

**Implementation of
EN 61158-2:1994**

Fieldbus standard for use in industrial control systems —

**Part 2: Physical layer specification and
service definition**

The European Standard EN 61158-2:1994, with the incorporation of its amendments A1:1996 and A2:1996, has the status of a British Standard

ICS 25.040.40; 35.100.10

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Advanced Manufacturing Technology Systems Standards Policy Committee (AMT/-) to Technical Committee AMT/7, upon which the following bodies were represented:

- Abb Kent plc
- Cegelec Industrial Controls Ltd.
- Department of Trade and Industry
- Fisher-Rosemount Ltd.
- Foxboro Great Britain
- Institution of Electrical Engineers
- Measurement Technology Ltd.
- Process Automation and Computer Systems Ltd. (PACS)
- Rockwell Automation
- Schneider Limited
- Siemens Automation plc

This British Standard, having been prepared under the direction of the Advanced Manufacturing Technology Standards Policy Committee, was published under the authority of the Standards Board and comes into effect on 15 August 1994

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The following BSI references relate to the work on this standard:
Committee reference AMT/7
Draft for comment 93/617007 DC

ISBN 0 580 23267 0

Amendments issued since publication

Amd. No.	Date	Comments
9265	November 1996	
9603	September 1997	Indicated by a sideline in the margin

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National foreword

This British Standard reproduces verbatim EN 61158-2:1994, together with its amendments A1:1996 and A2:1996, and implements it as the UK national standard.

This British Standard is published under the direction of the Advanced Manufacturing Technology Standards Policy Committee whose Technical Committee AMT/7 has the responsibility to:

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 117 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Fieldbus standard for use in industrial control systems Part 2: Physical layer specification and service definition

(includes amendments A1:1996 + A2:1996)
(IEC 1158-2:1993)

Bus de Terrain utilisé dans les systèmes de
contrôle industriels
Partie 2: Spécification de la couche physique et
définition du service
(inclut les amendements A1:1996 + A2:1996)
(CEI 1158-2:1993)

Feldbus für industrielle Leitsysteme
Teil 2: Spezifikation der
Bitübertragungsschicht (Physical layer) und
Definition deren Dienste
(enthält Änderungen A1:1996 + A2:1996)
(IEC 1158-2:1993)

This European Standard was approved by CENELEC on 1993-09-22. Amendment A1 was approved by CENELEC on 1995-11-28. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 65C(CO)34, as prepared by Sub-Committee 65C: Digital communications, of IEC Technical Committee 65: Industrial-process measurement and control, was submitted to the IEC-CENELEC parallel vote in November 1992.

The reference document was approved by CENELEC as EN 61158-2 on 22 September 1993.

The following dates were fixed:

- latest date of publication of an identical national standard (dop) 1994-12-15
- latest date of withdrawal of conflicting national standards (dow) 1995-12-15

Annexes designated “normative” are part of the body of the standard. Annexes designated “informative” are given only for information. In this standard, Annex A and Annex ZA are normative and Annex B and Annex C are informative.

Foreword to amendment A1

The text of document 65C143/DIS, future amendment 1 to IEC 1158-2:1993, prepared by SC 65C: Digital communications, of IEC TC 65, Industrial-process measurement and control, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as amendment A1 to EN 61158-2:1994 on 1995-11-28.

The following dates were fixed:

- latest date by which the amendment has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1996-09-01
- latest date by which the standards conflicting with the amendment have to be withdrawn (dow) —

Annexes designated “informative” are given for information only. In this standard, Annex D, Annex E and Annex F are informative.

Foreword to amendment A2

The text of document 65C/158/FDIS, future amendment 2 to IEC 1158-2:1993, prepared by SC 65C, Digital communications, of IEC TC 65, Industrial-process measurement and control, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as amendment A2 to EN 61158-2:1994 on 1996-10-01.

The following dates were fixed:

- latest date by which the amendment has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1997-08-01
- latest date by which the national standards conflicting with the amendment have to be withdrawn (dow) —

Annexes designated “normative” are part of the body of the standard. In this standard, Annex ZA is normative. Annex ZA has been added by CENELEC.

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Introduction

A Fieldbus is a digital, serial, multidrop, data bus for communication with low-level industrial control and instrumentation devices such as transducers, actuators and local controllers. The Physical Layer specified in this part of IEC 1158 provides for transparent transmission of data units between Data Link Layer entities across physical connections.

The Physical Layer receives data units from the Data Link Layer, adds preamble and delimiters, provides encoding and transmits the resulting physical signals to the transmission medium at one node. Signals are then received at one or more other nodes, decoded and stripped of preamble and delimiters, before being passed to the Data Link Layer of the receiving device.

Currently this part of IEC 1158 only specifies wire media. The common characteristics for wire media are as follows:

- a) digital data transmission;
- b) self-clocking;
- c) half-duplex communication (bidirectional but in only one direction at a time);
- d) Manchester coding.

The major variations for these media are two modes of coupling and three signalling speeds as follows:

- 1) voltage mode (parallel coupling), 31,25 kbit/s;
- 2) voltage mode (parallel coupling), 1,0 Mbit/s;
- 3) current mode (serial coupling), 1,0 Mbit/s;
- 4) voltage mode (parallel coupling), 2,5 Mbit/s.

The voltage mode variations 1), 2), and 4) may be implemented with inductive coupling using transformers. This is not mandatory if the isolation requirements of this part of IEC 1158 are met by other means.

Alternative media (e.g. coaxial cable, optical fibre and radio transmission) and speeds are not included in this edition of this part of IEC 1158.

The Physical Layer provides the options:

- i) no power via the bus conductors; not intrinsically safe;
- ii) power via the bus conductors; not intrinsically safe;
- iii) no power via the bus conductors; intrinsically safe;
- iv) power via the bus conductors; intrinsically safe.

A Fieldbus communication element is considered to be implemented in two parts, the Data Terminal Equipment (DTE) and the Data Communication Equipment (DCE). The DTE includes only one part of the Physical Layer, the DCE Independent Sublayer (DIS). The DIS transfers Interface Data Units (octets) across a Data Link Layer — Physical Layer interface which is not exposed to the user. The DIS then passes the Interface Data as a serial stream of binary Physical Layer Service Data Units (bits) across the DTE – DCE interface, which may optionally be exposed to the user, to a Medium Dependent Sublayer (MDS).

Three alternative types of MDS are currently envisaged; one for wire media, one for optical media, and one for radio. The MDS adds preamble plus start delimiter before the data block, adds an end delimiter after the data block and encodes the data. In the reverse direction it decodes signals received via the medium, removing preamble and delimiters and providing signal quality error checking.

Serial encoded signals are passed across an interface, which may optionally be exposed, to a Medium Attachment Unit (MAU) which transmits and receives Physical Layer signals via the medium.

A general model of the Physical Layer is shown in Figure 1.

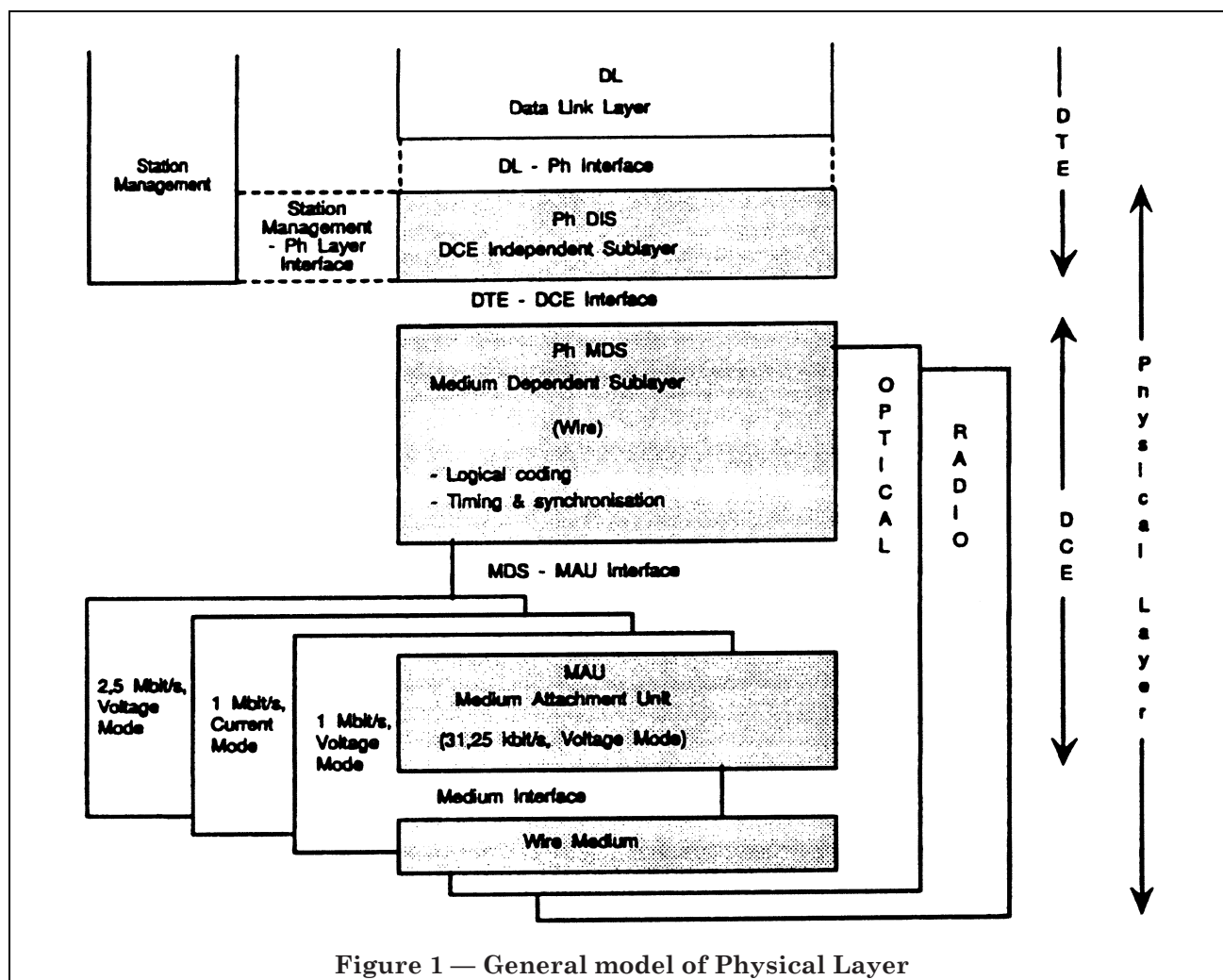


Figure 1 — General model of Physical Layer

1 Scope

This part of IEC 1158 specifies the requirements for Fieldbus component parts. It also specifies the media and network configuration requirements necessary to ensure agreed levels of:

- data integrity before Data Link Layer error checking;
- interoperability between devices at the Physical Layer.

The Fieldbus Physical Layer conforms to layer 1 of the OSI 7-layer model as defined by ISO 7498 with the exception that frame delimiters are in the Physical Layer.

