EtherCAT Specification – Part 2

Physical Layer service and protocol specification

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0 Introduction

0.1 General

This part of the ETG.1000 series is one of a series produced to facilitate the interconnection of automation system components. It is related to other standards in the set as defined by the “three-layer” fieldbus reference model described in IEC/TR 61158-1.

0.2 Physical layer overview

The primary aim of this standard is to provide a set of rules for communication expressed in terms of the procedures to be carried out by peer Ph-entities at the time of communication.

The physical layer receives data units from the data-link Layer, encodes them, if necessary by adding communications framing information, and transmits the resulting physical signals to the transmission medium at one node. Signals are then received at one or more other node(s), decoded, if necessary by removing the communications framing information, before the data units are passed to the data-link Layer of the receiving device.

0.3 Document overview

A general model of the physical layer is shown in Figure 1.

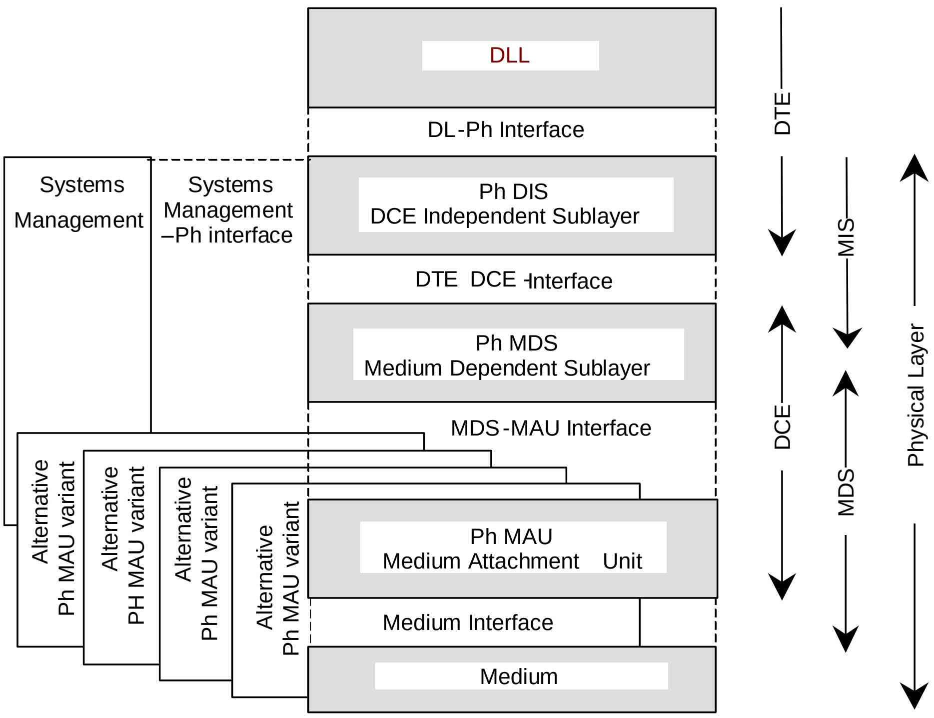


Figure 1 — General model of physical layer

The common characteristics for all variants and types are as follows:

- digital data transmission;
- no separate clock transmission;
- either half-duplex communication (bi-directional but in only one direction at a time) or full-duplex communication.

0.4 Major physical layer variations specified in this standard

EtherCAT specifies wire media with the following characteristics:

- LVDS wire medium up 100 Mbit/s.

1 Scope

1.1 Scope of this standard and accordance to IEC Standards

The ETG.1000 series specifies the EtherCAT Technology within the EtherCAT Technology group. It is devided into the following parts:

ETG.1000.2: Physical Layer service definition and protocol specification

ETG.1000.3: Data Link Layer service definition

ETG.1000.4: Data Link Layer protocol specification

ETG.1000.5: Application Layer service definition

ETG.1000.6: Application Layer protocol specification

These parts are based on the corresponding parts of the IEC 61158 series Type 12. EtherCAT is named Type 12 in IEC 61158 to avoid the usage of brand names.

