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File No. GENL-09

Systems

IBM Synchronous Data Link Control General Information

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Third Edition (March 1979)
This is a major revision of, and obsoletes, GA27-3093-1. This edition has an expanded section on loop applications of SDLC. In addition, terminology has been updated to agree with American National Standards Institute (ANSI) and International Standardization Organization (ISO) standards; thus, some commands and responses have new names or acronyms. Extensive technical and editorial changes have been made throughout; therefore, no vertical bars appear in the margins and the manual should be reviewed in its entirety.

Revisions are periodically made to this manual; before using this publication in connection with the operation of IBM systems or equipment, refer to the latest *IBM System/370 Bibliography,* GC20-0001, and associated Technical Newsletters, for the editions that are applicable and current. For information pertaining to a specific IBM machine or system, refer to the appropriate IBM publication for that machine or system.

Publications are not stocked at the address given below: requests for IBM publications should be made to your IBM representative or to the IBM branch office serving your locality.

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Preface

This manual describes IBM Synchronous Data Link Control (SDLC). It includes a brief communications overview, a basic description to familiarize the reader with the terminology and concepts of SDLC, and some representative examples of the uses of SDLC.

Readers with no prior knowledge of data communications line control may wish to consider purchasing the materials for the self study course entitled "Communication System Concepts." The course comes in three parts:

- Textbook (order number SR20-7184)
- Workbook (order number SR20-7185)
- Two audio tapes (order number SR20-7186)

(The course materials can be purchased through your IBM representative or the IBM branch office serving your locality.)

A reader who is familiar with other data link control procedures should not assume that familiar terms have the same definitions in SDLC procedures, or that familiar functions have the same names. The *IBM Data Processing Glossary,* GC20-1699, is a useful reference for the definitions of terms used in this manual.

This manual does not provide instructions for implementing SDLC, nor does it describe any specific equipment or programs that may be needed to implement SDLC. For specific information about an IBM SDLC implementation, refer to the appropriate IBM publication for that machine or system. For information on Systems Network Architecture (SNA), within which SDLC is the data link control, refer to *IBM Systems Network Architecture Introduction,* GA27-3116; *IBM Systems Network Architecture General Information* GA27-3102; and *Systems Network Architecture Format and Protocol Reference Manual,* SC30-3112. Refer to the *IBM System/370 Bibliography,* GC20-0001, for currently available editions.

This manual contains three chapters and four appendixes:

Chapter 1, *Introduction,* contains general information on telecommunications and data link control.

Chapter 2, *SDLC: The Pieces,* presents the basic concepts involved in understanding SDLC.

Chapter 3, *SDLC: Final Pieces, Applications, and Examples,* provides specific descriptions of SDLC's parts and operation followed by specific examples.

Appendix A, *Hexadecimal Notation and Frame Summary,* contains the hexadecimal and binary codes for SDLC commands and responses.

Appendix B, *SDLC Computation of the FCS Field,* describes the operation of Cyclic Redundancy Checking and its use in the SDLC Frame Check Sequence.

Appendix C, *SDLC Commands and Responses: Acronym Update,* gives a listing of SDLC commands and responses along with the former terms which may appear in older SDLC publications.

Appendix D, *IBM SDLC and Data Link Control Standards,* shows the relationship between SDLC and data link control standards and explains IBM's conformance to these standards.

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Figures

Data Link Control standardization activity on both the national and international level has heightened interest in the relationship between these standards and IBM's SDLC.

Appendix D. describes this relationship and covers SDLC conformance with these standards.

Chapter 1. Introduction

Synchronous Data Link Control (SDLC) is a discipline for serial-by-bit information transfer over a data communication channel. Transmission exchanges may be two-way simultaneous or two-way alternate. The communication channel configuration may be point-to-point or multipoint; a point-to-point configuration may be nonswitched or switched. SDLC includes comprehensive detection and recovery procedures for transmission errors that may be introduced by the communication channel.

Readers who are familiar with the concepts of information transfer over the various communication channel configurations may skip to Chapter 2. Other readers should continue reading here or refer to the Preface of this manual for reading references.

Data Link

The basic purpose of a data link is to allow information exchange between components of a data processing system. When the components of a data processing system are separated by a distance that makes a privately owned, direct-wired connection impractical, such components can be interconnected by a common-carrier data communication path (see Figure 1-1). This path is often a line or facility that is already available for voice communications.

When voice facilities are used in a data link, the binary digital information that is characteristic of data processing machines must be converted to a form similar to that used for transmitting sound. Two fundamental adaptations are necessary:

1. All data and control information is converted to a serial stream of binary digits (0's and 1's). Data terminal equipment (DTE) makes this adaptation. (See Figure 1-2.)
2. The binary signals are made compatible with voice-grade transmission equipment by data communication equipment (DCE).
   The DCE may be an integral part of the DTE.

Receiving equipment reverses both processes: binary information is recovered from received signal tones by DCE, and is then deserialized (regrouped) by DTE. (See Figure 1-2.)

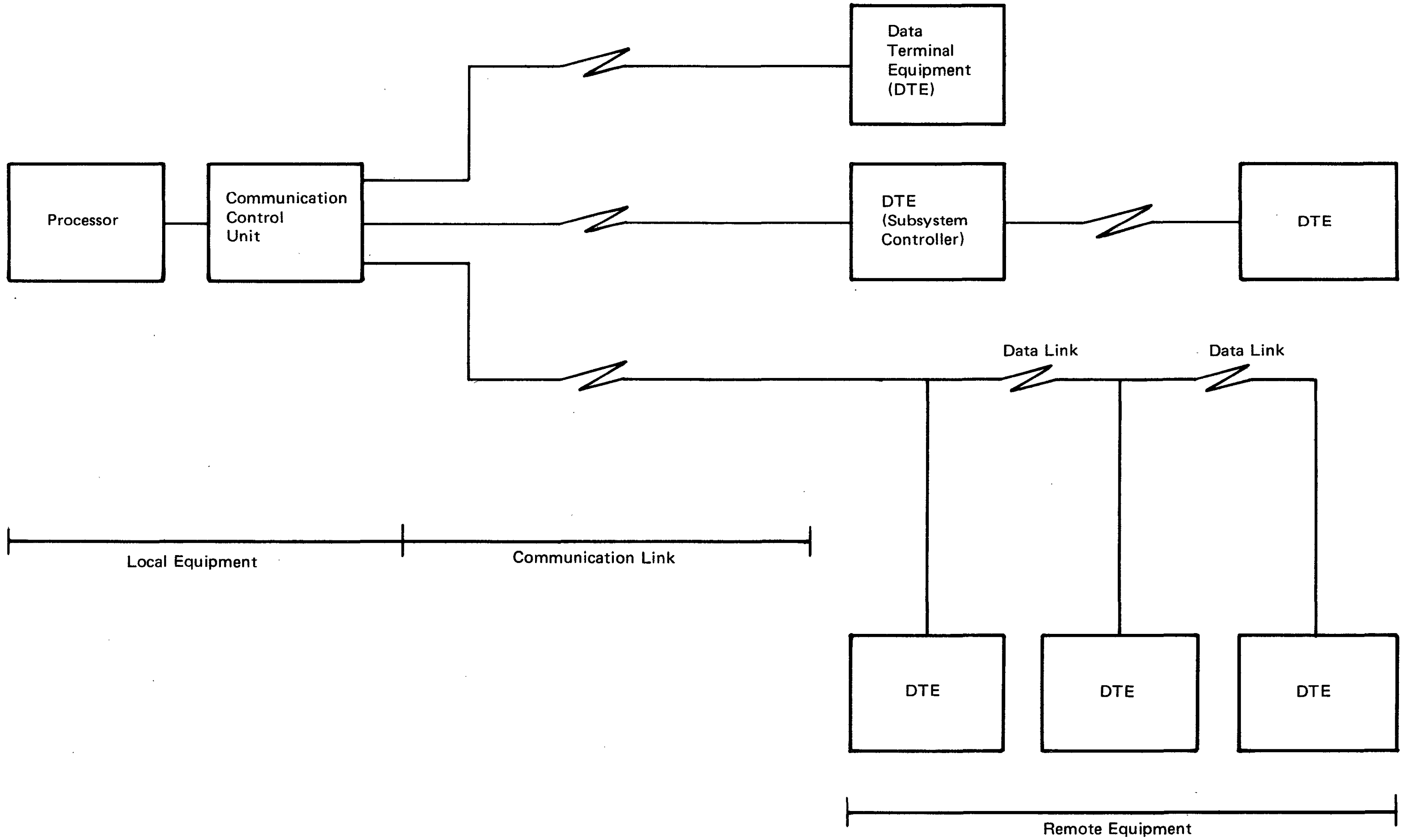


Figure 1-1. System with Remote Components

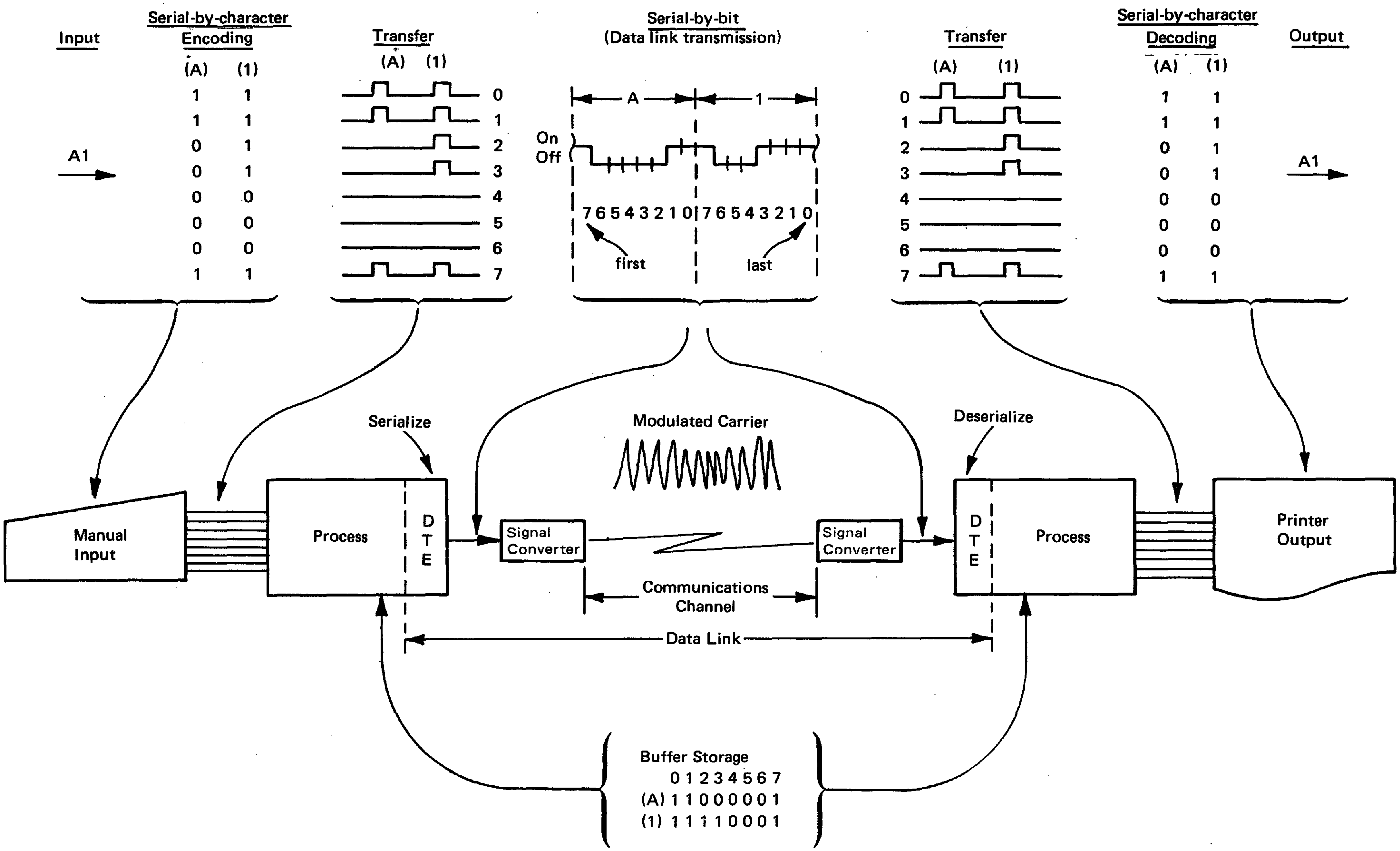


Figure 1-2. Data Conversion for Data Link Transfer

The actual transfer of data, however, requires nondata transmissions for setting up, controlling, checking, and terminating the information exchange. Such transmissions are a part of data link control.

System control information, such as input/output device controls, are not considered data link controls. The following are data link control activities (see Figure 1-3):

- Synchronizing—getting the receiver in step with the transmitter.
- Detecting and recovering from transmission errors.
- Controlling send/receive—using a primary station to manage each data link (others are secondary stations).
- Reporting unacceptable data link conditions.

Data Link Configurations

A data link is made up of data communication equipment (or DCEs) and the communication channel (see Figures 1-2 and 1-3). The combination of DTEs, DCEs, and channel determine what is possible to accomplish with the data link. A number of communication configurations are possible depending on the capabilities of the communication channel.

There are two basic configurations for a communication channel: (1) point-to-point and (2) multipoint. (See Figure 1-4.)

A point-to-point configuration is a data link with two stations. A multipoint configuration is a data link with three or more stations.

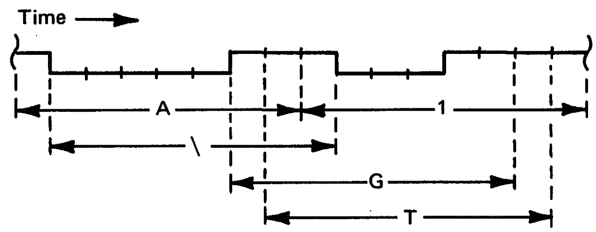
In addition, a point-to-point or multipoint configuration can operate either two-way alternate or two-way simultaneous. In two-way alternate operation, the stations take turns transmitting, one at a time. This is similar to conversations using citizen's band radios in which speakers alternate talking and listening. Two-way simultaneous operation allows two stations to transmit and receive at the same time. A telephone conversation, in which a person can talk and hear the other person at the same time, is very similar.

A duplex channel may be used as two half-duplex channels. For example, in some multipoint configurations a station may transmit to one station while receiving from another station.

Further, a point-to-point half-duplex channel may be nonswitched or switched. A nonswitched channel is one that is permanently connected. A switched channel, on the other hand, is a temporary connection such as the temporary connection you make when you place a telephone call.

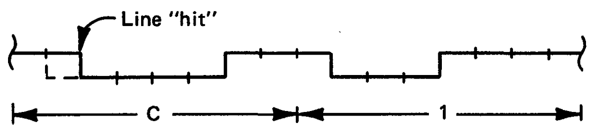
To summarize, there are five basic data link configurations

- Half-duplex, point-to-point, nonswitched
- Duplex, point-to-point, nonswitched
- Half-duplex, multipoint, nonswitched
- Duplex, multipoint, nonswitched
- Half-duplex, point-to-point, switched



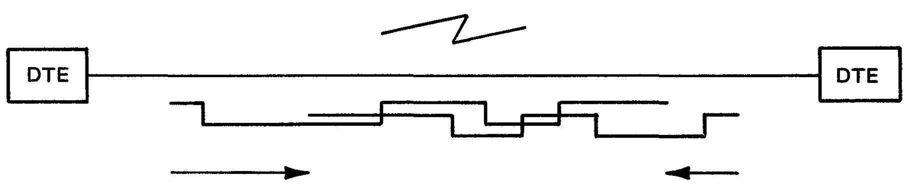
Is the sequence of these binary digits "A1", or
is there a "\", "G", or "T"?

A. Synchronization makes the difference.



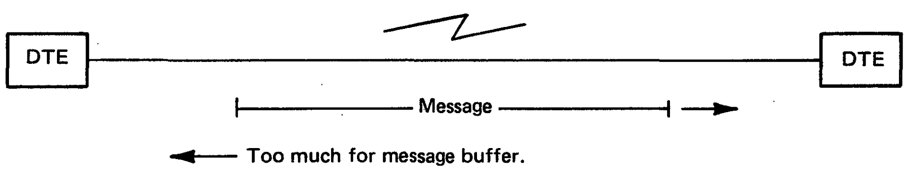
A single binary digit is changed by a transmission error. The
receiver must recognize that the error has occurred.

B. Transmission errors change data.



When one station transmits, the other station
must receive; otherwise, there is no communication.

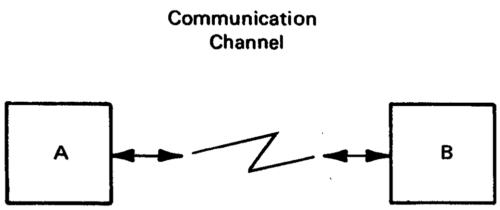
C. Send or receive control is important.



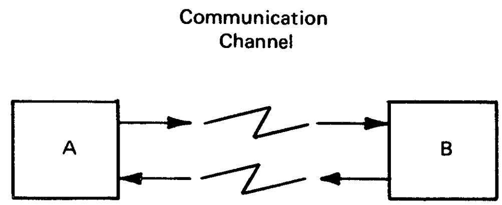
Too much for message buffer.

