INTERNATIONAL STANDARD

ISO/IEC 4335

Fourth edition
1991-09-15

Information technology — Telecommunications and information exchange between systems — High-level data link control (HDLC) procedures — Elements of procedures

Technologies de l'information — Télécommunications et échanges d'information entre systèmes — Procédures de commande de liaison de données à haut niveau (HDLC) — Eléments de procédures

Reference number
ISO/IEC 4335 : 1991 (E)

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Full document details: ISO_IEC 4335_1991

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

International Standard ISO/IEC 4335 was prepared by Joint Technical Committee ISO/IEC JTC1, *Information technology*.

This fourth edition cancels and replaces the third edition (ISO 4335 : 1987), which has been technically revised.

Annexes A, B and C of this International Standard are for information only.

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Introduction

General

High-level data link control (HDLC) procedures are designed to permit synchronous or start/stop, code-transparent data transmission. This International Standard describes the HDLC elements of procedures. Further studies are in progress to identify and define additional elements of procedures which may be included at a later date.

In HDLC procedures, the normal cycle of the code-transparent data communication between two data stations consists of the transfer of frames containing information from the data source to the data sink acknowledged by a frame in the opposite direction. Until the data station comprising the data source receives an acknowledgement, it holds the original information in memory in case the need should arise for retransmissions.

Data sequence integrity between the data source and the data sink is effected by means of a numbering scheme, which is cyclic within a modulus specified in this International Standard and measured in terms of frames. An independent numbering scheme is used for each data source/data sink combination on the data link.

The acknowledgement function is accomplished by the data sink informing the data source of the next expected sequence number. This can be done in a separate frame, not containing information, or within the control field of a frame containing information.

HDLC procedures are applicable to unbalanced data links and to balanced data links.

Unbalanced data links

An unbalanced data link involves two or more participating data stations. For control purposes, one data station on the data link assumes responsibility for the organization of data flow and for unrecoverable data link level error conditions. The data station assuming these responsibilities is known as the primary station, and the frames it transmits are referred to as command frames. The other data stations on the data link are known as the secondary stations, and the frames they transmit are referred to as response frames.

For the transfer of data between the primary station and the secondary stations, two cases of data link control are considered (see figures 1 and 2). In the first case, the data station comprising the data source performs a primary station data link control function and controls the data station comprising the data sink that is associated with a secondary station data link control function, by select-type commands.

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In the second case, the data station comprising the data sink performs a primary station data link control function and controls the data station comprising the data source that is associated with a secondary station data link control function, by poll-type commands.

The information flows from the data source to the data sink, and the acknowledgements are always transmitted in the opposite direction.

These two cases of control may be combined so that the data link becomes capable of two-way alternate communication, or two-way simultaneous communication.

Balanced data links

A balanced data link involves only two participating data stations. For control purposes, each data station assumes responsibility for the organization of its data flow and for unrecoverable data link level error conditions associated with the transmissions that it originates. Each data station is known as a combined station and is capable of transmitting and receiving both command and response frames.

For the transfer of data between combined stations, the data link control functions illustrated in figure 3 are utilized. The data source in each combined station controls the data sink in the other combined station by the use of select-type commands. The information flows from the data source to the data sink, and the acknowledgements are always transmitted in the opposite direction. The poll-type commands may be used by each combined station to solicit acknowledgements and status responses from the other combined station.

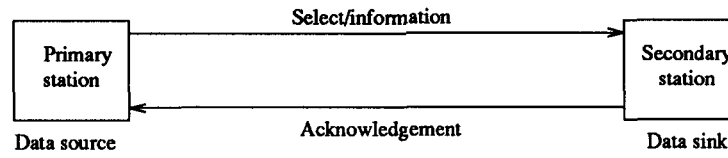

Figure 1 — Unbalanced data link configuration (case 1)

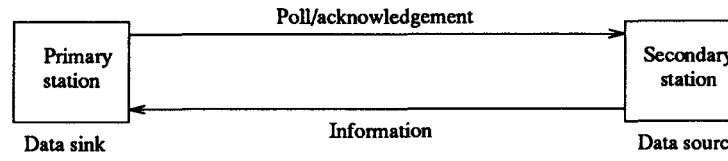

Figure 2 — Unbalanced data link configuration (case 2)

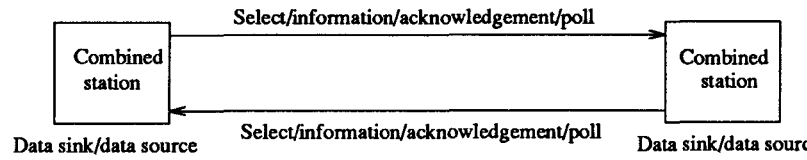

Figure 3 — Balanced data link configuration

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Information technology — Telecommunications and information exchange between systems — High-level data link control (HDLC) procedures — Elements of procedures

1 Scope

This International Standard specifies elements of data link control procedures for synchronous or start/stop, code-transparent data transmission using the HDLC frame structure specified in ISO 3309 and independent frame numbering in both directions.

