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IEEE Standard for Medical Device Communications—Physical Layer Interface—Cable Connected

Sponsor

**Medical Information Bus Committee
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IEEE Engineering in Medicine and Biology Society**

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Abstract: A physical interface for the interconnection of computers and medical devices in the IEEE 1073 family of standards is defined. This interface is intended to be highly robust in an environment where devices are frequently connected to and disconnected from the network. The physical and electrical characteristics of the connector and signals necessary to exchange digital information between cable-connected medical devices and host computer systems are specified.

Keywords: bedside communications controller (BCC), bedside medical device, cable-connected medical devices, Data Link layer, device communications controller (DCC), electromagnetic noise, electrostatic discharge (ESD), high-level data link control (HDLC), high-speed frame encoding, Manchester biphase encoding, Physical layer, special function signals

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Introduction

(This introduction is not a part of IEEE Std 1073.4.1, 2000 Edition, IEEE Standard for Medical Device Communications—Physical Layer Interface—Cable Connected.)

This standard is a member of the IEEE 1073 family of standards for medical device communications. This particular standard specifies the services and protocols for the Physical layer connection between a device communications controller (DCC) and a bedside communications controller (BCC) using an electrical cable for connection.

This standard is intended to facilitate fast, reliable, and robust communications with a variety of medical devices at a single patient bedside in an integrated manner. The defined services and protocols address the special requirements of the medical users in the patient bedside environment. These requirements include providing some degree of electromagnetic noise elimination, immunity to electrostatic discharge (ESD), dynamic connection and disconnection, and provision of power from the BCC to the DCC.

The 1994 standard was amended in 1999 to correct and clarify the original standard.

There are no restrictions on the user entities that make use of this standard. The scope of this standard does not preclude the use of the standard for domains outside of the medical bedside environment. However, it is not the intent to define the requirements for, nor to optimize this standard for, those other domains.

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IEEE Standard for Medical Device Communications—Physical Layer Interface—Cable Connected

1. Overview

1.1 Scope

The specifications set forth in this standard are intended to define a physical interface for the interconnection of computers and medical devices. The scope of this standard is the Physical layer interface for cable-connected medical devices in the IEEE 1073 family of standards.

1.2 Purpose

The purpose of this standard is to specify the physical and electrical characteristics of the connector and signals necessary to exchange digital information between cable-connected medical devices and host computer systems. The interface is intended to be highly robust in an environment where devices are frequently connected to and disconnected from the network.

2. References

This standard shall be used in conjunction with the following standards. When the following standards are superseded by an approved revision, the revision shall apply.

ANSI/AAMI ES1-1993, Safe Current Limits for Electromedical Apparatus.¹

CENELEC HD21.1, Polyvinylchloride insulated cable of rated voltage up to and including 450/750 V Part 1—General requirements.²

CSA C22.2 No. 601.1-M90, Medical Electrical Equipment—Part 1: General Requirements for Safety.³

¹ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

²CENELEC publications are available from the European Committee for Electrotechnical Standardization, 35, rue de Stassart, B-1050 Brussels, Belgium (<http://www.cenelec.be/>).

³CSA publications are available from the Canadian Standards Association (Standards Sales), 178 Rexdale Blvd., Etobicoke, Ontario, Canada M9W 1R3 (<http://www.csa.ca/>).

EN 60601-1:1995, Medical electrical equipment—Part 1: General requirements for safety.⁴

EN 60601-1-1:1993, Medical electrical equipment—Part 1: General requirements for safety—Collateral standard: Safety requirements for medical electrical systems. IEC 60601-1-1:1992.

EN 60601-1-2:1993, Medical electrical equipment—Part 1: General requirements for safety—Collateral standard: Electromagnetic compatibility—Requirements and tests. IEC 60601-1-2:1993.

IEC 60601-1:1988, Medical electrical equipment—Part 1: General requirements for safety.⁵

IEC 60601-1-1:1992, Medical electrical equipment—Part 1: General requirements for safety. 1. Collateral standard: Safety requirements for medical electrical systems.

IEC 60601-1-2:1993, Collateral Standard: Electromagnetic Compatibility—Requirements and tests.

IEEE Std 1073-1996, IEEE Standard for Medical Device Communications Overview and Framework.⁶

IEEE P1073.1, Draft D.09, Medical Device Communications—Medical Device Data Language (MDDL) Overview, May 1993.

IEEE Std 1073.3.1-1994, IEEE Standard for Medical Device Communications—Transport Profile—Connection Mode.