D. Receivers may have limitations.

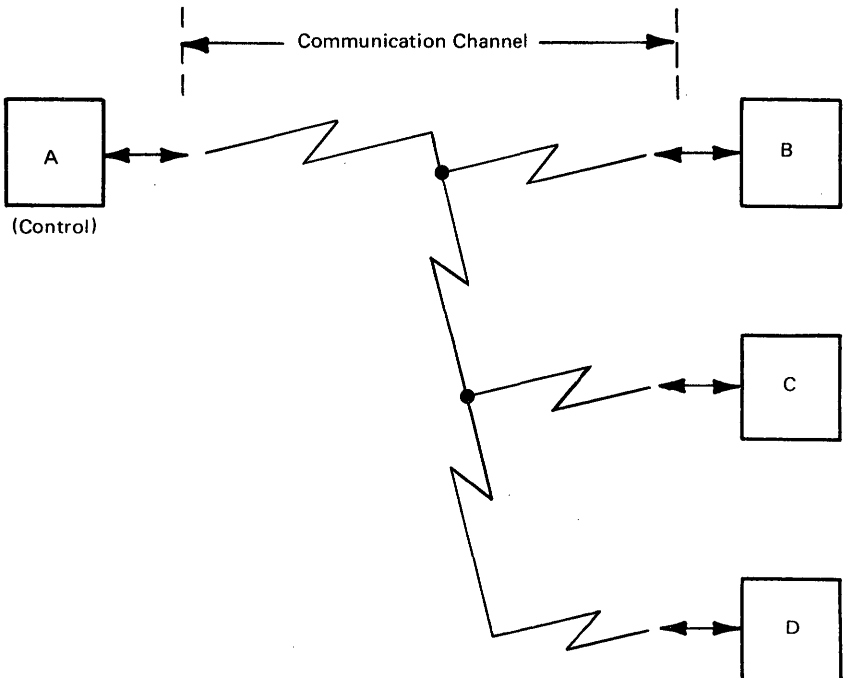
Figure 1-3. Some Data Link Control Considerations



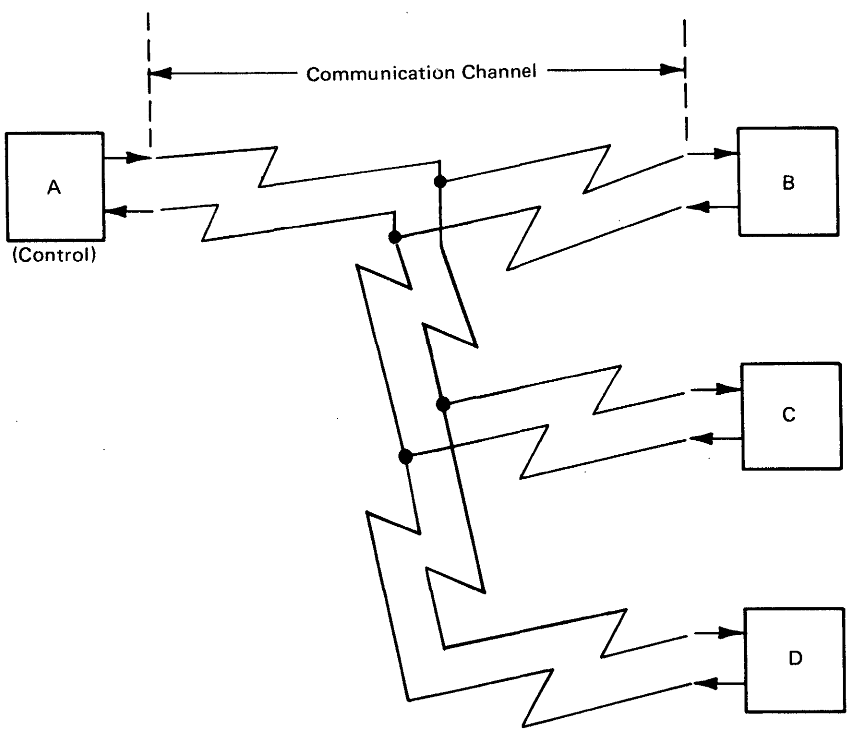
A. Point-to-Point, Half-Duplex (Nonswitched)



B. Point-to-Point, Duplex (Nonswitched)



C. Multipoint, Half-Duplex (Nonswitched)



D. Multipoint, Duplex (Nonswitched)

Figure 1-4. Communication Configurations (Part 1 of 2)

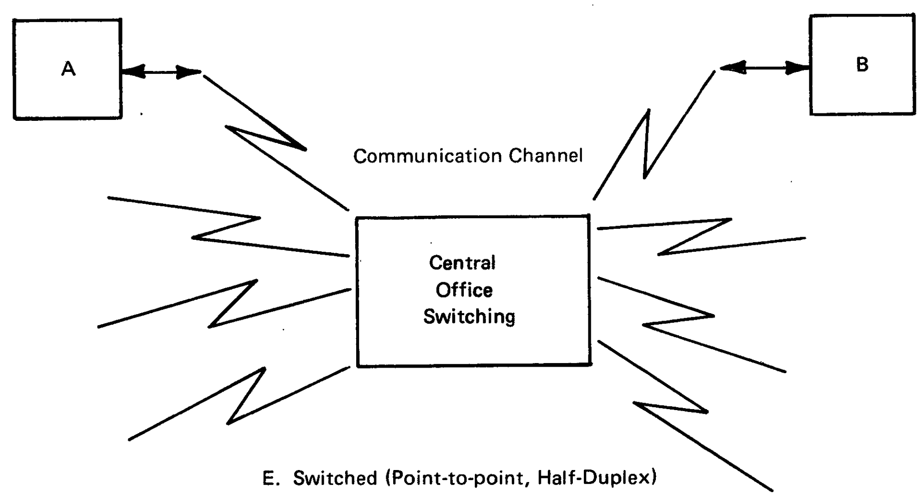


Figure 1-4. Communication Configurations (Part 2 of 2)

Data Link Operating Characteristics

The combination of DTE, DCE, and channel capabilities determine the operating characteristics of a data link. A certain level of capability is required for a DTE to operate two-way alternate. If operation is to be two-way simultaneous, an increase in capability is needed. If the station is to be the primary (controlling) station on the link, still additional capability is required (see Figures 1-5A and 1-5B).

The DTE may operate two-way alternate on a duplex channel. For example, a controlling primary station operating two-way simultaneous on a duplex channel may transmit to one station while receiving from another. This is called duplex-multipoint operation (see Figure 1-5C).

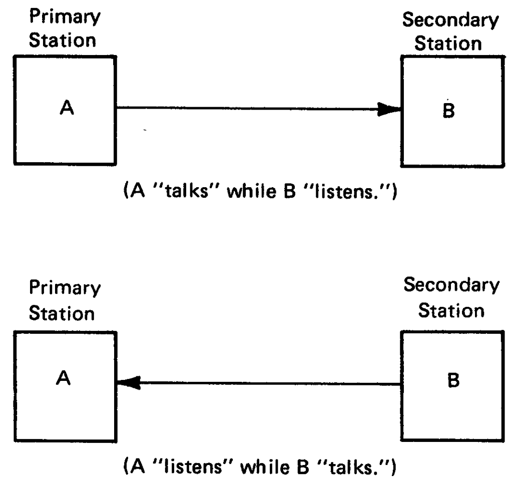
Bit Synchronization and Invert-On-Zero Coding

A synchronous transmission is time-based to enable the identification of sequential binary digits (see Figure 1-6). SDLC procedures assume that bit synchronization is provided by either the DCE or the DTE.

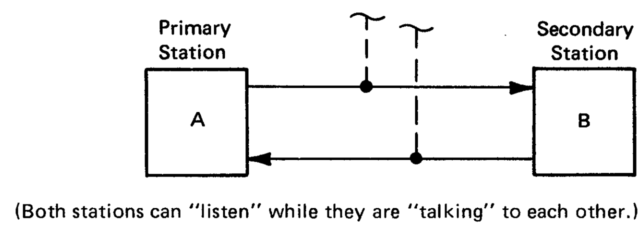
A receiver samples the value of the incoming signal at the same rate used for transmitting the signal. There may be minor variations in timing between transmitter and receiver, however, that make it necessary for the receiver to dynamically adjust sample timing to keep sample times midway between transitions. DCEs that provide received-data timing to the DTE perform this function.

If the DCE does not provide received-data timing, the DTE must provide and adjust the sample timing. In this case, an invert-on-zero transmission coding method (also known as NRZI, Non-Return to Zero Inverted) is used, in which the DTE holds the signal condition in the same state to send a binary 1. To send a binary 0, the DTE changes the signal condition to the opposite state (see Figure 1-7). Thus, the long periods of binary 0 data that sometimes occur have successive transitions in the transmitted bit stream. (Zero insertion, a characteristic of SDLC procedures that is explained later, creates transitions when extended periods of binary 1 transmission occur.) If invert-on-zero transmission coding is used, it must be used by all DTEs on the data link.

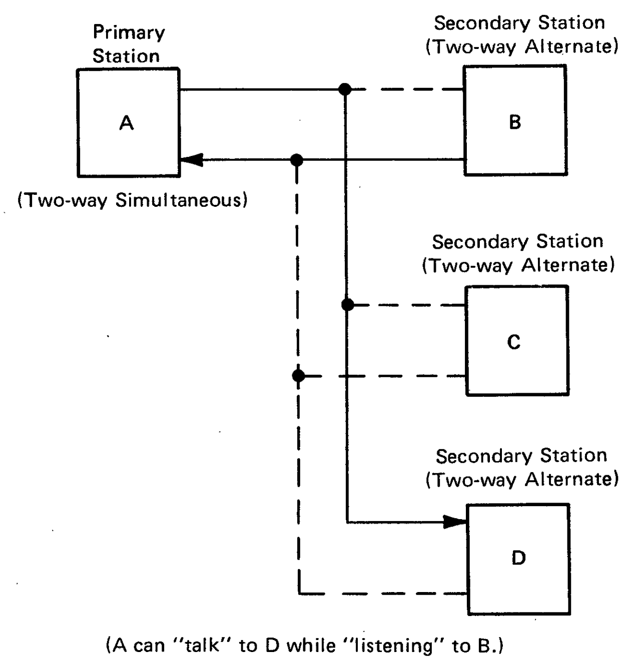
SDLC is a bit-oriented procedure and any receiving error invalidates that segment of the transmission that contains the error, so it is important that bit synchronization be maintained. When DCEs do not provide received-data timing, the DTE must provide invert-on-zero transmission coding to reduce the probability of losing synchronization. Invert-on-zero coding may be required or prohibited for DCEs with specific pattern sensitivities.



A. Half-Duplex Data Link (Point-to-Point, Nonswitched or Switched)

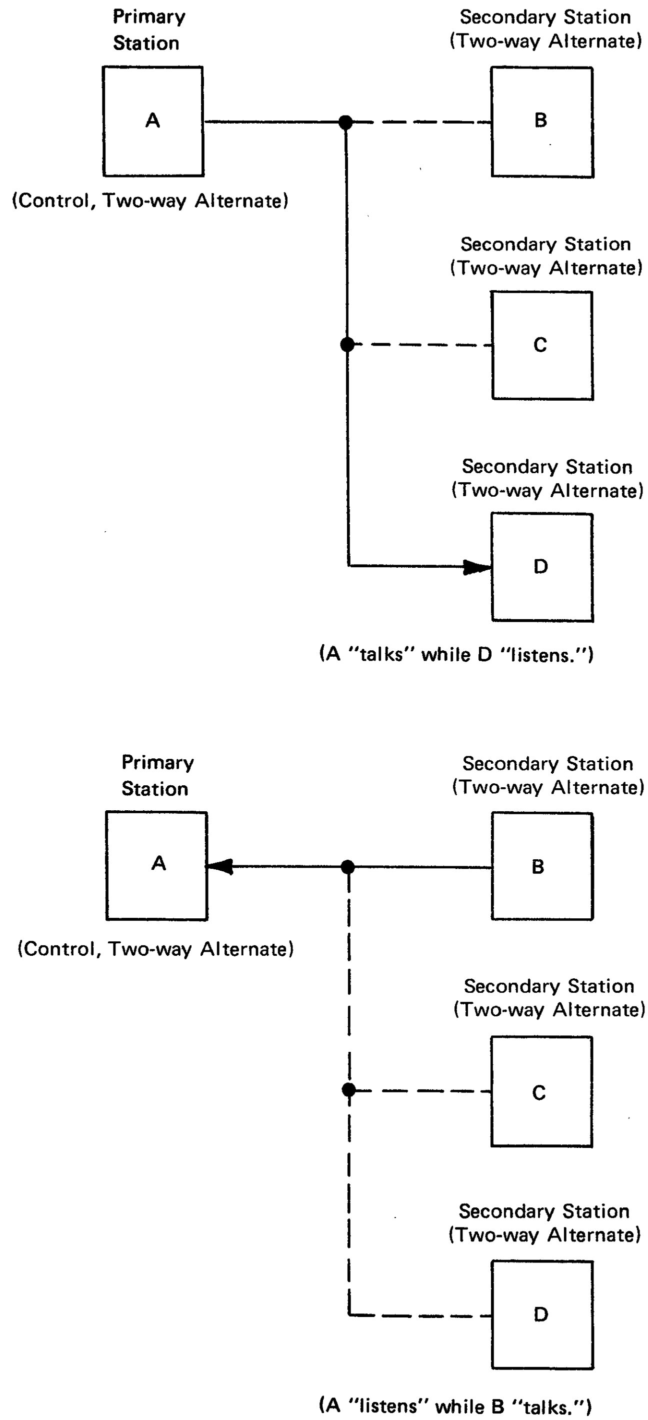


B. Duplex Data Link (Point-to-Point or Multipoint)



C. "Duplex-multipoint" Duplex Data Link

Figure 1-5. Data Link Configurations (Part 1 of 2)



D. Multipoint Half-Duplex Data Link

Figure 1-5. Data Link Configurations (Part 2 of 2)

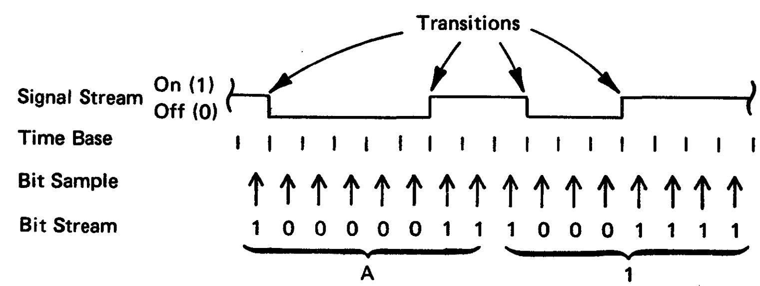


Figure 1-6. Receive Sample Time (Discrete Transmission Coding)

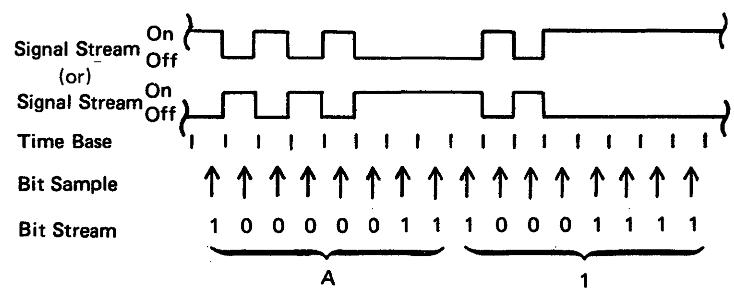


Figure 1-7. Invert-On-Zero Transmission Coding

Chapter 2. SDLC: The Pieces

Four basic concepts are fundamental to the understanding of SLDC. From the understanding of these concepts comes the ability to place them together into the whole picture that makes SDLC. These building blocks for understanding SDLC are:

- The definitions of primary and secondary stations and their responsibilities
- The definitions of the transmission states that affect information transfer
- The way that information is formatted into groups for transfer
- The way these formatted groupings are organized into larger sequences

This chapter describes these four concepts and then tells how other SDLC procedures are designed for recovering when transmissions are received with errors.

Primary and Secondary Stations

Two types of stations are used in SDLC communications: primary stations and secondary stations. A primary station has the responsibility for controlling a data link; it issues commands. Secondary stations receive commands and return responses. All communications on a data link are from the primary station to one or more secondary stations, and from a secondary station to the primary station. There can be only one primary station on a data link at one time.

A DTE that can operate on more than one data link at the same time may be a primary station on some links and a secondary station on others (see Figure 2-1).

Transmission States

The physical communication channel, whether switched or nonswitched, is assumed to be constant, once it is established. The *communications* over this channel, however, are considered to be transitory. Three transmission states can exist on a communication channel:

- Transient state
- Idle state
- Active state

Only one of these states can exist on a channel at any one time.

Transient State

The transient state exists when the communication channel is being conditioned before initial transmission and after each transmit-receive reversal or turnaround (see Figure 2-2).

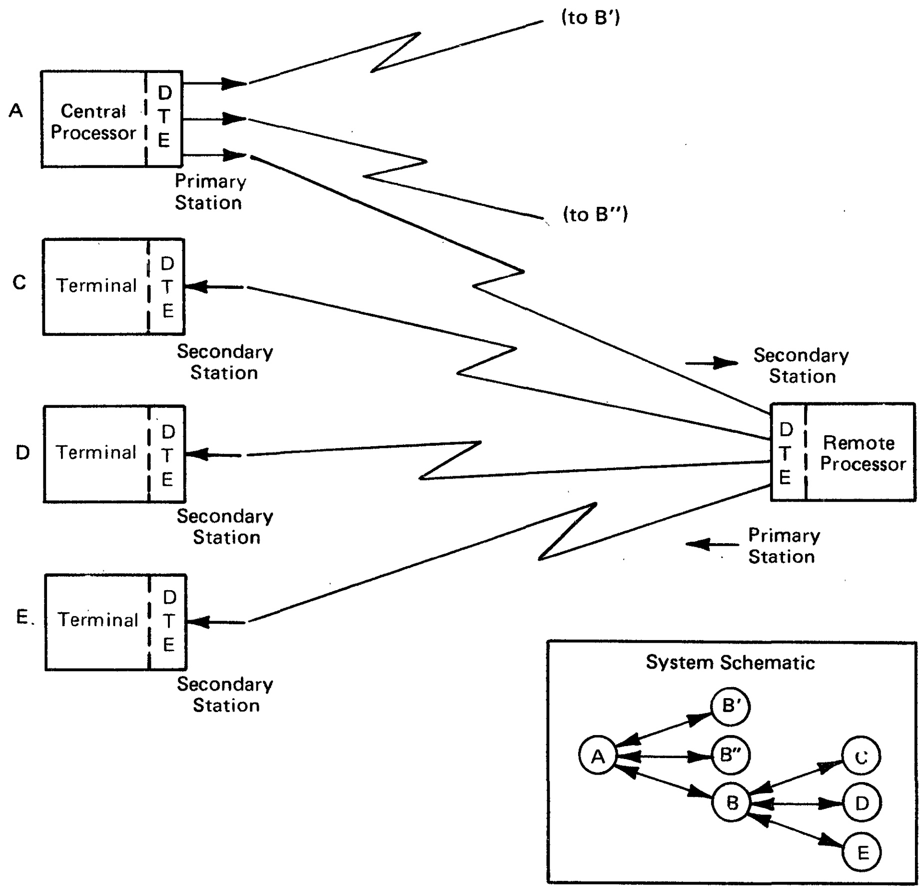


Figure 2-1. Dual Role of a Station in a Complex System

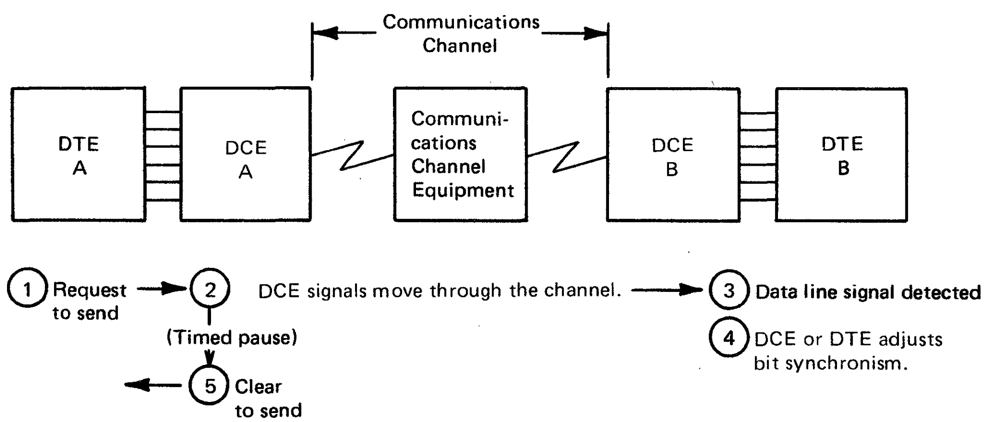


Figure 2-2. Period of the Transient State

Idle State

When a data link is operational, but there is no SDLC control or information transmission currently in progress, the idle state exists.

A station perceives the existence of an idle link when, after receiving a succession of 15 consecutive binary 1's, it continues to receive binary 1's.

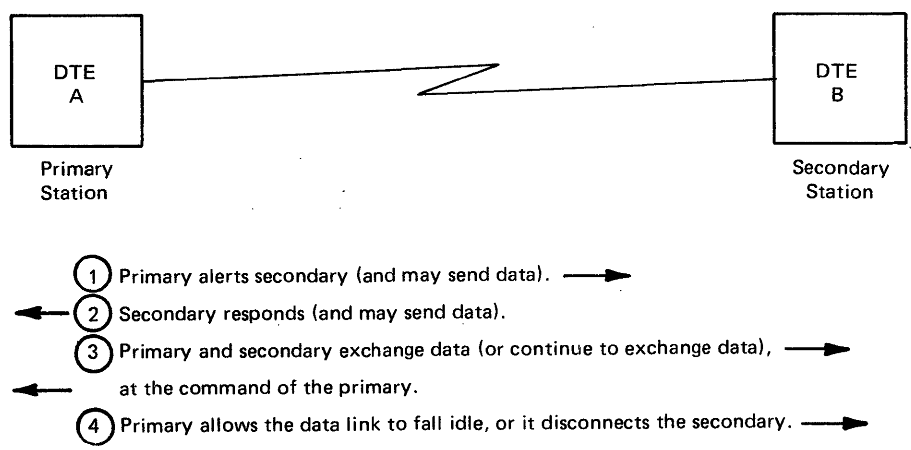
Note: A station that is not transmitting SDLC control or information data may, nevertheless, send signals onto the communications channel.