These HDLC elements of procedures are defined specifically in terms of the actions that occur on receipt of commands at a secondary station or a combined station.

This International Standard is intended to cover a wide range of applications; for example one-way, two-way alternate or two-way simultaneous data communication between data stations which are usually buffered, including operations on different types of data circuits; for example multipoint/point-to-point, duplex/half-duplex, switched/non-switched, synchronous/start-stop, etc.

The defined HDLC elements of procedures are to be considered as a common basis for establishing different types of control procedures. This International Standard does not define any single system and should not be regarded as a specification for a data communication system. Not all of the commands or responses are required for a particular system implementation.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO/IEC 2382-9 : 1984, *Information technology - Vocabulary - Part 9 : Data communication.*

ISO/IEC 3309 : 1991, *Information technology - Telecommunications and information exchange between systems - High-level data link control (HDLC) procedures - Frame structure.*

3 Definitions

For the purposes of this International Standard, the following definitions apply (see also ISO/IEC 2382-9).

3.1 abort : A function invoked by a sending primary, secondary or combined station causing the recipient to discard (and ignore) all bit sequences transmitted by the sender since the preceding flag sequence.

3.2 accept : The condition assumed by a data station (primary, secondary or combined station) upon accepting a correctly received frame for processing.

3.3 address field (A) : The sequence of eight (or any multiple of eight, if extended) bits immediately following the opening flag sequence of a frame identifying the secondary/combined station sending (or designated to receive) the frame.

3.4 address field extension : Enlarging the address field to include more addressing information.

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3.5 basic status : A secondary/combined station's capability to send or receive a frame containing an information field.

3.6 centralized control : A control in which all the primary station functions of the data link are centralized in one data station.

3.7 combined : That part of a data station that supports the combined station control functions of the data link.

NOTE — The combined station generates commands and responses for transmission and interprets received commands and responses. Specific responsibilities assigned to a combined station include:

a) initialization of control signal interchange;

b) organization of data flow;

c) interpretation of received commands and generation of appropriate responses; and

d) actions regarding error control and error recovery functions at the data link level.

3.8 command : In data communication, an instruction represented in the control field of a frame and transmitted by the primary/combined station. It causes the addressed secondary/combined station to execute a specific data link control function.

3.9 command frame :

a) All frames transmitted by a primary station.

b) Those frames transmitted by a combined station that contain the address of the other combined station.

3.10 contention mode : A mode of transmission in which a transmitter can send on its own initiative.

3.11 control escape (CE) : The unique sequence of eight bits (10111110) employed to indicate the following octet has been modified according to the transparency algorithm for start/stop transmission environments.

3.12 control field (C) : The sequence of eight (or sixteen, if extended) bits immediately following the address field of a frame.

NOTE — The content of the control field is interpreted by:

a) the receiving secondary/combined station, designated by the address field, as a command instructing the performance of some specific function; and

b) the receiving primary/combined station as a response from the secondary/combined station, designated by the address field, to one or more commands.

3.13 control field extension : Enlarging the control field to include additional control information.

3.14 data communication : See ISO/IEC 2382-9, term 09.01.03.

3.15 data link : An assembly of two or more terminal installations and the interconnecting line operating according to a particular method that permits information to be exchanged.

NOTE — In this context, the term "terminal installation" does not include the data source and the data sink.

3.16 data link level : The conceptual level of control or processing logic existing in the hierarchical structure of a data station (primary, secondary or combined station) that is responsible for maintaining control of the data link.

NOTE — The data link level functions provide an interface between the data station high level logic and the data link. These functions include:

a) transparency;

b) address/control field interpretation;

c) command/response generation, transmission and interpretation; and

d) frame check sequence computation and interpretation.

3.17 data transmission : See ISO/IEC 2382-9, term 09.01.02.

3.18 duplex transmission : See ISO/IEC 2382-9, term 09.03.01.

3.19 exception condition : The condition assumed by a secondary/combined station upon receipt of a frame which it cannot execute due either to a transmission error or to an internal processing malfunction.

3.20 flag sequence (F) : the unique sequence of eight bits (01111110) employed to delimit the opening and closing of a frame.

3.21 frame : The sequence of address, control, information, and FCS fields, bracketed by opening and closing flag sequences.

NOTE — A valid frame is at least 32 bits in length and contains an address field, a control field and a frame check sequence. A frame may or may not include an information field.

3.22 frame check sequence (FCS) : The field immediately preceding the closing flag sequence of a frame, containing the bit sequence that provides for the detection of transmission

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errors by the receiver.

3.23 half-duplex transmission : See ISO/IEC 2382-9, term 09.03.02.

3.24 higher level : The conceptual level of control or processing logic existing in the hierarchical structure of a data station (primary, secondary or combined station) that is above the data link level and upon which the performance of data link level functions are dependent; for example device control, buffer allocation, station management, etc.

3.25 information field (INFO) : The sequence of bits, occurring between the last bit of the control field and the first bit of the frame check sequence.

