with the data alignment within the time-division multiplexer bit stream of the SDDS, which does not necessarily correspond to their original placement (see Sections 2.2.1 and 2.2.2). Bipolar violation sequences other than those specified are blocked from reaching the distant end as bipolar violation sequences.

2.3 CSU Block Diagram

A simplified block diagram of the CSU is shown in Figure 11. Nominal 50 percent duty-cycle, bipolar pulses are accepted from the customer on the Transmitted Data leads DT1 and DR1. These pulses must be synchronous with the SDDS and must comply with the specifications listed in Section 2.6.2. The input bipolar pulses are amplified, filtered, and passed through the transmit repeat coil to the transmit pair.

The signal on the receive pair is amplified, equalized and sliced by the line receiver. The resultant bipolar pulses are then passed to the customer over the DT and DR Received Data leads. From these pulses the customer must recover the synchronous clock used for timing the transmitted data and sampling the received data.

2.4 CSU Physical Description

The CSU, shown in Figure 2, is designed for wall mounting. It measures approximately five inches high, 2-3/4 inches deep and eight inches wide. Visible through the face of the housing are two lights to indicate:

1. Power - PWR: when ac power is applied to the unit.

2. Test - TST: when the unit is being remotely tested from the Telephone Company test center.

The CSU will operate over a temperature range of +40°F to +120°F with a relative humidity less than 95 percent. The CSU weighs approximately 3 pounds.

Power is furnished to the CSU from a customer-provided 105-129 volt, 60 ±3 Hz, uninterrupted (see Section 3.2) source by means of a 3-foot cord with a U-ground type 3-conductor plug. The CSU consumes approximately 10 watts of ac power. The CSU should be located so that the customer-provided interface cable from the CSU to the data terminal will not exceed 100 feet. (See Section 2.5.2.)

For multiple installations, a multiunit cabinet is available for housing up to 20 CSUs.

2.5 CSU Interface Circuits

The interface discussed in this Technical Reference is the point of connection between the CSU of the SDDS and the customer's data terminal equipment. The interface that is provided consists of six leads: two pairs for data, a ground, and a Status Indicator (SI) lead.

As shown in Figure 11, leads DT1 and DR1 are the Transmitted Data pair, and leads DT and DR are the Received Data pair. The electrical characteristics of these leads are significantly different from those described in EIA Standard RS-232-C or in CCITT Recommendation V.35. For this reason, Section 2.6 in this Technical Reference covers the standards for the data interchange signals. These interface specifications are identical to those for the CSU interface in the Digital Data System, described in the Technical Reference PUB 41021. The parameters and specifications will be reexamined as user experience is acquired. In this light, the specifications should be considered as preliminary.

The Status Indicator (SI) lead conforms electrically to EIA Standard RS-232-C. When Circuit SI is on (voltage to ground between +3 and +25 volts), the local CSU is connected to ac power and is not in a test mode. Ground return for this circuit (GRD) is normally connected within the CSU to the power plug ground. It may be disconnected from power ground at the customer's option, subject to local noise conditions, grounding potentials and local safety regulations. The short circuit current on the SI lead is limited to 20 mA. The on condition should not be interpreted as either an indication that a communication channel has been established to a remote data station or the status of any remote station equipment. The off condition (voltage between -3 and -25 volts) is an indication that the data terminal equipment should disregard signals appearing on the Received Data circuit and should not attempt to originate calls or to transmit data over the Transmitted Data Circuit.

2.5.1 Interface Connector

The six leads are provided on a 15-pin female connector. The customer-provided plug must be a male 15-pin connector such as the DAMA-15-P plug manufactured by Cinch, or equivalent. The pin assignments for the connector are given below.

Pin Number	Function	Signal Direction
1	Ground (GRD)	-
2	Status Indicator (SI)	From CSU to Customer
3	Received Data (DT)	From CSU to Customer
4	Received Data (DR)	From CSU to Customer
5	Transmitted Data (DT1)	From Customer to CSU
6	Transmitted Data (DR1)	From Customer to CSU
7-15	Not Used*	

* Within the CSU these pins are not electrically terminated.

2.5.2 Interface Cable Requirements

The cable from the data terminal equipment to the CSU requires three twisted pairs. One twisted pair should be used for DT and DR, one pair for DT1 and DR1 and one pair for SI and GRD. To reduce the possibility of crosstalk between the various leads and assure proper operation, the characteristics of the interconnection cable between the CSU and the data terminal are specified below. An interconnecting cable meeting these specifications uniformly over its length should result in a transmission line with a characteristic impedance on the order of 100 ohms at frequencies where series inductance and shunt capacitance dominate (normally above 100 kHz). This characteristic should minimize pulse distortion between the nominally 135-ohm interface drivers and terminators.

Gauge	24 AWG for solid or stranded copper wire, or, for non-copper conductors, a size which yields a dc wire resistance < 30 ohms per 1000 feet per conductor.
Mutual Capacitance of Pair	20 pF/foot maximum
Capacitance of Single Lead to Ground - all other leads grounded	40 pF/foot maximum
Crosstalk Loss - Pair-to-Pair	40 dB minimum at 150 kHz
Cable Length	Cable between data terminal equipment and CSU < 100 feet in length.

2.6 Data Interchange Circuits

2.6.1 Introduction

The CSU is transformer coupled to the data interface leads. This interface is designed to be compatible with a wide variety of drivers and terminators in the user's equipment. Transformer coupling causes the CSU input and output impedances to be frequency dependent. It also means that the CSU neither responds to nor transmits dc voltages on the data interface leads.

The interface specifications for the data interface leads describe pulse characteristics when the drivers in the CSU and in the customer equipment are terminated with a 135-ohm resistance. To describe the opposite direction of transmission, the characteristics of pulses from a source having an internal impedance of 135-ohms, resistive, are used. That is, the terminators in the CSU and in the customer equipment are described by specifying the shape of pulses from a 135-ohm resistive source of pulses. Figure 12 shows two possible schematic diagrams for interface cable terminators in the customer's data equipment. Figure 13 shows two possible interface cable driver circuits.

2.6.2 Definitions and Limiting Specifications

In this section, various terms and parameters used to specify the data interchange circuits are introduced, defined and illustrated. Following the definition, the limiting specification is stated along with any explanatory comments.

2.6.2.1 Output Voltage (Vout)

Definition: Figure 14 shows the output voltage measured between leads A and B (Vout).

Specification: The transmission of a binary ONE or ZERO shall be indicated by the following differential ac output voltages measured across a 135-ohm resistive termination.

1. Customer Generator

ONE	1.4 volts $\leq$ |Vout| $\leq$ 2.1 volts
ZERO	|Vout| $\leq$ 0.14 volts

2. CSU Generator

ONE	1.33 volts $\leq$ |Vout| $\leq$ 2.1 volts
ZERO	|Vout| $\leq$ 0.21 volts

Where |Vout| denotes the absolute value.

These requirements are illustrated in Figure 15.

The differential dc output voltage of the customer generator shall not exceed 25 percent of the peak-to-peak ac signal. The differential dc output voltage of the CSU will be zero.

Comment: Greater range on the limits of the CSU output voltage reflects the fact that data signals are not retimed in the CSU. Some conversion of time to amplitude distortion may be expected.

2.6.2.2 Terminator Threshold Voltage (Vin)

Definition: Figure 14 shows the input voltage measured between leads A' and B' (Vin).

Specification: Figure 16 shows the differential ac input pulse amplitudes (Vin) that a terminating system will interpret as a binary ONE or ZERO when driven by a generator meeting the specifications in this section.

The threshold levels are said to be normalized when referred to the equivalent amplitude obtained at the input of a terminator having a 135-ohm resistive input impedance.

The following summarizes the normalized input voltages, which apply to both the customer terminator and the CSU.

ONE		$\lvert Vin \rvert \geq 1.05$ volts
Undefined	0.35 volts <	$\lvert Vin \rvert < 1.05$ volts
ZERO		$\lvert Vin \rvert \leq 0.35$ volts

Where |Vin| denotes the absolute value.

2.6.2.3 Rise and Fall Times (TR, TF)

Definition: Figure 17 shows the rise and fall times of the leading and trailing edges of a pulse.

Specification: The time (TR, TF) required for a generator to indicate a change in its binary state shall not exceed 5 percent of a bit interval. This is measured when the generator is terminated with a 135-ohm resistive load.

Comment: The rise and fall times shown on Figure 17 are exaggerated for additional clarity.

2.6.2.4 Pulse Width (W)

Definition: Figure 17 shows the pulse width at the nominal threshold level.

Specification:

1. Customer to CSU - The pulse width, measured across a 135-ohm resistance at the generator terminals, shall be 50 percent ± 2.5 percent of the bit interval at the nominal terminator threshold levels of ±0.7 volts.

2. CSU to Customer - The average pulse width, measured across a 135-ohm resistance at the generator terminals, will be greater than 45 percent and less than 90 percent of the bit interval at the nominal terminator threshold levels of ± 0.7 volts. This average will be reliably maintained when transmitting random (uncorrelated equiprobable) bipolar data. Pulse widths of isolated ones surrounded by zeroes may exceed 100 percent of the bit interval.

Comment: The CSU to customer specification reflects the fact that data signals are not retimed in the CSU. Random noise introduced in the cable pairs could cause data transitions anywhere within the bit interval. The specification covers pulse widths in the absence of random noise or when the received signal is averaged over many bit intervals.

2.6.2.5 Differential Impedance (Zin, Zout)

Definition: Figure 14 shows the points where the effective impedances (Zin, Zout) are measured. Figure 18 outlines a method for determining the impedance.

Specification: The following impedances apply to interface generators and terminators that are operating at the given bit rate and with the nominal signal levels and duty-cycle specified in this section. As shown in Figure 18, the impedance during the rise and fall intervals is not specified.

1. Generator - When transmitting a bipolar pulse train into a resistive load, Zout shall be 135 ohms ± 20 percent.

2. Terminator - When receiving a bipolar pulse train transmitted by a resistive source, Zin shall be 135 ohms ± 50 percent.

Comment: When the CSU is being tested by the Telephone Company from a test center (see Section 1.3.4), interface leads DT, DR, DT1 and DR1 will be open-circuited and disconnected from the SDDS access line.

2.6.2.6 Longitudinal (Common Mode) Noise

Definition: Noise currents and voltages may be introduced along the interface cable. If they cause an equal change in the potential of terminal A and of terminal B with respect to ground (Figure 19), they are called longitudinal noise sources.

2.6.2.7 Common Mode Impedance (ZCM)

Definition: Figure 19(a) illustrates the common mode impedance (ZCM), which is the impedance to ground with the A and B terminals shorted together.

Specification: None

Comment: Since the CSU data interface leads are coupled to the interface cable through a balanced, ungrounded transformer, it is expected that longitudinal noise current effects will be negligible. Consequently, ZCM of the customer generator or terminator may be chosen relatively low (about 135/4 or 34 ohms) to minimize interference caused by capacitive coupling of stray signals.

2.6.2.8 Common Mode Voltage (VCM)

Definition: As shown in Figure 19(b), the common mode voltage (VCM) is the arithmetic mean of the voltages on terminals A and B measured with respect to ground.

Specification: These specifications are based on measurements between ground and the midpoint of a 135-ohm resistive termination. The common mode output voltage must satisfy the following limits:

1. Customer generator or terminator to CSU

   (a) The dc component of VCM shall be between +5.5 volts and -5.5 volts.

   (b) The peak ac component of VCM is a function of ZCM, and shall not exceed the limits shown on Figure 19(c).

2. CSU to customer generator or terminator

   Specification: None

Comment: The CSU may impress a common mode signal at the data interface during instants of transition between binary states as a result of nonideal characteristics in the interface transformers. However, this signal is associated with the high common mode impedance of an ungrounded transformer and will be negligible relative to the differential signal power.

2.6.2.9 VCM Input Voltage Range

Definition: This characteristic describes the voltage range through which VCM may be varied without causing improper operation of a generator or terminator. That is, no change in binary state is caused, and the driver or terminator continues to meet all interface specifications.

Specification: A generator or terminator shall continue to operate satisfactorily when connected to the test source illustrated in Figure 20(a). This source has the pulse amplitude and impedance characteristics indicated in Figure 20(c). It produces a pulse train at the given bit rate.

Comment: This specification permits a comparison of generators and terminators that is independent of their common mode impedances. Comparison is on the basis of their ability to withstand longitudinal noise of equal available power.

2.6.2.10 Impedance Balance

Definition: As shown in Figure 21, this quantity is an expression of the difference in the impedance from terminal A to ground (ZA) and the impedance from terminal B to ground (ZB). The balance is measured indirectly by means of the test shown in Figure 21.

Specification: When driven by a sinusoidal test source, the ratio of applied common mode voltage (VT) to differential voltage (V) shall not be greater than the values shown on Figure 21. For example, at 56 kb/s the impedance balance must be greater than 40 db at 112 kHz and greater than 20 dB at 1.12 MHz.

2.6.2.11 Terminator Bias Current

Definition: This is the short-circuit dc current flow when the terminator leads are connected together.

Specification:

1. CSU generator to customer terminator - 0.1 mA.

2. Customer generator to CSU terminator - Not specified

Comment: Since a transformer is used as the output device from the CSU, dc current flow from DT to DR must be limited to avoid distortion of the data signals. The input transformer in the CSU has a series capacitor at the midpoint of its primary winding. This blocks any bias current from flowing.

2.6.2.12 Protection

Specification: The difference in ground potential between the CSU and the customer's terminal equipment shall not exceed a peak value of 1.0 volt. Under conditions of worst-case ground potential difference, the short-circuit current to ground from the customer's generator or terminator shall not exceed 120 mA.

The circuits used in this interface shall not be damaged by a short circuit between the balanced data leads or by a short circuit from either lead to ground or to the Status Indicator lead. The circuits shall not be damaged under open-circuit conditions.

Comment: Protection under conditions of accidental contact with other voltages or circuits is not specified, and circuit damage may result. The user is cautioned not to mix the interface leads with other circuits in the same cable.

2.6.2.13 Timing Accuracy

Definition: This term describes the difference between the frequency of the received pulses and the nominal data rate.

Specification:

1. Customer to CSU - The transmitted data shall be synchronous with the received data. The actual phase difference between the received data and the transmitted data may be an arbitrarily chosen value, so long as the jitter is held within the limits of Section 2.6.2.15.

2. CSU to Customer - Under normal conditions, the frequency of the received data will agree with the nominal data rate to within ± 2 parts in 10^9. Some trouble conditions will allow the frequency difference to vary ±0.005 percent of the nominal data rate.

2.6.2.14 Minimum Average Pulse Density

Definition: The average pulse density of a sequence is the total number of pulses (Bs or Vs) divided by the sequence length.

Specification:

1. Customer to CSU: The Data Mode Zero Suppression encoding rules given in Section 2.2.1 guarantee that the customer will deliver to the CSU a minimum average pulse density of 1 in 7.

2. CSU to Customer: The method used to generate Data Mode Zero Suppression sequences in the pulse stream from the CSU to the customer reflects a particular design that satisfies the rules given in Section 2.2.1, except that the sequence is always 6 bits long (see Section 2.2.2). Specifically, the Data Mode Zero Suppression sequences delivered to the customer are always generated in alignment with blocks of 7 bits of data, such that the maximum number of successive zeros which may be delivered is 11 bits. This assures a minimum average pulse density of 1 in 7.

Comment: The requirements for timing, phase detection and received level control are strongly dependent on the minimum average pulse density. The rules for customer to CSU Data Mode Zero Suppression sequences given in Section 2.2.1 permit a simple method to be adopted for meeting this requirement.

2.6.2.15 Isochronous Distortion (Jitter)

Definition: (See Appendix and Figure 22)

Specification:

1. CSU to Customer

Loop repeaters may be used to regenerate signals transmitted on 56 kb/s loops. Use of loop repeaters results in an increase in very low frequency perturbations occurring in the phase of the received data signals at 56 kb/s customer interfaces. The frequencies of these perturbations are nominally less than 0.007 percent of the signaling frequency (i.e., less than 4 Hz at 56 kb/s).

The amount of jitter measured is critically dependent on the reference timing source. With respect to a fixed reference timing source, the peak-to-peak jitter at very low frequencies is expected to be less than 30 percent. If the reference timing source is derived from the incoming data, and if the timing recovery circuit used has sufficient bandwidth to track the low frequency phase perturbations, the observed very low frequency jitter behavior with repeaters is improved. For a single transition between two worst-case repetitive data patterns, peak values on the order of 11 percent may be observed, if the reference timing source is derived from the incoming data with a timing recovery circuit that has a bandwidth of 0.015 percent of the signaling frequency (56 kHz). In this event, and using the recovered timing as the reference timing source, the isochronous distortion of the leading and trailing pulse edges is expected to be less than 31 percent.

The 56 kb/s loop repeaters have been designed to operate in conjunction with a station timing recovery circuit characterized as follows. In response to an input data phase change, θ, the phase of the recovered timing signal is changed at a rate not less than $S\theta/27$ Hz. Here, θ, is any phase shift less than or equal to 27 degrees (7.5 percent of a bit interval). The quantity S is a measure of system bandwidth. A nominal value of $S = 0.015$ percent of the signaling frequency (56 kHz) was assumed in the repeater design. Smaller values of S are to be avoided, since they will result in an increase of observed low frequency jitter. Too great a value of S will not sufficiently suppress high frequency jitter. Conservative estimates set S at 0.015 percent to 0.05 percent of the signaling frequency (56 kHz).

Comment: Careful clock recovery techniques and observations with an oscilloscope can be used for field evaluation of jitter and distortion. Note that the specification is given in terms of isochronous distortion of the leading and trailing pulse edges, and this distortion is defined independent of the ideal 50 percent duty cycle. Thus, test instrumentation can use a clock derived from the received pulse transitions, even though the average pulse width (as specified in Section 2.6.2.4) may differ significantly from the ideal 50 percent duty cycle. An understanding of the independence between the isochronous distortion and the ideal 50 percent duty cycle may be made clearer by referring to Figure 22 (d).

2. Customer to CSU

1. The customer's timing recovery circuit should respond to any instantaneous phase shift, θ, less than or equal to 27 degrees (7.5 percent of a bit interval) at a rate $S\theta/27$ Hz, such that S is not less than 0.012 percent of the signaling frequency (56 kHz).

Comment: The lower limit on S (0.012 percent) is intended to account for worst case component deviations, when S is nominally 0.015 percent of the signaling frequency.

2. The peak-to-peak self-jitter of the customer's timing recovery circuit, controlling data transitions from the customer to the CSU, shall not exceed 2.5 percent of a bit interval, when receiving random data or periodic patterns from the CSU.

Comment: Assuming addition of appropriate jitter mechanisms is valid, this implies that the isochronous distortion of data signals from the customer to the CSU will not exceed 13.5 percent. The appropriate reference timing source for this measurement is as described above, with S not less than 0.015 percent of the signaling frequency (56 kHz).

3. SYSTEM OPERATION

3.1 Station Addresses

For each SDDS station, the Telephone Company will assign a 7-digit address (NNX-XXXX, where N can be any digit 2-9 and X can be any digit 0-9) for use when placing calls to the station. Certain sets of addresses will be reserved for Telephone Company use. It is important to note that SDDS stations can only place calls to other SDDS stations, and that no voice capabilities are provided.

For a group of stations that are all in the same Switched DSA, a terminal hunting arrangement is available, in addition to the single line station arrangements. Up to 20 stations may belong to the same terminal hunting group. Each station in a hunting group will be assigned a separate 7-digit address by the Telephone Company, but the numbers will not necessarily be sequential. When one of the stations is called, but is either busy or signaling that it is not ready to answer calls, the call attempt is automatically rerouted to the station in the same hunting group that has the next higher 7-digit address. If that station is also busy or signaling that it is not ready to answer calls, the call attempt is rerouted to the next higher numbered station, and so on, until an idle station is found or until an attempt is made to reach the highest numbered station in the group. If that station is busy or signaling that it is not ready to answer calls, a "busy" call progress signal is returned to the calling station. It is important to note that no calls will be rerouted to the lowest numbered station in a hunting group, and that no calls initially directed to the highest numbered station in a hunting group will be rerouted to any other station.

3.2 Not Ready Condition

When an SDDS station is neither originating a call nor connected to another station via a switched connection, it should transmit either Idle or Not Ready bipolar violation sequences (see Section 2.2.1). Transmission of the Idle sequence indicates a state of readiness to answer incoming calls, as described in Section 3.4. Transmission of the Not Ready sequence, however, indicates that the station is not ready to answer incoming calls.

The network will not attempt to alert the station for any incoming calls while the station is transmitting the Not Ready sequence. Calls may be originated, as described in Section 3.3, immediately following transmission of the Not Ready sequence, and a station may revert to transmitting the Not Ready sequence to terminate a call (to avoid receipt of incoming calls).

Stations placing a call to a station that is transmitting the Not Ready sequence will receive the Not Ready call progress code from the network, as described in Section 3.3.1.5.

CAUTION: The SDDS has been designed such that a CSU should be continually transmitting either data or bipolar violation sequences. If a customer having a CSU does not continuously generate either the Idle sequence or the Not Ready sequence between calls, he will encounter difficulties in originating and answering calls. Also, if the power source for the CSU is removed, any call in progress will be disconnected by the network. With the power off, the CSU cannot communicate with the network, thus calls cannot be originated or answered. However, other stations calling a station whose power is off will receive the remote ring call progress code (see Section 3.3.1.5), which indicates that the called station is being alerted, but has not yet answered.

3.3 Call Origination and Termination

Certain of the bipolar violation sequences described in Section 2.2 are used in the procedures for originating and terminating calls, which are described in Section 3.3.1 and 3.3.2. Attempt control, a system feature intended to limit the number of unsuccessful call attempts during unusually heavy traffic periods, is described in Section 3.3.3.

3.3.1 Calling Procedures

Figure 23 illustrates the sequences of events that occur for calls in the SDDS, and should be referred to during the discussion that follows.

3.3.1.1 Idle

When the network is prepared for a station to originate a call, it will transmit the Idle sequence to the station (see Section 2.2.2). The Idle sequence will be transmitted to a station at all times between calls, unless the station is being tested by the Telephone Company from a remote test center, the access line is defective or the network is temporarily unable to handle new calls. (When the network recognizes that call originations should not be attempted, due to equipment outages, it will transmit Out-of-Service bipolar violation sequences to the station.) In between calls a station should transmit either the Idle sequence (indicating that it will accept incoming calls) or the Not Ready sequence (indicating that it is not ready to receive incoming calls). The Idle and Not Ready sequences are described in Section 2.2.1.

3.3.1.2 Call Request and Proceed to Select

To initiate a call origination, a station that has been transmitting either Idle or Not Ready sequences, as described in Section 3.3.1.1, should generate a "Call Request" signal by transmitting a series of Data Mode Zero Suppression sequences. Other combinations of Data Mode bits, with the exception of Data Mode Extension sequences, will also be accepted as a Call Request signal. However, many such sequences would cause operational difficulties. For example, a sequence of ASCII zero characters with odd parity would cause improper network synchronization (see Section 3.3.1.3). Also, a sequence containing more than 63 consecutive Data Mode 1s might be interpreted as the answering signal, if an incoming call arrives at approximately the same time as a call origination is initiated (see Section 3.4.2).

In response to this Call Request signal the network will begin transmitting Control State Active (CSA) sequences repetitively to the station. This Proceed to Select signal indicates that the station may initiate addressing. Its function is analogous to that of the dial tone signal in telephone service. As soon as the station recognizes the repetitive CSA sequences, the address of the called station may be transmitted to the network according to the format described below. It is recommended that more than one CSA sequence be identified to avoid false starts in the event that spurious transmission errors should simulate a CSA sequence. The SDDS DSU described in PUB 41452 requires eight successive error free CSA sequences for this purpose.

3.3.1.3 Addressing

Once the Proceed to Select signal (i.e. the CSA sequences) from the network is recognized, the station should immediately commence transmitting SYN characters, using the American Standard Code for Information Interchange (ASCII) with odd parity, as shown in Figure 24. A minimum of two consecutive SYN characters must be transmitted after the Proceed to Select signal is received to assure that the network attains 8-bit byte synchronism with the customer's 8-bit ASCII bytes. Immediately following the initial SYN characters, after receipt of the Proceed to Select signal, the station should transmit the seven digits of the called station's address, followed by the end-of-address indicator (ETB), also in the 8-bit ASCII format, using odd parity, as shown in Figure 24. Any number of SYN characters may be interspersed between the address digits or between the last address digit and the end-of-address indicator (ETB).

If the data terminal equipment does not maintain the 8-bit synchronism described above, the network will not resynchronize, and it will receive an incorrect address. If the resulting incorrect address is an invalid number, the network will abandon the call, as described in Sections 3.3.1.4 and 3.3.1.5. However, if the incorrect address is a valid number, the call attempt will be processed in the normal manner, resulting in a call to an incorrect address. In either case, the originating station should terminate the call as described in Section 3.3.2. Then a new call attempt may be initiated.

The network has a 20 second timer, which is reset to zero when the Proceed to Select signal is first generated and again after receipt of each address digit from the station. If this timer reaches 20 seconds at any time before the ETB character is received, the network will abort the call attempt as described in Section 3.3.2.

Following transmission of the ETB character the station may transmit any sequence of data bits or the Data Mode Extension (DME) sequence described in Section 2.2. Until the call is "cut-through", however (see Section 3.3.1.6), there is no assurance that the bits transmitted will be received at the other station.

3.3.1.4 Address Acknowledgment

After the network receives the seven digit address of the called station and the end-of-address indicator (ETB), it transmits the following sequence to acknowledge receipt of the address:

...(CSA) (CME) (ACK) (CSA)...

If the network receives an improper number of digits or recognizes a transmission error in the address, it will transmit NAK instead of ACK. CME is the Control Mode Extension bipolar violation sequence described in Section 2.2.2, and the bit configurations for ACK and NAK are shown in Figure 25. Note that the address acknowledgment does not use 8-bit ASCII characters. If NAK is sent to the originating station, it will be followed by a call progress code having the digits 3 and 0, according to the format described in Section 3.3.1.5.

3.3.1.5 Call Progress Codes

Following the address acknowledgment, the network will continue to transmit CSA sequences to the originating station until a connection is established to the called station or until it is determined that a connection cannot be established. If a connection cannot be established, the reason is communicated to the originating station in the form of a call progress code, according to the following format, which is transmitted 8 times:

...(CSA) (CME) (D1) (D2) (ETB) (CSA)...

Note that call progress codes do not use 8-bit ASCII characters. D1, D2 and ETB are 7-bit bytes. The relationships between these bit configurations and the decimal digits they represent in the SDDS are defined in Figure 26. Using those definitions, the call progress code digit pairs (D1 and D2) that can be transmitted to an originating station are as follows:

D1	D2		Meaning
1	0	-	Called station is busy.
1	1	-	Called station is Not Ready.
2	0	-	Time-out (switching equipment in network timed out due to network difficulties).
2	1	-	All trunks busy (no idle transmission path due to heavy traffic between switches).
3	0	-	Invalid address (invalid address received, possibly due to certain transmission errors or network timed out during call origination).

When any of these call progress codes are received, the call attempt must be terminated at the originating station, as described in Section 3.3.2, before a new call can be initiated. (Also see Section 3.3.3 on attempt control for unsuccessful call attempts during extremely heavy traffic periods.) The call progress code having D1, D2 equal to 3, 0 will be transmitted to the originating station, following a negative acknowledgment (NAK), as described in Section 3.3.1.4.

Following any of the above listed call progress codes, the network will abandon the call attempt as described in Section 3.3.2.

If the call origination attempt is successful (i.e. if the called station is Idle and a complete connection is available) the network will alert the called station as described in Section 3.4.1, and will also transmit the remote ring call progress code 8 times to the originating station.* The remote ring call progress code is shown below. Note that call progress codes do not use 8-bit ASCII characters. The binary representations for the decimal 0s and ETB shown below are defined in Figure 26.

...(CSA) (CME) (0) (0) (ETB) (CSA)...

3.3.1.6 Cut Through at the Originating Station

When the called station answers, it must transmit a series of data 1s in the bipolar format.** When the network recognizes this it completes the duplex connection, and then all following data (or DME bipolar violation sequences) transmitted by the called station are received at the originating station. Thus, the cut-through indication at the originating station is the reception of data bits (i.e., data 1's) from the called station, in place of the CSA sequences from the network. If the called station answers quickly, cut-through can occur at the originating station before all 8 of the remote ring call progress codes are completed. The SDDS DSU described in PUB 41452, when originating a call, requires that 56 successive data bits (or eight DME sequences) be received

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* If the called station answers quickly, the call can be cut-through at the originating station before all 8 remote ring call progress codes are received.

** Section 3.4.2 describes cut-through at the called station.

before it will signal the data terminal equipment at the originating station that the call has been cut-through. This avoids false interface signaling when spurious transmission errors occur while the called station is being alerted. This type of safeguard arrangement is recommended for use by customers having CSUs.

3.3.2 Abandoning a Call Origination and Terminating a Call

At any point during a call or call origination a station may commence transmitting Idle or Not Ready bipolar violation sequences. When the network recognizes Idle or Not Ready sequences from either the originating or the called station it will disconnect the call (or abandon the call origination attempt), and will transmit either Idle or Out-of-Service sequences to the stations. Idle sequences are normally transmitted, indicating that the network is prepared to receive a new call origination. Out-of-Service sequences are only transmitted when the network recognizes that it should not accept call originations, due to an equipment malfunction. The Idle or Out-of-Service sequences are also transmitted to a station whenever the network disconnects a call, due to network difficulties, or following transmission of call progress code sequences indicating an unsuccessful call origination attempt.

During some unusually heavy traffic periods, a 6-second delay may be inserted by the network immediately following every unsuccessful call attempt, before the originating station is permitted to originate a new call. This feature, called attempt control, is described in Section 3.3.3.

3.3.3 Attempt Control

Attempt control is a system feature intended to limit the number of unsuccessful call attempts at a switch during periods of unusually high traffic. If the number of unsuccessful call attempts at a switch were not limited during such periods, a number of the stations could originate an extremely large number of unsuccessful call attempts to stations that are busy or Not Ready, thus causing the "dial tone" delay period to increase for all customers served by the switch, and unnecessarily decreasing the traffic handling capability of the system.

The attempt control mode of operation is only used when an unusually large number of call attempts occur at a switch, and only affects an originating station for a period of 6 seconds immediately following an unsuccessful call attempt. During the attempt control mode of operation at a switch, an interval of 6 seconds is required after an unsuccessful call attempt before the switch will act on a new call origination attempt from the same originating station. For example, assume that a call is originated to a busy station during the attempt control mode of operation. If the originating station cancels that call, then attempts to originate another call 4 seconds later, the network will insert a delay of 2 seconds, in addition to the normal "dial tone" delay. (Performance objectives for "dial tone" delay are discussed in Section 1.3.1.3.)

3.4 Call Answering

Certain of the bipolar violation sequences described in Section 2.2 are used in the procedures for answering SDDS calls, which are described in this section. Figure 23 illustrates the sequences of events that occur for answering SDDS calls.

3.4.1 Idle Station Condition and Alerting

To indicate readiness to receive incoming calls, a station must be transmitting the Idle bipolar violation sequence. The network will also be transmitting Idle sequences to the station just prior to an incoming call. The network alerts the called station to an incoming call by halting transmission of the Idle sequences and transmitting a continuous stream of Control Mode Extension (CME) sequences to the station.

It is possible for a station to be alerted for an incoming call for a brief interval immediately after the station has changed from transmitting Idle sequences to transmitting Not Ready sequences, due to transmission delays in the network. If this should occur, the station may continue to transmit Not Ready sequences, and the network will cancel the incoming call, and begin transmitting Idle sequences to the station as soon as the

Not Ready sequences are recognized by the network. After alerting has begun, however, if the station changes from transmitting Idle sequences to transmitting Not Ready sequences, the network will normally continue to alert the station until the call is answered (see Section 3.4.2) or abandoned by the originating station.

3.4.2 Answering and Cut Through at the Called Station

While being alerted, as described in Section 3.4.1, a station may answer a call only by transmitting a continuous stream of data 1s. When the network recognizes this data signal, it will complete the connection to the originating station, and the called station will then begin to receive the data bits (or the DME sequences) being generated by the originating station. This indicates to the called station that the connection has been cut through.* The SDDS DSU described in PUB 41452, when answering a call, requires that 56 successive data bits (or eight DME sequences) be received before it will signal the data terminal equipment that the call has been cut-through. This minimizes false interface signaling when spurious transmission errors occur while the station is being alerted. This type of safeguard arrangement is recommended for use by customers having CSUs.

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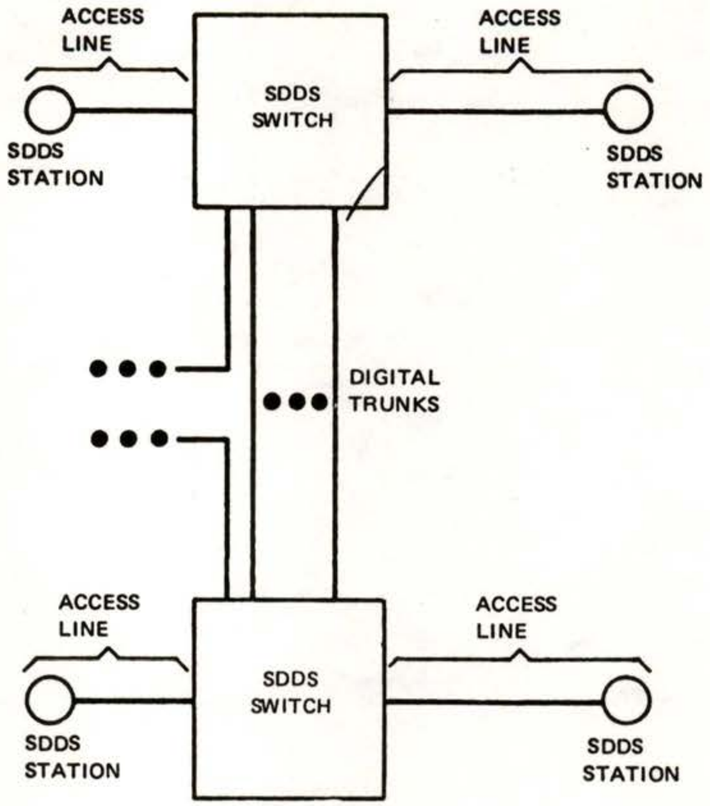
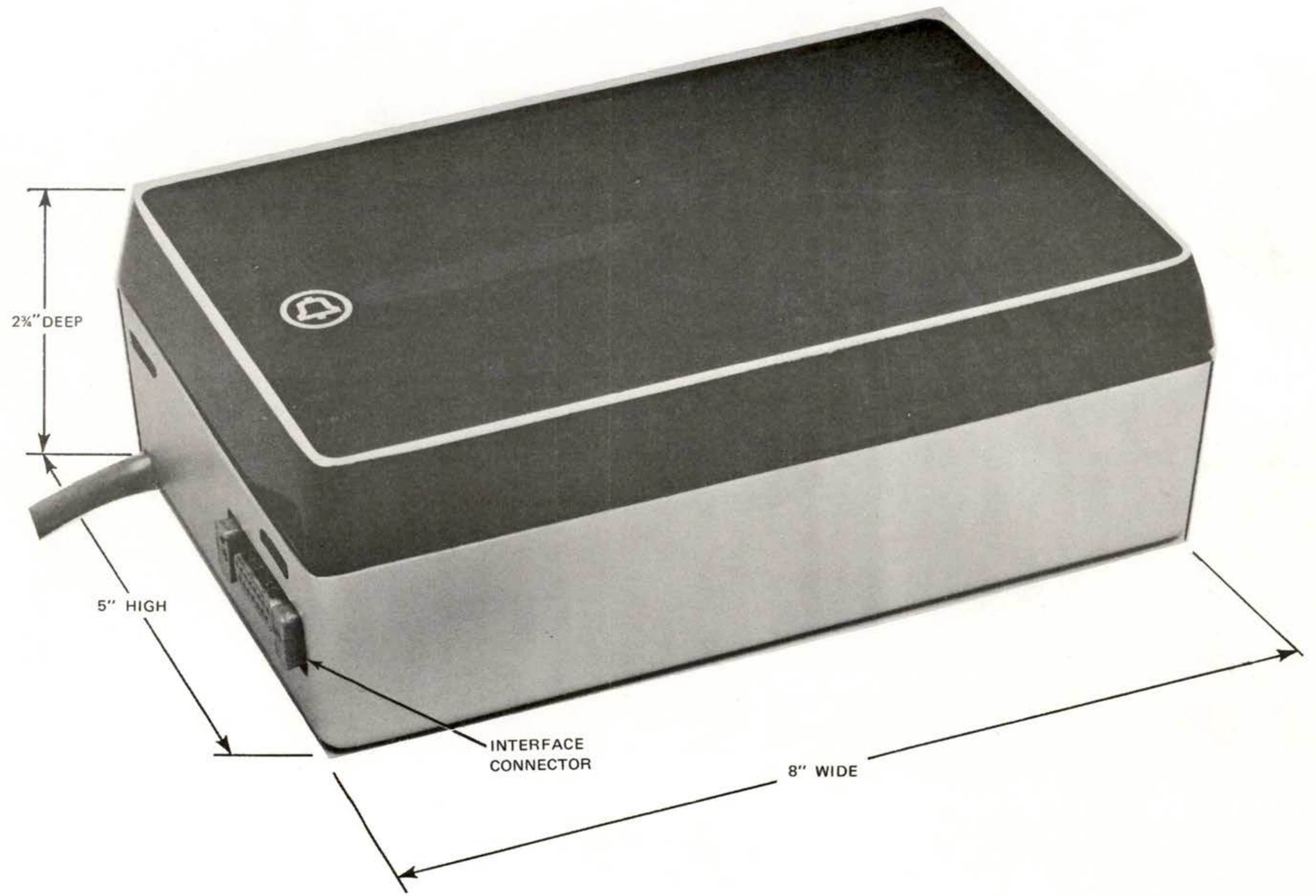
* Section 3.3.1.6 describes cut-through at the originating station.



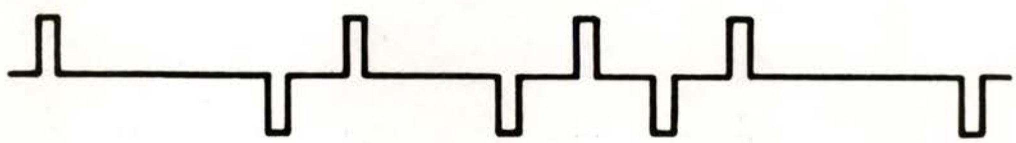
SWITCHED DIGITAL DATA SYSTEM
FIGURE 1



CHANNEL SERVICE UNIT
FIGURE 2

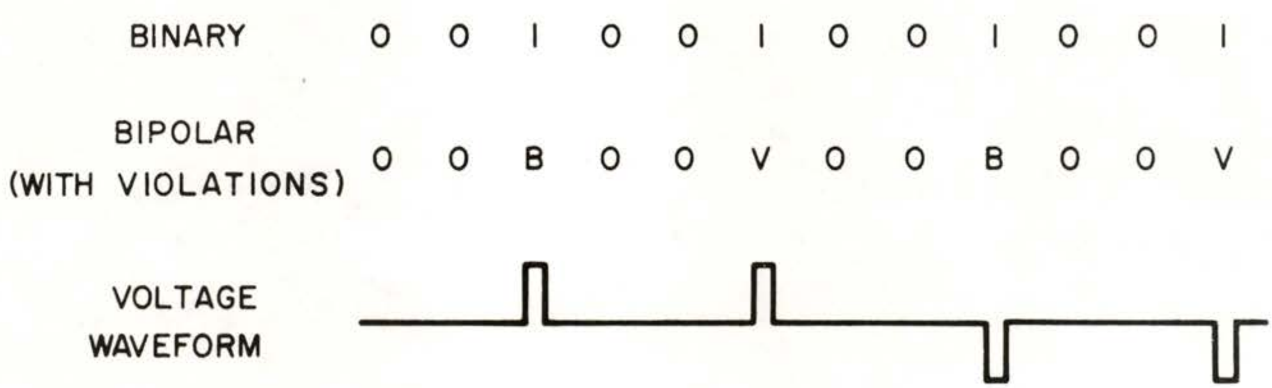
BINARY	1	0	0	1	1	0	1	1	1	1	0	0	1
BIPOLAR	+	0	0	–	+	0	–	+	–	+	0	0	–

VOLTAGE WAVEFORM



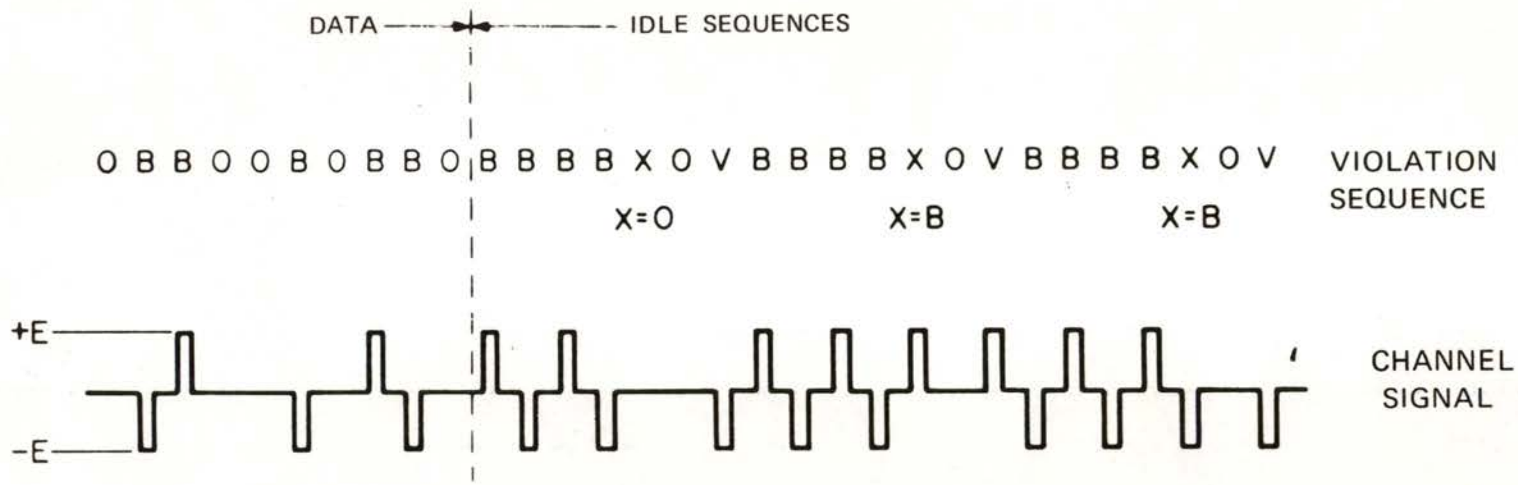
BIPOLAR SEQUENCES

FIGURE 3



BIPOLAR VIOLATIONS

FIGURE 4



Note:

O Denotes Zero Volts Transmitted – Binary Zero

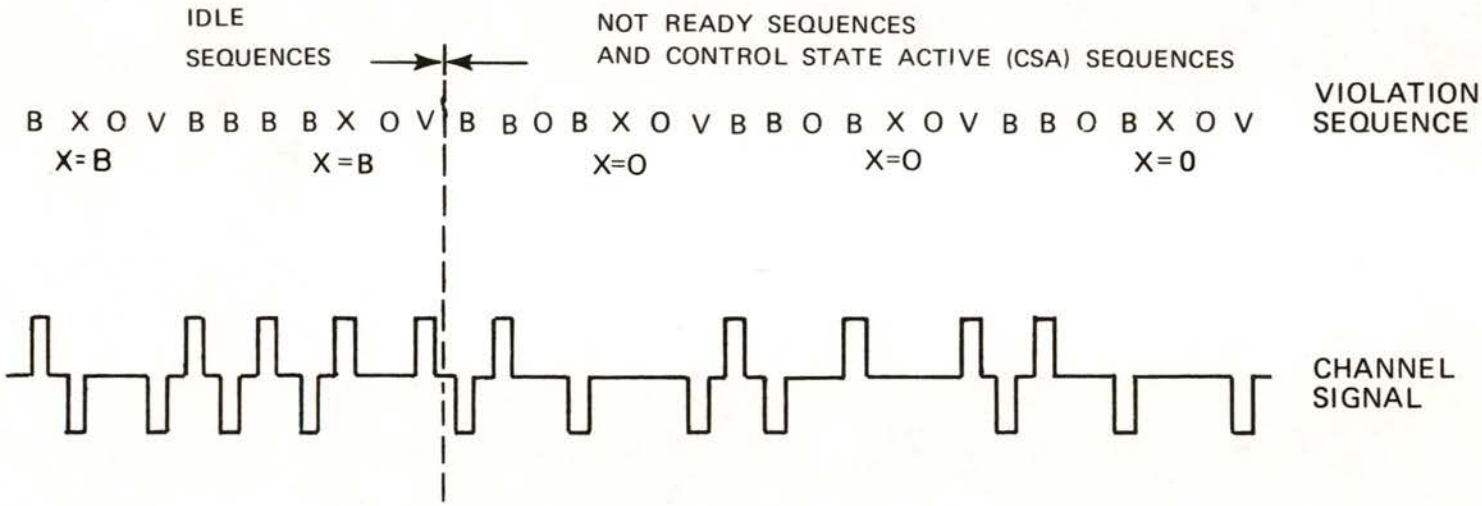
B Denotes ± E Volts Transmitted (Polarity Determined by Alternate Polarity Rule)

V Denotes ± E Volts Transmitted (Polarity in Violation of Alternate Polarity Rule)

X Equals O or B if Number of Bs Since Last V is Odd or Even, Respectively.
In Above Example the First X Equals O and all Remaning X's Equal B.

IDLE SEQUENCE

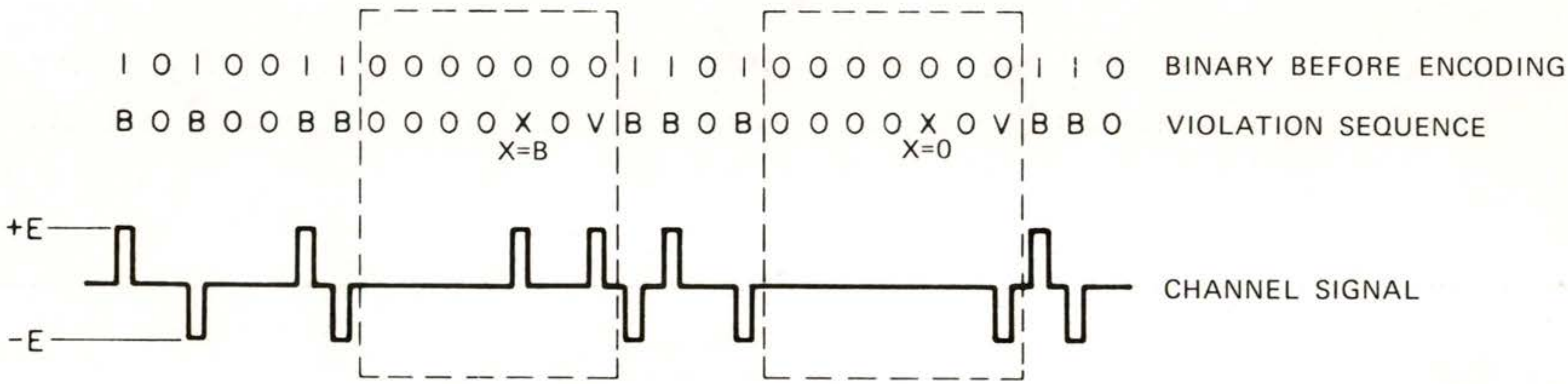
FIGURE 5



Notes:

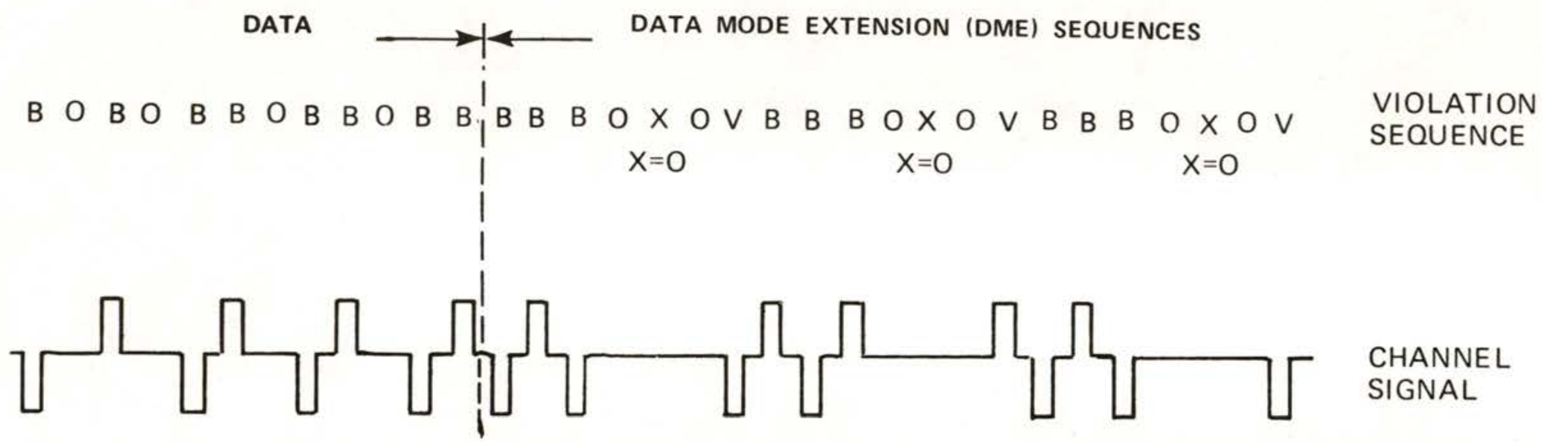
1. First X may be O or B depending on number of B's since last V. All remaining X's in Not Ready and CSA sequences are O's.
2. Not Ready sequence is transmitted from station to network. CSA sequence is transmitted from network to station.

NOT READY SEQUENCE (CSU TO NETWORK) AND CONTROL STATE ACTIVE SEQUENCE (NETWORK TO CSU)
FIGURE 6



NOTE:
DATA MODE ZERO SUPPRESSION SEQUENCES, SHOWN WITHIN DOTTED LINES, ILLUSTRATE ENCODING FOR THE DIRECTION FROM CSU TO NETWORK. FROM NETWORK TO CSU, OOOXOV MUST ALWAYS BE DECODED AS 6 ZEROS. EACH X MAY BE O OR B DEPENDING ON THE NUMBER OF B's SINCE LAST V.

DATA MODE
ZERO SUPPRESSION SEQUENCE
FIGURE 7



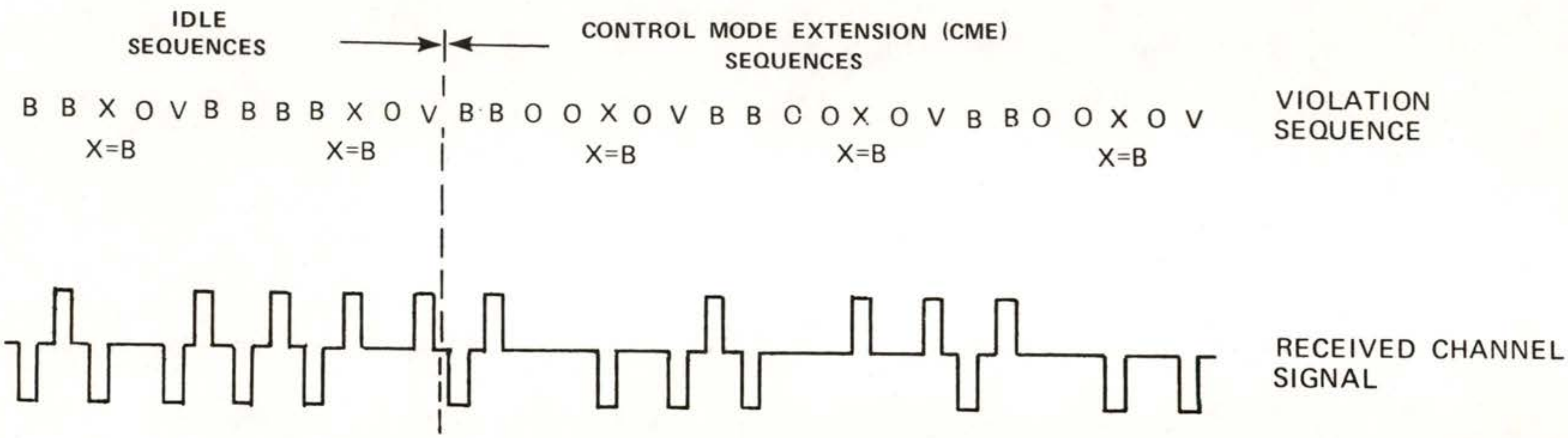
Note:

First X may be O or B depending on number of Bs since last V.

All remaining X's in DME sequences are O's.

DATA MODE EXTENSION (DME) SEQUENCE

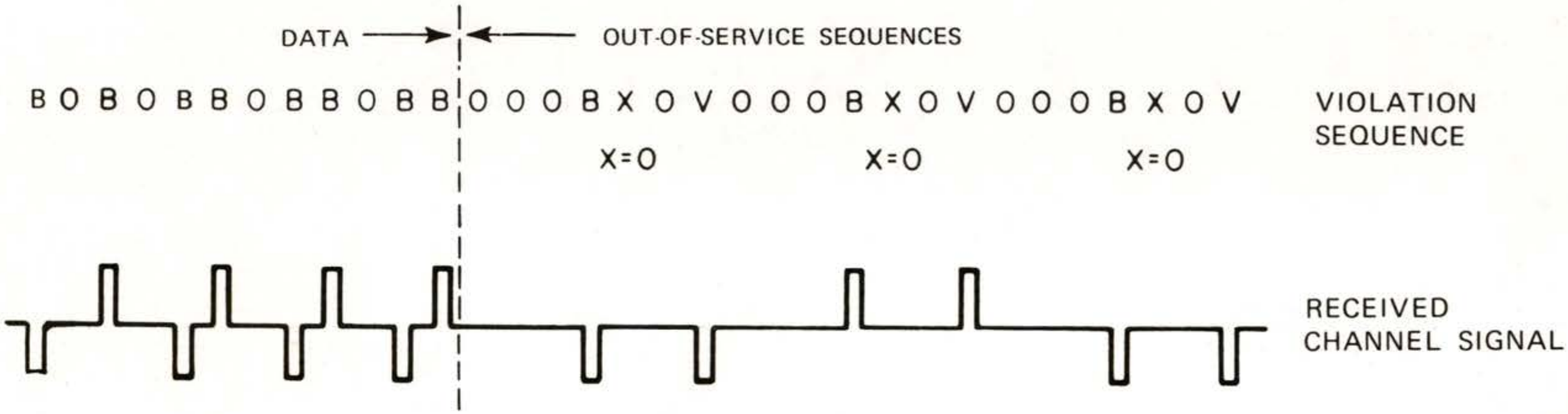
FIGURE 8



Note:
First X may be O or B depending on number of Bs since last V. All remaining Xs in CME sequences are Bs.