This part of IEC 1158 should be read in conjunction with Part 1, Introductory Guide, Part 3, Data Link Service Definition, and Part 7, Fieldbus Management. The conformance testing requirements will be contained in Part 8 of IEC 1158.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of IEC 1158. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this part of IEC 1158 are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 255-22-1:1988, *Electrical disturbance tests for measuring relays and protection equipment — Part 1: 1 MHz burst disturbance tests.*

- IEC 364-4-41:1992, *Electrical installations of buildings — Part 4: Protection for safety — Chapter 41: Protection against electric shock.*
- IEC 364-5-54:1980, *Electrical installations of buildings — Part 5: Selection and erection of electrical equipment — Chapter 54: Earthing arrangements and protective conductors.*
- IEC 529:1989, *Degrees of protection provided by enclosures (IP Code).*
- IEC 760:1989, *Flat, quick-connect terminations.*
- IEC 793-2:1992, *Optical fibres — Part 2: Product specifications.*
- IEC 801-1:1984, *Electromagnetic compatibility for industrial-process measurement and control equipment — Part 1: General introduction.*
- IEC 801-2:1984, *Electromagnetic compatibility for industrial-process measurement and control equipment — Part 2: Electrostatic discharge requirements.*
- IEC 801-3:1984, *Electromagnetic compatibility for industrial-process measurement and control equipment — Part 3: Radiated electromagnetic field requirements.*
- IEC 801-4:1988, *Electromagnetic compatibility for industrial-process measurement and control equipment — Part 4: Electrical fast transient/burst requirements.*
- IEC 807-3:1990, *Rectangular connectors for frequencies below 3 MHz — Part 3: Detail specification for a range of connectors with trapezoidal shaped metal shells and round contacts — Removable crimp contact types with closed crimp barrels, rear insertion/front release, with assessed quality.*
- IEC 1131-2:1993, *Programmable controllers — Part 2: Equipment requirements and tests.*
- IEC 1158-1, *Fieldbus — Part 1: Introductory Guide.* (under consideration)
- IEC 1158-3, *Fieldbus — Part 3: Data Link Service Definition.* (under consideration)
- IEC 1158-4, *Fieldbus — Part 4: Data Link Protocol Specification.* (under consideration)
- IEC 1158-5, *Fieldbus — Part 5: Application Service Definition.* (under consideration)
- IEC 1158-6, *Fieldbus — Part 6: Application Protocol Specification.* (under consideration)
- IEC 1158-7, *Fieldbus — Part 7: Fieldbus Management.* (under consideration)
- IEC 1158-8, *Fieldbus — Part 8: Conformance Testing.* (under consideration)
- ISO 7498:1984, *Information Processing Systems — Open Systems Interconnection — Basic Reference Model.*
- ISO/IEC 10022:1990, *Information technology — Open System Interconnection — Physical Service Definition.*

NOTE A list of standards referred to for information only in this part of IEC 1158 is given in Annex C.

3 Definitions

For the purpose of this part of IEC 1158, the following definitions apply together with those in ISO 7498.

3.1

activity

the presence of a signal or noise at the input terminals of a Fieldbus device which is of a level which is above the receiver signal level threshold of that device

3.2

barrier

physical entity which limits current and voltage into a hazardous area in order to satisfy Intrinsic Safety requirements

3.3

bus

the trunk and all devices connected to it

3.4

communication element

part of a Fieldbus device which communicates with other elements via the bus

3.5
connector

coupling device employed to connect the medium of one circuit or communication element with that of another circuit or communication element

NOTE This definition is taken from IEEE Std 100-1984, modified for this part of IEC 1158.

3.6
coupler

physical interface between trunk and spur or trunk and device

3.7
data communications equipment (DCE)

the embodiment of the media, modulation and coding-dependent portion of a Fieldbus-connected device, comprising the lower portions of the Physical layer within the device

3.8
data terminal equipment (DTE)

the embodiment of the media, modulation and coding-independent portion of a Fieldbus-connected device, comprising the upper-most portion of the Physical layer and all higher layers within the device

3.9
delimiter

flag that separates and organizes items of data

NOTE This definition is taken from IEEE Std 100-1984.

3.10
device

physical entity connected to the Fieldbus composed of at least one communication element (the network element) and which may have a control element and/or a final element (transducer, actuator, etc.)

3.11
frame

a set of consecutive digit time slots in which the position of each digit time slot can be identified by reference to a framing signal

NOTE This definition is taken from IEEE Std 100-1984.

3.12
intrinsic safety

design methodology for a circuit or an assembly of circuits in which any spark or thermal effect produced under normal operating and specified fault conditions is not capable under prescribed test conditions of causing ignition of a given explosive atmosphere

NOTE This definition is taken from EN 50020:1977 (Intrinsically safe electrical apparatus).

3.13
isolation

physical and electrical arrangement of the parts of a signal transmission system to prevent electrical interference currents within or between the parts

NOTE This definition is taken from IEEE Std 100-1984.

3.14
jabber

continuous transmission on the medium due to a faulty device

3.15
manchester encoding

means by which separate data and clock signals can be combined into a single, self-synchronizing data stream, suitable for transmission on a serial channel

3.16**medium**

cable, optical fibre, or other means by which communication signals are transmitted between two or more points

NOTE In this part of IEC 1158 “media” is used only as the plural of medium.

3.17**network**

all of the media, connectors, and associated communication elements by which a given set of communicating devices are interconnected

3.18**node**

end-point of a branch in a network or a point at which one or more branches meet

NOTE This definition is taken from the IEC Multilingual Dictionary.

3.19**repeater**

device used to extend the range over which signals can be correctly transmitted and received for a given medium

3.20**segment**

the section of a Fieldbus which is terminated in its characteristic impedance. Segments are linked by repeaters to form a complete Fieldbus

3.21**separately powered device**

device that does not receive its operating power via the Fieldbus signal conductors

3.22**shield**

surrounding earthed metallic layer to confine the electric field within the cable and to protect the cable from external electrical influence

NOTE Metallic sheaths, armours and earthed concentric conductors may also serve as a shield.

3.23**spur**

branch-line (i.e. a link connected to a larger one at a point on its route) which is a final circuit

NOTE This definition is taken from IEEE Std 100-1984.

3.24**transceiver**

combination of receiving and transmitting equipment in a common housing employing common circuit components for both transmitting and receiving

NOTE This definition is taken from IEEE Std 100-1984 (modified for non-radio use).

3.25**transmitter**

transmit circuitry of a communication element

3.26**trunk**

main communication highway acting as a source of main supply to a number of other lines (spurs)

NOTE This definition is taken from IEEE Std 100-1984 (modified).

4 Symbols and abbreviations

4.1 Symbols

For the purpose of this part of IEC 1158, the following symbols apply:

Symbol	Definition	Units
f_r	Frequency corresponding to the bit rate	Hertz (Hz)
N+	Non-data symbol — positive	none
N–	Non-data symbol — negative	none
P	Nominal period of octet transmission	seconds
V_{DD}	The most positive supply level	Volts (V)
V_{IH}	Minimum high-level input voltage	Volts (V)
V_{IL}	Maximum low-level input voltage	Volts (V)
V_{OH}	Minimum high-level output voltage	Volts (V)
V_{OL}	Maximum low-level output voltage	Volts (V)
Z	Impedance	Ohms (Ω)
Z_o	Characteristic impedance (of cable)	Ohms (Ω)

4.2 Abbreviations

The following abbreviations are used in this part of IEC 1158:

CTS	Clear To Send signal (from DCE)
DCE	Data Communication Equipment
DIS	DCE Independent Sublayer
DL	Data Link — Approximately Layer 2 of the OSI model (ISO 7498)
DLE	Data Link Entity
DLL	Data Link Layer — Defined in ISO 7498
DTE	Data Terminal Equipment
EMI	Electro-Magnetic Interference
IDU	Interface Data Unit — Defined in ISO 7498
I.S.	Intrinsic Safety
kbit/s	Thousand bits per second
LbE	Loopback Enable signal (to MAU)
MAU	Medium Attachment Unit — For wire media, MAU = transceiver
Mbit/s	Million bits per second
MDS	Medium Dependent Sublayer
NRZ	Non-return-to-zero code — High level = logic 1, Low level = logic 0
Ph	Physical — Approximately Layer 1 of the OSI model (ISO 7498)
PhE	Physical Layer Entity — Defined in ISO 7498
PhL	Physical Layer — Defined in ISO 7498
PhICI	Physical Layer Interface Control Information — Defined in ISO 7498
PhID	Physical Layer Interface Data — Defined in ISO 7498
PhIDU	Physical Layer Interface Data Unit — Defined in ISO 7498
PhPCI	Physical Layer Protocol Control Information — Defined in ISO 7498
PhPDU	Physical Layer Protocol Data Unit — Defined in ISO 7498
PhS	Physical Layer Service — Defined in ISO 7498
PhSAP	Physical Layer Service Access Point — Defined in ISO 7498
PhSDU	Physical Layer Service Data Unit — Defined in ISO 7498
pk	Peak
pk-pk	Peak-to-peak
RDF	Receive Data and Framing signal (from DCE)
RFI	Radio Frequency Interference
RTS	Request To Send signal (to DCE)
RxA	Receive Activity signal (from DCE)
RxC	Receive Clock signal (from DCE)
RxS	Receive Signal (from MAU)

TxC	Transmit Clock signal (from DCE)
TxD	Transmit Data signal (to DCE)
TxE	Transmit Enable signal (to MAU)
TxS	Transmit Signal (to MAU)
SDU	Service Data Unit — Defined in ISO 7498

5 Data Link — Physical Layer interface

This clause defines the required Physical Service (PhS) primitives and constraints on their use.

NOTE 1 The requirements for a Fieldbus Data Link Layer are specified in IEC 1158-4. Services at the interface between the Data Link Layer and Physical Layer are specified in 5.1 and 5.2.

NOTE 2 The Data Link — Physical interface is a virtual service interface between virtual machines; there are no requirements for physical signal lines as the standard does not require this interface to be exposed.

5.1 Required services

PhIDUs shall be transferred between the Data Link Layer and the Physical Layer in accordance with the requirements of ISO 7498 as shown in Figure 2.

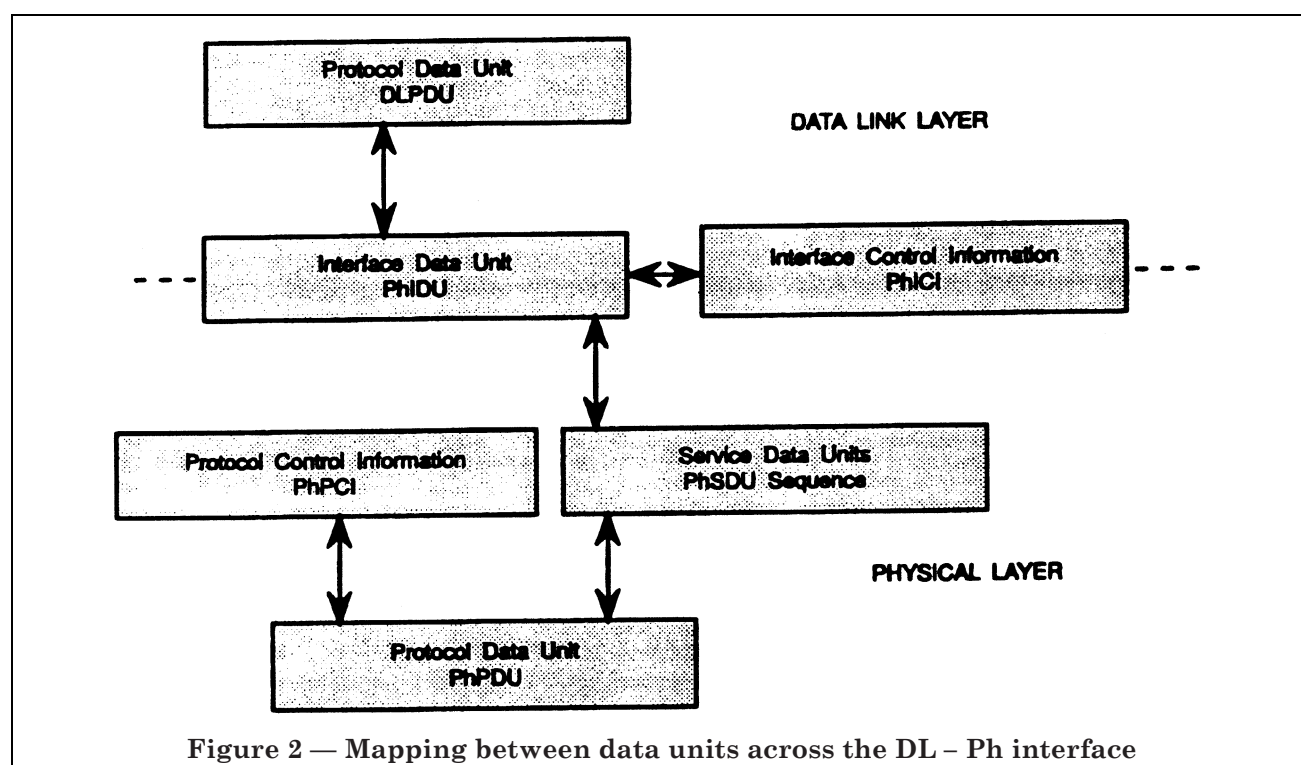


Figure 2 — Mapping between data units across the DL – Ph interface

NOTE 1 These services provide for the interchange of PhIDUs between a Data Link Layer entity and its associated Physical Layer entity. Such a transfer is part of a transaction between cooperating Data Link Layer entities. The services listed in this section are the minimum which can jointly provide the means by which cooperating Data Link Layer entities can coordinate their transmission and their exchange of data on the shared communication medium.