NOTE — The information field contents of I and UI frames are not interpreted at the data link level.

3.26 interframe time fill : The sequence or condition transmitted between frames.

3.27 intraframe time fill : In start/stop transmission, the sequence or condition transmitted within a frame when the next octet is not available for contiguous transmission immediately following the preceding octet. For synchronous transmission, there is no provision for intraframe time fill.

3.28 invalid frame : A sequence of bits, following the receipt of an apparent opening flag sequence, that either

a) is terminated by an abort sequence; or

b) contains less than 32 bits before an apparent closing flag sequence is detected.

3.29 primary station : The data station that supports the primary station control functions of the data link, i.e. that generates commands for transmission and interprets received responses.

NOTE — Specific responsibilities assigned to the primary station include:

a) initialization of control signal interchange;

b) organization of data flow; and

c) actions regarding error control and error recovery functions at the data link level.

3.30 primary/secondary station : The general case where the station may be either a primary station or a secondary station.

3.31 response : In data communication, a reply represented in the control field of a response frame that advises the primary/combined station with respect to the action taken by the secondary/combined station to one or more commands.

3.32 response frame:

a) All frames transmitted by a secondary station.

b) Those frames transmitted by a combined station that contain the address of the transmitting combined station.

3.33 secondary station : The data station that executes data link control functions as instructed by the primary station.

NOTE — A secondary station interprets received commands and generates responses for transmission.

3.34 secondary station status : The current condition of a secondary station with respect to processing the series of commands received from the primary station.

3.35 two-way alternate data communication : See ISO/IEC 2382-9, term 09.05.03.

3.36 two-way simultaneous data communication : See ISO/IEC 2382-9, term 09.05.02.

3.37 unnumbered commands : The commands that do not contain sequence numbers in the control field.

3.38 unnumbered responses : The responses that do not contain sequence numbers in the control field.

4 Data link channel states

4.1 Active data link channel state

4.1.1 General

A data link channel is in an active state when the primary station, a secondary station or a combined station is actively transmitting a frame, a single abort sequence, or interframe time fill. In the active state, the right to continue transmission shall be reserved.

4.1.2 Abort

4.1.2.1 Synchronous transmission

Aborting a frame shall be accomplished by transmitting at least seven contiguous "1" bits (with no inserted "0" bits) to end the frame. Receipt of seven contiguous "1" bits shall be interpreted as an abort and the receiving data station shall ignore the frame.

NOTE — If more than seven "1" bits are sent to abort, care should be taken because if 15 or more "1" bits are sent, including those already transmitted at the time of the decision to abort, an idle data link channel state will result.

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4.1.2.2 Start/stop transmission

Aborting a frame shall be accomplished by transmitting the two-octet sequence "control escape-closing flag". Receipt of this sequence shall be interpreted as an abort and the receiving data station shall ignore the frame.

4.1.3 Interframe time fill

4.1.3.1 Synchronous transmission

Interframe time fill shall be accomplished by transmitting contiguous flags between frames.

4.1.3.2 Start/stop transmission

Interframe time fill shall be accomplished by the transmission of either continuous flags or marking condition (logical "1" state) between frames. Selection of the interframe time fill method depends on systems requirements.

4.1.4 Intraframe time fill

4.1.4.1 Synchronous transmission

There is no provision for time fill within a frame.

4.1.4.2 Start/stop transmission

Inter-octet time fill within a frame shall be accomplished by transmitting continuous mark-hold condition (logical "1" state). There is no provision for time fill within an octet (i.e., between the start element and stop element).

4.2 Idle data link channel state

4.2.1 Synchronous transmission

A data link channel is in an idle state when a continuous "1" state is detected that has persisted for at least 15 bit times; detection of the idle state at the data link level shall be considered to indicate that the remote data station has relinquished its right to continue transmission.

4.2.2 Start/stop transmission

A data link channel is in the idle state when a continuous mark-hold condition persists for the period of time determined by a system-specified timeout function. The duration of this timer is not a subject of this International Standard.

5 Modes

Three operational modes and three non-operational modes are defined.

5.1 Operational modes

The three operational modes are:

a) normal response mode (NRM);

b) asynchronous response mode (ARM); and

c) asynchronous balanced mode (ABM).

5.1.1 Normal response mode (NRM)

In NRM, which is an unbalanced data link operation mode, the secondary station shall initiate transmission only as the result of receiving explicit permission to do so from the primary station. After receiving permission, the secondary station shall initiate a response transmission. The response transmission shall consist of one or more frames while maintaining an active data link channel state. The last frame of the response transmission shall be explicitly indicated by the secondary station. Following indication of the last frame, the secondary station shall stop transmitting until explicit permission is again received from the primary station.

5.1.2 Asynchronous response mode (ARM)

In ARM, which is an unbalanced data link operational mode, the secondary station may initiate transmission without receiving explicit permission to do so from the primary station. Such an asynchronous transmission may contain single or multiple frames and shall be used for information field transfer and/or to indicate status changes in the secondary station (for example, the number of the next expected information frame, transition from a ready to a busy condition or vice versa, occurrence of an exception condition).