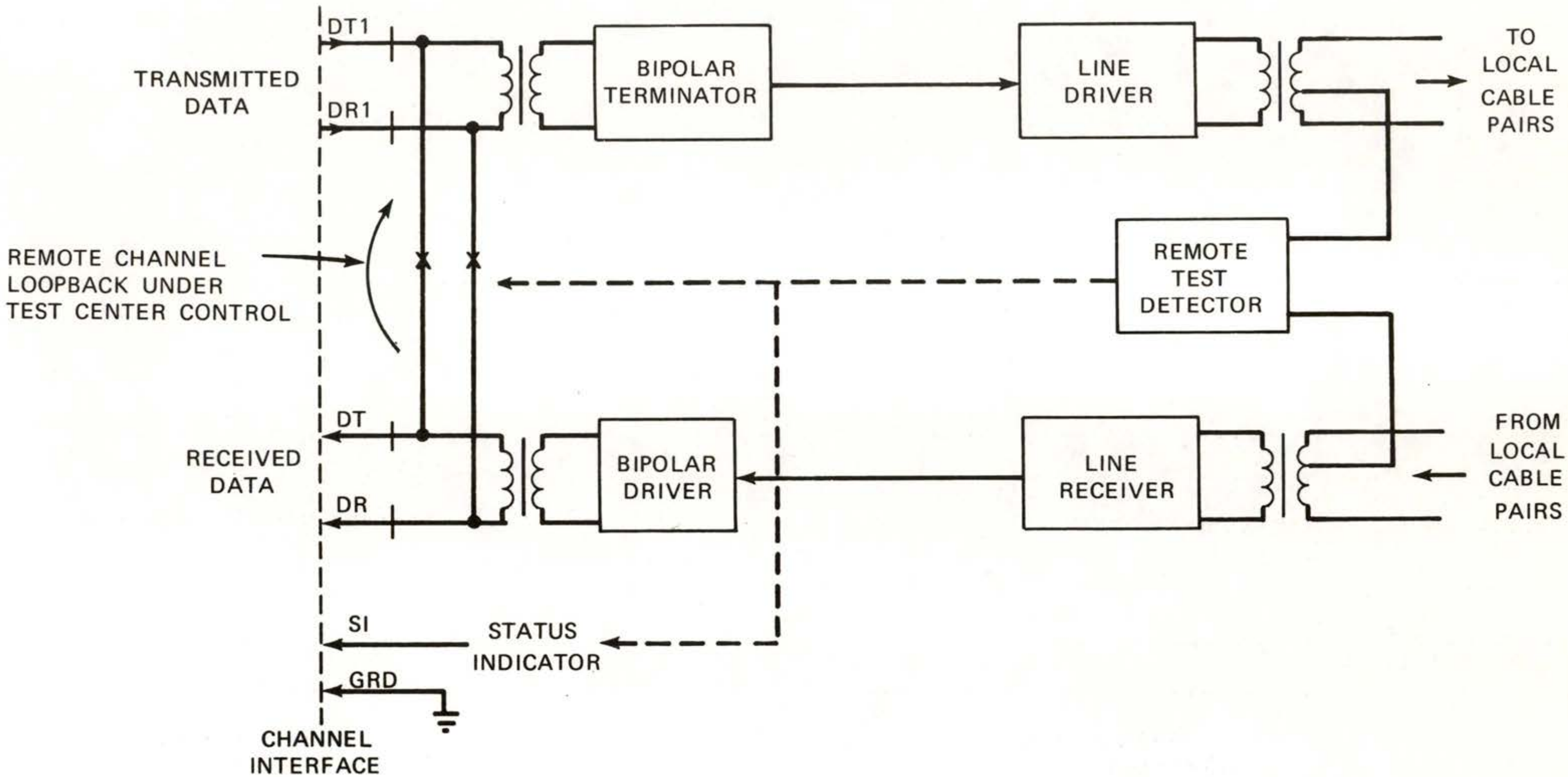
CONTROL MODE EXTENSION (CME) SEQUENCE

FIGURE 9

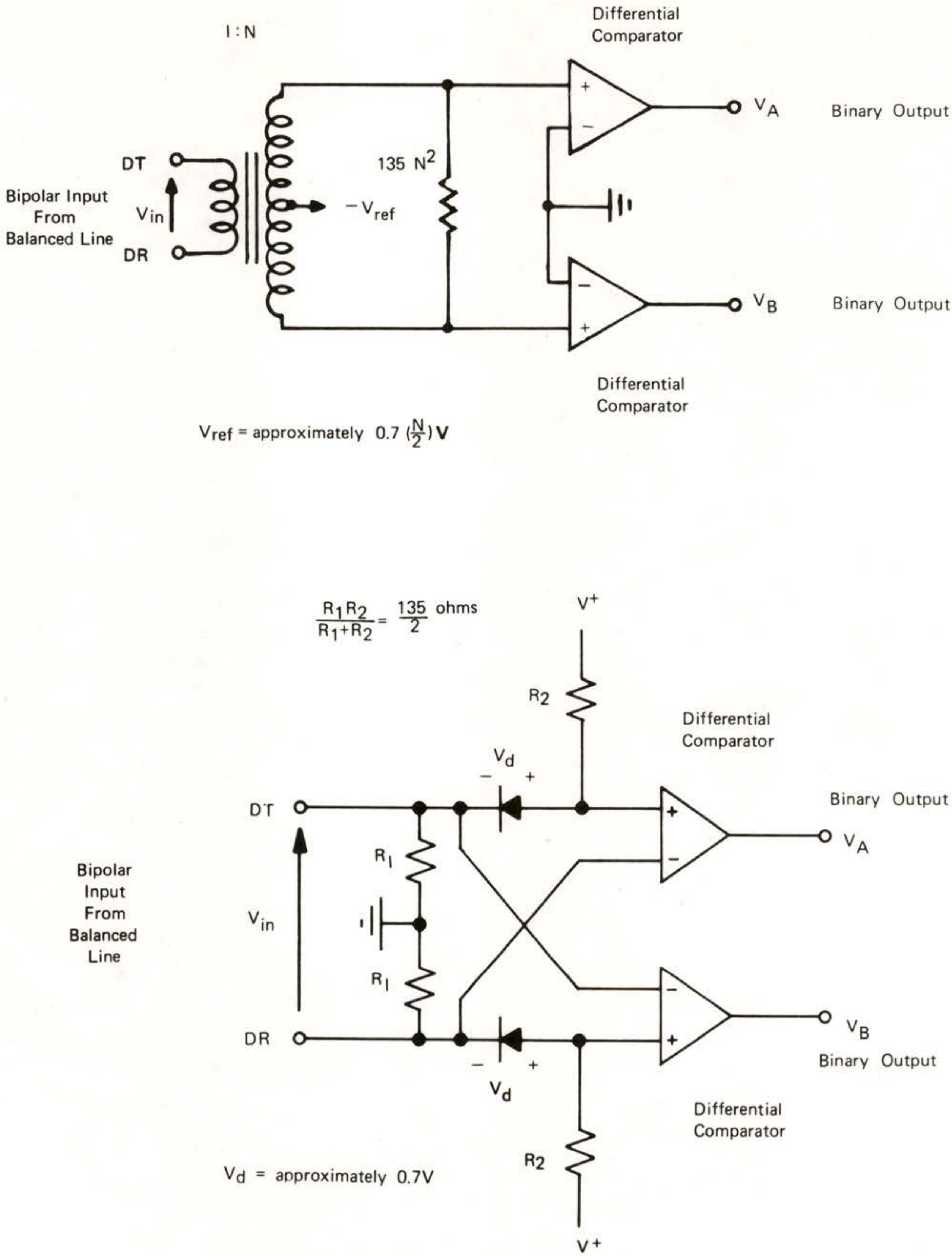


Note:
First X may be O or B depending on number of Bs since last V. All remaining Xs in Out-of-Service sequences are O's.

OUT-OF-SERVICE SEQUENCE
FIGURE 10

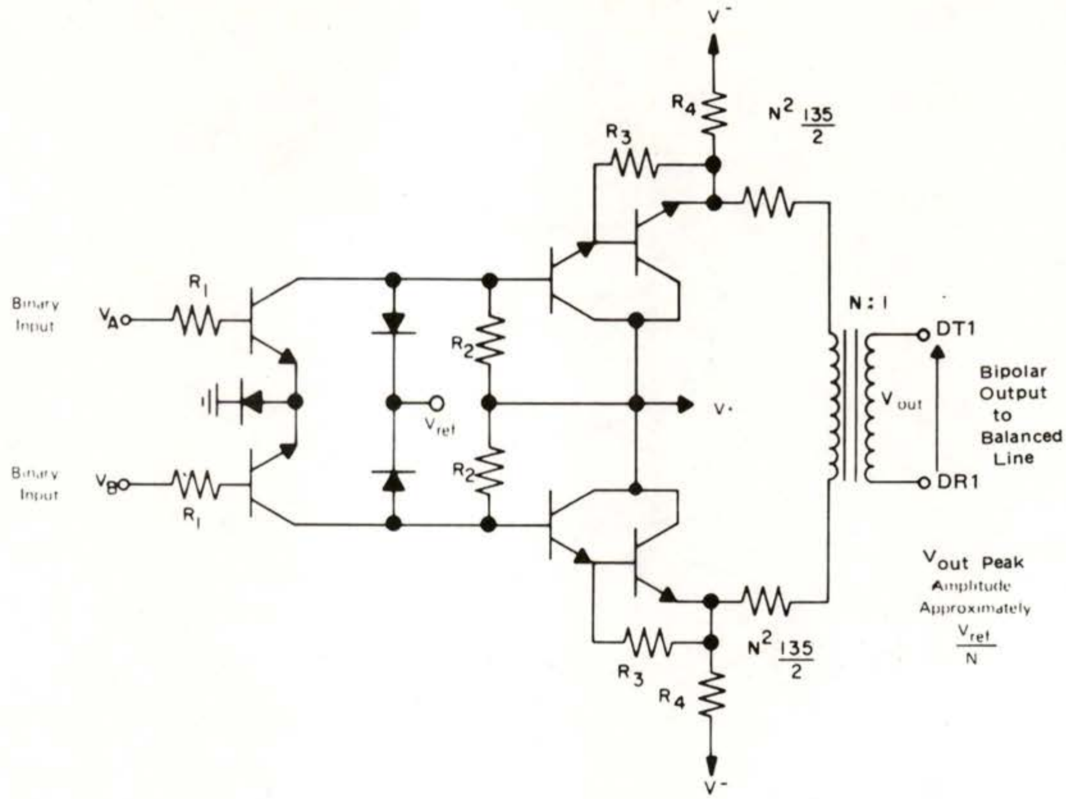


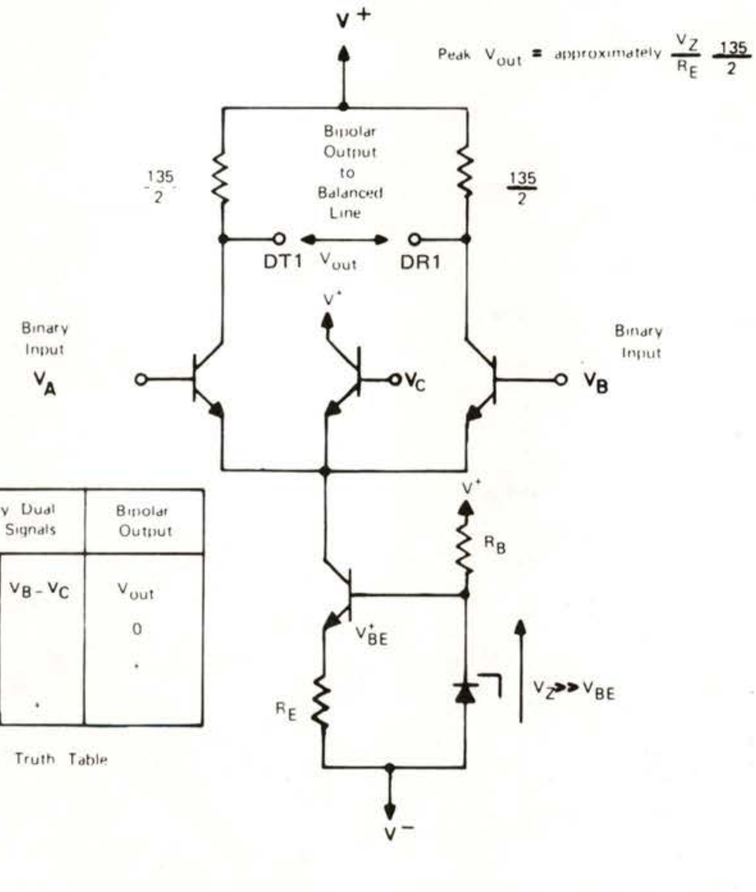
BLOCK DIAGRAM OF CHANNEL SERVICE UNIT (CSU)
FIGURE 11



BALANCED BIPOLAR INTERFACE CABLE TERMINATORS

FIGURE 12



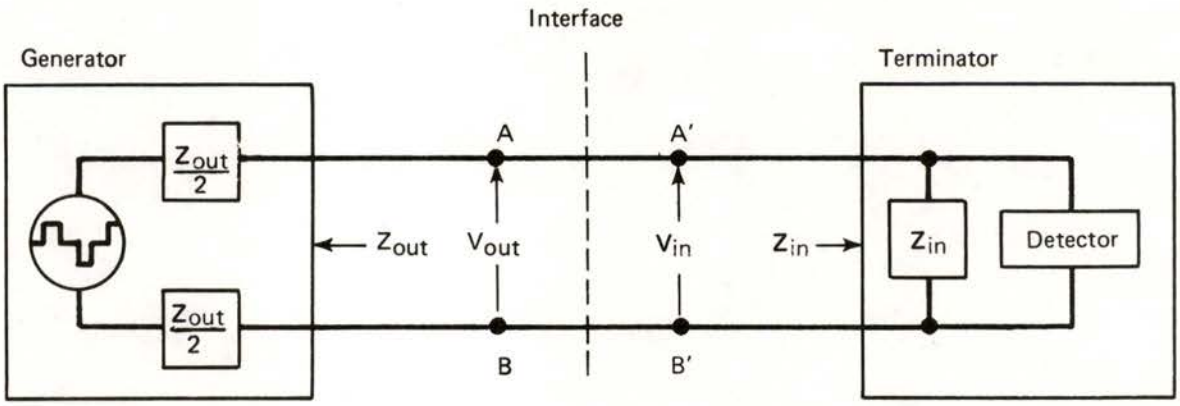


Binary Dual Rail Signals		Bipolar Output
$V_A - V_C$	$V_B - V_C$	V_{out}
-		0
+		+
-	+	

Truth Table

BALANCED BIPOLAR INTERFACE CABLE DRIVERS

FIGURE 13



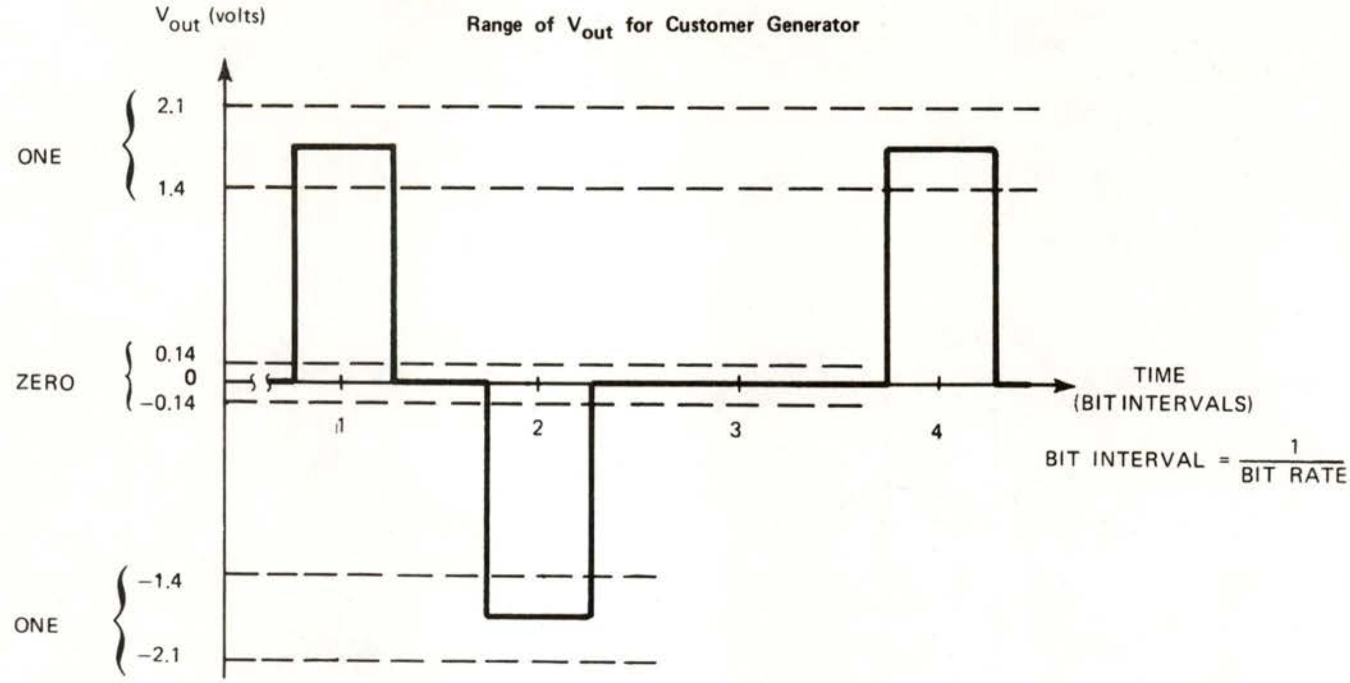
Notes:

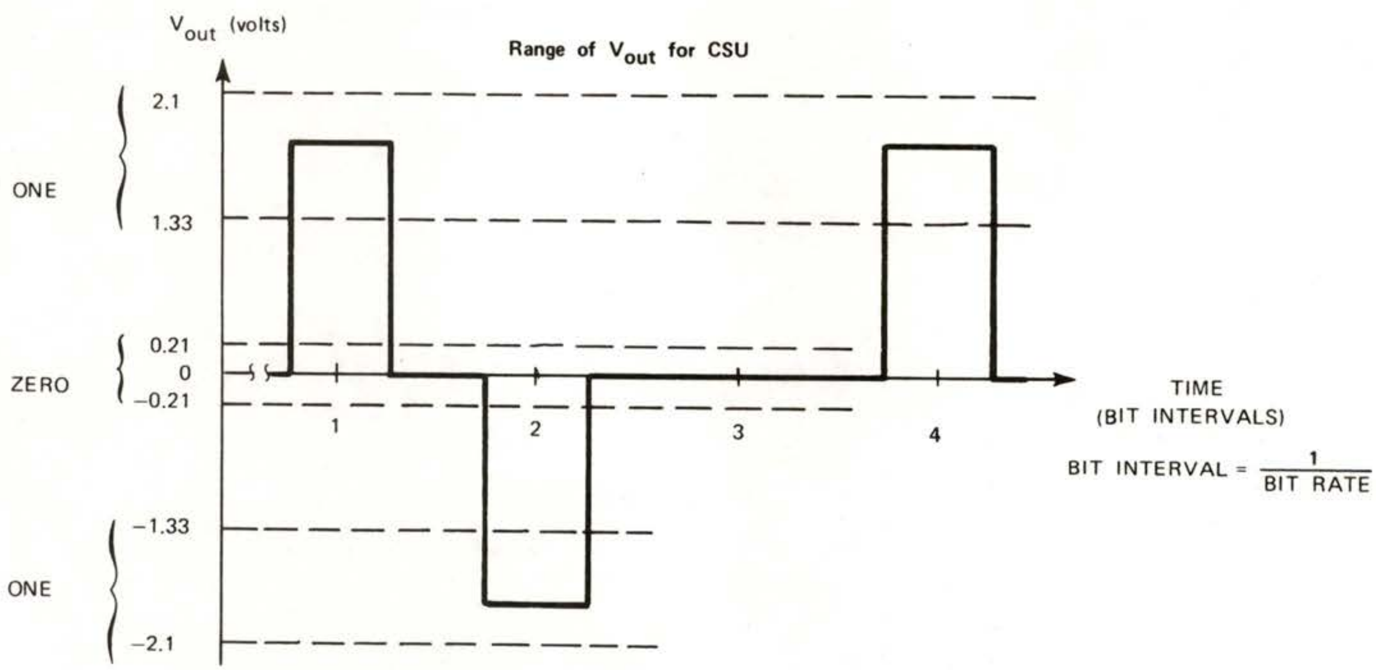
1. For signals on the Transmitted Data leads (DT1, DR1)
   - the generator is in the customer's equipment
   - the terminator is in the CSU

2. For signals on the Received Data leads (DT, DR)
   - the generator is in the CSU
   - the terminator is in the customer's equipment

3. The differential impedances, Z_{out} and Z_{in} are defined with respect to pulse-type signals rather than sinusoidal ones. The impedances are measured when transmitting or receiving a bipolar pulse train at the nominal bit rate, signal level and duty-cycle with a 135-ohm resistive load or source respectively.

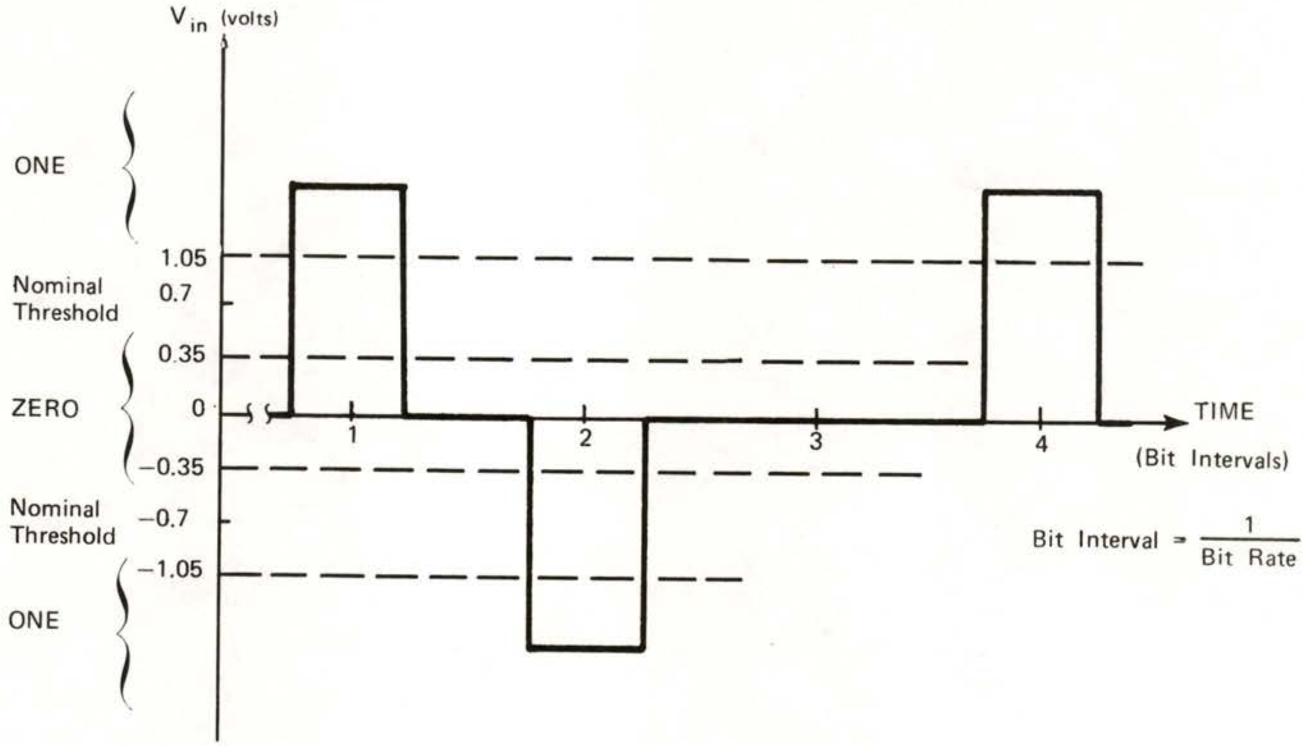
DIFFERENTIAL VOLTAGES
FIGURE 14





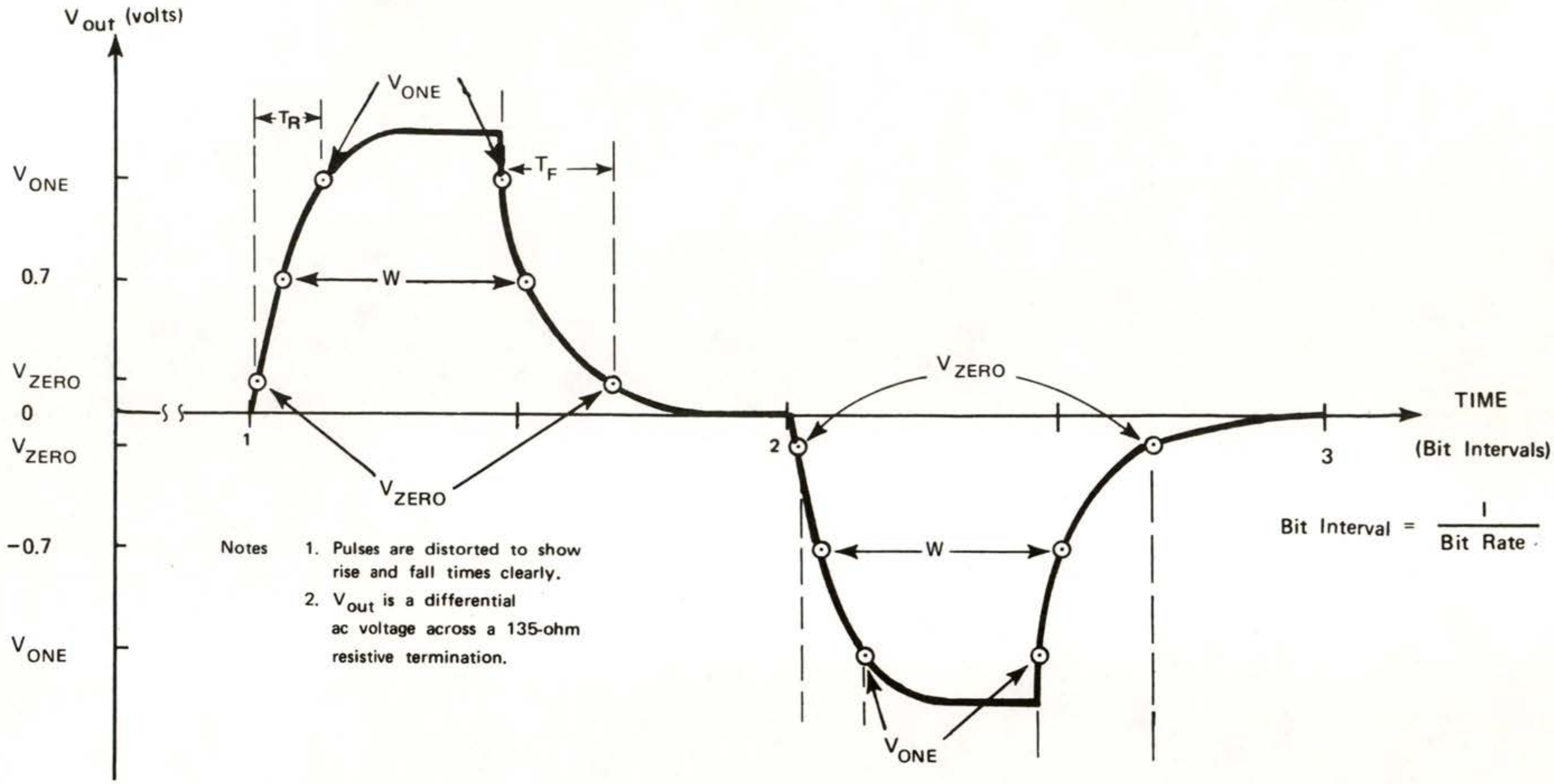
Note: V_{out} is a differential **ac** Voltage across a 135-ohm resistive termination.

OUTPUT VOLTAGE (Vout) RANGE
FIGURE 15



Notes: V_{in} is the normalized input voltage that is applied to a customer's terminator or the CSU terminator. V_{in} is said to be normalized when it is the voltage obtained when the source of test pulses has a 135-ohm resistive termination.

TERMINATOR THRESHOLD VOLTAGES
FIGURE 16

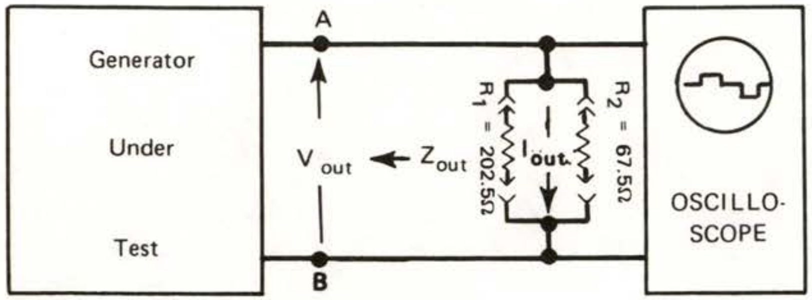


Symbol	Definition	Specification	
T_R	Rise Time	Not to exceed 5% of a Bit Interval	
T_F	Fall Time	Not to exceed 5% of a Bit Interval	
W	Pulse Width	Customer to CSU	– 47.5% to 52.5% of a Bit Interval
		CSU to Customer	– 45% to 90% of a Bit Interval
V_{ONE}	Minimum ac voltage for a binary one	Customer Generator	– 1.4 volts
		CSU Generator	– 1.33 volts
V_{ZERO}	Maximum ac voltage for a binary zero	Customer Generator	– 0.14 volts
		CSU Generator	– 0.21 volts

BILPOLAR PULSE CHARACTERISTICS

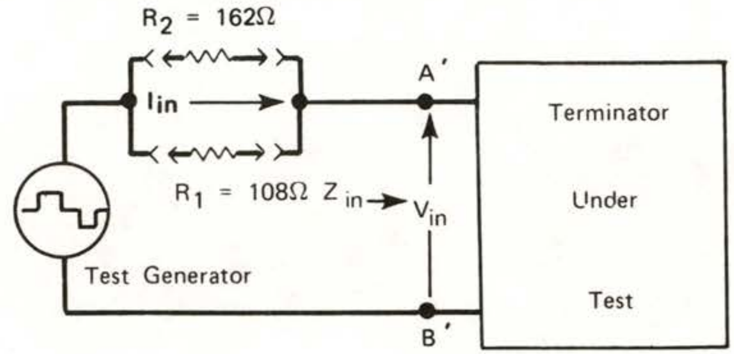
FIGURE 17

Simplified Generator Test Arrangement

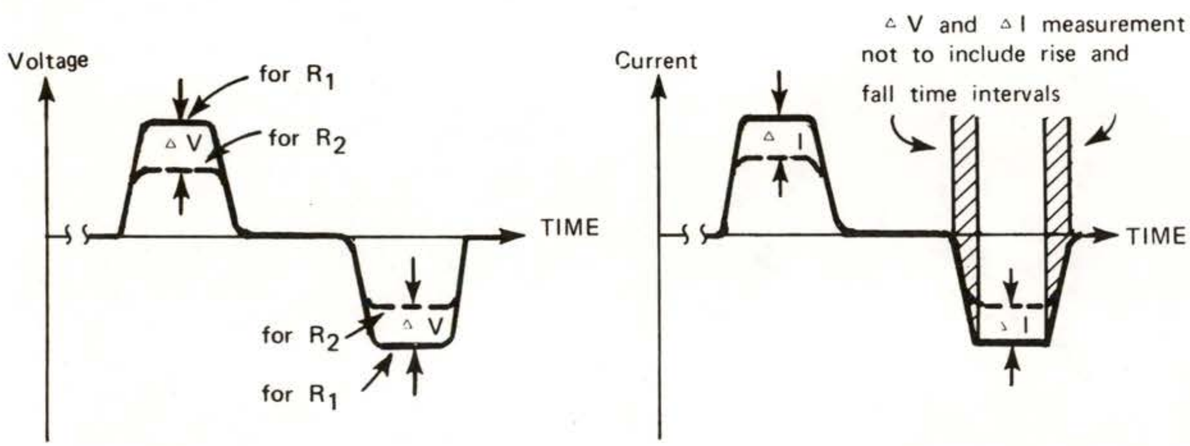


Resistances chosen to be 135 ohms ± 50%

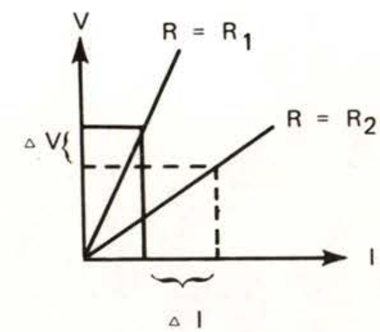
Simplified Terminator Test Arrangement



Resistances chosen to be 135 ohms ± 20%



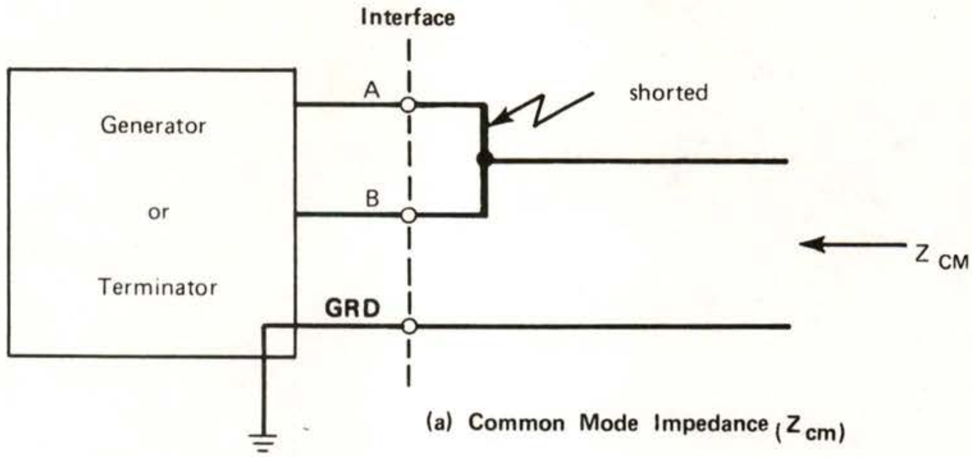
Observed Waveforms



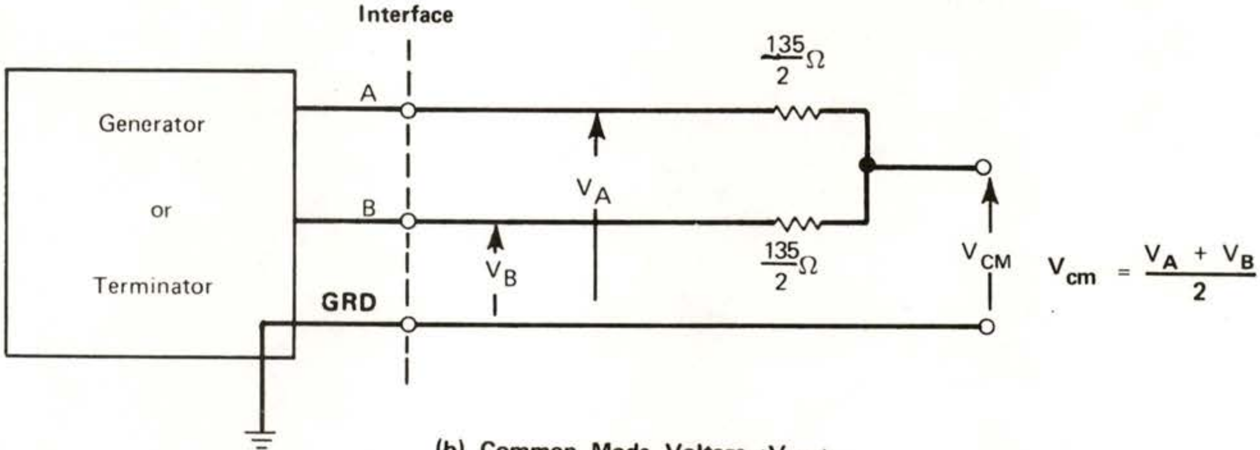
Compute		Specification
$\left\| Z_{out} \right\| = \left\| \frac{\Delta V_{out}}{\Delta I_{out}} \right\|$	=	135 ohms ± 20%
$\left\| Z_{in} \right\| = \left\| \frac{\Delta V_{in}}{\Delta I_{in}} \right\|$	=	135 ohms ± 50%

DIFFERENTIAL IMPEDANCE

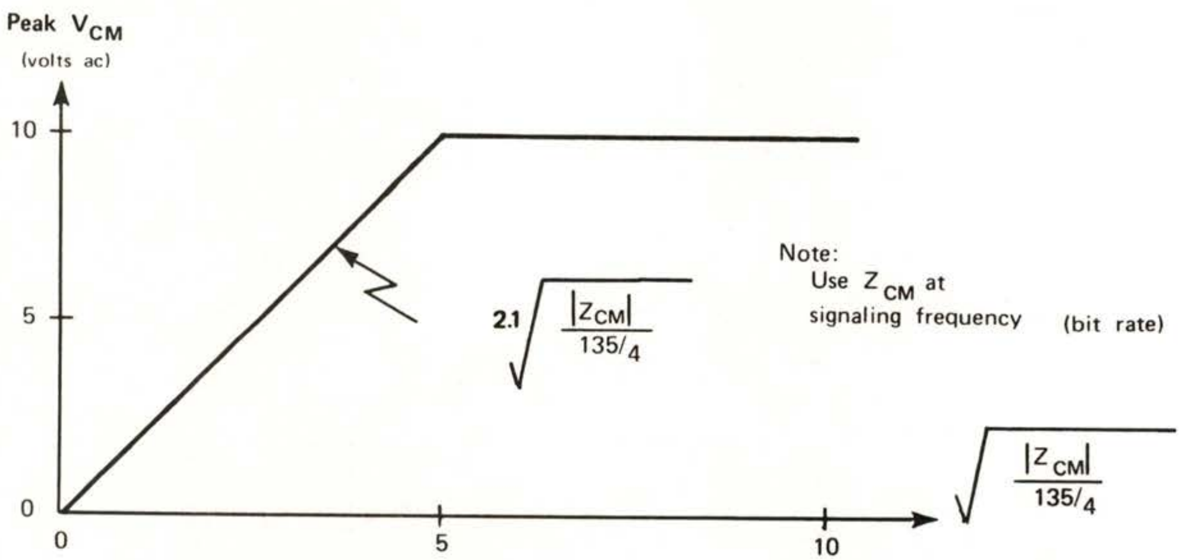
FIGURE 18



(a) Common Mode Impedance (Z_{cm})

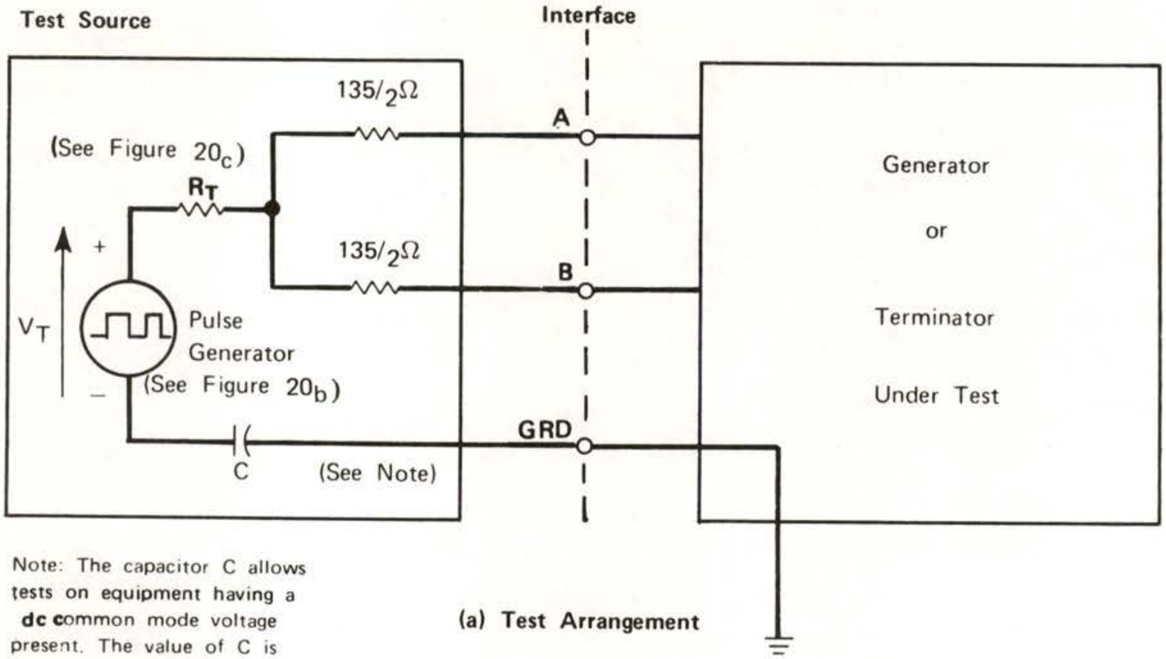


(b) Common Mode Voltage (V_{cm})



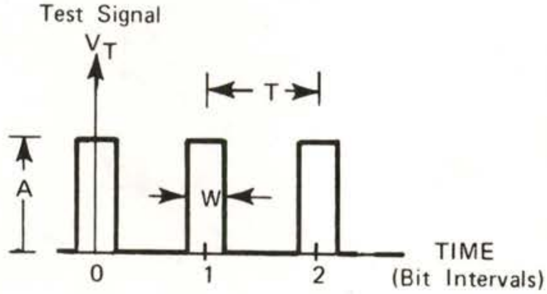
(c) Peak V_{CM} (ac) as a Function of Z_{CM} (output from generator or terminator)

COMMON MODE IMPEDANCE AND VOLTAGE
FIGURE 19



Note: The capacitor C allows tests on equipment having a **dc** common mode voltage present. The value of C is chosen so its impedance will be negligible at all significant frequencies.

(a) Test Arrangement

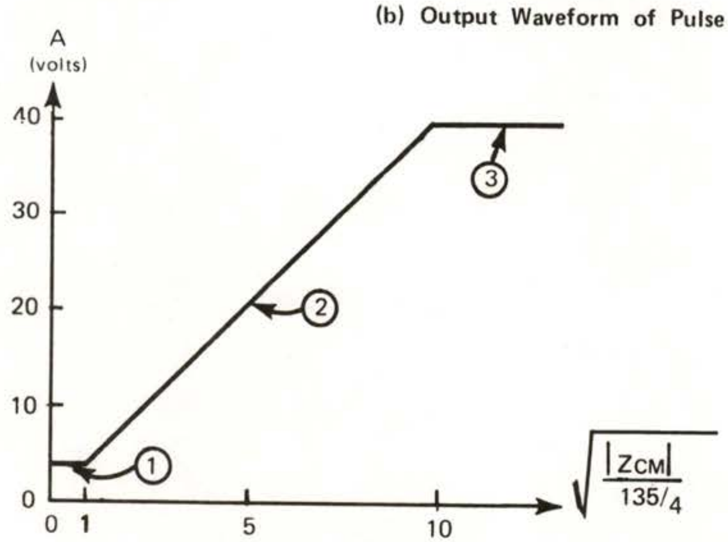


A = Pulse Amplitude (determined from Figure 20_c)

T = Bit Interval = $\frac{1}{\text{Bit Rate}}$

W = Pulse Width
$0.1T \leq W \leq 0.9T$
Rise and fall times $\leq 0.01T$

(b) Output Waveform of Pulse Generator



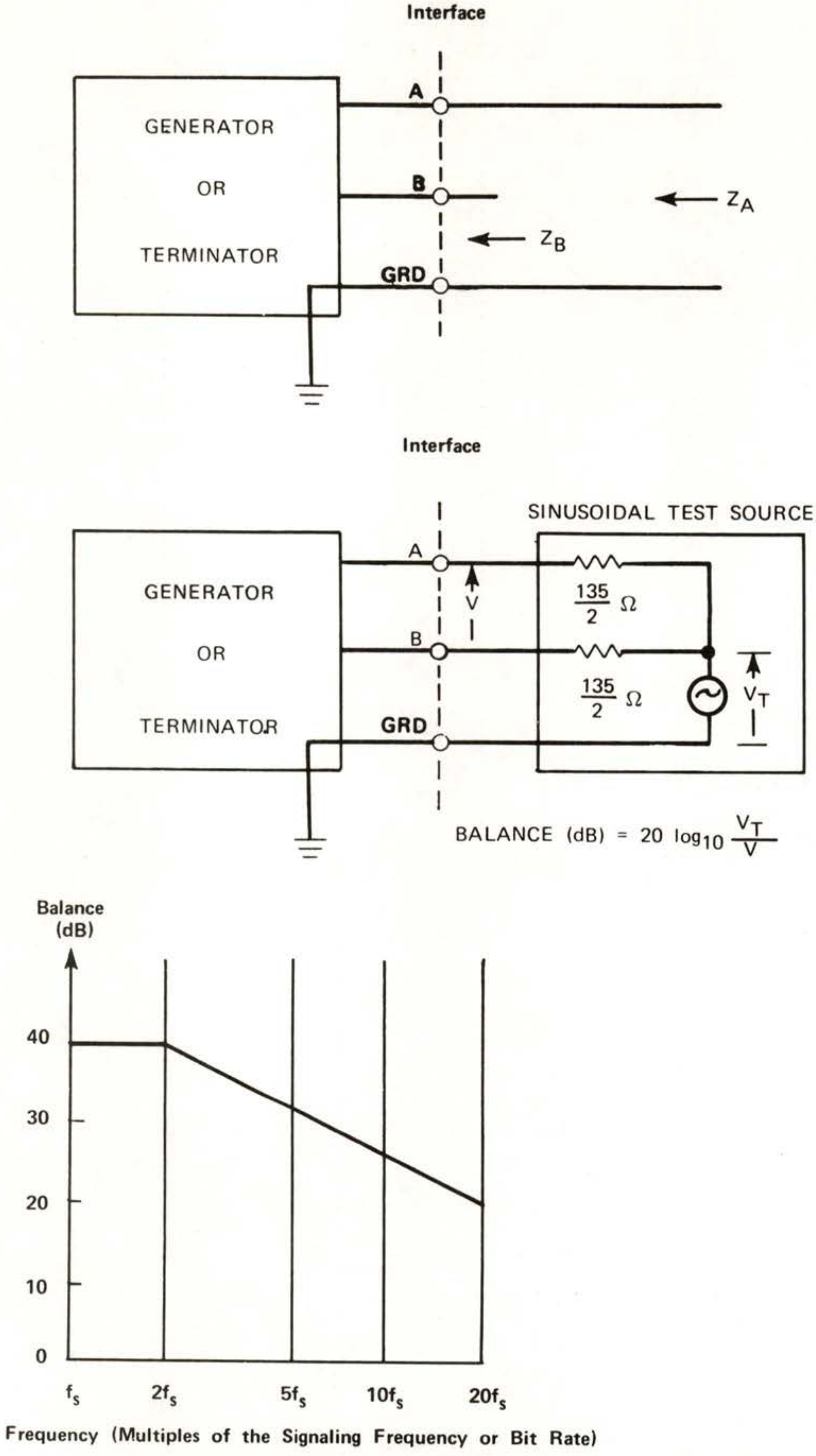
Region	R_T (ohms)
1	0
2	$\left\lvert Z_{CM} - \frac{135}{4} \right\rvert$
3	$10\left(\frac{135}{4}\right)^2$ or 11400

Note: Use Z_{CM} at signaling frequency (bit rate)

(c) Pulse Amplitude as a Function of Z_{CM}

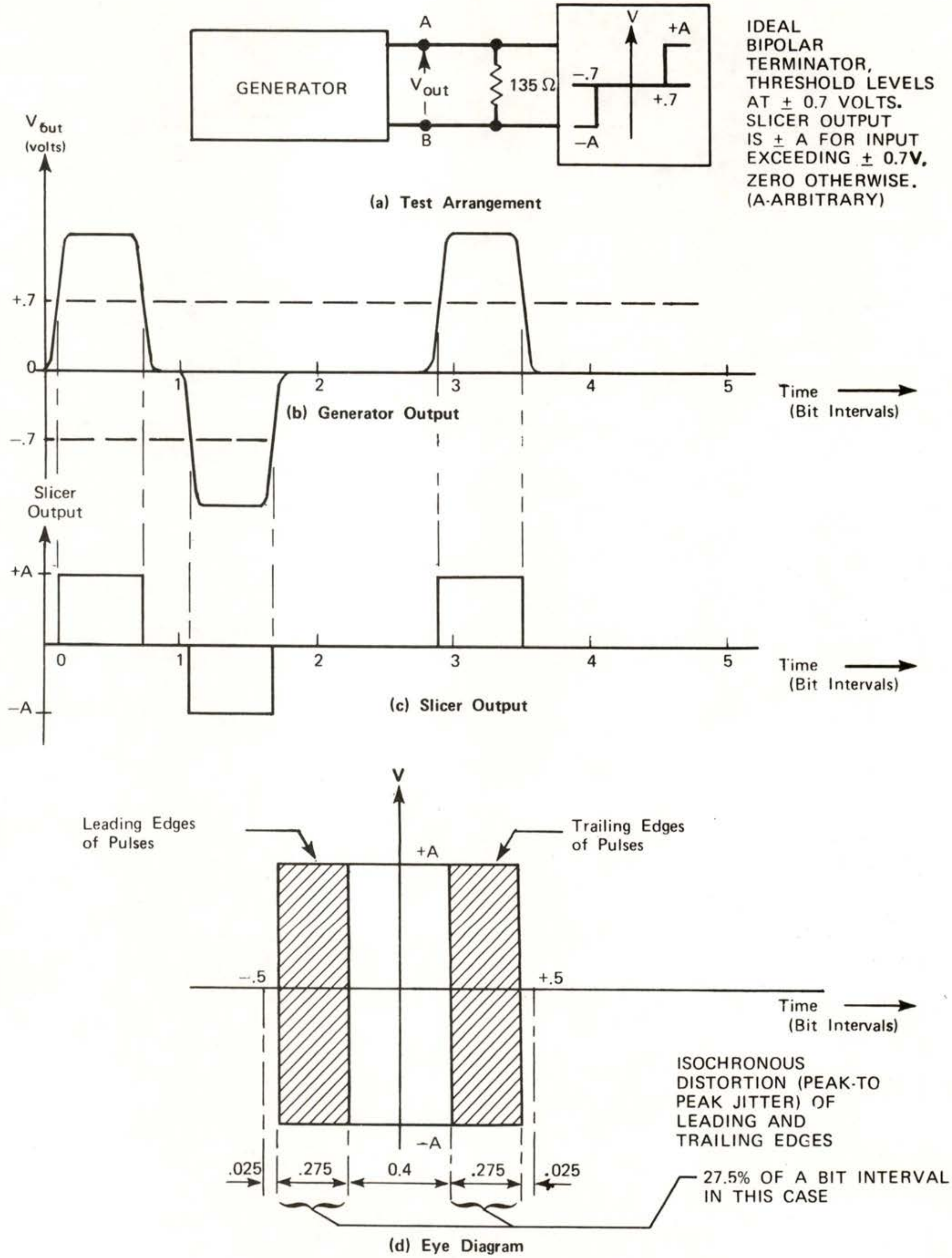
COMMON MODE INPUT VOLTAGE RANGE

FIGURE 20



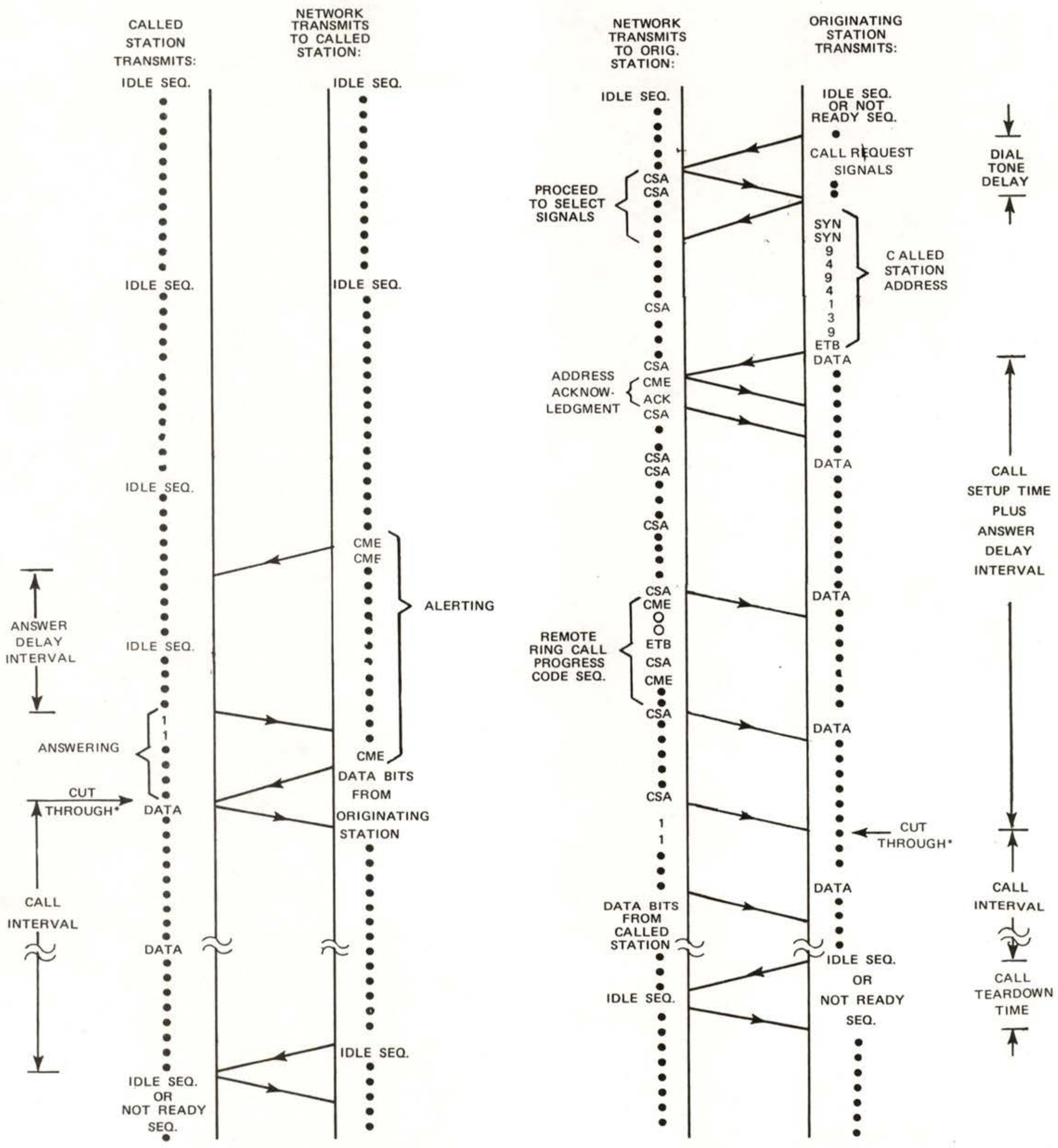
IMPEDANCE BALANCE

FIGURE 21



ISOCHRONOUS DISTORTION

FIGURE 22



* CUT THROUGH INDICATES THAT A COMPLETE DUPLEX CONNECTION HAS BEEN ESTABLISHED

SEQUENCE OF EVENTS
FOR SDDS CALLS
FIGURE 23

FIGURE 24

CHARACTERS USED IN TRANSMITTING CALLED STATION

ADDRESSES TO THE NETWORK

ADDRESS DIGITS	BITS TRANSMITTED*							
	1	2	3	4	5	6	7	8
SYN	0	B	B	0	B	0	0	0
0	0	0	0	0	0	B	B	B
1	0	0	0	B	0	B	B	0
2	0	0	B	0	0	B	B	0
3	0	0	B	B	0	B	B	B
4	0	B	0	0	0	B	B	0
5	0	B	0	B	0	B	B	B
6	0	B	B	0	0	B	B	B
7	0	B	B	B	0	B	B	0
8	B	0	0	0	0	B	B	0
9	B	0	0	B	0	B	B	B
ETB	B	B	B	0	B	0	0	B

*American Standard Code for Information Interchange (ASCII) is used. Bit No. 1 is transmitted first.

FIGURE 25

BIT CONFIGURATIONS FOR ACK AND NAK NETWORK RESPONSES

NETWORK RESPONSE	BITS TRANSMITTED*						
	1	2	3	4	5	6	7
ACK	B	O	B	B	O	O	O
NAK	B	B	O	B	O	B	O

*Bit No. 1 is transmitted first.

FIGURE 26

BIT CONFIGURATIONS FOR CALL PROGRESS CODE CHARACTERS

CHARACTERS	BITS TRANSMITTED*						
	1	2	3	4	5	6	7
0	B	0	0	0	0	B	B
1	B	B	0	0	0	B	B
2	B	0	B	0	0	B	B
3	B	B	B	0	0	B	B
ETB	B	B	B	B	0	B	0

* Bit No. 1 is transmitted first.

APPENDIX

Timing Recovery Definitions

This appendix is included to provide a convenient reference for the definition of isochronous and peak individual distortion of data signal transitions. These terms are also used and discussed in two publications:

> EIA Standard RS-334, "Signal Quality at Interface Between Data Processing Terminal Equipment and Synchronous Data Communication Equipment for Serial Data Transmission."
>
> EIA Industrial Electronics Bulletin No. 5, March, 1956, "Tutorial Paper on Signal Quality at a Digital Interface."

Definitions

In the following discussion, the term "unit interval" means the reciprocal of the data rate. The term "significant instant of modulation" with reference to a bipolar data signal, means the instant the signal crosses a preset threshold level. In the case of the CSU interface, the levels are ±0.7 volts, measured across a 135-ohm resistance at the generator terminals.

<u>Degree of Individual Distortion of a Particular Significant Instant</u> (from Bulletin No. 5):

"The ratio to the unit interval of the displacement, expressed algebraically, of this significant instant from an ideal instant. This displacement is considered positive when the significant instant occurs after the ideal instant. The degree of individual distortion is usually expressed as a percentage."

<u>Degree of Peak Individual Distortion</u> (from RS-334):

"The maximum individual distortion, irrespective of sign, of all significant instants occurring during a particular measuring period."

<u>Degree of Isochronous Distortion</u> (from RS-334):

1. "Ratio to the unit interval of the maximum measured difference, irrespective of sign, between the actual and the theoretical intervals separating

any two significant instants. . . , these instants being not necessarily consecutive."

2. "Algebraical difference between the highest and lowest value of individual distortion affecting the significant instants of an isochronous modulation. (This difference is independent of the choice of the reference ideal instant.)"

In the case of both isochronous and peak individual distortion, the length of observation is also important. In the case of a prolonged observation, it is appropriate to consider the probability that a given degree of distortion will be exceeded.

Applications

To apply these definitions to the CSU interface, the expected nature of the data signals must be considered. The Transmitted Data (DT1, DR1) from the customer data terminal to the CSU is expected to be synchronous with the SDDS, relatively noise-free, and well-controlled in width (nominal 50 percent duty-cycle).

The requirement of synchronism implies that the theoretical instants of transition are related to the average of the transitions of the received data. For example, a clock would have its negative-going transitions occurring midway between the average of the positive and negative-going transitions of the received data.*

The measurement of peak individual distortion then proceeds as illustrated in Figure A. Since the signals on DT1 and DR1 are relatively noise-free, fairly large measuring intervals may be used.

The distortion of signals transmitted from the CSU to the customer is largely determined by the characteristics of the cable pair from the Telephone Company office to the customer location. The duty-cycle is not controlled here. Noise bursts may cause data transitions to occur anywhere within the unit interval. In the theoretical noise-free case, the dispersion of the transitions from an ideal

---

* In this discussion, the transitions are intended to mean from the bipolar zero level to the bipolar one level of either polarity and then the return to the bipolar zero level.

instant will be due to intersymbol interference and data pattern variations.

Timing Recovery

Timing recovery in data transmission commonly involves applying the received signal, or a processed version thereof, to a high-selectivity circuit, such as an LC tank or a phase-locked loop, to extract the fundamental bit frequency. The equivalent circuit for these schemes usually reduces to a low-pass filter acting on the input jitter of the received data transitions.

The data signal is then sampled at clock transitions in phase with the nominal center of the received pulses.