ISO 7498:1984, Information processing systems—Open Systems Interconnection—Basic Reference Model.⁷

ISO/IEC 3309:1993, Information technology—Telecommunications and information exchange between systems—High-level data link control (HDLC) procedure—Frame structure.

ISO/IEC 4335:1993, Information technology—Telecommunications and information exchange between systems—High-level data link control (HDLC) procedures—Elements of procedures.

ISO/IEC 8482:1993, Information technology—Telecommunications and information exchange between systems—Twisted pair multipoint interconnections.

UL 1581:1991 (Revised 1994), Electrical Wires, Cables, and Flexible Cords.⁸

UL 2601-1:1994, Medical Electrical Equipment—Part 1: General Requirements for Safety.

⁴EN publications are available from the European Committee for Standardization (CEN), 36, rue de Stassart, B-1050 Brussels, Belgium (<http://www.cenorm.be/>).

⁵IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iec.ch/>). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

⁶IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

⁷ISO and ISO/IEC publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iso.ch/>). ISO publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

⁸UL standards are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>).

3. Definitions

3.1 abort: To terminate the transmission of a frame before it has been completely transmitted.

3.1.1 accompanying documents: Documents accompanying equipment or an accessory and containing all important documentation for the user, operator, installer, or assembler of equipment, particularly regarding safety.

3.1.2 American Wire Gauge (AWG): A system of measurement of the thickness and current carrying capacity of wire.

3.1.3 basic insulation: Insulation applied to live parts to provide basic protection against electric shock.

3.2 baud rate: For a given encoding scheme and data rate, the maximum number of signal transitions transmitted on a serial interface in a 1 s period.

3.3 bedside communications controller (BCC): A communications controller, typically located at a patient bedside, that serves to interface between one or more medical devices. The BCC may be embedded into local display, monitoring, or control equipment. Alternatively, it may be part of a communications router to a remote hospital host computer system.

3.4 bedside medical device: A medical device that directly interacts with, monitors, provides treatment to, or is in some way associated with a single patient.

3.5 binary encoding: An encoding scheme for serial communications in which the symbol for a logic “0” or “1” assumes a specified voltage level for the full duration of a signalling bit period.

3.6 confirm: A primitive provided from one layer entity to another layer entity to verify that the entity generating the confirm primitive responded to a request primitive originating from the entity that received the confirm primitive.

3.7 connect: Indicates that a device communications controller (DCC) has been physically attached to a bedside communications controller (BCC) port, by means of an interconnecting cable. Connect does not necessarily imply that communications have been logically established between the BCC and the DCC.

3.8 data bit: A single entity of information that is transmitted across a serial signalling medium. A bit assumes one of two values: logic “0” or logic “1.” A data bit may convey control, address, information, or frame check sequence (FCS) data.

3.9 data rate: The rate at which a data path (e.g., a channel) carries data, measured in bits per second.

3.10 delimiter: A nondata symbol transmitted on a serial link to delineate the beginning or end of a frame of data.

3.11 device communications controller (DCC): A communications interface associated with a medical device. A DCC may support one or more physically distinct devices acting as a single network communications unit. Its purpose is to provide a point-to-point serial communication link to a bedside communications controller (BCC).

3.12 differential signal: A signal that is conveyed between two separate conductors, instead of one active conductor and signal ground. The magnitude of the differential signal is the difference between the two signals, rather than the voltages between the two individual signals and ground.

3.12.1 double insulation: Insulation comprising both basic insulation and supplementary insulation.

3.13 electromagnetic compatibility (EMC): The requirements for electromagnetic emission and susceptibility dictated by the physical environment and regulatory governing bodies within whose jurisdiction a piece of equipment is operated. Compatibility requirements are thus site specific, and their definition is not within the scope of this standard.

3.14 encoding: The representation of data bits and nondata information for signal transmission across a serial communications medium. Nondata information includes indications of start and end of octets and frame transmission.

3.15 entity: An object that provides an implementation of the functions defined by this standard. In an Open Systems Interconnection (OSI) communication environment, separate entities exist for implementing the functions of separate layers.

3.16 frame: A continuous transmission of octets from one station [bedside communications controller (BCC) or device communications controller (DCC)] to the other station. A Physical layer frame is also referred to as a Physical layer protocol data unit (PhPDU). The Physical layer service data unit (PhSDU) passed between the Data Link layer and the Physical layer consists of the data octets portion of the frame. The PhSDU consists of an integral number of binary octets. The frame consists of these octets, plus other encoded symbols that are added by the Physical layer. For low-speed operation, each octet consists of a binary-encoded start bit, eight data bits, and a stop bit. The first octet of a low-speed frame consists of a flag octet. The last octet of a low-speed frame is either a flag octet or an abort octet. For high-speed operation, each octet consists of eight Manchester biphase-encoded data bits. For high-speed operation, each octet also has a start delimiter and either an end delimiter or an abort delimiter, indicating the beginning and end of individual frames, respectively. The operation of concatenating the delimiters to the data octets is performed by the Physical layer.