The channel configuration determines the appropriate action, as follows:

- Half-duplex, primary or secondary—no signal (carrier off)
- Duplex, multipoint, secondary—no signal (carrier off)
- Duplex, multipoint, primary—all 1's (mark hold)
- Duplex, point-to-point, primary or secondary—all 1's (mark hold)

Active State

When a station is transmitting or receiving either information or data link control signals (via transmission frames described later in this chapter), the active state exists. The active transmission state is the nonidle, nontransient state. The active state also exists when a series of flags (also described later in this chapter) are being transmitted. In this case no information is exchanged, but the line is held in the active state (see Figure 2-3). A duplex data link may be active in one direction and idle in the other.



Note: *During turnaround, a half-duplex data link is in the transient state.*

Figure 2-3. Period of the Active State

Transmission Frames

All transmissions on an SDLC data link are organized in a specific format called a frame (see Figure 2-4). This format enables the receiving station to determine where the transmission starts and stops, whether the transmission is for that station, what actions are to be performed with the transmission, specific information for that station, and data that is used to check whether the frame was received without error.

Frame Format

Each SDLC transmission frame has the same specific format. Each frame is made up of:

- A beginning flag (F) that indicates the beginning of the frame
- An address (A) field that identifies the secondary station that is sending (or is to receive) the frame

- A control (C) field that specifies the purpose of the particular frame
- An optional, information (I) field that contains information data
- A frame check sequence (FCS) field that enables the receiving station to check the transmission accuracy of the frame
- An ending flag (F) that signals the end of the frame

Each of these fields contain either 8 bits or a multiple of 8 bits. (See Figure 2-5.)

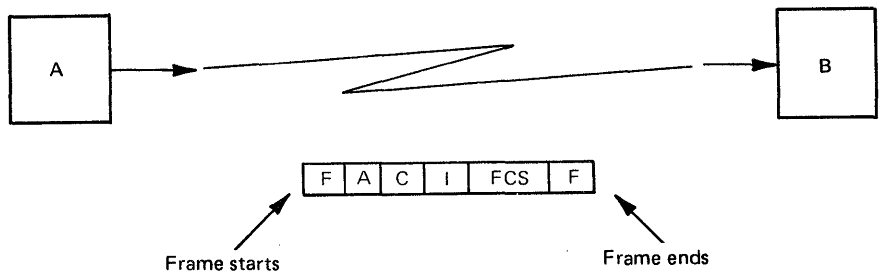


Figure 2-4. SDLC Transmission Frame

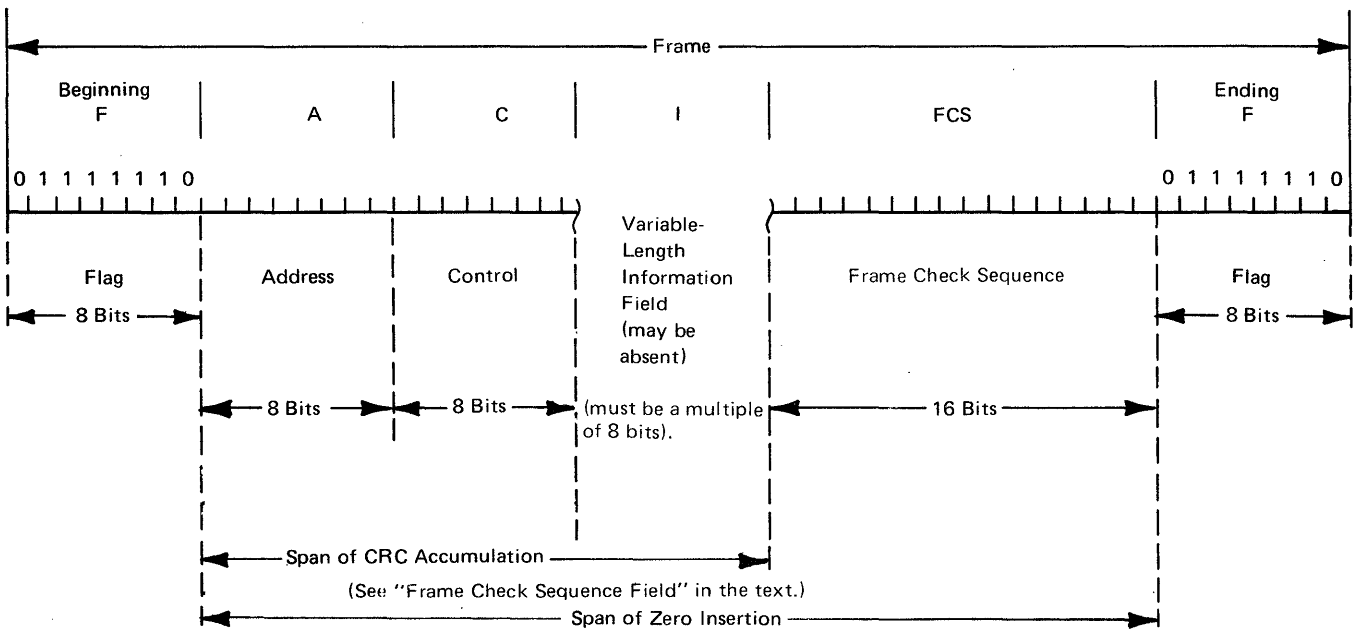


Figure 2-5. Fields of the SDLC Transmission Frame

Flag

The beginning flag and the ending flag (see Figure 2-6), enclose the SDLC frame. The beginning flag serves as a reference for the position of the A (address) and C (control) fields and initiates transmission error checking; the ending flag terminates the check for transmission errors. Both beginning and ending flags have the binary configuration 01111110. The ending flag for one frame may serve as the beginning flag for the next frame. Alternately, the ending 0 of an ending flag may serve as the beginning 0 of a beginning flag forming the pattern 011111101111110. Also, there may be multiple flags repeated between frames to maintain the active state (see "Active State" earlier in this chapter). Zero insertion (described later) prevents the flag pattern from occurring anywhere else in the frame.

Any ending flag may be followed by a frame, by another flag, or by an idle condition.

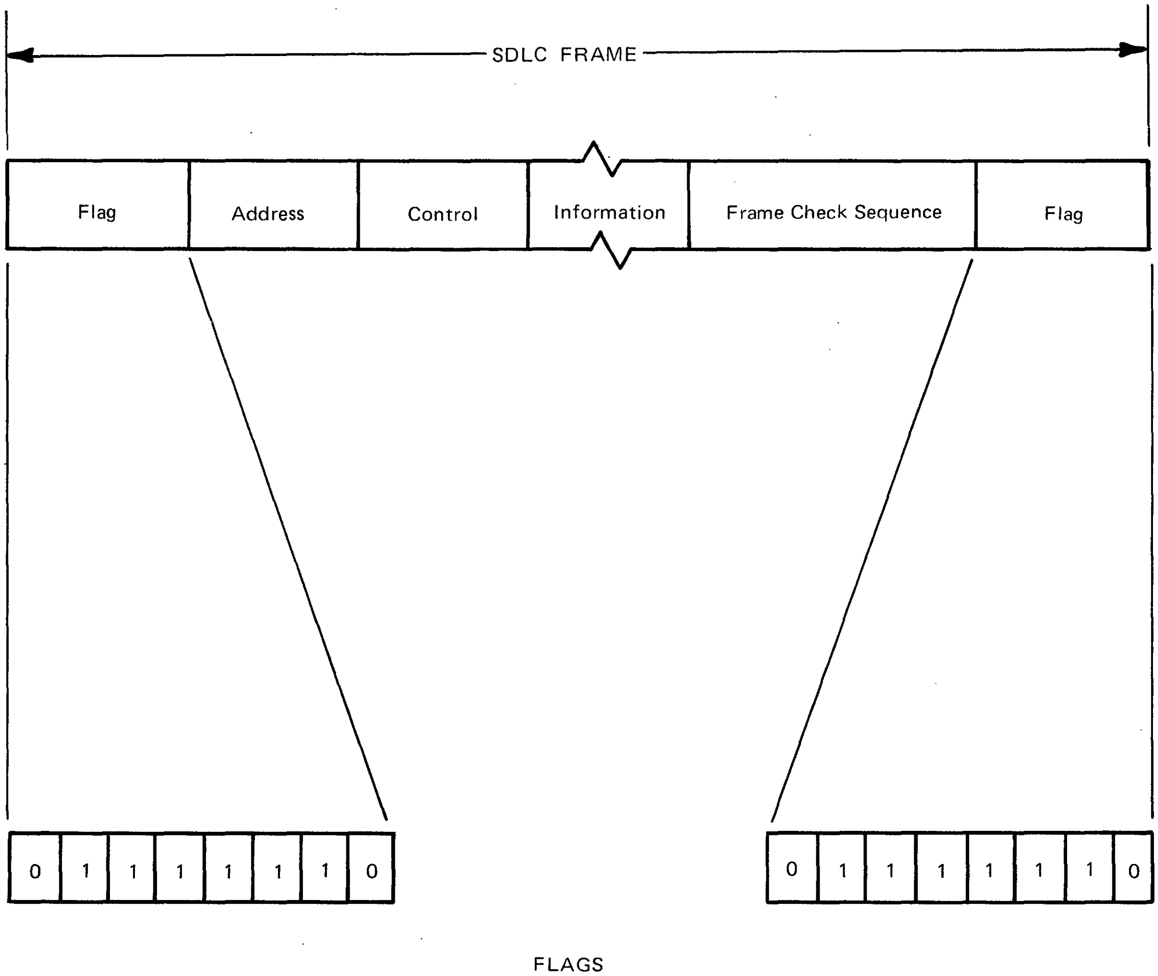


Figure 2-6. SDLC Frame: Flags

Address Field

The address field of an SDLC frame follows immediately after the beginning flag (see Figure 2-7). It serves the same purpose as the address or return address on a letter mailed through the Post Office. The address that is sent is always the address of the secondary station on the data link. If the primary station is transmitting the frame, the address is similar to the main address on a letter—it tells who a letter is to. If a secondary is transmitting the frame, the address is similar to the return address on a letter—it tells who the message is from.

For application purposes, it may be beneficial to have special addresses specified in a system that direct frames to a number of stations or to all the stations on the link. In this case, a secondary station may have three types of address:

- Its own individual address: a *station address*
- An address that is common to a number of stations: a *group address*

- An address that all stations on the data link will accept: a *broadcast address* (An address field of all 1's is reserved and used as the broadcast address only.)

Note: An all-zeros address field is reserved as a "no stations address;" therefore, no secondary station is assigned this as one of its addresses.

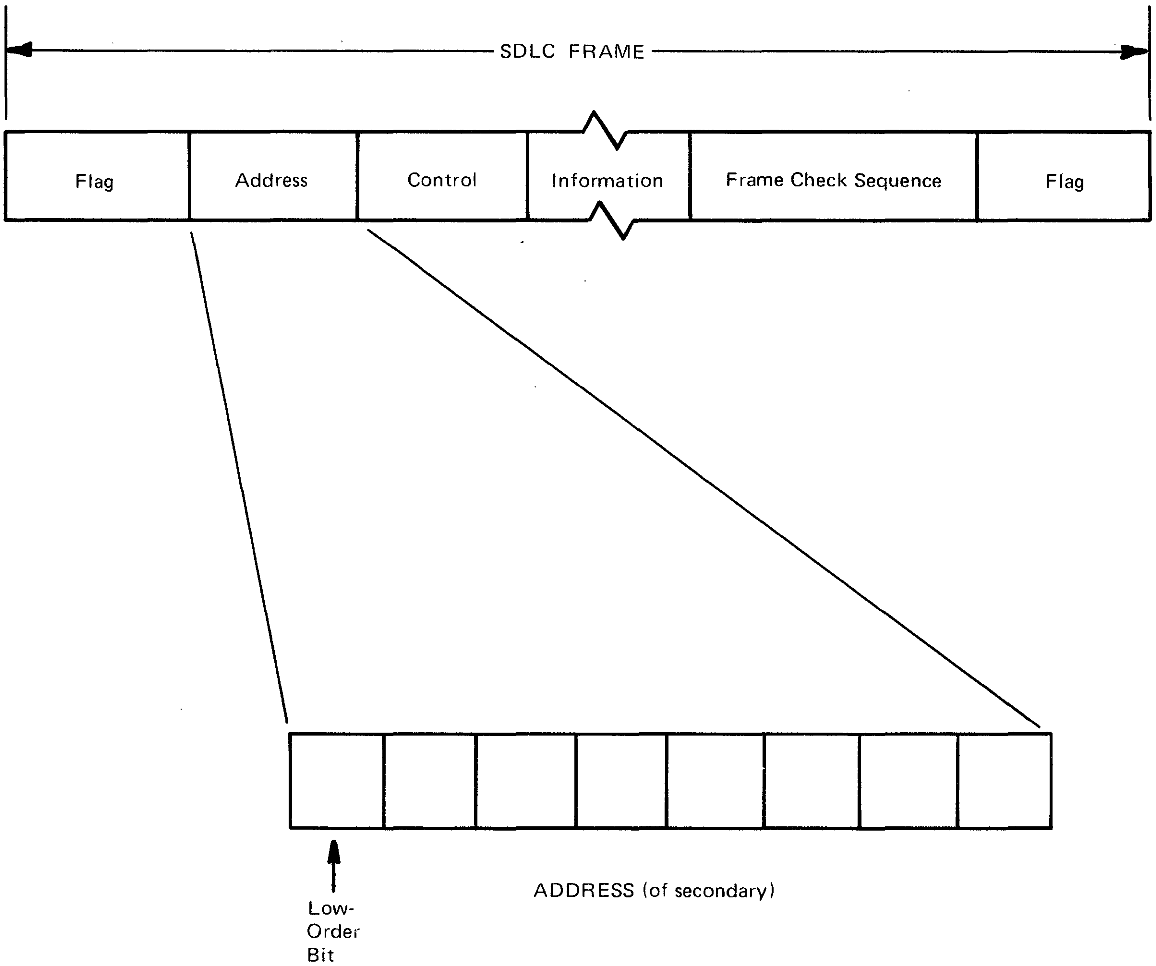


Figure 2-7. SDLC Frame: Address Field, As Transmitted

Control Field

Following the address field in an SDLC frame comes the control field. The control field defines the function of the frame. The control field can be in one of three formats (see Figure 2-8): unnumbered format, supervisory format, or information transfer format. Each format includes a special P/F bit among its 8 bits.

Unnumbered Format

Unnumbered-format frames are used for such functions as:

- Initializing secondary stations
- Controlling the response mode of secondary stations
- Reporting certain procedural errors

- Transferring data (when the data is not to be checked as to its location in a sequence of frames)

Supervisory Format

Frames with a control field of the supervisory format are used to assist in the transfer of information in that they are used to confirm preceding frames carrying information. The frames of the supervisory format do not carry information themselves. These frames are used to confirm received frames, convey ready or busy conditions, and to report frame numbering errors (indicating that a numbered information frame was received out of its proper sequence).

Information Transfer Format

Frames with a control field of the information transfer format are—as the name implies—the vehicle for information transfer in SDLC. The control field, besides indicating the format, contains send and receive counts (Ns and Nr), which are used to ensure that these frames are received in their proper order (Ns) and to confirm accepted information frames (Nr).

The Ns count indicates the number of the information frame within the sequence of information frames transmitted. The Nr count transmitted in a frame is the number (Ns) of the information frame that the station transmitting the Nr expects to receive next. "Frame Numbering," later in this chapter, gives more details on this process.

Note: The Ns count is present only in a C field of the information transfer format. An Nr count appears in C fields of the information transfer format and the supervisory format. Neither Nr nor Ns is present in a C field of the unnumbered format.

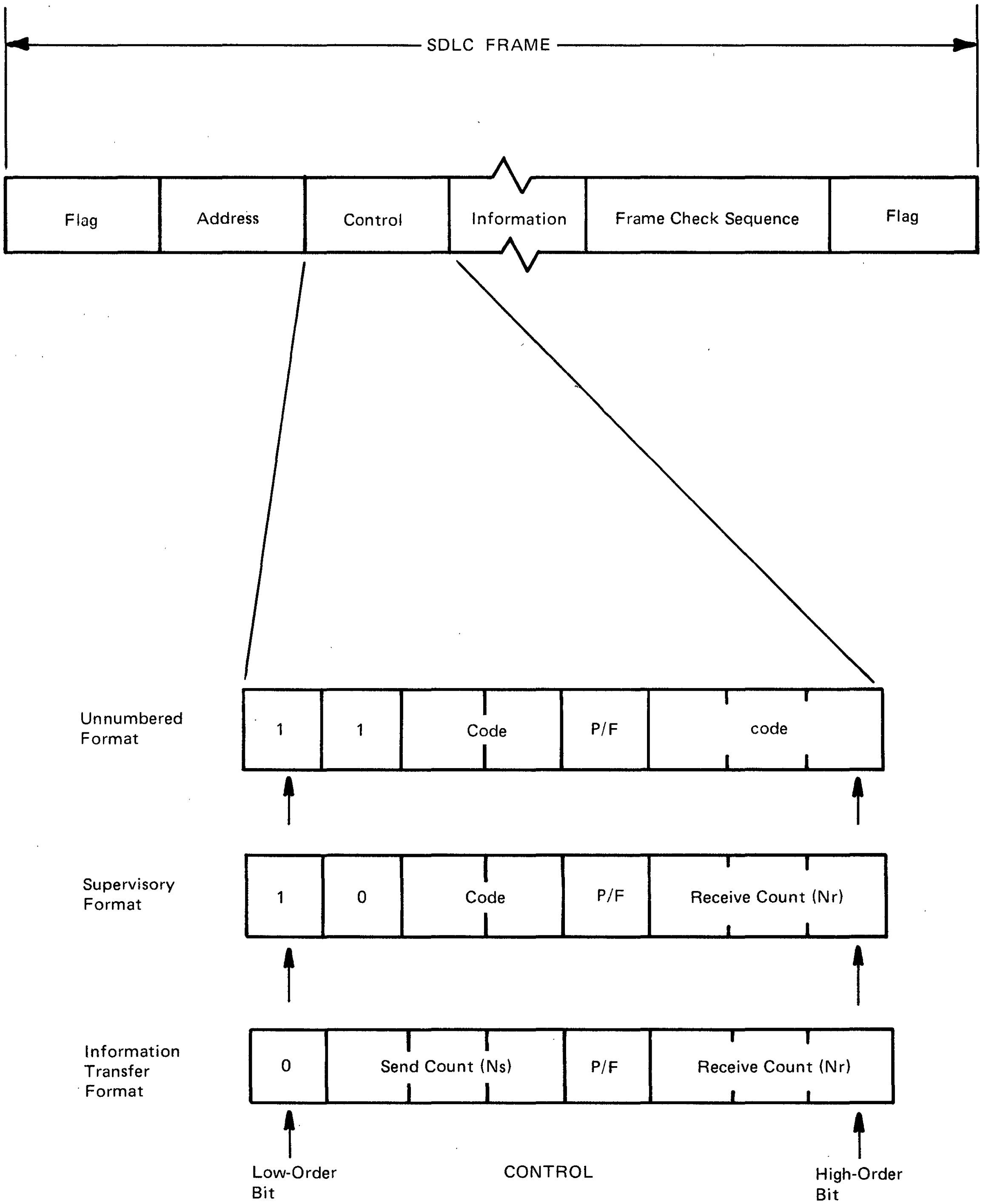


Figure 2-8. SDLC Frame: Control Field, As Transmitted

The P/F Bit

All three C field formats contain a poll/final (P/F) bit. A P (poll) bit is sent to a secondary station to require that it initiate transmission; an F (final) bit is sent to a primary station by a secondary station in the last frame of a transmission. (Do not confuse the F (final) bit with the F (flag) frame delimiter pattern.) Only one P bit may be outstanding (unanswered by an F bit) at one time on any of the data links described thus far.

Information Field

Following the control field, there may or may not be an information field. The supervisory format does not contain an information field (see Figure 2-9).

Data to be transferred on the data link is contained in the information field of a frame. The information field does not have a set length, but must be a multiple of 8 bits. In each 8-bit grouping (octet), the low-order bit is sent first and the high-order bit is sent last.