Since the low-pass character of the timing circuit attenuates high-frequency jitter, attention is focussed on the low-frequency input and output jitter. An empirically verified theory, discussed below, leads to a useful figure of merit for the quality of the received signal transitions and establishes performance limits for the synchronous sampling circuits described above.*

We suppose that the input jitter depends only on the last few bits transmitted, and consider a repetitive pattern with period much less than the reciprocal of the bandwidth, B. Associated with this periodic pattern is an average of dc phase shift, θ_1, corresponding to the location of the average of the pulse centers; the phase is measured with respect to the transitions of an appropriate ideal clock signal. Now suppose the pattern is suddenly switched to one with average phase, θ_2. The data transitions adjust their phase to θ_2 in a few bit's time, the assumed memory span of the jitter mechanism. The recovered clock phase, however, changes at a rate $B(\theta_2-\theta_1)$, and thus requires a time 1/B to adjust to the new phase (See Figure B.)

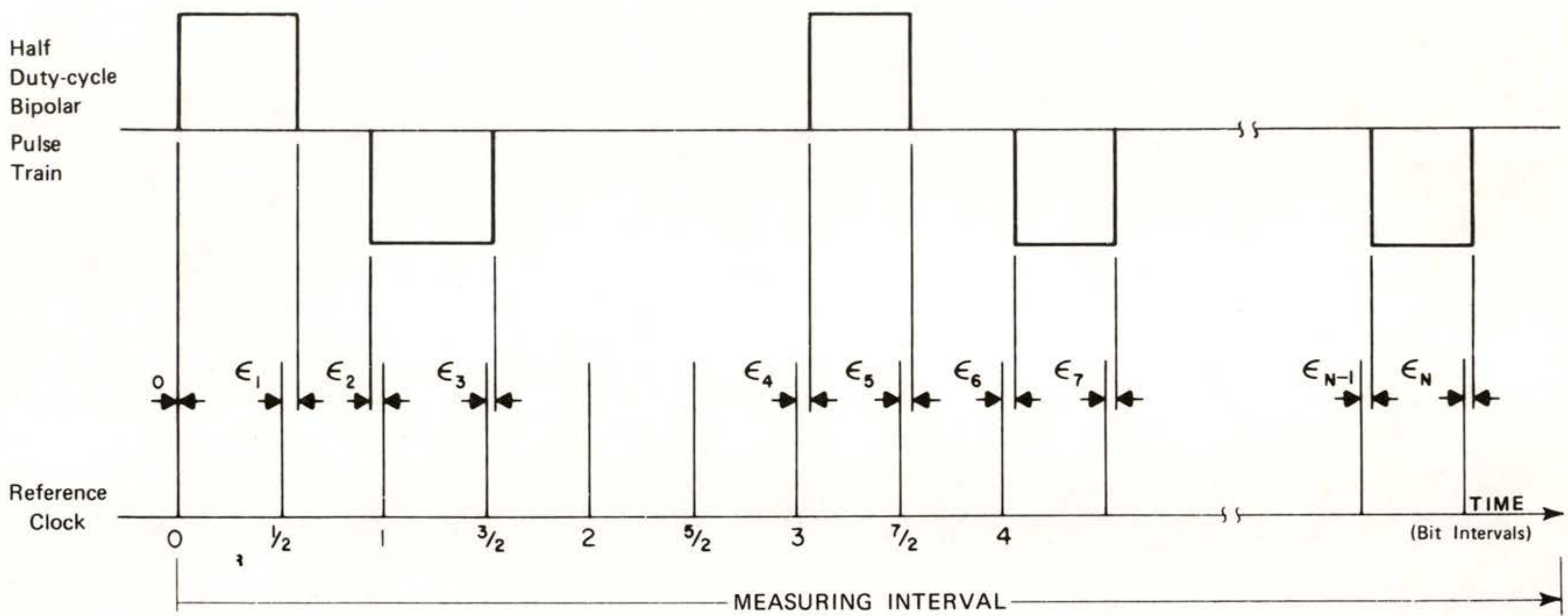
Evidently, the recovered timing signal has an irreducible phase jitter of $\theta_1-\theta_2$; moreover, the data sampling instant is offset from the nominal pulse center by $\theta_2-\theta_1$ immediately following the change in pattern.

---

* Byrne, C. J., Karafin, B. J., and Robinson, D. B., Jr., "Systematic Jitter in a Chain of Digital Regenerators," Bell System Technical Journal, November, 1963, pp. 2679-2714.

Thus, the worst-case peak-to-peak dc phase shift between any two repetitive patterns represents a figure of merit for the quality of the received data transitions.

It is independent of the particular realization in this class of timing and sampling circuits.



LEGEND:

$100.0 \times \epsilon_i$ = Individual Distortion of i^{th} significant instant (%) (i = 1, 2, . . . N)

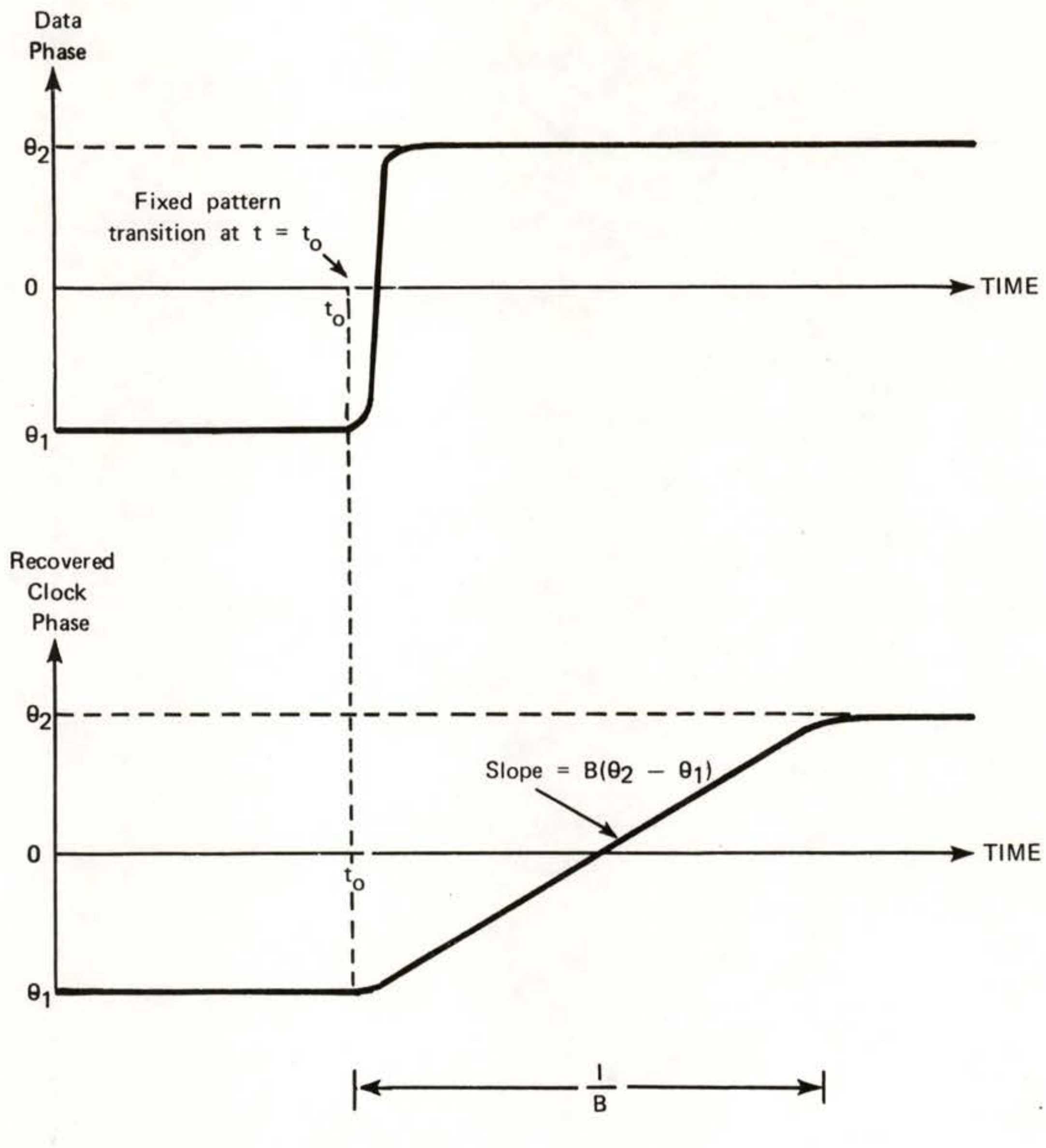
ϵ_{max} = Maximum $|\epsilon_i|$ observed in measuring interval (i = 1, 2, . . . N)

$100.0 \times \epsilon_{max}$ = Peak Individual Distortion

δ_{max} = Maximum $|\epsilon_i - \epsilon_j|$ between any two Individual Distortions observed in measuring interval. (i,j = 1, 2, . . . N) not necessarily consecutive pulses.

$100.0 \times \delta_{max}$ = Isochronous Distortion (%) Timing Distortion

TIMING DISTORTION
FIGURE A



B = Timing circuit bandwidth

EFFECT OF FIXED PATTERN TRANSITIONS
ON RECEIVED CLOCK PHASE

FIGURE B

PUB 41452

PRELIMINARY

Bell System Data Communications

TECHNICAL REFERENCE

DATAPHONE® SWITCHED DIGITAL SERVICE DATA SERVICE UNIT INTERFACE SPECIFICATIONS

MARCH 1976

ENGINEERING MANAGER – DATA NETWORK SERVICES

326-118

NOTICE

If further information is required, please contact:

Engineering Manager - Data Network Services
American Telephone and Telegraph Company
295 North Maple Ave.
Basking Ridge, New Jersey 07920

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501A DATA SERVICE UNIT

TECHNICAL SPECIFICATION SUMMARY

Data Rate: 56 kb/s

Operation: Synchronous with timing control from Switched Digital Data System at specified rate of 56 kb/s

Multiple Arrangements: Stackable units (up to 3)

Data Interchange Interface Signal Requirements:
EIA RS-232-C and CCITT Recommendation V.35

Automatic Calling Interface Requirements: EIA RS-366

Principal Operating Mode:
Duplex (Half-Duplex and Simplex Operation Possible)

Data Terminal Connector:
Automatic Calling Interface- 25 pin connector: Cinch or Cannon Type DB-19604-432 or AMP 205784-1 or equivalent plug with Cinch DB-51226-1 hood or equivalent
Data Interchange Interface - 34 pin connector: Winchester MRA (C)-34P-JTC6-H8, or Burndy MS34 PM-124, or AMP 5-202431-2 or equivalent

Environmental Requirements:
Ambient Temperature Range: 40° to 120°F
Relative Humidity: Less than 95%

Control Functions:
Request to Send - Clear to Send Delay - 22 to 23 bits (Terminal Controlled Carrier Option)
- no delay (Permanent Carrier Option)
Received Line Signal Detector Turn on Time (During a Call) - 14 bits

Turn off Time (During a Call) - 21 bits

Turn off Time (To Enter Out-of-Service Mode)-Approx. 1 sec. for local loop failures, 300 ms for failure in high order digital facilities

AC Power Requirements:
105-129V, 60±3 Hz, uninterrupted power source

Weight: Approximately 17.3 lbs. (7.9 kg.)

Dimensions: Approximately 16" (40.7 cm.) wide, 11.4" (29 cm.) deep, 4.3" (10.9 cm.) high

1. INTRODUCTION

The purpose of this Technical Reference is to define the interface specifications associated with the Data Service Unit (501A-type DSU). DSUs* are located at customers' premises as part of the Switched Digital Data System (SDDS), which is used to provide DATAPHONE Switched Digital Service. The SDDS is a common-user duplex** switched digital data network, which accommodates the synchronous data transmission speed of 56 kb/s. The DSU provides equalization, remote and local testing capabilities and the logic and timing necessary to provide a standard CCITT V.35 type interface.‡ In addition to controlling the transfer of data, this Data Interchange Interface may be used by customer data terminal equipment for answering and terminating calls automatically. The DSU also provides an optional capability for automatic call origination through a standard EIA RS-366 type Automatic Calling Interface. In addition to this automatic call originating option, manual calling and answering is made available optionally by the Manual Call Controller (also referred to as the 821A-type Data Auxiliary Set). The Manual Call Controller has a key pad for addressing similar to a TOUCH-TONE® pad, and lights and a character display for call status indications. It also contains an audible alerting device to indicate an incoming call.

If manual control, timing recovery, data encoding and decoding and the standard interface circuitry are not

---

* In this Technical Reference, the term Data Service Unit (DSU) will be used exclusively in referring to the 501A-type Data Service Unit. This DSU is physically different from the 500A-type DSU, which is used in the Digital Data System (DDS) but not in the Switched Digital Data System (SDDS). The 500A-type DSU is discussed in the Technical Reference titled "Digital Data System Data Service Unit Interface Specifications" (PUB 41450).

** Duplex operation, also called full-duplex operation, is the transmission of signals in both directions simultaneously.

‡ For ordering information on EIA and CCITT Standards, see Page 54.

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desired, a basic access line can be requested. A basic access line is terminated on the customer's premises by a Channel Service Unit (550A-type CSU) which provides only the minimum equipment required to produce a properly balanced and equalized loop termination and to permit rapid remote testing of the access line.* Additional information on the CSU interface for SDDS may be found in the Technical Reference titled "DATAPHONE Switched Digital Service Channel Interface Specifications" (PUB 41023).

Section 2 provides an overview of the SDDS and the services offered. Sections 3 through 8 provide a more detailed description of the DSU and Manual Call Controller, system operation and maintenance, and the specific service objectives.

2. OVERVIEW OF THE SWITCHED DIGITAL DATA SYSTEM (SDDS)

2.1 DATAPHONE Switched Digital Service Capability

DATAPHONE Switched Digital Service, which will use only digital facilities from end to end,** will be offered in selected geographical areas called Switched Digital Serving Areas (Switched DSAs) located in metropolitan areas throughout the United States. This duplex switched data transmission service will be offered on a common-user basis. Stations will be permitted to receive calls only from other SDDS stations that originate calls. During the data transfer phase of a call between two SDDS stations, the full 56 kb/s channel information capacity may be used, i.e., there are no restrictions on the bit patterns that may be transmitted.

Multiline hunting is available on an optional basis with DATAPHONE Switched Digital Service. Among a group of SDDS stations in a Switched DSA, which are designated by the customer to be in a multiline hunting group, the system hunts for an idle station in an attempt to complete an

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* An access line is a dedicated duplex SDDS channel between an individual station and its associated switch.

** No voice sharing or alternate voice/data capabilities are provided.

incoming call. Hunting takes place whenever some of the stations in the multiline hunting group are busy or signaling that they are not ready to receive calls. The type of multiline hunting provided is called terminal hunting. Terminal hunting is always carried out in a prescribed sequence, depending on the addresses of the stations in the hunting group and which station is being called. Stations having DSUs and stations having CSUs may belong to the same multiline hunting group. Further information on multiline hunting groups and their station addresses is provided in Sections 2.3, 5.1 and 6.2.

Service options are provided that permit SDDS stations having DSUs to originate and answer calls either manually or automatically. The capability to change between automatic and manual station control is also provided via a switch on the Manual Call Controller.

2.2 <u>SDDS Description</u>

The Switched Digital Data System (SDDS) is used to provide DATAPHONE Switched Digital Service. As shown in Figure 1, each SDDS station is connected to a switch by means of an access line. Switches are connected to other switches by means of digital trunks, so that any SDDS access line can be connected through switches and trunks to other SDDS access lines. The number of trunks and amount of switching equipment provided is sufficiently large so that call attempts will seldom be blocked, due to busy trunks or switching equipment. Automatic alternate routing is also provided, so that an alternate path may be used, in the event that all trunks along some given path are busy. Specific service objectives concerning quality, access availability, "dial tone" delay, call setup time and call teardown time are provided in Section 7.

For an SDDS station equipped with a DSU, the procedures for originating calls, answering calls and terminating calls are analogous to the procedures used in telephone service; but, in SDDS only digital signals are transmitted and received at the stations (no voice communication or coordination is provided). Thus, the originating station first signals the switch that the customer wishes to originate a call (analogous to the off-hook condition). The switch then signals the originating station that it is ready to receive the number (address) of the station to be called (analogous to dial tone). Then, in response to manual keying or under control of the Automatic Calling Interface, the station transmits this information to the switch. The switch receives the address of the called station, and proceeds to set up a connection between the two stations. During the call setup, certain digital "call progress" signals may be returned to the calling station indicating the status of the call (such as "Remote Ringing," which indicates to the calling station that the system is "ringing" the called station). After being alerted, the called station answers by transmitting another digital signal to the system. In telephone service, "cut-through" (completion of the connection) is signaled by removal of both ringing and remote ringing. Similarly, the SDDS signals cut-through by removal of the digital signals that the system had been transmitting to the stations. Once the cut-through indication is received at a station, all data transmitted by it will be delivered to the other station. Either station may terminate an SDDS call by appropriately signaling the system (analogous to on-hook). Before it can originate or receive other calls, a station must have terminated its previous call by appropriately notifying the system (analogous to on-hook).

2.3 Station Addresses

For each SDDS station, the Telephone Company will assign a 7 digit address NNX-XXXX, where N may be any digit 2-9 and X may be any digit 0-9. Some addresses are reserved for special SDDS purposes. The address assigned to a station must be used when placing a call to that station from any other SDDS station. As mentioned in Section 2.1, multiline hunting arrangements are provided, using terminal hunting. Each station in a terminal hunting group will be assigned an individual 7 digit address. Further information on multiline hunting groups and station addresses is provided in Sections 5.1 and 6.2.

3. DETAILED EQUIPMENT DESCRIPTION

This section provides general information about the DSU and the Manual Call Controller, including station arrangements, physical descriptions of the equipments and their interfaces, controls and lamp indications, power and grounding requirements and interface cable distance limitations.

3.1 Station Arrangements

Three basic station arrangements are available using the DSU and, where manual operation is employed, the Manual Call Controller. They are:

Automatic Answer-Only
Automatic Originate and Answer
Automatic and Manual Originate and Answer

A customer may select any of these three arrangements for each of his stations, including stations that are members of multiline hunting groups.

With the Automatic Answer-Only arrangement, a DSU presents a standard Data Interchange Interface containing data, timing and control signals. Control of the call answering and terminating functions is handled through this interface, but no capabilities are provided for originating calls or for manual control.

The Automatic Originate and Answer arrangement provides the same standard Data Interchange Interface (as is used with the Automatic Answer-Only arrangement) for the call answering and terminating functions and for data transfer, timing and control. In addition, a standard Automatic Calling Interface is also provided as part of the DSU, permitting automatic origination of calls; however, no capability is provided for manual control.

The Automatic and Manual Originate and Answer arrangement includes both the standard Data Interchange Interface and the standard Automatic Calling Interface used in the Automatic Originate and Answer arrangement. In addition, a Manual Call Controller is provided, which has the necessary control switches and displays to manually originate, answer and terminate SDDS calls, and to visually monitor the progress of the calls.

3.2 Interfaces

The Data Interchange Interface uses a 34-pin connector, and the Automatic Calling Interface uses a 25-pin connector.

The Data Interchange Interface provides a set of data, timing and control signals, which are defined by EIA

Standard RS-232-C, except that timing and data electrical signal characteristics are as defined in CCITT Recommendation V.35, Appendix 4. The Automatic Calling Interface provides a set of signals, which are defined by EIA Standard RS-366. Section 4.4 contains a more detailed discussion of the electrical characteristics.

3.3 Physical Description

Figure 2 shows a DSU connected with a Manual Call Controller. The cable normally used to connect these two units is approximately 6 feet (1.8 meters) in length; however, longer cables can be provided in lengths up to 50 feet (15.2 meters) at the customer's request. Both the DSU and the Manual Call Controller will operate over a temperature range of +40° F to +120° F and with a relative humidity less than 95 percent.

3.3.1 DSU

The DSU shown in Figure 2 measures approximately 16 in. (40.7 cm.) wide, 4.3 in. (10.9 cm.) high and 11.4 in. (29.0 cm.) deep. It weighs approximately 17.3 lb. (7.9 kg.). Mounting arrangements can provide for stacking up to three of these units, as shown in Figure 3.

3.3.2 Manual Call Controller

The Manual Call Controller shown in Figures 2 and 4 is approximately 6.5 in. (16.5 cm.) wide, 2.3 in. (5.9 cm.) high and 4.1 in. (10.4 cm.) deep. It weighs approximately 1.9 lb. (.87 kg.). To permit manual operation, each DSU requires one Manual Call Controller.

3.4 DSU - Manual Controls and Lamp Indications

A Lamp and Switch Assembly is provided on the DSU. It can be located in either the front or rear panel as a station option (see Section 5.2.6).

3.4.1 Switch for Testing

The switch on the Lamp and Switch Assembly is called the Test Switch. It is a 3-position slide switch, with the center position to be used during normal operation. When the Test Switch is placed in the left position, the DSU is in the Local Line (LL) Test mode. When the Test Switch is in the right position, the DSU is in the Remote Terminal (RT) Test mode. Use of this switch for testing purposes is discussed in Section 8.

3.4.2 Indicator Lamps

Four indicator lamps are located on the Lamp and Switch Assembly. These lamps, which are listed below, indicate that certain operating states have been entered.

(a) PWR: illuminated when power is on.

(b) NS: illuminated when no signal is being received by the DSU from the network.

(c) LL: illuminated when the DSU is in the Local Line (LL) Test mode for testing.

(d) RT: illuminated when the DSU is in the Remote Terminal (RT) Test mode for testing.

3.5 Manual Call Controller - Manual Controls and Lamp Indications

The Manual Call Controller shown in Figures 2 and 4 provides control switches and indicator lamps that allow SDDS calls to be originated, answered, and terminated manually. A brief functional description of each switch and lamp is given below.

(a) Manual Mode - MM - Switch and Lamp: The MM lamp is illuminated when the DSU is in the Manual Mode and extinguished when the DSU is in the Automatic Mode. Depressing the MM switch causes the DSU to exchange manual and automatic modes. When the DSU is in the Manual Mode, the Data Set Ready (CC) circuit at the Data Interchange Interface will be off.

(b) Call Mode - CALL - Switch and Lamp: The function of the CALL switch in the SDDS is analogous to that of the switchhook on a telephone. The Call-On State is analogous to the off-hook state in telephone service. The CALL lamp is illuminated in this state. The Call-Off State is analogous to on-hook in telephone service, in which case the CALL lamp is extinguished. SDDS calls are originated and answered by entering the Call-On State and terminated by entering the Call-Off State. When the DSU is in the Manual Mode, the CALL switch is active and by operating this switch the call state can be changed. In the Automatic Mode the CALL switch is capable of terminating a manually originated call origination attempt; however, once the call is established, the Call switch is disabled from terminating the call. The CALL lamp is also illuminated during the on intervals of the Ring Indicator lead (CE) to indicate an incoming call. The Ring Indicator (CE) lead is one of the Data Interchange Interface leads described in Section 4.1.

(c) Proceed Lamp - PROCEED: Illumination of this lamp indicates that the called party address digits can be sent by the calling party's DSU. If a call is being originated manually, a seven digit number followed by # is entered from the key pad. The PROCEED lamp is extinguished upon receipt by the DSU of an acknowledgment (ACK) or negative acknowledgment (NAK) code sent from the SDDS switch.

(d) Recall Lamp - RECALL: Illumination of this lamp indicates that the call attempt in progress cannot be completed successfully. The Two Digit Call Progress Display, described below, will be simultaneously illuminated, indicating the reason for the unsuccessful call attempt.

(e) Two Digit Call Progress Display: Two digit Call Progress Codes, which are discussed further in Section 6.5, are sent by the SDDS switch to an originating station to indicate remote ring, called station busy, called station Not Ready, time-out, trunk busy or invalid address. Call Progress Codes corresponding to conditions in which the called station is not rung (i.e., all codes except the remote ring) are indicated on the Two Digit Call Progress Display, which then remains illuminated until the Call-Off State is entered.

(f) Remote Ring Lamp - REMOTE RING: This lamp is illuminated when the originating DSU receives the Call Progress Code corresponding to remote ring. The REMOTE RING lamp remains illuminated until either (a) the DSU receives the cut-through signal, indicating that the call has been answered, or (b) the originating DSU goes to the Call-Off State, whichever occurs first.

(g) Connect Lamp - CONNECT: This lamp is illuminated when the DSU receives a cut-through indication from the network, as a result of either answering or originating a successful SDDS call. The CONNECT lamp will remain illuminated until the call is terminated.

(h) Not Ready Mode - Switch and Lamp: When the DSU is in the Manual Mode, the Not Ready Mode may be entered only by operating the NR switch, which will cause the NR lamp to illuminate. A second operation of the NR switch will then cancel the Not Ready condition, causing the NR lamp to extinguish. In the Automatic Mode the Not Ready condition may be achieved by operating the NR switch when the DSU is in the Call-Off State. In the Automatic Mode the Not Ready condition is also under control of the In Service (IS) interface lead. After operation of the NR switch, entering the Call-On State cancels the Not Ready condition. Hence, if the Not Ready condition is to be achieved via the NR switch, it must be operated after each call or call origination attempt.

(i) Key Pad: A 3x4 array of pushbutton keys is located on the Manual Call Controller. Individual keys are labeled with numerals 0 through 9 plus the characters * and # in the same pattern as TOUCHTONE key pads. When the PROCEED lamp is illuminated, pressing a key causes a single address character to be transmitted by the DSU. The character # is used as the end-of-address character, but the character * is not currently assigned.

(j) Tone Ringer and Level Control Switch: When the DSU is in the Manual Mode, an incoming call will cause an audible indication of nominally one second on, followed by a nominally three second off interval, repeated. The first on interval during an incoming call alert is a short (approximately 1/4 second) ring. The on interval is coincident with the on state of the Ring Indicator (CE) circuit of the Data Interchange Interface. Section 6.6.1 contains a detailed description of the SDDS alerting signals. A three position slide switch located beneath the Manual Call Controller can be used to control the sound level output of the tone ringer.

3.6 Power Requirements

Each DSU, including a Manual Call Controller when used, requires one 105-129 volt, 60 ±3 Hz, uninterrupted (see Section 6.3) power source. Total power consumption varies with the features provided, but is always less than 25 watts. A standard 5.5 foot 3-wire power cord equipped with a 3-prong plug is supplied with each DSU.

3.7 Grounding

Protective Ground is established for the DSU and Manual Call Controller through the ground wire of the power cord. The customer's terminal equipment Protective Ground should be connected to the same ground as the ground wire of the power cord, and should not rely on the Protective Ground circuit (AA) provided in the Data Interchange Interface. A signal ground circuit is provided to the customer as a common return for control and data interchange circuits. Protective Ground and Signal Ground are normally tied together by means of a strap in the DSU. The strap may be disconnected as a station option (see Section 5.2.1), subject to local noise conditions, ground potentials and local safety regulations.

3.8 Distance Limitations

The Data Interchange Interface cable should not exceed 100 feet in length.* The customer provided Automatic Calling Interface cable should not exceed 50 feet in length. In all installations care must be exercised to assure that the DSU and Manual Call Controller are not subject to stray

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* See Section 4.3 on Data Interchange Cable Requirements.

electromagnetic fields. In particular, the DSU and the Manual Call Controller must both be located at least one foot away from any substantial source of electromagnetic radiation.

4. INTERFACE SPECIFICATIONS

4.1 Functional Description of Interface Circuits

4.1.1 Data Interchange Interface

The DSU uses a 34-pin connector. The timing and data signals (DB, DD, BA, and BB) are dc-coupled balanced signals, and conform to the standards of CCITT Recommendation V.35. The control signals conform to the electrical characteristics of EIA Standard RS-232-C.

A brief functional description of each SDDS Data Interchange Interface signal is given below, along with its EIA RS-232-C circuit designation, where appropriate. The electrical characteristics of the interface signals are provided in Section 4.4. Signal definitions are the same irrespective of the electrical characteristics of the interface circuit.

(a) Protective Ground - AA: Connection through power cord to building ground.

(b) Transmitted Data - BA - To the DSU: Each change in the state of BA should coincide (within ±10 percent of the nominal duration of a signal element) with a transition of DB from a binary 1 to a binary 0. Data bits presented to the DSU by the data terminal are transmitted if the following control lead conditions are met: Data Set Ready (CC), on; Request to Send (CA), on; Clear to Send (CB), on; Data Terminal Ready (CD) on.

(c) Received Data - BB - From the DSU: Each change in the state of BB will coincide (within ±10 percent of the nominal duration of a signal element) with a transition of DD from a binary 1 to a binary 0. The data terminal equipment should sample each data bit presented on BB coincident with a transition of DD from a binary 0 to a binary 1.

BB will be held in the mark hold condition (steady 1s) when control signal Received Line Signal Detector (CF) is off.

(d) Request to Send - CA - To the DSU: An on condition must be present on this circuit prior to transmission of customer data. The Permanent On Request-to-Send option (see Section 5.2) causes the DSU to operate as if CA were constantly on.

(e) Clear to Send - CB - From the DSU: CB goes on in response to an on condition of CA and Data Terminal Ready (CD), and entry of the DSU into the Data Mode.*

(f) Data Set Ready - CC - From the DSU: An on condition on this circuit indicates that the DSU is powered, connected to an SDDS channel, has completed the call originating or call answer functions and is not in the manual or loopback mode.

(g) Signal Ground - AB: Common signal return path.

(h) Received Line Signal Detector - CF - From the DSU: An on condition on this circuit indicates that Data Mode signals are being received by the DSU from the network.

(i) Transmitter Signal Element Timing - DB - From the DSU: Timing signal that defines transmitted data bit intervals.

(j) Receiver Signal Element Timing - DD - From the DSU: Timing signal that defines received data bit intervals (identical to DB).

(k) In Service - IS - To the DSU: When the DSU is in the Automatic Mode an off condition on this circuit places the DSU in the Not Ready mode when the DSU is on-hook. This lead is not defined by EIA RS-232-C, and the operation described above is

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* Whenever a station is in the Automatic Mode (i.e., Manual Mode lamp off) and is connected to another station via the SDDS, it is said to be in the Data Mode.

available on an optional basis only (see Section 5.2.5).

(l) Data Terminal Ready - CD - To the DSU: When the DSU is in the Automatic Mode of operation, an on condition on this circuit, after a ringing signal has been placed on the Ring Indicator (CE) circuit, causes the DSU to answer an incoming call. The data terminal may leave CD on in preparation to answer an incoming call. Turning CD off during an established call causes the DSU to go on-hook, thereby terminating the call. When the DSU is in the Manual Mode or a test mode, it disregards the CD circuit.

(m) Ring Indicator - CE - From the DSU: An incoming call causes a ringing signal to appear on this lead. The ringing signal occurs for nominally one second, followed by a nominally three second off interval, repeated.

(n) Local Loop - LL - To the DSU: When the DSU is in the Automatic Mode, an on condition on this circuit places the DSU in the LL test mode. This lead is not defined by EIA RS-232-C.

4.1.2 Automatic Calling Interface

The Automatic Calling Interface uses a 25-pin customer interface connector. A brief functional description of each SDDS Automatic Calling Interface lead is given below, along with its EIA RS-366 circuit designation.

(a) Protective Ground - AA: Connection is through the power cord to building ground.

(b) Digit Present - DPR - To the DSU: The on condition on this lead indicates that a called party address digit is being presented by the customer equipment on leads NB1, NB2, NB4, and NB8. The Present Next Digit (PND) lead must be on prior to the turn on of DPR. DPR must then be held on until PND is turned off, at which time DPR must be turned off until the next address digit is to be presented. DPR must be held off subsequent to the final digit presented.

(c) Abandon Call and Retry - ACR - From the DSU:
An on condition on this lead indicates that successful completion of the current call attempt is very unlikely. Action should be taken to abort the call attempt either automatically, by turning off the Call Request (CRQ) lead, or manually, through the use of the Manual Call Controller. A default timer starts when CRQ turns on and restarts each time another digit or the end-of-address digit (#) is presented and when the Remote Ring Call Progress Code is received. If the timer times out (see Section 6.5.1.3) prior to successful completion of the call attempt, the ACR lead turns on.

(d) Call Request - CRQ - To the DSU: A call origination attempt can be initiated by turning CRQ on, providing PWI is on, and DLO is off. CRQ must then remain on during call origination until Call Origination Status (COS) is turned on. Turning off CRQ before COS turns on will terminate an automatic call origination that has not already been completed. After COS has turned on, depending on which one of two options is selected by the customer (see Section 5.2.4), turning off CRQ can be used to terminate a call. Regardless of which option is selected, CRQ should not remain on after the call is terminated.

(e) Present Next Digit - PND - From the DSU:
An on condition on this lead indicates that the DSU is ready to accept the next called party address digit from the customer equipment. For each address digit, PND is held on until Digit Present (DPR) is turned on and the digit accepted, at which point PND is turned off. After the DSU transmits any digit to the network, and the Digit Present (DPR) circuit from the customer equipment has been turned off, PND is again turned on. After the DSU transmits the end-of-address digit (#) and the DPR circuit has been turned off, PND is turned on for the duration of the call.

(f) Power Indication - PWI - From the DSU:
An on condition on this lead indicates that power is applied to the DSU.

(g) Signal Ground - AB: Common signal return path.

(h) Call Origination Status - COS - From the DSU: An on signal on this lead indicates that the Automatic Calling Interface has completed its call originating function, and that control of the channel has been transferred to the Data Interchange Interface under control of the Data Terminal Ready (CD) circuit. After COS is turned on, CRQ may be turned off without terminating the call, except as provided by the Automatic Call Termination Via CRQ or CD option (see Section 5.2.4).

(i) Digit Signal Circuits: Low Order Binary Digit - NB1
Second Order Binary Digit - NB2
Third Order Binary Digit - NB4
High Order Binary Digit - NB8

Called party address digits are presented to the DSU via the Automatic Calling Interface in binary coded decimal form as given in Table I. The customer must provide a # digit following the last address digit transmitted. He may, at his option, follow the # digit by an end-of-number (EON) digit as discussed in Section 6.5.1.1. Note that no SDDS use has yet been designated for * or for the digits labeled "Unassigned" in Table I.

(j) Data Line Occupied - DLO - From the DSU: An on condition on this lead indicates that the DSU is in either the Manual Mode, a test mode, or a call is in progress. DLO must be off prior to initiating a call attempt via the Automatic Calling Interface.

4.2 Interface Connectors

4.2.1 Data Interchange Interface Connector

The Data Interchange Interface is the point of connection for data transfers between the data terminal equipment and the DSU. Each DSU is equipped with one 34-pin (female) connector. The male 34-pin connector required for the data terminal equipment cable should be a Winchester MRA(C)-

34P-JTC6-H8* or Burndy MS34PM-124 or AMP 5-202431-2 or equivalent. The pin assignments for this connector are given on page 17.

Note that Pin m (or MM) on the DSU is reserved for future test purposes. The data terminal equipment must not be connected to this pin.

4.2.2 Automatic Calling Interface Connector

The Automatic Calling Interface is the point of connection for automatic calling information transfers between the data terminal equipment and the DSU. It is provided with the Automatic Originate and Answer station arrangement and the Automatic and Manual Originate and Answer station arrangement. Each DSU is equipped with one 25-pin (female) connector for this purpose. For the male 25-pin connector, a customer-provided plug such as the DB-19604-432 plug manufactured by Cannon or Cinch, or the AMP 205784-1 manufactured by AMP, Incorporated, or equivalent is required. This type of plug provides reliable, low-resistance contacts. In addition, a DB-51226-1 hood manufactured by Cinch (or equivalent) is recommended to protect the connections, anchor the cable to the plug, provide a finger grip for easy insertion or removal, and provide a positive screw-in locking arrangement to prevent the connector from being pulled out inadvertently. The pin assignments for the Automatic Calling Interface connector are given on page 18.

Note that pin assignments 9 and 10 on the DSU are reserved for future test purposes. The data terminal equipment must not be connected to these pins.

4.3 Data Interchange Interface Cable Requirements

The characteristics of the interconnection cable between the data terminal equipment and the DSU are specified in this section. An interconnecting cable meeting these specifications will result in a transmission line with a characteristic impedance on the order of 100 ohms at frequencies where series inductance and shunt capacitance

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* The (C) is specified for the Winchester connector if insertable pins are desired.

PIN ASSIGNMENTS FOR DATA INTERCHANGE INTERFACE CONNECTOR

Connector Pins: Winchester	Connector Pins: AMP and Burndy	Function	EIA RS-232-C Designation	CCITT Designation
A	A	Protective Ground	AA	101
B	B	Signal Ground	AB	102
C	C	Request to Send	CA	105
D	D	Clear to Send	CB	106
E	E	Data Set Ready	CC	107
F	F	Rec'd. Line Signal Detector	CF	109
H	H	Data Terminal Ready	CD	108.2
J	J	Ring Indicator	CE	125
R	R	Received Data*	BB(A)	104(A)
T	T	Received Data*	BB(B)	104(B)
V	V	Receiver Signal Element Timing*	DD(A)	115(A)
X	X	Receiver Signal Element Timing*	DD(B)	115(B)
P	P	Transmitted Data*	BA(A)	103(A)
S	S	Transmitted Data*	BA(B)	103(B)
Y	Y	Transmitter Signal Element Timing*	DB(A)	114(A)
a	AA	Transmitter Signal Element Timing*	DB(B)	114(B)
m	MM	Reserved for future testing	-	-
K	K	Local Loop (LL)	†	†
n	NN	In Service (IS)	†	†
L-N,U,W,Z	L-N,U,W,Z	Not Used‡	-	-
b-d, f-k	BB-FF, HH, JJ-LL	Not Used‡	-	-

* The signals on these leads are dc-coupled balanced.

† These leads are not defined by EIA RS-232-C or by the CCITT.

‡ Within the DSU, these pins are not electrically terminated.

PIN ASSIGNMENTS FOR AUTOMATIC CALLING INTERFACE CONNECTOR

Pin No.	Description	EIA RS-366 Designation	CCITT Designation
1	Protective Ground	AA	212
2	Digit Present	DPR	211
3	Abandon Call and Retry	ACR	205
4	Call Request	CRQ	202
5	Present Next Digit	PND	210
6	Power Indication	PWI	213
7	Signal Ground	AB	201
8	Not Used*	--	--
9-10	Reserved for future testing of automatic calling equipment.	--	--
11-12	Not Used*	--	--
13	Call Origination Status	COS	204
14	Digit Signal Circuit (Low Order Binary Digit)	NB1	206
15	Digit Signal Circuit (Second Order Binary Digit)	NB2	207
16	Digit Signal Circuit (Third Order Binary Digit)	NB4	208
17	Digit Signal Circuit (High Order Binary Digit)	NB8	209
18-21	Not Used*	--	--
22	Data Line Occupied	DLO	203
23-25	Not Used*	--	--

* Within the DSU, these leads are not electrically terminated.

dominate (normally above 100 kHz). This characteristic should minimize pulse distortion between the nominally 100-ohm interface drivers and terminators. The cable may be composed of twisted pairs or untwisted pairs (flat cable) possessing the following characteristics uniformly over its length:

Conductor Size. The cable shall be composed of pairs of wires of 24 gauge, or larger, conductor for solid or stranded copper wires, or for non-copper conductors, a sufficient size to yield a dc wire resistance not to exceed 30 ohms per 1000 feet per conductor.

Cable Length. The business machine cable should be less than 100 feet in length.

Mutual Pair Capacitance. The capacitance between one wire in the pair to the other wire shall not exceed 20 picofarads per foot, and the value shall be reasonably uniform over the length of the cable.

Stray Capacitance. The capacitance between one wire in the cable to all others in the cable sheath, with all others connected to ground, shall not exceed 40 picofarads per foot and shall be reasonably uniform for a given conductor over the length of the cable.

Pair-to-Pair Balanced Crosstalk. The balanced crosstalk from one pair of wires to any other pair in the same cable sheath shall have a minimum value of 40 decibels of attenuation measured at 150 kilohertz. To reduce the possibility of crosstalk between the leads, the following recommendations are made regarding the cable pair assignments for twisted pair cable. The greatest potential crosstalk problems are between the control signal circuits. It is recommended that one twisted pair be used for each control signal with one lead of the pair tied to Signal Ground at both ends of the cable. The amount of crosstalk depends on the cable, the cable driver characteristics and the cable terminator input impedance. In order to minimize crosstalk, the balanced data and clock signals should be assigned to pairs in the center of the cable. The cable pairs around the outside of the cable should be assigned to the control signals. An extra twisted pair with both leads tied to signal ground at the connector of the cable should be used between each control pair to provide isolation. This arrangement with the extra ground wires around the outside of the cable also provides some shielding from interfering signals in the outside environment.

4.4 Electrical Characteristics

Two types of interface signals are used: (1) data and timing signals, and (2) control signals. The electrical characteristics of the control signals conform to EIA Standard RS-232-C. The data and timing signals meet the balanced interface standard of CCITT Recommendation V.35. The cable drivers produce a nominal 1.1 volt peak-to-peak direct coupled signal balanced with respect to ground into 100 ohms. Figure 5 shows a typical balanced cable driver and cable terminator. For a binary "0," line A is nominally +.55 volts with respect to line B, and for a binary "1" line A is nominally -.55 volts with respect to line B. In making the transition from a "0" to a "1," line A goes from +.55 volts to -.55 volts with respect to line B for a swing of 1.1 volts peak-to-peak.

The interface driver meets the following requirements:

1. Differential output impedance is 100 ohms ± 50 percent.

2. Output impedance to ground with output terminals shorted together is 150 ohms ± 10 percent.

3. When terminated in a 100-ohm resistive load, the driver delivers a signal level of 1.1 volts peak-to-peak, ± 20 percent, i.e., the voltage between the two output leads is 0.55 volts ± 20 percent with the polarity of the output voltage for a transmitted binary "0" being the opposite of that for a transmitted binary "1."

4. Maximum rise and fall time between the 10 percent and 90 percent levels is less than 1 percent of the nominal duration of a signal element.

5. The arithmetic mean of the voltage of each output with respect to ground (DC line offset) does not

exceed 0.6 volts when the driver is terminated in 100 ohms.

The interface terminator meets the following requirements:

1. Input impedance is 100 ± 10 ohms.

2. Resistance to ground with the input terminals shorted together is 150 ± 15 ohms.

An interface driver complying with the above requirements when connected to an interface terminator complying with the above requirements will operate satisfactorily with a maximum of ± 4 volts difference in ground potential or with a maximum of ± 2 volts (peak) longitudinal noise. If margin is to be allocated to ground potential offset and longitudinal noise simultaneously, the driver-terminator should operate satisfactorily if the following is satisfied:

$$\frac{\text{Ground Potential Offset}}{2} + \text{Longitudinal Noise Voltage} \leq 2 \text{ volts}$$

Any balanced driver or terminator circuit in the interface should not be damaged by:

1. Shorting to ground.

2. Crossing with any other interchange lead.

Loop repeaters may be used to regenerate signals transmitted on 56 kb/s loops. Use of loop repeaters results in an increase in very low frequency perturbations occurring in the phase of the timing and received data signals at 56 kb/s customer interfaces; however, neither the phase differences between timing and data signals nor the symmetry of the timing signals are affected. (The duty cycle for the timing signals is 50 ±5 percent.) The frequencies of these phase perturbations are nominally less than 0.007 percent of the signaling frequency (i.e., less than 4 Hz at 56 kb/s). Including the increase in very low frequency jitter that is due to repeaters, when employed, the degree of isochronous distortion on the Received Data (BB) circuit is not expected to exceed 30 percent, and the peak individual distortion on each of the two timing circuits (DB and DD) is not expected to exceed 15 percent. If the customer, by use of a timing recovery circuit of sufficient bandwidth,* tracks the low frequency jitter on the Received Signal Element Timing (DD) circuit, the degree of isochronous distortion on the Received Data (BB) circuit, measured with respect to the recovered timing signal, is not expected to exceed 11 percent.

5. CUSTOMER OPTIONS

5.1 Service Options

Two basic service options must be specified for each SDDS station; type of station equipment arrangement and whether the station will be part of a multiline hunting group. These service options, which are described in this section, should be specified at the time an order is placed.

5.1.1 Station Equipment Arrangements

One of the following three basic station arrangements must be specified for each DSU station:

Automatic Answer-Only
Automatic Originate and Answer
Automatic and Manual Originate and Answer

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* Bandwidth recommendations for timing recovery are discussed in the Technical Reference "DATAPHONE Switched Digital Service Channel Interface Specifications" (PUB 41023).

With the Automatic Answer-Only arrangement, incoming calls can be answered and terminated automatically via the Data Interchange Interface of the DSU, but no calls can be originated.

The Automatic Originate and Answer arrangement provides for answering and terminating calls automatically, and also permits calls to be originated automatically via the Automatic Calling Interface of the DSU.

The Automatic and Manual Originate and Answer arrangement permits calls to be originated, answered and terminated automatically and, in addition, provides the capability to originate, answer and terminate calls via the Manual Call Controller. Further information on these station arrangements is included in Section 3.1.

5.1.2 Multiline Hunting Groups

For each station, the customer may select the basic single line service, or, if he has more than one station in a Switched DSA, he may select multiline terminal hunting. Single line stations will each be assigned one 7-digit address by the Telephone Company. This number should be used when calling the station from any other station. Whenever a single line station is busy or is signaling to the network that it is not ready to receive incoming calls, no calls addressed to the station will be completed.

When multiline hunting is selected, the stations to be included in each hunting group must be located in the same Switched DSA. Up to 20 stations may belong to the same terminal hunting group. Each station in a terminal hunting group will be assigned a separate 7-digit address by the Telephone Company, but the numbers assigned will not necessarily be sequential. When one of the stations is called, but it is either busy or signaling that it is not ready to receive calls, the call attempt is automatically rerouted to the station in the same hunting group, which has the next higher 7-digit address. If that station is busy or signaling that it is not ready to receive calls, the call attempt is rerouted to the next higher numbered station, and so on, until an attempt is made to reach the highest numbered station in the hunting group.

If that station is busy or signaling that it is not ready to receive calls, a Call Progress Code corresponding to "called station busy" is returned to the calling station. It is important to note that no call attempts will ever be rerouted to the station having the lowest numbered address in a terminal hunting group, and that no calls initially directed to the station having the highest numbered address in a terminal hunting group will ever be rerouted to any other station.

5.2 Station Options

For compatibility with various customer equipment arrangements and modes of operation, the following station options are provided, and should be specified at the time an order is placed.

5.2.1 Signal and Frame Ground

Signal Ground to Frame Ground Option:

This station option internally connects Signal Ground to Protective Ground for the Data Interchange Interface and for the Automatic Calling Interface.

Signal Ground Disconnected from Protective Ground Option:

This station option will provide a DSU with the Signal Ground disconnected from the Protective Ground. The option is subject to local noise conditions, grounding potentials and local safety regulations.

5.2.2 Request to Send Circuit Control

The Request to Send circuit for the Data Interchange Interface must be specified either as Permanent On or Terminal Controlled.

Permanent On Request to Send Option:

For customer data terminals that are not equipped to turn on the Request to Send circuit, a DSU option is provided to hold Request to Send on continuously. This option matches the EIA Type E interface of RS-232-C.

Terminal Controlled Request to Send Option:

This conforms to customer data terminals with an EIA RS-232-C Type D interface. Note that a customer data terminal with a Type D interface should not use the above Permanent On Request to Send Option. A data terminal with a Type D interface, following the recommendations of RS-232-C, shall not turn its Request to Send circuit on, unless the Clear to Send circuit from the data communication equipment is off. Since an operating DSU with the Permanent On Request to Send Option presents a permanent on condition to the Clear to Send circuit, a data terminal in strict compliance with a Type D interface could not turn its Request to Send circuit on again, once having turned it off. Thus, the terminal could not go back into the transmit mode of operation.

5.2.3 <u>Carrier Control</u>

For stations having the Terminal Controlled Request to Send Option (see Section 5.2.2), either Permanent Carrier or Terminal Controlled Carrier operation must be specified.

Permanent Carrier Option:

With this option, while a connection is established with another station, when the data terminal equipment turns off its Request to Send (CA) circuit, the DSU turns off the Clear to Send (CB) circuit. The output of the DSU is a continuous Data Mode marking signal when the CA circuit is off. When the CA circuit is turned on, the CB circuit goes on, and the DSU transmits whatever data is presented on the Transmitted Data (BA) circuit.

Terminal Controlled Carrier Option:

This option is designed to facilitate half duplex operation on the full duplex SDDS channels. With this option, while a connection is established with another station, when the data terminal equipment turns off its Request to Send (CA) circuit, the DSU turns off the Clear to Send (CB) circuit, and the DSU transmits the Data Mode Extension (DME) code, which is a special sequence of pulses used for station-to-station signaling in the SDDS. This code is in a modified bipolar format (see PUB 41023), which is distinct from any pattern associated with customer data, and imposes no restrictions on the customer data sequences. When the DSU at an SDDS station receives the DME characters, its Received Line Signal Detector (CF) circuit turns off. When the CA circuit is turned on, the CB circuit goes on after a delay sufficient to allow the CF lead at the distant DSU to turn on. This delay is approximately 21 bits. When the CB circuit turns on, the DSU transmits whatever data is presented to the Transmitted Data (BA) circuit.

5.2.4 <u>Automatic Call Termination</u>

For stations having the Automatic Calling Interface, one of the following two methods must be specified for terminating calls automatically while the Call Origination Status (COS) circuit is on at the Automatic Calling Interface. With either method, turning the Call Request (CRQ) circuit off before the COS circuit turns on will terminate an automatic call origination that has not yet been completed.

Automatic Call Termination Via CRQ or CD Option:

With this option, calls that are originated through the Automatic Calling Interface are terminated automatically by turning off either the Call Request (CRQ) circuit at the Automatic Calling Interface or the Data Terminal Ready (CD) circuit at the Data Interchange Interface. CD and CRQ must both be held on after COS goes on to maintain the Call-On State.

Automatic Call Termination Via CD Only Option:

With this option, turning off the CD circuit after COS has turned on will terminate a call automatically, but turning off the CRQ circuit will not. Only CD must be held on after COS goes on to maintain the Call-On State.

5.2.5 <u>Not Ready Control</u>

One of the following two methods must be selected concerning control of the DSU's state of readiness to accept incoming calls when in the Automatic Mode and in the Call-Off State.

Enable Not Ready Option:

The In Service (IS) circuit is enabled when this option is installed. It is effective only when the DSU is in the Automatic Mode and in the Call-Off State. An off condition presented to the IS circuit causes the DSU to transmit Not Ready control codes to the switch when the DSU is in the Call-Off State (analogous to on-hook in telephone service). An on condition presented to the IS circuit causes the DSU in the Automatic Mode to signal the switch that it is ready for incoming calls.

Disable Not Ready Option:

With this option installed, the DSU operates as if the IS circuit were permanently on, i.e., the DSU signals the switch that it is ready for incoming calls when the DSU is in the Automatic Mode and in the Call-Off State. Operation of the NR switch of the Manual Call Controller is not affected.

5.2.6 Test Switch and Indicator Lamp Location

Front Face Plate Option:

Depending on customer operating convenience the Test Switch and indicator lamps may be located on the front face plate of the DSU. (See Figure 6.)

Rear Face Plate Option:

The Test Switch and indicator lamps may alternatively be located on the rear face plate. (See Figure 6.) This end plate also contains the interface and ac power connectors.

6. SYSTEM OPERATION

6.1 Customer Operating Information

The information concerning system operation that is needed by a station attendant for originating, answering and terminating calls is included in an operator's manual, which will be provided at the time of service installation. This manual also summarizes the information on customer testing, trouble indications and trouble reporting, which are discussed in this Technical Reference.

6.2 Station Addresses

As mentioned in Section 2.3, each SDDS station will be assigned a 7-digit address (NNX-XXXX, where N can be any digit 2-9 and X can be any digit 0-9) for use when placing calls to the station. Some addresses are reserved for special purposes within the SDDS. It is important to note that SDDS stations can only place calls to other SDDS stations, and that no voice capabilities are provided.

In addition to the single line station arrangements, a terminal hunting arrangement is provided. In a terminal hunting group of stations, each station is assigned a unique 7-digit address. When a called station is busy or signaling that it is not ready to receive calls, an incoming call to that station is rerouted to the station in the group with the next numerically higher address for completion. If that station is also busy or signaling that it is not ready to receive calls, the call is again rerouted, and so on, until the call is routed to the station in the group having the numerically highest address. If that station is busy or signaling that it is not ready to receive calls, the Call Progress Code corresponding to "called station busy" is returned to the calling station.

6.3 Not Ready Condition

When a station is prepared to receive incoming calls, the DSU is said to be in the Idle State. When the customer's data terminal equipment is not ready to receive incoming calls, the DSU may be placed in the Not Ready condition. While in this condition, the Not Ready (NR) lamp on the Manual Call Controller is on, and the DSU continually signals the network to block all incoming calls. When a call is placed to a station that is in the Not Ready condition, the Not Ready Call Progress Code is returned to the calling station, as described in Section 6.5.

A station may be placed in the Not Ready condition under manual control by use of the Not Ready (NR) key on the Manual Call Controller. Independently, a station may be placed in the Not Ready condition under automatic control by use of the In Service (IS) signal at the Data Interchange Interface. (Use of the IS interface signal is optional, as described in Section 5.2.5). Either automatic or manual means may be used to maintain the Not Ready condition, until the terminal is ready to receive calls.

It is important to recognize that removing the power source for the DSU and Manual Call Controller does not cause the station to enter the Not Ready condition. Power to these units should not be interrupted. If power is removed, any call in progress will be disconnected, and the DSU will lose communication contact with the network. The station will not be able to originate calls, and it will not be able to answer incoming calls. However, other stations calling a station whose power is off will receive the Remote Ring Call Progress Code (see Section 6.5), which indicates that the called station is being alerted, but has not yet answered the call.

6.3.1 <u>Control By In Service (IS) Interface Signal</u>

When all four of the following conditions are satisfied, a DSU provided with the Enable Not Ready option will be held in the Not Ready condition, under control of the IS interface signal.

a. Power is on; and

b. The IS interface signal is off; and

c. The station is in the Automatic Mode (the Manual Call Controller MM lamp is off); and

d. No call is in progress, and the station is not in any test mode.

While in the Not Ready condition under control of the IS interface signal, calls may be originated either automatically or manually. This interrupts the Not Ready condition for the duration of the call, but the station reverts to the Not Ready condition immediately following call termination, if the above listed conditions are all satisfied at that time. Also, regardless of the conditions at the beginning of a call, if all four of the above conditions are satisifed at call termination, the station will immediately enter the Not Ready condition.

When the Enable Not Ready Option is used with the Automatic Answer - Only station arrangement, the customer's data terminal equipment should keep the IS interface signal on throughout each call.

6.3.2 Control By Not Ready (NR) Key

Depressing the Not Ready (NR) key once, while a station is in the Idle state, will place the station in the Not Ready condition, whenever either of the following two conditions is satisfied:

a. The station is in the Manual Mode (the Manual Call Controller MM lamp is ON), and the station is not in any test mode. If a call is in progress, depressing the NR key will also cause the call to be disconnected; or

b. The station is in the Automatic Mode (the Manual Call Controller MM lamp is OFF), no call is in progress, and the station is not in any test mode. If a call is in progress, depressing the NR key will have no effect.

While in the Not Ready condition as a result of depressing the Not Ready (NR) key, any one of the following conditions will cause the Not Ready condition to be cancelled, unless the station is held in the Not Ready condition by means of the In Service (IS) interface signal, as described in Section 6.3.1:

a. Depressing the NR key again; or

b. Removal of power. Note: After power is reapplied, the NR key must be depressed to resume the Not Ready condition under control of the NR key; or

c. Initiation of a call origination attempt, either manually by depressing the CALL key, or automatically by turning on the Call Request (CRQ) signal at the Automatic Calling Interface. Note: After each call is terminated, the NR key must be depressed to resume the Not Ready condition under control of the NR key; or

d. Entering the test mode, which causes the station to appear busy, with respect to incoming calls. Note: Having the Test Switch in the LL position, while the station is in the Manual Mode, will not cause the NR lamp to extinguish. This permits the Local Line Manual Test (see Section 8.1.3) to be conducted. Also, returning the Test Switch from the LL position to the center off position, while the station is in the Manual Mode with the NR lamp lit, will cause the station to enter the Not Ready condition. Following any station tests, of course, the NR lamp on the Manual Call Controller should be checked to assure that the station is in the desired operating state (Idle or Not Ready).

6.4 Terminal Operation - Duplex or Half-Duplex

This section discusses terminal operation, with emphasis on the differences between duplex and half duplex operation. With duplex operation, also called full-duplex operation, customer data is transmitted in both directions simultaneously. With half-duplex operation, customer data is transmitted in both directions, but not at the same time. The Not Ready condition and the procedures for originating, answering and terminating calls are the same for duplex and half-duplex terminals, and are discussed in Sections 6.3, 6.5 and 6.6.

The SDDS provides for switched four-wire duplex digital data transmission. Although four-wire duplex service will be provided, customers may also conduct data transfers in one-way and half-duplex manners. Between calls, when a station is Idle or transmitting Not Ready signals to the network, it is said to be in the "call-off" condition or "on-hook." During an established call or while a station is in the process of originating a call, a station is said to be in the "call-on" or "off-hook" condition. Whenever a station is in the Automatic Mode and is connected to another station via the SDDS, it is said to be in the "Data Mode." While in the Data Mode, the Clear to Send (CB) circuit at the Data Interchange Interface turns on in response to an on signal on the Request to Send (CA) circuit. With Clear to Send on, all data presented on the Transmitted Data (BA) circuit is transmitted to the other station. Thus, it is during the Data Mode that the differences between duplex and half-duplex operation are important.

6.4.1 Duplex Operation

Simultaneous transmission in both directions is provided by the SDDS. The DSU provides, in addition to terminal control of the Request to Send circuit, a Permanent On Request to Send option that holds the Request to Send circuit continuously in the on condition. With this option the Clear to Send circuit is always on while the station is in the Data Mode, and the data terminal equipment should have an EIA RS-232-C Type E interface. (See Section 5.2.2). When the Request to Send circuit is under the control of the data terminal equipment, the DSU has an EIA RS-232-C Type D interface.