3.17 frame validity checking: Verification, by a receiving station, of correct frame transmission by the transmitting station. Frame checking entails verifying for correct encoding of all transmitted delimiters and start and stop bits, data bits, and octet encoding. For the medical information bus (MIB), frame validity checking is performed by both the Physical layer and the Data Link layer.

3.18 host computer system: A computational-based system used for clinical support of patient care, limited to medical device data interchange. *Syn:* **patient care information system.**

3.19 idle state: The inactive (nontransmitting) state of a serial link transmitter. The output of an inactive transmitter shall present a high impedance to a bidirectional serial link.

3.20 indication: A mechanism informing an entity of the occurrence of an event in a lower layer entity. Alternatively, an indication may provide evidence of a request by a remote station entity.

3.21 interrupt: A mechanism provided to allow a device communications controller (DCC) to request service from a bedside communications controller (BCC) prior to the next scheduled polling time. Interrupt is also used to establish initial connection for high-speed DCCs.

3.22 layer: A subdivision of the Open Systems Interconnection (OSI) architecture, constituted by subsystems of the same rank.

3.22.1 leakage current: Current that is not functional, including current in earth conductors and enclosures.

3.22.2 live: State of a part that, when connection is made to that part, can cause a current exceeding the allowable leakage current for the part connected to flow from that part to an accessible part of the same equipment.

3.23 Manchester biphasic-L encoding: A signal transmission method defined for the representation of binary data bits. Manchester biphasic-L encoding specifies two “half-bits,” so that a guaranteed mid-bit transition occurs in the transmitted signal. The transition is defined to be positive for encoding a logic “0” and negative for encoding a logic “1.”

3.24 medical devices: Any product that interfaces to the patient directly or operates in the patient environment.

3.25 octet: A group of eight adjacent bits.

3.26 Open Systems Interconnection (OSI): Refers to ISO 7498:1984.⁹ A model that provides a common basis for the coordination of standards development for systems interconnection, while allowing existing standards to be placed into perspective within the overall reference model. The OSI model defines a seven-layer functional model, including descriptions of the functions defined for each layer.

3.26.1 Physical layer service access point (PhSAP): The interface between the Physical layer entity and the Physical layer user entity. It consists of the set of services performed by the Physical layer entity.

3.27 Physical layer protocol data unit (PhPDU): A frame, consisting of both nondata symbols (delimiters or start and stop bits) and data symbols (data bits), that is transmitted from a bedside communications controller (BCC) to a device communications controller (DCC) or from a DCC to a BCC. A PhPDU includes mechanisms indicating the start and end of transmission. PhPDUs may be preceded and followed by idle periods on the serial transmission medium. Conditions exist in which two consecutive PhPDUs may be transmitted contiguously by the same station.

3.27.1 physical service (PhS): The service performed by the Physical layer entity for the Physical layer user entity.

3.28 Physical layer service data unit (PhSDU): A set of octets, constituting a frame, that is transferred between the PhS_user layer entity and the Physical layer entity. A PhSDU transferred from the PhS_user layer entity is transmitted on the physical medium. Alternatively, a PhSDU is a frame of octets that is received from the physical medium and is transferred to the PhS_user layer entity.

3.29 physical service user (PhS_User): Refers to the Data Link layer entity, which is the user of a bedside communications controller (BCC) or a device communications controller (DCC) Physical layer entity.

3.30 primitive: A mechanism for communicating between the entities of different layers of the medical information bus (MIB) communications standard (e.g., between the Physical layer and Data Link layer entities). A primitive may request a particular service, provide indication of a request, provide a response to an indication, or provide confirmation of a response.

3.30.1 reinforced insulation: A single insulation system applied to live parts that provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in EN 60601-1:1995.

3.31 request: A type of primitive in which one layer entity solicits another layer entity to perform a particular function.

3.32 response: A reply represented in the control field of a response protocol data unit (PDU). It advises the address destination logical link control (LLC) of the action taken by the source LLC to one or more command PDUs.

⁹Information on references can be found in Clause 2.