NOTE 2 Proper layering requires that an (N+1)-layer entity not be concerned with, and that an (N)-service interface not overly constrain, the means by which an (N)-layer provides its (N)-services. Thus the Ph-service interface does not require DLEs to be aware of internal details of the PhE (e.g., preamble, postamble and frame delimiter signal patterns, number of bits per baud), and should not prevent the PhE from using appropriate evolving technologies.

5.1.1 Primitives of the PhS

The granularity of PhS-user data exchanged at the PhL – DLL interface is one octet.

5.1.1.1 Ph-Characteristics Indication

The PhS shall provide the following service primitive to report essential PhS characteristics (which may be used in DLL transmission, reception, and scheduling activities):

Ph-CHARACTERISTICS indication (minimum-data-rate, framing-overhead)

where

minimum-data-rate — shall specify the effective minimum rate of data conveyance in bits/second, including any timing tolerances.

NOTE A PhE with a nominal data rate of 1 Mbit/s $\pm$ 0,01 % would specify a minimum data rate of 0,9999 Mbit/s.

framing overhead — shall specify the maximum number of bit periods (where period is the inverse of the data rate) used in any transmission for PhPDUs which do not directly convey data (e.g., PhPDUs conveying preamble, frame delimiters, postamble, inter-frame “silence”, etc.).

NOTE If the framing overhead is F and two DL message lengths are L_1 and L_2 , then the time to send one message of length $L_1 + F + L_2$ will be at least as great as the time required to send two immediately consecutive messages of lengths L_1 and L_2 .

5.1.1.2 PhS transmission and reception services

The PhS shall provide the following service primitives for transmission and reception:

Ph-DATA request (class, data)

Ph-DATA indication (class, data)

Ph-DATA confirm (status)

where

class — shall specify the PhICI component of the PhIDU. For a Ph-DATA request, its possible values shall be:

START-OF-ACTIVITY — transmission of the PhPDUs which precede Ph-user data shall commence;

DATA — the single-octet value of the associated data parameter shall be transmitted as part of a continuous correctly formed transmission; and

END-OF-DATA-AND-ACTIVITY — the PhPDUs which terminate Ph-user data shall be transmitted after the last preceding octet of Ph-user data, culminating in the cessation of active transmission.

For a Ph-DATA indication, its possible values shall be:

START-OF-ACTIVITY — reception of an apparent transmission from one or more PhEs has commenced;

DATA — the associated data parameter was received as part of a continuous correctly formed reception;

END-OF-DATA — the ongoing continuous correctly formed reception of Ph-user data has concluded with correct reception of PhPDUs implying END-OF-DATA;

END-OF-ACTIVITY — the ongoing reception (of an apparent transmission from one or more PhEs) has concluded, with no further evidence of PhE transmission; and

END-OF-DATA-AND-ACTIVITY — simultaneous occurrence of END-OF-DATA and END-OF-ACTIVITY.

data — shall specify the PhID component of the PhIDU. It consists of one octet of Ph-user-data to be transmitted (Ph-DATA request) or which was received successfully (Ph-DATA indication).

status — shall specify either success or the locally-detected reason for inferring failure.

The Ph-DATA confirm primitive shall provide the critical physical timing feedback necessary to inhibit the DLE from starting a second transmission before the first is complete. The final Ph-DATA confirm of a transmission shall not be issued until the PhE has completed the transmission.

5.1.2 Notification of PhS characteristics

The PhE has the responsibility for notifying the DLE of those characteristics of the PhS which may be relevant to DLE operation. The PhE shall do this by issuing a single Ph-CHARACTERISTICS indication primitive at each of the PhE's PhSAPs at PhE start-up.

5.1.3 Transmission of Ph-user-data

The PhE shall determine the timing of all transmissions. When a DLE transmits a sequence of PhSDUs, the DLE shall send the sequence of PhSDUs by making a well-formed sequence of Ph-DATA requests, consisting of a single request specifying START-OF-ACTIVITY, followed by 3 to 300 consecutive requests, inclusive, specifying DATA, each conveying a PhSDU, and concluded by a single request specifying END-OF-DATA-AND-ACTIVITY.

The PhE shall signal its completion of each Ph-DATA request, and its readiness to accept a new Ph-DATA request, by issuing a Ph-DATA confirm primitive; the status parameter of the Ph-DATA confirm primitive shall convey the success or failure of the associated Ph-DATA request. A second Ph-DATA request shall not be issued by the DLE until after the Ph-DATA confirm corresponding to the first request has been issued by the PhE.

5.1.4 Reception of Ph-user-data

The PhE shall report a received transmission with a well-formed sequence of Ph-DATA indications, which shall consist of either

- a) a single indication specifying START-OF-ACTIVITY; followed by consecutive indications specifying DATA, each conveying a PhSDU; followed by a single indication specifying END-OF-DATA; and concluded by a single indication specifying END-OF-ACTIVITY; or
- b) a single indication specifying START-OF-ACTIVITY; followed by consecutive indications specifying DATA, each conveying a PhSDU; followed by a single indication specifying END-OF-DATA-AND-ACTIVITY; or
- c) a single indication specifying START-OF-ACTIVITY; optionally followed by one or more consecutive indications specifying DATA, each conveying a PhSDU; and concluded by a single indication specifying END-OF-ACTIVITY.

This last sequence is indicative of an incomplete or incorrect reception. Detection of an error in the sequence of received PhPDUs, or in the PhE's reception process, shall disable further Ph-DATA indications with a class parameter specifying DATA, END-OF-DATA, or END-OF-DATA-AND-ACTIVITY until after both the end of the current period of activity and the start of a subsequent period of activity have been reported by Ph-DATA indications specifying END-OF-ACTIVITY and START-OF-ACTIVITY, respectively.

6 Station Management — Physical Layer interface

NOTE 1 This interface provides services to the Physical Layer which are required for initialization and selection of options.

NOTE 2 One of the objectives of the Physical Layer is to allow for future variations such as radio, fibre optics, redundant channels (e.g. cables), different modulation techniques, etc. A general form of Station Management — Physical Layer Interface is specified which provides the services required by implementations of these variations. Services provided by this interface are specified in 6.1 and 6.2. The standard does not require this interface to be exposed.

NOTE 3 The complete set of management services can only be used when the device is directly coupled to the medium. In the case of actively coupled equipment (e.g. active coupler, repeater, radio/telephone modem, opto-electronics etc.) some of the services can be implicit to the active coupler. Moreover, each device can use a subset of the described primitives.

6.1 Required services

The minimum service primitive for Physical Layer (PhL) management shall be:

- a) Ph-RESET request — reset of the Ph-Layer.

The following additional services may be provided:

- b) Ph-SETVALUE request/Ph-SETVALUE confirm — set parameters;
- c) Ph-GETVALUE request/Ph-GETVALUE confirm — read parameters;
- d) Ph-EVENT indication — report Ph-Layer events.

6.2 Service primitive requirements

6.2.1 Ph-RESET request

This primitive has no parameter. Upon reception of this primitive the Physical Layer shall reset all its functions.

6.2.2 Ph-SETVALUE request (parameter name, new value)

If this primitive is used it shall allow Station Management to modify the parameters of the Physical Layer. Standard parameter names and value ranges are given in Table 1. The value assumed for each parameter at reset shall be the first of those shown for the parameter.

Table 1 — Parameter names and values for Ph-SETVALUE request

Parameter name	Range of values
Interface mode	● FULL_DUPLEX ● HALF_DUPLEX
Loop-back mode	● DISABLED ● in MDS at DTE – DCE interface ● in MAU near line connection
Preamble extension	● 0..7 (preamble extension sequences)
Post-transmission gap extension	● 0..7 (gap extension sequences)
Maximum inter-channel signal skew	● 0..7 (gap extension sequences)
Transmitter output channel N ($1 \leq N \leq 8$)	● ENABLED ● DISABLED
Receiver input channel N ($1 \leq N \leq 8$)	● ENABLED ● DISABLED
Preferred receive channel	● NONE ● 1..8

NOTE 1 Not all implementations require every parameter, and some may need more.

NOTE 2 Each DCE standard specifies both the basic and extension sequences of PhPDUs to be sent as preamble. These extension sequences are always prefixed to the basic sequence.

NOTE 3 Each DCE standard specifies the lengths of both the basic and extension sequences of post-transmission gap during which the transmitter should be silent.

NOTE 4 From the above, the default value at reset is minimum preamble (no extension), minimum post-transmission gap (no extension), full-duplex interface mode, not in loopback, with all transmit and receive channels enabled, and with no preferred receive channel.

6.2.3 Ph-SETVALUE confirm (status)

This primitive has a single parameter indicating the status of the request: Success or Failure. If this primitive is used it shall acknowledge completion of the Ph-SETVALUE request in the Physical Layer.

6.2.4 Ph-GETVALUE request (parameter name)

If this primitive is used it shall allow the Station Management to read the parameters of the Physical Layer. The parameter shall have one of the names given in Table 1.

6.2.5 Ph-GETVALUE confirm (current value)

This primitive is the response of the Physical Layer to the Ph-GETVALUE request. If this primitive is used it shall have a single parameter reporting either the failure of the request — Failure — or the present value of the requested parameter. The current value shall be one of those permitted by 6.2.2.

6.2.6 Ph-EVENT indication (parameter name)

If this primitive is used it shall notify the Station Management of a Physical Layer parameter modification which has not been requested by the Station Management. The parameter shall have one of the names and values given in Table 2, based on names specified in clause 8.

NOTE Additions to Table 2 are possible if required by specific implementations.

Table 2 — Parameter names for Ph-EVENT indication

Parameter name
DTE fault
DCE fault

7 DCE Independent Sublayer (DIS)

NOTE 1 The Physical Layer entity is partitioned into a Data Terminal Equipment (DTE) component and a Data Communication Equipment (DCE) component. The DTE component interfaces with the Data Link Layer entity, and forms the DCE Independent Sublayer (DIS). It exchanges Interface Data Units across the DL – Ph interface defined in clause 5, and provides the basic conversions between the PhIDU “at-a-time” viewpoint of the DL – Ph interface and the bit serial viewpoint required for physical transmission and reception.

NOTE 2 This sublayer is independent of all the Physical Layer variations, including encoding and/or modulation, speed, voltage/current/optical mode, medium etc. All these variations are grouped under the designation Data Communication Equipment (DCE).

The DIS shall sequence the transmission of the PhID as a sequence of serial PhSDUs. Similarly, the DIS shall form the PhID to be reported to the Data Link Layer from the sequence of received serial PhSDUs.

The PhID shall be converted to a sequence of PhSDUs for serial transmission in octets up to a maximum of 300 octets. A PhSDU representing more significant octets of the PhID shall be sent before or at the same time as a PhSDU representing less significant octets and such that within each octet, a PhSDU representing a more significant bit will be transmitted before or at the same time as a PhSDU representing a less significant bit. On reception, each sequence of PhSDUs shall be converted to PhID such that, in the absence of errors, the PhIDU indicated to the receiving Data Link Layer entity shall be unchanged from the PhIDU whose transmission was requested by the originating Data Link Layer entity.

NOTE 3 This is a guarantee of transparency.

8 DTE – DCE interface

NOTE 1 The Physical Layer entity is partitioned into a Data Terminal Equipment (DTE) component containing the MIS and higher layers, and a Data Communication Equipment (DCE) component containing the MDS and lower sub-layers. The DTE – DCE interface connects these two physical components.

NOTE 2 It is not mandatory for the DTE – DCE interface, or any other interface, to be exposed.

NOTE 3 The DTE – DCE interface is a functional and electrical, but not mechanical, interface which supports a set of services. Each of these services is implemented by a sequence of defined signalling interactions at the interface.