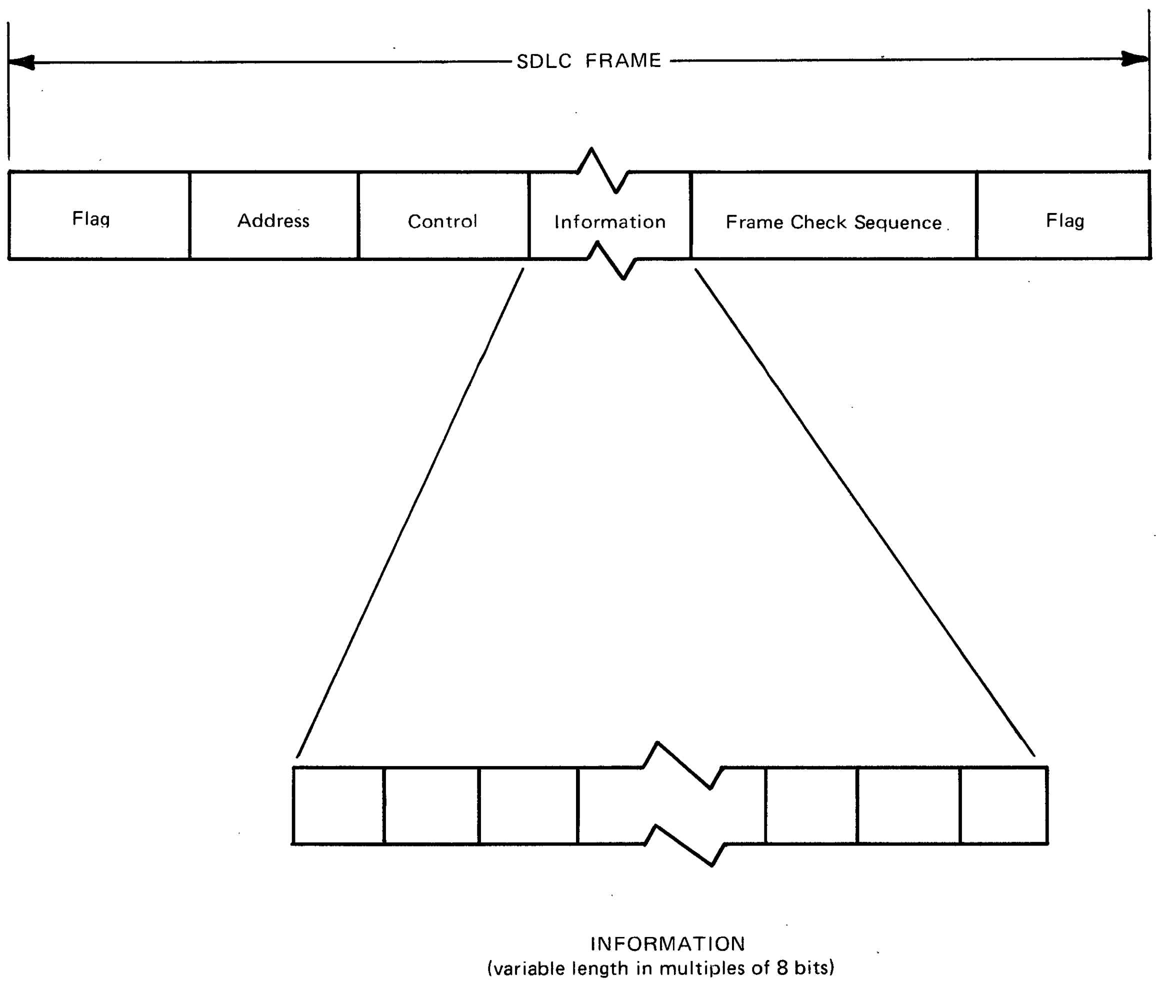


Figure 2-9. SDLC Frame: Information Field

Frame Check Sequence Field

Following the information field (or control field if no information field) is the frame check sequence field (see Figure 2-10). The purpose of the frame check sequence (FCS) field is to check the received frame for errors that may have been introduced by the communication channel. This field contains a 16-bit check sequence that is the result of a computation on the contents of the A, C, and I fields at the transmitter. The computation method used is called cyclic redundancy checking (CRC).

The receiver performs a similar computation and checks its results. The receiver accepts no frame that is found to be in error.

The FCS field is followed by the ending flag, closing the frame.

Refer to Appendix B for more details on the FCS field and on CRC.

Note: Appendix B is not intended as a text on CRC.

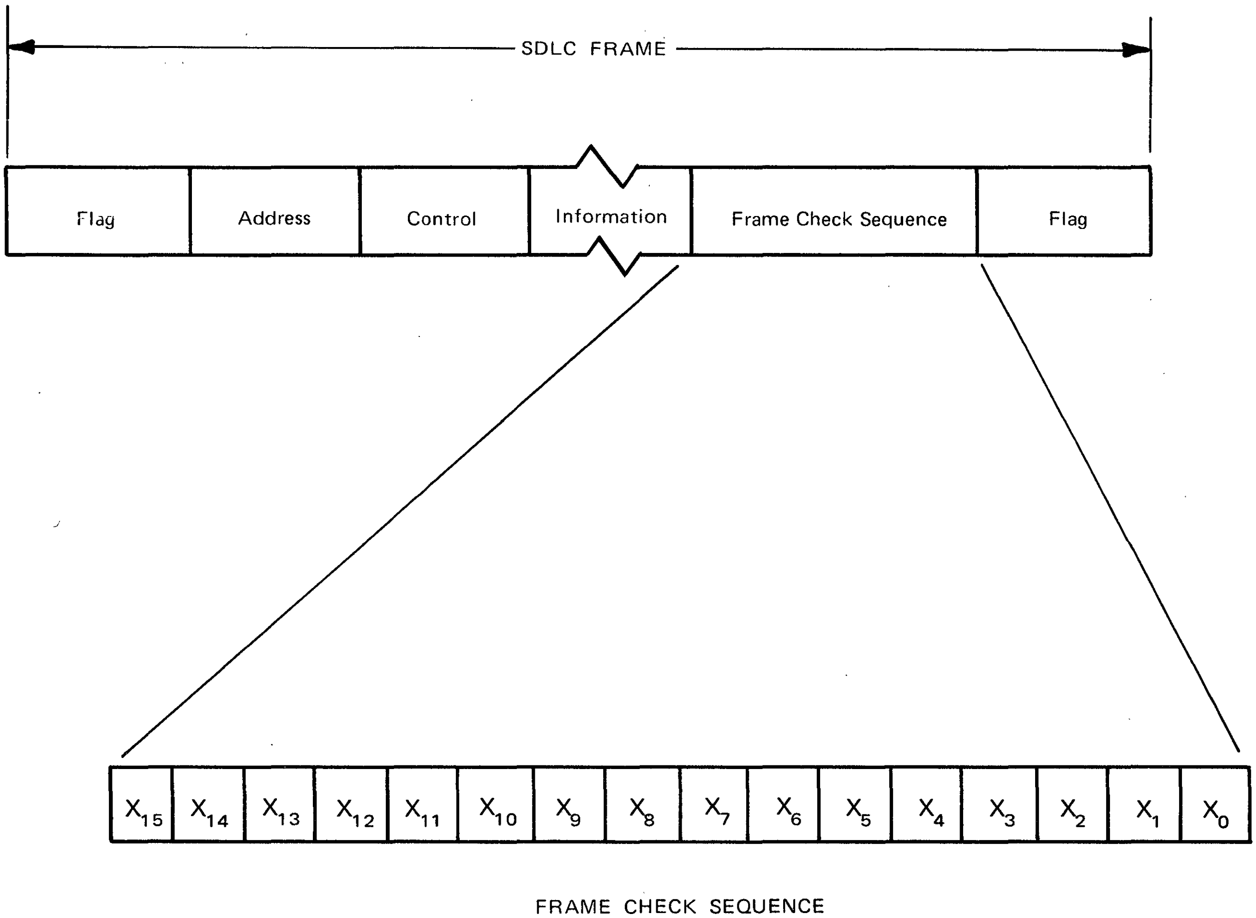


Figure 2-10. SDLC Frame: Frame Check Sequence Field, As Transmitted

Frame Numbering

A provision is made for transmitting a sequence of numbered information frames and making sure that they are received in the proper order.

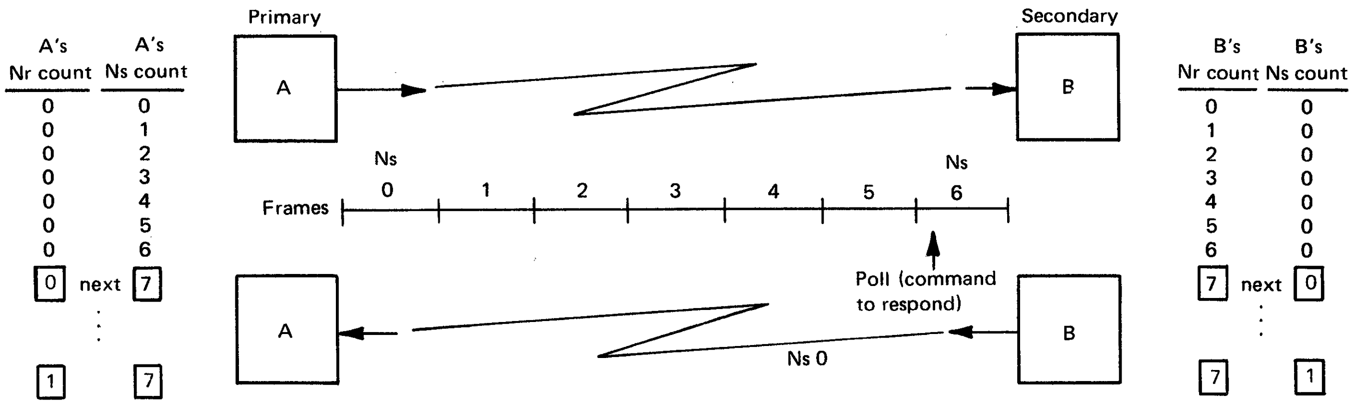
A station transmitting numbered information frames counts each such frame, and sends the count with the frame. This count is a sequence number known as Ns. This sequence number is checked at the receiver for missing or duplicated frames.

A station receiving numbered information frames accepts each numbered information frame that it receives (that is error-free and in-sequence) and advances its receive count for each such frame. The receiver count is called Nr. If the received frame is error-free, a receiving station's Nr count is the same as the Ns count that it will receive in the next numbered information frame; that is, a count of one greater than the Ns count of the last frame received. The receiver confirms accepted numbered information frames by returning its Nr count to the transmitting station.

The Nr count at the receiving station advances when a frame is checked and found to be error-free and in sequence; Nr then becomes the count of the "next-expected" frame and should agree with the next incoming Ns count. If the incoming Ns does not agree with Nr, the frame is out of sequence and Nr does not advance. Out-of-sequence frames are not accepted. The receiver does, however, accept the incoming Nr count (for confirmation purposes) if the out-of-sequence frame is otherwise error free.

The counting capacity for Nr and Ns is 8, using the digits 0 through 7. These counts "wrap around"; that is, 7 is sequentially followed by 0. Up to seven, unconfirmed, numbered information frames may be outstanding (transmitted but not confirmed) at the transmitter. All unconfirmed frames must be retained by the transmitter, because it may be necessary to retransmit some or all of them if transmission errors or buffering constraints occur. The reported Nr count is the number of the next frame that the receiver expects to receive, so if, at a checkpoint, it is not the same as the transmitter's next frame (Ns) number, some of the frames already sent must be retransmitted (see Figure 2-11).

The Nr and Ns counts of both stations are initialized to 0 by control of the primary station. At other times, the counts advance as numbered frames are sent and received.



If B responds to the poll with Nr =:	A may send Ns frames:
7 (as above, all frames check OK)	7, 0, 1, 2, 3, 4, 5 (continue)
6 (frame 6 discarded because of error)	6, 7, 0, 1, 2, 3, 4 (retransmit and continue)
5 (error on frame 5, 5 and 6 discarded)	5, 6, 7, 0, 1, 2, 3 (retransmit and continue)
4 (error on frame 4, 4-6 discarded)	4, 5, 6, 7, 0, 1, 2 (retransmit and continue)
3 (error on frame 3, 3-6 discarded)	3, 4, 5, 6, 7, 0, 1 (retransmit and continue)
2 (error on frame 2, 2-6 discarded)	2, 3, 4, 5, 6, 7, 0 (retransmit and continue)
1 (error on frame 1, 1-6 discarded)	1, 2, 3, 4, 5, 6, 7 (retransmit and continue)
0 (error on frame 0, no frames accepted)	0, 1, 2, 3, 4, 5, 6 (retransmit)

Figure 2-11. Numbered Information Frames

Zero Insertion

A frame is identifiable because it begins and ends with a flag and contains only nonflag bit patterns between the flags. This characteristic does not restrict the contents of a frame because SDLC procedures require that a binary 0 must be inserted by the transmitter after any succession of five contiguous 1's within the frame (see Figure 2-7). Thus, no pattern of 01111110 (a flag) is ever transmitted between the beginning and ending flags. Zero bit insertion is disabled when the flag is being transmitted. After testing for flag recognition, the receiver removes a 0 that follows five contiguous 1's (see Figure 2-12). Inserted and removed 0's are not included in the frame check sequence computation. (A 1 that follows five 1's is not removed.)

Note: When invert-on-zero transmission coding is used, zero insertion eliminates the remaining possibility of prolonged transitionless periods (continuous 1 bits) in the active state. See "Bit Synchronization and Invert-On-Zero Coding" in Chapter 1.

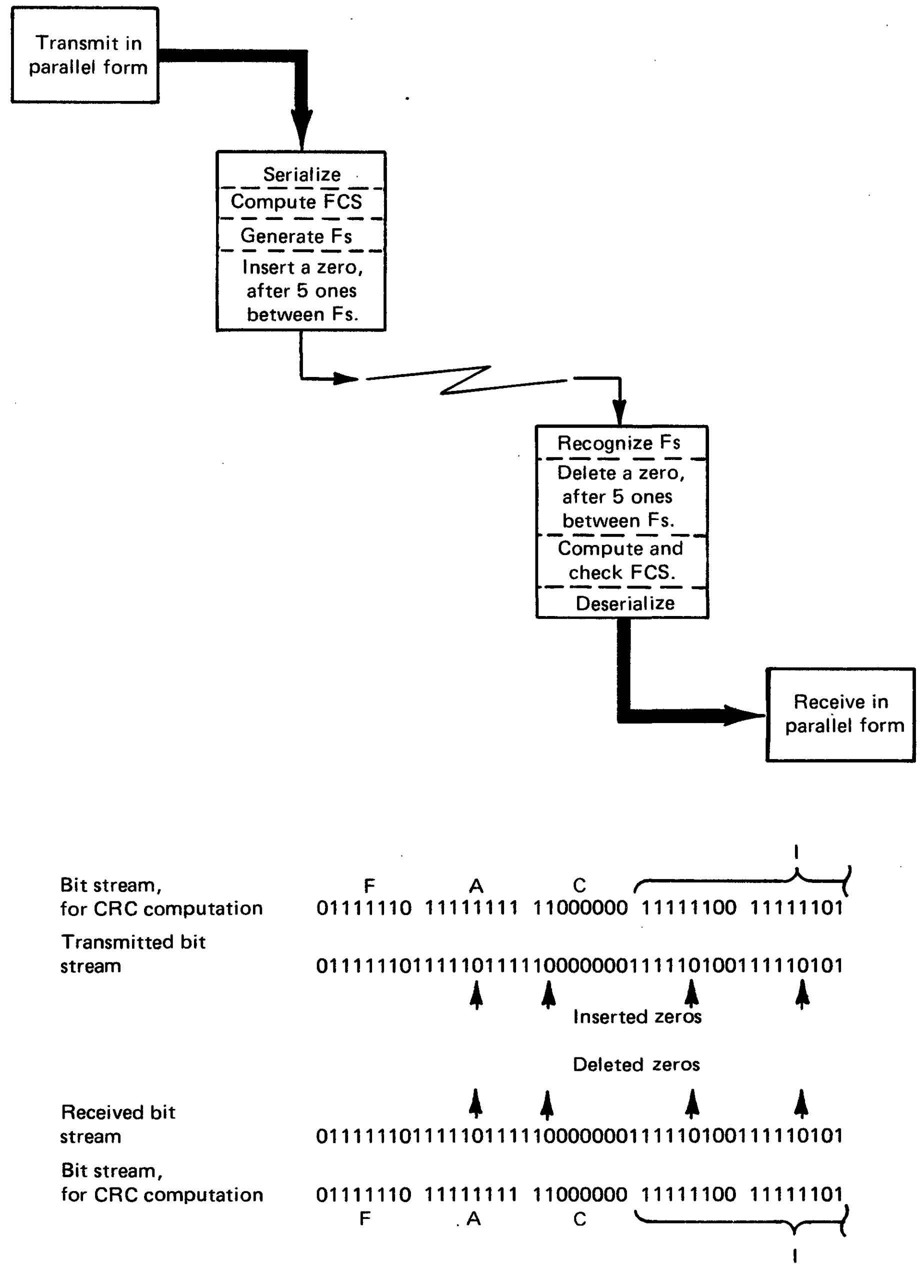


Figure 2-12. Zero Insertion and Deletion

Timeouts

The primary station is responsible for the orderly, continuous operation of a data link, and it must check for responses to its commands. Two basic timeouts are operated by a primary station for these purposes: (1) idle detect and (2) nonproductive receive.

Idle Detect

When the primary station transmits a frame with the P bit on in the C field, a response is expected to be initiated within a certain period of time. In two-way alternate operation, the data link is normally in the idle state when no transmission is taking place. If the idle state (or nonresponse condition) continues past the time when a response should have been initiated (for example, if the secondary station does not respond to a frame), the primary station detects the idle condition and should initiate recovery action.

The interval that should be allowed before recovery action includes:

1. propagation time to the secondary station
2. clear-to-send time at the secondary station DCE
3. appropriate time for secondary station processing
4. propagation time from the secondary station

Factors (1), (2), and (4) vary as follows:

Communication Channel (see Figure 2-13)	*Secondary Station DCE Clear-to-Send*	*Approx. Two-Way Propagation Time (See Figure 2-13)*
Switched (through local exchange only) or very short (distance) nonswitched line	0 ms to 25 ms	2 ms per 15 miles (X)
Long (distance) duplex (nonswitched line)	0 ms to 25 ms	2 ms per 150 miles + 24 ms (Y)
Long (distance) half-duplex (switched or nonswitched)	75 ms to 250 ms	2 ms per 150 miles + 24 ms (Y)
Satellite duplex (switched or nonswitched)	0 ms to 250 ms	600 ms + 24 ms (Z)

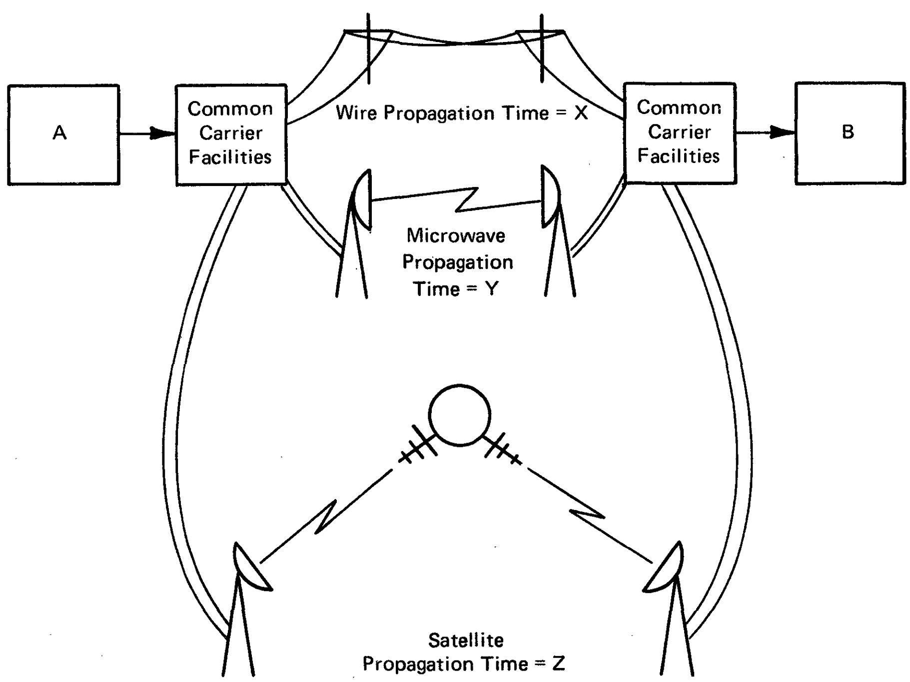


Figure 2-13. Examples of Transmission Facilities

With each type of communication configuration, the minimum timeout includes an allowance for processing time at the secondary station. The sum of other times may be as great as 850-900 milliseconds (for a satellite data link). If a response is received or being received before the timeout expires, the timeout is reset.