5.1.3 Asynchronous balanced mode (ABM)

In ABM, which is a balanced data link operation mode, either combined station may send commands at any time and may initiate response frame transmission without receiving explicit permission to do so from the other combined station. Such an asynchronous transmission may contain single or multiple frames and shall be used for information field transfer and/or to indicate status changes in the combined station (for example, the number of the next expected information frame, transition from a ready to a busy condition or vice versa, occurrence of an exception condition).

5.2 Non-operational modes

The three non-operational modes are:

a) normal disconnected mode (NDM);

b) asynchronous disconnected mode (ADM); and

c) initialization mode (IM).

The disconnected modes (NDM and ADM) differ from the operational modes in that the secondary/combined station is logically disconnected from the data link; i.e. no information (I) or supervisory frames are transmitted or accepted. The initialization mode (IM) differs from the operational modes in that the secondary/combined station data link control program is either in need of regeneration or is in need of an exchange

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of the parameters to be used in an operational mode.

These two disconnected modes (NDM and ADM) are provided to prevent a secondary/combined station from appearing on the data link in a fully operational mode during unusual situations or exception conditions since such operation could cause:

a) unintended contention in ARM;

b) sequence number mismatch between the primary station and the secondary station, or between combined station; or

c) ambiguity in the primary/combined station as to the status of the secondary/other combined station.

A secondary station shall be system predefined as to the condition(s) that causes it to assume a disconnected mode. The disconnected mode (NDM or ADM) shall also be system predefined. A combined station shall be system predefined as to the condition(s) that causes it to assume the asynchronous disconnected mode (ADM).

The secondary station capability is a disconnected mode shall be limited to:

a) accepting and responding to one of several appropriate mode-setting commands [set normal response mode (SNRM), set asynchronous response mode (SARM), set normal response mode extended (SNRME), set asynchronous response mode extended (SARME), set initialization mode (SIM), and disconnect (DISC)];

b) accepting and responding to an exchange identification (XID) command;

c) accepting and responding to a test (TEST) command;

d) accepting and responding to an unnumbered poll (UP) command;

e) transmitting a disconnected mode (DM), request initialization mode (RIM), exchange identification (XID), or request disconnect (RD) response frame at a respond opportunity to solicit a specific action on the part of the primary station;

f) accepting an unnumbered information (UI) command; and

g) transmitting a UI response at a respond opportunity.

The capability of a combined station, as a receiver of commands, in the asynchronous disconnected mode, shall be the same as that stated above for a secondary station (appropriate mode setting commands for a combined station include the set asynchronous balanced mode (SABM), set asynchronous balanced mode extended (SABME), SIM and DISC commands]. In addition, since the combined station has the ability to transmit commands at any time, the combined station may transmit an appropriate mode setting, XID, UI or TEST command.

A secondary/combined station in a disconnected mode (NDM or ADM) shall, as a minimum capability, be capable of generating the DM response with the F bit set to "1" in response to a command frame received with the P bit set to "1".

A secondary/combined station in a disconnected mode (NDM or ADM) receiving a DISC command shall respond with the DM responses. A secondary/combined station in the initialization mode receiving a DISC command shall respond with the unnumbered acknowledgement (UA) response if it is capable of actioning the command. A secondary/command station in an operational mode receiving a DISC command shall respond with the UA response.

Examples of possible conditions (in addition to receiving a DISC command) which shall cause a secondary/combined station to enter a disconnected mode are:

a) the secondary/combined station power is turned on, or restored following a temporary loss of power;

b) the secondary/combined station data link level logic is manually reset; and

c) the secondary/combined station terminal is manually switched from a local (home) condition to a connected-on-the-data-link (on-line) condition.

A secondary/combined station in a non-operational mode shall not establish a frame reject exception condition.

5.2.1 Normal disconnected mode (NDM)

In NDM, which is an unbalanced data link non-operational mode, the secondary station shall be logically disconnected from the data link and shall, therefore, not be permitted to accept information in I command frames or to transmit information in I response frames. The secondary station shall, however, be permitted to accept information in UI command frames and to transmit information in UI response frames. The secondary station has normal mode respond opportunity and shall initiate a single frame response transmission, indicating its status, as a result of receiving a command frame with the P bit set to "1"; optionally, it may initiate such a response as the result of receiving a UP command with the P bit set to "0".