8.1 Services

The following services, defined in this sub-clause, shall be supported by the DTE – DCE interface:

- a) DTE to DCE reset service;
- b) DTE to DCE configuration service;
- c) DTE to DCE message-transmission service;
- d) DCE to DTE fault notification service;
- e) DCE to DTE media-activity indication service;
- f) DCE to DTE message-reporting service.

8.1.1 DTE to DCE reset service

This service shall provide a means by which the DTE, at any time, can reset the DCE to its initial (power-on) state.

8.1.2 DTE to DCE configuration service

This service shall provide a means by which the DTE can configure various characteristics of the DCE, including those characteristics which station management can adjust via Ph-SETVALUE requests (see Table 1). It also shall provide a DCE-optional means by which the DTE can initiate reporting of DCE status by preemptive use of the DCE to DTE message-reporting service.

8.1.3 DTE to DCE message-transmission service

This service shall provide a means by which the DTE can transmit a message through the DCE to either the connected medium (media), or back to the DTE, or both, as determined by the current operational values of the parameters specified in Table 1. The DCE shall provide the pacing for this service.

This service is invoked upon receipt of a Ph-DATA request specifying START-OF-ACTIVITY at the PhL service interface, and runs until receipt of and completion of the Ph-DATA request specifying END-OF-DATA-AND-ACTIVITY.

8.1.4 DCE to DTE fault notification service

This service shall provide a means by which the DCE, at any time, can report a fault. The specific nature of the fault is not reported by this service, but may be determinable by use of the DTE to DCE configuration service to initiate a DCE-optional DCE status report.

8.1.5 DCE to DTE media-activity indication service

This service shall provide a means by which the DCE reports the inferred detection, on any of its connected media for which receiving is enabled (see Table 1), of signalling from itself or other Ph-Layer entities. While loopback is enabled, this service reports only the signalling of the DCE itself.

When the DTE – DCE interface is in half-duplex mode and loopback is not enabled, this service need not report media activity resulting directly from the DTE to DCE message-transmission service.

8.1.6 DCE to DTE message-reporting service

This service shall provide a means by which the DCE reports the receipt of a sequence of PhPDUs from any one of the connected media for which receiving is enabled. This service terminates with an indication of whether the sequence of received PhPDUs was well formed. Errors in the sequence, including number of PhPDUs such that they could not have been a correct transmission resulting from an invocation of the DCE to DTE message-transmission service shall be reported as a malformed (erroneous) sequence.

NOTE Errors in the octet alignment of a received end delimiter with respect to the preceding start delimiter (i.e., not separated by an integral number of octets of data bits) is to be reported as a malformed sequence.

When the DTE – DCE interface is in half-duplex mode and loopback is not enabled, this service need not report the message transmitted by the DCE to DTE message-transmission service.

8.2 Interface signals

If the DTE – DCE interface is exposed it shall provide the signals specified in Table 3.

Table 3 — Signals at DTE – DCE interface

Signal	Abbreviation	Source
Transmit Clock	TxC	DCE
Request to Send	RTS	DTE
Clear to Send	CTS	DCE
Transmit Data	TxD	DTE
Receive Clock	RxC	DCE
Receive Activity	RxA	DCE
Receive Data and Framing	RDF	DCE

The signal levels shall be as shown in Table 4. In general, both sides of the interface shall operate with the same approximate value of V_{DD} . However, it is recognized that a DTE and a DCE with separate power supplies may not both reach operational V_{DD} simultaneously. It is desirable, but not mandatory, that the DTE to DCE reset service be operational when the DCE has not yet reached operational V_{DD} . It is also desirable that the DTE invoke this service whenever its own V_{DD} is below operational margins.

Table 4 — Signal levels for an exposed DTE – DCE interface

Symbol	Parameter	Conditions	Limits	Units	Remarks
V_{OL}	Maximum low-level output voltage	$I_{out} = \pm 100 \mu A$	0,1	V	See Note 1
		$I_{out} = + 1,6 \text{ mA}$	0,4	V	
V_{OH}	Minimum high-level output voltage	$I_{out} = \pm 100 \mu A$	$V_{DD} - 0,1$	V	See Note 1
		$I_{out} = - 0,8 \text{ mA}$	$V_{DD} - 0,8$	V	See Note 2
V_{IL}	Maximum low-level input voltage		$0,2 V_{DD}$	V	
V_{IH}	Minimum high-level input voltage		$0,7 V_{DD}$	V	See Note 3

NOTE 1 Provides the capability to drive two typical CMOS loads.

NOTE 2 CMOS input compatibility with TTL output requires a “pull-up” resistor from signal input to V_{DD} .

NOTE 3 Compatible with CMOS output for $3,0 \text{ V} \leq V_{DD} \leq 5,5 \text{ V}$. Compatibility with TTL output ($4,75 \text{ V} \leq V_{DD} \leq 5,25 \text{ V}$) requires a “pull-up” resistor from signal input to V_{DD} .

The timing characteristics of these signals shall be at least equal to those specified for the relevant DCE in the requirements of this part of IEC 1158. However, in no case shall the transition time between $0,3 V_{DD}$ and $0,6 V_{DD}$ be greater than either 100 ns or $0,025 P$, whichever is smaller. P is defined as the nominal period of octet transmission — the inverse of the nominal PhSDU rate.

An implementation of the DTE – DCE interface shall function correctly with transmit and receive (TxC and RxC) clock frequencies between 1 kHz and 8,8 times the highest supported PhSDU rate of the DTE or DCE implementation.

NOTE The PhSDU and equivalent bit data rates available in an implementation are stated in the Protocol Implementation Conformance Statement (PICS).

8.2.1 Transmit Clock (TxC)

The Transmit Clock signal (TxC) shall provide the DTE with a continuous timing signal, such that any eight consecutive full cycles of this signal shall have the same octet period as the nominal transmit period for one data octet. The DCE shall source this nominally two-phase signal such that each phase has a duration of at least $0,04 P$.

NOTE This specification permits TxC to be a continuous, constant-period clock at the nominal bit rate (8 times the nominal octet rate) with a duty cycle of 32 % to 68 %, or for TxC to be a higher-frequency clock with some cycles omitted and with a duty cycle closer to 50 %. This permits, for example, simple clocking in a DCE that recodes each 4 bits into 5 bauds; the DCE could have a clock 10 times the nominal octet rate, with a duty cycle of between 40 % and 60 %, and would omit (the same) two cycles every octet. TxC supports the DTE to DCE configuration and message-transmission services.

8.2.2 Request to Send (RTS)

The Request to Send (RTS) signal supports the DTE to DCE reset, configuration, and message-transmission services. The DTE shall source this signal. The initial (power-on) and idle (no DTE to DCE service active) state of this signal shall be low.

When referenced to TxC at the DTE – DCE interface, this signal shall have a minimum setup time of the smaller of either 100 ns or $0,025 P$; the hold time shall be zero or greater.

8.2.3 Clear to Send (CTS)

The Clear to Send (CTS) signal supports the DTE to DCE configuration and message-transmission services. The DCE shall source this signal. The initial (power-on) and idle (no DTE to DCE service active) state of this signal shall be low.

When referenced to TxC at the DTE – DCE interface, this signal shall have a minimum setup time of the smaller of either 100 ns or $0,025 P$; the hold time shall be zero or greater.

8.2.4 Transmit Data (TxD)

The Transmit Data (TxD) signal supports the DTE to DCE reset, configuration, and message-transmission services. Binary data is transmitted from DTE to DCE during one phase of the latter two services, and during this phase a binary 0 is represented by a low level on TxD and a binary 1 by a high level on TxD, both sampled at the falling edge of TxC.

The DTE shall source this signal. The initial (power-on) and idle (no DTE to DCE service active) state of this signal shall be high.

When referenced to TxC at the DTE – DCE interface, this signal shall have a minimum setup time of the smaller of either 100 ns or $0,025 P$; the hold time shall be zero or greater.

8.2.5 Receive Clock (RxC)

The Receive Clock signal (RxC) shall provide the DTE with an intermittent (semi-continuous) nominally two-phase timing signal which defines the timing of information being reported via the RDF signal. The DCE shall source this signal such that, where RxC is defined to be meaningful (see 8.3.6), each phase has a duration of at least $0,04 P$.

NOTE This specification permits RxC to be a recovered clock at the nominal bit rate (8 times the nominal octet rate) with a duty cycle of 32 % to 68 %, or to be a higher-frequency clock with some cycles omitted and with a duty cycle closer to 50 %. This permits, for example, simple clocking in a DCE that decodes 4 bits from each received 5 bauds; the DCE could have a clock 10 times the nominal octet rate, with a duty cycle of between 40 % and 60 %, and would omit two cycles every octet. This specification also permits the DCE to omit cycles of RxC during recognition of long end-delimiter sequences of PhPDUs, so that the delimiter can be reported in real time using 8 or fewer cycles of RxC (see 8.3.6).

RxC shall support the DCE to DTE message-reporting service.

8.2.6 Receive Activity (RxA)

The Receive Activity (RxA) signal shall support the DCE to DTE fault notification, media-activity indication, and message-reporting services. The DCE shall source this signal. The initial (power-on) and idle (no DCE to DTE service active) state of this signal shall be low.

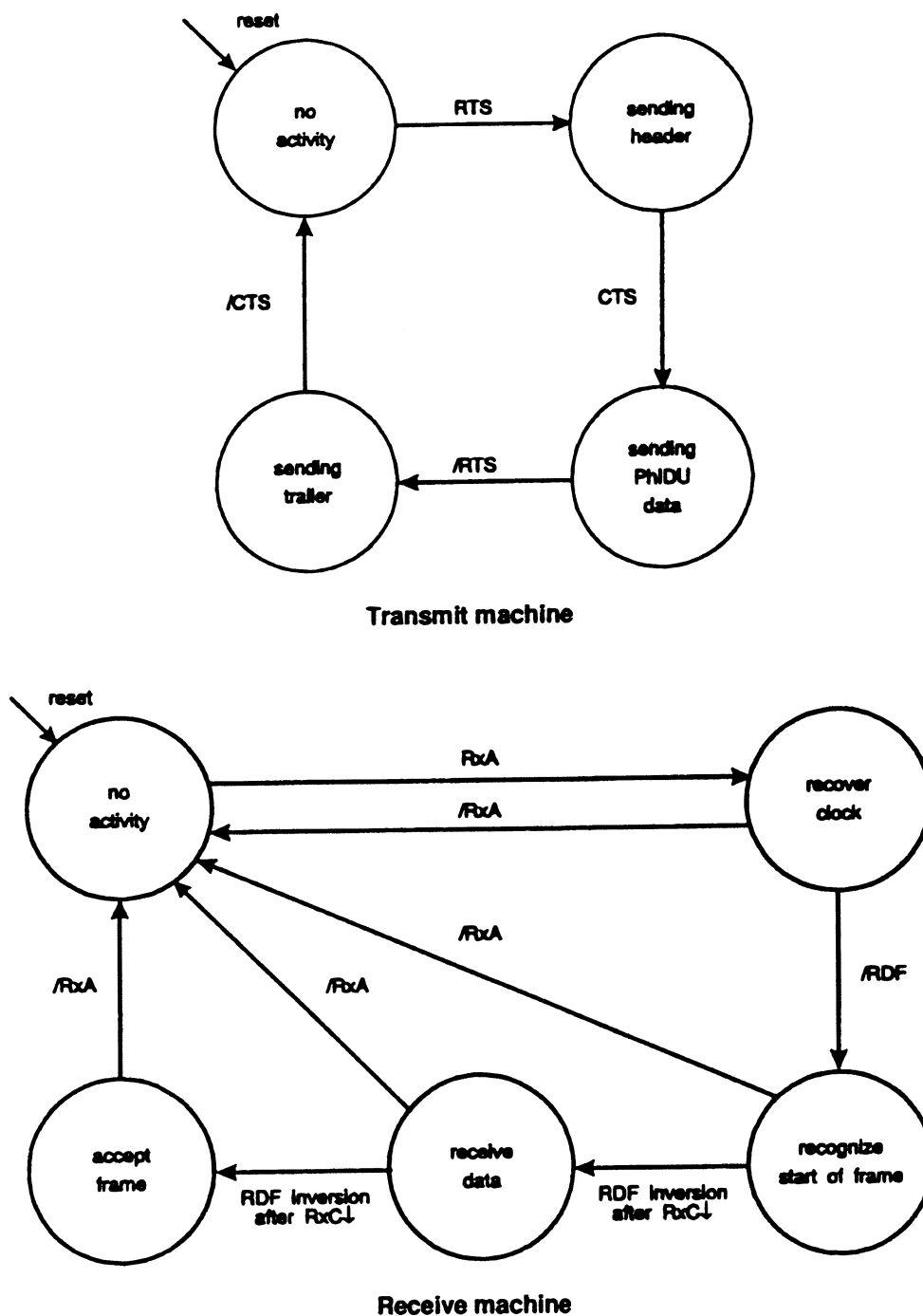


Figure 3 — DTE/DCE sequencing machines

8.2.7 Receive Data and Framing (RDF)

The Receive Data and Framing (RDF) signal shall support the DCE to DTE fault notification and message-reporting services. Binary data is transmitted from DCE to DTE during some phases of the latter service, and during these phases a binary 0 is represented by a low level on RDF and a binary 1 by a high level on RDF, both sampled at the falling edge of RxCl.