6.4.2 Half-Duplex Operation

In half-duplex operation only one terminal transmits customer data at a time. While in the Data Mode, a data terminal desiring to transmit turns on its Request to Send circuit (see Terminal Controlled Request to Send option, Section 5.2.2). In response, the Clear to Send circuit turns on, and customer data may then be transmitted. To accommodate the "channel turn-around" type of half duplex operation commonly used in analog communication systems, the Terminal Controlled Carrier option is provided (see Section 5.2.3). With this option, Data Mode Extension (DME) characters, which are special sequences of pulses used for station-to-station signaling while in the Data Mode, are transmitted whenever the Request to Send circuit is off. When DME characters are received at any DSU that is in the Data Mode, the Received Line Signal Detector (CF) interface circuit turns off, indicating that no customer data is being received from the distant station. This signal can be used in controlling half duplex transmissions between stations. With the Terminal Controlled Carrier Option a delay is inserted after Request to Send turns on and before Clear to Send is turned on to allow sufficient time for the Received Line Signal Detector circuit at the distant station to turn on (see Section 5.2.3).

6.5 Call Origination and Termination

In the Automatic Mode, calls may be originated automatically by means of the Automatic Calling Interface or manually by means of the Manual Call Controller. In the Manual Mode, calls may be originated only manually by means of the Manual Call Controller. In the Automatic Mode, calls in progress may only be terminated automatically; however, manually originated call attempts, while in the automatic mode, may be terminated manually at any time before the called station answers. In the Manual Mode, calls may be terminated only manually by means of the Manual Call Controller. Procedures for originating and terminating calls are described in Sections 6.5.1 and 6.5.2. Attempt control, a system feature intended to limit the number of unsuccessful call attempts during unusually heavy traffic periods, is described in Section 6.5.3.

6.5.1 Automatic Call Origination

Calls may be originated automatically using the Automatic Calling Interface circuits, which are described in Section 4.1.2. Figure 7 illustrates the normal sequence for interface signaling during a call origination. To originate a call automatically, the Power Indication (PWI) circuit from the DSU must be on, and the Data Line Occupied (DLO) circuit from the DSU must be off.

6.5.1.1 Automatic Calling Procedure

Automatic call origination attempts are initiated by turning on the Call Request (CRQ) circuit to the DSU. The DLO circuit then turns on, and the DSU signals the network that a call request has been made. The DLO circuit remains on during all calls and also whenever the station is in any test mode or the Manual Mode or when the NS lamp is illuminated. After a period called "dial tone" delay (although only digital signals are used), the network signals the DSU that it is ready to receive the address of the station to be called. The DSU then turns on the Present Next Digit (PND) circuit at the Automatic Calling Interface, indicating that the first called party address digit may be transmitted.

The first called party address digit is then placed on the Digit Signal Circuits (NB1, NB2, NB4 and NB8) in binary coded decimal form, as shown in Table I. Then the Digit Present (DPR) circuit to the DSU is turned on, and the digit presented on the Digit Signal Circuits is read by the DSU. Following this, the DSU turns off the PND circuit, indicating that the digit has been accepted. The DPR circuit to the DSU should then be turned off until PND is again turned on. PND will be turned on after the entire digit is transmitted to the network, but only after DPR has been turned off. The remaining six called party address digits, followed by the # digit shown in Table I, are then conveyed to the network in the same manner.

Following #, the EON digit may also be transmitted, although it is not required by the SDDS. When EON is transmitted, the DSU receives it according to the above procedure, then immediately turns on the Call Origination Status (COS) circuit, indicating that the call origination functions of the Automatic Calling Interface are completed. The Data Set Ready (CC) circuit at the Data Interchange Interface also turns on. If EON is not transmitted, the COS and CC circuits will turn on only after a complete connection has been established and the called station has answered. In either case, after receiving the last digit, the DSU will again turn on the PND circuit, after DPR is turned off and the final address information has been transmitted to the network. PND, COS and DLO will all remain on for the remainder of the call.

When the called station answers, and a complete connection is established, the DSU indicates this by turning on the Data Set Ready (CC) circuit at the Data Interchange Interface; however, if the EON digit is transmitted via the Automatic Calling Interface, the Data Set Ready circuit will turn on immediately, before the connection is established, as an indication that an automatic call origination attempt is in progress. When Data Set Ready is turned on early (before a complete connection is established) turning on the Request to Send (CA) circuit will not cause the Clear to Send (CB) circuit to turn on until a complete connection is established. Also, the Received Line Signal Detector (CF) circuit will be held off during the entire call origination attempt and will turn on only when a complete connection is established.

6.5.1.2 Abandoning a Call Origination Automatically and Terminating a Call Automatically

If, for any reason, it is necessary for the customer terminal equipment to abandon a call origination attempt automatically before the COS circuit is turned on, this can be accomplished by turning off the CRQ circuit.

After COS has turned on, a call may be terminated automatically in either of two ways, depending on which one of two station options is provided (as described in Section 5.2.4). If the DSU has the Automatic Call Termination Via CRQ or CD option, turning off either CRQ at the Automatic Calling Interface or Data Terminal Ready

(CD) at the Data Interchange Interface, after COS has turned on, will cause the call to be terminated. If the DSU has the Automatic Call Termination via CD Only option, the only way a call may be terminated automatically after COS has turned on, is by turning off the Data Terminal Ready (CD) circuit at the Data Interchange Interface. Calls or call origination attempts may be terminated manually at any time, by means of the Manual Call Controller, as described in Section 6.5.2. Also, if the power source to the DSU is turned off, any call in progress will be disconnected, after the hold-over period of the station power supply is exceeded.

While a station is in the automatic mode during a call, its DSU will be notified by the network of any disconnection of the call and will automatically enter the call-off (on-hook) condition.

6.5.1.3 <u>Timeout Periods</u>

The DSU has a timer, which is reset to zero when CRQ is turned on at the beginning of an automatic call origination, and again after each address digit and the # character is transmitted to the DSU via the Automatic Calling Interface. It is also reset after the remote ring signal is received from the network, indicating that the called station is receiving a ringing signal. This timing function is canceled only when the called station answers or the automatic call origination attempt is aborted. If the timer "times out",* it causes the Abandon Call and Retry (ACR) circuit from the DSU to be turned on at the Automatic Calling Interface. This signal indicates that the probability of successful call completion is very small. However, if calls are originated automatically to stations that use manual answering, it must be recognized that the ACR circuit may turn on before the call is answered manually, even though no difficulties have been encountered. If a call is completed after ACR has turned on, ACR will then turn off.

The SDDS network has a timer that has a nominal "time out" value of 20 seconds. This timer is set at zero when

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* The "time out" period is greater than 8 and less than 15 seconds.

the "dial tone" signal is first transmitted to an originating station, and again after each address digit is received from the station. When the network receives the # character from the originating station, which indicates that a complete address has been transmitted, this timing function is no longer active. If this timer "times out," it will cause the call origination attempt to be cancelled, and the Call Origination Status (COS) circuit from the DSU will not turn on. COS will not be turned off, however, if it has already been turned on, due to use of the EON signal (see Section 6.5.1.1). Furthermore, the timer in the DSU will have already caused the Abandon Call and Retry (ACR) circuit to turn on at the Automatic Calling Interface.

6.5.2 Manual Call Origination and Termination

Calls may be originated manually using the Manual Call Controller. Figure 8 illustrates the normal sequence of events during a manual call origination. The functions of the individual keys and lamps on the Manual Call Controller are described in Section 3.5.

A manual call origination is initiated by depressing the CALL key on the Manual Call Controller (see Figure 4) while the station is either in the Idle condition or the Not Ready condition. This will cause the CALL lamp to light, and is analogous to going "off hook" in telephone service. While in the Idle condition, however, it is possible for an incoming call to arrive just before the CALL key is depressed. In this case, the call origination attempt is cancelled. Also, depressing the CALL key inadvertently answers the call, if the station is in the Manual Mode. This cannot happen if the station is in the Not Ready condition when the CALL key is depressed. When the station is in the Automatic Mode, it is also possible for an automatic call origination to be initiated just before the CALL key is depressed, thus causing the station to ignore the manual call origination attempt. This cannot happen if the station is in the Manual Mode when the CALL key is depressed.

After the CALL key is depressed once, and the CALL lamp is lit, it will remain lit throughout the duration of the call. It will also be lit during automatically originated calls. If the station is in the Automatic Mode, and a call or an automatically initiated call origination is in progress, depressing the CALL key will have no effect. However, if the station is in the Manual Mode, and the CALL key is depressed while a call or manually initiated call origination attempt is in progress, the Call-On condition will be cancelled, and the station will immediately enter the Idle condition. Similarly, depressing the Not Ready (NR) key, while the station is busy and in the Automatic Mode, will have no effect. However, if the station is busy and in the Manual Mode, depressing the NR key will cause the Call-On condition to be cancelled, and the station will immediately enter the Not Ready (NR) condition. Calls and call origination attempts may be terminated manually by depressing either the CALL key or the NR key, while the station is in the Manual Mode. While the station is in the Automatic Mode, a manually initiated call origination may be terminated by depressing the CALL key at any time before the call is answered, but a call in progress may be terminated only automatically as described in Section 6.5.1.2.

Upon detection by the network of the call origination, the network transmits to the station the digital "dial tone" signal indicating that the network is ready to receive the address of the station to be called. Receipt of the digital "dial tone" signal causes the PROCEED light on the Manual Call Controller to turn on, indicating that the 7 digit address of the called station should be entered via the keys numbered 0-9. Then the # key should be depressed. Care should be taken to avoid long delays while entering the address and depressing the # key. Once the PROCEED lamp is lit, if (approximately) 20 seconds expires with no digit being entered, the network will cancel the call origination attempt. When this happens, the Two Digit Call Progress display will indicate the number 30, meaning "invalid address," and the call attempt must be terminated at the originating station before a new call attempt can be made.

When the 7 digit address has been entered and the # key depressed, the network signals the DSU to turn off the PROCEED lamp. When the called station receives the digital ringing signal, the originating station receives the digital signal corresponding to remote ringing, and the REMOTE RING lamp turns on. If it is not possible to ring the called station, the RECALL lamp will turn on, and one of the following two-digit displays will be provided on the Two Digit Call Progress Display located to the right of the RECALL lamp.*

Call Progress Code		Meaning
10	-	Called station is busy.
11	-	Called station is Not Ready.
20	-	Time-out (switching equipment in network timed out due to network difficulties).
21	-	Trunk busy (no idle transmission path available due to heavy traffic in the network).
30	-	Invalid address (invalid address received, possibly due to certain transmission errors, or network timed out during call origination).

When any of these displays are received, the call attempt must be terminated at the originating station before a new call can be initiated. (Also see Section 6.5.3 on attempt control for unsuccessful call attempts during extremely heavy traffic periods.)

When the called station answers, the REMOTE RING lamp turns off and the CONNECT lamp turns on. While the station is in the Automatic Mode, the Call-On condition is maintained by holding the Data Terminal Ready (CD) circuit on at the Data Interchange Interface, and data transmissions may take place. While the station is in the Manual Mode, the Call-On condition is maintained unless either the NR key or the CALL key is depressed.

When depressing the MM key to transfer from the Automatic Mode to the Manual Mode, it is possible to interrupt an automatically originated call. The state of the automatically originated call will be indicated by the lamps on the Manual Call Controller. This can usually be avoided by verifying that the CALL lamp is off just before depressing the MM key. However, if an automatically originated call is inadvertently interrupted by depressing the MM key, the MM key may be depressed again to place the station back in the Automatic Mode or the automatically originated call may be terminated by depressing the CALL

* When an automatically originated call cannot be completed, the appropriate call progress code will also be displayed on the Manual Call Controller until the call attempt is terminated either by the automatic calling interface or by the Manual Call Controller.

key. It should be noted that the Data Set Ready (CC) circuit at the Data Interchange Interface will be off, while the station is in the Manual Mode. Also, if an automatic call origination is interrupted by depressing the MM key, depressing the MM key again will permit the automatic call origination to resume, if it has not been aborted due to a timeout and if the Call Request (CRQ) circuit at the Automatic Calling Interface is still on when automatic control is resumed.

6.5.3 Attempt Control

Attempt control is a system feature intended to limit the number of unsuccessful call attempts at a switch during periods of unusually high traffic. If the number of unsuccessful call attempts at a switch were not limited during such periods, a number of stations (especially those using automatic calling) could originate an extremely large number of unsuccessful call attempts to stations that are busy or Not Ready. This could cause the "dial tone" delay period to increase for all customers served by the switch, and unnecessarily decrease the traffic handling capability of the system.

The attempt control mode of operation is only used when an unusually large number of call attempts occur at a switch, and only affects an originating station for a period of 6 seconds immediately following termination of an unsuccessful call attempt. During the attempt control mode of operation at a switch, an interval of approximately 6 seconds is required after termination of an unsuccessful call attempt before the switch will act on a new call origination attempt from the same originating station. Also, during this 6 second interval, the station will appear busy, with respect to incoming calls. For example, assume that a call is originated manually to a busy station during the attempt control mode of operation. If the attendant at the originating station cancels that call by depressing either the CALL or NR key, then attempts to originate another call 4 seconds later by depressing the CALL key, the PROCEED lamp will be delayed in turning on for a period of approximately 2 seconds, in addition to the normal "dial tone" delay. (The service objective for "dial tone" delay is discussed in Section 7.3). For automatically originated calls the additional delay would occur after the Call Request (CRQ) circuit to the DSU turns on and before the Present Next Digit (PND) circuit from the DSU turns on.

6.6 Call Answering

The conditions governing whether a station is Idle (available to receive calls) and a description of how the station is alerted by an incoming call are described in Section 6.6.1. If these conditions are satisifed at an SDDS station, calls may be answered either automatically by means of the Data Interchange Interface or manually by means of the Manual Call Controller. These answering procedures are described in Sections 6.6.2 and 6.6.3.

6.6.1 Idle Station Condition and Alerting

To be available to receive incoming calls a station must be in the Idle condition. A station is in the Idle condition when all of the following requirements are satisfied.

a. Power is on; and

b. The station is not in any test mode either by the Test Switch on the DSU or by the LL interface signal lead, and the Telephone Company is not testing the station; and

c. The station is not in the Not Ready condition (see Section 6.3); and

d. No call is in progress, nor is one being originated by the station. In this call-off condition the CALL lamp on the Manual Call Controller is off, the Data Line Occupied (DLO) circuit from the DSU at the Automatic Calling Interface is off and the Data Set Ready (CC) circuit at the Data Interchange Interface is off.

At an Idle station, alerting signals are given to indicate the presence of an incoming call. The Ring Indicator (CE) circuit is used at the Data Interchange Interface, and the CALL lamp and a tone ringer are used at the Manual Call Controller. The tone ringer is activated only if the station is in the Manual Mode, but the other two alerting signals occur for every incoming call. While active, each of the alerting signals turns on for nominally

1 second, then off for nominally 3 seconds repetitively, except that the initial on interval is approximately 1/4 second. The alerting signals all cease as soon as the call is abandoned by the originating station or answered by the called station. A three position slide switch located beneath the Manual Call Controller can be used to control the sound level output of the tone ringer. During alerting the Data Line Occupied (DLO) circuit from the DSU at the Automatic Calling Interface is turned on to prevent automatic call origination attempts.

6.6.2 Automatic Answering

Calls can be answered automatically only while a station is in the Automatic Mode (the Manual Call Controller MM lamp is off). If ringing commences while a station is in the Manual Mode, the station may be placed in the Automatic Mode by depressing the MM key on the Manual Call Controller to permit the call to be answered automatically.

While the station is in the Automatic Mode, an on condition on the Data Terminal Ready (CD) circuit to the DSU coincident with or following an on signal on the Ring Indicator (CE) circuit from the DSU causes the incoming call to be answered automatically. As a result of the CD circuit being turned on, the DSU signals the network that the call has been answered. At this time the complete switched connection is established. The DSU indicates this by turning on the Data Set Ready (CC) circuit at the Data Interchange Interface. At the Manual Call Controller the CALL lamp remains on (it had been turning on and off as an alerting signal), and the CONNECT lamp turns on. The CONNECT and CALL lamps remain on for the remainder of the call, but the Data Set Ready (CC) circuit is on during a call only while the station is in the Automatic Mode.

6.6.3 Manual Answering

Calls can be answered manually only while a station is in the Manual Mode (the Manual Call Controller MM lamp is on). If alerting commences while a station is in the Automatic Mode, but the call has not yet been answered automatically (see Section 6.6.2), the station may be placed in the Manual Mode by depressing the MM key on the Manual Call Controller to permit the call to be answered manually. At the Manual Call Controller, depressing the

CALL key while in the manual mode during alerting causes the DSU to signal the network that the call has been answered. Then the complete switched connection is established, and at the Manual Call Controller the CALL lamp remains on (it had been turning on and off as an alerting signal), the tone ringer stops ringing, and the CONNECT lamp turns on. The CONNECT and CALL lamps remain on for the remainder of the call.

6.7 Minimum Interface Requirements

The minimum Data Interchange Interface circuits necessary to provide service with the Permanent On Request to Send Option and the Disable Not Ready Option, where call originating and answering functions are performed manually by means of the Manual Call Controller, are listed below for duplex, half-duplex, transmit-only and receive-only operation.

Minimum Interface Circuits

	Data Interchange Interface Circuits		
Operation	Signal Ground and Data Terminal Ready	Transmitted Data and Transmit Timing	Received Data and Receive Timing
Duplex	X	X	X
Half-Duplex	X	X	X
Transmit-Only	X	X	
Receive-Only	X		X

With the circuits indicated by Xs it is possible to communicate. However, there is no information on the status of the associated equipment across the interface, not even by "fail safe" circuitry (see EIA RS-232-C, Section 2.5), nor is there any assurance of circuit continuity, except as indicated by the lamps on the Manual Call Controller. Calls can be answered automatically without using the Ring Indicator circuit, if the Data Terminal Ready circuit is turned on again after being turned off to terminate each call; however, no indication of the call status is provided.

It is possible to originate calls automatically without using the Power Indicator or the Abandon Call and Retry circuits at the Automatic Calling Interface, but all of the other circuits are necessary. It should also be noted that automatic call origination without use of the Power Indicator circuit would violate standard RS-366.

6.8 System Parameters

The objectives for DATAPHONE Switched Digital Service are given in Section 7. However it is felt that two parameters of the SDDS, which are not specified, are also useful in aiding the customer in appropriately implementing software, administrative procedures, etc. These parameters, propagation delay and network blocking, are discussed in this section.

6.8.1 Propagation Delay

Propagation delay, the one-way time delay encountered when transmitting data between two stations, is not specified for the SDDS. Normal network reconfigurations, tolerances, and alternate routing during heavy traffic periods would make such a specification impractical. However, preliminary estimates, assuming the use of only terrestrial circuits, indicate that the propagation delay between stations in a mature SDDS network should seldom exceed 50 msec. A typical propagation delay between cities that are 1000 airline miles apart is expected to be approximately 15 msec.

6.8.2 Network Blocking

The SDDS network* has been engineered to assure that the necessary switching equipment and trunk facilities, which are shared by many customers, will be available for use when a customer places a call. During very busy periods,

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* The term "network" includes all parts of the SDDS except the access lines, which are dedicated full-duplex SDDS channels between the individual stations and their associated switches.

however, message traffic congestion can occur, and can occasionally prevent a call attempt from being successful. When this happens, the originating station will receive the appropriate Call Progress Code, as described in Section 6.5, which will be displayed on the Manual Call Controller for manually originated calls, or, for automatically originated calls, will cause the Abandon Call and Retry (ACR) circuit at the Automatic Calling Interface to turn on. It will then be necessary for the customer to terminate the first call attempt and to originate a second call attempt.

The probability that a call attempt between any two stations will succeed is not specified for the SDDS. Normal network reconfiguartions, occasional unusually high traffic peaks and alternate routing during heavy traffic periods would make such a specification impractical. Preliminary estimates, however, indicate that no more than one percent of the SDDS calls should require a second attempt due to message traffic congestion.

7. DATAPHONE SWITCHED DIGITAL SERVICE OBJECTIVES

The Switched Digital Data System (SDDS) is intended to provide an excellent communications medium for the transfer and switching of digital data between customer terminals. This leads to a set of design objectives which are aimed at the primary concerns that a data customer has about the communication system which he uses.

Overall performance will depend on the characteristics of the data terminal equipment provided and maintained by the customer as well as the characteristics of the SDDS. The quantitative objectives listed below apply to the SDDS exclusively.

The following are Preliminary Design Objectives only and are not to be construed as performance guarantees. The objectives are subject to change as experience with the SDDS dictates.

7.1 Quality

The objective is to provide an average performance exceeding 99.5 percent error-free seconds. Quality is the fraction of one-second intervals that are error-free during transmission of customer data.

7.2 Access Availability

The objective is to provide at least 99.98 percent access availability, which translates to an average annual downtime of 105 minutes. Access availability is the ability of the system to provide a Proceed to Select* signal to the station in response to a Call Request signal* from the station, and to present an incoming call to the station. It should be noted that this average is that value which would be observed over a period of several years. Some of the causes of downtime are failures which occur infrequently but which may have long outages associated with them when they do occur. While these infrequent long outages represent small contributions to the long-term average, they may significantly affect the downtime seen in a shorter period of time (even as long as a year).

7.3 "Dial Tone" Delay

The objective is that at least 99 percent of the call attempts should experience a "dial tone" delay less than 3 seconds. "Dial tone" delay is defined as the time between a Call Request* signal and a Proceed to Select* signal at the originating station.

7.4 Call Setup Time

The objective is that the network average call setup time not exceed 3 seconds. The call setup time is defined as the time between transmission of the End of Address signal and establishment of a data connection (excluding customer delays in answering).

7.5 Call Teardown Time

The objective is that the call teardown time be less than 100 milliseconds. Call teardown time is defined as the

---

* The Call Request and Proceed to Select signals are analogous to going off-hook and receiving dial tone in telephone service.

time between a Clear Request* signal and a Clear Confirmation* signal at the station originating the Clear Request signal.

8. TESTING AND MAINTENANCE

8.1 Customer Testing and Trouble Reporting

In any system, outages will occassionally occur, and it is important for the customer and the Telephone Company that prompt and efficient corrective actions be taken in all such situations. A telephone number will be provided at the time of service installation for customer use in reporting troubles in his service. Telephone Company testing and repair can be accomplished most efficiently if a complete and accurate description of the difficulty is provided by the customer.

When operating difficulties are encountered by a customer, it is expected that he will check his terminal equipment for proper operation prior to reporting a trouble to the Telephone Company. Considerable expense can be saved by making a careful initial evaluation of a trouble condition. Such things as unplugged power cords, tripped circuit breakers and loose interface connectors can completely disable a customer's system, but may be corrected by customer personnel with little delay. For this reason, it is recommended that customer personnel be acquainted with the basic equipment layout and instructed in fundamental maintenance techniques.

SDDS station equipment contains certain built-in trouble isolation and testing features, which customers are encouraged to become familiar with and to utilize. Use of these features will aid the customer in verifying whether problems exist in SDDS station equipment, and can provide information useful to the Telephone Company in diagnosing problems more quickly. In addition to the basic checks for power and interface cable connections, the following observations and tests may be conducted by a customer to aid in identifying station problems prior to reporting a trouble condition to the Telephone Company.

---

* Either station may originate the Clear Request signal. It is analogous to going on-hook during a call in telephone service. The Clear Confirmation signal from the network indicates that the call has been disconnected and that the system is ready to process new call attempts from the station.

CAUTION: Customer tests should not be conducted after a station has been released for testing by the Telephone Company, except as described in Section 8.2. Such testing could interfere with Telephone Company tests and yield misleading results.

8.1.1 Monitoring Interface Circuits

If the customer's data terminal equipment provides interface trouble indications, these may be useful to the customer in determining the source of a difficulty. For example, knowledge of the point reached in the call setup procedure before an automatic call attempt was aborted might aid in determining the most likely cause. If a call attempt or data transfer is unsuccessful because the other station is busy, Not Ready or becomes disconnected before normal call completion etc., interface signals provided by the DSU and described in Section 4.1 will be generated as discussed in Section 6. Knowledge of which interface signals are being generated when a problem exists should be helpful in determining the trouble source. For stations having a Manual Call Controller, specific tests that check DSU and Manual Call Controller functions are discussed in Section 8.1.3.

8.1.2 Local Line (LL) Automatic Test

A Test Switch is provided on the DSU. It can be used by a customer for testing his station as described below, while the DSU is in the Automatic Mode. Alternatively, the Local Loop (LL) interface circuit may be used instead of the Test Switch, as described below. (Also see Figure 9.) Local Line testing while in the Manual Mode, with a Manual Call Controller, is discussed in Section 8.1.3, and use of the Remote Test (RT) position of the Test Switch is discussed in Section 8.1.4.

While the DSU is in the Automatic Mode, if the Test Switch is in the Local Line (LL) position or if the Local Loop (LL) interface circuit is on, the DSU is in the Local Line test mode. The LL test permits a customer with an appropriately designed duplex terminal to test the back-to-back performance of the data terminal equipment and DSU by connecting the transmitter section of the DSU to the receiver section. For this test the Data Set Ready circuit is off, but the other Data Interchange Interface

Control circuits, Request to Send, Clear to Send and Received Line Signal Detector operate as in the Data Mode. Thus, much of the transmit and receive logic in the DSU can be exercised through the Data Interchange Interface.

The following steps are suggested for the LL automatic test, which can be performed with any of the SDDS station arrangements, when no call is in progress. (A station will not be alerted for an incoming call while in the Local Line test mode.) Signals on the Automatic Calling Interface, if present, should be ignored for this test; the interface circuits used are all in the Data Interchange Interface.

1. Check the power and interface cable connections to assure that they are properly in place. Place the Test Switch in its center off position. The DSU PWR indicator should be lit, but the other three indicator lamps on the DSU (RT, LL and NS) should be off. The Telephone Company should be notified if any of those indicators are on at this point in the test. If the station arrangement includes a Manual Call Controller, put the unit in the Automatic Mode of operation by depressing the switch designated MM to extinguish the lamp.

2. Either place the Test Switch on the DSU in the LL position or turn on the Local Loop (LL) interface circuit. The LL indicator on the DSU and the CALL lamp on the Manual Call Controller should turn on. The NS and RT indicators on the DSU should remain off.

3. Turn on the Request to Send (CA) interface circuit. Interface circuits Clear to Send (CB) and Received Line Signal Detector (CF) should turn on. Transmit any desired data patterns on the Transmitted Data (BA) interface circuit. The DSU should loop back this data and transmit it error free to the data terminal equipment via the Received Data (BB) interface circuit.

4. Turn off the Request to Send (CA) interface circuit. If the station has the Permanent Request to Send Option, this should cause no changes to occur on other interface circuits. If, instead, the station has the Terminal Controlled Request to Send option the Clear to Send (CB) interface circuit should go off when CA is turned off and on when CA is

turned on. If, in addition to the Terminal Controlled Request to Send option, the station also has the Terminal Controlled Carrier option, then the Received Line Signal Detector (CF) interface circuit should also go off when CA is turned off and on when CA is turned on.

5. Restore the Test Switch to its center off position (or turn off the LL interface circuit) to return the station to its normal operating condition. The LL lamp and the CALL lamp should go off.

8.1.3 Local Line (LL) Manual Test

At stations having a Manual Call Controller, a Local Line (LL) test may be conducted manually. This test exercises all functions of the Manual Call Controller and many functions of the DSU, without requiring any special test equipment or calls to other stations. Specific procedures for this test are described below. (A station will not be alerted for an incoming call while in the Local Line test mode.)

1. Check the power and interface cable connections to assure that they are properly in place. Place the Test Switch on the DSU in its center off position. The DSU PWR indicator should be lit, but the other three indicator lamps on the DSU (RT, LL and NS) should be off. The Telephone Company should be notified if any of those indicators are on at this point in the test. Place the station in the Automatic Mode by depressing the switch designated MM on the Manual Call Controller until the lamp associated with it is extinguished. All indications on the Manual Call Controller should be off. Depress the MM switch again to place the station in the Manual Mode. The corresponding lamp should go on.

2. Place the Test Switch on the DSU in the LL position. The LL indicator should go on. The NS and RT indicators on the DSU should remain off.

3. Press the NR switch on the Manual Call Controller until the lamp associated with it is on. This causes the "Not Ready" code to be generated in the DSU by the transmit logic and looped back to the receive logic. The PROCEED lamp should also go on.

4. Digits can be generated and displayed as follows. Press any two digits to be displayed except 00, then press the # button twice. The two digits should be displayed, the RECALL lamp should go on, and the PROCEED lamp should go off.

5. Pressing the CALL switch once should cause the CALL and CONNECT lamps to go on and the NR, REMOTE RING, RECALL and digit displays to extinguish if illuminated.

6. A second operation of the CALL switch should cause the CALL and CONNECT lamps to go off.

7. Other digits may be displayed by repeating steps 3 through 6.

8. To illuminate the REMOTE RING lamp, repeat step 3, then press the digit 0 twice and # twice. This should cause the PROCEED lamp to go off and the REMOTE RING lamp to go on. Repeat steps 5 and 6 to clear the lamp indicators.

9. Pressing and holding the * button should cause the CALL lamp to flash and the tone ringer to sound at intervals of approximately one second on and approximately three seconds off. The tone ringer level control can be tested by changing the three position switch on the bottom of the Manual Call Controller.

10. Restore the Test Switch to its center off position to return the station to its normal (Manual Mode) operating condition. The LL lamp should go off.

8.1.4 <u>Digital Test Line and Remote Terminal Loopback Tests</u>

At the time of service installation a 7-digit address called a Digital Test Line number will be provided for customer use in testing between his station and its associated switching center on a loopback basis. Calls placed manually or automatically to this number will be answered automatically by a Digital Test Line circuit located at the switching center, thus permitting any customer to check out his own call originating procedures and interfaces. Calls placed to a Digital Test Line will be treated by the network in the same manner as calls placed to other customer stations. After the call is answered, the Digital Test Line will provide a loopback, as shown in Figure 9, so that all data transmitted by the calling station will be looped back toward the calling station. This permits the customer to monitor the data transmission accuracy of the entire (two-way) connection between his station and the Digital Test Line. When testing is completed, the call should be terminated by the calling station in the same manner as for calls to another customer station.

Remote Terminal (RT) tests may be conducted in much the same manner as tests with a Digital Test Line, except that tests are conducted between two customer stations instead of between one station and a Digital Test Line. For this test, either station places a normal call to the other station. After the call is answered, either station attendant may place the test switch on his DSU in the Remote Terminal (RT) position.* The RT lamp on that DSU should turn on. When the Test Switch is in the RT position at a station, and the station is in the Automatic Mode, the DSU provides a loopback for data received from the other station. This permits the other station to monitor the data transmission accuracy of the entire (two-way) connection between the Data Interchange Interfaces at the two stations. (Regardless of the position of the Test Switch, whenever the station is in the Manual Mode, the DSU transmits a data signal of all 1s to the distant station during a call.)

With the Test Switch in the RT position, the output of the Received Data (BB) interface circuit is connected to the input of the Transmitted Data (BA) interface circuit at the Data Interchange Interface of the DSU, as shown in Figure 9. When the station is in the Automatic Mode, this causes data signals received from the line to be regenerated and looped back to the line. With the Test Switch in the RT position, the Data Interchange Interface

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* If a Data Interchange Interface problem is suspected, it is best to originate and answer test calls manually, and to set the test switch in the RT position before placing the station in the automatic mode.

circuit drivers to the data terminal equipment are turned off and the Transmitted Data and Received Data leads from and to the customer's terminal equipment are open circuited.

When testing is completed the Test Switch should be returned to its center off position. This returns the station to its normal operating condition. Further loopback testing may be conducted by placing the test switch at either station in the RT position, or the call may be terminated in the normal manner. It is important to note that a call may be terminated manually, but not automatically via the Data Terminal Ready (CD) interface signal, while the Test Switch is in the RT position. However, if the Test Switch is changed to the center off position while the station is in the Automatic Mode, the Data Terminal Ready (CD) signal must be on to avoid terminating the call. Also, a station will not be alerted for incoming calls while the Test Switch is in the RT position.

8.2 Telephone Company Testing and Repair

Most SDDS equipment malfunctions that can degrade system performance will be detected automatically, and standby equipment will be placed in service automatically. Consequently neither routine maintenance nor routine testing periods that would interrupt customer service are required by the Telephone Company to keep the SDDS operating properly. In the event of trouble, the Telephone Company will test the service. Of course, the Telephone Company will not intentionally disturb the service without first receiving permission from the user.

It is expected that the customer will check his terminal equipment for proper operation prior to reporting a trouble to the Telephone Company. When a customer experiences a trouble condition and his terminal equipment is operating properly, he should call the number for trouble reporting that is furnished when the service is installed. Testing and repair can be accomplished most efficiently if a complete and accurate description of the difficulty is provided by the customer. Results of any troubles detected while conducting the customer tests described in Section 8.1 will be helpful in diagnosing most types of trouble conditions. Also, if a station attendant is available to assist in performing tests, some trouble conditions may be isolated quickly without requiring a service call by a Telephone Company representative. Once the trouble has been reported, the DSU should be placed in the Not Ready condition.

> CAUTION: After a station is released for testing by the Telephone Company, the customer should not change the settings on the DSU or the Manual Call Controller, unless requested to do so by the Telephone Company test person. Otherwise the Telephone Company tests could yield misleading results.

When maintenance tests are conducted for a station from a Telephone Company test center, the functions of the Test Switch on the DSU - Remote Test (RT) and Local Loop (LL) - can be actuated by remote control, and the RT or LL indicator lamps will turn on during the tests.

STANDARDS INFORMATION

1. EIA RS-232-C
   EIA RS-366

   Electronic Industries Association (EIA)
   Engineering Department
   2001 Eye Street, N.W.
   Washington, D. C. 20006

2. The International Telegraph and Telephone
   Consultative Committee (CCITT)
   Vol. 8, Recommendation
   V.35, Appendix 4

   United Nations Bookstore
   General Assembly Building
   United Nations, N. Y. 10017

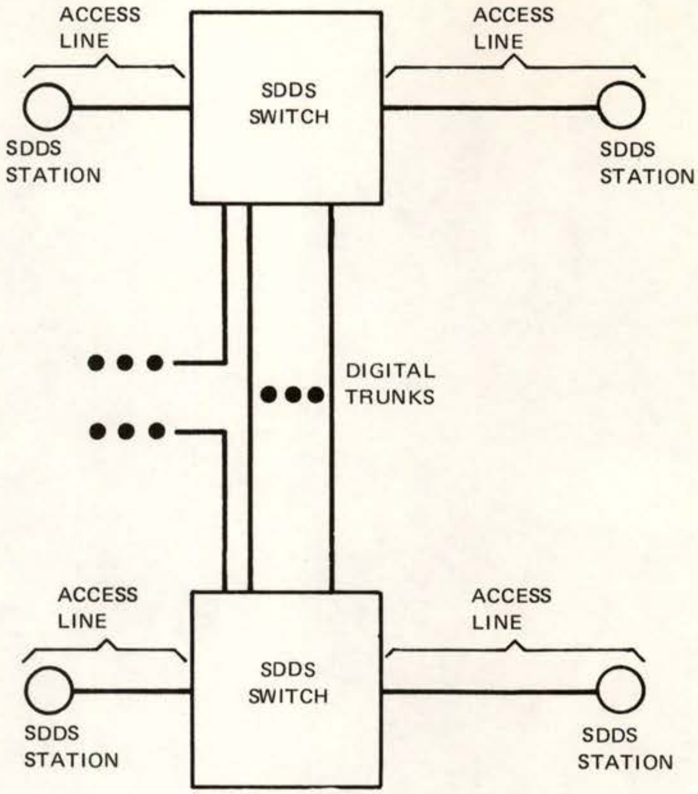
TABLE I

DIGIT SIGNAL CHARACTER SET

REQUIRED BY THE

AUTOMATIC CALLING INTERFACE

Digit	Digit Signal States			
	NB8	NB4	NB2	NB1
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
*	1	0	1	0
#	1	0	1	1
EON	1	1	0	0
Unassigned	1	1	0	1
Unassigned	1	1	1	0
Unassigned	1	1	1	1



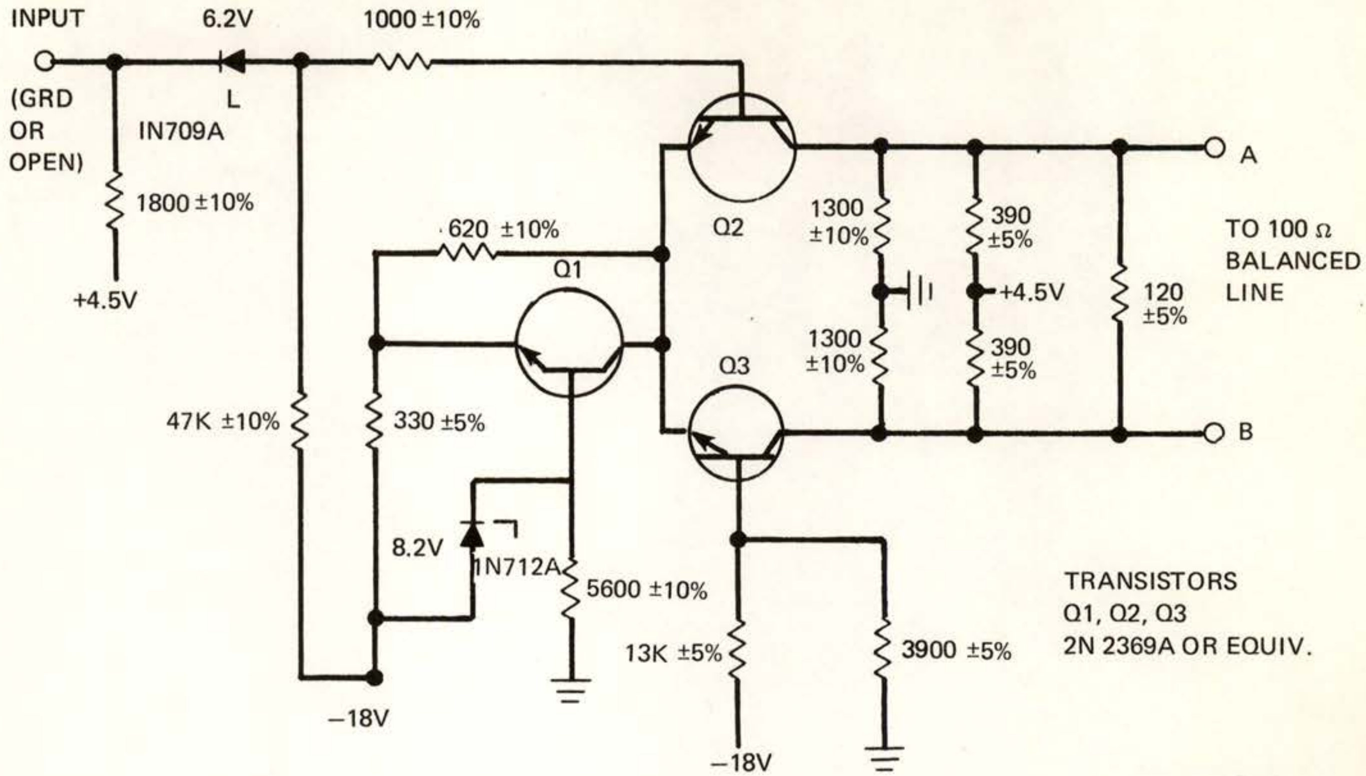
SWITCHED DIGITAL DATA SYSTEM
FIGURE 1

501A DATA SERVICE UNIT
AND MANUAL CALL CONTROLLER
FIGURE 2

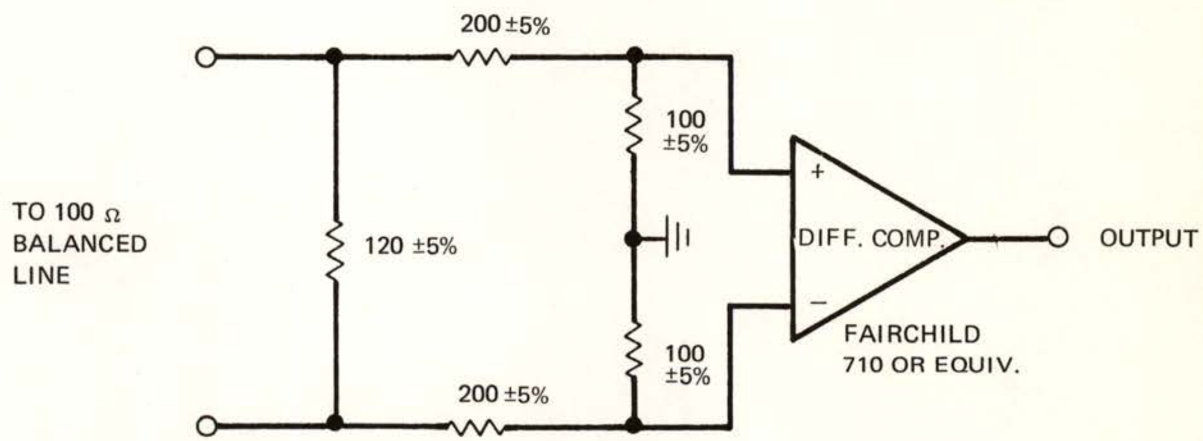
501A DATA SERVICE UNITS-STACKED
ARRANGEMENT OF THREE
FIGURE 3

MANUAL CALL CONTROLLER
(821A DATA AUXILIARY SET)
FIGURE 4

CABLE DRIVER



CABLE TERMINATOR



NOTE:
1. ALL RESISTANCE VALUES ARE IN OHMS

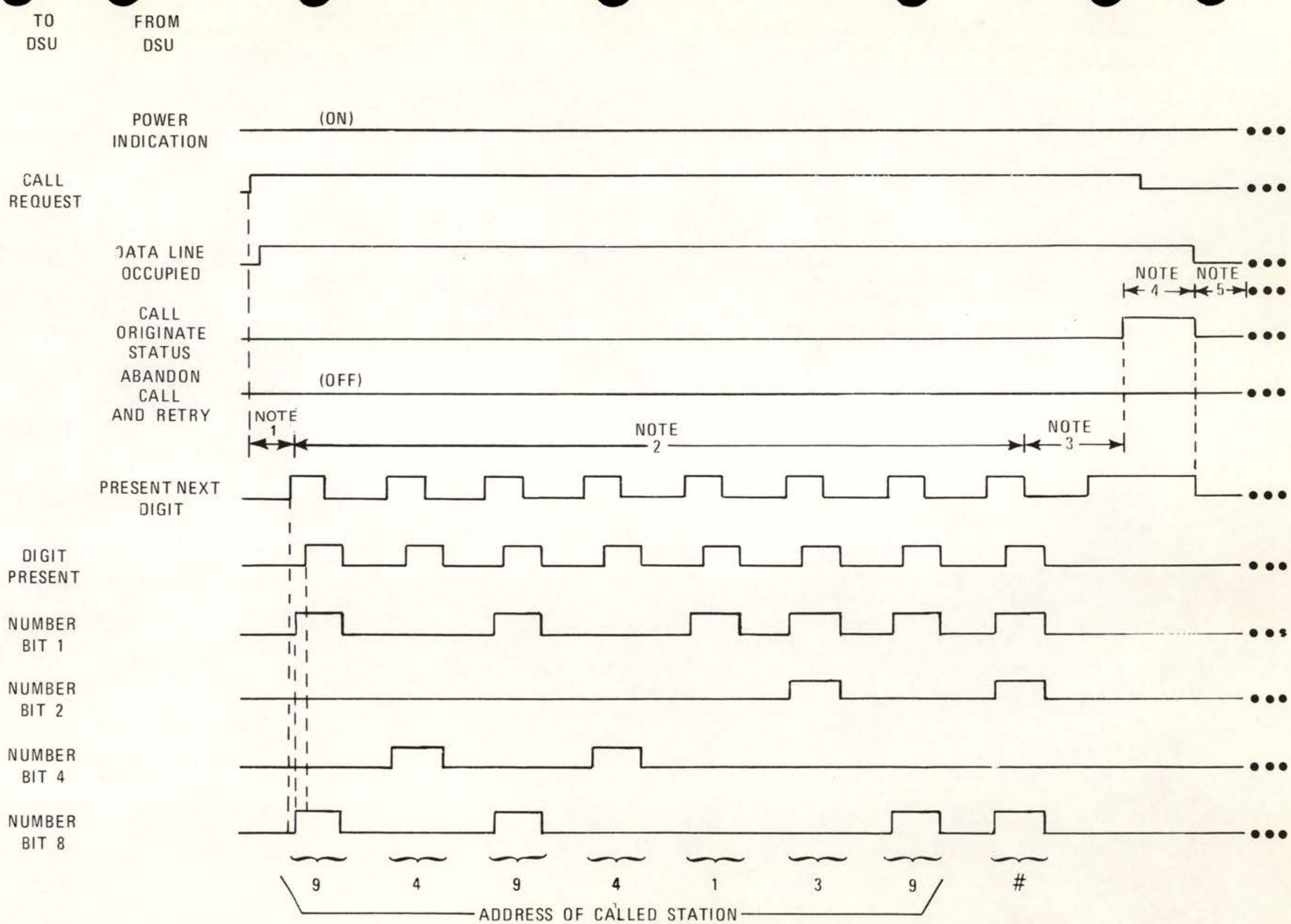
TYPICAL 56 KB/S BALANCED INTERFACE
CABLE DRIVER AND TERMINATOR CIRCUITS

FIGURE 5

FRONT VIEW

REAR VIEW

501A DATA-SERVICE UNIT
FIGURE 6

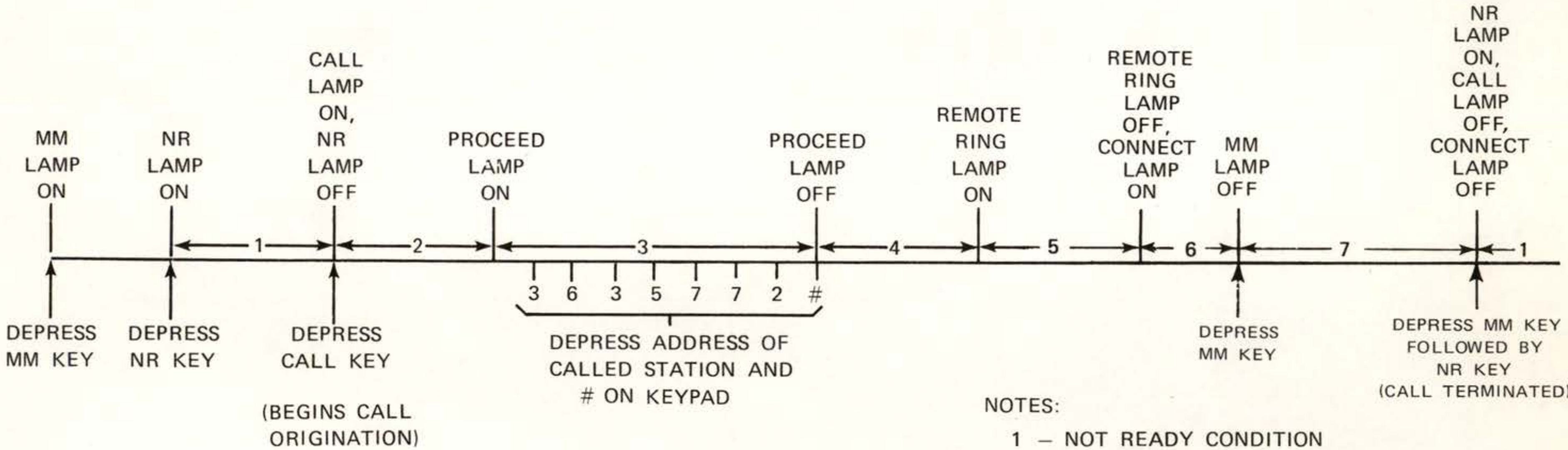


AUTOMATIC CALL ORIGINATION INTERFACE SIGNALING

FIGURE 7

NOTES:

1 – DIAL TONE DELAY
2 – DIALING
3 – CALL SETUP AND ALERTING
4 – CALL HOLDING AND TEARDOWN
5 – IDLE OR NOT READY CONDITION

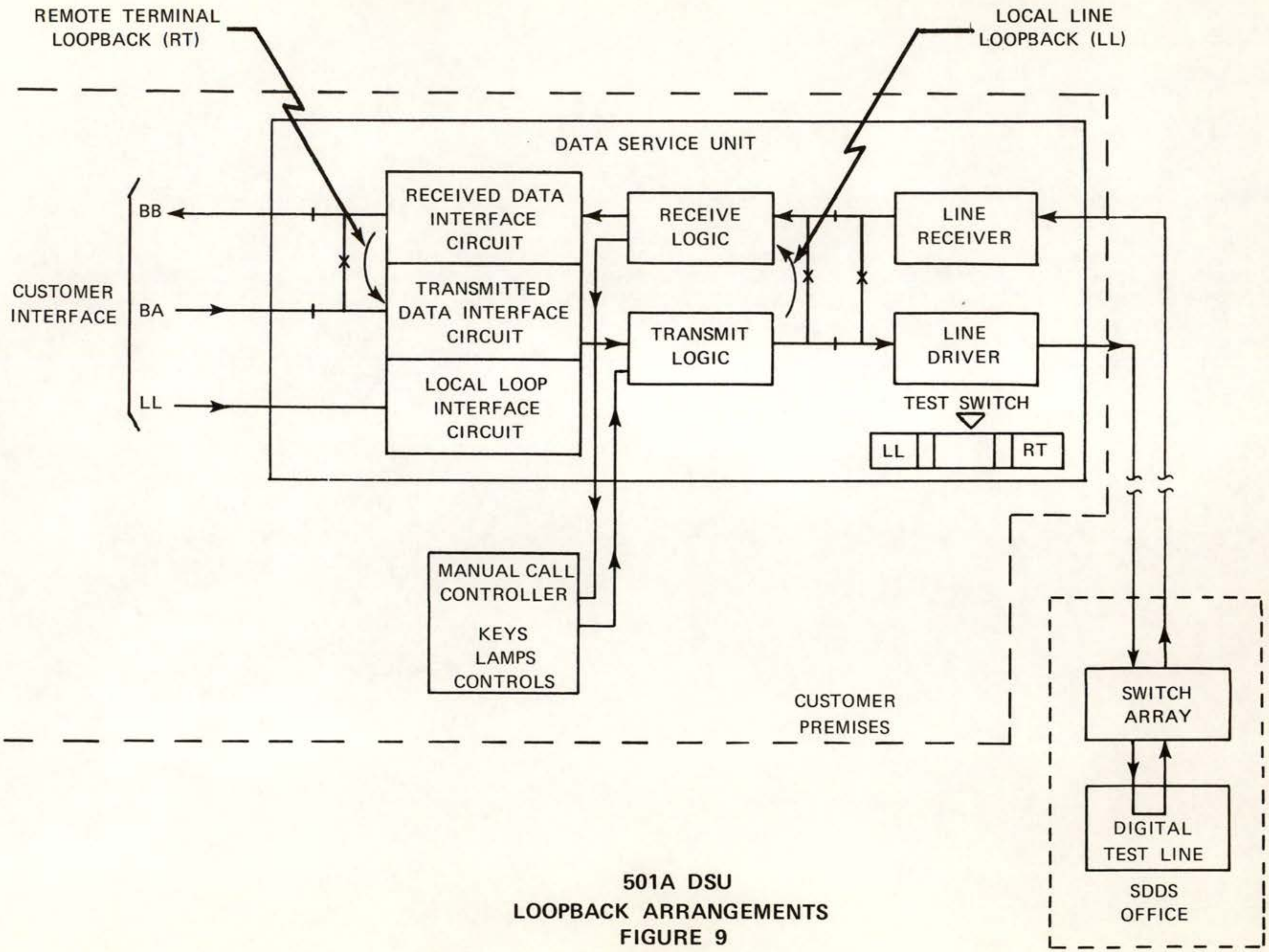


NOTES:

1 – NOT READY CONDITION
2 – DIAL TONE DELAY
3 – DIALING
4 – CALL SETUP
5 – ALERTING
6 – CALL HOLDING (MANUAL MODE)
7 – CALL HOLDING (AUTOMATIC MODE)

MANUAL CALL ORIGINATION
SEQUENCE OF EVENTS

FIGURE 8



501A DSU
LOOPBACK ARRANGEMENTS
FIGURE 9

PUB 41021

PRELIMINARY

Bell System Data Communications
TECHNICAL REFERENCE

DIGITAL DATA SYSTEM CHANNEL INTERFACE SPECIFICATIONS

March 1973

ENGINEERING DIRECTOR - TRANSMISSION SERVICES

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NOTICE

This Technical Reference is published by American Telephone and Telegraph Company as a guide for the designers, manufacturers, consultants and suppliers of customer-provided systems and equipment which connect with Bell System communications systems or equipment. American Telephone and Telegraph Company reserves the right to revise this Technical Reference for any reason, including, but not limited to, conformity with standards promulgated by ANSI, EIA, CCITT, or similar agencies, utilization of new advances in the state of the technical arts, or to reflect changes in the design of equipment or services described herein. Liability for difficulties arising from technical limitations is disclaimed.

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If further information is required, please contact:

Engineering Director - Transmission Services
American Telephone and Telegraph Company
195 Broadway
New York, New York 10007

TABLE OF CONTENTS

LIST OF FIGURES

1. DIGITAL DATA SYSTEM - GENERAL

This document describes the Bell System Digital Data System (DDS) and the interface between the channel termination equipment of the DDS, contained in a Channel Service Unit (CSU) and the customer's data terminal equipment. There are two sections:

Section 1 - Briefly describes the DDS, introduces the CSU and covers performance objectives, testing and maintenance considerations.

Section 2 - Covers technical details on the channel interface specifications.

1.1 Service Provided

Initially DDS provides two-point*, duplex, private line data transmission at synchronous data rates of 2.4, 4.8, 9.6, or 56 kilobits per second (kb/s). The data rate must be specified in the request for service. No alternate voice or voice coordination is provided. Data transfer to and from the customer must be synchronized with the network clocking system.

1.2 System Description

The DDS shown schematically in Figure 1 is functionally discrete from but physically integrated into the existing Bell System network. This concept allows DDS to share the Bell System's extensive routing flexibility and 24-hour maintenance coverage.

DDS uses the existing and planned hierarchy of digital transmission systems. Cable routes and T1 digital systems are currently deployed in many metropolitan areas. They provide a basic means of distributing service within the network's metropolitan serving areas. In addition, radio and coaxial systems are used to interconnect the various metropolitan areas into a nationwide network.

The end-to-end transmission delay depends largely on the propagation time of signals on these intercity facilities. The delay will generally not exceed 50 ms.

1.2.1 Channel Service Unit (CSU) Interface

The basic customer interface unit for a DDS channel is the CSU. The unit, pictured in Figure 2, provides the ability to quickly and decisively test (remotely from a Telephone Company test center) a DDS channel up to the point of interface with the customer. The CSU is essential for this purpose and contains the minimum amount of hardware required.

A six-wire interface permits the customer to connect his data communication equipment to a DDS channel. When interfaced with the CSU, the cus-

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* A multipoint service is also planned to be available using the same interface arrangements as two-point service. This Technical Reference will be modified as required to describe multipoint service.

tomer's equipment must perform the following functions:

1. Proper coding and decoding of signals
2. Timing recovery
3. Synchronous sampling
4. Formatting
5. Generation and recognition of control signals

The specifications for these functions are contained in Section 2 of this Technical Reference.

1.2.2 Data Service Unit (DSU) Interface

The Bell System also provides a unit that performs the functions listed above. This Data Service Unit (DSU) is described in the Technical Reference, "Digital Data System - Data Service Unit Interface Specifications" (PUB 41450). The DSU includes the functions of the CSU along with the additional circuitry to provide an EIA RS-232-C interface at the subrate speeds of 2.4, 4.8 and 9.6 kb/s. At the 56 kb/s rate, the interface conforms with CCITT Recommendation V.35.

1.2.3 Office Channel Unit (OCU)

The DSU (or CSU working in conjunction with customer-provided equipment) transmits data over cable pairs to a DDS office. In the office, this local loop is terminated by an Office Channel Unit (OCU). Four OCU speeds are available to match the four customer speeds. The functions of the OCU are to

1. Transmit outgoing loop signals to the station
2. Reshape, retime and regenerate incoming loop signals
3. Assemble the data into a format suitable for multiplexing
4. Transmit and detect control signals with bipolar violations (see Section 2)

1.2.4 Time-Division Multiplexers

The DDS uses synchronous time-division multiplexing to pack the data for efficient transmission between DDS offices. Figure 1 shows two stages of multiplexing.

One multiplexing stage combines channels at the subrate speeds of 9.6, 4.8 and 2.4 kb/s.

The 56 kb/s speed is fed directly to another synchronous time-division multiplexing stage. This multiplexing stage can combine data streams from customers and/or the subrate multiplexer mentioned above.

The same structure as described above is used to demultiplex the streams, with each of the equipment pieces performing the reverse of the function it performs in the multiplexing process. Since this is a duplex system, (it has independent paths for both directions of transmission) multiplexing and demultiplexing take place simultaneously.

1.2.5 Network Synchronization

A timing control network is employed in the DDS to ensure that data signals are synchronous. This means that sampling takes place at the same frequency throughout the network.

The synchronous timing control for the network is derived from a single master supply. The timing is distributed to each digital equipment location through a treelike timing network. This network is an important part of the Digital Data System. The timing supplies provide timing for the data multiplexers, office channel units, and other office terminals. Timing is transmitted to the station by means of the bipolar bit stream which has a sufficient number of pulses to permit timing recovery.

The timing system is designed so that phase jitter and phase hits do not propagate through the network. If branches of the timing tree become severed, the individual timing supplies continue without interruption.

1.3 Design Objectives, System Tests and Maintenance Considerations

The Digital Data System is intended to provide an excellent communications medium for the transfer of digital data between customer terminals. This leads to a set of design objectives which are aimed at the primary concerns that a data customer has about the communications channel which he uses.