1.2 Overview

This part of the ETG.1000 series specifies the requirements for fieldbus component parts. It also specifies the media and network configuration requirements necessary to ensure agreed levels of

a) data integrity before data-link Layer error checking;

b) 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, for some types, frame delimiters are in the physical layer while for other types they are in the data-link Layer.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60079-11, *Explosive atmospheres – Part 11: Equipment protection by intrinsic safety "i"*

IEC 60079-14, *Explosive atmospheres – Part 14: Electrical installations in hazardous areas (other than mines)*

IEC 60079-25, *Electrical apparatus for explosive gas atmospheres, Part 25: Intrinsically safe systems*

ISO/IEC 7498 (all parts), *Information technology – Open Systems Interconnection – Basic Reference Model*

ISO/IEC 8802-3, *Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 3: Standard for Ethernet*

ANSI TIA/EIA-644-A, *Electrical Characteristics of Low Voltage Differential Signaling (LVDS) Interface Circuits*

3 Terms and definitions

For the purposes of this document, the terms and definitions of ISO/IEC 7498, and the following definitions apply.

3.1 Common terms and definitions

NOTE Many definitions are common to more than one protocol type; they are not necessarily used by all protocol types.

3.1.1
activity
presence of a signal or noise at the input terminals of a fieldbus device that is of a level that is above the receiver signal level threshold of that device

3.1.2
barrier
physical entity that limits current and voltage into a hazardous area in order to satisfy intrinsic safety requirements

3.1.3
bit
unit of data consisting of a 1 or a 0

NOTE A bit is the smallest data unit that can be transmitted.

3.1.4
bus
trunk and all devices connected to it

3.1.5
cable plant interface connector
CPIC
point at which test and conformance measurements are made and that the interface between the network device and the cable plant

3.1.6
communication element
part of a fieldbus device that communicates with other elements via the bus

3.1.7
connector
coupling device employed to connect the medium of one circuit or communication element with that of another circuit or communication element
[IEEE Std 100-1996, modified]

3.1.8
coupler
physical interface between trunk and spur or trunk and device

3.1.9
Data Communications Equipment
DCE
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

3.1.10
Data Terminal Equipment
DTE
embodiment of the media, modulation and coding-independent portion of a fieldbus-connected device, comprising the uppermost portion of the physical layer and all higher layers within the device

3.1.11
decibel(milliwatt)
dB(mW)
logarithmic unit of power, referenced to 1 mW. (Also written **dBm**.)

$$P_{dBm} = 10 \log \left(P_{mW}\right)$$

NOTE If P_{mW} is the measured power in mW, then P_{dBm} is the power expressed logarithmically in dB(mW), or equivalently, dBm.

3.1.12
delimiter
flag that separates and organizes items of data

3.1.13
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.)

NOTE A device may contain more than one node.

3.1.14
effective launch power
effective power coupled into the core of a fiber optic waveguide by the transmitter. This power is measured with a standard test fiber connected to the CPIC

3.1.15
effective power
the difference, expressed in dBm, between the absolute optical power measured in milliwatt at the midpoint in time of the Hi level to the absolute optical power measured in milliwatt at the midpoint of the Lo level

NOTE Effective power is believed to give a more accurate measurement of the conditions that affect the receivers than traditional measurements, such as peak and average power. Methods for measuring effective power are for further study.

3.1.16
error
discrepancy between a computed, observed or measured value or condition and the specified or theoretically correct value or condition

3.1.17
extinction ratio
ratio of the absolute optical power measured in milliwatt at the midpoint in time of the Hi level to the absolute optical power measured in milliwatt at the midpoint in time of the Lo level.

NOTE The following gives an example of the computation of effective power and extinction ratio. If the midpoint of Hi level is measured as 105 µW, and if the midpoint of Lo level is measured as 5 µW, then the difference is 100 µW. Therefore, the effective power is 10 log ((100 µW) / 1 mW)), which equals –10,0 dBm. The extinction ratio is (105/5), which equals 21:1.