The DCE shall source this signal. The initial (power-on) and idle (no DCE to DTE service active) state of this signal shall be high.

When referenced to RxC at the DTE – DCE interface, this signal shall have a minimum setup time of the smaller of either 100 ns or 0,025 P ; the hold time shall be zero or greater.

8.3 Encoding of services in signals

The services of 8.1 shall be implemented by the following sequences and combinations of the signals of 8.2.

NOTE Typical transmit and receive sequencing machines are shown in Figure 3. Figure 3 is included in this part of IEC 1158 for explanatory purposes and does not imply a specific implementation.

8.3.1 DTE to DCE reset service

This service shall be mutually exclusive with the DTE to DCE configuration and message-transmission services; at most one of them may be active at any given time. This service may preempt the DTE to DCE configuration and message-transmission services at any time.

This service shall be encoded as a simultaneous low level on both RTS and TxD. When asserted by the DTE, this simultaneous low level shall be held for at least the nominal transmission period of two PhSDUs (octets).

NOTE 1 This is an asynchronous service, and is not referenced to TxC.

NOTE 2 When a DTE is itself being reset, possibly during power-up, it should attempt to reset the DCE even when the DTE's own V_{DD} is below normal operational limits.

NOTE 3 This reset is under the control of the DTE. It does not preclude the existence of a separate reset pin on the DCE.

If the DTE concurrently changes both RTS and TxD during the implementation of either the DTE to DCE configuration or message-transmission services, then the DTE shall ensure that an interval of at least the minimum required setup time exists between changing the one signal to a high level, and subsequently changing the other signal to a low level, to eliminate potential logic hazards in the DCE's implementation of the DTE to DCE reset service.

8.3.2 DTE to DCE configuration service

This service is mutually exclusive with the DTE to DCE reset and message-transmission services; at most one of them may be active at any given time. This service may initiate the DOE to DTE message-reporting service to report DCE-internal status. The DTE to DCE reset service may preempt this service at any time. This service shall be implemented in three phases; each of the latter two phases shall follow immediately upon completion of the prior phase.

NOTE 1 These phases can be implemented as a minor variation on the three phaseS specified for the DTE to DCE message-transmission service. As a result, the DTE to DCE configuration service induces very little added complexity on the DTE and DCE.

- 1) The DTE shall assert (raise) RTS after the falling edge, and before the rising edge, of TxC. The DCE shall respond by anticipating configuration data.
- 2) When it is ready for configuration data from the DTE, the DCE shall raise CTS before the falling edge of TxC. The DTE shall respond by encoding the first bit of configuration data (high = 1, low = 0) on TxD before the falling edge of the next TxC, and shall continue this process without interruption until between 2 and 200 bits of data (see 8.4) have been so encoded. The DTE shall then assert (raise) TxD and negate (lower) RTS before the falling edge of the next TxC.

NOTE 2 The DTE should ensure that TxD is raised at least one setup time before RTS is lowered, to avoid potential logic hazards in the DCE implementation of the DTE to DCE reset service.

- 3) The DCE shall conclude any necessary reconfiguration before negating (lowering) CTS, which shall occur between two consecutive falling edges of TxC.

Both standardized and extendible configuration messages are defined in 8.4. Standardized messages cover the ranges of application of this interface which are anticipated to be most cost sensitive. Extendible messages permit differing forms of DCE configuration where required, and can serve to initiate the DCE to DTE message-reporting service to report DCE-internal status (a DCE option further described in 8.4).

8.3.3 DTE to DCE message-transmission service

This service is mutually exclusive with the DTE to DCE reset and configuration services; at most one of them may be active at any given time. The DTE to DCE reset service may preempt this service at any time.

This service shall be implemented in three phases; each of the latter two phases shall follow immediately upon completion of the prior phase.

- 1) The DTE shall assert (raise) RTS after the rising edge, and before the falling edge, of TxC. The DCE shall respond by generating and transmitting the appropriate-length sequence of preamble and start delimiter PhPDUs.

2) When it is ready for transparent data from the DTE, the DCE shall raise CTS before the falling edge of TxC. The DTE shall respond by encoding the first bit of transparent data (high = 1, low = 0) on TxD before the next falling edge of TxC, and shall continue this process without interruption until between 3 and 300 integral octets of data have been so encoded. The DTE shall then assert (raise) TxD and negate (lower) RTS before the next falling edge of TxC.

NOTE The DTE shall ensure that TxD is raised at least one setup time before RTS is lowered, to avoid potential logic hazards in the DCE implementation of the DTE to DCE reset service.

3) The DCE shall conclude transmission of all of the encoded transparent data received from the DTE, shall then generate and transmit the appropriate-length sequence of end delimiter PhPDUs, and shall then cease transmission. The DCE shall then wait an amount of time equal to the configured minimum post-transmission gap (see Table 1) before negating (lowering) CTS, which shall occur after a falling edge, and before the next falling edge, of TxC.

8.3.4 DCE to DTE fault notification service

This service shall be mutually exclusive with the DCE to DTE media-activity indication and message-reporting services; at most one of them may be active at any given time. This service may preempt the DCE to DTE media-activity indication and message-reporting services at any time.

This service shall be encoded as a simultaneous low level on both RxA and RDF. Once asserted by the DCE, this simultaneous low level shall be held until activation of either the DTE to DCE reset or configuration services.

NOTE This is an asynchronous service, and is not referenced to RxC.

The DCE may concurrently change both RxA and RDF during the concurrent termination of the DCE to DTE media-activity indication and message-reporting services. The DTE is responsible for avoiding any logic hazards induced by this concurrent change.

8.3.5 DCE to DTE media-activity indication service

This service is mutually exclusive with the DCE to DTE fault notification service; at most one of them may be active at any given time. The DCE to DTE fault notification service may preempt this service at any time.

This service shall be encoded as a high level on RxA. Once asserted by the DCE, this high level enables recognition of a high-to-low transition on RDF to initiate the DCE to DTE message-reporting service. Any subsequent high-to-low transition on RxA terminates that DCE to DTE message-reporting service.

NOTE The DCE to DTE media-activity indication service is an asynchronous service, and is not referenced to RxC.

8.3.6 DCE to DTE message-reporting service

This service is mutually exclusive with the DCE to DTE fault notification service; at most one of them may be active at any given time. This service can only occur while the DCE to DTE media-activity indication service is active. The DCE to DTE fault notification service may preempt this service at any time.

8.3.6.1 Non-erroneous reception

This service shall be implemented in four phases when reporting a well-formed message, each of which shall follow immediately upon completion of the prior phase.

The following description applies to DCEs which have end delimiter sequences of eight PhPDUs or less, and which do not require any extra decoding delay for an FEC (forward error correcting) code. DCEs which do not meet these conditions may introduce extra delay into their decoding and reporting processes so that, with respect to signalling on RxC and RDF, they do meet these conditions.

1) After detecting received signalling, training on that signalling, and recovering a data clock from that signalling whose nominal octet frequency is the same as TxC, the DCE shall initiate the DCE to DTE message-reporting service by sourcing that recovered clock on RxC and then negating (lowering) RDF after the rising edge, and before the next falling edge, of RxC.

NOTE 1 RxA is already asserted at this time.

2) The DCE shall continue training and attempting to match the received signalling against its expected preamble and start delimiter PhPDUs.

If the DCE supports N channels of redundant media, then it may report on RDF the identity of the channel from which the signalling is being received by encoding that channel number, in the range 0 to $N - 1$, as a binary number which is reported most significant bit first during reception of the last three of those start delimiter PhPDUs. The bits reported on RDF shall be presented in series after successive rising edges of Rx C , each before the immediately subsequent falling edge of Rx C .

Upon detecting an exact match between the received signalling and the expected start delimiter, the DCE shall invert RDF after the falling edge, and before the next rising edge, of Rx C .

NOTE 2 If the identity of the receiving channel was being reported on RDF, then this inversion will occur during the low phase of Rx C which immediately follows the high phase (of Rx C) during which the last (low-order) bit of the channel number was reported.

3) The DCE shall continue reception and attempting to match the received signalling against potential data and expected end delimiter PhPDUs.

The DCE shall report each data bit decoded from the received signalling on RDF. The bits reported on RDF shall be presented in series after successive rising edges of Rx C , each before the immediately subsequent falling edge of Rx C . In the absence of errors these bits shall be reported in the same order and with the same values as they were transmitted by a peer PhL entity.

NOTE 3 This is a guarantee of transparency.

An end delimiter may be composed of both data and non-data PhPDUs. The DCE may report similarly on RDF each data bit decoded from an end delimiter, and may report also on RDF an appropriate number of data values for the non-data PhPDUs decoded from an end delimiter, except that

- a) the total number of “bits” so reported shall be 7 or less, and
- b) upon detecting an exact match between the received signalling and the expected end delimiter, the DCE shall not report on RDF another bit corresponding to the end delimiter’s last “bit”, but rather shall first assert (raise) RDF after the rising edge, and before the next falling edge, of Rx C , and then shall negate (lower) RDF after the falling edge, and before the next rising edge, of Rx C .

NOTE 4 Most implementations will decode, and report on RDF as data, any initial data PhPDUs in a received end-delimiter sequence. The first non-data PhPDU, and subsequent PhPDUs, need not be reported. However, a final report will be made on RDF, indicating correct end-delimiter recognition.

NOTE 5 Each reported bit, except the last, is maintained on RDF for a full cycle of Rx C . The last bit is replaced by a high-low sequence, each of which is maintained for just one phase of Rx C .

NOTE 6 This terminating high-low sequence will occur during the first eight “bit” reports which occur after the last (pre-delimiter) data bit was reported. That last (pre-delimiter) data bit will have been the $8N$ th data bit so reported in this phase, where N should be at least 3 and no greater than 300.

4) The DCE shall assert (raise) RDF before the next falling edge of Rx C and shall not initiate another instance of the DCE to DTE message-reporting service until after the conclusion of the current DCE to DTE media-activity indication service.

8.3.6.2 Erroneous reception

An error may be detected during any phase of the reception process described in 8.3.6.1. When that occurs, the DCE shall modify its sequencing of those phases as follows.

If the DCE should detect invalid PhPDUs, or an invalid sequence of PhPDUs, or a valid end delimiter sequence of PhPDUs which is not separated from the start delimiter PhPDUs by an integral number of data-octets of PhPDUs; and if the DCE can establish a valid signal on Rx C (for example, by substituting Tx C or some other local signal for the recovered clock source, if necessary); then

- a) If phase 2 has not already been initiated, then the DCE shall immediately initiate phase 2;
- b) If phase 2 has not already been concluded, then the DCE shall immediately conclude phase 2 as rapidly as possible, ignoring the requirement for matching of the start delimiter PhPDU sequence;
- c) Otherwise, the DCE shall immediately negate (lower) RDF after the rising edge, and before the next falling edge, of Rx C , and then shall assert (raise) RDF after the falling edge, and before the next rising edge, of Rx C .

NOTE This sequence permits the DCE to

- enable DTE use of Rx C ;
- identify the channel with the erroneous signalling; and
- indicate a reception error.