Overall performance will depend on the characteristics of data communications equipment that is provided and maintained by the customer as well as those of the DDS. The quantitative objectives listed below apply to the DDS exclusively.

1.3.1 Design Objectives

The following are preliminary design objectives only and are not to be construed as minimum performance guarantees. The objectives are subject to change as experience with the DDS dictates.

Quality - To average at least 99.5% error-free seconds at 56 kb/s and better performance at the lower rates of 9.6, 4.8, and 2.4 kb/s.

Availability - To average at least 99.96% channel availability, i.e., annual downtime less than 0.04%. It should be noted that this average is that value which would be observed over a period of several years. Some of the causes of downtime are failures which occur infrequently but which may have long outages associated with them when they do occur. While these infrequent long outages represent small contributions to the long-term average, they may significantly affect the downtime seen in a shorter period of time (even as long as a year.)

1.3.2 Testing and Maintenance

Testing and maintenance features are an integral part of the DDS. Centralized test centers, as shown in Figure 3, can conduct tests with both ends of each circuit in their area. These features permit rapid isolation and correction of trouble conditions. The Telephone Company will be aware of most trouble conditions that occur in the DDS, and repair will be undertaken prior to reports from customers. If the customer suspects an undetected trouble condition in his DDS channel, he should call the number for trouble reporting that is furnished when the channel is installed. A customer operating procedure that provides indications of specific problems (e.g., no signal, first bit in error, etc.) on the communications channel is a great aid in expediting repairs. It is expected that the reporting customer will assist in analysis of the trouble. It is also expected that the customer will check his terminal equipment for proper operation prior to calling the Telephone Company.

In the event of trouble the Telephone Company will test the DDS channel. Such tests require the brief removal of customer data. These tests should be infrequent and short, but it is essential to good service that the DDS user be willing to release his channel when testing is required. Of course, the Telephone Company will not intentionally disturb the channel without first receiving permission to test from the user.

1.3.3 Remote Testing

Most tests of a DDS channel will not require a visit to the user's premises. Remote tests of the DDS channel are under the control of a test center. They can remotely loop back the channel at the user's premises permitting the Telephone Company to evaluate overall operation.

1.3.4 Trouble Conditions

Where there is a failure in the higher order digital facilities, a repetitive Out-of-Service sequence (see Part 2.2.2) is sent to the customer equipment. A failure on the local cable pair that carries signals from the OCU to the customer's location is not detected by the DDS. However, the customer's equipment can detect local loop failure by an absence or distortion of digital signals. If there is a failure on the cable pair that is carrying signals to the OCU, the DDS equipment at the central office detects this condition and transmits the repetitive Idle sequence (see Part 2.2.1) to the far-end terminal. This same sequence results when no pulses are being transmitted. Therefore, if a terminal receives this Idle sequence when it expects to receive data, the user should check his far-end transmitting equipment. If the Idle sequence is received when the far-end is transmitting data, the user should report this to the Telephone Company.

2. INTERFACE DESIGN CONSIDERATIONS

This section is directed to those who use the channel interface provided by the CSU described in Part 1.2.1. For the DSU interface described in Part 1.2.2, refer to the Technical Reference, "Digital Data System - Data Service Unit Interface Specifications" (PUB 41450).

Detailed specifications for transmission using the DDS are discussed in this section. Included are the encoding and decoding requirements that the customer's equipment must observe in order to operate over a DDS channel equipped with CSUs. If a customer chooses to use DSUs, these requirements are met by circuitry within the DSU. In such cases the following material merely provides background information about the DDS.

2.1 Transmission Plan

Baseband, bipolar return-to-zero signaling is used for transmission over the local loop and is described by the following coding rules: A binary 0 is transmitted as zero volts. A binary 1 is transmitted as either a positive or negative pulse, opposite in polarity to the previous 1. An example of bipolar signaling is shown in Figure 4.

Through the use of bipolar violations, additional information capacity is achieved to provide a convenient way of transmitting network control information. A bipolar violation occurs when the alternate polarity rule is violated. For example, the bipolar rule is violated if the last 1 was transmitted as a positive pulse, and the next 1 is also transmitted as a positive pulse. Using the following notations, Figure 5 shows a typical bipolar sequence containing bipolar violations.

- 0 - denotes zero volts transmitted
- B - denotes $\pm E$ volts (polarity determined by bipolar rule)
- V - denotes $\pm E$ volts (polarity in violation of bipolar rule)

2.2 Encoding and Decoding Rules

To be compatible with the DDS, the transmit and receive data signals must use bipolar violations to indicate control information (Idle and Out-of-Service) and Zero Suppression. The Zero Suppression sequence is necessary since long sequences of zeros do not provide the transitions necessary to maintain timing recovery. The encoding and decoding rules that the customer must follow are outlined below. The notation is the same as in Part 2.1 with the following addition.

Unrestricted insertion of violations in the pulse stream would produce an undesirable dc component. A means of solving this problem is to reserve a time slot prior to a violation for application of a binary pulse or no-pulse in such a way that successive violations (V) alternate in polarity. The reserved time slot is designated by the symbol X. The desired polarity alternation of Vs is achieved by assigning a value 0 or B to the X such that the total number of Bs since the last V is odd.

If pulses of the same polarity were adjacent, performance would have been degraded. Therefore, X and V bits are separated by a ZERO, resulting in an XOV pattern in each bipolar violation sequence.

2.2.1 Transmitting Sequences Containing Bipolar Violations

1. Idle Sequence - This sequence may be used as a supervisory signal. For example, it could indicate that the terminal

does not have data to transmit. Such usage is analogous to the Request-to-Send OFF indication in EIA Standard RS-232-C. The Idle sequence consists of one or more repetitions of the sequence BBBXOV at 2.4, 4.8, or 9.6 kb/s or BBBBXOV at 56 kb/s. (See Figure 6.)

2. Zero Suppression Sequence - At 2.4, 4.8, or 9.6 kb/s any sequence of 6 consecutive 0s must be encoded as 000XOV; at 56 kb/s, any sequence of 7 consecutive 0s must be encoded as 0000XOV. (See Figure 7.)

2.2.2 Receiving Sequences Containing Bipolar Violations

1. Idle Sequence - This is the same as the transmitting Idle sequence described above. (See Figure 6.)

2. Zero Suppression Sequence - Reception of 000XOV for any speed must be decoded as 6 0s. (See Figure 7.)

3. Out-of-Service Sequence - This sequence is an indication of trouble in the DDS. It consists of one or more repetitions of the sequence 00BXOV at 2.4, 4.8, or 9.6 kb/s or 000BXOV at 56 kb/s. (See Figure 8.)

2.2.3 System Response to Bipolar Violation Sequences

A single bit transmission error could change a data sequence into a bipolar violation sequence. This would not be particularly serious if data were changed to the Zero Suppression sequence. One or two errors would be the result. However, if data were changed to the Idle sequence or Out-of-Service sequence, it could seriously affect the operation of data terminal equipment unless spurious occurances of these sequences are ignored.

The design of the logic circuitry associated with the coding and decoding functions in the data communication equipment can reduce the effect of short bursts of errors. For example, the Bell System Data Service Unit (DSU) requires three repetitions of the Idle or Out-of-Service sequences before detecting these conditions and turning OFF the Received Line Signal Detector (CF) lead. To turn ON this lead the DSU must receive 12 bits (2.4, 4.8, or 9.6 kb/s) or 14 bits (56 kb/s) of data containing neither Idle nor Out-of-Service sequences.

The customer's data terminal may transmit Idle sequences through a DDS channel for supervisory signaling purposes. The transmission delay will not necessarily be the same for Idle sequences as for data. This difference in delay may cause signals to be modified when going between the Idle and data modes. The transition from data to Idle adds a number of pulses between the last data bit and the first pulse of the Idle sequence. The transition from Idle to data will replace the same number of the initial data bits with the bits of the Idle sequence. The additional delay for Idle sequences will be less than six bits at 2.4, 4.8 and 9.6 kb/s. At 56 kb/s the additional delay will be less than seven bits.

It is important to note that a Zero Suppression sequence may not be received when one was transmitted and vice versa. If a Zero Suppression sequence follows a B00000 data sequence, then the received data could have ten consecutive zeros.

2.2.4 Other Bipolar Violation Sequences

The Idle and Zero Suppression sequences from the data communication equipment at the customer's location are detected at the Telephone Company central office and are transmitted to the distant central office with a signal format that does not involve bipolar violations. At the distant central office the bipolar violations are inserted in the pulse train that is transmitted to the customer's location in accordance with the data alignment within the time-division multiplexer bit stream which does not necessarily correspond to their original placement. Bipolar violation sequences other than those specified will reach the distant end as bipolar pulses (B) rather than bipolar violations (V).

2.3 CSU Block Diagram

A simplified block diagram of the CSU is shown in Figure 9. Nominal 50 percent duty-cycle, bipolar pulses are accepted from the customer on the Transmitted Data leads DT and DR. These pulses must be synchronous with the DDS and must comply with the specifications listed in Section 2.7. The input bipolar pulses are amplified, filtered, and passed through the transmit repeat coil to the transmit pair.

The signal on the receive pair is amplified, equalized and sliced by the line receiver. The resultant bipolar pulses are then passed to the customer over the DT1 and DR1 Received Data leads. From these pulses the customer must recover the synchronous clock used for timing the transmitted data and sampling the received data.

2.4 CSU Physical Description

The CSU, shown in Figure 2, is designed for wall mounting. It measures approximately five inches high, 2-3/4 inches deep, and eight inches wide. Visible through the face of the housing are two lights to indicate

1. PWR - when ac power is applied to the unit.

2. TST - when the unit is being remotely tested from the test center.

The CSU will operate over a temperature range of +40°F to +120°F with a relative humidity less than 95 percent. The CSU weighs approximately 3 pounds.

Power is furnished to the CSU from a customer-provided 105-129 volt, 60 ±3 Hz, nonswitched source by means of a 3-foot cord with a U-ground type 3-conductor plug. The CSU consumes approximately 10 watts of ac power. The CSU should be located so that the customer-provided interface cable from the CSU to the data terminal will not exceed 100 feet. (See Part 2.5.2).

2.5 CSU Interface Circuits

The interface discussed in this Technical Reference is the point of connection between the CSU of the DDS and the customer-provided terminal equipment. The interface that is provided consists of six leads: two pairs for data, a ground (normally connected to the power ground but may be optionally disconnected), and a Status Indicator lead.

As shown in Figure 9, leads DT and DR are the Transmitted Data pair, and leads DT1 and DR1 are the Received Data pair. The electrical characteristics of these leads are significantly different from those described in RS-232-C. For this reason, Parts 2.7.1 through 2.7.13 in this Technical Reference cover the standards for the data interchange signals. This is the first time these interface characteristics have been used. The parameters and specifications will be reexamined as user experience is acquired. In this light, the specifications should be considered as preliminary.

The Status Indicator (SI) lead conforms electrically to EIA Standard RS-232-C. It is analogous to Data Set Ready (CC) described in RS-232-C. When Circuit SI is ON, (voltage to ground between +3 and +25 volts), the local CSU is connected to ac power and is not in a test mode. Ground return for this circuit is normally connected within the CSU to the power plug ground. It may be disconnected at the customer's request. The short circuit current on the SI lead is limited to 20 mA. The ON condition should not be interpreted as either an indication that a communication channel has been established to a remote data station or the status of any remote station equipment. The OFF condition (voltage between -3 and -25 volts) is an indication that the data terminal equipment should disregard signals appearing on the Received Data Circuit and should not attempt to transmit data over the Transmitted Data Circuit.

2.5.1 Interface Connector

The six leads are provided on a 15-pin female connector. The customer-provided plug must be a male 15-pin connector such as the DAMA-15-P plug manufactured by Cinch, or the equivalent. The pin assignments for the connector are given below.

Pin Number	Function	Signal Direction
1	Ground (GRD)	-
2	Status Indicator (SI)	From CSU to Customer
3	Received Data (DT1)	From CSU to Customer
4	Received Data (DR1)	
5	Transmitted Data (DT)	From Customer to CSU
6	Transmitted Data (DR)	
7-15	Not Used	-

2.5.2 Interface Cable Requirements

The cable from the data terminal equipment to the CSU requires three twisted pairs. One twisted pair should be used for DT and DR, one pair for DT1 and DR1 and one pair for SI and GRD. To reduce the possibility of crosstalk between the various leads and assure proper operations, the following recommendations are made regarding the cable parameters.

Gauge	24 AWG
Characteristic Impedance of Pair	120 ohms ± 10% at 150 kHz 100 ohms ± 10% above 400 kHz
Mutual Capacitance of Pair	1600 pF/100 feet ± 20%
Capacitance of Single Lead to Ground - all other leads grounded	4000 pF/100 feet maximum
Crosstalk Loss - Pair-to-Pair	40 dB minimum at 150 kHz

2.6 Data Interchange Circuits - Introduction

The CSU is transformer coupled to the data interface leads. This interface is designed to be compatible with a wide variety of drivers and terminators in the user's equipment. Transformer coupling causes the CSU input and output impedances to be frequency dependent. It also means that the CSU neither responds to nor transmits dc voltages.

The interface specifications describe pulse characteristics when the drivers in the CSU and in the customer equipment are terminated with a 135-ohm resistance. To describe the opposite direction of transmission, the characteristics of pulses from a source having an internal impedance of 135-ohms, resistive, are used. That is, the terminators in the CSU and in the customer equipment are described by specifying the shape of pulses from a 135-ohm resistive source of pulses. Figure 10 shows two possible schematic diagrams for interface cable terminators in the customers data equipment. Figure 11 shows two possible interface cable drivers.

2.7 Definitions and Limiting Specifications

In this Part, various terms and parameters used to specify the data interchange circuits are introduced, defined and illustrated. Following the definition, the limiting specification is stated along with any explanatory comments.

2.7.1 Output Voltage (V_{out})

Definition: Figure 12 shows the output voltage measured between leads A and B (V_{out}).

Specification: The transmission of a binary ONE or ZERO shall be indicated by the following differential ac output voltages measured across a 135-ohm resistive termination.

1. Customer Generator

   ONE $1.4 \text{ volts} \leq |V_{out}| \leq 2.1 \text{ volts}$

   ZERO $|V_{out}| \leq 0.14 \text{ volts}$

2. CSU Generator

   ONE $1.33 \text{ volts} \leq |V_{out}| \leq 2.1 \text{ volts}$

   ZERO $|V_{out}| \leq 0.21 \text{ volts}$

   Where $|V_{out}|$ denotes the absolute value.

These requirements are illustrated in Figure 13.

The differential dc output voltage of the customer generator shall not exceed 25% of the peak-to-peak ac signal. The differential dc output voltage of the CSU will be zero.

Comment: Greater tolerance on the CSU output voltage limits reflects the fact that data signals are not retimed in the CSU. Some conversion of time to amplitude distortion may be expected.

2.7.2 Terminator Threshold Voltage (V_{in})

Definition: Figure 14 shows the differential ac input pulse amplitudes (V_{in}) that a terminating system will interpret as a binary ONE or ZERO when driven by a generator meeting the specifications in this Section.

The threshold levels are said to be normalized when referred to the equivalent amplitude obtained at the input of a terminator having a 135-ohm resistive input impedance.

Specification: The following normalized input voltages apply to both the customer terminator and the CSU.

ONE	$\lvert V_{in} \rvert \geq 1.05$ volts
Undefined	$0.35 \text{ volts} < \lvert V_{in} \rvert < 1.05$ volts
ZERO	$\lvert V_{in} \rvert \leq 0.35$ volts

Where $\lvert V_{in} \rvert$ denotes the absolute value.

These requirements are illustrated in Figure 14.

2.7.3 Rise and Fall Times (T_R, T_F)

Definition: Figure 15 shows the rise and fall times of the leading and trailing edges of a pulse.

Specification: The time (T_R, T_F) required for a generator to indicate a change in its binary state shall not exceed 5% of a bit interval. This is measured when the generator is terminated with a 135-ohm resistive load.

Comment: The rise and fall times shown on Figure 15 are exaggerated for additional clarity.

2.7.4 Pulse Width (W)

Definition: Figure 15 shows the pulse width at the nominal threshold level.

Specification:

1. Customer to CSU - The pulse width, measured across a 135-ohm resistance at the generator terminals, shall be 50% ± 2.5% of the bit interval at the nominal terminator threshold levels of ± 0.7 volts.

2. CSU to Customer - The average pulse width, measured across a 135-ohm resistance at the generator terminals, will be greater than 45% and less than 90% of the bit interval at the nominal terminator threshold levels of ± 0.7 volts.

Comment: The CSU to customer specification reflects the fact that data signals are not retimed in the CSU. Random noise introduced in the cable pairs could cause data transitions anywhere within the bit interval. The specification covers pulse widths in the absence of random noise or when the received signal is averaged over many bit intervals.

2.7.5 Differential Impedance (Z_{in}, Z_{out})

Definition: Figure 12 shows the points where the effective impedances (Z_{in}, Z_{out}) are measured. Figure 16 outlines a method for determining the impedance.

Specification: The following impedances apply to interface generators and terminators that are operating at the given bit rate and with the nominal signal levels and duty-cycle specified in this Section. As shown in Figure 16, the impedance during the rise and fall intervals is not specified.

1. Generator - When transmitting a bipolar pulse train into a resistive load, Z_{out} shall be 135 ohms ±20%.

2. Terminator - When receiving a bipolar pulse train transmitted by a resistive source, Z_{in} shall be 135 ohms ±50%.

Comment: When the CSU is in the test mode (see Part 1.3.3), interface leads DT, DR, DT1 and DR1 will be open-circuited and disconnected from the DDS channel.

2.7.6 Longitudinal (Common Mode) Noise

Definition: Noise currents and voltages may be introduced along the interface cable. If they cause an equal change in the potential of terminal A and of terminal B (Figure 17) with respect to ground, they are called longitudinal noise sources.

2.7.7 Common Mode Impedance (Z_{CM})

Definition: Refer to Figure 17 for common mode impedance and voltage illustrations. The impedance to ground with the A and B terminals shorted together is the common mode impedance, Z_{CM}.

Specification: None

Comment: Since the CSU is coupled to the interface cable through a balanced, ungrounded transformer, it is expected that longitudinal noise current effects will be negligible. Consequently, Z_{CM} of the customer generator or terminator may be chosen relatively low (about 135/4 or 34 ohms) to minimize interference caused by capacitive coupling of stray signals.

2.7.8 Common Mode Voltage (V_{CM})

Definition: As shown in Figure 17(b), this is the arithmetic mean of the voltage on terminals A and B measured with respect to ground.

Specification: These specifications are based on measurements between ground and the midpoint of a 135-ohm resistive termination. The common mode output voltage must satisfy the following limits:

1. Customer generator or terminator to CSU

   (a) The dc component of V_{CM} shall be between +5.5 volts and -5.5 volts.

   (b) The peak ac component of V_{CM} shall not exceed the limits shown on Figure 17(c).

2. CSU to customer generator or terminator

   Not specified

Comment: The CSU may impress a common mode signal at the interface during instants of transition between binary states as a result of nonideal characteristics in the interface transformers. However, this signal is associated with the high common mode impedance of an ungrounded transformer and will be negligible relative to the differential signal power.

2.7.9 V_{CM} Input Voltage Range

Definition: This characteristic describes the voltage range through which V_{CM} may be varied without causing improper operation of a generator or terminator. That is, no change in binary state is caused, and the driver or terminator continues to meet all interface specifications.

Specification: A generator or terminator shall continue to operate satisfactorily when connected to the test source illustrated in Figure 18(a). This source has the pulse amplitude and impedance characteristics indicated in Figure 18(c). It produces a pulse train at the given bit rate.

Comment: This specification permits a comparison of generators and terminators that is independent of their common mode impedances. Comparison is on the basis of their ability to withstand longitudinal noise of equal available power.

2.7.10 Impedance Balance

Definitions: As shown in Figure 19, this quantity is an expression of the difference in the impedance from terminal A to ground (Z_A) and the impedance from terminal B to ground (Z_B). The balance is measured indirectly by means of the test shown in Figure 19.

Specification: When driven by a sinusoidal test source, the ratio of applied common mode voltage (V_T) to differential voltage (V) shall not be greater than the values shown on Figure 19. For example at 4.8 kb/s, the impedance balance must be greater than 40 dB at 9.6 kHz and greater than 20 dB at 96 kHz.

2.7.11 Terminator Bias Current

Definition: This is the short-circuit dc current flow when the terminator leads are connected together.

Specification:

1. CSU generator to customer terminator - 0.1 mA

2. Customer generator to CSU terminator - Not specified

Comment: Since a transformer is used as the output device from the CSU, dc current flow from DT1 to DR1 must be limited to avoid distortion of the data signals. The input transformer in the CSU has a series capacitor at the midpoint of its primary winding. This blocks any bias current from flowing.

2.7.12 Protection

Specification: The difference in ground potential between the CSU and the customer's terminal equipment shall not exceed a peak value of 1.0 volt. Under conditions of worst-case ground potential difference, the short-circuit current to ground from the customer's generator or terminator shall not exceed 120 mA.

The circuits used in this interface shall not be damaged by a short circuit between the balanced data leads or by a short circuit from either lead to ground or to the Status Indicator lead. The circuits shall not be damaged under open-circuit conditions.

Comment: Protection under conditions of accidental contact with other voltages or circuits is not specified, and circuit damage may result. The user is cautioned not to mix the interface leads with other circuits in the same cable.

2.7.13 Timing Accuracy

Definition: This term describes the difference between the frequency of the received pulses and the nominal data rate.

Specification:

1. Customer to CSU - The transmitted data shall be synchronous with the received data.

2. CSU to Customer - Under normal conditions, the frequency of the received data will agree with the nominal data rate to within ±2 parts in 10^9. Some trouble conditions will allow the frequency difference to vary ±0.005% of the nominal data rate.

2.7.14 Minimum Average Pulse Density

Definition: The average pulse density of a sequence is the total number of non-zero pulses (Bs or Vs) divided by the sequence length.

Specification:

1. Customer to CSU: The Zero Suppression encoding rule given in Part 2.2.1 guarantees that the customer will deliver to the CSU a minimum average pulse density of 1 in 6 (at 2.4, 4.8 and 9.6 kb/s) or 1 in 7 (at 56 kb/s.)

2. CSU to Customer: The rule controlling the generation of Zero Suppression codes in the pulse stream from the CSU to the customer differs somewhat from that given in Part 2.2.1. Specifically, the Zero Suppression sequences are always generated in alignment with blocks of 6 (at 2.4, 4.8 and 9.6 kb/s) or 7 (at 56 kb/s) bits of data passed from the multiplexer to the OCU. The effect of this is to increase the maximum number of successive zeros which may appear to 10 (at 2.4, 4.8 and 9.6 kb/s) or 11 (at 56 kb/s) bits, but to maintain a minimum average pulse density of 1 in 6 (or 7.)

Comment: The problems of timing, phase detection and received level control are strongly dependent on the minimum average pulse density. The rule for customer to CSU Zero Suppression given in Part 2.2.1 provides a simple method for meeting this requirement.

2.7.15 Isochronous and Peak Individual Distortion (Jitter)

Definition: (See Appendix)

1. Customer to CSU:

   Specification: The peak individual distortion of the data signals from the customer to the CSU shall not exceed 5% of a bit interval relative to a reference clock in phase with the mean of the significant transitions when receiving random data from a CSU having the distortion characteristics shown in Figure 20 (d).

   The isochronous distortion of data signals from the customer to the CSU shall not exceed 10% of a bit interval when receiving random data or periodic patterns from the CSU.

   Comment: A maximum jitter bandwidth for the customer's timing recovery circuit is estimated conservatively at 0.01% to 0.05% of the signaling frequency* (bit rate).

*See Appendix

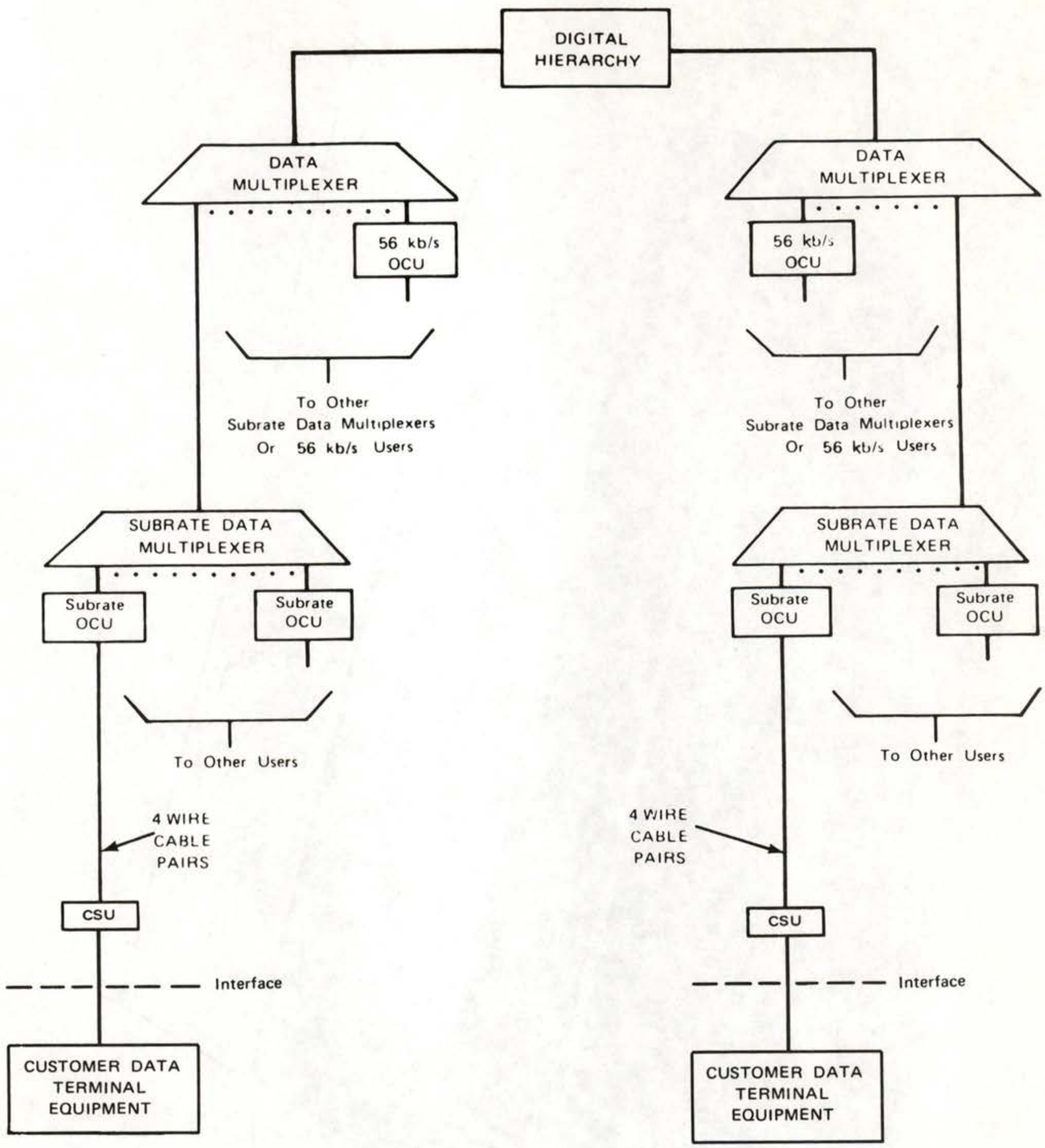
2. <u>DSU to Customer</u>:

Comment: Signals transmitted from the central office to the customer location are not retimed in the CSU. Consequently, the effects of random noise, intersymbol interference and data pattern variations may cause data transitions to occur anywhere within the unit signaling interval. However, it is expected that intersymbol interference and pattern variations will be dominant in establishing the average statistics of the received data signal.

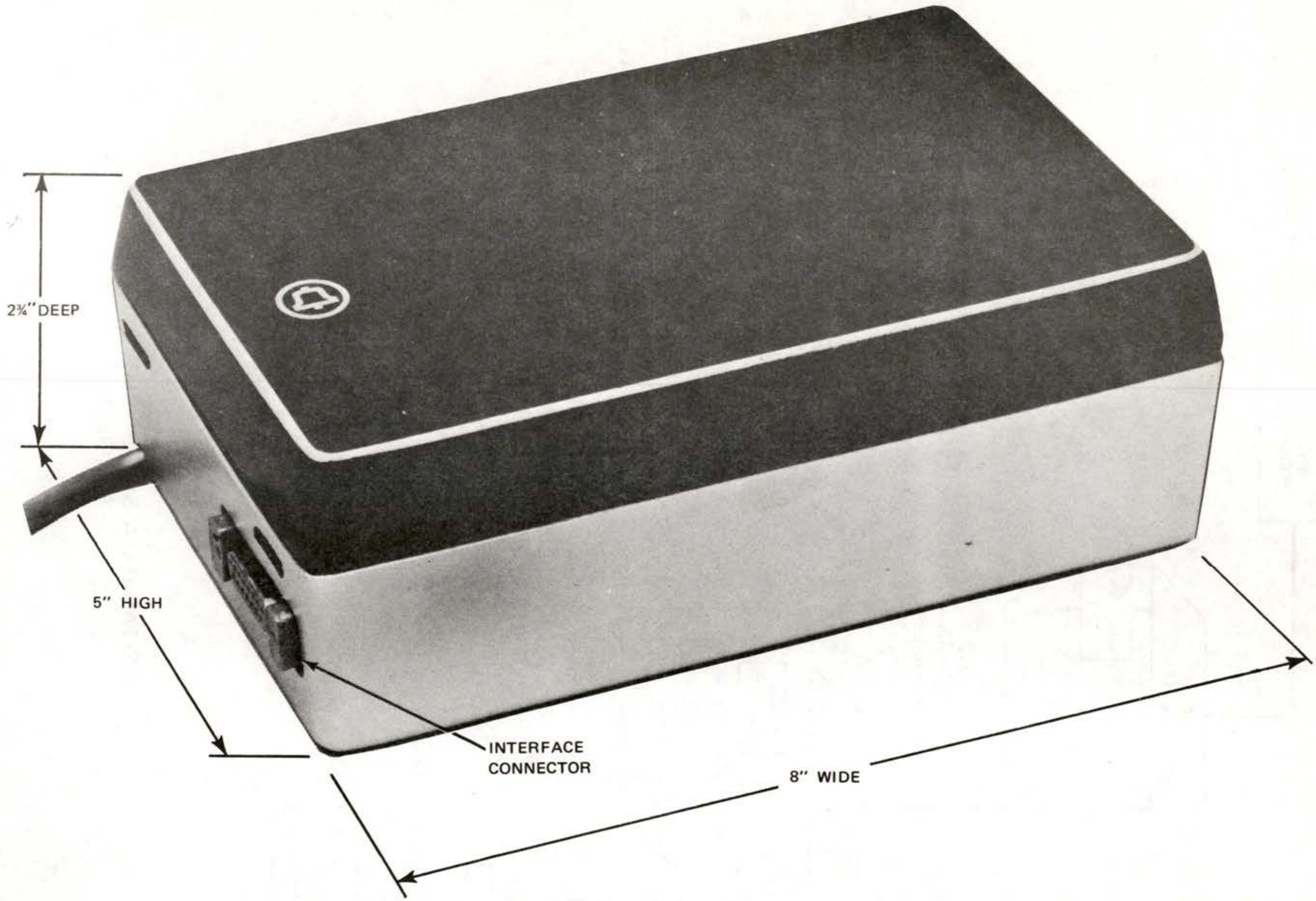
Measurements in the absence of noise indicate that a bipolar eye diagram as shown in Figure 20 (d) may be obtained under worst-case conditions. This corresponds to 27.5% isochronous distortion (also called peak-to-peak jitter) of the leading and trailing pulse edges. This measurement would be taken at the nominal threshold levels of ±0.7 volts with a 135-ohm resistive termination.

The phase difference between the average pulse centers (midpoint of the ±0.7-volt transitions) of any two repetitive patterns is not expected to exceed 7.5% of a bit interval.*

*See Appendix

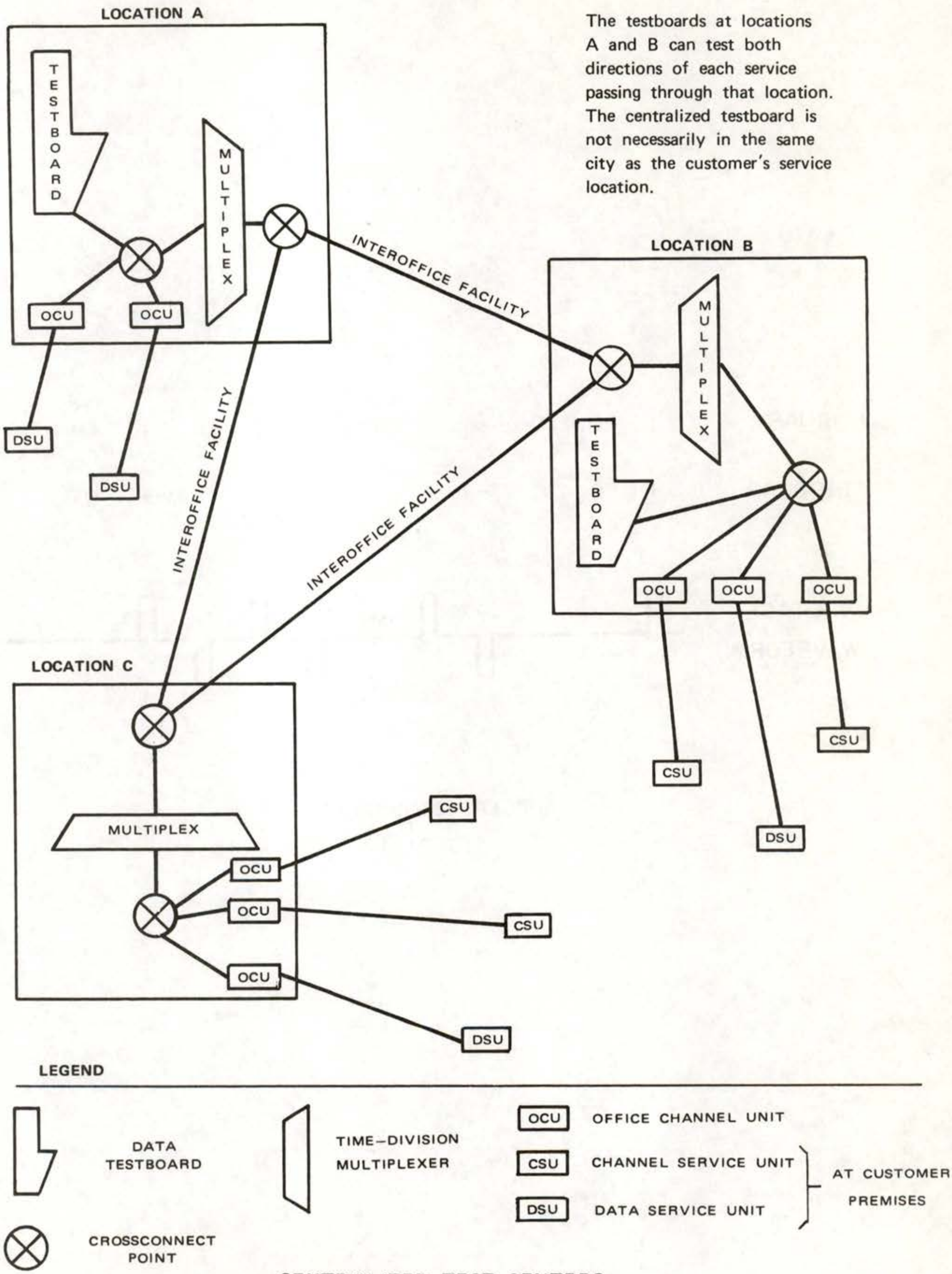


DIGITAL DATA SYSTEM BLOCK DIAGRAM
FIGURE 1

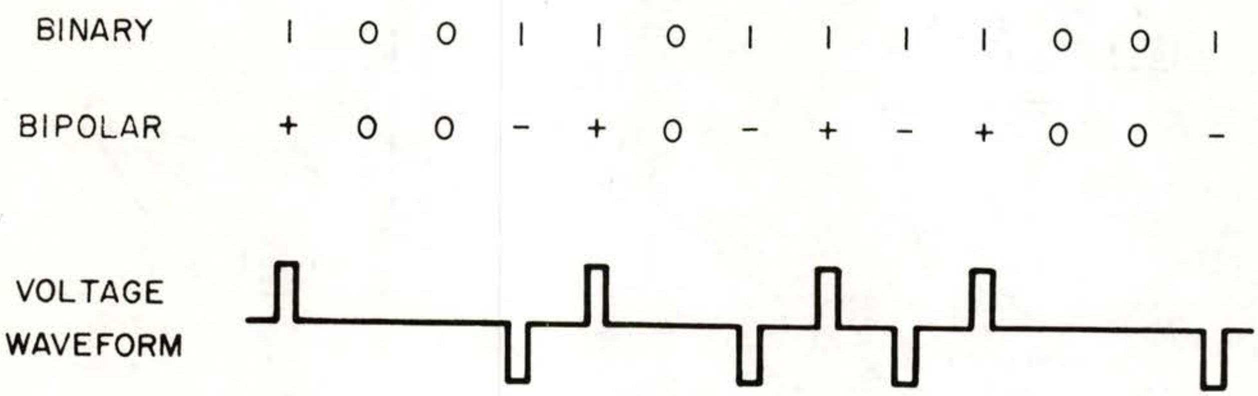


CHANNEL SERVICE UNIT
FIGURE 2

The testboards at locations A and B can test both directions of each service passing through that location. The centralized testboard is not necessarily in the same city as the customer's service location.

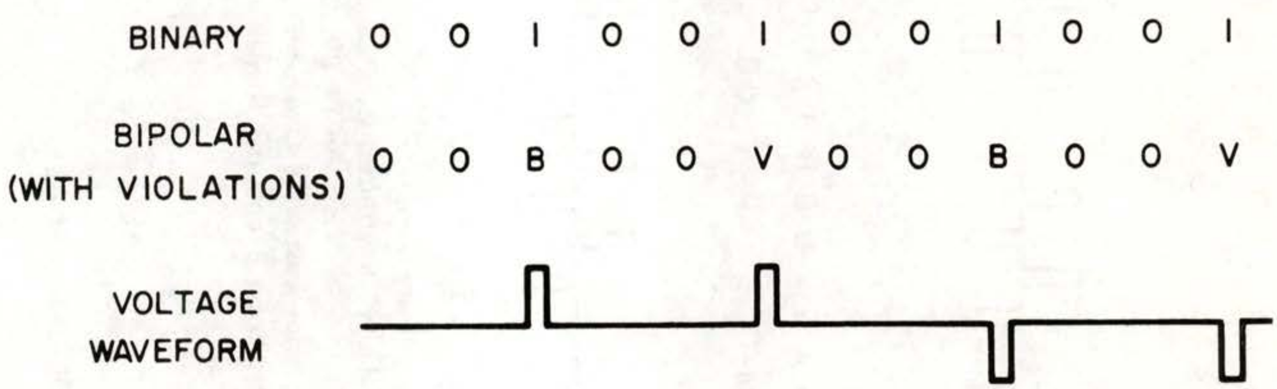


CENTRALIZED TEST CENTERS
FIGURE 3



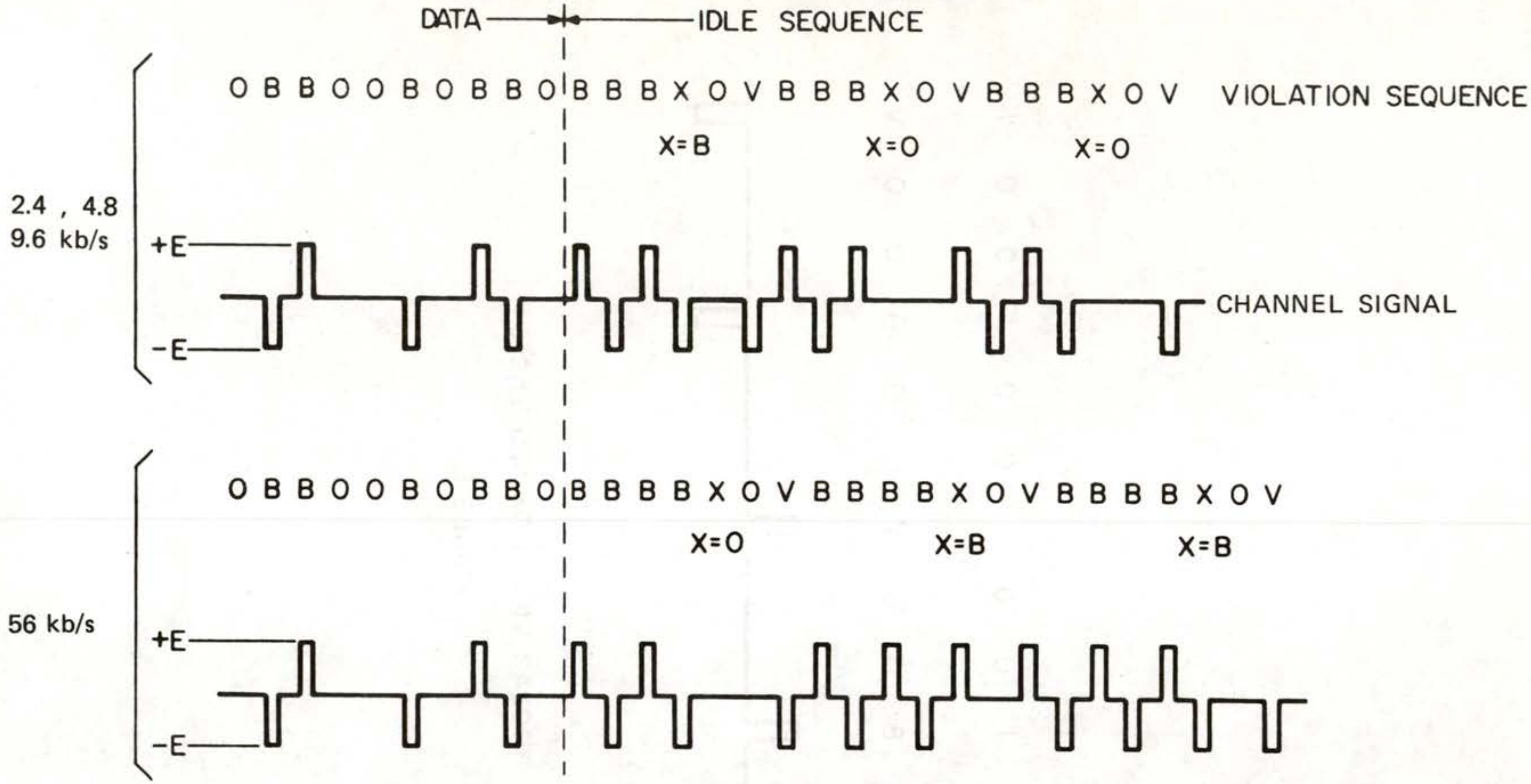
BIPOLAR SEQUENCES

FIGURE 4



BIPOLAR VIOLATION SEQUENCES

FIGURE 5

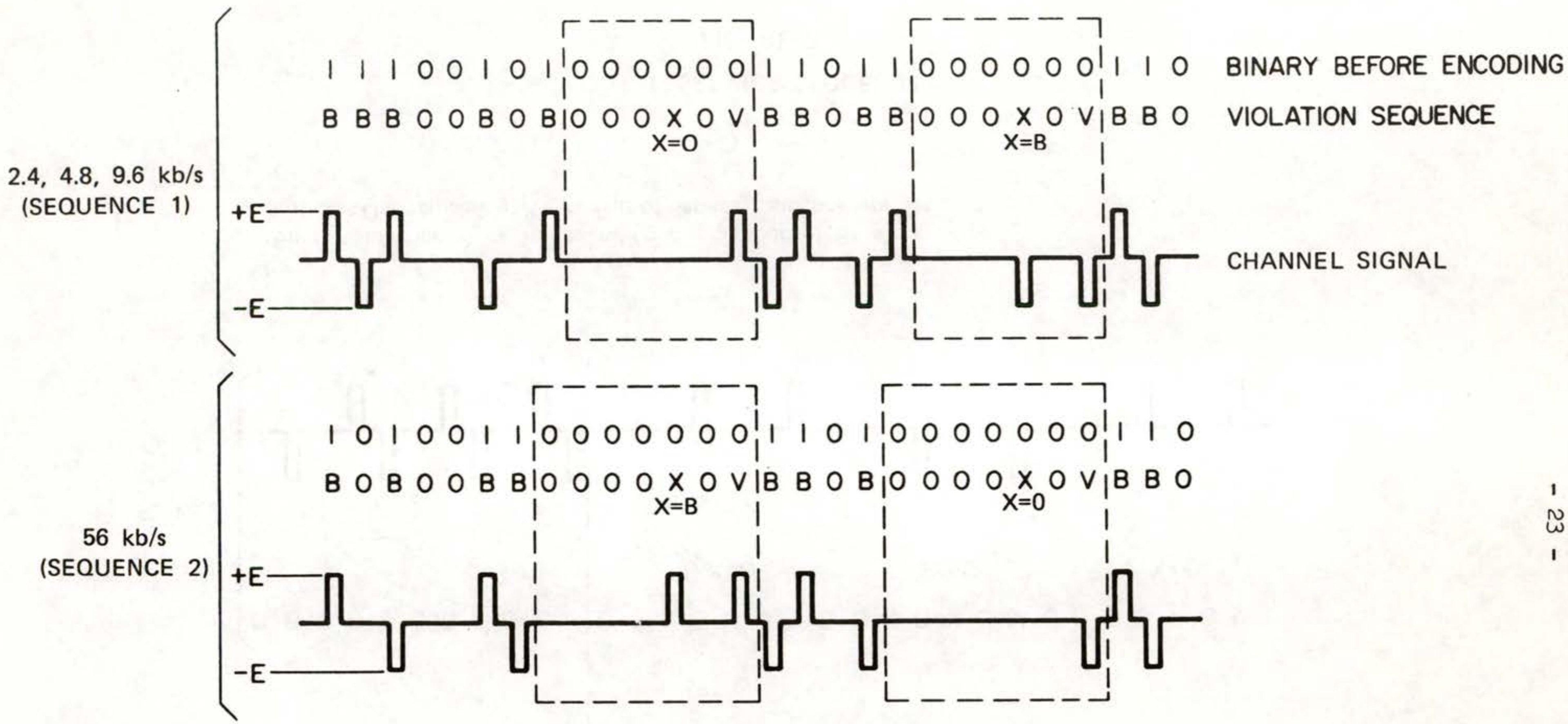


NOTE:

- O Denotes Zero Volts Transmitted — Binary Zero
- B Denotes ±E Volts Transmitted (Polarity Determined by Bipolar Rule) —Binary One
- V Denotes ±E Volts Transmitted (Polarity in Violation of Bipolar Rule) —Binary One
- X Equals O or B if Number of Bs Since Last V is Odd or Even, Respectively in Above Example the First X Equals O or B and the Remaining Xs Equal 0 for 2.4, 4.8 and 9.6 kb/s and B for 56 kb/s.

IDLE SEQUENCE

FIGURE 6

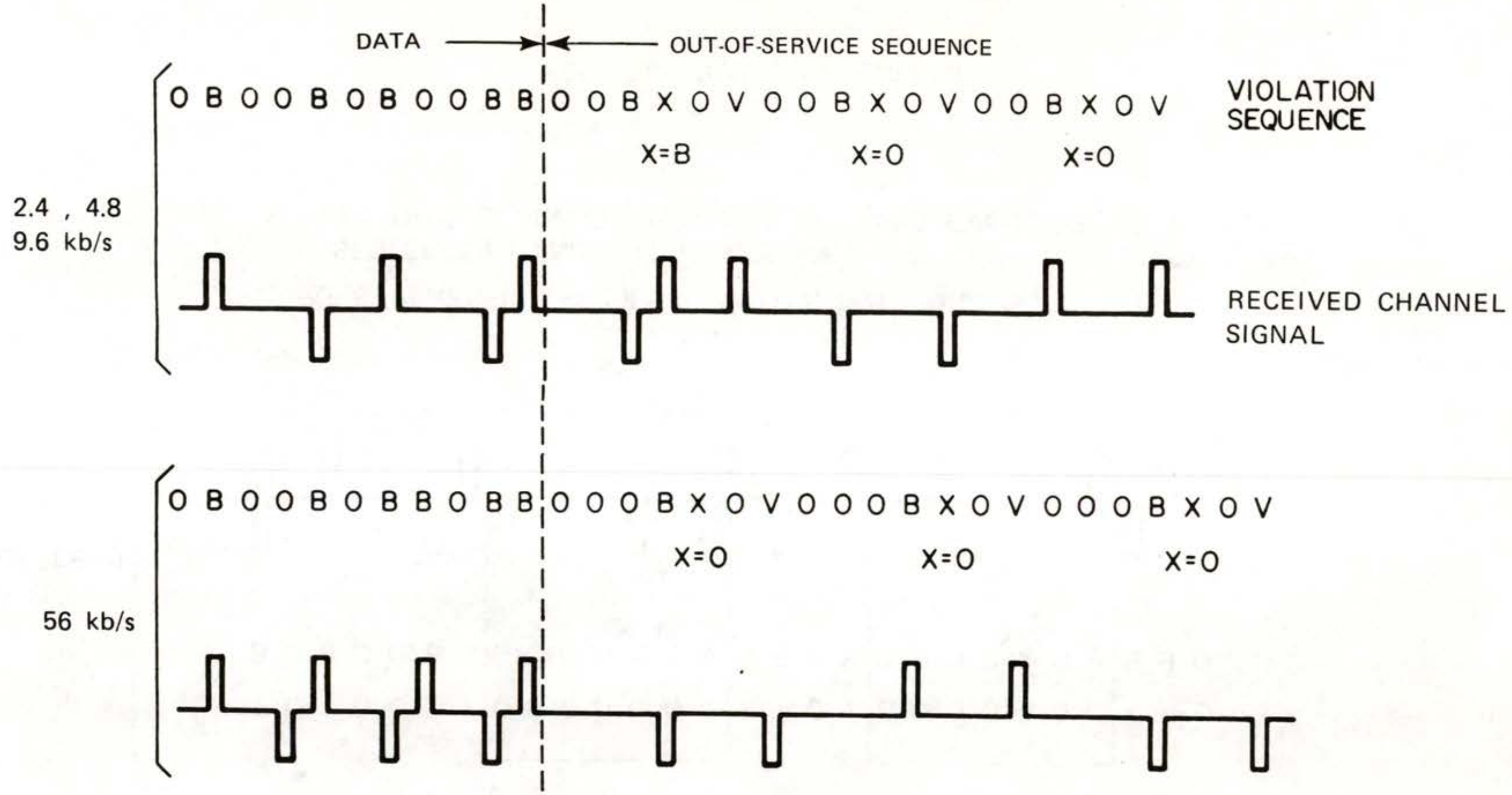


NOTE:

ZERO SUPPRESSION SEQUENCE WITHIN DOTTED LINES

FOR SEQUENCES I AND 2 IT IS ASSUMED THAT FOR THE FIRST X THE NUMBER OF B'S SINCE LAST V IS ODD AND EVEN, RESPECTIVELY

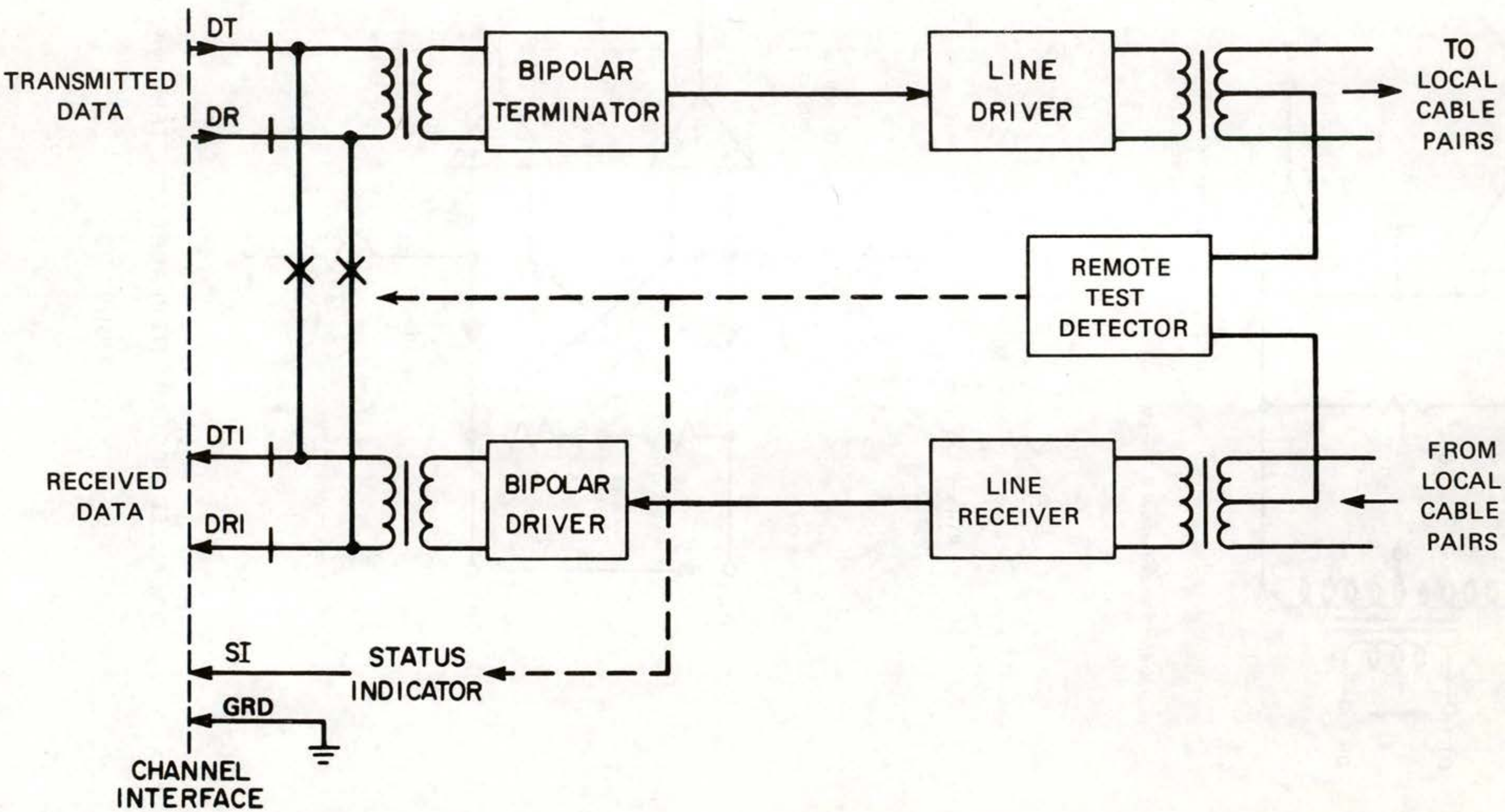
ZERO SUPPRESSION SEQUENCE
FIGURE 7



Note:
First X may be O or B depending on number of Bs since last V. The remaining Xs in Out-of-Service sequence are Os.