3.1.18
fiber optic cable
cable containing one or more fiber optic waveguides with jacketing material provided to facilitate handling and to protect the fiber

3.1.19
fiber optic receiver
combined optics and electronics in the communicating device that accept the optical signal received by the communicating device through the CPIC

3.1.20
fiber optic receiver operating range
range of optical power that must be present at the CPIC to ensure that the bit error rate specifications are met

3.1.21
fiber optic transmitter
device that emits optical signals for propagation into a fiber optic waveguide through the CPIC

3.1.22
fiber optic waveguide
flexible, optically transparent strand that is used to transport optical signals from one geographic point to another geographic point

3.1.23
frame
set of consecutive digit time slots in which the position of each digit time slot can be identified by reference to a framing signal
[IEEE Std 100-1996]

3.1.24
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
[IEC 60079-11]

3.1.25
isolation
physical and electrical arrangement of the parts of a signal transmission system to prevent electrical interference currents within or between the parts
[IEEE Std 100-1996]

3.1.26
jabber
continuous transmission on the medium due to a faulty device

3.1.27
jitter
offset of the 50 % transition points of pulse edges from their ideal position as the result of all causes

3.1.28
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

3.1.29
medium
cable, optical fiber, or other means by which communication signals are transmitted between two or more points

NOTE In this standard, "media" is used only as the plural of medium.

3.1.30
network
all of the media, connectors, repeaters, routers, gateways and associated node communication elements by which a given set of communicating devices are interconnected

3.1.31
node
end-point of a branch in a network or a point at which one or more branches meet
[IEV 131-02-04]

3.1.32
optical active star
active device in which a signal from an input fiber is received, amplified and retransmitted to a larger number of output optical fibers. Retiming of the received signal is optional.

3.1.33
optical fall time
time it takes for a pulse to go from 90 % effective power to 10 % effective power, specified as a per cent of the nominal bit time

3.1.34
optical passive star
passive device in which signals from input fibers are combined and then distributed among output optical fibers

3.1.35
optical rise time
time it takes for a pulse to go from 10 % effective power to 90 % effective power, specified as a per cent of the nominal bit time

3.1.36
peak emission wavelength
λp
wavelength at which radiant intensity is maximized

3.1.37
receiver
receive circuitry of a communication element

3.1.38
repeater
Two–port active physical layer device that receives and retransmits all signals to increase the distance and number of devices for which signals can be correctly transferred for a given medium

3.1.39
segment
trunk–cable section of a fieldbus that is terminated in its characteristic impedance

NOTE Segments are linked by repeaters within a logical link and by bridges to form a fieldbus network

3.1.40
separately powered device
device that does not receive its operating power via the fieldbus signal conductors

3.1.41
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.

3.1.42
spur
branch-line (i.e. a link connected to a larger one at a point on its route) that is a final circuit

NOTE The alternative term ‘drop cable’ is used in this standard.

3.1.43
terminator
resistor connecting conductor pairs at both ends of a wire medium segment to prevent reflections from occurring at the ends of cables

NOTE For Type 2, the terminator is mounted in a BNC or TNC plug.

3.1.44
transceiver
combination of receiving and transmitting equipment in a common housing employing common circuit components for both transmitting and receiving
[IEEE Std 100-1996 modified for non-radio use]

NOTE A medium attachment unit can be the transceiver or can contain the transceiver, depending on Type and implementation.

3.1.45
transmitter
transmit circuitry of a communication element

3.1.46
trunk
main communication highway acting as a source of main supply to a number of other lines (spurs)

3.1.47
typical half-intensity wavelength
$\Delta\lambda$
range of wavelength of spectral distribution in which the radiant intensity is no less than one-half of the maximum intensity

3.2 EtherCAT: Terms and definitions

3.2.1
activity
[see 3.1.1]

3.2.2
bit
[see 3.1.3]

3.2.3
connector
[see 3.1.7]

3.2.4
coupler
[see 3.1.8]

3.2.5
Data Communications Equipment (DCE)
[see 3.1.9]

3.2.6
Data Terminal Equipment (DTE)
[see 3.1.10]

3.2.7
delimiter
[see 3.1.12]

3.2.8
device
[see 3.1.13]

3.2.9
error
[see 3.1.16]

3.2.10
frame
[see 3.1.23]

3.2.11
idle
symbol at the media between EOF and SOF

3.2.12
isolation
[see 3.1.25]

3.2.13
jitter
[see 3.1.27]

3.2.14
Manchester encoding
[see 3.1.28]

3.2.15
medium
[see 3.1.29]