When the DCE has completed as many of the above steps a), b) and c) as appropriate and possible, the DCE shall immediately initiate phase 4.

8.4 DCE configuration messages

This sub-clause defines both standardized configuration messages, and the standardized portion of extendible configuration messages. Standardized messages cover the ranges of application of this interface which are anticipated to be most commonly used. Extendible messages permit differing forms of DCE configuration where required, and can serve to initiate the DCE to DTE message-reporting service to report DCE-internal status (a DCE option).

Two standardized messages, and two classes of extendible messages, are defined. All messages are transmitted across the interface in the order in which the bits are defined. Integers are transmitted most-significant-bit (MSB) first.

The two standardized messages and two classes of extendible messages are distinguished by the first two data bits of the configuration message, as follows:

- 00 — Basic configuration message
- 01 — Path-diversity control message
- 10 — Extendible configuration message
- 11 — Extendible status-report invocation message

8.4.1 Basic configuration message

Following its initial two bits of (00), the basic configuration message specifies operational aspects common to most DCEs. The defined components of this message are, in order of transmission:

- a) The operational mode of the DCE, encoded in one data bit as shown. The value for this parameter after activation of the DTE to DCE reset service is 0.

0 Two-way simultaneous (full-duplex), where each invocation of the DTE to DCE message-transmission service automatically activates the DCE to DTE media-activity indication and message-reporting services;

NOTE 1 This mode is desirable for dual-channel media such as fibre-optic-pair cabling. Some DTEs may only be able to operate in this mode.

1 Two-way alternate (half-duplex), where an invocation of the DTE to DCE message-transmission service does not automatically activate the DCE to DTE media-activity indication and message-reporting services.

NOTE 2 This mode minimizes DCE and DTE – DCE interface power consumption. Some DTEs may only be able to operate in this mode.

- b) The selection of the DCE-internal data source for the message-reporting service, encoded in two data bits as shown. (See Table 1.) The value for this parameter after activation of the DTE to DCE reset service is 00. When this selection is non-zero, transmission on all attached media shall be disabled and the DTE – DCE interface shall operate in two-way simultaneous (full-duplex) mode.

00 decoded signalling, received from one of the attached media as specified in 8.4.2 b) and 8.4.2 c). The interface mode is as specified in 8.4.1 a).

01 internal-status reporting, see 8.4.4 and 8.5.

10 loopback as close as possible to the DTE – DCE interface, with no transmission to connected media, where each invocation of the DTE to DCE message-transmission service automatically activates the DCE to DTE media-activity indication and message-reporting services;

NOTE 3 This mode is desirable for DCE vs. DTE vs. inter-connect fault localization.

11 loopback as close as possible to the media interface(s), with no transmission to connected media, where each invocation of the DTE to DCE message-transmission service automatically activates the DCE to DTE media-activity indication and message-reporting services.

NOTE 4 This mode is desirable for self-assessment before entry to an operating network.

- c) The amount by which the preamble, which is the initial sequence of PhPDUs in each transmission, should be extended. Its range is zero to seven units of extension, encoded in three data bits as 0 (000) to 7 (111). The value for this parameter after activation of the DTE to DCE reset service is 0 (000). (See note 2 of 6.2.3.)

- d) The amount by which the mandatory post-transmission gap, which is the period of non-transmission between successive sequences of PhPDUs, should be extended. Its range is zero to seven units of extension, encoded in three data bits as 0 (000) to 7 (111). The value for this parameter after activation of the DTE to DCE reset service is 0 (000). (See note 3 of 6.2.3.)

8.4.2 Path-diversity control message

Following its initial two bits of (01), the path-diversity control message specifies additional configuration data commonly required for management and fault-assessment of redundant paths: separate transmission and reception controls for each of the attached redundant media (channels and paths). The defined components of this message are, in order of transmission:

- a) Two bits of zero (00), which provide quartet and octet alignment within the message for the following fields.
- b) The algorithm for choosing between redundant media as the source of received signalling when more than one of the media is enabled for reception, coded in four bits as shown. The value for this parameter after activation of the DTE to DCE reset service is 0000.
 0000 — The medium selected for reception should be the first medium on which signalling which is suitable for receiver-training is detected.
 1000 to 1111 ($= 7 + N$, $1 \leq N \leq 8$) — The N th medium should be selected, except when signalling suitable for receiver-training has been detected on another medium for a period of time equal to the extra period of inter-frame-gap extension specified in 8.4.1 d), in which case that other medium should be selected.
- c) The selection of whether reception is enabled (0) or inhibited (1) on each of eight or fewer redundant media, coded in eight consecutive bits for channels 1 through 8, respectively. (See Table 1.) The value for this parameter after activation of the DTE to DCE reset service is 0000 0000.
- d) The selection of whether transmission is enabled (0) or inhibited (1) on each of eight or fewer redundant media, coded in eight consecutive bits for channels 1 through 8, respectively. (See Table 1.) The value for this parameter after activation of the DTE to DCE reset service is 0000 0000.
- e) The amount of post-transmission gap extension due to potential signal skew between redundant media. Its range is zero to seven units of extension, encoded in three data bits as 0 (000) to 7 (111). The value for this parameter after activation of the DTE to DCE reset service is 0 (000). (See 8.4.1 d), 8.4.2 b), and note 3 of 6.2.2.)

8.4.3 Extendible configuration messages

Following its initial two bits of (10), the coding of extendible configuration messages may be implementation dependent. The structure and form of extendible configuration messages shall be the same as the basic configuration message specified in 8.4.1.

8.4.4 Extendible status-report invocation messages

Following its initial two bits of (11), the coding of extendible status-report invocation messages may be implementation dependent. The structure and form of extendible status-report invocation messages shall be the same as the basic configuration message specified in 8.4.1. The information specified shall select some DCE-internal source of received signalling, and if the DCE-internal-data-source mode is status-reporting [see 8.4.1 b)], then the DCE shall generate a multi-data-octet message, padded as necessary to an octet multiple, and shall report it using the DCE to DTE media-activity indication and message-reporting services.

8.5 DCE-generated status reports

These reports are generated within the DCE upon request, and reported when the DCE-internal-data-source is internal-status report. [See 8.4.1 b).]

9 Medium Dependent Sublayer (MDS): Wire media

NOTE The Medium Dependent Sublayer (MDS) is part of the Data Communication Equipment (DCE). It exchanges serial PhSDU sequences across the DTE – DCE interface specified in clause 8 and it communicates encoded bits across the MDS – MAU interface specified in Clause 10. The MDS functions are logical encoding and decoding for transmission and reception respectively and the addition/removal of preamble and delimiters together with timing and synchronization functions.

9.1 PhPDU

The MDS shall produce the PhPDU shown in Figure 4 by adding preamble and delimiters to frame the serial sequence of PhSDUs (bits) transferred from the DIS across the DTE – DCE interface. Transmission sequence shall be from left to right as shown in Figure 4, i.e. preamble first, followed by start delimiter, PhSDU sequence and finally end delimiter.

PREAMBLE	START DELIMITER	PhSDU SEQUENCE	END DELIMITER
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Figure 4 — Protocol Data Unit (PhPDU)

Conversely the MDS shall remove preamble and delimiters from a received PhPDU to produce a corresponding serial sequence of PhSDUs. If a non-binary data unit is detected in the received PhSDU sequence, the MDS shall immediately stop transferring PhSDUs to the DIS, the MDS shall report an error, and the MDS shall indicate the end of activity to the DIS when it happens.

9.2 Encoding and decoding

Data units shall be encoded by the MDS for application to the MAU using the code shown in Figure 5 (Manchester Biphase L). The encoding rules are formally given in Figure 6 and Table 5.

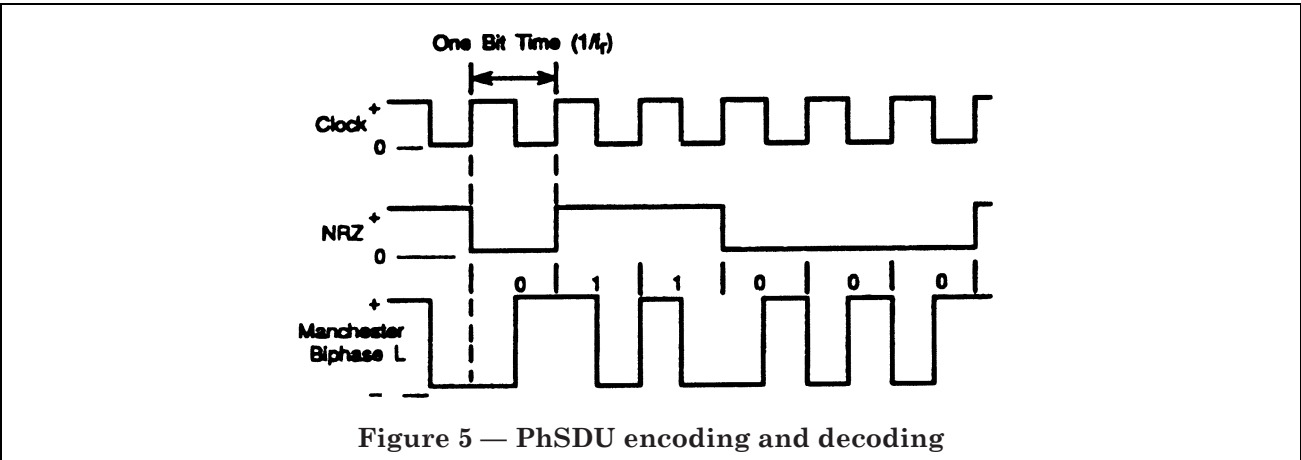


Figure 5 — PhSDU encoding and decoding

NOTE 1 Figure 5 is included in this part of IEC 1158 for explanatory purposes and does not imply a specific implementation.

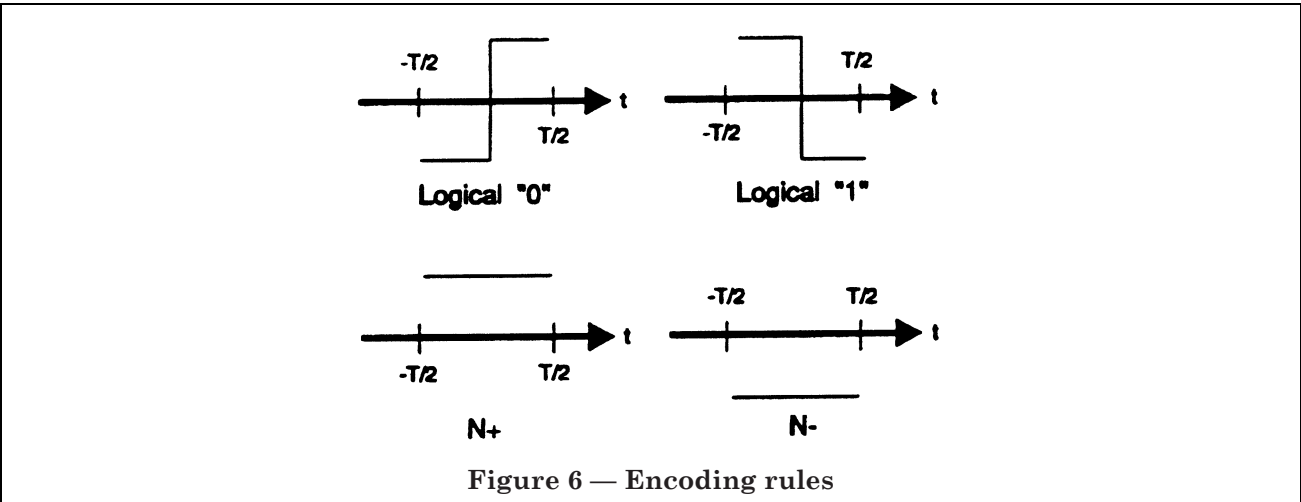


Figure 6 — Encoding rules

Table 5 — Encoding rules

Symbols	Encoding
1 (ONE)	Hi-Lo transition (mid-bit)
0 (ZERO)	Lo-Hi transition (mid-bit)
N+ (NON-DATA PLUS)	Hi (No transition)
N- (NON-DATA MINUS)	Lo (No transition)

NOTE 2 It may be seen that data symbols (1 and 0, conveyed by PhSDUs) are encoded to always contain a mid-bit transition. Non-data symbols (N+ and N-) are encoded so that they never have a mid-bit transition. Frame delimiters (see 9.4 and 9.5) are constructed so that non-data symbols are conveyed in pairs of opposite polarity.