3.33 SENSE/INT/SYNC-IN: A special function signal from the bedside communications controller (BCC) to the device communications controller (DCC) in a BCC-to-DCC interconnection cable used for three purposes. The signal allows the DCC to sense whether it has been physically connected to a BCC port, allows a BCC to send sync pulses to the DCC, and allows the BCC to send interrupt deactivate pulses to the DCC.

3.34 SENSE/INT/SYNC-OUT: A special function signal from the device communications controller (DCC) to the bedside communications controller (BCC) in a BCC-to-DCC interconnection cable used for three purposes. The signal allows the BCC port to sense whether a DCC has been physically connected, allows a DCC to send sync pulses to the BCC, and allows the DCC to send interrupt activate and interrupt deactivate pulses to the BCC.

3.35 signal transition distortion: The deviation from the ideal time between signal transitions of a signal on a serial communication link. Contributing factors to signal transition distortion include clock oscillator frequency differences, variations in transmitter delay times and rise/fall times, and phase shifts introduced by cables. For a 1 Mb/s Manchester-encoded signal, the ideal times between transitions are 500 ns and 1 μ s. A transition is defined as the time that a differential signal passes through 0 V.

3.36 special function signal: A signal line in a connecting cable from a bedside communications controller (BCC) to a device communications controller (DCC) that conducts other than serial data or power. The two special function signals are SENSE/INT/SYNC-IN and SENSE/INT/SYNC-OUT. Special function signals convey indications of physical connection and disconnection, use of interrupts, frame transmission, interrupt requests, and synchronization pulses.

3.37 start bit: For the low-speed version of the Physical layer, a bit that is encoded identically to a logic “0” data bit that is used to delineate the beginning of each individual octet transmission.

3.38 station: A physical device that may be attached to a shared medium local area network (LAN) to transmit and receive information on that shared medium. A data station is identified by a destination address. For this standard, a station shall be either a device communication controller (DCC) or a bedside communication controller (BCC). *Syn:* **data station**.

3.39 stop bit: For the low-speed version of the Physical layer, a bit that is encoded identically to a logic “1” that is used to delineate the end of each individual octet transmission.

3.39.1 supplementary insulation: Independent insulation applied in addition to basic insulation to protect against electric shock if the basic insulation fails.

3.40 sync: A function in which a bedside communications controller (BCC) may precisely synchronize a common fiduciary (now) maintained by multiple device communications controllers (DCCs) to the value of its own real-time clock, to an accuracy of approximately 1 ms. The BCC implements this function by transmitting a 3 μ s pulse to one or more DCCs. A sync pulse may also be transmitted by a BCC or a DCC for reasons other than time synchronization.

3.41 transmission format: The specified arrangement of delimiter symbols or start and stop symbols and of data bit symbols that constitute a complete transmitted signal frame (PhPDU). Data bit symbols are always arranged in octets (8 b groupings). The definition of the transmission format also includes the selected encoding scheme, which is binary for low-speed operation and Manchester biphase-L for high-speed operation.

4. Abbreviations and acronyms

BCC	bedside communications controller
DCC	device communications controller
EMC	electromagnetic compatibility
EMI	electromagnetic interference
ESD	electrostatic discharge
FCS	frame check sequence
HDLC	high-level data link control
LAN	local area network
LLC	logical link control
MIB	medical information bus
NRZI	nonreturn to zero inverted
OSI	Open Systems Interconnection
PDU	protocol data unit
PhPDU	Physical layer protocol data unit
PhS	physical service
PhSAP	Physical layer service access point
PhSDU	Physical layer service data unit
UART	universal asynchronous receiver transmitter
XID	exchange identification

5. Bedside communications controller (BCC) and device communications controller (DCC) capabilities

For BCC-to-DCC interconnects, Table 1 lists the required and optional capabilities for BCCs, high-speed DCCs, and low-speed DCCs.

6. Communications nodes on the subnet

6.1 Overview

The IEEE 1073.4.1 Physical layer requires each device to have its own interface port. Two types of communications nodes are allowed on the interface. The BCC is the primary node and functions as the interface controller. A device connects to the BCC port through its DCC.