3.2.16
network
[see 3.1.30]

3.2.17
receiver
[see 3.1.37]

3.2.18
shield
[see 3.1.41]

3.2.19
terminator
[see 3.1.43]

4 Symbols and abbreviations

4.1 Symbols

Symbol	Definition	Unit
fr	Frequency corresponding to the nominal bit rate	MHz
N+	Non-data symbol – positive; Manchester coded signal with a high level for one bit time, used for delimiters, carrying no data	–
N–	Non-data symbol – negative; Manchester coded signal with a low level for one bit time, used for delimiters, carrying no data	–
T_{bit}	Nominal bit duration	µs
Z	Impedance; vector sum of resistance and reactance (inductive or capacitive)	Ω
Z_O	Characteristic impedance ; impedance of a cable, and of its terminators, over the defined frequency range	Ω

4.2 Abbreviations

EBUS	An EtherCAT physical layer as described in this international standard
EOF	End of Frame
LVDS	Low Voltage Differential Signaling
PCB	Printed Circuit Board
RxS	Receive Signal
SOF	Start of Frame
TxS	Transmit Signal

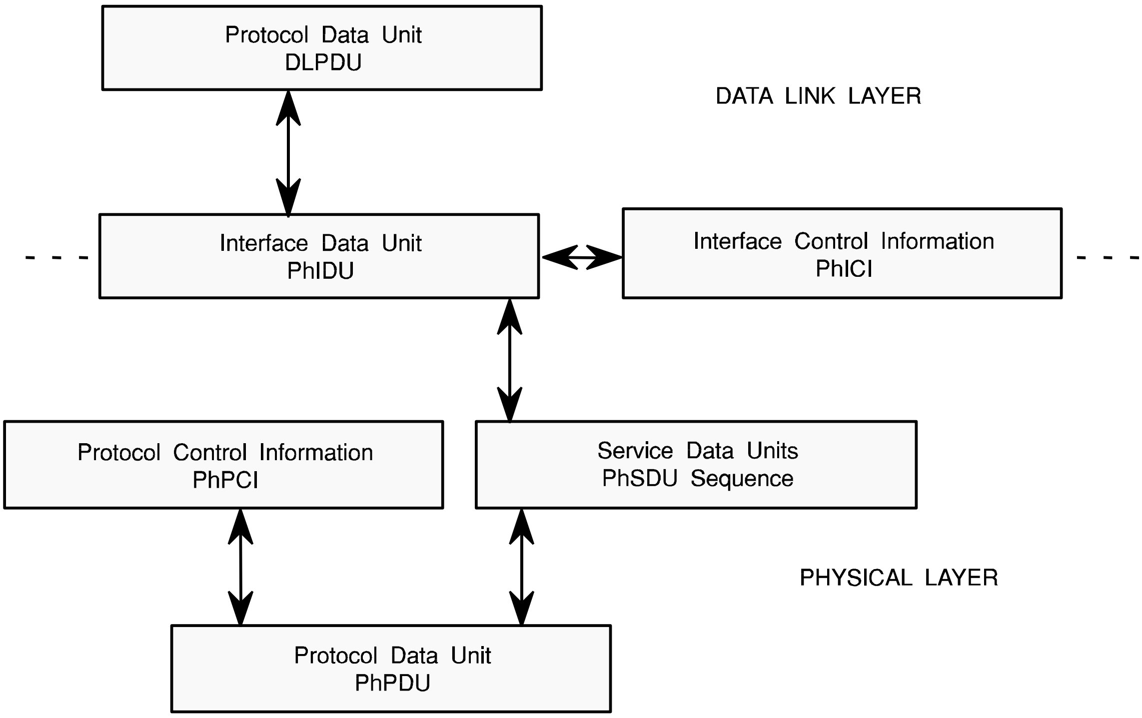
5 DLL – PhL interface

5.1 General

This clause defines the required physical service (PhS) primitives and constraints on their use.

NOTE 1 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.

PhIDUs shall be transferred between the DLL and the PhL in accordance with the requirements of ISO/IEC 7498 as shown in Figure 2.



NOTE PhPCI and PhICI support are type specific.