Decoding shall normally be the opposite of encoding. At reception, the MDS shall verify that each symbol is encoded in accordance with Figure 6 and Table 5 and shall detect the following errors:

- a) invalid Manchester code;
- b) half-bit-slip errors.

Any of these errors shall be reported as Ph-DATA indication (PhIDU, error).

9.3 Polarity detection

The option of automatic polarity detection of the received Manchester encoded signal shall be required where it is specified in the relevant MAU.

9.4 Start of frame delimiter

The following sequence of symbols, shown from left to right in order of transmission, shall immediately precede the PhSDU sequence to delimit the start of a frame:

1, N+, N-, 1, 0, N-, N+, 0.

(shown as a waveform in Figure 7)

The MDS shall only accept a received signal burst as a PhPDU after verifying this sequence and shall remove this sequence before transferring the PhSDU sequence to the DIS.

9.5 End of frame delimiter

The following sequence of symbols, shown from left to right in order of transmission, shall immediately follow the PhSDU sequence to delimit the end of a frame:

1, N+, N-, N+, N-, 1, 0, 1.

(shown as a waveform in Figure 7)

The MDS shall remove this sequence from the PhPDU before transferring the PhSDU sequence to the DIS. The MDS shall report to the corresponding Data Link Layer entity any frames received via the medium which do not include this sequence within 300 octets of start of frame (from beginning of start delimiter) as Ph-DATA indication (PhIDU, frame_too_long). The MDS shall report to the corresponding Data Link Layer entity, via the corresponding DIS, any frames received via the medium which have an end delimiter which is not located at an octet boundary as Ph-DATA indication (PhIDU, received_timing_error).

9.6 Preamble

In order to synchronize bit times a preamble shall be transmitted at the beginning of each PhPDU consisting of the following sequence of bits, shown from left to right in order of transmission:

1, 0, 1, 0, 1, 0, 1, 0.

(shown as a waveform in Figure 7)

NOTE Received preamble can contain as few as four bits due to loss of one bit through each of four repeaters (as specified in the MAU Network Configuration Rules).

The period may be extended, but not reduced, by Station Management as given in Table 1. A preamble extension sequence as listed in Table 1 shall be defined as the following sequence of bits, shown from left to right in order of transmission:

1, 0, 1, 0, 1, 0, 1, 0.

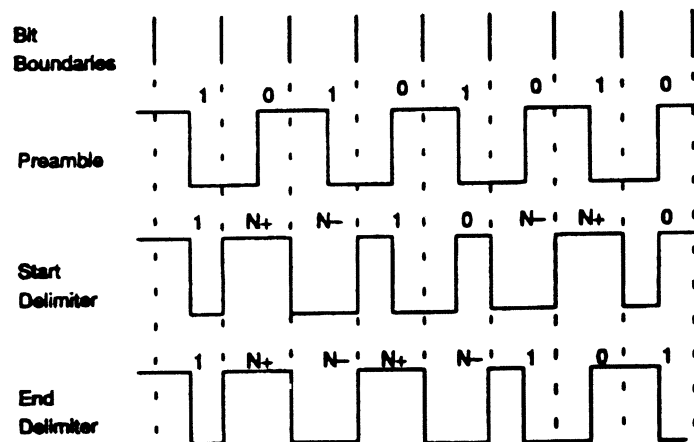


Figure 7 — Preamble and delimiters

NOTE These waveforms do not extend the frequency range outside the band required for transmission of binary PhSDUs (conveying data symbols) in accordance with Figure 6 and Table 5.

9.7 Synchronization

After the reception of the fourth bit of the frame and until end of frame or frame termination the receiver shall detect and report half-bit-slip errors.

NOTE 1 This synchronization specification allows the loss of four bits of the preamble.

After the preamble, half-bit-slip errors shall be reported as Ph-DATA indication (PhIDU, error).

NOTE 2 Half-bit-slip errors can be detected as excessive bit cell jitter and/or excessive variation in bit period.

9.8 Post-transmission gap

After transmission of a PhPDU there shall be a minimum period during which a subsequent transmission shall not commence. For the same minimum period after reception of a PhPDU the receiving Physical Layer entity shall ignore all received signalling. An MDS entity shall set a minimum post transmission period of four nominal bit times. The period may be extended, but not reduced, by Station Management as given in Table 1 or by an associated MAU entity. A gap extension sequence as listed in Table 1 shall be defined as four nominal bit times.

NOTE The MAU transmit enable/disable time may reduce the duration of silence between frames.

9.9 Inter-channel signal skew

If the device is configured (by Station Management) to receive concurrently on more than one channel then the maximum accepted differential delay between any two active channels, as measured from the first PhPDU of a start delimiter, shall not exceed five nominal bit times. This period may be extended, but not reduced, by Station Management as given in Table 1. A gap extension sequence as listed in Table 1 shall be defined as four nominal bit times. The value of post-transmission gap shall be greater than the value of inter-channel skew.

10 MDS – MAU interface: Wire media

NOTE The Medium Attachment Unit (MAU) is an optionally separate part of a communication element which, connects to the medium directly or via passive components. For electrical signalling variants the MAU is the transceiver, which provides level shifting and wave shaping for transmitted and received signals. The MDS – MAU interface links the MAU to the MDS. The services are defined as physical signals to facilitate this interface being optionally exposed. Figure 6 lists the minimum set of required services at the MDS – MAU interface. See clause 6 for management services.

10.1 Services

If the MDS – MAU interface is exposed it shall support at least the set of required services given in Table 6 and specified in 10.2.

Table 6 — Minimum services at MDS – MAU interface

Service	Abbreviation	Direction
Required:		
Transmit Signal	TxS	To MAU
Receive Signal	RxS	From MAU
Transmit Enable	TxE	To MAU
Optional:		
Loopback enable	LbE	To MAU

10.2 Service specifications**10.2.1 Transmit Signal (TxS)**

The Transmit Signal service (TxS) shall transfer the encoded PhPDU signal sequence across the MDS – MAU interface to the MAU, where the sequence shall be transmitted on to the medium if the Transmit Enable (TxE) is set to logic 1 (high level).

10.2.2 Receive Signal (RxS)

The Receive Signal service (RxS) shall transfer the encoded PhPDU signal sequence or silence across the MAU – MDS interface to the MDS. The RxS shall echo the signal transmitted via TxS by simultaneously receiving the transmissions from the medium.

10.2.3 Transmit Enable (TxE)

The Transmit Enable service (TxE) shall provide the MDS with the facility to enable the MAU to transmit. The TxE shall be set to logic 1 (high level) at the commencement of preamble transmission and then set to logic 0 (low level) after the last bit of the end delimiter has been transmitted.

If redundant media are in use and the method of implementing redundancy is to receive on all channels but transmit on only one then the channel (cable) which is currently used for transmission shall be selected by setting its TxE to logic 1 (high level). All channels which are not currently in use for transmission shall be disabled by setting the TxE to logic 0 (low level).

10.2.4 Loopback Enable (LbE)

If the optional Loopback Enable (LbE) service shown in Table 1 is used it shall disable the final output stage of the MAU transmit circuit, connect the output of the previous stage of the MAU transmit circuit to the MAU receive circuit and disconnect the MAU receive circuit from the medium. The state of the Loopback Enable shall not change while the MAU is transmitting or receiving.

NOTE This is confirmation service of local significance only which provides a device with the facility to test the integrity and functionality of the Physical Layer circuitry, excluding the medium.

10.3 Signal characteristics

Timing characteristics shall be compatible with those specified in the requirements of this part of IEC 1158 for the relevant MDS.

If the MDS – MAU interface is exposed it shall operate with digital signal levels as shown in Table 7. Both sides of the interface shall operate with the same value of V_{DD} .

10.4 Communication mode

The communication mode at this interface shall allow simultaneous transmission and reception.

10.5 Timing characteristics

The MDS – MAU interface shall function correctly with a PhSDU bit rate of between 1 kbit/s and 1,1 times the highest stated MAU bit rate.

NOTE The bit rates available in an implementation are stated in the Protocol Implementation Conformance Statement (PICS).

Table 7 — Signal levels for an exposed MDS – MAU interface

Symbol	Parameter	Conditions	Limits	Units	Remarks
V_{OL}	Maximum low-level output voltage	$I_{out} = \pm 100 \mu A$	0,1	V	See Note 1
		$I_{out} = \pm 1,6 \text{ mA}$	0,4	V	
V_{OH}	Minimum high-level output voltage	$I_{out} = \pm 100 \mu A$	$V_{DD} - 0,1$	V	See Note 1
		$I_{out} = - 0,8 \text{ mA}$	$V_{DD} - 0,8$	V	See Note 2
V_{IL}	Maximum low-level input voltage		$0,2 V_{DD}$	V	
V_{IH}	Minimum high-level input voltage		$0,7 V_{DD}$	V	See Note 3
NOTE 1 Provides the capability to drive two typical CMOS loads.					
NOTE 2 CMOS input compatibility with TTL output requires a “pull-up” resistor from signal input to V_{DD} .					
NOTE 3 Compatible with CMOS output for $3,0 \text{ V} \leq V_{DD} \leq 5,5 \text{ V}$. Compatibility with TTL output ($4,75 \text{ V} \leq V_{DD} \leq 5,25 \text{ V}$) requires a “pull-up” resistor from signal input to V_{DD} .					

11 Medium Attachment Unit (MAU): 31,25 kbit/s, voltage mode, wire medium

NOTE 1 The 31,25 kbit/s voltage-mode MAU simultaneously provides access to a communication network and to an optional power distribution network. Devices attached to the network communicate via the medium and may or may not be powered from it. If bus-powered, power is distributed as direct voltage and current, and communications signals are superimposed on the d.c. power. In Intrinsically Safe applications, available power may limit the number of devices.

NOTE 2 The network medium consists of twisted pair cable. Independent of topology, all attached devices, other than possibly the transmitting device, are high impedance to prevent significant network loading. Trapezoidal waveforms are used to reduce electromagnetic emissions.

NOTE 3 Bus and tree topologies are supported. In either topology a network contains one trunk cable, terminated at both ends. In the bus topology, spurs are distributed along the length of the trunk. In the tree topology, spurs are concentrated at one end of the trunk. A spur may connect more than one device to the network, the number of devices depending on spur length.

NOTE 4 At the power frequency (d.c.), devices appear to the network as current sinks, with a limited rate of change of the supply current drawn from the medium. This prevents transient changes in load current from interfering with communication signals.

11.1 Transmitted bit rate

The transmitted bit rate shall be $31,25 \text{ kbit/s} \pm 0,2 \%$, averaged over a frame having a minimum length of 16 octets. The instantaneous bit time shall be $32 \mu\text{s} \pm 0,9 \mu\text{s}$.

11.2 Network specifications

NOTE A 31,25 kbit/s voltage-mode MAU operates in a network composed of the following components:

- Cable;
- Terminators;
- Couplers;
- Devices (containing at least one communication element).

A wire network in 31,25 kbit/s voltage mode may optionally include the following components:

- Connectors;
- Power supplies;
- Devices which include power supplies;
- Intrinsic Safety barriers.

11.2.1 Topologies

A wire MAU shall operate in a network with a linear bus topology, consisting of a trunk, terminated at each end as specified in 11.7.5, to which communication elements are connected via couplers and spurs.

NOTE 1 The coupler and communication element may be integrated in one device (i.e. zero length spur).

NOTE 2 Tree topology with all the communication elements located at the ends of the trunk is regarded as a special case of a bus for the purpose of this part of IEC 1158.

NOTE 3 Several communication elements may be connected to the trunk at one point using a multi-port coupler. An active coupler may be used to extend a spur to a length which requires termination to avoid reflections and distortions. Active repeaters may be used to extend the length of the trunk beyond that of a single segment as permitted by the network configuration rules.

11.2.2 Network configuration rules

A 31,25 kbit/s voltage-mode MAU shall be required to conform to the requirements of this part of IEC 1158 when used in a network which complies with these rules.