In this mode, a secondary station shall action only mode setting, XID, UI and TEST commands. Mode setting commands, except the DISC command, that can be actioned shall be responded to with the UA response at the earliest respond opportunity. A XID or TEST command that can be actioned shall be responded to with the XID and TEST response, respectively, at the earliest respond opportunity. Receipt of an implemented mode setting, XID or TEST command that cannot be actioned, or receipt of any other command (except a UI command) with the P bit set to "1", shall cause a secondary station in NDM to respond at the earliest respond opportunity with the DM response, or, if the secondary station determines it is unable to function, with the

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RIM response. Receipt of a UI command with the P bit set to "1" shall cause a secondary station in NDM to respond at the earliest respond opportunity with a UI response, with a DM response, or with a RIM response. In the case where an implemented mode setting, XID or TEST command has been received but cannot be actioned or a status condition is to be reported, a UP command with the P bit set to "0" shall cause a secondary station in NDM to respond with a DM or RIM response, as appropriate. Any command with the P bit set to "0", other than the implemented mode setting, XID, UI, TEST or UP commands as described above, may be ignored by the secondary station in NDM.

5.2.2 Asynchronous disconnected mode (ADM)

In ADM, which is an unbalanced data link or balanced data link non-operational mode, the secondary/combined station shall be logically disconnected from the data link and shall, therefore, not be permitted to accept information in I command frames/I command or response frames, respectively, or to transmit information in I response frames/I command or response frames, respectively. The secondary/combined station shall, however, be permitted to accept information in UI command frames/UI command or response frames, respectively, or to transmit information in UI response frames/UI command or response frames, respectively. The secondary station, or combined station as a receiver of commands, has asynchronous mode respond opportunity and may initiate a response transmission in two-way alternate exchange upon detection of an idle data link channel state, and in two-way simultaneous exchange at any time. Such a response transmission shall only consist of a UI response frame, a request for a mode setting command (DM), a request for exchange of identification (XID), or a request for initialization (RIM) if the secondary station, or combined station as a receiver of commands, determines it is unable to function. The combined station, as a transmitter of command frames, is also permitted to send a UI command frame at any asynchronous mode respond opportunity.

In this mode a secondary station, or combined station as a receiver of commands, shall action only mode setting, XID, UI and TEST commands. Mode setting commands, except the DISC command, that can be actioned shall be responded to with the UA response at the earliest respond opportunity. A XID or TEST command that can be actioned shall be responded to with the XID or TEST response, respectively, at the earliest respond opportunity. Receipt of an implemented mode setting, XID or TEST command that cannot be actioned, or receipt of any other command (except a UI command) with the P bit set to "1", shall be responded to with a DM response, or, if the secondary station, or combined station as a receiver or commands, determines it is unable to function, with the RIM response. Receipt of a UI command with the P bit set to "1" shall cause a secondary/combined station in ADM to respond at the earliest respond opportunity with a UI response, with a DM response, or with a RIM response. Any command with the P bit set to "0", other than the implemented mode setting, XID, UI, TEST or UP commands as described above, may be ignored by the secondary/combined station in ADM.

Because a combined station is also a generator of commands, it can terminate a disconnected mode at any time by transmitting an appropriate mode setting command (SABM, SABME, or SIM). Such action can be taken spontaneously or as a result of transmission received from the other combined station (for example, a DM or RIM response).

5.2.3 Initialization mode (IM)

In IM, which is an unbalanced data link or balanced data link non-operational mode, a secondary/one combined station data link control program may be initialized or regenerated by the primary/other combined station action, or other parameters to be used in the operational mode may be exchanged. IM is invoked when the primary/one combined station concludes that a secondary/other combined station is operating abnormally and needs its data link control program corrected, and for upgrading a secondary/other combined station data link control program. Similarly, a secondary/one combined station may determine it is unable to function due to program checks and request IM to obtain a good program from the primary/other combined station.

A secondary/combined station shall enter IM upon sending a UA response, at its system predefined respond opportunity, in response to the receipt of a SIM command. A secondary/combined station may request a SIM command by sending a RIM response. In IM, the primary/one combined station and a secondary/other combined station may exchange information in the predetermined manner specified for that secondary/each combined station (for example, UI or I frames).

IM shall be terminated when a secondary/combined station receives and acknowledges (via a UA response) one of the other mode setting commands, or when entering the disconnected mode caused by internal constraints such as loss of power.

6 Control field and parameters

6.1 Control field formats

6.1.1 General

The three formats defined for the control field (see table 1) are used to perform numbered information transfer, numbered supervisory functions and unnumbered control functions and unnumbered information transfer.

6.1.2 Information transfer (I) format

The I format is used to perform an information transfer. The functions of N(S), N(R) and P/F are independent; i.e. each I frame shall have an N(S) sequence number, an N(R) sequence number which may or may not acknowledge additional I frames at the receiving data station, and a P/F bit that may be set to "1" or "0".

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Table 1 — Control field formats

Control field format for	Control field bits*							
	1	2	3	4	5	6	7	8
Information transfer command/ response (I format)	0	N(S)			P/F	N(R)		
Supervisory commands/ responses (S format)	1	0	S	S	P/F	N(R)		
Unnumbered commands/ responses (U format)	1	1	M	M	P/F	M	M	M

* N(S) = transmitting send sequence number (bit 2 = low-order bit)

N(R) = transmitting receive sequence number (bit 6 = low-order bit)

S = supervisory function bit

M = modifier function bit

P/F = poll bit — primary station or combined station command frame transmissions/final bit — secondary station or combined station response frame transmissions (1 = poll/final)

6.1.3 Supervisory (S) format

The S format is used to perform data link supervisory control functions such as acknowledging I frames, requesting retransmission of I frames, and requesting a temporary suspension of transmission of I frames. The functions of N(R) and P/F are independent; i.e. each S format frame shall have an N(R) sequence number which may or may not acknowledge additional I frames at the receiving data station, and a P/F bit that may be set to "1" or "0".