Figure 2 — Mapping between data units across the DLL – PhL interface

NOTE 2 These services provide for the interchange of PhIDUs between a DLL entity and its associated PhL entity. Such a transfer is part of a transaction between cooperating DLL entities. The services listed in this section are the minimum that can jointly provide the means by which cooperating DLL entities can coordinate their transmission and their exchange of data on the shared communication medium. Synchronization of data exchange and related actions is also provided if needed.

NOTE 3 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.

NOTE 4 A number of different DLL – PhL interfaces are specified, based on industry practice.

5.2 Required services

5.2.1 Primitives of the PhS

5.2.1.1 General

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

5.2.1.2 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 1 A PhE with a nominal data rate of 100 Mbit/s ± 0,01 % would specify a minimum data rate of 99,99 Mbit/s.

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

NOTE 2 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.

5.2.1.3 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-FRAME – 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-FRAME – the PhPDUs that terminate Ph-user data shall be transmitted after the last preceding octet of Ph-user data.

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

- START-OF-FRAME – 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-FRAME – the ongoing continuous correctly formed reception of Ph-user data has concluded with correct reception of PhPDUs;
- END-W-ERROR – the ongoing continuous correctly formed reception of Ph-user data was disrupted with not correct formed reception implying END-OF-FRAME WITH ERROR;
- 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.

5.2.2 Notification of PhS characteristics

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

5.2.3 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-FRAME, followed by 72 to 1 535 consecutive requests, inclusive, specifying DATA, each conveying a PhSDU, and concluded by a single request specifying END-OF-FRAME.

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.

5.2.4 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

a) a single indication specifying START-OF-FRAME; followed by consecutive indications specifying DATA, each conveying a PhSDU; and concluded by a single indication specifying END-OF-FRAME; or

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

This last sequence is indicative of an incomplete or incorrect reception. Detection of an error in the sequence of received PhPDUs, or in the PhEs reception process, shall disable further PH-DATA indications with a class parameter specifying DATA, or END-OF-FRAME 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 START-OF-FRAME.

6 Systems management – PhL interface

6.1 General

This interface provides services to the PhL, which are required for initialisation and selection of options.

One of the objectives of the PhL is to allow for future variations such as radio, fiber optics, redundant channels (e.g. cables), different modulation techniques, etc. A general form of Systems management – PhL Interface is specified which provides the services required by implementations of these variations.

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.

NOTE A number of different Systems management – PhL interfaces are specified, based on industry practice.

6.2 Systems management – PhL interface

6.2.1 Required service

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

PH-RESET request – reset of the Ph-Layer.

6.2.2 Service primitive PH-RESET request

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

7 DCE independent sublayer (DIS)

7.1 General

The PhL entity is partitioned into a Data Terminal Equipment (DTE) component and a Data Communication Equipment (DCE) component. The DTE component interfaces with the DLL 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.

This sublayer is independent of all the PhL 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).

NOTE A number of different DIS entities are specified, based on industry practice.

7.2 DIS

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 DLL from the sequence of received serial PhSDUs.

The PhID shall be converted to a sequence of PhSDUs for serial transmission in octets from a minimum of 72 octets up to a maximum of 1 535 octets.

For the serial transmission, a sequence of PhIDUs shall be converted into a sequence of PhSDUs. A PhSDU that represents a more significant bit is transferred after a PhSDU that represents a less significant bit.

When it is received, each sequence of PhSDUs shall be converted into a sequence of PhIDUs so that the sequence of PhIDUs formed in such a way corresponds to the one that is transmitted from the MAC sublayer to the PhL.

8 DTE – DCE interface and MIS-specific functions

8.1 General

The PhL entity is partitioned into a Data Terminal Equipment (DTE) component containing the DIS, and a Data Communication Equipment (DCE) component containing the MDS and lower sublayers. The DTE – DCE interface connects these two physical components, and is itself within the MIS. (See Figure 1.)

NOTE A number of different DTE – DCE interfaces are specified, based on industry practice.

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

8.2 DTE – DCE interface

The DTE – DCE interface is not exposed for EtherCAT transmission.

9 Medium dependent sublayer (MDS)

9.1 General

The medium dependent sublayer (MDS) is part of the data communication equipment (DCE). (See Figure 1.) It exchanges information across the DTE – DCE interface specified in clause 8 and it communicates encoded Ph-symbols 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.