Rule 1: One Fieldbus shall be capable of communication between the following numbers of devices, all operating at the same bit rate:

- a) between two and 32 devices for a non-I.S. Fieldbus without power supplied via the signal conductors;
- b) between two and six bus-powered devices for an I.S. Fieldbus, of which between one and four shall be in the hazardous area;
- c) between one and 12 bus-powered devices at the remote end from the power supply communicating with one device at the power supply end, for a non-I.S. Fieldbus with power supplied via the signal conductors.

NOTE 1 Rule 1 does not preclude the use of more than the specified number of devices in an installed system. The numbers of devices were calculated on the assumption that a bus-powered device draws $9 \text{ mA} \pm \text{mA}$. Item b) assumes that the I.S. barrier operates with a 19 V d.c. output and provides 40 to 60 mA to the devices in the hazardous area. Item c) assumes that the minimum power supply voltage is 20 V d.c.

Rule 2: A fully loaded (maximum number of connected devices) 31,25 kbit/s voltage-mode Fieldbus segment shall have a total cable length, including spurs, between any two devices, of up to 1 900 m.

NOTE 2 1 900 m maximum cable length is the requirement for conformance to this part of IEC 1158 but this does not preclude the use of longer lengths in an installed system.

Rule 3: The total number of waveform regenerations by repeaters and active couplers between any two devices shall not exceed four.

Rule 4: The maximum propagation delay between any two devices shall not exceed 20 nominal bit times.

NOTE 3 For efficiency of the network, that part of the turn-around time of any device on the network caused by a PhE between the end of a received frame and the beginning of the transmitted frame containing an associated immediate response should not exceed 5 bit times, no more than 2 bit times of which should be due to the MAU. As it is not mandatory to expose the DLL – PhL interface or the MDS – MAU interface, that part of the turn-around time of a Fieldbus device caused by the PhL or the MAU cannot be specified or conformance tested.

Rule 5: The Fieldbus shall be capable of continued operation while a device is being connected or disconnected. Data errors induced during connection or disconnection shall be detected.

Rule 6: Failure of any communication element or spur (with the exception of a short circuit, low impedance, or jabber) shall not interfere with transactions between other communication elements for more than 1 ms.

Rule 7: In polarity sensitive systems the medium twisted pairs shall have distinctly marked conductors which uniquely identify individual conductors. The polarization shall be maintained at all connection points.

Rule 8: The degradation of the electrical characteristics of the signal, between any two devices, due to attenuation, attenuation distortion and mismatching shall be limited to the values indicated below.

- a) Signal attenuation: The configuration of the bus (trunk and spur lengths, number of devices, I.S. barriers, galvanic isolators, and possible matching devices) shall be such that the attenuation between any two devices at the frequency corresponding to the bit rate shall not exceed 10,5 dB.
- b) Attenuation distortion: The configuration of the bus (trunk and spur lengths and number of devices, I.S. barriers, and galvanic isolators) shall be such that between any two devices:

$$[\text{Attenuation}(1,25 f_r) - \text{Attenuation}(0,25 f_r)] \leq 6 \text{ dB}$$

$$\text{Attenuation}(1,25 f_r) \geq \text{Attenuation}(0,25 f_r)$$

where f_r is the frequency corresponding to the bit rate. Attenuation shall be monotonic for all frequencies from $0,25 f_r$ to $1,25 f_r$ (7,8 kHz to 39 kHz).

- c) Mismatching Distortion: Mismatching (due to spurs or any other effect, including one open circuit spur of maximum length) on the bus shall be such that, at any point along the trunk, in the frequency band $0,25 f_r$ to $1,25 f_r$ (7,8 kHz to 39 kHz):

$$|(Z - Z_0)/(Z + Z_0)| \leq 0,2$$

where Z_0 is the characteristic impedance of the trunk cable and Z is the parallel combination of Z_0 and the load impedance at the coupler.

The concentration of couplers shall be less than 15 per 250 m.

NOTE 4 Rule 8 minimizes restrictions on trunk and spur length, number of devices etc. by specifying only the transmission limitations imposed by combinations of these factors. Different combinations may be used depending on the needs of the application.

Rule 9: The following rules shall apply to systems implemented with redundant media:

- a) each channel (cable) shall comply with the network configuration rules;
- b) there shall not be a non-redundant segment between two redundant segments;
- c) repeaters shall also be redundant;
- d) if the system is configured (by Station Management) to transmit on more than one channel simultaneously then the propagation time difference between any two devices on any two channels shall not exceed five bit times;
- e) channel numbers shall be maintained throughout the Fieldbus, i.e. channels 1,2,3... from Station Management shall always connect to physical channels 1,2,3...

11.2.3 Power distribution rules for network configuration

The cable shield shall not be used as a power conductor.

11.3 Transmit circuit specification for 31,25 kbit/s voltage-mode MAU

NOTE For ease of reference, the requirements of 11.1 and 11.3 are summarized in Table 8 and Table 9.

Table 8 — Transmit level specification summary for 31,25 kbit/s voltage-mode MAU

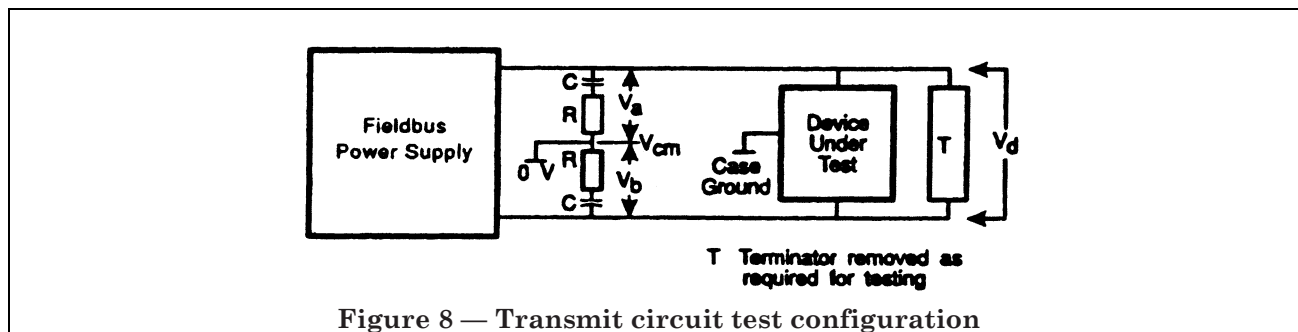
Transmit level characteristics, values referred to trunk (but measured using test load as shown in Figure 8)	Limits for 31,25 kbit/s (bus-powered and/or I.S.)
Output level (peak-to-peak, see Figure 9) With test load (0,5 nominal Z_0 of trunk cable)	0,75 V to 1 V $50 \Omega \pm 1 \%$
Maximum positive and negative amplitude difference (signalling bias) as shown in Figure 10	$\pm 50 \text{ mV}$
Output Level; with one terminator removed (peak-to-peak) With test load (nominal Z_0 of trunk cable)	$\leq 2,0 \text{ V}$ $100 \Omega \pm 1 \%$
Output Level; open circuit (peak-to-peak)	$\leq 3,0 \text{ V}$
Maximum output signal distortion; i.e., overvoltage, ringing and droop (See Figure 9)	$\pm 10 \%$
Quiescent transmitter output; i.e. transmitter noise (measured over the frequency band 1 kHz to 100 kHz)	$\leq 1 \text{ mV (r.m.s.)}$

Table 9 — Transmit timing specification summary for 31,25 kbit/s voltage-mode MAU

Transmit timing characteristics, values referred to trunk (but measured using test load as shown in Figure 8)	Limits for 31,25 kbit/s (bus-powered and/or I.S.)
Transmitted bit rate	31,25 kbit/s $\pm 0,2 \%$
Instantaneous bit time	$32 \mu\text{s} \pm 0,9 \mu\text{s}$
Rise and fall times (10 % to 90 % of pk-pk signal, see Figure 9)	$\leq 0,25$ nominal bit time
Slew rate (at any point from 10 % to 90 % of pk-pk signal)	$\leq 0,2 \text{ V}/\mu\text{s}$
Maximum transmitted bit cell jitter (zero crossing-point deviation, see Figure 10)	$\pm 0,025$ nominal bit time
Transmit enable/disable time (i.e. time during which the output waveform may not meet the transmit requirements)	$\leq 2,0$ nominal bit times

11.3.1 Test configuration

Figure 8 shows the configuration which shall be used for testing.

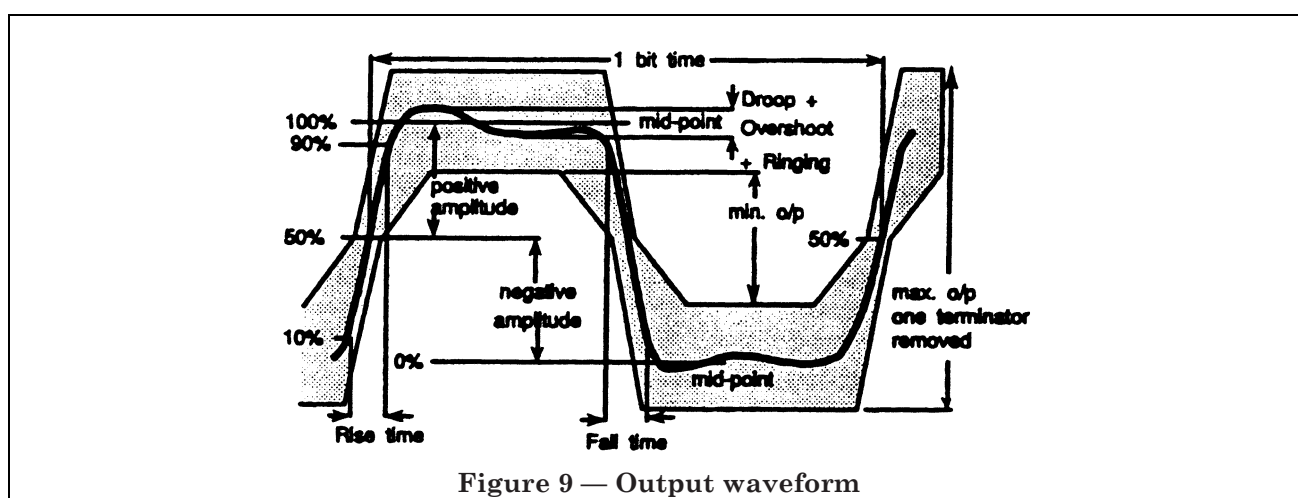


Differential signal voltage: $V_d = V_a - V_b$

Test load resistance $R = 50 \, \Omega$ ($0,5$ cable Z_0) and $C = 10 \, \mu\text{F}$ except where otherwise stated in a specific requirement.

11.3.2 Output level requirements

NOTE Figure 9 shows an example of the a.c. component of one cycle of a Fieldbus waveform, illustrating some key items from the transmit circuit specification. Only signal voltages are shown; this diagram taken no account of power supply voltages.



A 31,25 kbit/s MAU transmit circuit shall conform to the following output level requirements, all amplitudes being measured at the estimated mid-point between any peaks or troughs in the top and bottom of the waveform (“mid-point” in Figure 9):

- the output voltage across the test load after transformer step up/down (if applicable) shall be between 0,75 V and 1,25 V peak-to-peak, with a load resistance of $50 \, \Omega \pm 1 \, \%$ (“min o/p” in Figure 9);
- the output voltage at the trunk, or at the transmit terminals, with a load resistance of $100 \, \Omega$ (i.e. with one trunk terminator removed) shall not exceed 2,0 V peak-to-peak (“max o/p one terminator removed” in Figure 9);
- the output voltage at the trunk, or at the transmit terminals, with any load including an open circuit shall not exceed 3,0 V peak-to-peak. For test purposes open circuit shall be defined as a load of $100 \, \text{k}\Omega$ resistance in parallel with $15 \, \text{pF}$ capacitance;
- during transmission a device shall not suffer permanent failure when a load resistance of $\leq 1 \, \Omega$ is applied for 1 s;
- the difference between positive amplitude and negative amplitude, measured as shown in Figure 10, shall not exceed $\pm 50 \, \text{mV}$ peak;