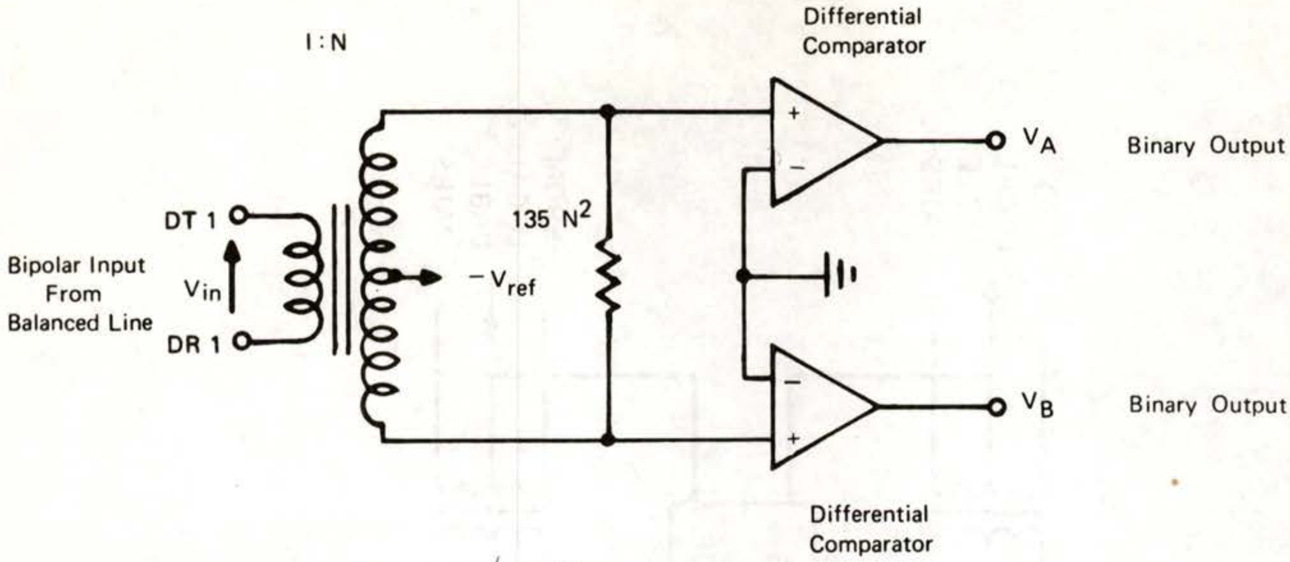
OUT-OF-SERVICE SEQUENCE

FIGURE 8



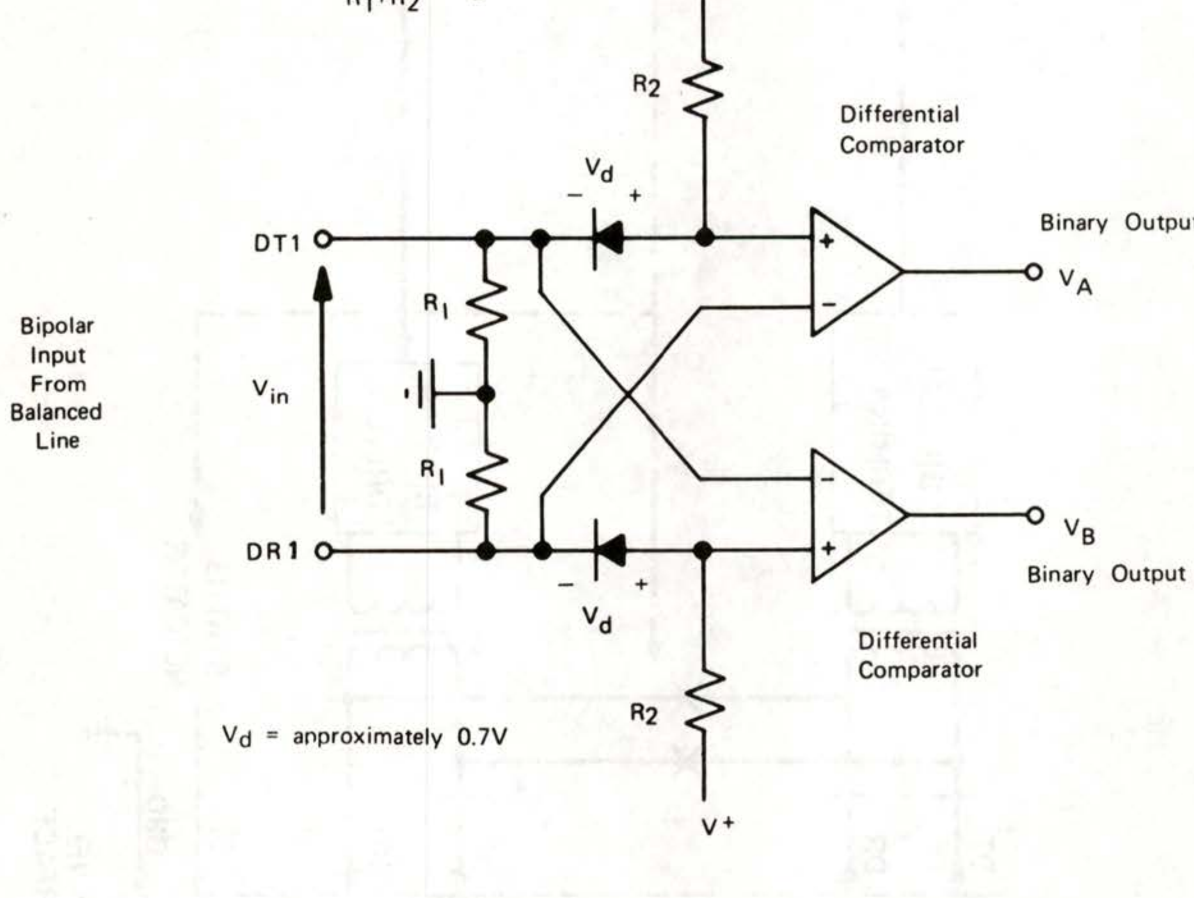
BLOCK DIAGRAM OF CHANNEL SERVICE UNIT

FIGURE 9



V_{ref} = approximately $0.7\ (\frac{N}{2})$ V

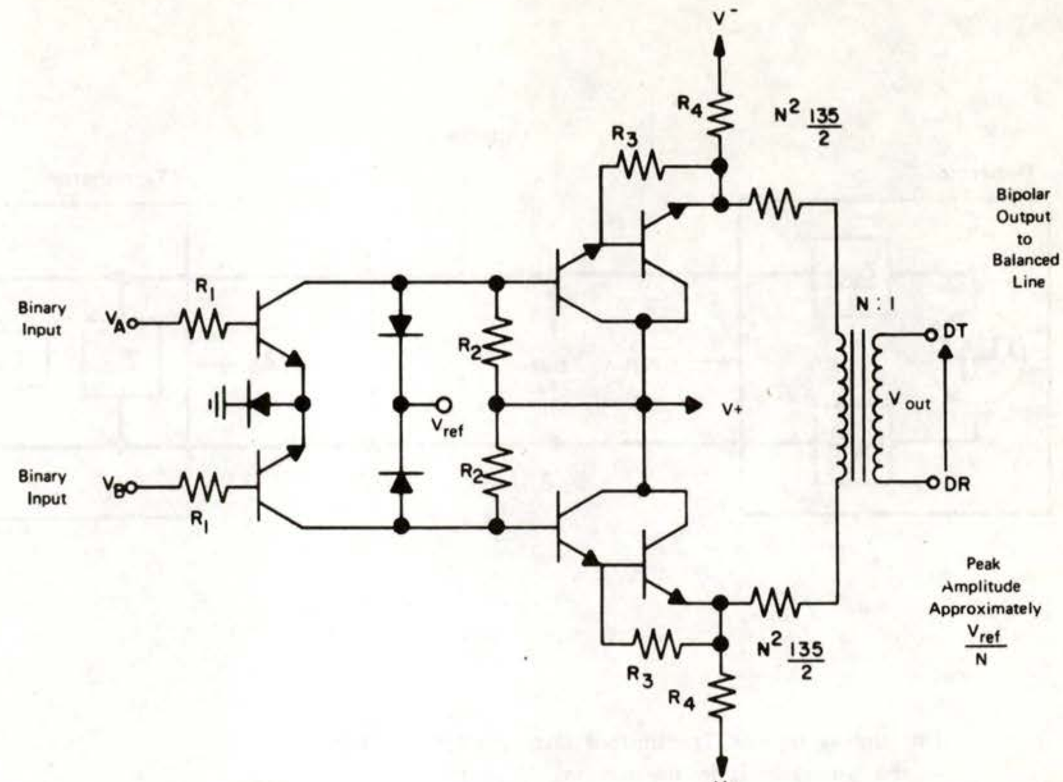
$$\frac{R_1 R_2}{R_1 + R_2} = \frac{135}{2} \text{ ohms}$$

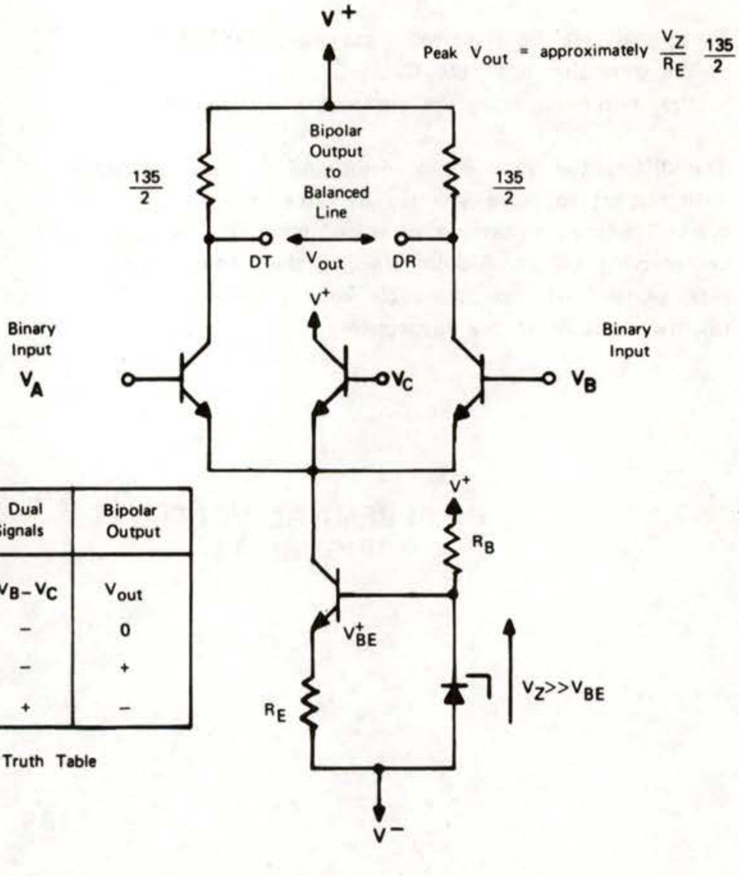


V_d = approximately 0.7V

BALANCED BIPOLAR INTERFACE CABLE TERMINATOR

FIGURE 10



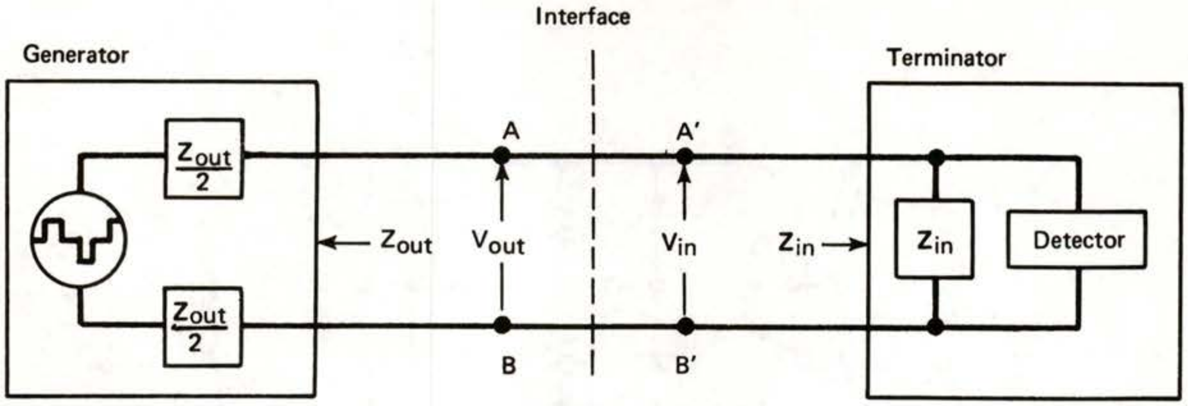


Binary Dual Rail Signals		Bipolar Output
$V_A - V_C$	$V_B - V_C$	V_{out}
–	–	0
+	–	+
–	+	–

Truth Table

BALANCED BIPOLAR INTERFACE CABLE DRIVER

FIGURE 11



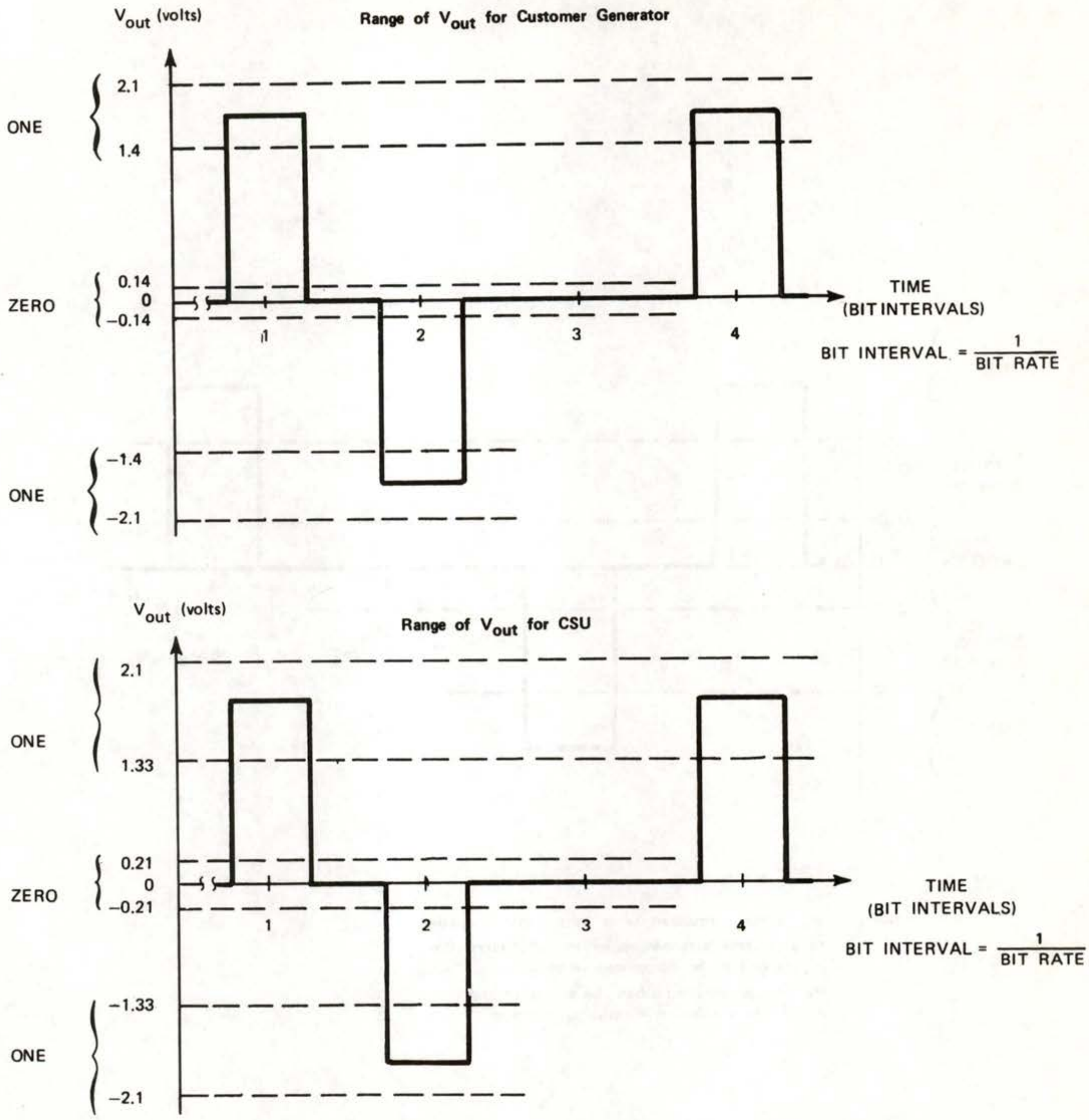
Notes:

1. For signals on the Transmitted Data leads (DT, DR)
   - the generator is in the customer's equipment
   - the terminator is in the CSU

2. For signals on the Received Data leads (DT1, DR1)
   - the generator is in the CSU
   - the terminator is in the customer's equipment

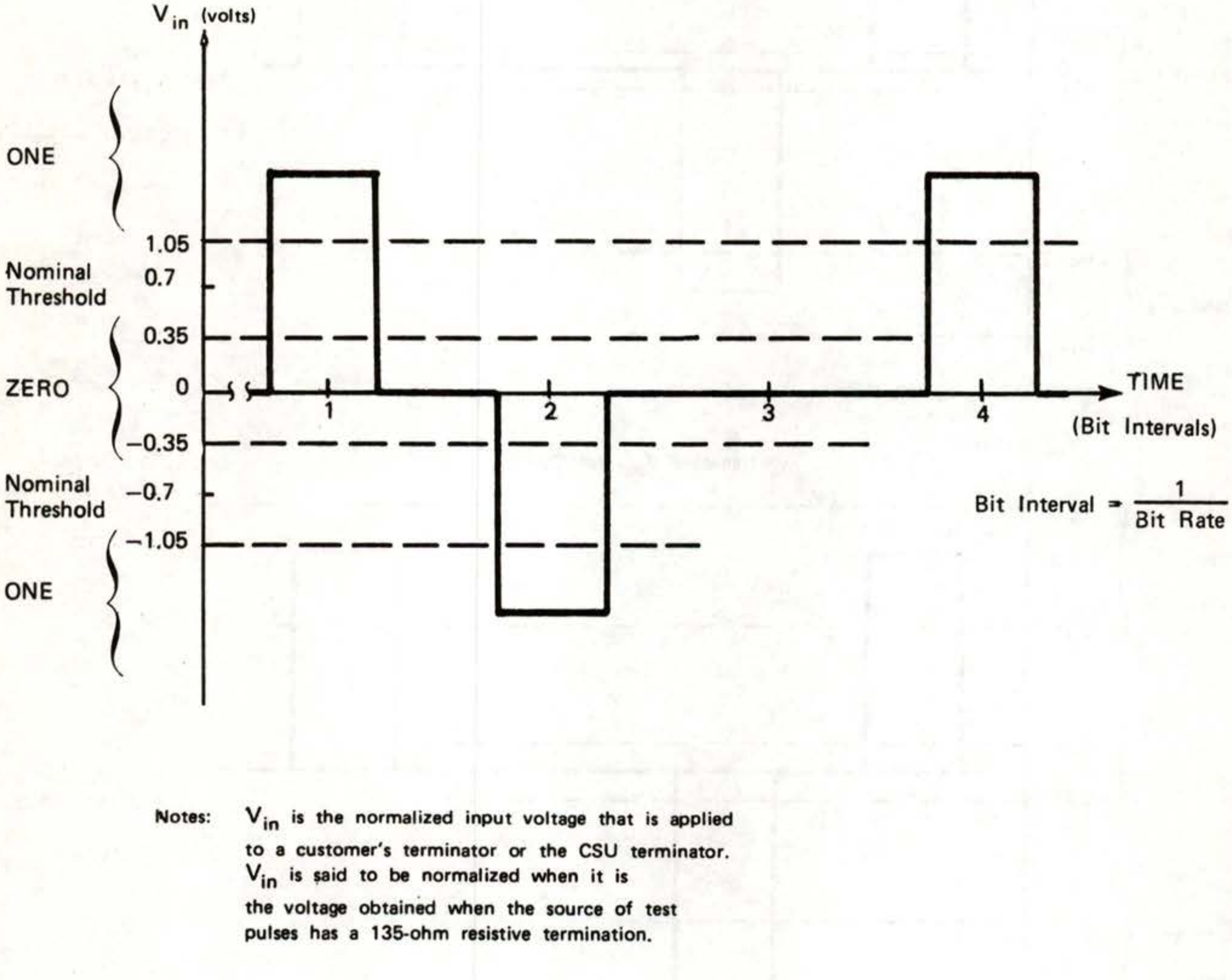
3. The differential impedances, Z_{out} and Z_{in} are defined with respect to pulse-type signals rather than sinusoidal ones. The impedances are measured when transmitting or receiving a bipolar pulse train at the nominal bit rate, signal level and duty-cycle with a 135-ohm resistive load or source respectively.

DIFFERENTIAL VOLTAGES
FIGURE 12



Note: V_{out} is a differential **ac** Voltage across a 135-ohm resistive termination.

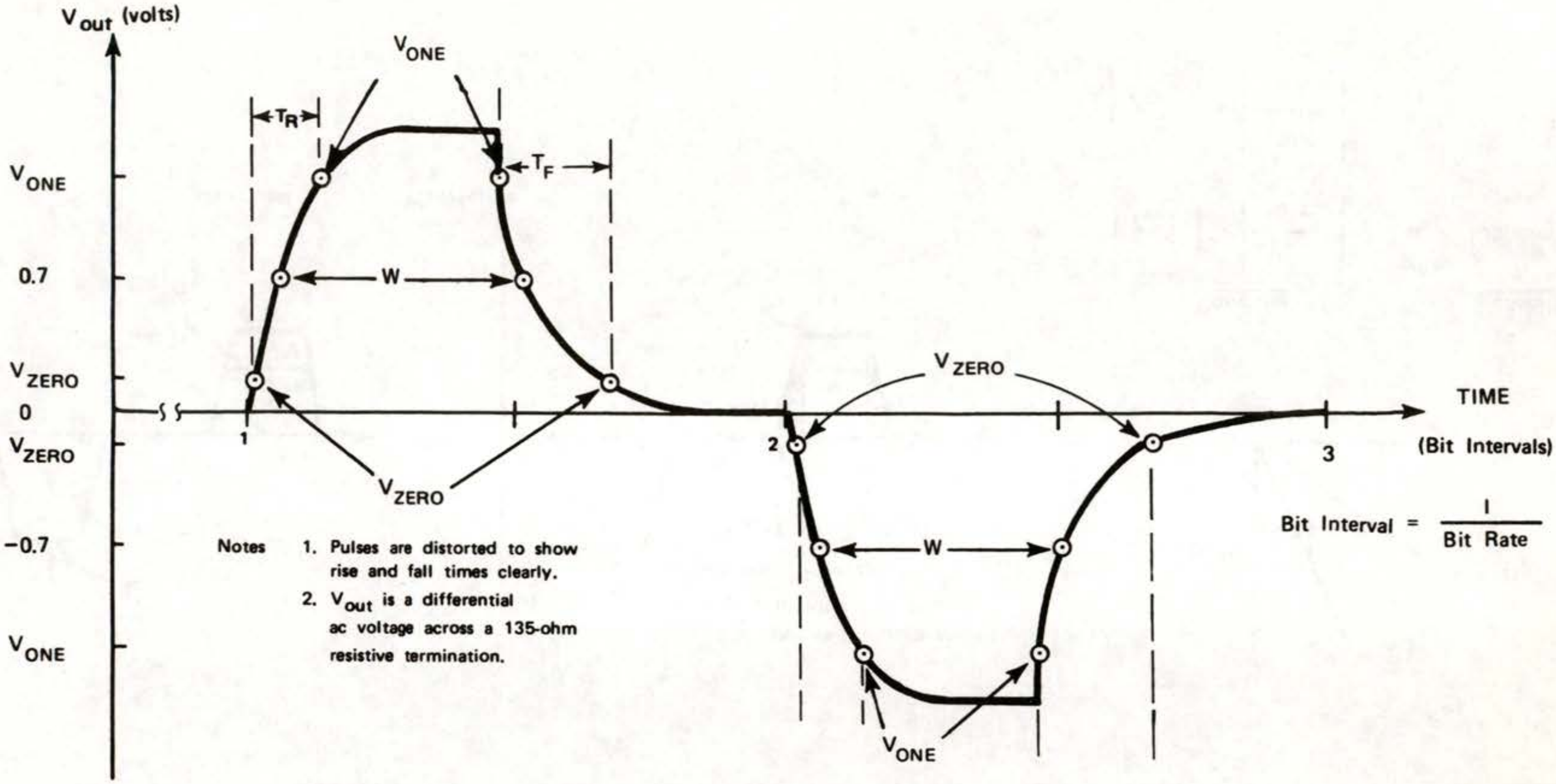
OUTPUT VOLTAGE RANGE
FIGURE 13



Notes: V_{in} is the normalized input voltage that is applied to a customer's terminator or the CSU terminator. V_{in} is said to be normalized when it is the voltage obtained when the source of test pulses has a 135-ohm resistive termination.

TERMINATOR THRESHOLD VOLTAGES

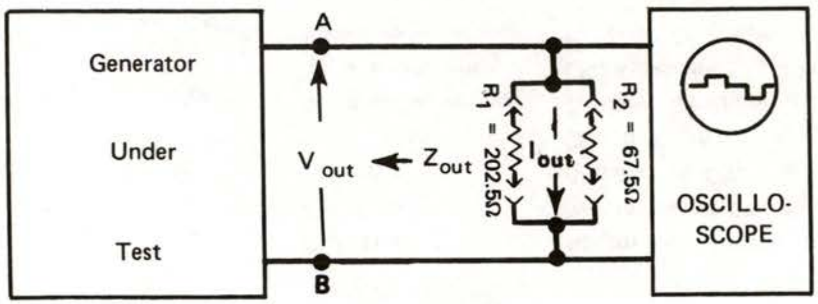
FIGURE 14



Symbol	Definition	Specification	
T_R	Rise Time	Not to exceed 5% of a Bit Interval	
T_F	Fall Time	Not to exceed 5% of a Bit Interval	
W	Pulse Width	Customer to CSU	– 47.5% to 52.5% of a Bit Interval
		CSU to Customer	– 45% to 90% of a Bit Interval
V_{ONE}	Minimum ac voltage for a binary one	Customer Generator	– 1.4 volts
		CSU Generator	– 1.33 volts
V_{ZERO}	Maximum ac voltage for a binary zero	Customer Generator	– 0.14 volts
		CSU Generator	– 0.21 volts

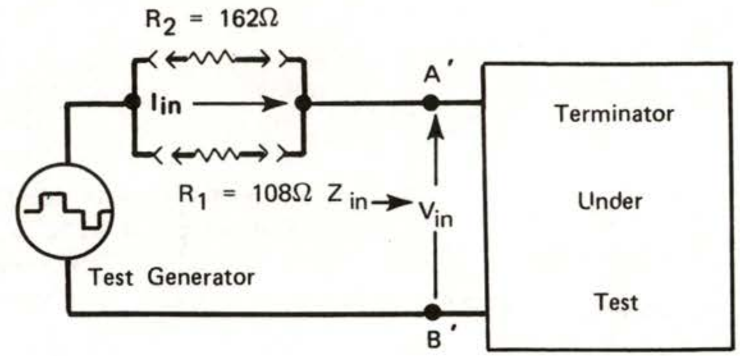
BIPOLAR PULSE CHARACTERISTICS
FIGURE 15

Simplified Generator Test Arrangement

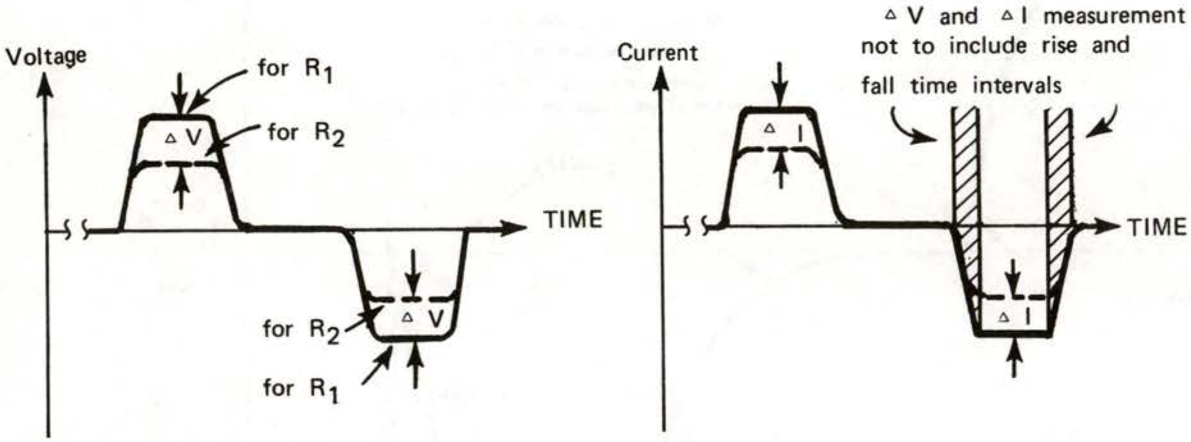


Resistances chosen to be 135 ohms ± 50%

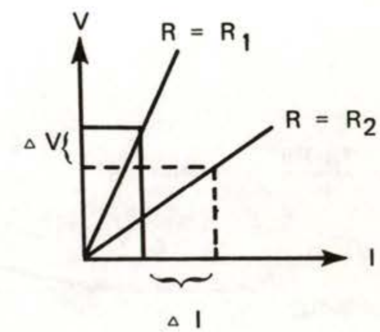
Simplified Terminator Test Arrangement



Resistances chosen to be 135 ohms ± 20%

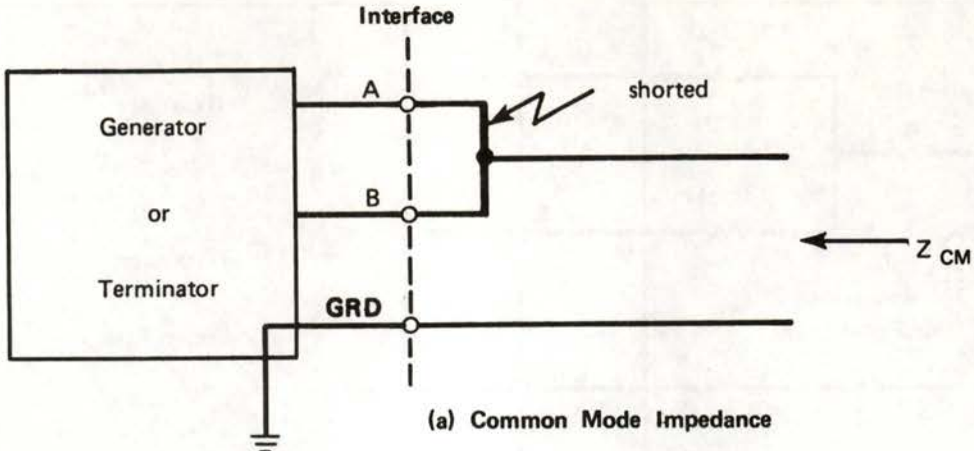


Observed Waveforms

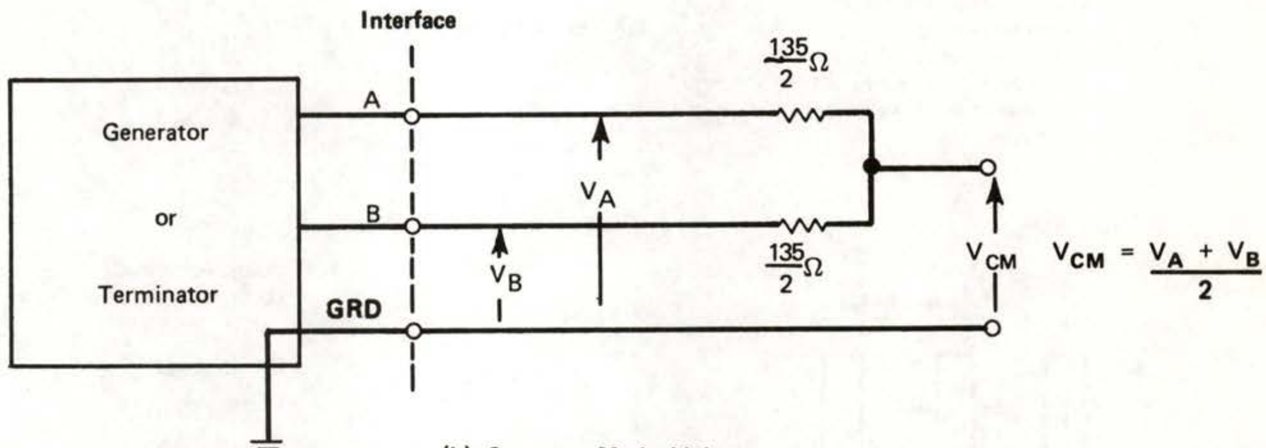


Compute		Specification
$\left\| Z_{out} \right\| = \left\| \frac{\Delta V_{out}}{\Delta I_{out}} \right\|$	=	135 ohms ± 20%
$\left\| Z_{in} \right\| = \left\| \frac{\Delta V_{in}}{\Delta I_{in}} \right\|$	=	135 ohms ± 50%

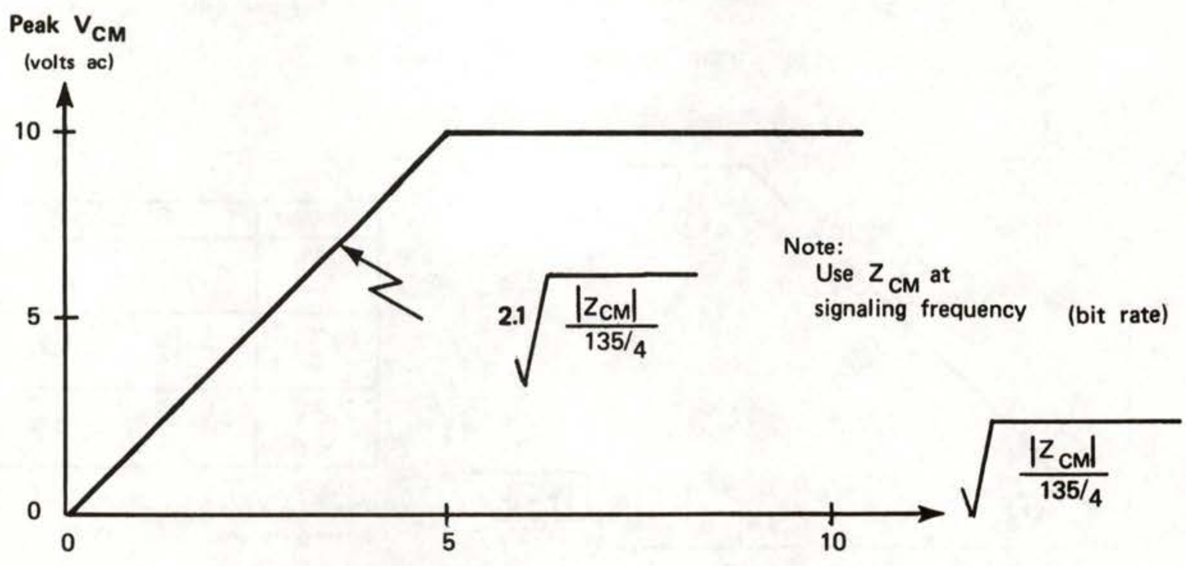
DIFFERENTIAL IMPEDANCE
FIGURE 16



(a) Common Mode Impedance

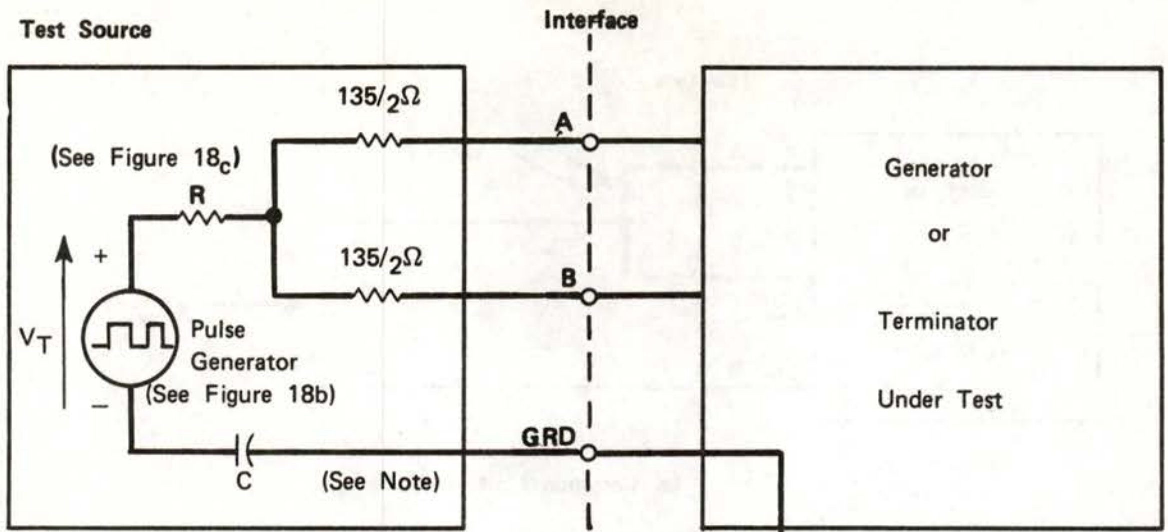


(b) Common Mode Voltage



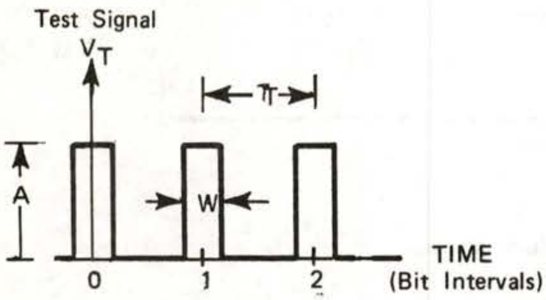
(c) Peak V_{CM} (ac) as a Function of Z_{CM} (output from generator or terminator)

COMMON MODE IMPEDANCE AND VOLTAGE
FIGURE 17



Note: The capacitor C allows tests on equipment having a dc common mode voltage present. The value of C is chosen so its impedance will be negligible at all significant frequencies.

(a) Test Arrangement

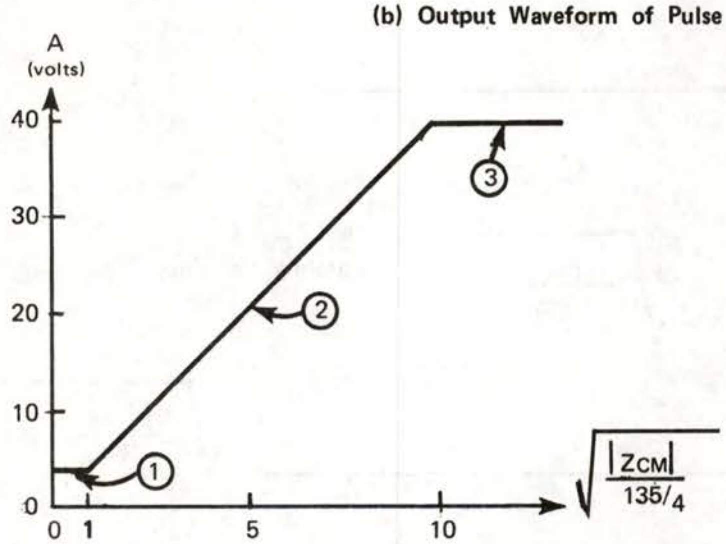


A = Pulse Amplitude (determined from Figure 18c)

$$T = \text{Bit Interval} = \frac{1}{\text{Bit Rate}}$$

W = Pulse Width
$0.1T \leqslant W \leqslant 0.9T$
Rise and fall times $\leqslant 0.01T$

(b) Output Waveform of Pulse Generator

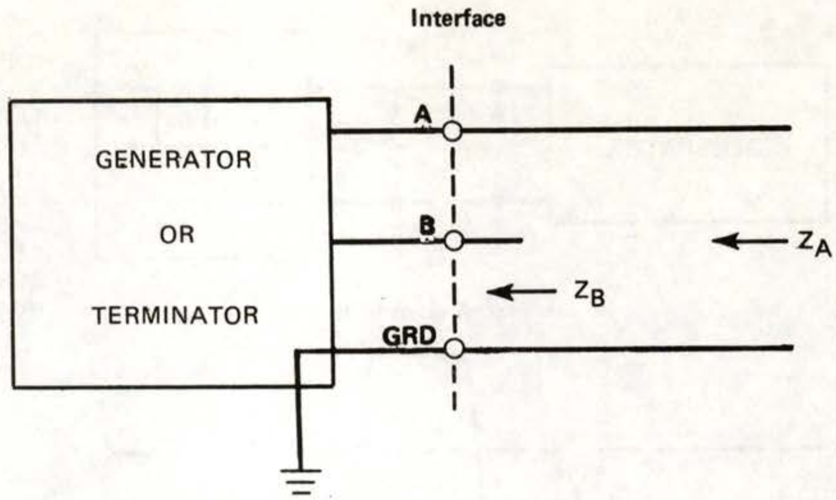


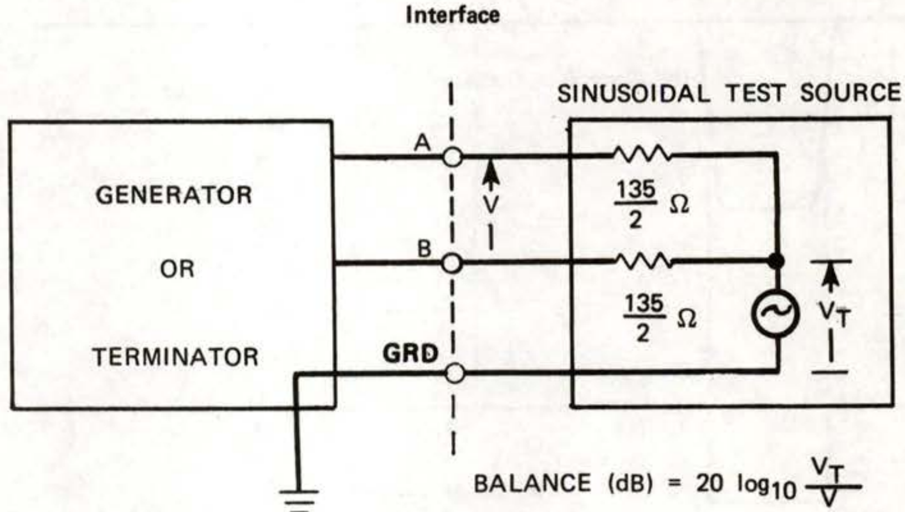
Region	R_T (ohms)
1	0
2	$\left\lvert Z_{CM} - \frac{135}{4} \right\rvert$
3	$10\left(\frac{135}{4}\right)^2$ or 11400

Note: Use Z_{CM} at signaling frequency (bit rate)

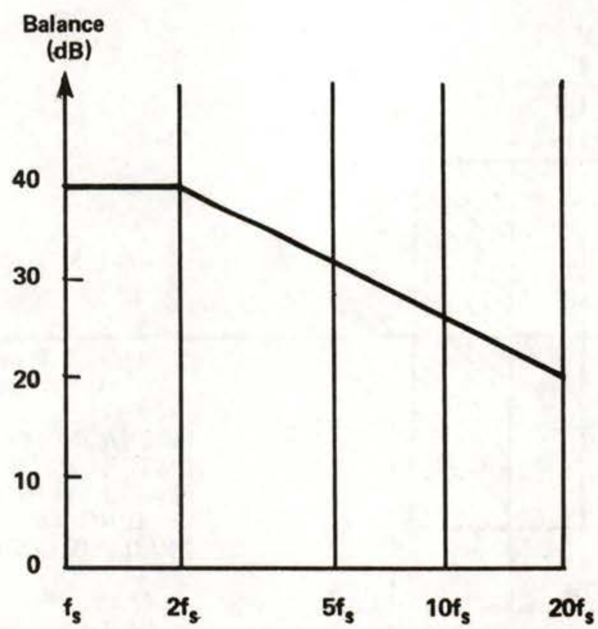
(c) Pulse Amplitude as a Function of Z_{CM}

COMMON MODE INPUT VOLTAGE RANGE
FIGURE 18

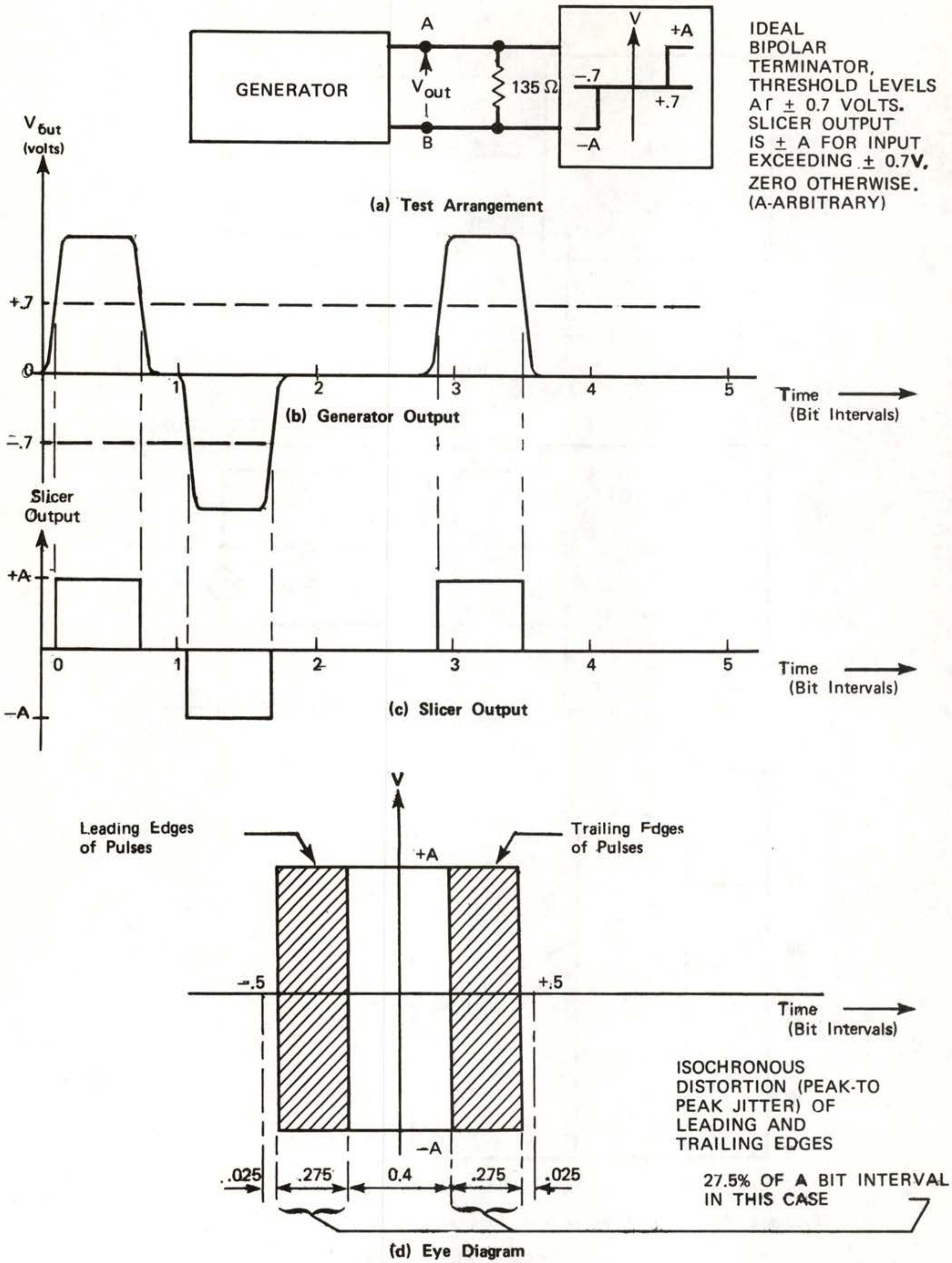




$$\text{BALANCE (dB)} = 20 \log_{10} \frac{V_T}{V}$$



IMPEDANCE BALANCE
FIGURE 19



ISOCHRONOUS DISTORTION
FIGURE 20

APPENDIX

Timing Recovery Definitions

This appendix is included to provide a convenient reference for the definition of isochronous and peak individual distortion of data signal transitions. These terms are also used and discussed in two publications:

EIA Standard RS-334, "Signal Quality at Interface Between Data Processing Terminal Equipment and Synchronous Data Communication Equipment for Serial Data Transmission."

EIA Industrial Electronics Bulletin No. 5, March, 1956, "Tutorial Paper on Signal Quality at a Digital Interface."

Definitions

In the following discussion, the term "unit interval" means the reciprocal of the data rate. The term "significant instant of modulation" with reference to a bipolar data signal, means the instant the signal crosses a preset threshold level. In the case of the CSU interface, the levels are ±0.7 volts, measured across a 135-ohm resistance at the generator terminals.

Degree of Individual Distortion of a Particular Significant Instant (from Bulletin No. 5):

"The ratio to the unit interval of the displacement, expressed algebraically, of this significant instant from an ideal instant. This displacement is considered positive when the significant instant occurs after the ideal instant. The degree of individual distortion is usually expressed as a percentage."

Degree of Peak Individual Distortion (from RS-334):

"The maximum individual distortion, irrespective of sign, of all significant instants occurring during a particular measuring period."

Degree of Isochronous Distortion (from RS-334):

1. "Ratio to the unit interval of the maximum measured difference, irrespective of sign, between the actual and the theoretical intervals separating any two significant instants . . . , these instants being not necessarily consecutive."

2. "Algebraical difference between the highest and lowest value of individual distortion affecting the significant instants of an isochronous modulation. (This difference is independent of the choice of the reference ideal instant.)"

In the case of both isochronous and peak individual distortion, the length of observation is also important. In the case of a prolonged observation, it is appropriate to consider the probability that a given degree of distortion will be exceeded.

Applications

To apply these definitions to the CSU interface, the expected nature of the data signals must be considered. The Transmitted Data (DT, DR) from the customer data terminal to the CSU is expected to be synchronous with the DDS, relatively noise-free, and well-controlled in width (nominal 50% duty-cycle.)

The requirement of synchronism implies that the theoretical instants of transition are related to the average of the transitions of the received data. For example, a clock would have its negative-going transitions occurring midway between the average of the positive and negative-going transitions of the received data.

The measurement of peak individual distortion then proceeds as illustrated in Figure A. Since the signals on DT and DR are relatively noise-free, fairly large measuring intervals may be used.

The distortion of signals transmitted from the CSU to the customer is largely determined by the characteristics of the cable pair from the Telephone Company office to the customer location. The duty-cycle is not controlled here. Noise bursts may cause data transitions to occur anywhere within the unit interval. In the theoretical noise-free case, the dispersion of the transitions from an ideal instant will be due to intersymbol interference and data pattern variations.

Timing Recovery

Timing recovery in data transmission commonly involves applying the received signal, or a processed version thereof, to a high-selectivity circuit, such as an LC tank or a phase-locked loop, to extract the fundamental bit frequency. The equivalent circuit for these schemes usually reduces to a low-pass filter acting on the input jitter of the received data transitions.

The data signal is then sampled at clock transitions in phase with the nominal center of the received pulses.

Since the low-pass character of the timing circuit attenuates high-frequency jitter, attention is focussed on the low-frequency input and output jitter. An empirically verified theory, discussed below, leads to a useful figure of merit for the quality of the received signal transitions and establishes performance limits for the synchronous sampling circuits described above.*

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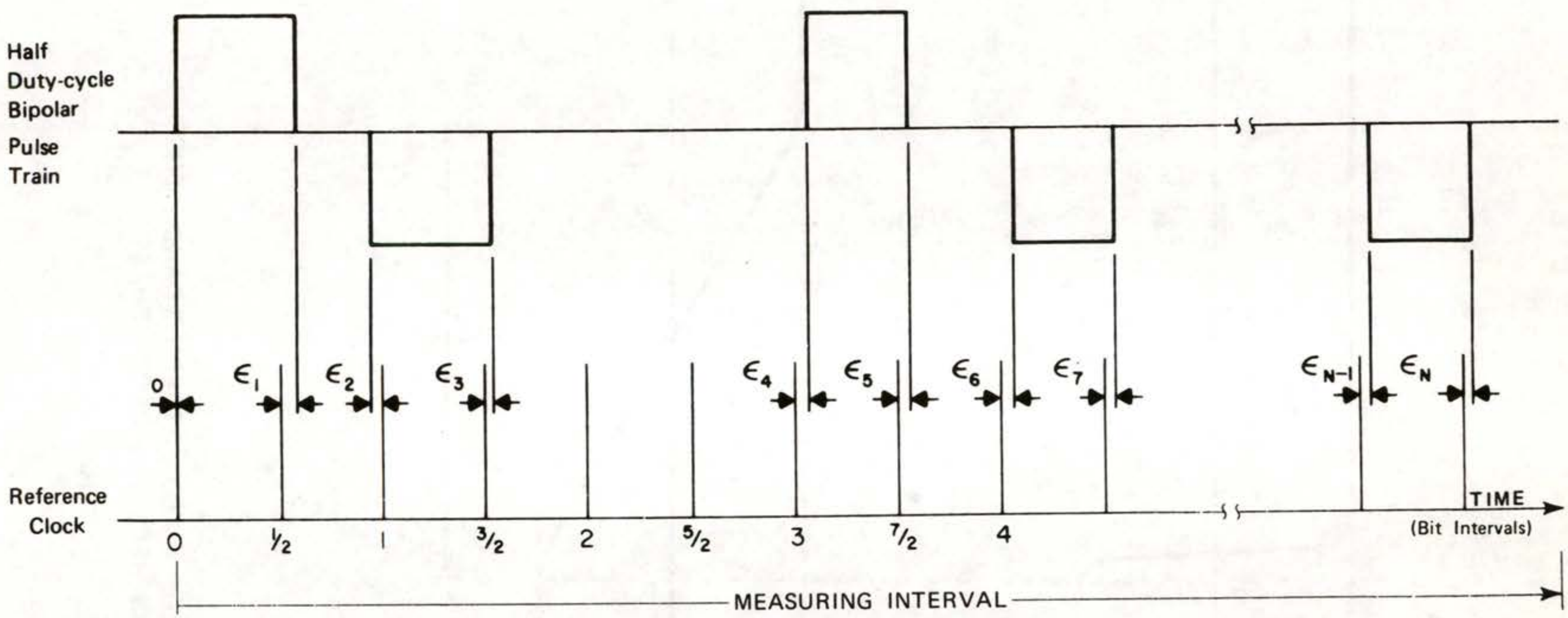
* Byrne, C.J., Karafin, B. J., and Robinson, D. B., Jr., "Systematic Jitter in a Chain of Digital Regenerators, "Bell System Technical Journal, November, 1963, pp. 2679-2714.

We suppose that the input jitter depends only on the last few bits transmitted, and consider a repetitive pattern with period much less than the reciprocal of the bandwidth, B. Associated with this periodic pattern is an average or dc phase shift, θ_1, corresponding to the location of the average of the pulse centers; the phase is measured with respect to the transitions of an appropriate ideal clock signal. Now suppose the pattern is suddenly switched to one with average phase, θ_2. The data transitions adjust their phase to θ_2 in a few bit's time, the assumed memory span of the jitter mechanism. The recovered clock phase, however, changes at a rate $B(\theta_2-\theta_1)$, and thus requires a time 1/B to adjust to the new phase (See Figure B.)

Evidently, the recovered timing signal has an irreducible phase jitter of $\theta_1-\theta_2$; moreover, the data sampling instant is offset from the nominal pulse center by $\theta_2-\theta_1$ immediately following the change in pattern.

Thus, the worst-case peak-to-peak dc phase shift between any two repetitive patterns represents a figure of merit for the quality of the received data transitions.

It is independent of the particular realization in this class of timing and sampling circuits.



LEGEND:

$100.0 \times \epsilon_i$ = Individual Distortion of i^{th} significant instant (%) (i = 1, 2, . . . N)

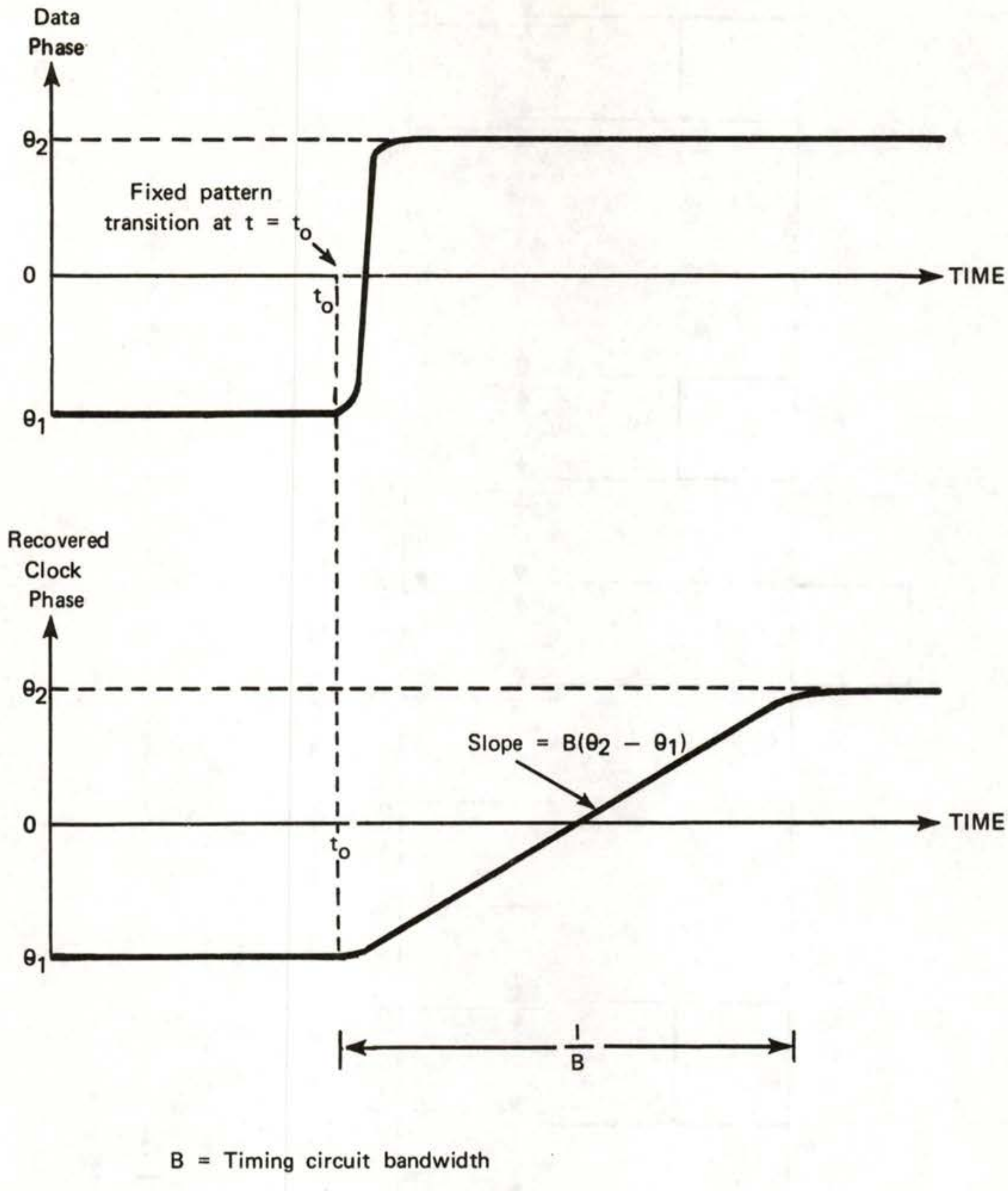
ϵ_{max} = Maximum $|\epsilon_i|$ observed in measuring interval (i = 1, 2, . . . N)

$100.0 \times \epsilon_{max}$ = Peak Individual Distortion

δ_{max} = Maximum $|\epsilon_i - \epsilon_j|$ between any two Individual Distortions observed in measuring interval. (i,j = 1, 2, . . . N) not necessarily consecutive pulses.