NOTE A number of different MDS sublayer entities are specified, based on industry practice.

9.2 MDS: Wire media

9.2.1 PhPDU

The MDS shall produce the PhPDU shown in Figure 3 by adding delimiters and minimal idle sequences 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 3, i.e. SOF first, followed by PhSDU sequence and finally EOF.

idle	SOF	PhSDU SEQUENCE	EOF	idle

Figure 3 — Protocol data unit

Conversely, the MDS shall remove idle, SOF and EOF 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.

9.2.2 Encoding and decoding

Data units shall be encoded by the MDS for application to the MAU using the code shown in Figure 4 (Manchester Biphase L). The encoding rules are given formally in Figure 5 and Table 1.

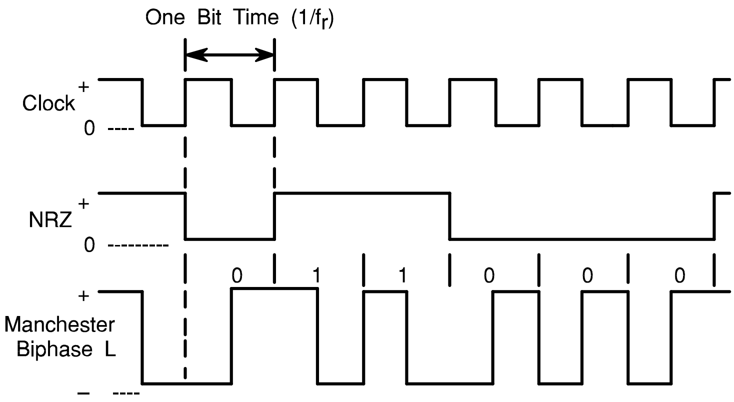


Figure 4 — PhSDU encoding and decoding

NOTE Figure 4 is included for explanatory purposes and does not imply a specific implementation.

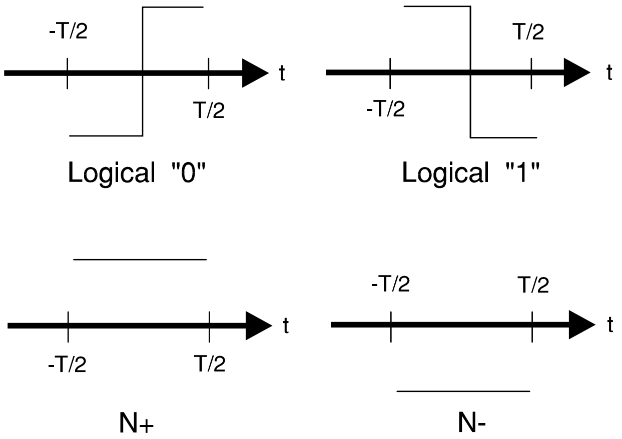


Figure 5 — Manchester encoding rules

Table 1 — Manchester 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 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.	

Decoding shall normally be the opposite of encoding. At reception, the MDS shall verify that each symbol is encoded in accordance with Figure 5 and Table 1 and shall detect the following errors:

a) invalid Manchester code;

b) half-bit-slip errors;

c) misalignment of EOF (number of bits is not a multiple of 8).

Any of these errors shall be reported as:

PH-DATA indication (class=END-W-ERROR, data=error).

9.2.3 Polarity detection

There is no automatic polarity detection of the received Manchester Biphase L encoded signal.

9.2.4 SOF

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:

0, N+

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.

9.2.5 EOF

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:

N–, 0

The MDS shall remove this sequence from the PhPDU before transferring the PhSDU sequence to the DIS. The MDS shall report to the corresponding DLL entity any frames received via the medium which do not include this sequence within 1 535 octets of start of frame (from end of SOF) as:

PH-DATA indication (class=END-W-ERROR, data=frame_too_long).

The MDS shall report to the corresponding DLL entity, via the corresponding DIS, any frames received via the medium that have an end delimiter which is not located at an octet boundary as:

PH-DATA indication (class=END-W-ERROR, data=alignment_error).

9.2.6 Idle

In order to synchronize bit times, an idle sequence shall be send out if no PhSDU or SOF/EOF are transmitted:

0

An idle sequence is always bit aligned.