6.1.4 Unnumbered (U) format

The U format is used to provide additional data link control functions and unnumbered information transfer. This format shall contain no sequence numbers, but shall include a P/F bit that may be set to "1" or "0". Five "modifier" bit positions are available, this allowing definition of up to 32 additional command functions and 32 additional response functions.

6.2 Parameters

6.2.1 Modulus

Each I frame shall be sequentially numbered with a number which may have the value 0 to modulus minus one inclusive (where modulus is the modulus of the sequence number). The modulus equals 8 or 128. The sequence numbers cycle through the entire range. The control field formats for modulo 8 are shown in table 1. The control field formats for modulo 128 are shown in table 4 (see 7.4).

The maximum number of sequentially numbered I frames that a primary, secondary or combined station may have outstanding (i.e. unacknowledged) at any given time shall never exceed one less than the modulus of the sequence numbers. This restriction is to prevent any ambiguity in the association of transmitted I frames with sequence numbers during normal operation and/or error recovery action.

NOTE — The number of outstanding I frames may be further restricted by the data station frame storage capability; for example, the number of I frames that can be stored for transmission and/or retransmission in the event of a transmission error. Optimum data link efficiency can only be obtained, however, if the minimum data station frame storage capacity is sufficient for the maximum anticipated round trip transmission delay.

6.2.2 Frame state variables and sequence numbers

6.2.2.1 General

In HDLC operations, each data station shall maintain an independent send state variable V(S) and an independent receive state variable V(R) for the I frames it sends to and receives from another data station. Each secondary station shall maintain a V(S) for the I frames it transmits to the primary station and an V(R) for the I frames it correctly receives from the primary station. In the same manner, the primary station shall maintain an independent V(S) and V(R) for I frames sent to and received from, respectively, each secondary station on the data link. Each combined station shall maintain a V(S) for the I frames it transmits to the other combined station, and a V(R) for the I frames it correctly receives from the other combined station.

6.2.2.2 Send state variable V(S)

The send state variable denotes the sequence number of the next in-sequence I frame to be transmitted. The send state variable can take the value 0 to modulus minus one inclusive (where modulus is the modulus of the sequence numbering scheme and the numbers cycle through the entire range). The value of the send state variable shall be incremented by one with each successive I frame transmission, but shall not exceed N(R) of the last received frame by more than modulus minus one.

6.2.2.3 Send sequence number N(S)

Only I frames shall contain N(S), the send sequence number of transmitted frames. Prior to transmission of an in-sequence I frame, N(S) shall be set equal to the value of the send state variable.

6.2.2.4 Receive state variable V(R)

The receive state variable denotes the sequence number of the next in-sequence I frame expected to be received. The receive state variable can take the value 0 to modulus minus

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one inclusive (where modulus is the modulus of the sequence numbering scheme and the numbers cycle through the entire rate). The value of the receive state variable shall be incremented by one on receipt of an error-free, in-sequence I frame whose send sequence number N(S) equals the receive state variable.

6.2.2.5 Receive sequence number N(R)

All I frames and S format frames shall contain N(R) which with the exception of the selective reject (SREJ) supervisory frame with the P/F bit set to "0" shall indicate the N(S) sequence number of the next expected I frame.

With this exception, prior to transmission of an I frame or S format frame, the N(R) shall be set equal to the current value of the receive state variable. The N(R) indicates that the station transmitting the N(R) has correctly received all I frames numbered up to N(R) - 1 inclusive.

In the case of the SREJ frame with the P/F bit set to "0". the N(R) indicates only that the I frame with N(S) equal to N(R) has not been received.

As more than one SREJ frame with the P/F bit set to "0" may be outstanding at any one time, it is necessary to ensure that all non-received I frames are ultimately correctly received. This may be achieved by multiple variable counters or by other means.

(See 7.2.4 for definition of the use of the SREJ command and response.)

6.2.3 Poll/final (P/F) bit

The poll (P) bit set to "1" shall be used by the primary/combined station to solicit (poll) a response or sequence of responses from the secondary station(s)/combined station.

The final (F) bit set to "1" shall be used:

a) by a secondary station in NRM to indicate the final frame transmitted as the result of a previous soliciting (poll) command; and

b) by a secondary station in ARM and by a combined station in ABM to indicate the response frame transmitted as the result of a soliciting (poll) command.

6.3 Functions of the poll/final (P/F) bit

The poll/final (P/F) bit shall serve a function in both command frames and response frames. (In command frames, the P/F bit is referred to as the P bit. In response frames, it is referred to as the F bit.)