$100.0 \times \delta_{max}$ = Isochronous Distortion (%)

TIMING DISTORTION
FIGURE A



EFFECT OF FIXED PATTERN TRANSITIONS
ON RECEIVED CLOCK PHASE

FIGURE B

INDEX

PUB 41022

PRELIMINARY

Bell System Data Communications
TECHNICAL REFERENCE

MULTISTATION DATAPHONE® DIGITAL SERVICE (USOC DDZ)

SEPTEMBER 1974

ENGINEERING MANAGER - DATA NETWORK SERVICES

326-306

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Engineering Manager - Data Network Services
American Telephone and Telegraph Company
195 Broadway
New York, New York 10007

TABLE OF CONTENTS

LIST OF FIGURES

1. INTRODUCTION

This Technical Reference describes multistation DATAPHONE® Digital Service, which utilizes the Digital Data System (DDS). The DDS provides a private line, duplex[1] transmission capability at synchronous data rates of 2.4, 4.8, 9.6 and 56 kilobits per second (kb/s) with no alternate voice or voice coordination provisions. Two different service units are available for use at a customer's premises, the Data Service Unit (DSU) and the Channel Service Unit (CSU). The DSU is used when a standard EIA or CCITT interface is desired. It provides equalization, remote and local testing capabilities and the logic and timing recovery necessary to provide a standard interface. If timing recovery, encoding and decoding of signals and the standard interface circuitry are not desired, the digital access line can be terminated on the customer's premises by a CSU, which provides only the minimum elements of plant required to produce a properly balanced and equalized loop termination and to permit rapid remote testing of the channel. Additional information on the DSU and CSU interfaces may be found in the Technical References titled - "Digital Data System, Data Service Unit Interface Specifications" (PUB 41450) and "Digital Data System, Channel Interface Specifications" (PUB 41021).

Multistation DATAPHONE Digital Service provides duplex communication between a control station[2] and two or more remote[3] stations. Throughout this Technical Reference the terms multistation and multipoint are used interchangeably to describe a configuration using duplex Multipoint Junction Units (MJUs) located at Telephone Company offices. As shown in Figure 1, all data transmitted by the control station is delivered to each of the remote stations. In the reverse direction, the MJUs combine bit streams transmitted by the remote stations into a single serial bit stream for delivery to the control station. Thus, to prevent errors in data transmitted toward the control station, only one remote station should transmit data at any given time. Direct data transmission between remote stations is not provided. Each control or remote station may have either a DSU or a CSU, but all stations on the same multipoint circuit[4] must operate at the same bit rate, which may be any one of the DDS customer service

---

[1] Duplex operation, also called full-duplex operation, is the capability for transmission of signals in both directions simultaneously.

[2] The terms control station and master station are synonymous.

[3] The terms remote station and outlying station are synonymous.

[4] A multipoint circuit comprises one control station, all of its remote stations, and all of the channels, MJUs and digital access lines used to interconnect the stations.

rates. A typical configuration for multistation service is illustrated in Figure 2. Note that stations may be located in several different cities.

It is expected that many customers having multistation service will utilize polling techniques to maintain network discipline. Use of appropriate polling procedures assures that no more than one remote station transmits data at one time. These polling procedures can also be used to identify the remote stations to which each transmission from the control station is directed. When polling is used, polling messages transmitted from the control station direct individual remote stations to respond (one at a time), and to indicate whether they have data to transmit to the control station. Further information on polling and polling response delays is provided in Section 3. This information should be helpful in estimating the efficiency of various polling procedures and in determining appropriate timeout values to use when polling.

In addition to the polling information provided in Section 3, other sections discuss the station arrangements for multistation service, system operation, performance objectives and special features provided for testing and maintenance.

2. STATION ARRANGEMENTS

A user's interface with multistation service is the same as that for two station service. Ths DSU interface is described in PUB 41450, "Digital Data System, Data Service Unit Interface Specifications." The CSU interface is described in PUB 41021, "Digital Data System, Channel Interface Specifications." No other station equipment is necessary for multistation service.

3. SYSTEM DESCRIPTION

3.1 MJU Operation

Stations on a multipoint circuit are interconnected by means of duplex Multipoint Junction Units (MJUs) located at Telephone Company offices. Each MJU has one port for duplex data transmission with the control station and a number of ports for duplex transmission with the remote stations. The duplex data paths from an MJU toward remote stations are called branches. All data received at an MJU from the control station is delivered to all branches connected to the MJU. All data received at an MJU from its branches is combined in the MJU, and the resulting data is transmitted toward the control station. Hence, the functional operation of multipoint circuits in the DDS is like that of broadcast polling multipoint channels or "split bridge" operation used in analog data transmission systems.

As shown in Figure 2, MJUs may be cascaded to permit stations located in several different cities to be joined together in a multipoint circuit. MJUs may also be arranged to serve a number of stations within the same city. The MJU locations and configuration for each multipoint circuit will be assigned by the Telephone Company.

Logic in the MJUs allows two different polling disciplines. Properly utilized, an MJU can block many of the bit errors received from branches that are not in use, so that the performance quality for data transmitted from each remote station to the control station can be about as high as that for two station service. For this reason, the customer should take into account the manner in which an MJU combines data from its branches into a single data stream for transmission to the control station. When all stations have permanent Request to Send with idle stations in a mark-hold condition, performance is described in the following paragraph (a). When idle stations turn OFF their Request to Send (CA) interface circuit, performance is described in paragraph (b).

(a) Data bits received by an MJU from its branches are combined, such that a SPACE (0) bit is transmitted toward the control station whenever a SPACE (0) bit is received by the MJU from any one or more of its branches. If all branches transmit MARK (1) bits to the MJU, then the MJU transmits MARK (1) bits toward the control station. Thus, if one remote station transmits data (0 and 1 bits), and all of the other remote stations transmit only MARK (1) bits, only the data from the one active remote station is transmitted to the control station. With this arrangement, however, all bit errors received by an MJU from branches not carrying the data would be combined with the data, thus degrading the performance quality for all data received at the control station.

(b) Many errors of the type described above will be blocked by protective circuits in the MJUs if each remote station not transmitting data to the control station is held in the idle mode. For a CSU, this is accomplished by transmitting the idle sequence from the station having the CSU. The idle sequence is described in PUB 41021. For a DSU, the idle mode is maintained at the station having the DSU by holding the Request to Send (CA) interface circuit in the OFF state as described in PUB 41450. If one remote station transmits data, and all other remote stations remain in the idle mode, the data will be transmitted through the MJUs to the control station. Thus, to minimize the number of errors in the data received at the control station, it is recommended that each remote station be held in the idle mode, except while it is transmitting data to the control station.

When all of the remote stations on a multipoint circuit are in the idle mode, the idle sequence is transmitted to the control station. If the control station has a DSU, receipt of the idle sequence causes the Received Line Signal Detector (CF) interface circuit from the DSU to be placed in the OFF condition, following a turn-off delay. The turn-off delay for 2.4, 4.8, or 9.6 kb/s service is 18 bits, and for 56 kb/s service the turn-off delay is 21 bits. Delays such as this have been included in the DSU logic circuitry to reduce the effect of short error bursts, which can simulate control code sequences.

3.2 Polling

In many multipoint circuits, it is expected that the control station will poll each remote station to determine if it has traffic to send. The time required to poll each remote station influences the efficiency of the data communications system. The steps in polling a remote station are illustrated in Figure 3 and may include the following:

1. A polling message is initiated at the control station.

2. The polling message is transmitted to the remote station.

3. A response message is initiated at the remote station.

4. The response message is transmitted to the control station.

Generally, some delay is associated with each of these steps due to such things as processing time, propagation delays, Request to Send - Clear to Send delays, etc. These delays limit the number of polling cycles that can be accomplished per unit time. The following discussion describes the amount of delay that may be expected from the DDS.

No delay (Request to Send - Clear to Send timing interval) need be encountered at the control station in Step 1. This is because the control station may remain on-line continuously (Request to Send ON) during all normal operations. Step 2 includes a one-way transmission delay between the control station and the remote station being polled. This delay consists of the propagation time through the various DDS equipment and facilities encountered in transmission from the control station to the remote station. Step 3 includes one turn-on period (Request to Send - Clear to Send timing interval) for equipment at the remote station. For the DSU, this timing delay is given below for each of the customer service rates.

Customer Service Rate	Request to Send - Clear to Send Timing Delay
2.4 kb/s	8 $\pm$ 0.4 ms
4.8 kb/s	4 $\pm$ 0.2 ms
9.6 kb/s	2 $\pm$ 0.1 ms
56 kb/s	0.4 $\pm$ 0.02 ms

Step 4 includes a one-way transmission delay for the response message from the remote station to the control station. All other delays (due to message lengths, processing times, etc.) depend upon the customer's procedures, and are not included in the polling response delay information provided herein; only the round trip transmission delay and one DSU turn-on delay are included.

It should be noted that the polling sequence for the next remote station to be polled may begin as soon as the last data bit from the previously polled remote station is recognized by the customer at the control location, providing that each remote station turns OFF its Request to Send interface signal immediately after transmitting the last data bit of each transmission. When this type of operation is used to minimize polling delays, it is possible that some remote stations located near the control station may respond to their polling messages so quickly that the Received Line Signal Detector interface signal at the control station may not go OFF between polling sequences. An alternative operating procedure would be to begin each polling sequence at the control station only if the Received Line Signal Detector interface signal is OFF, but the total time required to poll each remote station would then be increased by the turn-off delay of the Received Line Signal Detector interface signal.

Figure 4 provides information on estimated polling response delays for DDS multipoint circuits as a function of the total distance in airline miles from the control station to the remote station being polled. These curves result from a computer simulation of multipoint circuits. The individual polling response delays for any particular multipoint circuit may be larger or smaller than the values shown.

Maximum polling response delays cannot be specified, because circuit rearrangements and emergency measures to restore service if failures occur make such a specification impractical. However, polling response delays greater than 150 ms should seldom be experienced, even on the longest connections.

3.3 CSU/DSU Operation

The information in Figure 4 is based on use of DSUs at the remote stations being polled. If a remote station has a CSU, the time required to respond to a polling message depends to some extent upon the customer's procedures, because there is no Request to Send - Clear to Send delay in a CSU. However, at any station having a CSU, a minimum delay interval (five bits for 2.4, 4.8, and 9.6 kb/s service and six bits for 56 kb/s service) must be inserted by the customer immediately following transmission of the last bit of idle sequence, before transmitting data. This allows time for completion of the idle sequence transmission in progress to the other station(s) and assures that all data bits will be delivered to the other station(s). An additional delay (twelve bits for 2.4, 4.8, and 9.6 kb/s service and fourteen bits for 56 kb/s service) must be inserted if the CSU is transmitting to a DSU at the control station. This delay allows for the turn-on interval for the Received Line Signal Detector interface circuit at the DSU.

3.4 Example

To illustrate use of the polling response delay information provided in Figure 4, refer to Figure 2, and assume that the distance between City "A" and City "B" is 500 airline miles, and that the distance between City "A" and City "C" is 1,000 airline miles. Also assume that the stations operate at 4.8 kb/s and have DSUs. A reasonable estimate for the polling response delay for each station, based on the information in Figure 4, is shown below.

Remote Station	Airline Miles	Polling Response Delay at 4.8 kb/s*
1	0	18 ms
2	500	37 ms
3	1000	53 ms
4	1000	53 ms

*A polling response delay comprises one round trip transmission delay plus one DSU turn-on delay at the remote station.

4. PERFORMANCE OBJECTIVES

DDS performance objectives are stated below in terms of the goals that were established during the system design. These goals are not to be construed as minimum performance guarantees.

Quality - To average at least 99.5 percent error-free seconds at 56 kb/s and better performance at the lower rates of 9.6, 4.8, and 2.4 kb/s.

Availability - To average at least 99.96 percent channel availability, i.e., annual downtime less than 0.04 percent. It should be noted that this average is that value which would be observed over a period of several years. Some of the causes of downtime are failures which occur infrequently but which may have long outages associated with them when they do occur. While these infrequent long outages represent small contributions to the long-term average, they may significantly affect the downtime seen in a shorter period of time (even as long as a year).

For multistation service, these goals apply for communication between the control station and each remote station, while all inactive remote stations are maintained in the idle mode, as described in Section 3.

5. TESTING AND MAINTENANCE

5.1 Trouble Reporting

Most equipment malfunctions that can degrade the performance of multistation service will be detected automatically, and standby equipment will be placed in service automatically. Consequently neither routine maintenance nor routine testing periods are required to keep multistation service operating properly. In the event of trouble, the Telephone Company will test the service. Of course, the Telephone Company will not intentionally disturb the service without first receiving permission to test from the user.

It is expected that the customer will check his terminal equipment for proper operation prior to reporting trouble to the Telephone Company. When the customer suspects a trouble condition in his service, he should call the number for trouble reporting that is furnished when the service is installed. Testing and repair can be accomplished most efficiently if a complete and accurate description of the difficulty is provided by the customer. In the case of multistation service, the most important information required is the location of the stations that are experiencing problems. Different maintenance procedures are followed depending on whether these station locations are identified when a user reports trouble.

1. If the locations are reported by the customer, it will usually by possible to isolate those stations, then diagnose and repair the fault without disrupting service for the unaffected stations.

2. When the identity of the affected locations is not provided to our maintenance forces, one-person diagnostic procedures permit each part of an entire multipoint circuit to be tested from the Telephone Company test center associated with the control station. Such tests require the removal of customer data. It is essential to good service that the user be willing to release his channel when such testing is required. The channel, digital access line or station having a failure can be identified during these tests. Once this identification is made, it will usually be possible to restore operation to the unaffected stations while the faults are being diagnosed and repaired.

Trouble indications for multistation service are the same as those for two station service and are described in PUB 41021 and PUB 41450.

5.2 Loopback Testing

A test switch is provided on DSUs, which can be used by a customer for testing his multipoint circuit as described below. Also see Figure 5.

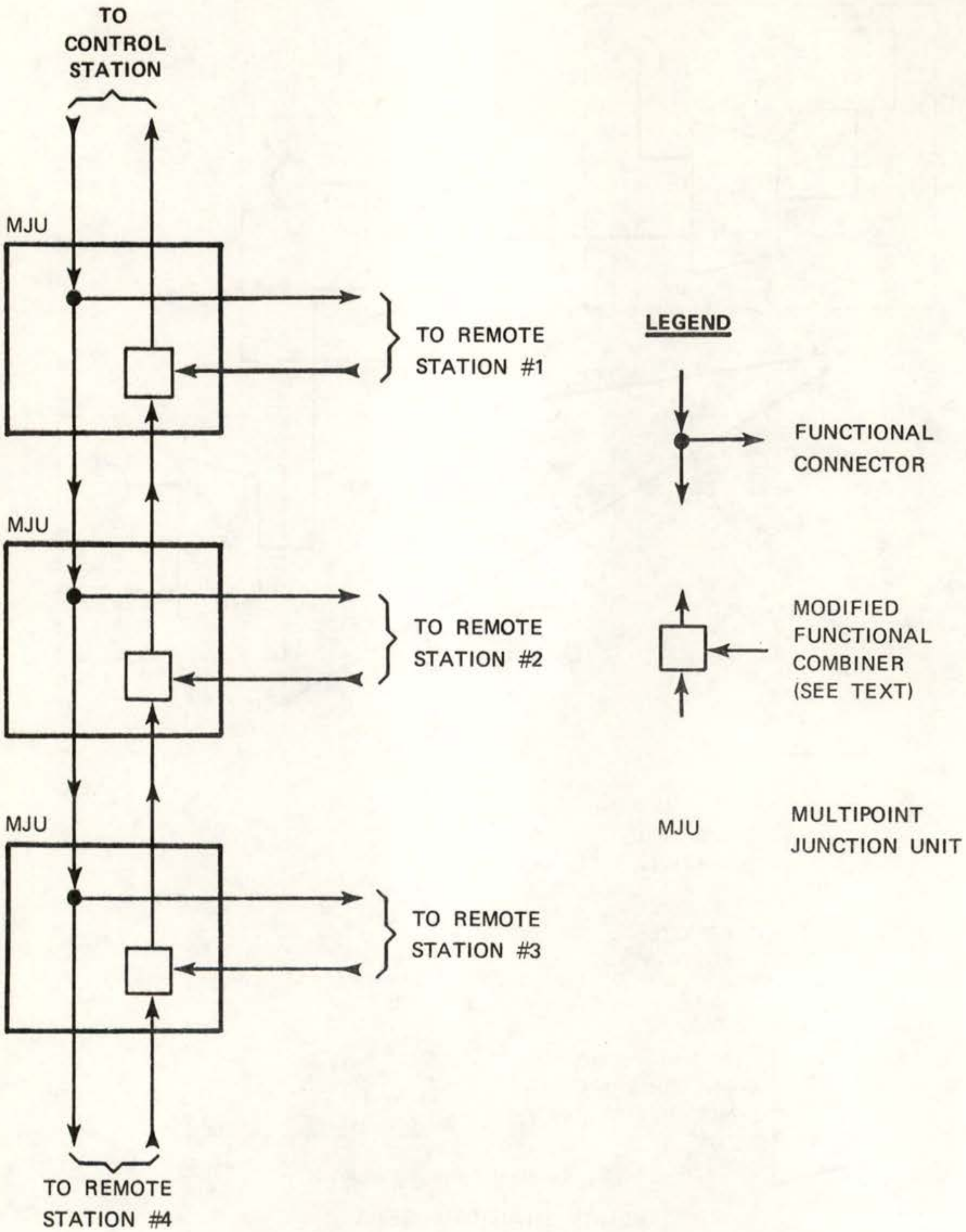
1. With the test switch in the Local Line (LL) position, the DSU is in the Local Line test mode. The LL test permits a customer with an appropriately designed duplex terminal at his control station to test the back-to-back performance of the data terminal equipment and DSU by connecting the transmitter section of the DSU to the receiver section. In addition, the receive line is connected through terminating equipment to the transmit line to allow a signal to be maintained in both directions on the loop. For this test the Data Set Ready circuit is OFF, but the other control interface circuits, Request to Send, Clear to Send and Received Line Signal Detector operate as in the control idle or data mode.

   To avoid accidental interruption of service, manual operation of the Local Line loopback is inhibited at remote stations. Its use at a remote station would loop all data signals from the control station back to the control station, and could cause garbling of data being transmitted from some other remote station to the control station. Loopback testing by customers at remote stations must be coordinated through the control station, as described in (2) below.

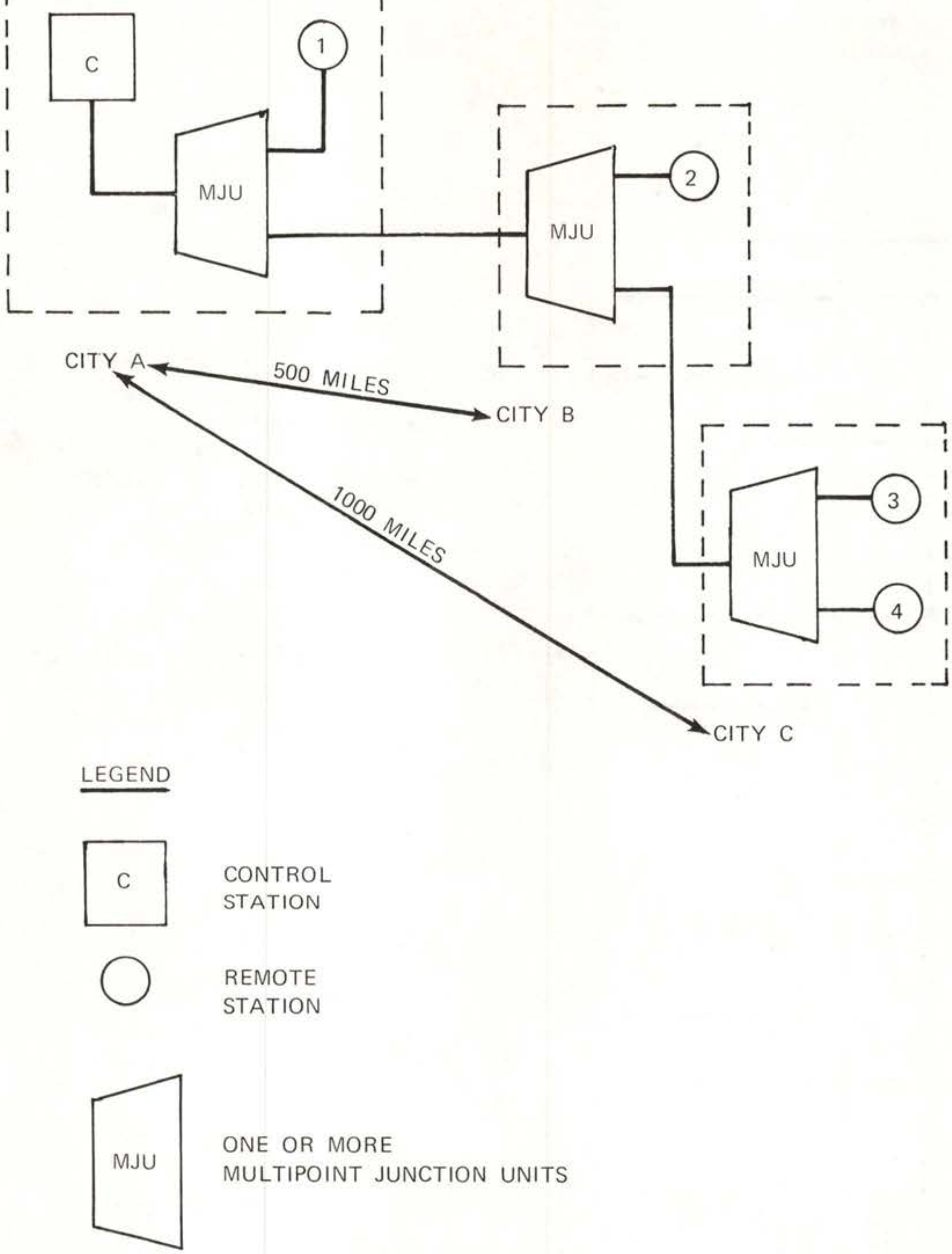
2. With the test switch in the Remote Terminal (RT) position, which is permitted at a control station or a remote station, the DSU is in the Remote Terminal test mode. In this test mode the output of the Received Data interface circuit is connected to the input of the Transmitted Data interface circuit at the data terminal interface of the DSU, causing data signals received from the line to be looped back to the line. (If the idle sequence or the out-of-service sequence is being received, a data signal of all 1's will be looped back to the line.) For this test the control interface circuit drivers to the data terminal equipment are turned OFF and the Transmitted Data and Received Data leads from and to the customer's terminal equipment are open circuited.

   With the DSU at any one remote station in the RT test mode, an appropriately designed data terminal at the control station has the capability of testing system operation with that one remote station (exclusive of the data terminal at the remote station) by transmitting test sequences to the remote station, and checking the sequences after they are received back at the control station. With the DSU at the control station in the RT test mode, an appropriately designed data terminal at any one of the remote stations has the capability of checking system operation with the control station (exclusive of the data terminal at the control station) by transmitting test sequences to the control station, and checking the sequences after they are received back at the remote station. To prevent garbling of test data, only one station should be in the RT test mode at a time, and only one station should transmit test data at a time. Remote stations not participating in a test should remain in the idle mode, and should not respond to the test sequences received from the control station. RT tests permit the customer to verify circuit operation and to deduce whether any data terminal is responsible for a system trouble condition. Caution: Operation of the test switch to the RT position could cause garbling of data being transmitted from some remote station to the control station. When a DSU is in the RT test mode, its Data Set Ready, Received Line Signal Detector and Clear to Send circuits are OFF.

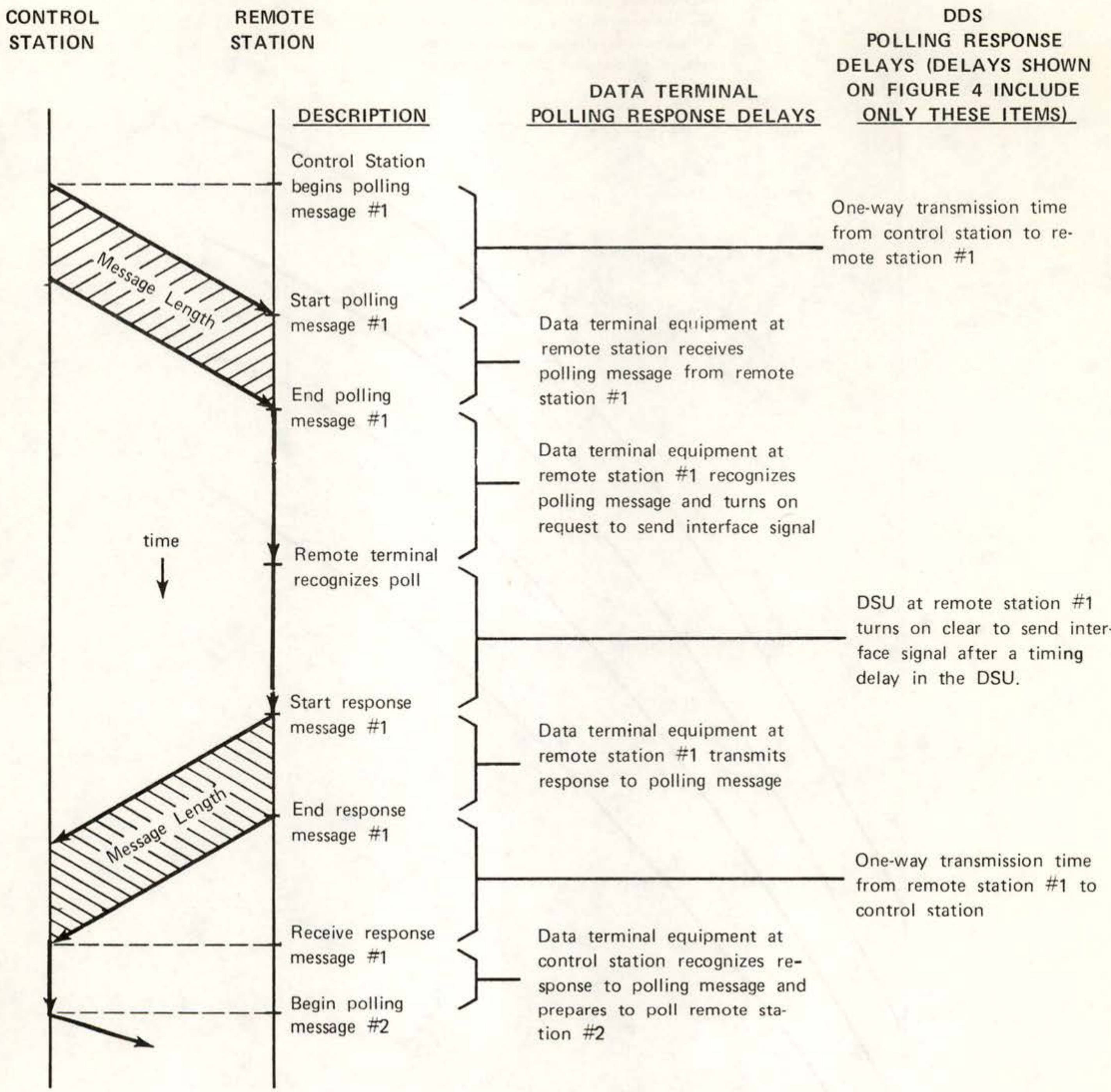
When maintenance tests are conducted from the Telephone Company's test center, the RT or LL switch function at a DSU is actuated by remote control, and the RT or LL Test lamp will turn ON. Similarly, a station having a CSU can be tested from the test center, but no test switches are provided with a CSU. When a CSU is being tested, its Status Indicator (SI) interface signal will be OFF, and its test (TST) lamp will be ON.



FUNCTIONAL REPRESENTATION OF MULTIPOINT JUNCTION UNITS (MJU s)
FIGURE 1

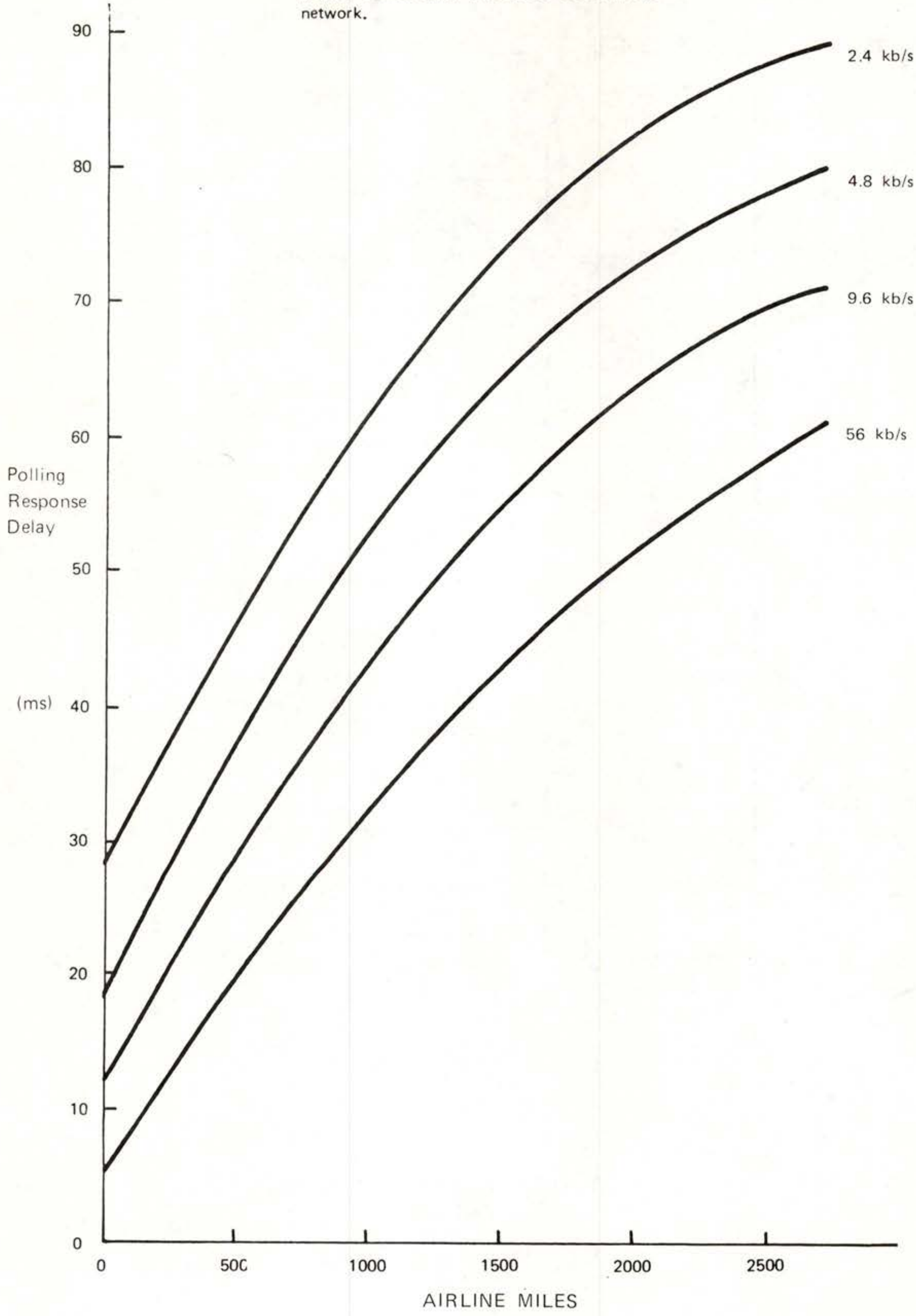


BLOCK DIAGRAM OF A
TYPICAL MULTIPOINT CIRCUIT
FIGURE 2



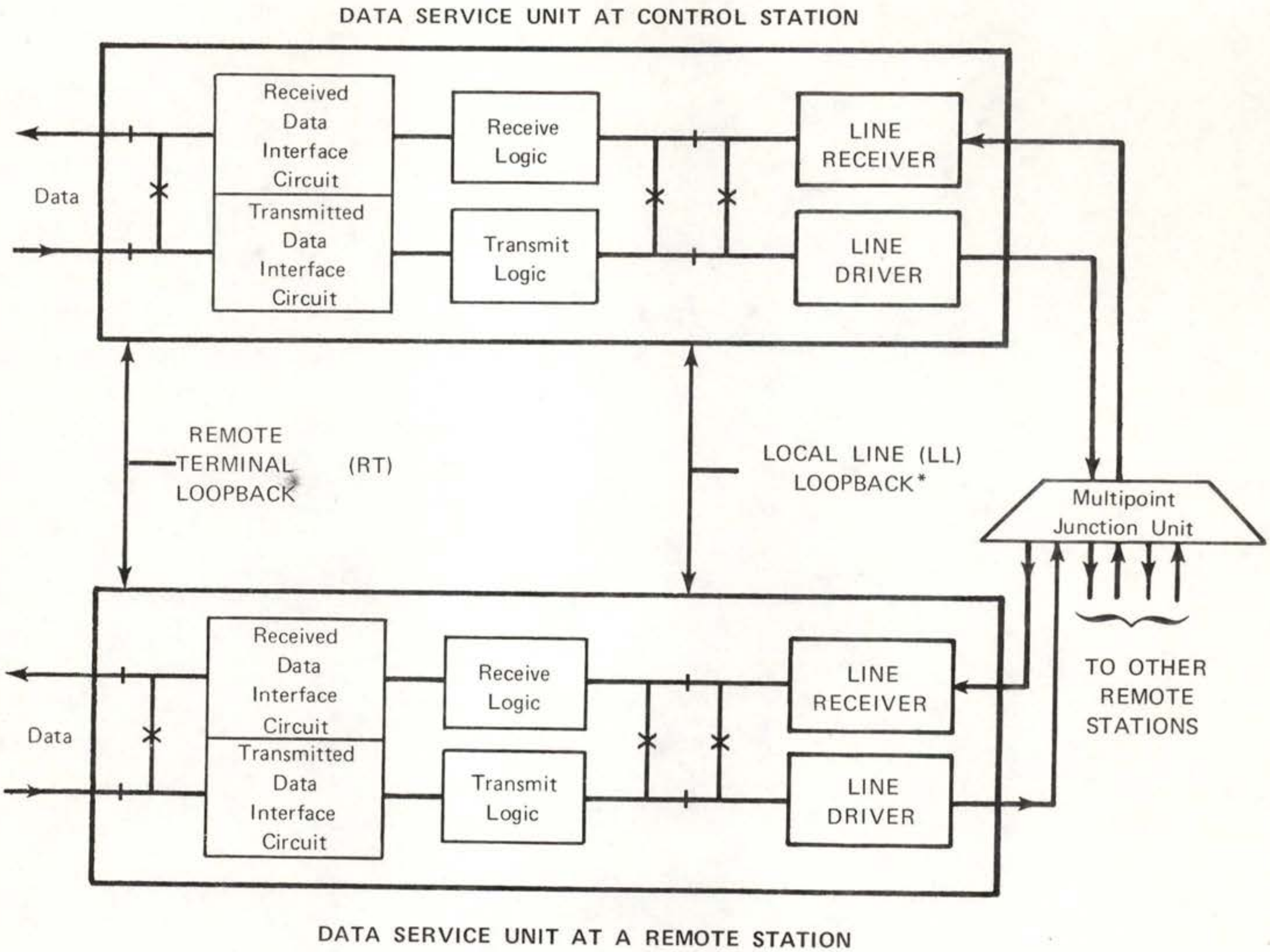
POLLING SEQUENCE DIAGRAM
FIGURE 3

NOTE: The polling response delay time between any two stations may occasionally change by a few milliseconds to a new fixed value, should a multiplexer reframe, causing a different number of customer bits to be stored in the network.



ESTIMATED POLLING RESPONSE DELAY

FIGURE 4



*Manual control of the Local Line (LL) loopback is available only at the control station. The LL switch is mechanically blocked at all remote stations.

DATA SERVICE UNIT
LOOPBACK ARRANGEMENTS
FIGURE 5

PUB 41450

PRELIMINARY

Bell System Data Communications
TECHNICAL REFERENCE

DIGITAL DATA SYSTEM
DATA SERVICE UNIT
INTERFACE SPECIFICATIONS

March 1973

ENGINEERING DIRECTOR - TRANSMISSION SERVICES

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If further information is required, please contact:

Engineering Director - Transmission Services
American Telephone and Telegraph Company
195 Broadway
New York, New York 10007

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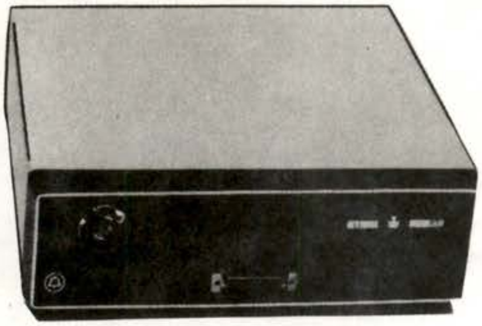


Rear View

DATA SERVICE UNIT

(Loopback switch and indicator lamps shown mounted on rear faceplate)

TECHNICAL SPECIFICATION SUMMARY

Data Rates: 2.4, 4.8, 9.6 or 56 kb/s

Operation: Synchronous with timing control from Digital Data System (clock) at specified bit rate

Multiple Arrangements: Stackable units (up to 3) Multi-Unit cabinet (up to 10)

Interface Signal Requirements: 2.4, 4.8, or 9.6 kb/s - EIA RS-232-C and RS-334
56 kb/s - EIA RS-232-C and CCITT Recommendation V.35

Principal Operating Mode: Duplex (Half-Duplex and One-Way Operation Possible)

Data Terminal Connector: 2.4, 4.8, 9.6 kb/s - 25 pin Cinch or Cannon or equivalent Type DB-19604-432 plug with DB-51226-1 hood or equivalent
56 kb/s - 34 pin Winchester MRA-34 P-JTC6-H8 or equivalent

Environmental Requirements: Ambient Temperature Range: 40° to 120°F
Relative Humidity: Less than 95%

Dimensions: Approximately 11-1/2" wide, 10-1/2" deep, 4" high

Control Functions: Request to Send - Clear to Send Delay
2.4, 4.8, 9.6 kb/s - 19 to 20 bits
56 kb/s - 22 to 23 bits

Receive Line Signal Detector
Turn ON Time (Idle to Data Mode)
2.4, 4.8, 9.6 kb/s - 12 bits
56 kb/s - 14 bits

Turn OFF Time (Data to Idle Mode)
2.4, 4.8, 9.6 kb/s - 18 bits
56 kb/s - 21 bits

Turn OFF Time (Data to Out-of-Service Mode)
Approx. 1 Sec. for local loop failure
300 ms for failure in high order digital facilities

AC Power Requirements: 105-129 V, 60 ± 3 Hz Pow source. Three-wire outlet not under the contro of switch.

Weight: Approximately 10 lbs.

1. INTRODUCTION

The purpose of this Technical Reference is to define clearly the interface specifications associated with the Data Service Unit (DSU). The DSU is used only on data services provided via the Digital Data System (DDS) and only when a standard EIA* or CCITT* interface is desired. It provides equalization, remote and local testing capabilities and the logic and timing recovery necessary to provide a standard interface. If timing recovery, data encoding and decoding and the standard interface circuitry are not desired, a basic DDS channel can be requested. A basic DDS channel is terminated on the customer's premises by a Channel Service Unit (CSU) which provides only the minimum elements of plant required to produce a properly balanced and equalized loop termination and to permit rapid remote testing of the channel. Additional information on the CSU interface may be found in the Technical Reference titled -"Digital Data System Channel Interface Specifications" (PUB 41021).

The following section will briefly describe the Digital Data System and the type of service it offers. The remaining sections will concentrate on a description of the Data Service Unit and its interface characteristics.

2. OVERVIEW OF THE DIGITAL DATA SYSTEM

This section briefly discusses how the Data Service Unit fits into the overall Digital Data System. The overview is divided into two parts: The Service Capability and the System Description.

2.1 Service Capability

The Digital Data System (DDS) will provide a private line, two-point or multipoint** full duplex transmission capability at

* An EIA RS-232-C interface is available at the subrate speeds of 2.4, 4.8, and 9.6 kb/s. At 56 kb/s the interface conforms to CCITT recommendation V.35. For ordering information on EIA and CCITT Standards, see Page 28.

**The multipoint capability will not be available initially but will be added during the first year of service.

synchronous data rates of 2400, 4800, 9600 and 56,000 bits per second with no alternate voice or voice coordination provisions. The customer data is synchronized to a network clocking system. The channel imposes no restrictions on the format of the data to be transmitted.

Shortly after the above service capabilities are introduced, arrangements will be made available for interconnecting with off-net customers served via analog facilities in non-DDS locations.

A smooth conversion from present day analog channels and modems to the DDS is made possible by the new Data Service Unit (DSU) which was designed to provide plug-for-plug interchangeability with existing EIA type D or E interfaces at the subrate speeds of 2400, 4800 and 9600 bits per second. At 56,000 bits per second the DSU provides the standard CCITT balanced dc interface.

2.2 System Description

The Digital Data System (DDS), illustrated in Figure 1, is functionally discrete but physically integrated into the existing Bell System Network. It takes advantage of the existing and planned digital hierarchy, consisting of T1, T2, radio and coaxial transmission systems. At the T1 level and below, new arrangements are installed to provide service. These include data multiplexers to derive the 2.4, 4.8, 9.6 and 56 kb/s synchronous data channels from a T1 line. Transmission from the serving office to the customer's premises is accomplished using baseband transmission over 4-wire loops. Located on the customer's premises, the Data Service Unit (DSU) interfaces directly with the customer's data terminal equipment. Timing information required at the station is derived from the network through the DSU.

The DDS synchronous timing network is based on the use of one master clock with several subordinate clocks located at cities throughout the country. These clocks are configured such that all elements of the DDS including the DSU are maintained at the same time base.

On rare occasions, disruptions in the timing distribution system may isolate certain geographical segments. During these rare occasions the resulting subnetworks will run independently. This may result in the deletion or repetition of customer bits (a "slip") without any indication to the DSU. (In a multiple DSU installation, this effect may occur simultaneously to all DSUs). However, the accuracy and configuration of the clocks is such that the time between the occurrence of a disruption and the first "slip" between the subnetworks is on the order of several days.

3. GENERAL - DATA SERVICE UNIT

The Data Service Unit (DSU) consists of two basic sections, a channel terminator and an encoder-decoder. The function of the channel terminator is to provide basic loop equalization, network protection and a maintenance loopback. The encoder-decoder contains the transmitter, the receiver, the clock recovery circuitry, the interface loopback and the necessary EIA and CCITT drivers and terminators required to interface with the customer's data terminal equipment. The basic function of this unit is the conversion of EIA RS-232-C or CCITT V.35 interface signals to baseband bipolar line signals and vice versa.

3.1 Data Terminal Physical Interface

The Data Service Unit uses one of two interface connectors, depending on the service offering. A 25 pin connector is used for subrate (2.4 kb/s, 4.8 kb/s and 9.6 kb/s) services and a 34 pin connector is used for the 56 kb/s service.

3.2 Compatibility

The subrate Data Service Unit has an interface that conforms with the EIA Standard RS-232-C, interface type D or E. These units should, therefore, be directly compatible with any business machine which also conforms to this standard. The 56 kb/s Data Service Unit interface differs from the subrate in that the clock and data signals are balanced, dc coupled as described in CCITT Recommendation V.35, Appendix 4. See Section 4.4 for a more detailed discussion of the electrical characteristics.

3.3 Physical Description

The DSU housing shown in Figure 2A measures approximately 11-1/2 inches wide, 4 inches high and 10-1/2 inches deep.

The DSU will operate over a temperature range of +40°F to +120°F and with a relative humidity less than 95 percent. The DSU weighs approximately 10 pounds. Mounting arrangements provide for stacking up to three of these units and a multiunit cabinet is available for housing up to 10 DSUs. (See Figures 2B and 2C.)

3.4 Manual Loopback Controls and Lamp Indications

3.4.1 Loopback Switch

A three position switch provides the capability of performing local or remote transmission tests. With the switch in the Local Line (LL) position, a two way loopback is provided. (See Figure 3.) The transmitter section of the DSU is connected to the receiver section and the receive line is connected to the transmit line through the loop terminating circuitry. With the switch in the Remote Terminal (RT) position, the output of the Received Data (BB) circuit is connected to the input of the Transmitted Data (BA) circuit at the data terminal interface. The BA and BB circuits are also disconnected from the customer terminal equipment. When the switch is in either Test position, an appropriate light indication is given. To avoid accidental interruption of service the manual operation of the Local Line loopback is inhibited in multipoint service applications. A detailed description of testing operations is given in Section 8.

3.4.2 Indicator Lamps

The following indicator lamps provide information on the status of the DSU.

a. Power On - This lamp (PWR) goes ON when AC power is supplied to the DSU.

b. Loopback Mode - Two loopback lamps are provided, one for the Local Line (LL) test and the other for the Remote Terminal (RT) test. The DSU can be placed in these loopback modes either locally by operating the loopback switch on the DSU (with the exception of the LL loopback in multipoint applications) or remotely by the Telephone Company from a Serving Test Center.

c. No Signal Indication - The No Signal lamp (NS) goes ON when no digital signals are received due to a failure on the receive leg of the 4-wire loop. The No Signal condition is detected approximately one second after a local loop failure.

   There may be instances when the Telephone Company is unaware of the trouble condition. Therefore, when the No Signal lamp goes ON, the customer should call the Repair Service telephone number given to him at the time the DSU is installed.

3.5 Power Requirements

Electric power is fed to the DSU from a customer-provided 105-129 volt 60 $\pm$ 3 Hz, nonswitched source. A standard ten foot 3-wire power cord equipped with a 3-prong plug is supplied with each DSU. The DSU consumes approximately 15 watts of AC power.

3.6 Grounding

Protective Ground is established for the DSU through the ground wire of the power cord. The customer's terminal equipment Protective Ground should be connected to the same ground as the ground wire of the power cord and should not rely on the Protective Ground Circuit (AA) provided in the data terminal interface. A Signal Ground circuit is provided to the customer as a common return for control and data interchange circuits. Protective Ground and Signal Ground are normally tied together by means of a strap in the DSU. The strap may be disconnected on request of the customer, subject to local noise conditions, ground potentials, and local safety regulations.

3.7 Distance Limitations

For 2.4, 4.8, or 9.6 kb/s service, in accord with recommendations of EIA RS-232-C, the DSU should be located so that the customer provided interface cord to the data terminal will not exceed 50 feet in length, while for 56 kb/s service the interface cord should not exceed 100 feet in length. (See Section 4.3 on Interface Cable Requirements for 56 kb/s Service.) In all installations care must be exercised to insure that the DSU is not subject to stray fields which may emanate from the customer data terminal. In particular the DSU must be located at least one foot away from any source of electromagnetic radiation.

4. INTERFACE SPECIFICATIONS

4.1 Functional Description of Interface Circuits

A description of signals between the DSU and the data terminal equipment follows. The EIA RS-232-C abbreviation for the circuit is also shown.

4.1.1 Protective Ground (AA)

This conductor is electrically bonded to the equipment frame of the DSU. It is further connected to external grounds through the power cord.

4.1.2 Signal Ground (AB)

This circuit establishes the common ground reference potential for all interchange circuits except protective (frame) ground. It is normally connected to the Protective Ground Circuit to minimize the introduction of longitudinal power line noise into electronic circuitry through the power transformer. Depending on local regulations and conditions, this connection may be removed by the installer if the customer requests.

4.1.3 Transmitter Signal Element Timing (DB)

Direction: FROM DSU

Signals on this circuit are used to provide the data terminal equipment with transmit signal element timing information. The DSU provides continuous timing information. Since the transmitter timing is derived from the network, and is the same as the receiver timing, the peak individual distortion of the transmit clock is identical to that found on the Receiver Signal Element Timing circuit and is less than 5 percent.

For 56 kb/s service the DSU transmits a balanced clock signal to the data terminal equipment over the DB(A) and DB(B) circuits. The symmetry of the DB signal is determined by the zero crossings of the DB(A) minus the DB(B) signal. The time between zero crossings is between 0.45 and 0.55 of a clock period.

4.1.4 Receiver Signal Element Timing (DD)

Direction: FROM DSU

Signals on this circuit are used to provide the data terminal equipment with Receiver Signal Element Timing information. The DSU provides continuous timing information. Peak individual distortion on this circuit is less than 5 percent.

For 56 kb/s service the DSU transmits a balanced clock signal to the data terminal equipment over the DD(A) and DD(B) circuits.

The symmetry of the DD signal is defined by the zero crossings of the DD(A) minus DD(B) signal. The time between the zero crossings is between 0.45 and 0.55 of a clock period.

4.1.5 Transmitted Data (BA)

Direction: TO DSU

The Transmitted Data Circuit accepts serial binary data from the data terminal for transmission to the remote data terminal equipment. The data terminal equipment should not attempt to transmit data unless an ON condition is present on the Clear to Send Circuit. The DSU transmits a control idle signal when the Request to Send Circuit is OFF and a Steady MARK during the interval between Request to Send Circuit ON and Clear to Send ON independent of customer signals on the Transmitted Data Circuit. The DSU transmits a steady MARK when either a short or open circuit condition appears on circuit BA.

The BA signal must be properly aligned with the Transmitter Signal Element Timing (DB) signal. The state of the BA signal should be changed within ± 10 percent of a clock cycle of the positive going transition of the DB signal.

For 56 kb/s service, Circuit BA is a balanced signal transmitted to the DSU over the BA(A) and BA(B) circuits, and state changes should occur within ± 10 percent of a clock cycle on the positive going transition of the DB(A) minus the DB(B) signal. The Circuit BA(A) should be negative with respect to the Circuit BA(B) for a MARK or binary ONE condition.

The BA signal is sampled by the DSU coincident with the negative going zero crossing of the DB signal, or the DB(A) minus DB(B) signal for 56 kb/s service. The transmitted data signal should be maintained on the BA circuit for the full period of each signal element duration.

4.1.6 Received Data (BB)

Direction: FROM DSU

Signals on this circuit are generated by the receiving DSU in response to the data signal received from the network. The Received Data Circuit will be held in the "MARK HOLD" condition when the Received Line Signal Detector Circuit is OFF.

For 56 kb/s service, Received Data is a balanced signal delivered serially on the BB(A) and BB(B) circuits to the data terminal equipment. During the "MARK HOLD" condition, the BB(A) Circuit is negative with respect to the BB(B) Circuit which is equivalent to receiving a binary ONE.

The data on Circuit BB is changed coincident, within 10 percent of a clock cycle, with the positive going zero crossing of the Receiver Signal Element Timing (DD) signal or the DD(A) minus the DD(B) signal for 56 kb/s service. The data terminal equipment should sample the data received on the Circuit BB coincident with the negative going zero crossing of the DD signal, or the DD(A) minus the DD(B) for 56 kb/s service.

4.1.7 Data Set Ready (CC)

Direction: FROM DSU

Signals on this circuit are used to indicate the status of the local DSU. The ON condition on this circuit indicates that the local DSU is connected to ac power and is not in a Test (local or remote) mode. It should be noted that tests of the channel other than the DSU tests will not result in an OFF condition on Circuit CC. The ON condition should not be interpreted as either an indication that a communication channel exists to a remote data station or the status of any remote station equipment.

The OFF condition is an indication that the data terminal equipment should disregard signals appearing on any other interchange circuit.

With the System Status option, the Data Set Ready Circuit is OFF when no incoming signal is received or the Out of Service Code indication is given to the DSU (see Section 5.4 for additional details).

4.1.8 Request to Send (CA)

Direction: TO DSU

Signals on this circuit are generated by the data terminal equipment to condition the local DSU to enter transmit Data mode. The ON condition must be maintained whenever the data terminal equipment has information ready for transmission.

Data terminal equipment designed for either transmit-only or duplex operation may hold Request to Send in the ON condition all the time, or use the Permanent Request to Send Option in the DSU.

When the remote data terminal uses the Circuit Assurance Option, the local terminal must keep the Request to Send Circuit ON if the remote terminal is to get a Clear to Send indication. If the Request to Send Circuit is used for "interrupt" or "start" type signaling purposes, the minimum OFF interval that can be detected by the transmitting remote DSU is equal to 25 bits for 2.4, 4.8, or 9.6 kb/s service, or 29 bits for 56 kb/s service.

4.1.9 Clear to Send (CB)

Directions: FROM DSU

Signals on this circuit are generated by the DSU to indicate whether or not the DSU is ready to transmit data. The ON condition is a response to an ON condition on interchange Circuit Request to Send delayed by a 19 to 20 bit interval for 2.4, 4.8, or 9.6 kb/s service and a 22 to 23 bit interval for 56 kb/s service. The Request to Send - Clear to Send timing delay for each of the data rates is given below.

Data Rate	Request to Send - Clear to Send Timing Delay
2.4 kb/s	8 ± 0.4 ms
4.8 kb/s	4 ± 0.2 ms
9.6 kb/s	2 ± 0.1 ms
56 kb/s	0.4 ± 0.02 ms

The OFF condition is an indication to the data terminal equipment that it should not attempt to transfer data on the Transmitted Data circuit. When Request to Send is turned OFF, Clear to Send is turned OFF within 1 bit interval. The Clear to Send Circuit must be ON before data can be transmitted (see Section 4.1.5).

With the Circuit Assurance Option, the Clear to Send indication is a result of an ON condition on both the Request to Send Circuit and the Received Line Signal Detector Circuit (CF) (see Section 5.3). With this option the Clear to Send Circuit is turned OFF if Circuit CF turns OFF in response to a system failure or if the remote data terminal turns Circuit CA OFF.

4.1.10 Received Line Signal Detector (CF)

Direction: FROM DSU

The ON condition on this circuit indicates that customer digital data signals (not the control-idle or Out-of-Service code) are being received and have been received for a 12 bit interval for 2.4, 4.8, or 9.6 kb/s service and for a 14 bit interval for 56 kb/s service due to an ON condition of the Request to Send circuit at the remote terminal.

The Received Line Signal Detector is turned OFF when:

1. An Out of Service condition exists due to a failure in the receive side of the local loop or a failure in the higher order digital facilities in the transmission path towards the local DSU.
2. The remote station's transmit pair to the DDS serving central office has failed.
3. The remote data terminal has turned its Request to Send Circuit OFF.
4. Data Set Ready Circuit is turned OFF except when the DSU is in the Local Line Test (see Section 8.1.1).
5. The DSU is in the Remote Terminal Test Mode.
6. The ac power is off.

The Received Line Signal Detector circuit turns OFF after customer data signals are no longer received. The turn OFF delay for 2.4, 4.8, or 9.6 kb/s service is 18 bits and for 56 kb/s service the turn OFF delay is 21 bits.

When this circuit is OFF, the Received Data Circuit is held in the "MARK HOLD" condition.

4.1.11 DSU Testing Circuits

Pin assignments 9 and 10 on the 25-pin connector and Pin m on the 34-pin connector are used on the DSU for test purposes by Telephone Company personnel. The data terminal equipment must not be connected to these pins.

4.2 Interface Connectors

The interface is the point of connection between the data terminal equipment and the Data Service Unit. Each DSU is equipped with one 25-pin (female) connector for 2.4, 4.8, or 9.6 kb/s service or one 34-pin (female) connector for 56 kb/s service. For the male 25-pin connector, a customer-provided plug such as the DB-19604-432 plug manufactured by Cannon or Cinch, or the AMP 205784-1 manufactured by AMP, Incorporated or equivalent is required. This type of plug provides reliable, low-resistance contacts. In addition, a DB-51226-1 hood manufactured by Cinch (or equivalent) is recommended to protect the connections, anchor the cable to the plug, provide a finger grip for easy insertion or removal, and provide a positive screw-in locking arrangement to prevent the connector from being pulled out inadvertently.

For 56 kb/s service, the male 34-pin connector required for the data terminal equipment cable should be a Winchester MRA(C)-34P-JTC6-H8 or Burndy MS34TM-124 or AMP 5-202431-2 or equivalent. The (C) is specified for the Winchester connector if insertable pins are desired. The pin assignments for the 25- and 34-pin connectors are given below.

PIN ASSIGNMENTS FOR 25-PIN CONNECTOR
2.4, 4.8, 9.6 kb/s SERVICE

Pin Number	Function	EIA RS-232-C Designation	CCITT Designation
1	Protective Ground	AA	101
2	Transmitted Data	BA	103
3	Received Data	BB	104
4	Request to Send	CA	105
5	Clear to Send	CB	106
6	Data Set Ready	CC	107
7	Signal Ground	AB	102
8	Received Line Signal Detector	CF	109
9	Reserved for DSU Testing	-	-
10	Reserved for DSU Testing	-	-
11-14	Not Used	-	-
15	Transmitter Signal Element Timing	DB	114
16	Not Used	-	-
17	Receiver Signal Element Timing	DD	115
18-25	Not Used	-	-

PIN ASSIGNMENTS FOR 34-PIN CONNECTOR
56 kb/s SERVICE

Pin	Function	EIA RS-232-C Designation	CCITT Designation
A	Protective Ground	AA	101
B	Signal Ground	AB	102
C	Request to Send	CA	105
D	Clear to Send	CB	106
E	Data Set Ready	CC	107
F	Received Line Signal Detector	CF	109
R	Received Data	BB(A)	104
T	Received Data	BB(B)	104
V	Receiver Signal Element Timing	DD(A)	115
X	Receiver Signal Element Timing	DD(B)	115
P	Transmitted Data	BA(A)	103
S	Transmitted Data	BA(B)	103
Y	Transmitter Signal Element Timing	DB(A)	114
a	Transmitter Signal Element Timing	DB(B)	114
m	Reserved for DSU Testing	-	-
H, J, K, L, M, N	Not Used	-	-
U, W, Z, b, c, d, f, g,	Not Used	-	-
h, i, j, k, n	Not Used	-	-

4.3 Interface Cable Requirements for 56 kb/s Service

The cable from the data terminal equipment to the DSU should be a 24-gauge, 25- twisted pair cable. To reduce the possibility of crosstalk between the various leads and assure proper operation, the following recommendations are made regarding the cable parameters and cable pair assignments.