Nonproductive Receive

When bits are being received that do not result in frames, a nonproductive receive condition exists. This condition could be caused by secondary station malfunctions that cause continuous transmission. The primary station must provide a timeout period when nonproductive receive occurs. The usual time period is in the range of 3 to 30 seconds. If the nonproductive receive condition continues after the timeout, the problem is normally not recoverable at the data link control level and must be handled by some method above the data link control level.

Abort Conditions

The act of prematurely terminating the transmission of a frame is called "abort".

The transmitting station aborts by sending a minimum of seven consecutive binary 1's with no zero insertion (see Figure 2-14). (Unintentional abort is prevented by zero insertion.) The abort pattern terminates the frame without an FCS field or an ending flag.

Following transmission of the abort, the link may be permitted to go to idle (15 or more contiguous 1's) or may remain in the active state.

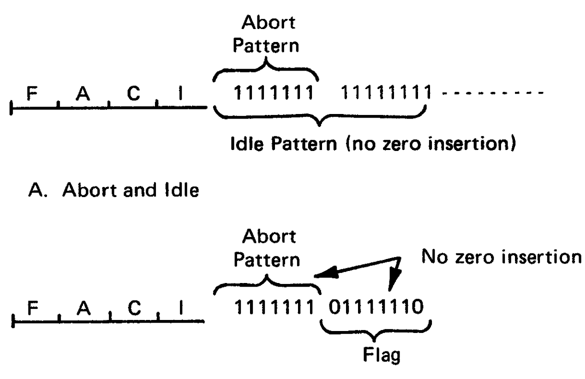


Figure 2-14. Transmitting-Station Aborts

Either a primary or secondary station may abort. An abort pattern of seven 1's may be followed by eight (minimum) additional 1's (a total of at least 15 contiguous 1's), which idles the data link as long as the 1's continue, or it may be followed by a frame. Seven to fourteen 1's constitute an abort; fifteen or more 1's constitute an idle.

Recovery from Data Link Impasse

There are two methods that are used to recover from a data link impasse: Link-Level Recovery and Higher Level Recovery.

Link-Level Recovery

At the data link level, SDLC procedures detect discrepancies that may be recovered from by retry or retransmission. For example:

- A busy station is temporarily unable to continue to receive. It reports this condition to the transmitting station.
- A received Nr count does not confirm the appropriate numbered information frames previously transmitted. Retransmission is initiated.
- A receiving station discards a frame because: there is a CRC error, a numbered frame is out of numerical order, an I (information transfer) frame is not accepted because of a busy condition, the ending flag is not displaced from the beginning flag by a multiple of 8 bits, or a frame is less than 32 bits long.
- A response to a poll is not received; the poll is normally repeated.
- An attempt to bring a secondary station online does not succeed; the command is repeated.

Retries and retransmissions may be counted by a using system to detect that the situation is not considered to be link-level recoverable. The counting of retry or retransmission attempts is not specified by SDLC procedures. Usually, they are counted within the DTE and, at some planned number "n," correct station action is reported as unrecoverable at the data link level. Among those actions that should be retried are attempts to:

- Obtain acknowledgement of a command
- Resume communication with a busy station
- Achieve initial, online status at a secondary station
- Initiate active communication at a secondary station

Higher-Level Recovery

Link-level error detection applies to the A, C, I, and FCS fields of the frame. Some detected errors cannot be recovered from at the link-level; for example:

- If a secondary station responds by rejecting a command with which the station it is not compatible, only an acceptable alternative command can relieve its error condition. Intervention from a higher level is required to analyze and act upon the status report in the secondary station response. See "FRMR" under "Command and Response Definitions" in Chapter 3.
- If the transmitting station has aborted transmission because of an internal malfunction or an expended retry count, intervention from a higher level is required to analyze and act upon the situation.
- If a secondary station response to the exchange of station identification (see "SDLC on a Switched Data Link" in Chapter 3) contains the wrong identification, intervention from a higher level is required to analyze and act upon the situation.

The type of intervention required depends upon the station's decision-making power at a level higher than the data link level. At a terminal, for example, operator intervention may be needed.

Chapter 3. SDLC: Final Pieces, Applications, and Examples

This chapter provides definitions of various parts of SDLC not covered in Chapter 2. These definitions are followed by (1) descriptions of applications and (2) examples.

Secondary-Station Mode Definitions

A secondary station may be in one of three modes: initialization mode, normal response mode, or normal disconnected mode.

- *Initialization Mode:* Procedures for initialization mode are specified by the using system components.

- *Normal Response Mode (NRM):* A secondary station in NRM (normal response mode) does not initiate unsolicited transmissions. It transmits only in response to a poll (a frame received from the primary station, with the P bit on in the C field). The secondary station response may consist of one or more frames. The F bit will be on only in the last response frame of this sequence. A primary station will not issue another P bit to any secondary station until it receives the F bit response to an outstanding P bit or a timeout has completed.

- *Normal Disconnected Mode (NDM):* A secondary station that receives and accepts a DISC (Disconnect) command assumes NDM; it also assumes NDM at these times:
  - When power is turned on, or when the station is enabled for data link operation
  - Following a transient disabling condition (such as a power failure)
  - When a switched connection is made

A secondary station is in NDM when it is offline. In this mode, a secondary station will respond only as the result of receiving a command with the P bit on and may accept only a TEST, XID, CFGR, SNRM, or SIM command from the primary station. One of these commands which is not accepted, or any other command with the P bit on, cause a disconnected secondary station to respond with a disconnect mode status or initialization request.

Command and Response Definitions

The following paragraphs describe the commands and responses contained in the C field of an SDLC frame. When a frame is received by a secondary station, it is a command; when it is received by a primary station, it is a response. Figure 3-1 summarizes commands and responses; each is described in more detail in the following text.

U (Unnumbered) Format

A C field in the unnumbered format (see Figure 2-8) has the 2 low-order bits on (11). (These are the first C field bits sent.) Unnumbered frames are not sequence-checked and do not use Nr or Ns; mode-setting unnumbered commands reset Nr and Ns to 0. Excluding the P/F bit, the other 5 C field bits are available for encoding the commands and responses listed here (see Figure 3-1):

UI	unnumbered information frame (command or response) (formerly NSI—nonsequenced information frame)
SNRM	set normal response mode (mode-setting command)
DISC	disconnect (command)
RD	request disconnect (response) (formerly RQD-request disconnect)
UA	unnumbered acknowledgement (response) (formerly NSA—nonsequenced acknowledgement)
RIM	request initialization mode (response) (formerly RQI—request for initialization)
SIM	set initialization mode (mode-setting command)
DM	disconnect mode (response) (formerly ROL—request online)
FRMR	frame reject (response) (formerly CMDR—command reject)
TEST	test (command or response)
XID	exchange station identification (command or response)
UP	unnumbered poll (command) (formerly NSP Non-Sequenced Poll)
BCN	beacon (response)
CFGR	configure (command or response)

Format (Note 1)	Binary Configuration (Sent Last → Sent First)	Acronym	Command	Response	I-Field Prohibited	Resets Nr and Ns	Confirms frames through Nr-1	Defining Characteristics
U	000 P/F 0011	UI	X	X				Unnumbered command or response that carries information.
	000 F 0111	RIM		X	X			Initialization needed; expect SIM.
	000 P 0111	SIM	X		X	X		Set initialization mode; the using system prescribes the procedures.
	100 P 0011	SNRM	X		X	X		Set normal response mode; transmit on command only.
	000 F 1111	DM		X	X			This station is in disconnected mode.
	010 P 0011	DISC	X		X			Do not transmit or receive information.
	011 F 0011	UA		X	X			Acknowledgement for unnumbered commands (SNRM, DISC, SIM).
	100 F 0111	FRMR		X				Invalid frame received; Must receive SNRM, DISC, or SIM.
	111 F 1111	BCN		X	X			Signals loss of input.
	110 P/F 0111	CFGR	X	X				Contains function descriptor in information field.
	010 F 0011	RD		X	X			This station wants to disconnect.
	101 P/F 1111	XID	X	X				Idendification in information field.
	001 P 0011	UP	X		X			Response optional if P bit not on.
	111 P/F 0011	TEST	X	X				Test pattern in information field.
S	Nr P/F 0001	RR	X	X	X		X	Ready to receive.
	Nr P/F 0101	RNR	X	X	X		X	Not ready to receive.
	Nr P/F 1001	REJ	X	X	X		X	Transmit or retransmit, starting with frame Nr.
I	Nr P/F Ns 0	I	X	X			X	Sequenced I-frame.

Note: U=unnumbered, S=supervisory, I=information.

Figure 3-1. Summary of Command or Response C Fields

Note: For descriptions of UP, BCN, and CFGR, refer to "SDLC In a Loop Configuration" later in this chapter.

- *UI (Unnumbered Information):* As a command or a response, a UI frame is the vehicle for transmitting unnumbered information.

- *SNRM (Set Normal Response Mode):* This command places the secondary station in normal response mode (NRM) for information transfer. UA is the expected response. The primary and secondary station Nr and Ns counts are reset to 0. No unsolicited transmissions are allowed from a secondary station that is in NRM. The secondary station remains in NRM until it receives a DISC or SIM command.

- *DISC (Disconnect):* This command terminates other modes and places the receiving (secondary) station in disconnected mode. The expected response is UA. (A switched data link station then disconnects, which is similar to hanging up a telephone.) A secondary station in disconnected mode cannot receive or transmit information or supervisory frames.

- *RD (Request Disconnect):* This request is sent by a secondary station desiring to be disconnected (by a DISC command).

- *UA (Unnumbered Acknowledgment):* This is the affirmative response to an SNRM, DISC, or SIM command.

- *RIM (Request Initialization Mode):* An RIM frame is transmitted by a secondary station to notify the primary station of the need for an SIM command.

- *SIM (Set Initialization Mode):* This command initiates system-specified procedures for the purpose of initializing link-level functions. UA is the expected response. The primary and secondary station Nr and Ns counts are reset to 0.

- *DM (Disconnect Mode):* This response is transmitted by a secondary station to indicate that it is in disconnected mode.

- *FRMR (Frame Reject):* This response is transmitted by a secondary station in NRM only when it receives an invalid frame. A received frame may be invalid for several reasons:
  - It's C Field is not implemented at the receiving station. This category includes unassigned commands.
  - The information field is too long to fit into the receiving station buffers. This use is optional.
  - The C field in the received frame does not allow an I field to be received with the frame.
  - The Nr that was received from the primary station is invalid.

The secondary station cannot release itself from the FRMR condition, nor does it act upon the frame that caused the condition. It repeats FRMR whenever it responds, except to an acceptable mode-setting command: SNRM, DISC, or SIM that resets the FRMR condition.

The secondary station sends an information field containing status as part of the FRMR response frame (see Figure 3-2).

- *TEST (Test):* As a command, a TEST frame may be sent to a secondary station in any mode to solicit a TEST response. If an information field is included with the command, it is returned in the response. If the secondary station has insufficient buffering available for the information field, a TEST response with no information field is returned.

- *XID (Exchange Station Identification):* As a command, XID solicits the identification of the receiving (secondary) station. An information field may be included in the frame to convey identification of the transmitting (primary) station. An XID response is required from the secondary station. An information field in the response may be used for identification of the responding secondary station.

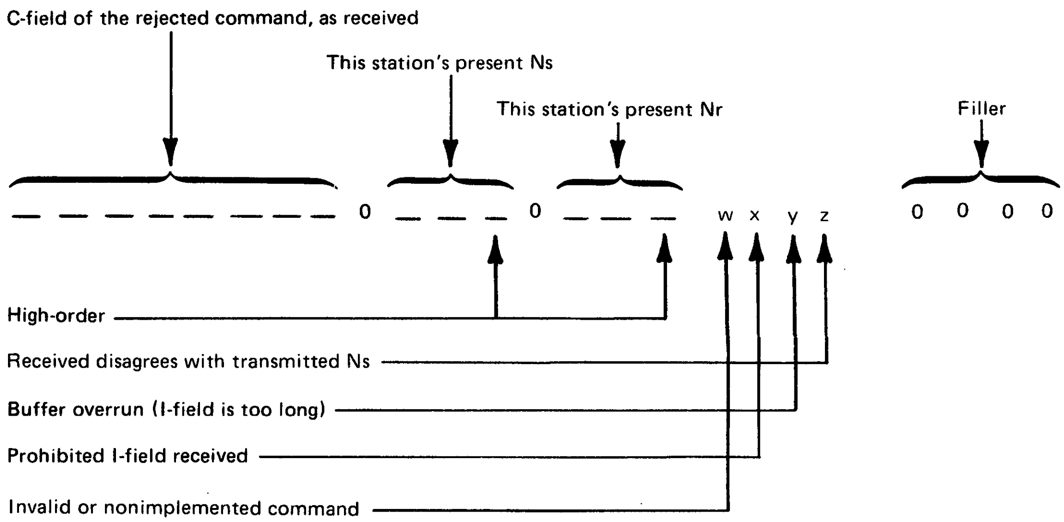


Figure 3-2. Information Field of the FRMR Response, as Transmitted

S (Supervisory) Format

Frames with the S format may be used to acknowledge receipt of I frames and to control information interchange. No information field is permitted in the S frame itself. The 2 low-order bits of the C field in this format (the first 2 bits sent) are 1 and 0 (binary 10) (see Figure 2-8). Excluding the 4 bits for P/F and the Nr count, 2 bits remain for encoding the commands and responses of the S format. These commands and responses are (see Figure 3-1):

RR	receive ready (command or response)
RNR	receive not ready (command or response)
REJ	reject (command or response)

- *RR (Receive Ready):* Sent by either a primary or secondary station, RR confirms numbered frames through Nr-1 and indicates that the originating station is ready to receive.

- *RNR (Receive Not Ready):* Sent by either a primary or secondary station, RNR indicates a temporarily busy condition due to buffering or other internal constraints.

As a command or response, RNR confirms numbered information frames through Nr-1 and indicates that frame Nr is expected next.

A secondary station reports the clearing of an RNR condition by transmitting an I frame with the F bit on or an RR or REJ frame with the F bit on or off.

A primary station indicates the clearing of an RNR condition by transmitting an I frame with the P bit on or an RR or REJ frame with the P bit on or off.

- *REJ (Reject):* This command/response may be transmitted to request transmission or retransmission of numbered information frames. REJ confirms frames through Nr-1 and requests the retransmission of numbered information frames starting at the Nr contained in the REJ frame.

An REJ command or response may be interspersed in the sequence of transmitted frames. The REJ condition is cleared when the requested frame or a mode setting command has been correctly received.

I (Information) Format

I (Information) frames are numbered. The Ns count provides for numbering the frame being sent and the Nr provides acknowledgement for the I frames received. When duplex information exchange is in continual process, each station reports its current Ns and/or Nr counts in each I or S frame exchanged.

The expected acknowledgment is an S or I format frame whose Nr count confirms correctly received frames. (Frames of the S format may be interspersed with I format frames, as needed.)

SDLC On a Switched Data Link

One of the participating stations on a switched data link must act as a primary station. The other station must assume the secondary station role. The acting primary station manages the data link; it initiates and controls the information exchange.

The SDLC procedures allow the stations to identify themselves to each other using an XID command/response exchange. The use of XID is *not* restricted to a switched data link.

The SDLC procedures for a switched data link are basically the same as for a nonswitched, point-to-point, half-duplex data link. An "inactivity" timeout (on conditions similar to nonproductive receive, described under "Timeouts" in Chapter 2) is required to alert switched stations of link inactivity. If the timeout expires at either station, that station may attempt to alert the other. After a user-specified number of unsuccessful attempts, the station with the expired timeout disconnects the switched communications channel by going "on hook". This is equivalent to "hanging up" the handset in a telephone system.

SDLC In a Loop Configuration

For some applications, a loop configuration may be preferable for the interconnection of multiple secondary stations to the primary station.

In a loop, a one-way communications channel originates at the transmitting port of the primary station, connects one or more secondary stations in a serial fashion, and then terminates back at the receive port of the primary station (see Figure 3-3).

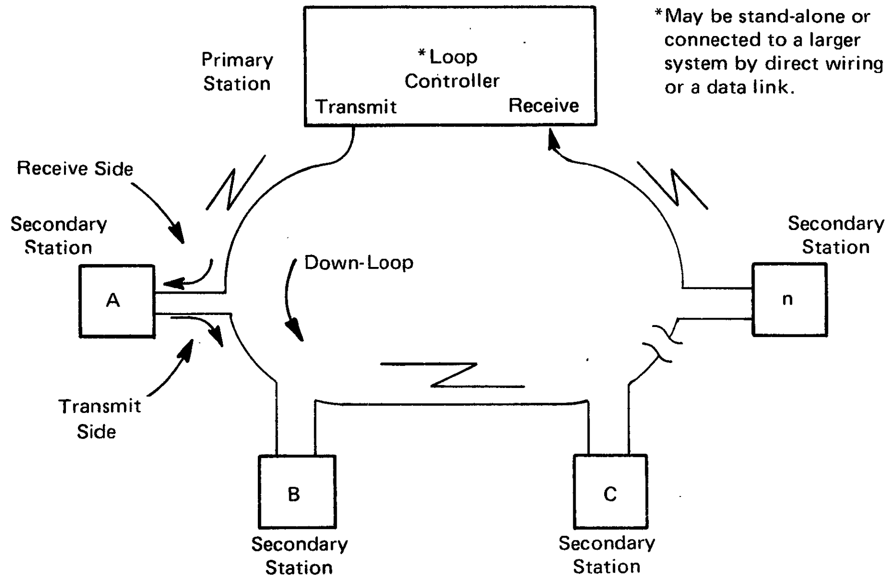


Figure 3-3. Loop Configuration

Loop Operation

The loop configuration is logically operated as a half-duplex data link. The difference between the loop and a regular half-duplex link is that, in a loop, all the transmissions travel the same direction on the communication channel.

In a loop configuration, only one station transmits at any one time, the primary station or a secondary station. The secondary stations transmit sequentially, as required, by their order on the link.

Primary Station Transmitting

The primary station sends command frames that are addressed to any or all the secondary stations on the loop. Each frame transmitted by the primary carries the address of the secondary station or stations to which the frame is directed.

Every secondary station on the loop decodes the address field of each frame transmitted by the primary station and serves as a repeater for all primary transmissions to the down-loop stations. (See Figure 3-4.) When a secondary detects a frame with its address (station address, group address, or broadcast address), it accepts this frame from the loop for processing. This frame is also passed to down-loop stations.

When the primary has finished transmitting frames, it follows the last flag with a minimum of eight consecutive 0's (a flag followed by eight 0's is a turnaround sequence). It then transmits continuous 1's which create a go-ahead sequence (01111111). In this way, the primary totally controls all loop communications. The primary, while continuing to transmit 1's, goes into receive mode.