NOTE A series of 1 in a PhSDU can be interpreted as idle. Following 0-symbols or EOF will readjust bit cell detection.

9.2.7 Synchronization

After activation and reception of a sufficient number of signals, the receiver shall detect and report half-bit-slip errors.

NOTE 1 This synchronization specification allows the loss of 4 bits of the preamble.

After SOF, half-bit-slip errors shall be reported as:

PH-DATA indication (class=END-W-ERROR, data=half_bit_slip_error).

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

9.2.8 Inter frame 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 PhL entity shall ignore all received signaling. An MDS entity shall set a minimum post transmission period of 92 nominal bit times (96 with SOF, EOF). The period may be extended, but not reduced, by systems management.

10 MDS — MAU interface

10.1 General

The medium attachment unit (MAU) is an optionally separate part of a communication element that connects to the medium directly or via passive components. (See Figure 1.) For electrical signaling 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 optional exposure of this interface. See Clause 6 for management services.

NOTE A number of different MDS – MAU interfaces are specified, based on industry practice.

11 Medium attachment unit: electrical medium

11.1 Electrical characteristics

This MAU specification describes a balanced-line unidirectional transmission via a pair of wires corresponding to ANSI TIA/EIA-644-A. A terminator, located at the receiving end of the wire, enables the PhL to support in particular higher speed transmission. The maximum wire length should not exceed 20 m. This transmission method is offered in addition to the ISO/IEC 8802-3 technologies known as 100BASE-TX and 100BASE-FX. Its main purpose is to connect devices within a control cabinet. Thus, it assumes a common signal ground.

Manchester bit encoding is combined with ANSI TIA/EIA-644-A signaling targeted to low cost line couplers, which may not isolate the station from the line (galvanic isolation); a line terminator is required (recommended resistor value is 100 Ω).

The topology supported is a pair of wires with exactly one sender and one receiver on a single pair.

A connection consists of two pairs of wire which connects exactly two DTE.

The term wire specifies a media which is able to transmit signals according to ANSI TIA/EIA-644-A at the specified length. A conformance statement of the device manufacturer shall specify these parameters.

11.2 Medium specifications

11.2.1 Connector

There is no connector specified for this media. A conformance statement of the device manufacturer shall specify the connection capabilities.

11.2.2 Wire

The medium is a pair of wires. Shielding can be used to improve the electromagnetic compatibility (EMC). Unshielded wires can be used if there is no severe electromagnetic interference (EMI).

The characteristic impedance Z_O of the wire pair should be in the range between 80 and 120 Ω, the wire capacity (conductor - conductor) should be less than 60 pF/m. Wire selection criteria should follow the ANSI TIA/EIA-644-A implementation guidelines, especially for backplane and PCB interconnection.

NOTE Assuming an output common-mode voltage of approximately 1.2 V, the output resistor can be modelled as two 50 Ω resistors in series with their center-tap sitting at 1.2 V. This provides a match to a typical PCB trace characteristic impedance (Z_O) of 50 Ω and minimizes reflections.

A pair of wire should have a symmetrical design (same length, closely related to each other and same distance to ground signal). The two pair of wires shall have the same length. A skew of less than 2 ns is acceptable.

11.3 Transmission method

11.3.1 Bit coding

The Manchester-coded data from DLL is transmitted via a pair of wires. A binary "1" (N+ or first half of DL_symbol = “ONE” or second half of DL_symbol = “ZERO”) is represented by a constant positive differential voltage on TxS/RxS and a binary "0" (N- or first half of DL_symbol = "ZERO" or second half of DL_symbol = “ONE”) by a constant negative differential voltage on TxS/RxS.

11.3.2 Representation as ANSI TIA/EIA-644-A signals

TxS will be represented as OUT+ and OUT- in ANSI TIA/EIA-644-A terms. RxS inputs at ANSI TIA/EIA-644-A level will be denominated as IN+ and IN-.

NOTE Assuming an output current of 3.5 mA common-mode voltage of approximately 1.2 V, the nominal voltage difference between OUT+ and OUT- is 350 mV (in a range between 247 mV and 454 mV). A differential voltage of 100 mV is needed to detect a signal.

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