Table 1—BCC and DCC capabilities

Capability	Applicability for		
	BCC	High-speed DCC	Low-speed DCC
2400 Bd low-speed operation	Required	Optional (see Note 1)	Optional (see Note 1)
9600 Bd low-speed operation	Required	Optional (see Note 1)	Optional (see Note 1)
High-speed (1 Mb/s) operation	Required	Required (see Note 1)	Optional (see Note 1)
EIA-485 transmit/receive capability	Required	Required	Required
+12 V power	Required	Optional use of +12 V from medical information bus (MIB) connector	Optional use of +12 V from MIB connector
Physical connection indication function	Required	Required	Required
Connection sense function	Required	Required (see Note 2)	Optional (see Note 2)
Interrupt function	Required	Required (see Note 2)	Optional (see Note 2)
BCC-to-DCC sync function	Required	Required (see Note 2)	Optional (see Note 2)
DCC-to-BCC sync function	Required	Required (see Note 2)	Optional (see Note 2)
NOTES 1—The DCC shall provide either 2400 Bd low-speed, 9600 Bd low-speed, and/or high-speed operation. A DCC may provide operation at multiple data rates. However, a DCC may not change its data rate between the time of logical connection establishment and the time of physical disconnect. 2—Connection sensing, and interrupt and sync capability are required for a high-speed DCC and are optional for a low-speed DCC.			

6.2 BCC port

The BCC port functions as the interface between a DCC and a host computer system needing to exchange messages with the device associated with that DCC.

6.3 DCC port

The DCC port is the interface for each device into the BCC at the bedside. All connections are initiated by the DCC.

7. Service specification

This clause specifies the services offered by the Physical layer to the media user (PhS_user). The primary service is to allow the transmission of data octets over a physical media. The three data rates described in this standard are 2400 Bd, 9600 Bd, and 1 Mb/s. Henceforth, the 2400 Bd and 9600 Bd versions will be referred to as “low speed,” while the 1 Mb/s version will be referred to as “high speed.”

Other services allow a PhS_user layer local entity to determine physical connection and disconnection, provide BCC/DCC time synchronization and event synchronization, and allow a DCC to issue interrupt requests to a BCC. These services are described in an abstract way; no specific implementation is implied by this standard.

7.1 Overview of Physical User layer and Physical layer interactions

7.1.1 Ph-Characteristics indication

The Physical layer entity shall provide the following service primitive to report essential Physical layer characteristics that may be used by the PhS_user.

The primitive associated with physical characteristics indication is

PH_CHARACTERISTICS.indication

The parameters associated with this primitive provide indications of the following capabilities to the Data Link layer:

- a) Low-speed operation
- b) High-speed operation
- c) +12 V provided to MIB connector
- d) +12 V used from MIB connector
- e) BCC capability
- f) DCC capability
- g) Connection sense capability
- h) Capability for DCC interrupt function
- i) Capabilities to enable BCC-to-DCC and/or DCC-to-BCC sync pulses

7.1.2 DCC connection to BCC

A mechanism is provided to allow the BCC to determine whether a DCC is connected to a particular port without having to poll a vacant port. The same mechanism also allows a DCC to determine whether it is connected to a BCC port.

Two primitives are associated with the BCC or DCC physical connect/disconnect function.

The primitives associated with BCC or DCC connect/disconnect determination are

PH_CONNECT.indication
PH_DISCONNECT.indication

PH_CONNECT.indication is passed from the BCC or DCC Physical layer to indicate that a DCC has been connected to a BCC port. PH_DISCONNECT.indication is passed from the BCC or DCC Physical layer to indicate that a device/DCC or device/DCC cable has been disconnected from a BCC port.

7.1.3 Speed and data rate designation

The Physical layer operates at one of two speeds and at one of three data rates. The two speeds are “low” and “high.” There are two low-speed data rates (2400 Bd and 9600 Bd) and one high-speed data rate (1 Mb/s). A multirate BCC is able to communicate with DCCs that operate at different data rates. The BCC PhS_user entity issues a PH_DATA_RATE.request primitive to inform the BCC Physical layer of current speed and data rate.

The primitive associated with data rate designation is

PH_DATA_RATE.request

PH_DATA_RATE.request includes a speed parameter and a separate rate parameter. The speed parameter can assume the possible values of “low” and “high.” The rate parameter can assume values of 2400 Bd, 9600 Bd, and 1 Mb/s.

If the speed parameter is “low,” the Physical layer will anticipate receiving and outputting pulse widths of 50 μ s, 100 μ s, and 150 μ s for the sync, INTERRUPT_ACTIVATE, and INTERRUPT_DEACTIVATE pulses, respectively.

If the speed parameter is “high,” the Physical layer will anticipate receiving and outputting pulse widths of 3 μ s, 5 μ s, and 7 μ s for the sync, INTERRUPT_ACTIVATE, and INTERRUPT_DEACTIVATE pulses, respectively.

The rate parameter informs the BCC Physical layer what data rate to transmit and receive over the ISO/IEC 8482:1993 serial link.