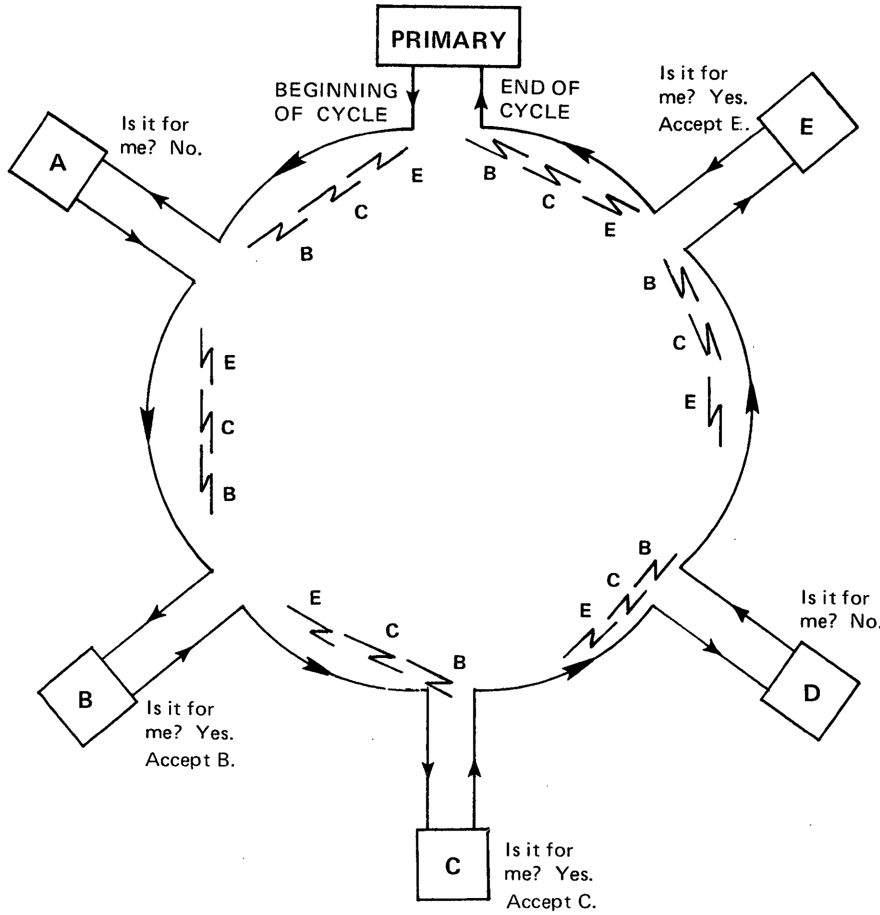


Figure 3-4. SDLC Loop Exchanges: Primary Station Transmitting

Secondary Stations Transmitting

In this description, the primary station has completed transmission, has placed itself in receive mode, and is transmitting continuous 1's (go-ahead sequence).

Before transmitting on the loop, a secondary station must have received a frame addressed to it with the P bit on, or received a UP-command frame with the P bit off. In the case of a UP frame with the P bit off, a secondary station transmission is optional if a response is not required for acknowledgement or status purposes.

The first down-loop secondary detects the go-ahead sequence. If the secondary has a response to send, it changes the seventh 1-bit to a 0-bit, thereby creating a flag. It follows the flag with a response frame or frames that contain its individual address. Following its last frame, it then again becomes a repeater, forwarding the continuous 1-bits it receives from the primary station.

The next down-loop secondary operates similarly when it detects the go-ahead sequence, which results from the continuous 1-bits.

This procedure continues until the last down-loop secondary to transmit completes its transmission. (See Figure 3-5.)

The cycle completes when the primary receives its own turnaround sequence and a series of response frames from all the secondary stations that responded, if any.

Note 1: If a secondary does not convert the go-ahead sequence it receives after the turnaround sequence into a flag, it forfeits this opportunity to transmit.

Note 2: To abort, a secondary only needs to terminate transmission and pass on the incoming 1-bits. It need not generate its own abort sequence.

Note 3: If when transmitting a secondary receives 8 contiguous 0-bits, it must terminate its transmission. This is called the shut-off sequence and is originated by the primary.

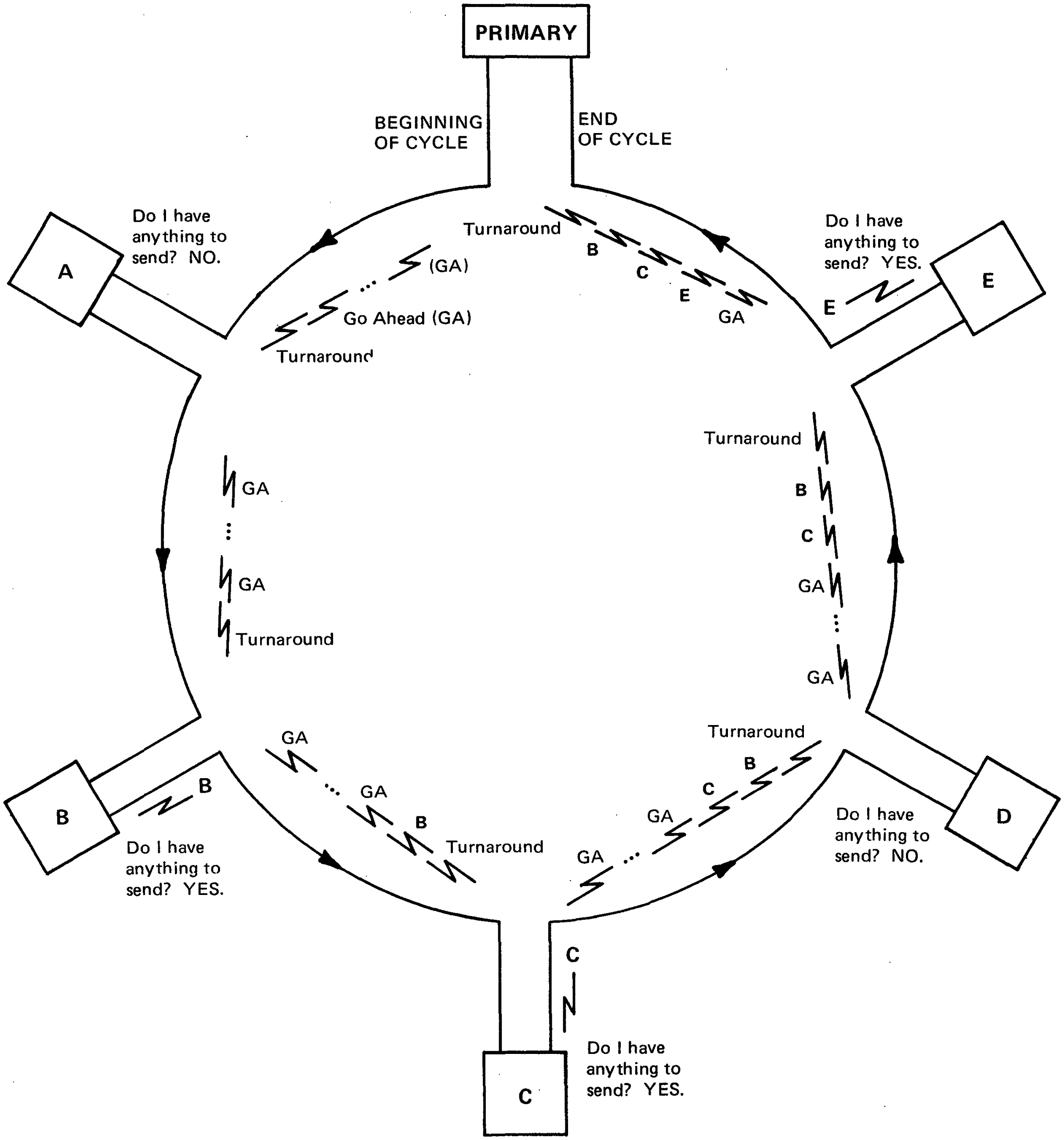


Figure 3-5. SDLC Loop Exchanges: Secondary Stations Transmitting

Loop Commands

Unnumbered Polls (UP)

The unnumbered poll command with the P bit set to 0 provides a function that is particularly useful in loop configurations. While a poll of all addressed (station, group, or broadcast) secondary stations is being performed, a response transmission is optional and depends on the actual need for each secondary station to transmit.

UP With P Bit Set To 0: An optional response poll (UP with P bit set to 0) is sent out by the primary station to poll one station, a group of stations, or all the stations on the loop. A response is not necessarily required. Individual secondary stations will respond if one of the following conditions exists:

- The secondary has received a numbered I frame(s) since the last time it responded. It must send a confirming Nr to the primary signifying acceptance of the frame(s).

- The secondary has received an unnumbered command that requires a response since the last time it responded.

- An exception condition has occurred since a previous response opportunity and an appropriate response frame is pending transmission or retransmission.

  Note: Exception conditions are problems that occur because of transmission errors, station malfunctions, or operational constraints. Examples include busy conditions; frame numbering errors; and frames rejected because of invalid control fields, invalid Nr counts, or overlong information fields.

- The secondary has changed from ready-to-receive to not-ready-to-receive since the last time it responded.

- The secondary has changed from not-ready-to-receive to ready-to-receive since the last time it responded.

- The primary has not acknowledged an I frame(s) transmitted by the secondary and the secondary retransmits the unacknowledged I frame(s).

- The secondary is in disconnected mode and sends a DM response to request a set mode command (SNRM) to become operational.

If none of the preceding conditions exists, the response is optional and may be sent if information frames are pending initial transmission.

UP with P Bit Set to 1: A mandatory response poll (UP with P bit set to 1) is addressed to an individual station, group of stations, or all of the stations on a loop. It serves to perform an unnumbered poll of the addressed secondary stations. The stations that are addressed by a mandatory response poll *must* respond.

A polled station will respond either with frames it has waiting to transmit or retransmit, or, if no such frames exist, with another appropriate response (RR, RNR, or DM).

Configure (CFGR)

The configure command contains a function descriptor (a subcommand) in a single-byte information field. (Receipt of the CFGR command is acknowledged by the secondary station when it transmits a configure response.) If the last bit of the first byte in the information field (the low-order bit) is set to 1, a specified function is to be set. If the low-order bit is set to 0, the function is to be cleared (reset).

The following is a list of the function subcommands that can be placed in the configure command's function field:

1. Clear 00000000
   Clear causes all functions that were previously set by the configure command to be cleared by the secondary.

2. Beacon Test 0000001X
   Beacon test causes the secondary receiving it to suppress the transmission of the carrier, or to begin transmitting the carrier again after suppressing it. If X is a 1-bit, the secondary is to suppress transmission. If X is a 0-bit, the secondary is to resume transmission.

   Note: If the carrier is ordered suppressed at a secondary station, the next down-loop secondary will transmit beacon responses indicating loss of the carrier.

3. Monitor Mode 0000010X
   This command causes the addressed secondary to place itself in a monitor mode, that is, a receive-only mode. Once a secondary is in the monitor mode, it cannot transmit until it receives a monitor mode clear (00000100) or clear (00000000).

4. Wrap 0000100X
   The wrap command causes the secondary station to wrap its transmission output directly into its receiving input. This effectively places the secondary station offline for the duration of the wrap test.

5. Self-Test 0000101X
   The self test function descriptor causes the addressed secondary to begin a series of internal diagnostic tests. The secondary will not respond until the tests are complete. If the poll bit in the configure command was set to 1, the secondary will respond following completion of the internal tests at its earliest response opportunity. However, if the poll bit in the configure command was set to 0, the secondary will, following completion of the test, respond to the next poll type frame it receives. All other transmissions are ignored by the secondary while it is testing after receiving a self test command.

   The secondary indicates the results of the tests by setting the low-order bit (X) in the information field of its response to either 1 or 0. A 1 indicates that the tests were unsuccessful. A 0 indicates that they were successful. Despite the results of the tests, the test function is reset (cleared).

6. Modified Link Test 0000110X
   This function descriptor (if incorporated) provides an alternative form of link test to that previously described for the TEST command and response (See "TEST" under "Unnumbered Format" earlier in this chapter). If the

modified-link-test function is set (X bit set to 1), the secondary station will respond to a TEST command with a TEST response that has an information field containing the first byte of the TEST command information field repeated n times. The number n is implementation dependent. If the TEST command has no information field, the TEST response will contain n bytes; the configuration of these bytes is implementation dependent. If the modified-link-test function has not been set, the secondary station will respond to a TEST command, with or without an information field, with a TEST response with a zero-length information field.

Loop Responses

Beacon (BCN)

When a secondary station detects the loss of communication at its input, it begins to transmit a beacon response. This allows the primary station to locate the problem in the loop and to take appropriate action. In the beacon response, the F bit can be either a 1 or a 0. As soon as the input resumes normal status (the problem that caused the secondary to beacon is solved), the secondary stops transmitting the beacon response.

Configure (CFGR)

The configure response is transmitted by secondary stations only in response to a configure command. The structure of the configure responses are identical to those of the configure commands. If the low-order bit in the information field of the response is set to 1, the configure function in the information field has been set. If the low-order bit in the information field is set to 0, the configure function in the information field has been cleared. The function described in the first 7 bits of the information field are the same as the configure function that the secondary station is responding to.

Note: When performing *some* configure functions (for example, self-test) the secondary may not respond to configure commands until the function is completed.

Examples.

These examples present some SDLC exchanges of control and information. (These examples are not necessarily restricted to the configuration in which they are shown.) The symbolic format for the transmission shown, following, is:

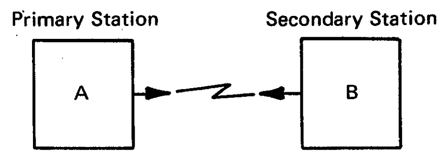
A, C/R (0) P/F (0)

- address — A
- command or response — C/R
- Ns count, if required; hyphen (-) if not required — (0)
- *poll or final bit, as appropriate — P/F
- Nr count, if required — (0)

*P=poll bit on (primary)
F=final bit on (secondary)
$\bar{P}$=poll bit off (primary)
$\bar{F}$=final bit off (secondary)

Time progresses downward in the following charts; trailing vertical lines indicate a duration of I-field transmission. Transmission order of the A and C fields is left-to-right, regardless of the direction of the arrow.

Point-to-Point Half-Duplex Exchanges



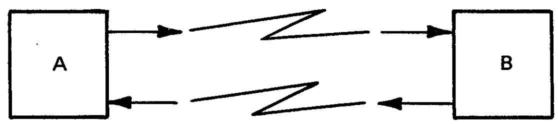
	Primary Station	Secondary Station	
Negative response to poll	B,SNRM-P →		A sets B's response mode. Nr and Ns counts are reset to 0.
		← B,UA-F	B acknowledges.
	B,RR-P(0) →		A polls B for transmission.
		← B,RR-F(0)	B has nothing to transmit. (B remains in NRM.)
Affirmative response to poll; secondary station sends numbered frames	B,RR-P(0) →		A polls B for transmission.
		← B,I(0)F(0)	B sends final I-frame.
	B,RR-P(1) →		A confirms frame 0 and polls B for transmission.
		← B,I(1)$\bar{F}$(0)	B sends numbered I-frames.
		← B,I(2)$\bar{F}$(0)	
		← B,I(3)F(0)	B sends final I-frame.
	B,I(0)$\bar{P}$(4) →		A confirms frames 1-3 and starts sending numbered I-frames.
	B,I(1)$\bar{P}$(4) →		
	B,I(2)P(4) →		A sends poll I-frame. B must respond.
		← B,RR-F(3)	B confirms frames 0-2.
Online and offline status changes	B,DISC-P →		A sets B offline.
		← B,UA-F	B acknowledges. (B assumes NDM.)
	B,RR-P(0) →		A polls B.
		← B,DM-F	B reports disconnected status.
	B,SNRM-P →		A sets B online. Nr and Ns counts are reset to 0.
		← B,UA-F	B acknowledges. (B assumes NRM.)

Primary and secondary stations exchange numbered frames

B,I(0)$\overline{P}$(0) →		A sends frame 0.
B,I(1)P(0) →		A sends poll I-frame. B must respond.
	← B,I(0)F(2)	B confirms frames 0-1 and sends frame 0.
B,RR-P(1) →		A confirms frame 0 and polls B for transmission.
	← B,I(1)$\overline{F}$(2)	B sends numbered I-frames.
	← B,I(2)$\overline{F}$(2)	
(CRC error)		**A discards frame 2 because of a CRC error.**
	← B,I(3)$\overline{F}$(2)	
	← B,I(4)F(2)	B sends final I-frame.
B,RR-P(2) →		A confirms frame 1 Only.
	← B,I(2)$\overline{F}$(2)	B sends frames 2-4 again.
	← B,I(3)$\overline{F}$(2)	
	← B,I(4)F(2)	B sends final I-frame.
B,RR-$\overline{P}$(5) →		A confirms frames 2-4. (B remains in NRM.)

Point-to-Point Duplex Exchanges

Primary Station | Secondary Station



Secondary station comes online; primary and secondary stations exchange numbered frames

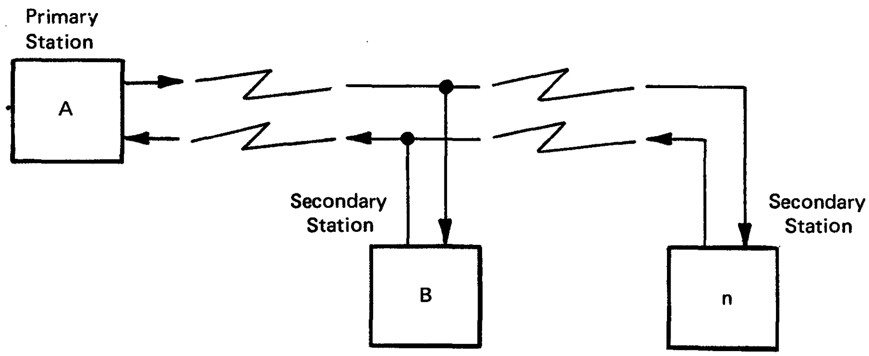
Primary Station	Secondary Station	Description
B,RR-P(0) →		A polls B.
	← B,RIM-F	B requests initialization.
B,SIM-P →		A sets B to initialization mode.
	← B,UA-F	B acknowledges.
		B is brought online through system procedures when initialization is complete.
B,SNRM-P →		A sets B's response mode. Nr and Ns counts are reset to 0.
	← B,UA-F	B acknowledges.
B,RR-P(0) →		A polls B for transmission.
B,I(0)$\bar{P}$(0) →	← B,I(0)$\bar{F}$(0)	Duplex exchange of numbered I-frames. (B uses longer frames than A.)
B,I(1)$\bar{P}$(0) →		A sends frame 1.
B,I(2)$\bar{P}$(0) →	← B,I(1)$\bar{F}$(2)	A sends frame 2. B confirms frames 0-1 and sends frame 1.
B,I(3)$\bar{P}$(1) →		A confirms frame 0 and sends frame 3.
	← B,I(2)F(3)	B confirms frame 2 and sends frame 2.
B,RR-P(3) →		A confirms frames 1-2.
	← B,RR-F(4)	B confirms frame 3. (B remains in NRM.)

Busy secondary station

Primary Station	Secondary Station	Description
B,I(4)$\bar{P}$(3) →		A sends numbered I-frames.
B,I(5)$\bar{P}$(3) →		
B,I(6)$\bar{P}$(3) →		
B,I(7)$\bar{P}$(3) →		
B,I(0)P(3) →		A polls B.
	← B,RNR-F(0)	B becomes busy, but confirms frames 4-7.
B,RR-P(3) →		A asks if B is still busy.
	← B,RR-F(0)	B can receive again and expects frame 0.
B,I(0)$\bar{P}$(3) →		A sends frame 0 again.
B,I(1)$\bar{P}$(3) →		A continues with frame 1.
B,I(2)P(3) →		A sends poll I-frame.
	← B,RR-F(3)	B confirms frames 0-2. (B remains in NRM.)