6.3.1 Functions of the poll bit

6.3.1.1 General

The P bit set to '1" shall be used to solicit a response frame with the F bit set to "1" from the secondary/combined station.

On a data link, only one frame with a P bit set to "1" shall be outstanding in a given direction at a given time. Before a primary/combined station issues another frame with the P bit set to "1", it shall have received a response frame from the secondary/combined station with the F bit set to "1". If no valid response frame is obtained within a system-defined time-out period, the retransmission of a command with the P bit set to "1" for error recovery purposes shall be permitted.

6.3.1.2 Functions of the poll bit in NRM

In NRM, the P bit shall be set to '1" to solicit response frames from the secondary station. The secondary station shall not transmit until it receives either a command frame with the P bit set to "1" or a UP command.

The secondary station may send I frames upon receipt of an I frame with the P bit set to "1", certain S frames (RR, REJ or SREJ) with the P bit set to "1", a UI command with the P bit set to "1", or a UP command with the P bit set to "1" or "0".

6.3.1.3 Functions of the poll bit in ARM and ABM

In ARM and ABM, the P bit set to "1" shall be used to solicit a response, at the earliest respond opportunity, with the F bit set to "1".

NOTE — For example, if the primary/combined station requires positive acknowledgement that a particular command has been received, it sets the P bit in the command to "1". This forces a response from the secondary/combined station as described in 6.3.2.2.

6.3.2 Functions of the final bit

A response frame with the F bit set to "1" shall be used by the secondary/combined station to acknowledge the receipt of a command frame with the P bit set to "1".

6.3.2.1 Functions of the final bit in NRM

In NRM, if the right to transmit was acquired by the receipt of a P bit set to "1", then the secondary station shall set the F bit to "1" in the last frame of its response transmission. If the right to transmit was acquired by the receipt of a UP command with the P bit set to "0", then the secondary station shall set the F bit to "0" in each frame (including the last frame) of its response transmission.

Following transmission of the last frame of its response transmission, the secondary station shall stop transmitting until either a subsequent command frame with a P bit set to "1" is received, or a UP command is received.

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6.3.2.2 Functions of the final bit in ARM and ABM

In ARM and ABM, the secondary station and the combined station, respectively, may transmit response frames with the F bit set to "0" at any respond opportunity on an asynchronous basis. Following the receipt of a command frame and the P bit set to "1", the secondary/combined station shall initiate transmission of a response frame with the F bit set to "1" at the earliest respond opportunity.

In the case of a two-way simultaneous communication where the secondary/combined station is transmitting when the command frame with the P bit set to "1" is received, the F bit shall be set to "1" in the earliest possible subsequent response frame to be transmitted.

In ARM and ABM, the transmission of a response frame with the F bit set to "1" shall not require the secondary station or the combined station, respectively, to stop transmitting response frames. Additional response frames may be transmitted following the frame which had the F bit set to "1". Thus, in ARM and ABM, the F bit shall not be interpreted as the end of transmission by the secondary station or the combined station, respectively; it shall only be interpreted as indicating the response frame from the secondary/combined station sent as a reply to the previous command frame received with the P bit set to "1".

In ABM, if a combined station receives a command with the P bit set to "1", transmission of a response with the F bit set to "1" shall take precedence over transmission of commands, with the exception of the mode setting commands (SABM or SABME, SIM, DISC) and the reset (RSET) command.

6.3.3 Use of the P/F bit to assist in error recovery (see also clause 8)

6.3.3.1 General

As the P and F bits set to "1" are always exchanged as a pair (for every P bit there shall be one F bit, and another P bit shall not be issued until the previous P bit has been matched with an F bit, and, similarly, another F bit shall not be issued until another P bit is received), the N(R) contained in a received frame with a P bit (see 8.2.1h) or F bit set to "1" can be used to detect that I frame retransmission is required. This capability provides early detection of I frames not received by the remote data station and indicates the frame sequence number where retransmission shall begin. This capability is referred to as checkpointing. The N(R) of a correctly received I frame or S format frame, except for a SREJ frame with the P/F bit set to "0", shall acknowledge previously transmitted I frames to N(R) - 1 inclusive.

6.3.3.2 Checkpointing in NRM

In NRM, the N(R) of a received I, receive ready (RR) or receive not ready (RNR) command/response frame which has the P/F bit set to "1" shall cause the secondary/primary station to initiate appropriate error recovery if the N(R) does not acknowledge at least all I frames transmitted by the secondary/primary station previous to, and concurrent with, the last frame which was transmitted by the secondary/primary station with the F/P bit set to "1".

6.3.3.3 Checkpointing in ARM

In ARM, the N(R) of a received I, RR or RNR command/response frame which has the P/F bit set to "1" shall cause the secondary/primary station to initiate appropriate error recovery if the N(R) does not acknowledge at least all I frames transmitted by the secondary/primary station previous to, and concurrent with, the last frame which was transmitted by the secondary/primary station with the F/P bit set to "1".