The business machine cable should have the following characteristics:

Gauge	24
Characteristics Impedance of Pair	120 ohms ± 10% at 150 kHz 100 ohms ± 10% above 400 kHz
Mutual Capacitance of Pair	1600 pF/100 feet ± 20%
Capacitance of Single Lead to Ground - all other leads grounded	4000 pF/100 feet maximum
Crosstalk Loss - pair-to-pair	40 dB minimum at 150 kHz

The greatest crosstalk problems are between the control signal circuits. It is recommended that one twisted pair be used for each control signal with one lead of the pair tied to signal ground at the connector of the cable. The amount of crosstalk depends on the cable, the cable driver characteristics and the cable terminator input impedance. In order to minimize crosstalk the balanced data and clock signals should be assigned to pairs in the center of the cable. The cable pairs around the outside of the cable should be assigned to the control signals. An extra twisted pair with both leads tied to signal ground at the connector of the cable should be used between each control pair to provide isolation. This arrangement with the extra ground wires around the outside of the cable also provides some shielding from interfering signals in the outside environment. The cable drivers and cable terminators will operate satisfactorily with up to 100 feet of 24 gauge cable.

4.4 Electrical Characteristics

4.4.1 2.4, 4.8, or 9.6 kb/s Service

For 2.4, 4.8, or 9.6 kb/s service the interface signals between the data terminal equipment and the DSU conform to the electrical characteristics of EIA Standard RS-232-C. In addition, the data and clock signals conform to EIA Standard RS-334 for synchronous channels except for the degree of peak individual distortion presented on the transmit clock. Since transmitter timing is derived from the network, the distortion of the transmit clock is identical to that found on the receive clock interface circuit. Consequently, the peak distortion of the transmit clock, as well as the receive clock, meets the 5 percent requirement imposed by RS-334 for synchronous data receivers. The duty cycle for both clocks is 50 ± 10 percent.

The degree of isochronous distortion of the signals on the Received Data Circuit as defined in RS-334 does not exceed 10 percent. The interval between any transition on the Received Data Circuit and any ON to OFF transitions on the Received Signal Element Timing Circuit is not less than 25 percent of the nominal unit interval of the data signal.

4.4.2 56 kb/s Service

For 56 kb/s service, two types of interface signals are used: (1) data and clock signals, and (2) control signals. The former meet the balanced interface standard of CCITT recommendation V.35. The cable drivers produce a nominal 1.1 volt peak-to-peak direct coupled signal balanced with respect to ground into 100 ohms. Figure 4 shows a typical balanced cable driver and cable terminator. For a binary "0" line A is nominally +.55 volts with respect to line B and for a binary "1" line A is nominally -.55 volts with respect to line B. In making the transition from a "0" to a "1" line A has gone from +.55 volts to -.55 volts with respect to line B for a swing of 1.1 volts peak-to-peak.

The interface driver meets the following requirements:

1. Differential output impedance is 100 ohms ± 50 percent.
2. Output impedance to ground with output terminals shorted together is 150 ohms ± 10 percent.
3. When terminated in a 100-ohm resistive load, the driver delivers a signal level of 1.1 volts peak-to-peak, ± 20 percent, i.e., the voltage between the two output leads is 0.55 volts ± 20 percent with the polarity of the output voltage for a transmitted binary "0" being the opposite of that for a transmitted binary "1."
4. Maximum rise and fall time between the 10 percent and 90 percent levels is less than 1 percent of the nominal duration of a signal element.
5. The arithmetic mean of the voltage of each output with respect to ground (DC line offset) does not exceed 0.6 volts when the driver is terminated in 100 ohms.

The interface terminator meets the following requirements:

1. Input impedance is 100 ± 10 ohms.
2. Resistance to ground with the input terminals shorted together is 150 ± 15 ohms.

An interface driver complying with the above requirements when connected to an interface terminator complying with the above requirements will operate satisfactorily with a maximum of ± 4 volts difference in ground potential or with a maximum of ± 2 volts (peak) longitudinal noise. If margin is to be allocated to ground potential offset and longitudinal noise simultaneously, the driver-terminator should operate satisfactorily if the following is satisfied:

$$\frac{\text{Ground Potential Offset}}{2} + \text{Longitudinal Noise Voltage} \leq 2 \text{ volts}$$

Any balanced driver or terminator circuit in the interface should not be damaged by:

1. Shorting to ground.
2. Crossing with any other interchange lead.

5. CUSTOMER OPTIONS

For compatibility with existing services and customer convenience the following options are provided, and should be specified at the time an order is placed.

5.1 Request to Send

The Request to Send circuit must be specified either as Permanent On or Terminal Controlled.

Permanent On:

For customer data terminals that are not equipped to turn ON the Request to Send Circuit, an installer option is provided in the DSU to hold Request to Send ON permanently. This option is provided for all service offerings (2.4, 4.8, 9.6 or 56 kb/s) and matches the EIA Type E interface of RS-232-C for dedicated line service.

Terminal Controlled:

This conforms to customer data terminals with an EIA RS-232-C Type D interface. Note that a customer data terminal with a Type D interface should not use the above Permanent On Request to Send Option. A data terminal with a Type D interface, following the recommendations of RS-232-C, must turn OFF its Request to Send Circuit when the Clear to Send Circuit turns OFF and cannot turn its Request to Send Circuit on again until the data communications equipment turns its Clear to Send

Circuit OFF. Since an operating DSU with the Permanent Request to Send Option and without the Circuit Assurance Option (see Section 5.3) presents a permanent ON condition to the Clear to Send Circuit, a data terminal in strict compliance with a Type D interface could not turn its Request to Send Circuit on again once having turned it OFF. Thus, the terminal could not go back into the transmit mode of operation.

5.2 Signal and Frame Grounding

Signal Ground to Frame Ground:

This installer's option internally connects signal ground to frame ground.

Signal Ground Disconnected from Frame Ground:

The Signal Ground may be disconnected from Frame Ground on customer request subject to local noise conditions, grounding potentials and local safety regulations.

5.3 Circuit Assurance

Circuit Assurance Indication from the Data Service Unit:

With this option, the ON condition of the Clear to Send circuit requires that both the clear to send timing delay (see Section 4.1.9) has expired and the Received Line Signal Detector circuit is ON. During operations, an OFF condition of the Received Line Signal Detector circuit will cause the Clear to Send circuit to turn OFF, but the DSU does not transmit the control idle code until the Request to Send circuit is turned OFF. If the Permanent Request to Send option is employed in combination with the Circuit Assurance option, the Clear to Send indications follow the Received Line Signal circuit conditions. (See Sections 6 and 6.2.1).

No Circuit Assurance Indication from the Data Service Unit:

If the Circuit Assurance option is not employed the Clear to Send indication is the result of an ON condition on the Request to Send circuit.

5.4 System Status

System Status Interface Indication:

With this option, the Data Set Ready circuit is turned OFF when the DSU receives the Out of Service code or when it receives no signals from the network. Loss of signals on a station's transmitting local loop will not be detected by this option. (See Sections 6 and 6.2.2).

No System Status Interface Indication:

If the System Status option is not employed, the OFF condition on the Data Set Ready circuit occurs only when the ac power is OFF or the DSU is in one of the two loopback test modes.

5.5 Loopback Switch and Indicator Lamp Location

Front Face Plate:

Depending on customer operating convenience the loopback switch and indicator lamps may be located in the upper right-hand corner of the front plate. See Figure 2A.

Rear Face Plate:

The loopback switch and indication lamps may alternately be located in the upper right-hand corner of the rear face plate. (See Figure 2A.) This end plate also contains the interface and ac power connectors. This configuration is always used when the units are housed in the multi-unit cabinet.

6. SYSTEM OPERATION

The DDS, as mentioned earlier, provides for two-point four-wire duplex private line digital data transmission. Although four-wire duplex service will be provided on DDS, customers may also operate in one-way and half-duplex manners. In describing the various DSU operations the DSU can be thought of as comprising separate transmitter and receiver portions. There are three modes of operation which are common to both portions, they are Data, Idle and Test. A fourth mode, Out of Service, is applicable to the receiver portion. The Out-of-Service mode is the result of the DSU receiving the Out of Service control code or the loss of received line signals from the network. The transmitter of the DSU can attain the Data or Idle mode, independent of the state of the receiver. Similarly, the receiver can attain the Data, Idle, or Out-of-Service mode, independent of the state of the transmitter. The Test mode involves both the transmitter and receiver. (See Section 8.)

The transmitting Data mode is achieved by turning ON the Request to Send Circuit, after which the DSU responds by turning ON the Clear to Send Circuit. When the Request to Send Circuit is OFF, the transmitter is in the Idle mode and produces a control idle signal on the line. In the receiving Data mode, non-control data signals are being received and the Received Line Signal Detector Circuit is ON. In the receiving Idle mode, control idle signals are being received and CF is OFF. In the Out-of-Service mode, either control signals indicating a trouble condition are being received or no signals are being received; in both cases CF is OFF. (With the System Status Option, in the Out-of-Service mode the Data Set Ready circuit is OFF.) In the Remote Terminal (RT) Test mode, both CF and the Data Set Ready (CC) Circuits are OFF.

6.1 Duplex Operation

Simultaneous transmission in both directions is one of the basic premises around which the Digital Data System was designed. The DSU provides in addition to terminal control of the Request to Send circuit a Permanent ON option that holds the Request to Send circuit permanently in the ON condition. With this option the Clear to Send Circuit is always ON and the data terminal equipment should have an EIA RS-232-C Type E interface. (See Section 5.1). When the Request to Send Circuit is under the control of the data terminal equipment, the DSU has an EIA RS-232-C Type D interface.

6.2 Half-Duplex Operation

In half-duplex operation only one terminal transmits at a time. The data terminal desiring to transmit turns ON its Request to Send Circuit. After a delay, (see Section 5.4.9) the Clear to Send Circuit turns ON, indicating that the data terminal may begin transmission. The receiving data terminal has its Request to Send Circuit OFF.

Figure 5 shows the signals on the interface circuits of the local and remote DSU during a turnaround sequence when the transmitting (local) DSU(A) enters the receive Data mode, and the remote DSU enters the transmit Data mode. To change directions of transmission, the transmitting data terminal equipment should turn its Request to Send Circuit OFF. The receiving data terminal equipment turns the Request to Send Circuit ON and after a short delay receives a Clear to Send ON signal. If the Permanent Request to Send Option is used, the receiving terminal may start transmitting immediately after an end of transmission code is received. The transmission delay between terminals consists of the propagation delay of the specific circuit and a fixed delay through the Data Service Units. The transmission delay for one-way transmission will generally be less than 50 milliseconds.

For Transmit-Only service, it is advisable that the Permanent Request to Send Option be used to avoid the Clear to Send delay.

6.2.1 Half-Duplex Operation with Circuit Assurance

Half-duplex data terminals that are not capable of monitoring the Received Line Signal Detector or the Received Data interface circuit when in the transmit mode can use the Circuit Assurance option. This option provides an indication that either the receiving terminal wishes to interrupt the transmission or that the transmission path from the receiving terminal has been interrupted.

Terminals using the Circuit Assurance option as a signaling scheme must have prearranged agreements on the meaning of the interrupt signal and the procedures to be followed. Figure 6 shows the interface signals when using this option.

6.2.2 Operation with the System Status Option

The System Status option permits the customer to distinguish between the control idle mode and a trouble condition as evidenced by receipt of the Out of Service code or by absence of digital signals on the receive loop. In each case the Received Line Signal Detector circuit will be turned OFF, but with the System Status option system trouble conditions will also cause the Data Set Ready circuit to be turned OFF.

6.3 Minimum Interface Requirement

The minimum interface circuits necessary to provide service with the Permanent Request to Send Option are listed below for duplex, half-duplex, transmit-only and receive-only operation.

Minimum Interface Circuits

Operation	Interface Circuits				
	Signal Ground	Transmitted Data	Received Data	Transmit Timing	Receive Timing
Duplex	X	X	X	X	X
Half-Duplex	X	X	X	X	X
Transmit-Only	X	X		X	
Receive-Only	X		X		X

With these circuits it is possible to communicate. However, there is no information on the status of the associated equipment across the interface, not even by "fail safe" circuitry (see EIA RS-232-C, Section 2.5), nor is there any assurance of circuit continuity.

7. DIGITAL DATA SYSTEM OBJECTIVES

The Digital Data System is intended to provide an excellent communications medium for the transfer of digital data between customer terminals. This leads to a set of design objectives which are aimed at the primary concerns that a data customer has about the communications channel which he uses.

Overall performance will depend on the characteristics of data communications equipment that is provided and maintained by the customer as well as those of the DDS. The quantitative objectives listed below apply to the DDS exclusively.

The following are <u>preliminary design objectives only</u> and are <u>not</u> to be construed as minimum performance guarantees. The objectives are subject to change as experience with the DDS dictates.

Quality -To average at least 99.5% error-free seconds at 56 kb/s and better performance at the lower rates of 9.6, 4.8, and 2.4 kb/s.

Availability -To average at least 99.96% channel availability, i.e., annual downtime less than 0.04%. It should be noted that this average is that value which would be observed over a period of several years. Some of the causes of downtime are failures which occur infrequently but which may have long outages associated with them when they do occur. While these infrequent long outages represent small contributions to the long-term average, they may significantly affect the downtime seen in a shorter period of time (even as long as a year.)

8. TESTING AND MAINTENANCE

The DSU contains two loopbacks. Both can be operated either manually at the station (with the exception of the Local Line Loopback in multipoint applications) or remotely from the Serving Test Center (STC). The first loopback shown in Figure 3 is referred to as the Local Line (LL) loopback and provides a loopback both towards the line and towards the customer. If the customer experiences trouble and no network trouble indication is given the customer terminal equipment should be verified for proper operation prior to calling the Telephone Company. The terminal equipment should be designed to utilize the Local Line (LL) loopback for this verification as discussed in Section 8.1.1.

The second loopback is referred to as the Remote Terminal (RT) loopback. It disconnects the customer equipment and loops toward the line at the interface connector (see Figure 3). This loopback can also be utilized by the customer to verify that his remote terminal is operating properly. The Remote Terminal loopback together with the Local Line loopback permits the Serving Test Center to isolate trouble to either the DSU or the local line. The RT loopback also permits the Serving Test Center to verify whether the circuit meets the quality objective for the Digital Data System.

When the DSU is in either of the test modes a lamp and interface lead (CC) indication is given to the customer. When a steady No Signal lamp or interface lead indication is received, the customer should call the Repair Service telephone number given to him at the time of service installation. The user's permission will be obtained prior to Telephone Company testing.

No routine maintenance is required for the DSU.

8.1 Manual Control of Test Modes

A test switch provides the customer with the capability of performing a Local Line Test (LL) or a Remote Terminal Test (RT). To avoid accidental interruption of service the manual operation of the Local Line loopback is inhibited in multipoint service application. When the DSU is in either of the test modes the Data Set Ready circuit is OFF, therefore, the terminal should be designed to recognize this condition in order to utilize the DSUs test features.

8.1.1 Local Line (LL) Loopback (Two Point Service Only)

With the Test Switch in the LL position, the DSU is in the Local Line Test mode. The LL test permits the customer with a properly designed duplex terminal to test the back-to-back performance of his data terminal equipment and DSU by connecting the transmitter section of the DSU to the receiver section. In addition, the receive line is connected through terminating equipment to the transmit line to allow a signal to be maintained in both directions. For this test the Data Set Ready circuit is OFF, but the other control interface circuits, Request to Send, Clear to Send, and Received Line Signal Detector operate as in the control idle or data mode.

Figure 7 shows the signals on the interface circuits of the DSU when the DSU is placed in the LL Test mode. The delays between Request to Send (CA) turning ON and an ON condition on the Clear to Send (CB) and Received Line Signal Detector (CF) circuits are given below for the four service offerings. In addition, the received data is delayed by approximately 5 bits with respect to the transmitted data in passing through the transmitter and receiver sections.

Local Test Timing Delays

Data Rate	CA-CB Delay	CA-CF Delay
2.4 kb/s	8 ± 0.4 ms	4.8 ± 2 ms
4.8 kb/s	4 ± 0.2 ms	2.4 ± 1 ms
9.6 kb/s	2 ± 0.1 ms	1.2 ± .5 ms
56 kb/s	0.4 ± 0.02 ms	0.23 ±.1 ms

With the Permanent Request to Send Option the CB circuit is ON all the time.

8.1.2 Remote Terminal (RT) Loopback

With the Test switch in the RT position, the DSU is in the Remote Terminal Test mode. In this Test mode the output of the Received

Data Circuit is connected to the input of the Transmitted Data Circuit at the data terminal interface of the DSU as shown in Figure 3. For this test the control interface circuit drivers to the data terminal equipment are turned OFF and the Transmitted Data and Received Data Circuits from and to the customer are open circuited.

With the local DSU in the RT test mode, the properly designed remote data terminal has the capability of checking system operation exclusive of the local data terminal. This permits the customer to deduce whether the local data terminal is responsible for a system trouble condition. When the local DSU is in the RT test mode its Data Set Ready, Received Line Signal Detector and Clear to Send circuits are OFF.

8.2 Remote Control of Test Modes from the Serving Test Center

In addition to the manual control of the Test modes, the Telephone Company's Serving Test Center (STC) can place the DSU in either the Local Line or Remote Terminal Test mode in order to test the operations of the line and DSU. The state of the interface circuits in these test modes are the same as described in Sections 8.1.1 and 8.1.2. When the STC places the DSU in either of the Test modes, the appropriate Test lamp, LL or RT, will turn ON.

In the Remote Terminal (RT) Test mode the STC ascertains whether there are any defects in the transmitter, receiver, and interface circuits of the DSU and the transmission path to and from the customer. The STC does not ascertain whether the customer is putting proper signals on the interface circuits.

If the results of the Remote Terminal (RT) Test show that there is a trouble condition, then the STC can place the DSU in the Local Line (LL) Test mode to isolate the trouble condition between the DSU and the transmission facility.

The Test switch on the DSU must not be operated when the Telephone Company is performing its tests. If the DSU is placed manually in the Local Line (LL) Test mode, the STC cannot place the DSU in the Remote Terminal (RT) Test mode and, therefore, cannot determine if the DSU is defective. Before the Telephone Company performs any tests, customer clearance will be obtained.

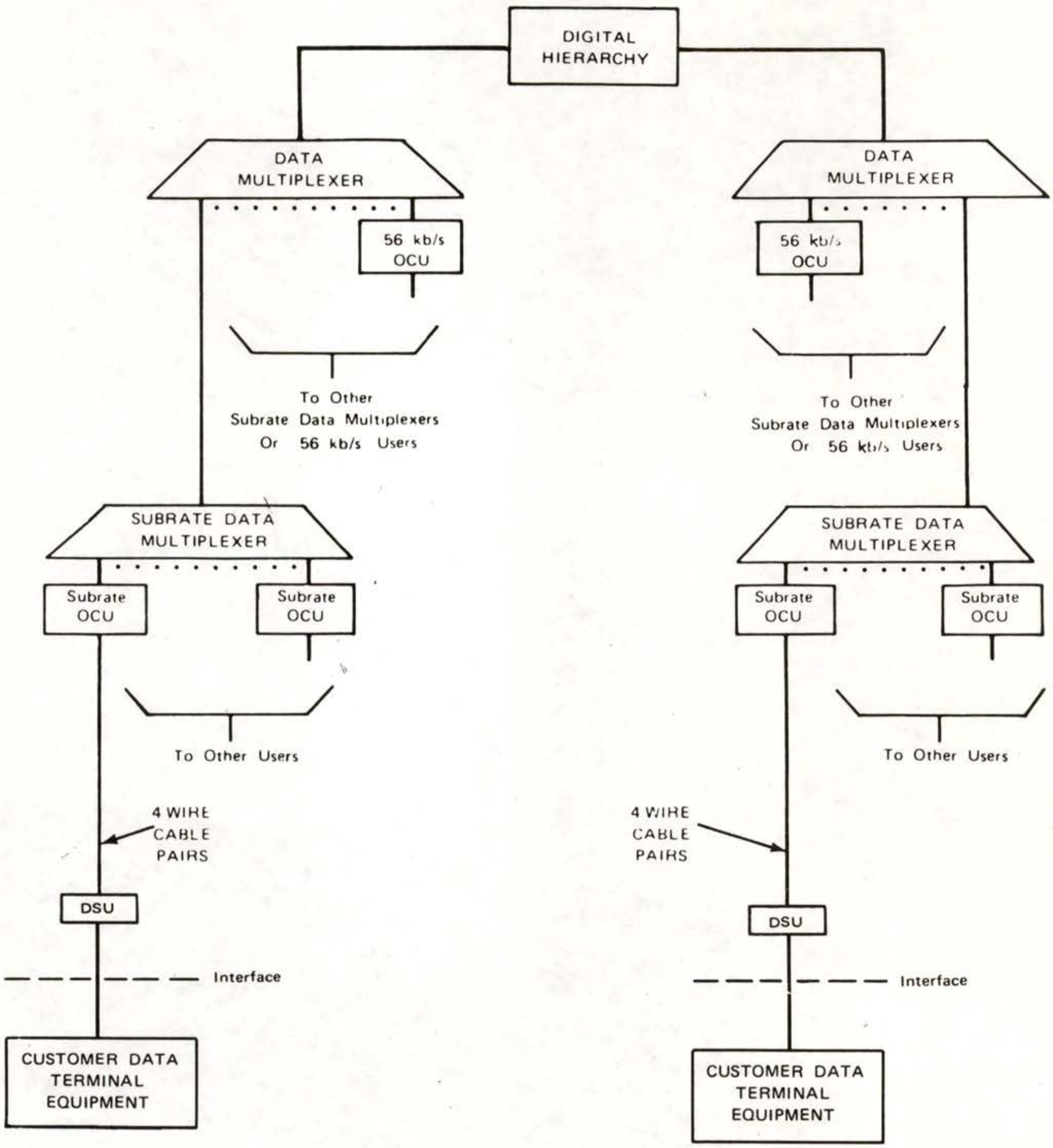
STANDARDS INFORMATION

1. EIA RS-232-C
   EIA RS-334

   Electronic Industries Association (EIA)
   Engineering Department
   2001 Eye Street, N.W.
   Washington, D. C. 20006

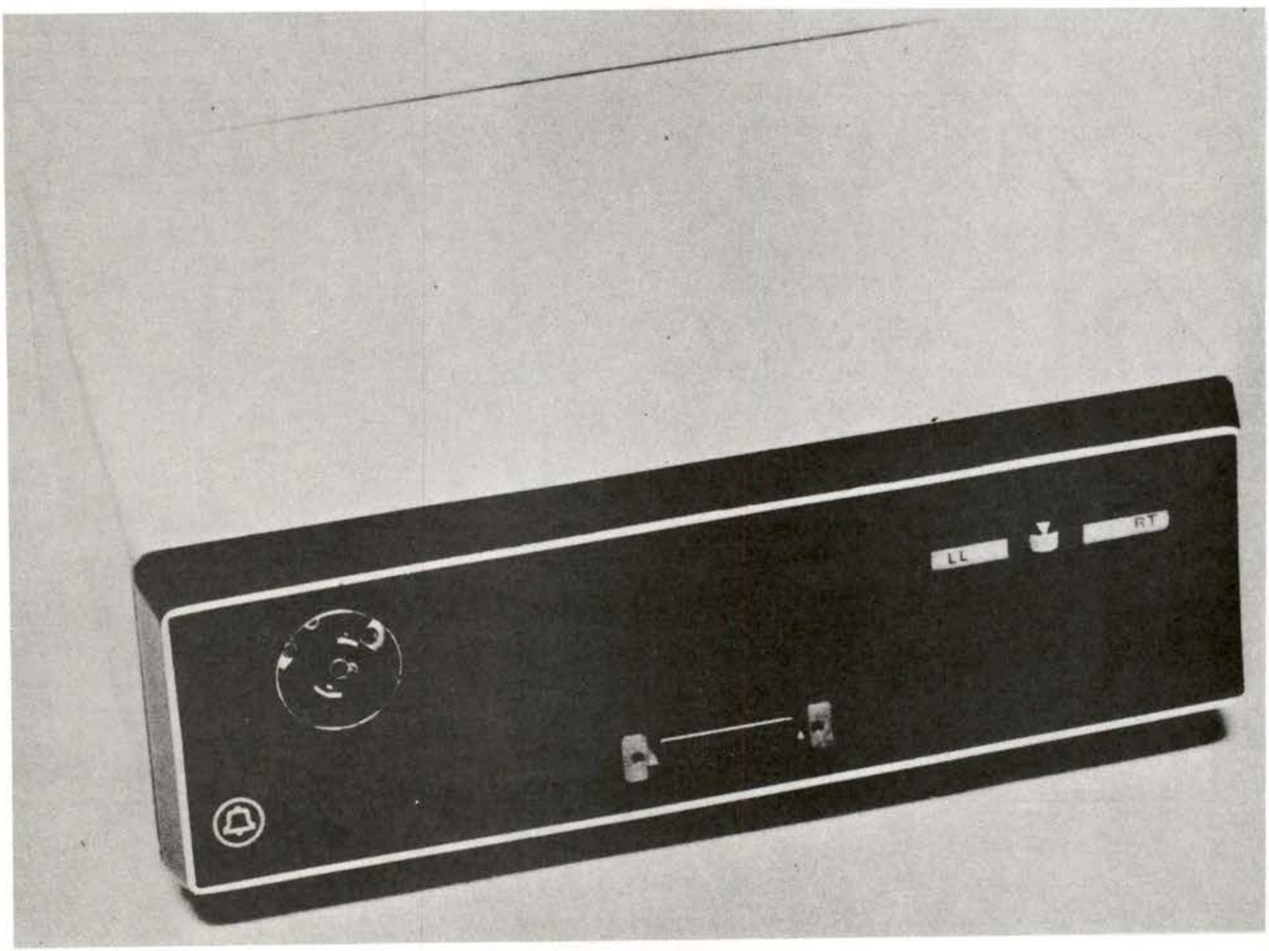
2. The International Telegraph and Telephone Consultative Committee (CCITT)
   Vol. 8, Recommendation
   V.35, Appendix 4

   United Nations Bookstore
   General Assembly Building
   United Nations, N. Y. 10017



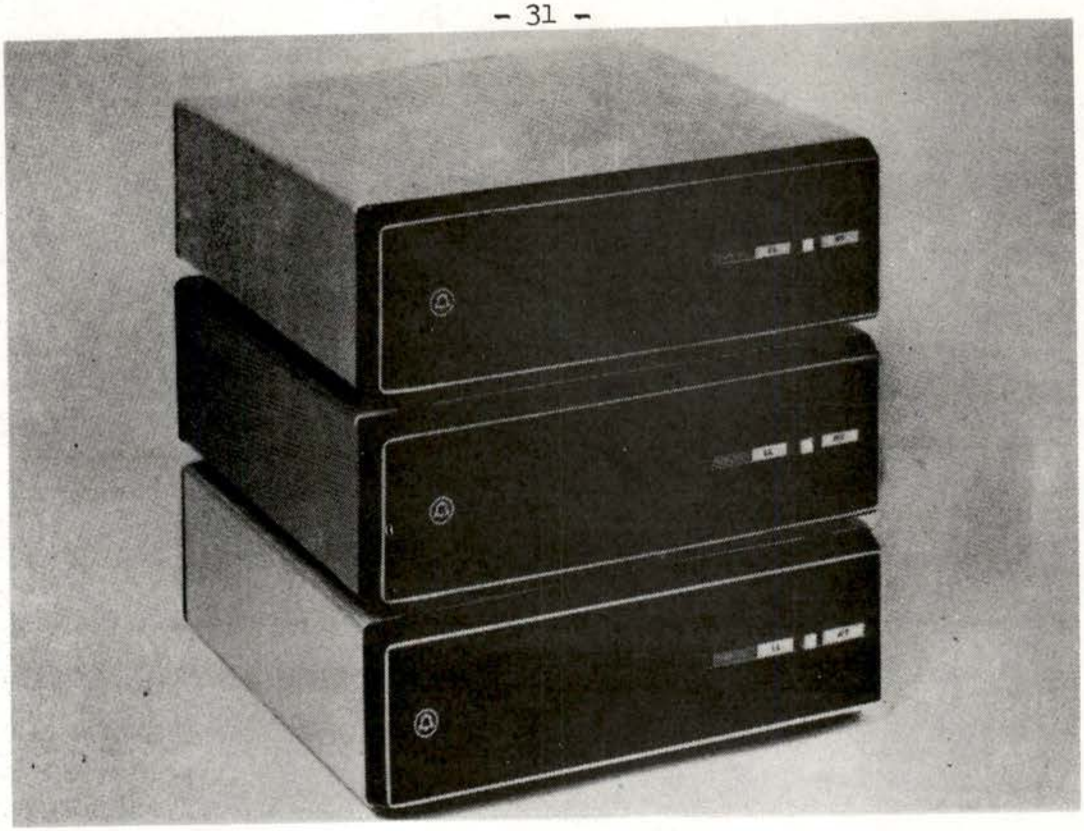
DIGITAL DATA SYSTEM BLOCK DIAGRAM
FIGURE 1

FRONT VIEW
(Switch and Lamps Shown on Front Panel)

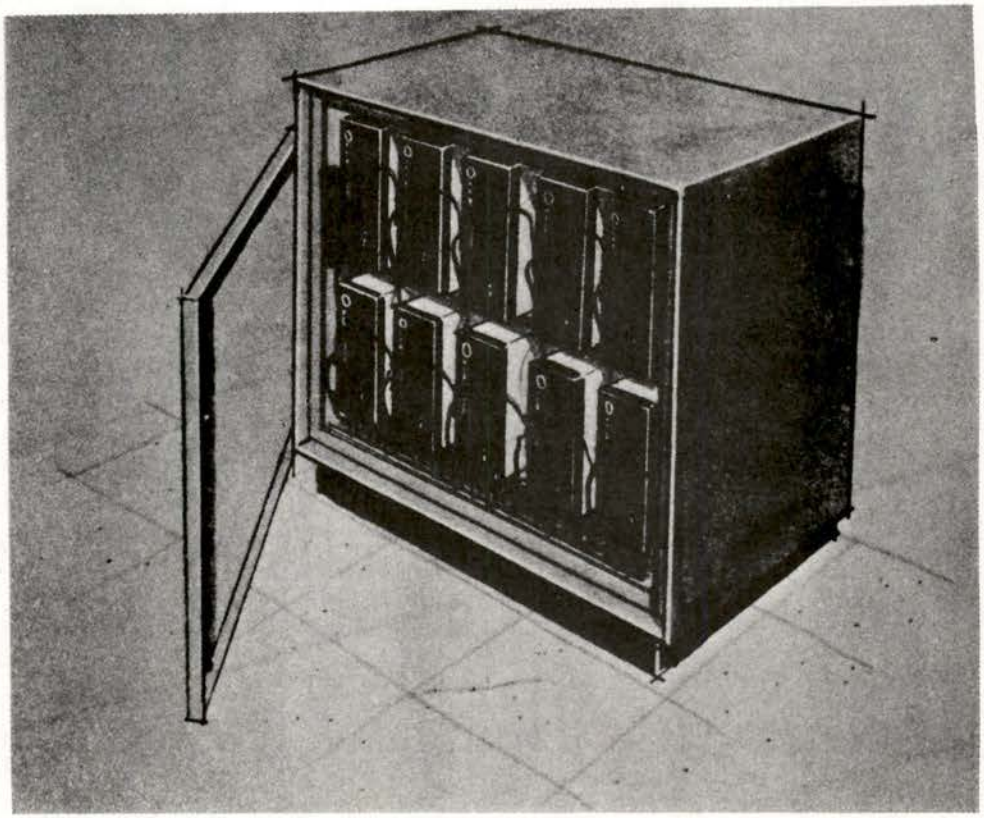


REAR VIEW
(Switch and Lamps Shown on Rear Panel)

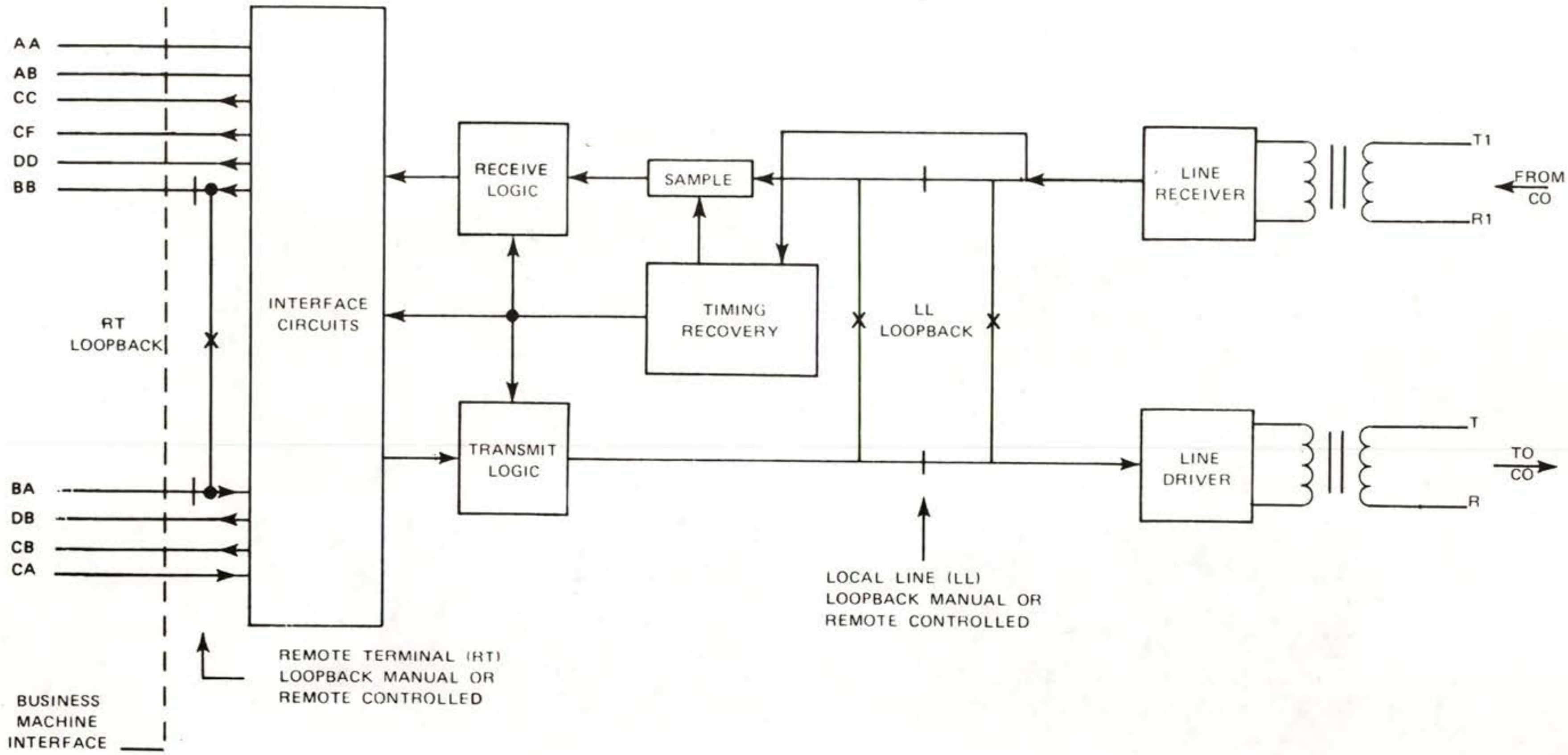
DATA SERVICE UNIT
SINGLE UNIT
FIGURE 2A



DATA SERVICE UNITS
THREE STACKED ARRANGEMENT
FIGURE 2B

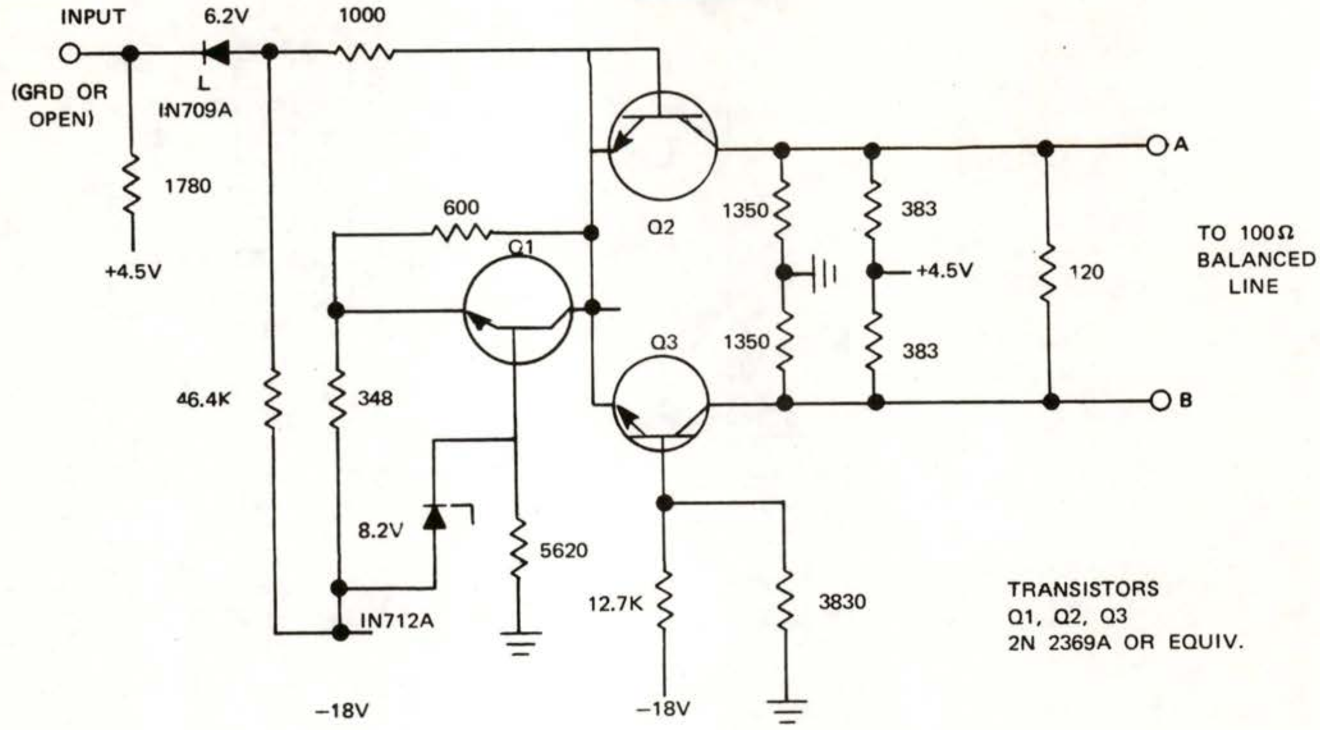


DATA SERVICE UNITS
MULTIUNIT CABINET ARRANGEMENT
FIGURE 2C

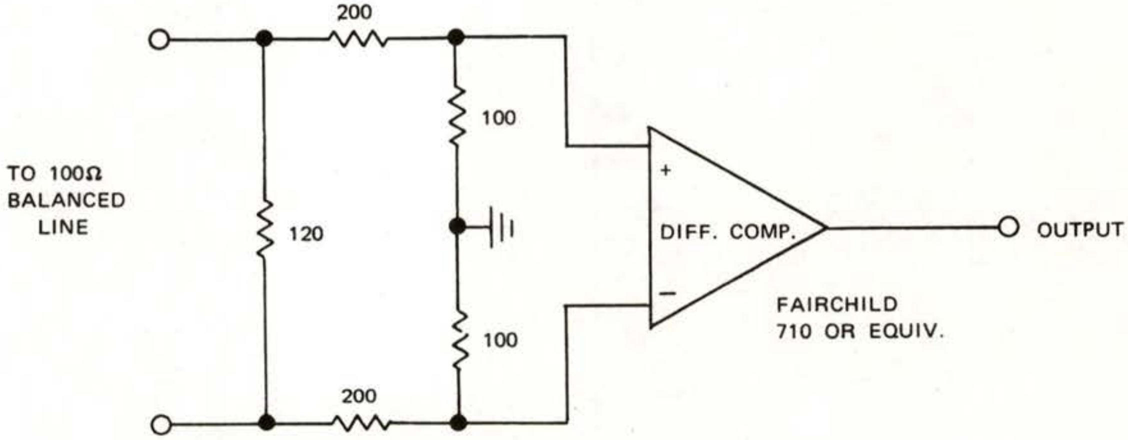


BLOCK DIAGRAM OF DATA SERVICE UNIT
FIGURE 3

CABLE DRIVER

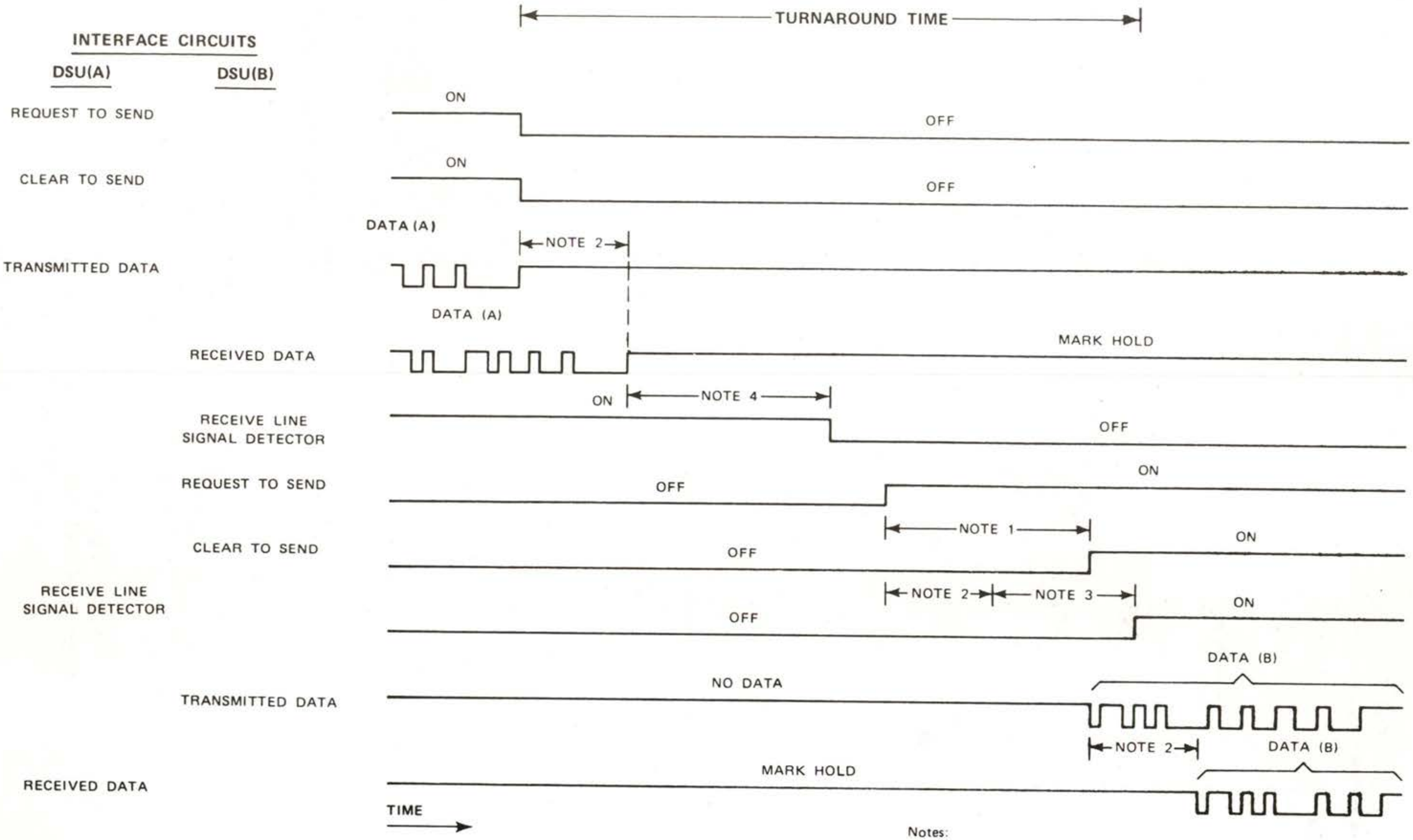


CABLE TERMINATOR



NOTE:
1. ALL RESISTANCE VALUES ARE IN OHMS

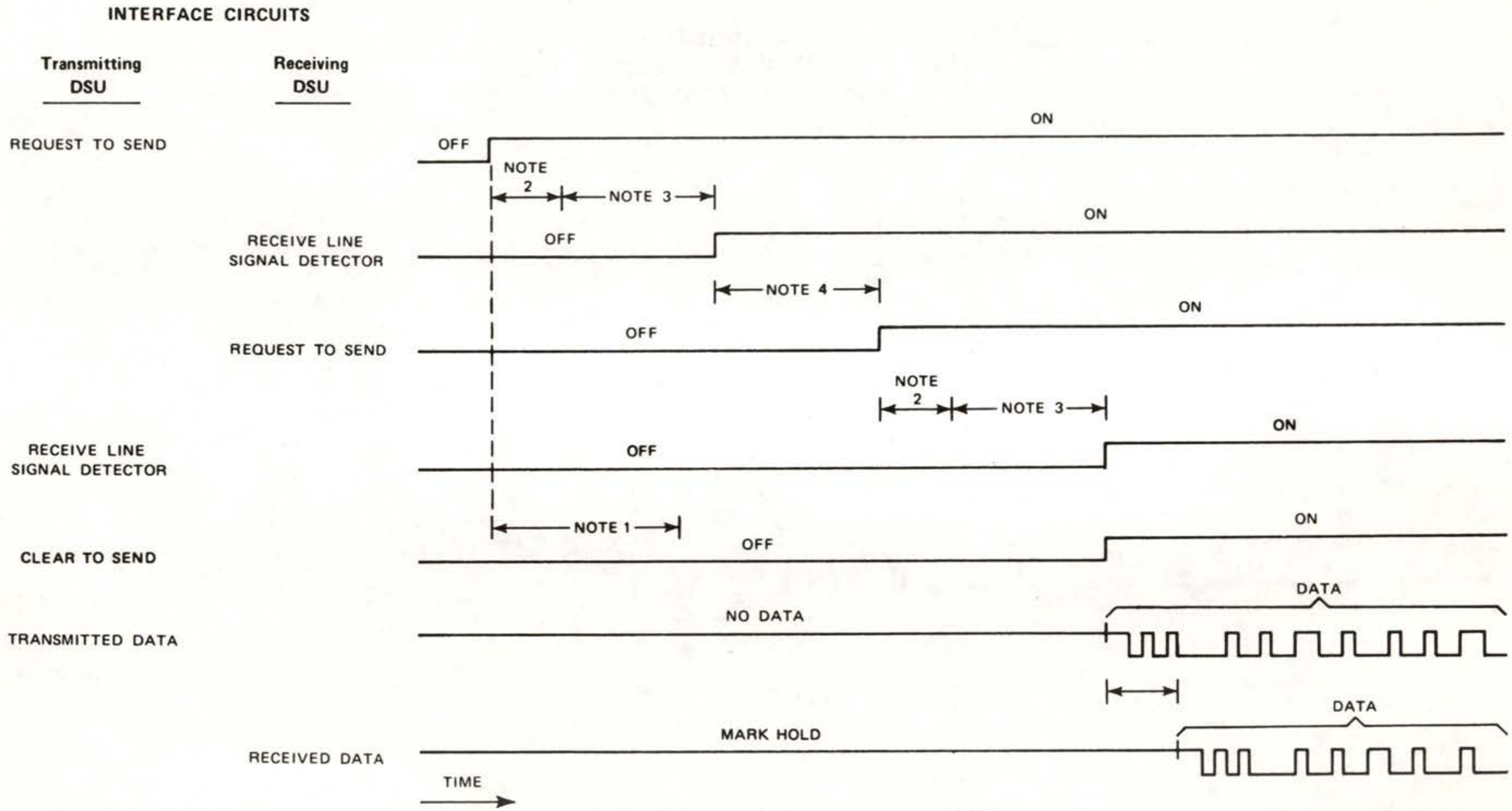
TYPICAL 56 KB/S BALANCED INTERFACE
CABLE DRIVER AND TERMINATOR CIRCUITS
FIGURE 4



Notes:

1. Request to Send – Clear to Send Delay
2. Transmission Delay (Not to Scale; Generally Under 50 msec.)
3. Receive Line Signal Detector Turn-On Time
4. Receive Line Signal Detector Turn-Off Time

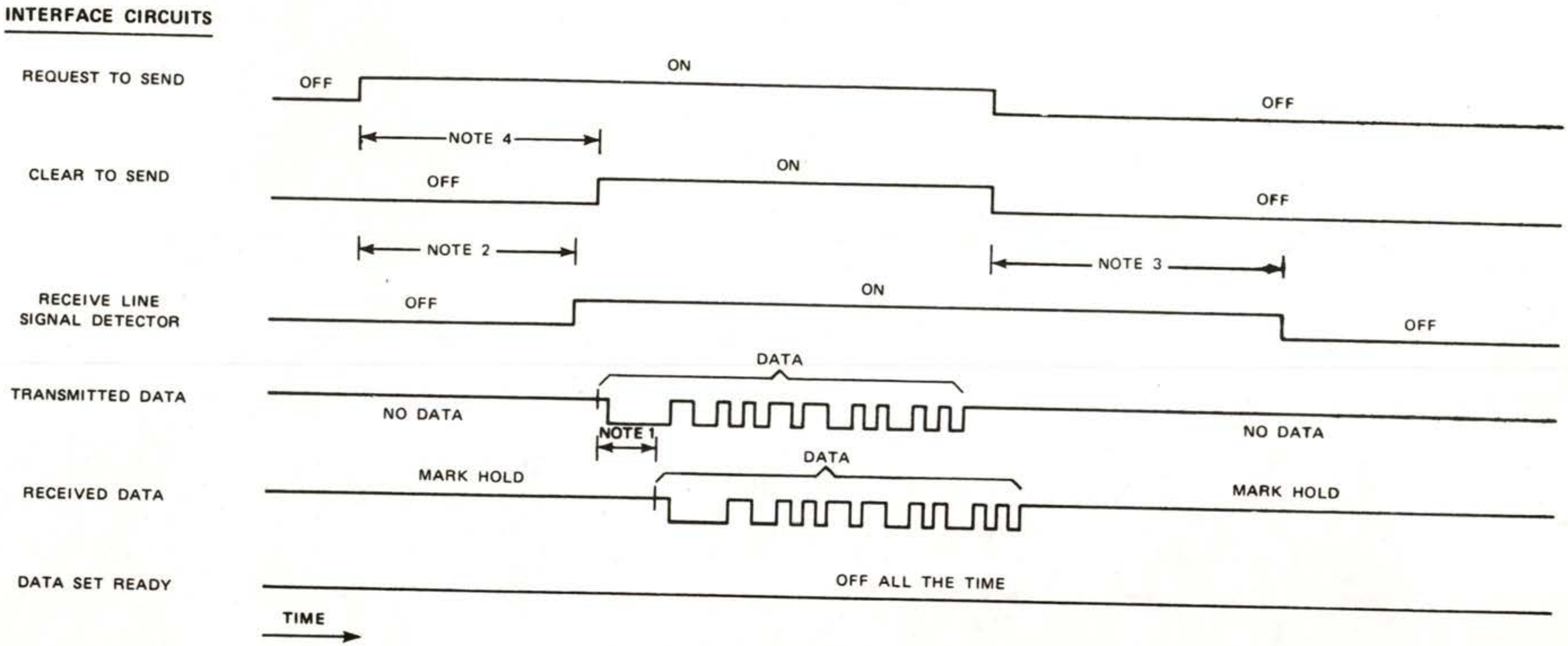
TURNAROUND SEQUENCE FOR HALF-DUPLEX OPERATION
FIGURE 5



NOTES:

1. Minimum Clear to Send Timing Delay (See Section 4.1.9)
2. Transmission Delay (Not to Scale, Generally under 50 msec.)
3. Receive Line Signal Detector Turn On Time
4. Customer Data Terminal Reaction Time

CIRCUIT ASSURANCE OPTION FOR HALF-DUPLEX OPERATION
FIGURE 6



Notes	DELAY (BITS) SUBRATE	56 kb/s
1. Transmission Delay through DSU	5	5
2. CA-CF Turn-on Time	8 to 15	10 to 17
3. CA-CF Turn-off Time	23	26
4. Request to Send—Clear to Send Delay	19 to 20	22 to 23

INTERFACE SIGNALS FOR LOCAL TEST OF DATA SERVICE UNIT
FIGURE 7

PUB 41450A

PRELIMINARY

Bell System Data Communications
TECHNICAL REFERENCE

DIGITAL DATA SYSTEM
DATA SERVICE UNIT
INTERFACE SPECIFICATIONS

ADDENDUM
NOVEMBER 1974

ENGINEERING MANAGER – DATA NETWORK SERVICES

326-462

This addendum covers changes in preliminary Technical Reference (PUB 41450), "Digital Data System - Data Service Unit Interface Specifications" since its publication in March, 1973.

These changes reflect the fact that the Circuit Assurance and System Status customer options are not available in the Data Service Unit (DSU) as described on pages 19 and 20 of PUB 41450. In addition, AMP and Burndy pin designations are added to the Table of 56 kb/s interface connector pin assignments shown on page 14, and the interface cable requirements stated on page 15 are relaxed as described below.

The following items cover section-by-section changes to the original Technical Reference. Also make the appropriate deletions from the Table of Contents (viz., Sections 5.3, 5.4, 6.2.1, 6.2.2).

Section 4.1.7 (page 10)

Delete last sentence.

Section 4.1.8 (page 10)

Delete first sentence of the last paragraph.

Section 4.1.9 (page 11)

Delete last paragraph.

Section 4.1.10 (page 12)

Change the next to the last paragraph to read as follows:

The Received Line Signal Detector circuit will turn OFF approximately 1 second after a transition from a received data to a no signal condition. After a transition from received data to idle signal, the turn OFF delay is 18 bits for 2.4, 4.8, or 9.6 kb/s service and 21 bits for 56 kb/s service.

Section 4.2 (page 14)

Replace page 14 with the following which adds AMP and Burndy pin designations to the 56 kb/s connector pin assignment Table:

PIN ASSIGNMENTS FOR 34-PIN CONNECTOR

56 kb/s SERVICE

Winchester Connector Pin	AMP and Burndy Connector Pin	Function	EIA RS-232-C Designation	CCITT Designation
A	A	Protective Ground	AA	101
B	B	Signal Ground	AB	102
C	C	Request to Send	CA	105
D	D	Clear to Send	CB	106
E	E	Data Set Ready	CC	107
F	F	Received Line Signal Detector	CF	109
R	R	Received Data	BB(A)	104
T	T	Received Data	BB(B)	104
V	V	Receiver Signal Element Timing	DD(A)	115
X	X	Receiver Signal Element Timing	DD(B)	115
P	P	Transmitted Data	BA(A)	103
S	S	Transmitted Data	BA(B)	103
Y	Y	Transmitter Signal Element Timing	DB(A)	114
a	AA	Transmitter Signal Element Timing	DB(B)	114
m	MM	Reserved for DSU Testing	-	-
H, J, K, L, M, N, U, W, Z		Not Used	-	-
b-d	BB-FF	Not Used	-	-
f-k	HH, JJ-LL,	Not Used	-	-
n	NN	Not Used	-	-

<u>Section 4.3 (page 15)</u> - replace Section as follows:

The characteristics of the interconnection cable between the data terminal equipment are specified below. An interconnecting cable meeting these specifications will result in a transmission line with a nominal characteristic impedance on the order of 100 ohms to frequencies greater than 100 kHz. The cable may be composed of twisted pairs or untwisted pairs (flat cable) possessing the following characteristics uniformly over its length:

<u>Conductor Size.</u> The cable shall be composed of pairs of wires of 24 gauge, or larger, conductor for solid or stranded copper wires,

or for non-copper conductors, a sufficient size to yield a dc wire resistance not to exceed 30 ohms per 1000 feet per conductor.

Mutual Pair Capacitance. The capacitance between one wire in the pair to the other wire shall not exceed 20 picofarads per foot, and the value shall be reasonably uniform over the length of the cable.

Stray Capacitance. The capacitance between one wire in the cable to all others in the cable sheath, with all others connected to ground, shall not exceed 40 picofarads per foot and shall be reasonably uniform for a given conductor over the length of the cable.

Pair-to-Pair Balanced Crosstalk. The balanced crosstalk from one pair of wires to any other pair in the same cable sheath shall have a minimum value of 40 decibels of attenuation measured at 150 kilohertz.

The cable drivers and cable terminators will operate satisfactorily with up to 100 feet of 24 gauge copper conductor cable.

To reduce the possibility of crosstalk between the various leads, the following recommendations are made regarding the cable pair assignments for a twisted pair cable. The greatest crosstalk problems are between the control and signal circuits. It is recommended that one twisted pair be used for each control signal with one lead of the pair tied to signal ground at the connector of the cable. The amount of crosstalk depends on the cable, the cable driver characteristics and the cable terminator input impedance. In order to minimize crosstalk the balanced data and clock signals should be assigned to pairs in the center of the cable. The cable pairs around the outside of the cable should be assigned to the control signals. An extra twisted pair with both leads tied to signal ground at the connector of the cable should be used between each control pair to provide isolation. This arrangement with the extra ground wires around the outside of the cable also provides some shielding from interfering signals in the outside environment.

Section 5 (page 18) - Replace first sentence as follows:

There are three customer options that must be specified at the time an order is placed: Request to Send, Signal and Frame Grounding, and Loopback Switch and Indicator Lamp Location. The following paragraphs describe these options in detail.

Section 5.1 (page 19) - Change sentence at top of page 19 to read as follows:

Since an operating DSU with the Permanent Request to Send Option presents a permanent ON condition to the Clear to Send Circuit, a data terminal in strict compliance with a type D interface could not turn its Request to Send Circuit ON again once having turned it OFF. Thus the terminal could not go back into the transmit mode of operation.

Section 5.3 (page 19)

Delete.

Section 5.4 (page 20)

Delete.

Section 6.0 (page 21)

Delete next to the last sentence which is the parenthetical sentence describing the System Status option.

Section 6.2.1 (pages 22 and 23)

Delete.

Section 6.2.2 (page 23)

Delete.

Figure 6 (page 35)

Delete.