Sequence	A (primary)	B (secondary)	Explanation
Busy primary station	B,SNRM-P →		A sets B's response mode to reset the Nr and Ns counts to 0.
		← B,UA-F	B acknowledges.
	B,RR-P(0) →		A polls B.
		← B,I(0)$\overline{F}$(0)	B sends numbered I-frames.
		← B,I(1)$\overline{F}$(0)	
		← B,I(2)$\overline{F}$(0)	
	B,RNR-$\overline{P}$(3) →	← B,I(3)$\overline{F}$(0)	A becomes busy, but confirms frames 0-2.
		← B,RR-F(0)	B stops sending.
	B,RR-P(3) →		A polls B.
		← B,I(3)$\overline{F}$(0)	B retransmits frame 3.
		← B,I(4)F(0)	B sends frame 4.
	(CRC error)		A has a CRC error on frame 4. (idle detect timeout)
	B,RR-P(4) →		A polls B, confirms frame 3.
		← B,I(4)F(0)	B sends frame 4 again.
	B,RR-$\overline{P}$(5) →		A confirms frame 4. (B remains in NRM.)
Invalid command	B,XXX-P →		A sends frame with an undefined C field.
		← B,FRMR-F	B rejects the frame.
			Higher level at A processes the status reported by B in the FRMR response.
	B,SNRM-P →		A resets B's error condition. Nr and Ns counts are reset to 0.
		← B,UA-F	B acknowledges. (B remains in NRM.)
Numbering error in duplex exchange	B,RR-P(0) →		A polls B for transmission.
		← B,I(0)$\overline{F}$(0)	B sends numbered I-frames.
	B,I(0)$\overline{P}$(0) →	← B,I(1)$\overline{F}$(0)	Duplex exchange of numbered I-frames. (A uses longer frames than B.)
		← B,I(2)$\overline{F}$(0)	
		(CRC error)	B receives frame 0 with a CRC error.
	B,I(1)$\overline{P}$(2) →		
		← B,I(3)$\overline{F}$(0)	
		← B,I(4)$\overline{F}$(0)	A's frame 1 is out of numerical order.
	B,I(0)$\overline{P}$(5) →	← B,REJ-$\overline{F}$(0)	B expects frame 0. A sends frame 0 again and confirms frames 0-4.
		← B,I(5)F(0)	B sends final I-frame.
	B,I(1)$\overline{P}$(5) →		A retransmits frame 1.
	B,RR-P(6) →		A confirms frame 5 and polls B for confirmation.
		← B,RR-F(2)	B confirms. (B remains in NRM.)

Multipoint Duplex Exchanges



Secondary stations come online; primary station sends to one and receives from the other

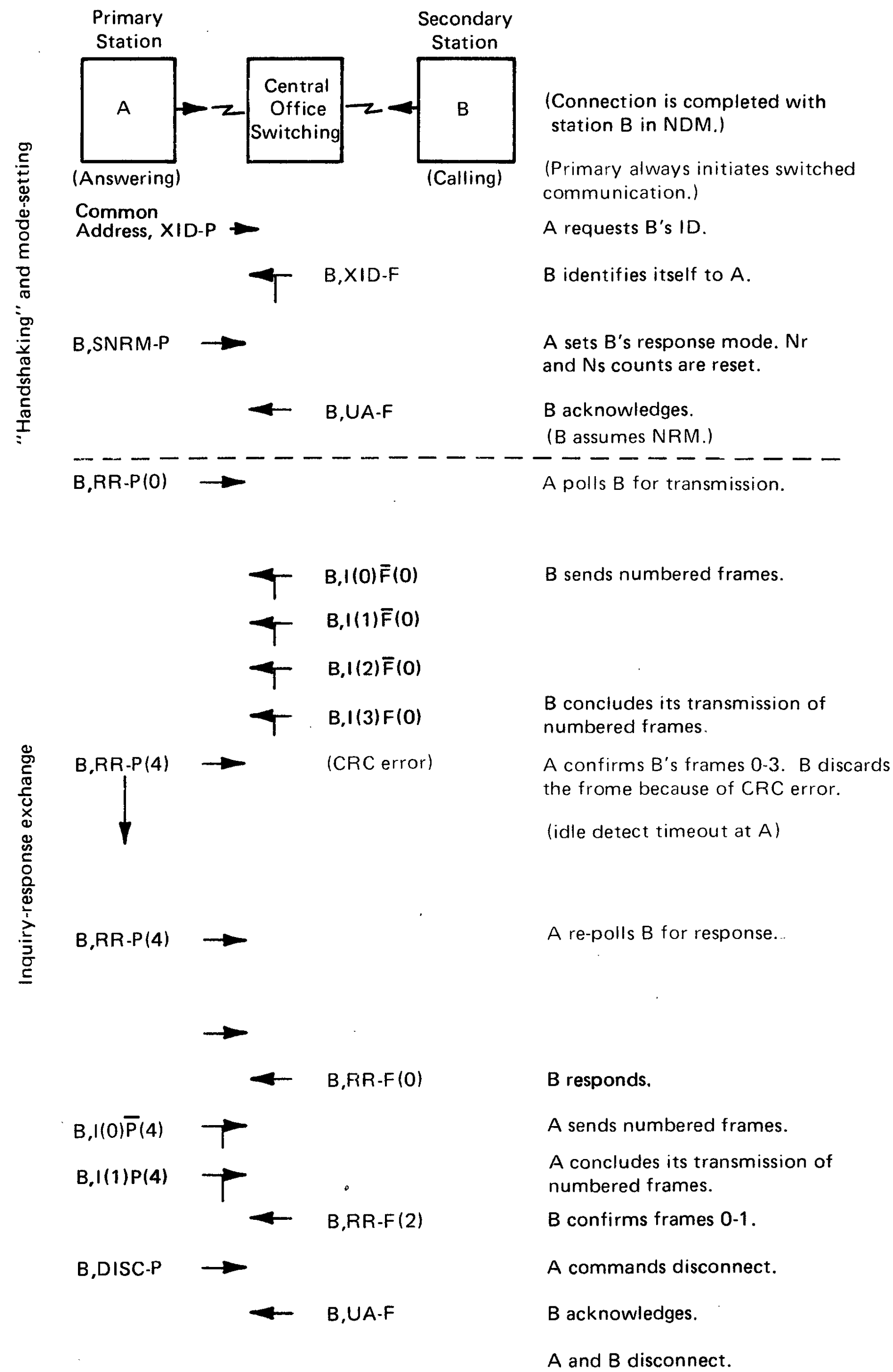
	Comes on in NDM.		Comes on in NRM.
B,RR-P			A polls B for status.
	B,RIM-F		B asks for initialization mode.
B,SIM-P			A sets B to initialization mode.
	B,UA-F		B acknowledges.
			B is brought online through system procedures when initialization is complete.
B, SNRM-P			A sets B online. Nr and Ns counts are reset.
	B,UA-F		B acknowledges.
n,RR-P(0)			A polls n for transmission.
B,I(0)-$\overline{\text{P}}$(0)		n,I(0)$\overline{\text{F}}$(0)	n sends numbered frames to A while A sends to B.
B,I(1)$\overline{\text{P}}$(0)		n,I(1)$\overline{\text{F}}$(0)	
		n,I(2)$\overline{\text{F}}$(0)	
		n,I(3)F(0)	n completes its transmission of numbered frames.
B,RR-P(0)			A polls B for confirmation.
	B,RR-F(2)*		B confirms frames 0-1.
n,RR-$\overline{\text{P}}$(4)			A confirms frames 0-3. (B and n remain in NRM.)

Interleaved primary station transmission

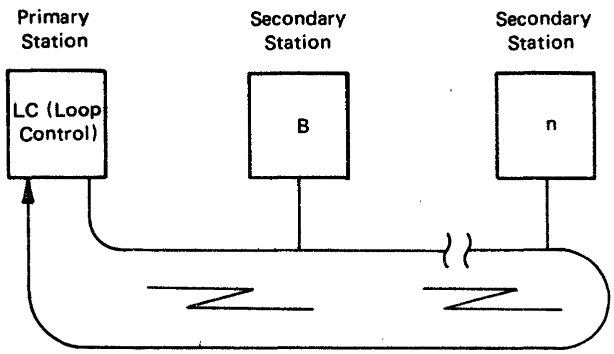
n,I(0)$\overline{\text{P}}$(4)			A sends numbered frames to n.
B,I(2)$\overline{\text{P}}$(0)			A sends numbered frames to B.
n,I(1)P(4)			A concludes sending to n and requests confirmation.
B,I(3)$\overline{\text{P}}$(0)		n,RR-F(2)*	A continues sending to B; n confirms frames 0-1.
B,I(4)P(0)			A concludes sending to B and requests confirmation.
	B,RR-F(5)*		B confirms. (B and n remain in NRM).

*If a secondary station has information to send, this confirmation may be in the I format.

Point-to-Point Half Duplex Switched Exchanges



Loop Exchanges



Secondary stations come on in NDM.
ca = common address (established by the using system)
flag = SDLC F(01111110)
GA = go-ahead (see "Loop Operation", earlier in this chapter).

1s →	1s →	1s	LC receives 1's; loop is complete.
ca,UP-P →	ca,UP-P →	ca,UP-P	LC polls for status.
GA,1s →	B,DM-F →	B,DM-F	B requests online status.
1s →	GA →	n,DM-F	n requests online status.
1s →	1s →	GA	LC receives 1's.
B,SNRM-$\overline{P}$ →	B,SNRM-$\overline{P}$ →	B,SNRM-$\overline{P}$	Set B's online response mode.
n,SNRM-$\overline{P}$ →	n,SNRM-$\overline{P}$ →	n,SNRM-$\overline{P}$	Set n's online response mode.
ca,UP-$\overline{P}$ →	ca,UP-$\overline{P}$ →	ca,UP-$\overline{P}$	
GA,1s →	B,UA-$\overline{F}$ →	B,UA-$\overline{F}$	B acknowledges.
1s →	GA →	n,UA-$\overline{F}$	n acknowledges.
1s →	1s →	GA	LC receives 1's.
ca,UP-$\overline{P}$ →	ca,UP-$\overline{P}$ →	ca,UP-$\overline{P}$	LC starts a poll cycle.
GA,1s →	B,I(0)$\overline{F}$(0) →	B,I(0)$\overline{F}$(0)	B responds to the poll.
1s →	B,I(1)$\overline{F}$(0) →	B,I(1)$\overline{F}$(0)	
1s →	B,I(2)$\overline{F}$(0) →	B,I(2)$\overline{F}$(0)	B concludes its transmission of numbered frames.
1s →	GA →	n,I(0)$\overline{F}$(0)	n responds to the poll.
1s →	1s →	GA	LC receives 1's.
B,RR-$\overline{P}$(3) →	B,RR-$\overline{P}$(3) →	B,RR-$\overline{P}$(3)	LC confirms B's frames.
n,RR-$\overline{P}$(1) →	n,RR-$\overline{P}$(1) →	n,RR-$\overline{P}$(1)	LC confirms n's frame.
B,I(0)$\overline{P}$(3) →	B,I(0)$\overline{P}$(3) →	B,I(0)$\overline{P}$(3)	LC sends numbered frames to B.
B,I(1)P(3) →	B,I(1)P(3) →	B,I(1)P(3)	LC concludes its transmission of numbered frames.
GA,1s →	B,RR-F(2) →	B,RR-F(2)	B confirms frames 0-1.
1s →	GA →	GA	LC receives 1's.

Retransmission on poll cycle

ca,UP-$\overline{P}$ →	ca,UP-$\overline{P}$ →	ca,UP-$\overline{P}$	LC starts a poll cycle.
GA,1s →	GA,1s →	n,I(1)$\overline{F}$(0)	n responds to the poll, but LC receives the frame with a CRC error.
(CRC error)			
1s →	1s →	GA	LC receives 1's.
ca,UP-$\overline{P}$ →	ca,UP-$\overline{P}$ →	ca,UP-$\overline{P}$	LC starts a poll cycle.
GA,1s →	GA,1s →	n,I(1)$\overline{F}$(0)	n retransmits the unconfirmed frame on a poll cycle.
1s →	1s →	GA	LC receives 1's.
n,RR-$\overline{P}$(2) →	n,RR-$\overline{P}$(2) →	n,RR-$\overline{P}$(2)	LC confirms n's frame.
ca,UP-$\overline{P}$ →	ca,UP-$\overline{P}$ →	ca,UP-$\overline{P}$	LC starts a poll cycle.
GA,1s →			Loop operation continues.

Appendix A. Hexadecimal Notation and Frame Summary

Unnumbered Commands

	P	¬P
SNRM	'93'	'83'
DISC	'53'	'43'
SIM	'17'	'07'
UI	'13'	'03'
UP	'33'	'23'
XID	'BF'	
TEST	'F3'	'E3'
CFGR	'D7'	'C7'

Unnumbered Responses

	F	¬F
UA	'73'	'63'
DM	'1F'	'0F'
FRMR	'97'	'87'
RIM	'17'	'07'
UI	'13'	'03'
XID	'BF'	
TEST	'F3'	'E3'
RD	'53'	'43'
CFGR	'D7'	'C7'
BCN	'FF'	'EF'

Supervisory Commands/Responses
(See Legend)

RR	'—1'
RNR	'—5'
REJ	'—9

Information Commands/Responses
(See Legend)

I	'_*'

Legend

Hexadecimal digit for "–"

Nr=	*P/F*	$\overline{P/F}$
0	1	0
1	3	2
2	5	4
3	7	6
4	9	8
5	B	A
6	D	C
7	F	E

Hexadecimal digit for "*"

Ns=	*Hex*
0	0
1	2
2	4
3	6
4	8
5	A
6	C
7	E

Figure A-1. SDLC Commands and Responses in Hexadecimal Notation

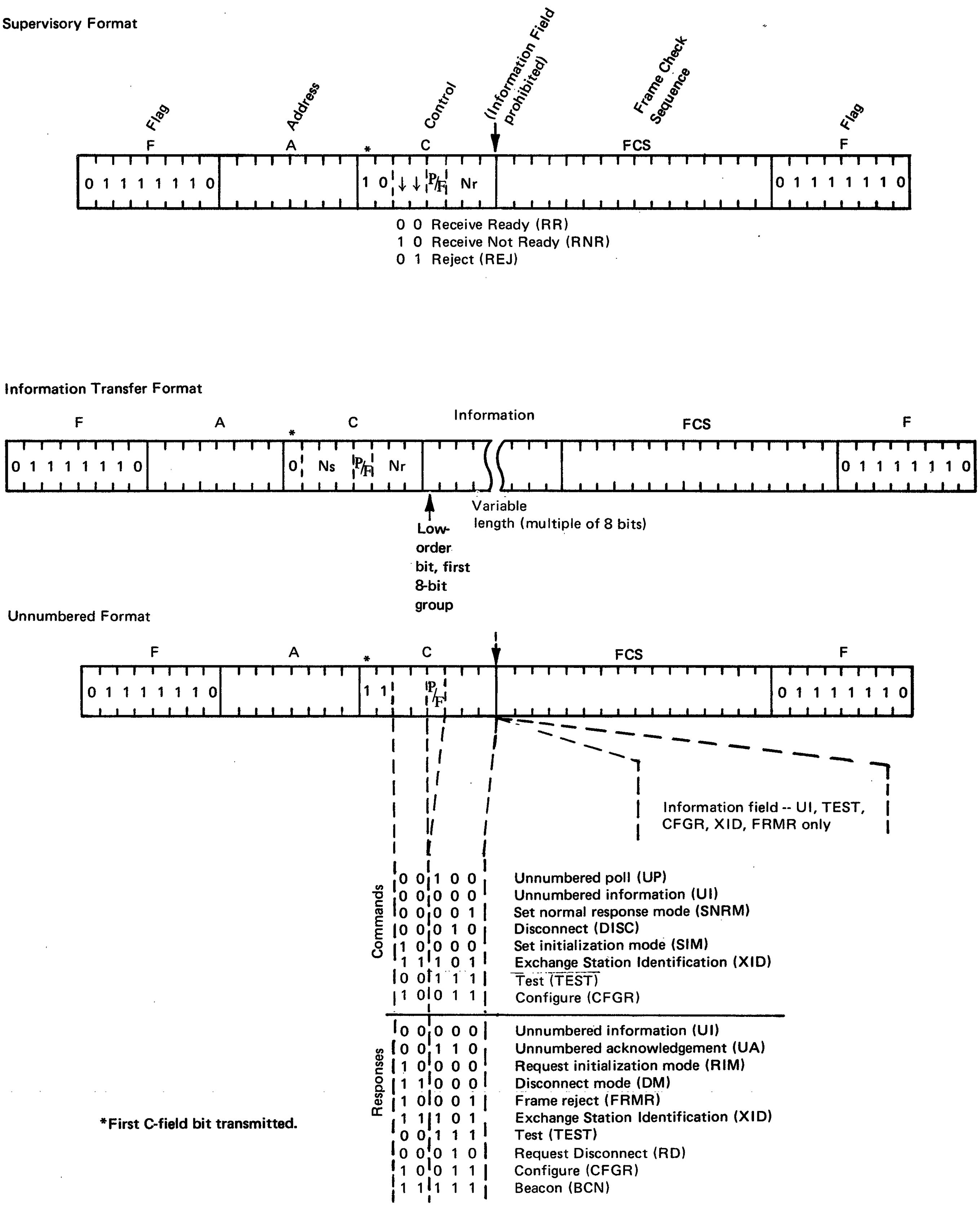


Figure A-2. SDLC Frames, as Transmitted

Appendix B. SDLC Computation of the FCS Field

Note 1: Refer to "Frame Check Sequence Field" under "Frame Format" and to Figures 2-10 and 2-12, in Chapter 2, for an overview of the FCS field.

Note 2: This appendix is not intended as a text on the use and computation of the FCS field.

In the SDLC implementation of cyclic redundancy checking (CRC) for the FCS field, the CRC computation at the transmitter starts with the first bit following the opening flag (A field) and stops at the end of the data (I field or C field). (The FCS field is an inversion, or ones-complement, of the transmitter's remainder at that point.) The result of a transmission correctly received is a constant: 1111000010111000 (x_0 through x_{15}, see Figure B-1).

In the SDLC application of CRC, a modified polynomial expression (modulo 2) of the transmission to be checked is divided by the generating polynomial, $X^{16} + X^{12} + X^5 + X^1$. Integer quotient digits are ignored, and the transmitter sends the complement of the resulting remainder value as the FCS field (see Figure B-2).

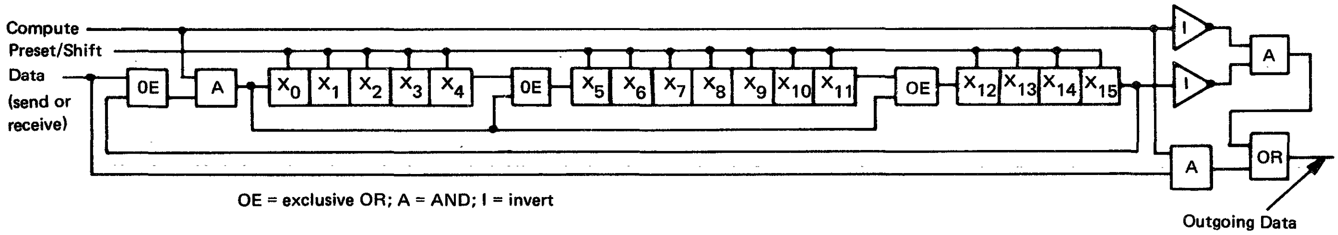
In addition to the division of the binary value of the data by the generating polynomial to generate a remainder for checking, the following manipulations occur:

1. The dividend is initially preset to all-1's (see Figure B-1). This adds the binary value of the preset bits to that of the data bits.
2. The transmitter's remainder is inverted bit-by-bit (FCS field) as it is sent to the receiver. The high-order bit of the FCS field is transmitted first (x_{15}, x_{14}, x_{13},...,x_0).
3. The receiver treats the FCS field as part of its dividend. Continued computation raises the value of the dividend polynomial by the factor X^{16}. Since the dividend/remainder at the receiver is equal to that at the transmitter at the beginning of the FCS field, the remainder at the receiver at the end of FCS field is a constant that is characteristic of the divisor.