NOTE—During initial data link connection establishment, the speed parameter will initialize to “high,” while the rate parameter will alternate between 2400 Bd and 9600 Bd. Following connection establishment, the speed and rate parameters will be consistent (i.e., “low” speed with rate = 2400 Bd or 9600 Bd or “high” speed with rate = 1 Mb/s).

7.1.4 Direction control

The Physical layer uses a half-duplex data transfer media. There are three primitives for direction control of the media.

The primitives associated with direction control are

PH_ACTIVATE.request
PH_DEACTIVATE.request
PH_ABORT.request

PH_ACTIVATE.request sets the media connection at the local node into a transmit mode. PH_DEACTIVATE.request sets the media connection at the local node into receive mode.

PH_ABORT.request is similar to PH_DEACTIVATE.request, except that it causes a frame to be terminated prior to its complete transmission. For the high-speed version of the Physical layer, the PH_ABORT.request primitive causes the Physical layer entity to transmit an abort delimiter at the end of the shortened frame.

NOTE—The PH_ABORT.request primitive is only applicable for high-speed operation. For low-speed operation, an aborted low-speed frame will be terminated by the transmission of a control escape octet, followed by transmission of a flag octet. The appending of these two octets is performed by the PhS_user entity.

7.1.5 End of received frame indication

The Physical layer determines when the end of received frames occurs and performs a degree of validity checking on received frames. The Physical layer provides indications to the PhS_user of valid received frames and invalid received frames.

The primitives associated with end of frame indication are

PH_VALID_FRAME_RECEIVED.indication
PH_INVALID_FRAME_RECEIVED.indication

PH_VALID_FRAME_RECEIVED.indication is issued to the PhS_user to indicate that a completed frame that passed all of the Physical layer validation checks has been received. PH_INVALID_FRAME_RECEIVED.indication is transmitted to the PhS_user to indicate that a completed frame that failed to pass all of the Physical layer validation checks has been received.

7.1.6 Special function signal error indication

The Physical layer provides an indication to the PhS_user layer system management entity following reception of an invalid pulse width on the SENSE/INT/SYNC-IN input for a DCC or the SENSE/INT/SYNC-OUT input for a BCC.

The primitive associated with special function signal error indication is

PH_PULSE_ERROR.indication

PH_PULSE_ERROR.indication is issued to the PhS_user system management entity to indicate that an incorrect pulse width was received on the special function input signal.

7.1.7 Data transfer

All application messages are sent using the data transfer service, using the PH_DATA.request primitive.

The primitives associated with data transfer are

PH_DATA.request
PH_DATA.indication

The PH_DATA.request primitive is passed to the Physical layer to request that a Physical layer service data unit (PhSDU) be transmitted. The PH_DATA.indication is passed from the Physical layer to indicate the arrival of a PhSDU.

7.1.8 DCC interrupt requests

The Physical layer provides a mechanism to allow a DCC to issue interrupt requests to the BCC. The use of interrupts is intended for the notification of alarms and other asynchronous events. The BCC acknowledges the request by initiating a polling frame sequence with the DCC. Interrupt request capability is required for all BCC ports and high-speed DCCs and is optional for low-speed DCCs.

The primitives associated with DCC interrupt requests are

PH_INTERRUPT_ACTIVATE.request
PH_INTERRUPT_ACTIVATE.indication
PH_INTERRUPT_DEACTIVATE.request
PH_INTERRUPT_DEACTIVATE.indication

PH_INTERRUPT_ACTIVATE.request is passed from the DCC's PhS_user entity to its Physical layer to direct the DCC to output an interrupt activate pulse on its SENSE/INT/SYNC-OUT output signal. PH_INTERRUPT_ACTIVATE.indication is passed from the BCC Physical layer to the BCC PhS_user layer to indicate reception of an interrupt request from the DCC. The BCC physical entity then acknowledges the interrupt request by initiating a connection establishment or interrupt acknowledge frame sequence. After the respective sequence of ISO/IEC 8482:1993 serial frame transmissions has been successfully completed, the PH_INTERRUPT_DEACTIVATE.request primitive is passed from the BCC (for connection establishment) or DCC (for interrupt acknowledgement) PH_user entity to the local BCC's or DCC's physical entity. When the local BCC (for connection establishment) or DCC (for interrupt acknowledgement) physical

entity receives this primitive, it will transmit an interrupt deactivate pulse on the BCC's $\overline{\text{SENSE/INT/SYNC-}}\overline{\text{IN}}$ output or the DCC's $\overline{\text{SENSE/INT/SYNC-OUT}}$ output.