6.3.3.4 Checkpointing in ABM

In ABM, the N(R) of a received I, RR or RNR response frame which has the F bit set to "1" shall cause the received combined station to initiate appropriate error recovery if the N(R) does not acknowledge at least all I frames transmitted by the receiving combined station previous to, and concurrent with, the last frame which was transmitted by the receiving combined station with the P bit set to "1".

6.3.4 Summary of P/F bit functions

The applicability of the P/F bit functions in the three operational modes (NRM, ARM, and ABM) and on data links employing two-way alternate and two-way simultaneous data communication is summarized in table 2.

Table 2 - P/F bit functions

Operational mode	NRM		ARM		ABM	
Data communication	TWA	TWS	TWA	TWS	TWA	TWS
P/F bit in command/response	P/F	P/F	P/F	P/F	P/F	P/F
Solicit information	x/	x/				
Last frame indication	x/x	/x				
Solicit supervisory or unnumbered response	x/	x/	x/	x/	x/	x/
Checkpointing	x/x	x/x	x/x	x/x	x/x	x/x

Key:

x indicates that the function is applicable

TWA - two-way alternate

TWS - two-way simultaneous

7 Commands and responses

The set of commands and responses is summarized in table 3.

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Table 3 - Commands and responses

Information transfer format commands	Information transfer format responses
I - Information	I -Information
Supervisory format commands	**Supervisory format responses**
RR - Receive ready RNR - Receive not ready REJ - Reject SREJ - Selective reject	RR - Receive ready RNR - Receive not ready REJ - Reject SREJ - Selective reject
Unnumbered format commands	**Unnumbered format responses**
SNRM - Set normal response mode	UA - Unnumbered acknowledgement
SARM - Set asynchronous response mode	DM - Disconnected mode
SABM - Set asynchronous balanced mode	RIM - Request initialization mode
DISC - Disconnect	RD - Request disconnect
SNRME - Set normal response mode extended	UI - Unnumbered information
SARME - Set asynchronous response mode extended	XID - Exchange identification
SABME - Set asynchronous balanced mode extended	FRMR - Frame reject
SIM - Set initialization mode	TEST - Test
UP - Unnumbered poll	
UI - Unnumbered information	
XID - Exchange identification	
RSET - Reset	
TEST - Test	

7.1 Information transfer format command and response

The function of the information, I, command and response shall be to transfer sequentially numbered frames, each containing an information field, across a data link.

The encoding of the I command/response control field shall be as shown in figure 4.

The I frame control field shall contain two sequence numbers.

a) N(S), send sequence number, which shall indicate the sequence number associated with the I frame; and

b) N(R), receive sequence number, which shall indicate the sequence number (as of the time of transmission) of the next expected I frame to be received, and consequently shall indicate that the I frames numbered up to N(R) - 1 inclusive have been received correctly.

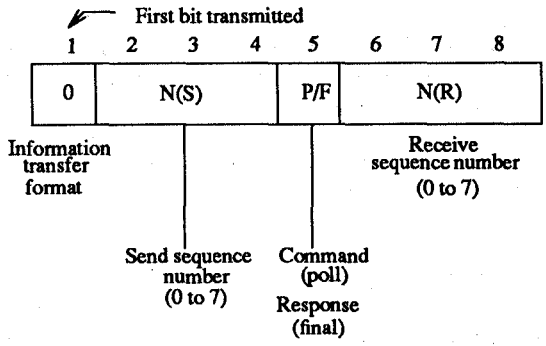

Figure 4 - Information transfer format of control field bits

(See 6.3 for a description of the functions of the P/F bit.)

7.2 Supervisory format commands and responses

Supervisory, S, commands and responses shall be used to perform numbered supervisory functions such as acknowledgement, polling, temporary suspension of information transfer, or error recovery.

Frames with the S format control field shall not contain an information field and, therefore, shall not increment the send state variable at the transmitter or the receive state variable at the receiver.

The encoding of the S format command/response control field shall be as shown in figure 5.

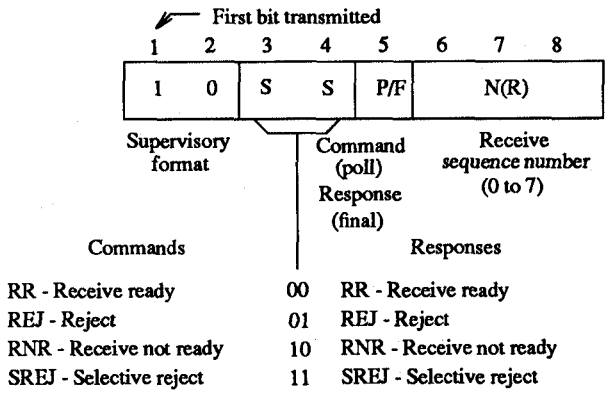

Figure 5 - Supervisory format of control field bits

An S format frame shall contain an N(R), receive sequence number. Except for the SREJ frame with the P/F bit set to "0", the N(R) shall indicate, at the time of transmission, the sequence number of the next expected I frame to be received,

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