If a receiver computation does not yield the constant, 1111000010111000, it is assumed that the frame was received in error. Its entire content is suspect and is discarded; no action is taken. It is the transmitter's responsibility to determine that the receiver has not accepted that frame.

	Input to Transmitter (Sent and computed)		Transmitter Computation— Dividend/Remainder (preset to 1's)* X_0	X_5	X_{12} X_{15}	Input to Receiver (Received and computed)	Receiver Computation— Dividend/Remainder (preset to 1's)* X_0	X_5	X_{12} X_{15}
Preset			11111	1111111	1111		11111	1111111	1111
	0		11111	0111111	0111	0	11111	0111111	0111
	1		01111	1011111	1011	1	01111	1011111	1011
	1		00111	1101111	1101	1	00111	1101111	1101
	1		00011	1110111	1110	1	00011	1110111	1110
	1	A	10001	0111011	0111	1	10001	0111011	0111
	0		11000	0011101	0011	0	11000	0011101	0011
	0		11100	1001110	0001	0	11100	1001110	0001
	1		01110	0100111	0000	1	01110	0100111	0000
	1		10111	1010011	0000	1	10111	1010011	0000
Hypothetical 19-bit Frame	0		01011	1101001	1000	0	01011	1101001	1000
	0		00101	1110100	1100	0	00101	1110100	1100
	1	C	10010	0111010	1110	1	10010	0111010	1110
	1		11001	1011101	1111	1	11001	1011101	1111
	0		11100	0101110	0111	0	11100	0101110	0111
	0		11110	1010111	1011	0	11110	1010111	1011
	0		11111	1101011	0101	0	11111	1101011	0101
	1		01111	1110101	1010	1	01111	1110101	1010
	1	I	10111	0111010	0101	1	10111	0111010	0101
	1		01011	1011101	0010	1	01011	1011101	0010
			00101	1101110	1001	1	10101	0101110	0001
			00010	1110111	0100	0	11010	0010111	1000
			00001	0111011	1010	1	11101	1001011	0100
			00000	1011101	1101	1	11110	0100101	0010
			00000	0101110	1110	0	01111	0010010	1001
			00000	0010111	0111	1	00111	1001001	0100
Invert and shift out FCS			00000	0001011	1011	0	00011	1100100	1010
			00000	0000101	1101	0	00001	1110010	0101
			00000	0000010	1110	0	10000	0111001	1010
			00000	0000001	0111	1	11000	1011100	0101
			00000	0000000	1011	0	11100	1101110	1010
			00000	0000000	0101	0	01110	0110111	0101
			00000	0000000	0010	0	10111	1011011	0010
			00000	0000000	0001	1	11011	0101101	0001
			00000	0000000	0000	0	11101	0010110	0000
			00000	0000000	0000	1	11110	0001011	1000
							X_0	X_5	X_{12} X_{15}

*Generator polynomial (divisor) = $X^{16} + X^{12} + X^5 + 1$, exemplified in shift register form:



OE = exclusive OR; A = AND; I = invert

Note: In hexadecimal (from storage), the A-field = '9E', the C-field = '19' and the FCS-field = '2 DA2'.

Figure B-1. An Example of Cyclic Redundancy Checking

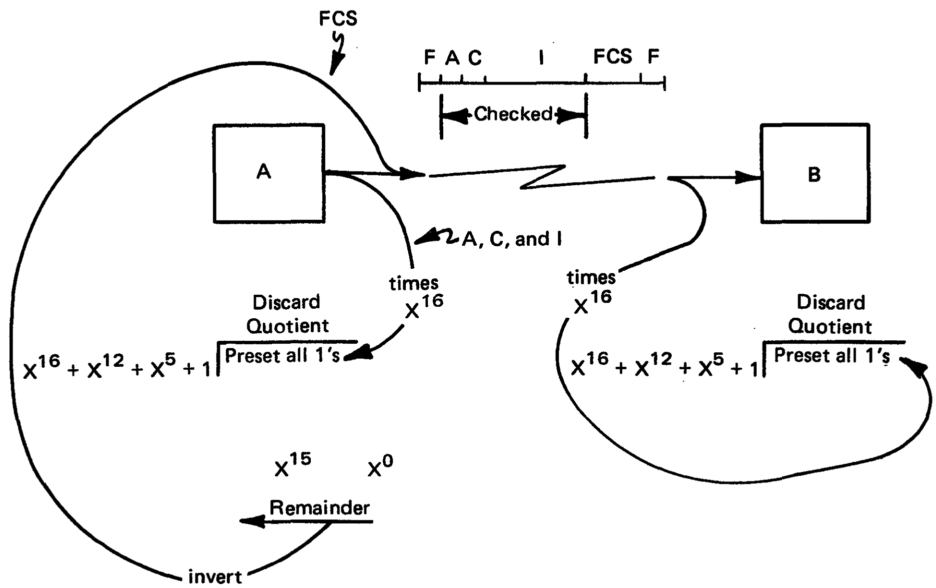


Figure B-2. CRC Operation with SDLC

Appendix C. SDLC Commands and Responses: Acronym Update

This appendix shows the relationship between the current acronyms for SDLC commands and responses and ones that a reader may encounter in earlier SDLC documentation.

NEW ACRONYM AND MEANING	OLD ACRONYM AND MEANING
UI—unnumbered information frame	NSI—nonsequenced information frame
SNRM—set normal response mode	unchanged
DISC—disconnect	unchanged
UA—unnumbered acknowledgement	NSA—nonsequenced acknowledgement
RIM—request initialization mode	RQI—request for initialization
SIM—set initialization mode	unchanged
DM—disconnect mode	ROL—request online
FRMR—frame reject	CMDR—command reject
TEST—test	unchanged
RD—request disconnect	RQD—request disconnect

Appendix D. IBM SDLC and Data Link Control Standards

Data-link-control standards development activity within the International Standards Organization (ISO) has created an interest in the relationship between IBM SDLC and ISO HDLC (High-Level Data Link Control).

Note: A similar standardization activity is also taking place within the American National Standards Institute (ANSI) in the United States. The proposed ANSI data link control standard, Advanced Data Communications Control Procedure (ADCCP), is essentially a functional equivalent of ISO HDLC.

It is IBM's technical judgment that SDLC, as implemented in IBM telecommunication products, conforms with a defined operational subset of ISO HDLC: the Unbalanced Normal Class of Procedure. An important point in understanding this technical judgment is that SDLC, as implemented in IBM telecommunication products, is more precise in certain aspects than the HDLC standards—both as approved and as currently proposed.

In general, international standards are written to provide a wide freedom of choice for both function and configuration selection depending on application needs and objectives.

The ISO HDLC approved and proposed standards comprise several interrelated standards, which are designated as follows:

- ISO International Standard (IS) 3309, Data Communications—High-Level Data Link Control Procedures—Frame Structure (1976)

  This standard specifies the format of the HDLC transmission unit (frame). It identifies the functional fields of the frame (address, control, information, and frame check sequence) and the location of each. In addition, it specifies (1) the unique eight-bit framing pattern (flag) used to begin and end the frame, (2) the bit insertion and deletion process used to provide code independence and data transparency, (3) the frame-check-sequence polynomial and algorithm, and (4) the order of bit transmission.

- ISO Draft International Standard (DIS) 4335, Data Communications—High-Level Data Link Control Procedures— Elements of Procedure (1976)

  This draft standard specifies the overall functional capabilities defined for HDLC within the frame structure standard. It defines possible operational modes and specifies the definition and encoding of the link level commands and responses that may be used in the control field of the frame. Protocols to be observed in the use of the commands and responses are described and illustrated by sequence diagrams of typical operational examples. This standard represents the superset or "menu" of HDLC functions that are available. It does not discuss how this superset may be limited in specific modes of operation, applications, or configurations.

- ISO DIS 4335/DAD1, Addendum to DIS 4335—Additional Elements of Procedure with initial approval for incorporation into DIS 4335 (1978)

This addendum specifies additional elements of procedure (functional capabilities) that are added to those currently contained in DIS 4335. These will be included in a comprehensive base document by future revision of DIS 4335.

- ISO TC97/SC6/N1464, Addendum to DIS 4335—Additional Elements of Procedure with initial approval for incorporation into DIS 4335 (1977)

  This addendum is similar to the one above. In particular, it specifies the elements of procedure necessary for the Asynchronous Balanced Mode of operation.

- ISO Draft International Standard (DIS) 6159, HDLC Unbalanced Classes of Procedures (1978)

  This draft standard specifies and describes the class of procedure applicable for centralized data link control of point-to-point and multipoint configurations for both Normal and Asynchronous Response Modes of operation. It provides the subset of HDLC functions (commands and responses) that are mandatory and those that are optional.

- ISO Draft International Standard (DIS) 6256, HDLC Balanced Class of Procedures (1978)

  This draft standard specifies and describes the Asynchronous Balanced Mode class of procedure applicable for peer-to-peer interchange in a point-to-point configuration. It provides the subset of HDLC functions that are mandatory and those that are optional.

As noted earlier, standards give implementors considerable latitude in the choice of functional options and alternative configurations. This freedom may result in incompatibilities between different products that individually conform to HDLC. The following two examples illustrate.

- HDLC permits any number of bits in the information field of an Information command or response frame; SDLC permits any number of 8-bit bytes. Thus SDLC is a subset of HDLC. However, the XYZ Corporation could choose 13-bit characters, which is also an allowable subset of HDLC. Yet one set of products expects the messages to consist of 8n bits; the other, 13n bits. Usually, when information received does not conform to an expected bit length, a "transmission error" or an "improper information field" status would be indicated by the receiver. So, in this case, while both products are in conformance with HDLC, they would be incompatible.

- HDLC also provides a number of optional functional extensions for special application considerations and/or performance improvement. IBM SDLC products, in general, incorporate one or more of these functional extensions. However, if two products do not have the same functional subset, effective and productive communications between the two may not be possible. When an IBM SDLC product receives a transmission that is undefined for that product, an exception condition results.

The judgment that SDLC is in conformance with ISO HDLC is also based on the following:

- SDLC complies with IS 3309, Frame Structure, for information fields with an integral number of 8-bit bytes.
- SDLC commands and responses (that is, Elements of Procedure) that have corresponding HDLC counterparts comply with the ISO HDLC definitions and protocols as specified in DIS 4335 and addendum DAD1.
- Announced IBM SDLC products conform to the Unbalanced Normal (UN) Class of Procedure as specified in DIS 6159 and the Normal Disconnected Mode (NDM) as specified in DIS 4335/DAD1. These IBM SDLC products provide the required basic (minimum) command and response repertoire, and particular products provide one or more of the available optional functions. Unbalanced Normal operation with Normal Disconnected Mode is the only class of procedure currently used in IBM SDLC products.

Figure D-1 lists the basic command and response requirements for the ISO Unbalanced Normal Class of Procedures (DIS 6159) as well as the commands and responses available for optional functional extensions. Figure D-2 contains the complete titles of the HDLC acronyms used for the commands and responses contained in Figure D-1. The parenthetical notes have been added to provide a bridge with earlier acronyms that may appear in older IBM SDLC publications.

All IBM SDLC products implement the basic repertoire of commands and responses of the Unbalanced Normal (UN) class. In addition, specific IBM SDLC products may support one or more of the available optional functions. For instance, particular IBM SDLC products support one or more of the following optional functions:
1 (XID-XID/RD), 2 (REJ-REJ), and 5 (SIM-RIM).

IBM SDLC does contain additional commands and responses not in the ISO Elements of Procedure (or addenda). For example, IBM SDLC products can exchange the TEST command and response for link testing purposes. The TEST command and response are not yet in the current ISO standards documentation although they were recently approved as additional elements of procedure.

Note: SDLC includes the Configure (CFGR) command and CFGR and Beacon (BCN) responses for application in loop configurations only. ISO HDLC does not include loop operation.

Some IBM SDLC products do not allow the use of the Request Disconnect (RD) response (this response is a recent addition to the ISO Elements of Procedure), and the REJ command and response are used only in those IBM SDLC products that provide two way simultaneous information interchange. To determine the SDLC capabilities and characteristics of a specific IBM product, refer to the appropriate publications for that product.

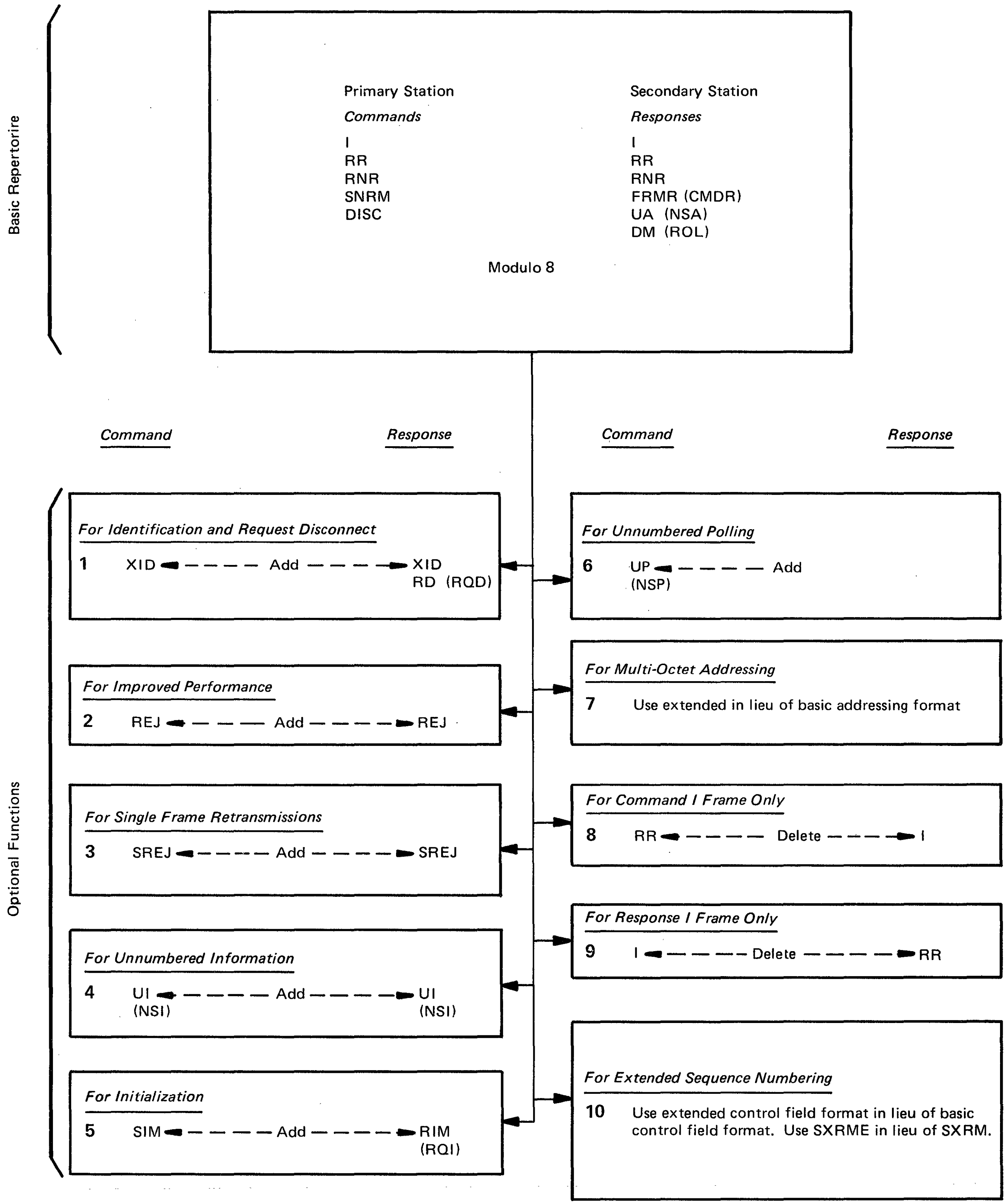


Figure D-1. HDLC Unbalanced Normal Class of Procedures

			Command	Response
I	=	Information frame	X	X
RR	=	Receive Ready	X	X
RNR	=	Receive Not Ready	X	X
REJ	=	Reject	X	X
SNRM	=	Set Normal Response Mode	X	
SIM	=	Set Initialization Mode	X	
DISC	=	Disconnect	X	
XID	=	Exchange Identification	X	X
US(NSI)	=	Unnumbered Information (nonsequenced information)	X	X
UP(NSP)	=	Unnumbered Poll (non-sequenced poll)	X	
UA(NSA)	=	Unnumbered Acknowledge (nonsequenced acknowledge)		X
DM(ROL)	=	Disconnected Mode (request online)		X
FRMR(CDMR)	=	Frame Reject (command reject)		X
RIM(RQI)	=	Request Initialization Mode (request initialization mode)		X
RD(RQD)	=	Request Disconnect (request disconnect)		X

Figure D-2. HDLC Command and Responses

Note: National and international standards, approved and proposed, are subject to continual review, modification, and enhancement. Any resulting changes, although they appear unlikely at this time, may alter IBM's judgment on SDLC conformance as stated in the preceding, which is based on the level of ISO HDLC documentation existing as of January 1, 1979.

Abbreviations

A	address (field)
BC	block check (field)
BCN	beacon
C	control (field)
CFGR	configure
CRC	cyclic redundancy check
DCE	data communication equipment
DISC	disconnect (command)
DM	disconnect mode
DTE	data terminal equipment
F	flag (pattern or field) or final (bit)
FCS	frame check sequence
FRMR	frame reject
I	information (field or frame or C-field format)
MRP	mandatory response poll
ms	millisecond
NDM	normal disconnected mode
Nr	receive count (next sequence number expected to receive)
NRM	normal response mode
NRZI	nonreturn-to-zero inverted (zero-complementing differential coding)
Ns	send count (transmitter's sequence number)
ORP	optional response poll
P/F	poll/final bit
RD	request disconnect
REJ	reject
RIM	request initialization mode
RNR	receive not ready (busy)
RR	receive ready
S	supervisory (format or C field)
SDLC	synchronous data link control
SIM	set initialization mode
SNRM	set normal response mode
TEST	test
UA	unnumbered acknowledgement
UI	unnumbered information
UP	unnumbered poll
XID	exchange station identification

Glossary

buffer: A storage area reserved for use in performing input/output operations

carrier: A continuous frequency capable of being modulated or impressed with a second (information-carrying) signal.

command: A control signal; loosely, an instruction in machine language.

communication common carrier: Any government-regulated company that furnishes communication services to the general public.

communication channel: An electrical path that facilitates transmission of information from one location to another.

confirmation: A transmission by a receiver that permits a sender to continue.

control: The power to regulate or direct.

data: Any representation to which meaning is, or might be, assigned.

data link: The communication channel and communication controls of all stations connected to the communication channel, used in the transmission of information between two or more stations.

information: The meaning assigned to data by conventions used in data representation.

initialization: The setting of starting values at the beginning of a sequence.

invert on zero: A transmission coding method in which the DTE changes the signal to the opposite state to send a binary 0 and leaves it in the same state to send a binary 1.

numbered frames: Information segments arranged in numbered order for accountability.

poll: An interrogation to determine if a station requires servicing.

propagation time: The time necessary for a signal to travel from one point on a circuit to another.

recovery: The process of regaining the normal or usual condition.

response: A reply or answer; a reaction to a stimulus.

retransmit: To repeat the transmission of a message or segment of a message.

retry: To resend a transmission which did not achieve the desired or intended result; usually follows a timeout.

solicited: Stimulated, sought, or requested.

station: One of the input or output points of a communication system.

status: The state of affairs or the condition of a station that determines its ability to enter into exchanges of control or information.

synchronous: Occurring with a regular or predictable time relationship.

timeout: Measurement of time interval allotted for certain events to occur (such as a response to polling or other controls) before corrective (recovery) action is taken.

transparent: In communications, pertaining to transmissions that have no possibility of interference with data link control, regardless of format or content. Transparent transmissions are unrecognized by data link controls.

turnaround: The reversal of the direction of transmission from send to receive (or from receive to send); usually used in reference to a half-duplex communication channel.

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