For the station receiving the interrupt deactivate pulse, a `PH_INTERRUPT_DEACTIVATE.indication` is passed from the local physical entity to the local `PhS_user` entity.

NOTE—If the `PhS_user` entity is compliant with IEEE Std 1073.3.1-1994, reception of this `PH_INTERRUPT_DEACTIVATE.indication` results in the `PhS_user`'s issuing a `PH_INTERRUPT_DEACTIVATE.request` primitive to its physical entity. This results in the local physical entity's transmitting an interrupt deactivate pulse to the remote physical entity. This, in turn, results in the issuance of a `PH_INTERRUPT_DEACTIVATE.indication` to the BCC `PhS_user` entity to complete a connection establishment sequence or to the DCC `PhS_user` entity to complete an interrupt acknowledge sequence.

The interrupt activate pulse width is 5 μs for high-speed operation and 100 μs for low-speed operation. The interrupt deactivate pulse width is 7 μs for high-speed operation and 150 μs for low-speed operation.

7.1.9 Synchronize function

The synchronize function provides a mechanism that may be used to synchronize the values of real-time clocks for a BCC and one or more DCCs. Sync pulses may also be outputted by either BCCs or DCCs for event synchronization. Synchronization is a required capability for a BCC and a high-speed DCC and is optional for a low-speed DCC.

The primitives associated with the BCC-to-DCC synchronization function are

`PH_SYNC.request`
`PH_SYNC.indication`

`PH_SYNC.request` is passed to the Physical layer to cause the BCC or the DCC to output a sync pulse. `PH_SYNC.indication` is passed from the Physical layer to the `PhS_user` to indicate reception of a valid sync pulse. The pulse width for a synchronize pulse is 3 μs for high-speed operation and 50 μs for low-speed operation.

7.2 Detailed service specifications

The primitives and parameters associated with the services identified in 7.1 are described in detail in 7.2.1 through 7.2.18. The parameters are specified in an abstract sense. The parameters specify the information that shall be available to the receiving entity. No specific implementation is implied by this standard.

7.2.1 PH_CHARACTERISTICS.indication

7.2.1.1 Function

This primitive is the service indication primitive to indicate the capabilities of the Physical layer to the `PhS_user` layer.

7.2.1.2 Semantics of the service primitive

The primitive shall provide parameters as follows:

`PH_CHARACTERISTICS.indication`(
 9600-baud low-speed capability
 2400-baud low-speed capability
 High-speed capability
 +12 V from MIB connector used (DCC only)

```

    BCC capability
    DCC capability
    DCC connection determination sensing
    DCC interrupt request capability
    DCC sync reception capability
    DCC sync transmission capability
    Standard version/revision
  )

```

With the exception of the standard version/revision parameter, all of the parameters for the PH_CHARACTERISTICS.indication are Boolean, assuming values of true or false. The format of the standard/revision parameter is nine ASCII characters.

NOTE—For this standard, the value of the standard/revision parameter is “1073.4.1a.”

7.2.1.3 When generated

This primitive is passed by the BCC Physical layer to the BCC PhS_user at start-up for the Physical layer to inform the PhS_user layer of the Physical layer characteristics.

7.2.1.4 Effects on receipt

The effect of receipt will be to inform the PhS_user which of its optional capabilities may be used.

7.2.1.5 Additional comments

A possible logical sequence of primitives in successful data transfer is shown in Figure 1.

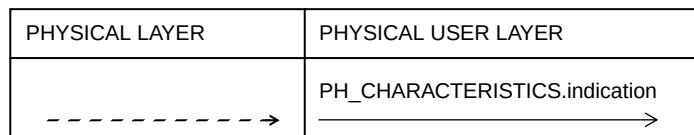


Figure 1—Timing sequence for physical characteristics primitive

7.2.2 PH_CONNECT.indication

7.2.2.1 Function

This primitive is the service indication primitive for a BCC port to indicate that a DCC has been physically connected or for a DCC to indicate that it has been physically connected to a BCC port.

7.2.2.2 Semantics of the service primitive

The primitive shall provide the following parameter:

```

PH_CONNECT.indication (
)

```

7.2.2.3 When generated

This primitive is passed by the BCC Physical layer to the PhS_user to indicate the connection of a DCC to a BCC port.

7.2.2.4 Effects on receipt

For a BCC, the effect of receipt by the physical user entity will be to commence a connection establishment frame sequence.

7.2.2.5 Additional comments

A possible logical sequence of primitives in successful data transfer is shown in Figure 2.

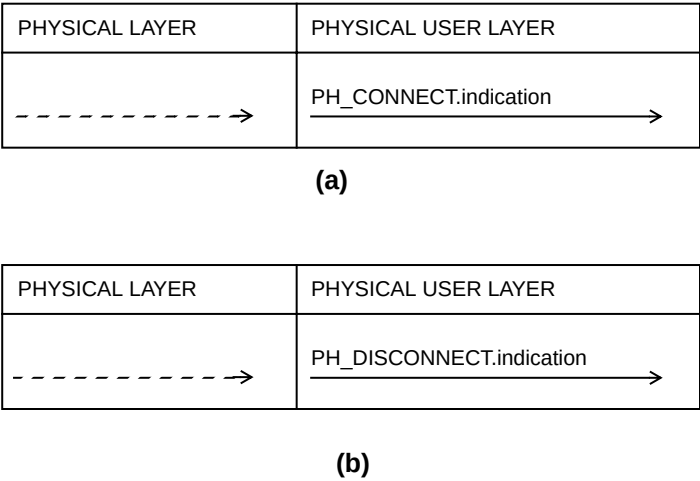


Figure 2—Timing sequence for BCC-to-DCC physical connection primitives:
(a) for PH_CONNECT.indication; (b) for PH_DISCONNECT.indication

7.2.3 PH_DISCONNECT.indication

7.2.3.1 Function

This primitive is the service indication primitive to indicate that a DCC has been disconnected from a BCC port.

7.2.3.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PH_DISCONNECT.indication (

)

7.2.3.3 When generated

This primitive is passed by the Physical layer to the PhS_user to indicate that a DCC has been disconnected from a BCC port.

7.2.3.4 Effects on receipt

The effect of receipt by the PhS_user is unspecified.

7.2.3.5 Additional comments

A possible logical sequence of primitives in successful data transfer is shown in Figure 2.

7.2.4 PH_DATA_RATE.request

7.2.4.1 Function

This primitive is the service request primitive to designate the speed (pulse widths for the special function signals) and the data rate for the ISO/IEC 8482:1993 serial link.

7.2.4.2 Semantics of the service primitive

The primitive shall provide the following parameters:

```
PH_DATA_RATE.request (speed  
                      rate  
                      )
```

The speed parameter may assume the possible values of “low” or “high.” The rate parameter may assume values of 2400 Bd, 9600 Bd, or 1 Mb/s.

7.2.4.3 When generated

This primitive is passed from the BCC or DCC physical user entity to the BCC or DCC Physical layer when the physical user entity needs to specify the speed (“low” or “high”) and ISO/IEC 8482:1993 serial data rate (2400 Bd, 9600 Bd, or 1Mb/s) to the Physical layer. For a BCC, this will occur during the data link connection establishment sequence. A DCC’s data rate may not be changed between the time of logical connection establishment and the time of physical disconnect.

NOTE—This primitive is applicable for both BCCs and DCCs.

7.2.4.4 Effects on receipt

The receipt of this primitive by the Physical layer specifies the widths of pulses received and sent on the special function signal lines and specifies the data rate for the ISO/IEC 8482:1993 serial link.

If the speed parameter is “low,” the Physical layer will anticipate receiving and outputting pulse widths of 50 μ s, 100 μ s, and 150 μ s for the sync, INTERRUPT_ACTIVATE, and INTERRUPT_DEACTIVATE pulses, respectively.

If the speed parameter is “high,” the Physical layer will anticipate receiving and outputting pulse widths of 3 μ s, 5 μ s, and 7 μ s for the sync, INTERRUPT_ACTIVATE, and INTERRUPT_DEACTIVATE pulses, respectively.

The rate parameter informs the BCC Physical layer what data rate to transmit and receive over the ISO/IEC 8482:1993 serial link.

NOTE—During initial data link connection establishment, the BCC’s speed parameter will default to “high,” while the BCC’s rate parameter will alternate between 2400 Bd and 9600 Bd. Following connection establishment, the BCC’s

speed and rate parameters shall be consistent (i.e., “low” speed with rate = 2400 Bd or 9600 Bd or “high” speed with rate = 1 Mb/s).

For a DCC, the speed and rate parameters shall always be consistent. In other words, the alternatives are “low” speed with rate = 2400 Bd or 9600 Bd or “high” speed with rate = 1Mb/s. A DCC may change its data rate only prior to logical connection. A DCC shall not change its data rate between the time of logical connection establishment and the time of physical disconnect.

7.2.4.5 Additional comments

A possible logical sequence of primitives associated with data rate designation is shown in Figure 3.

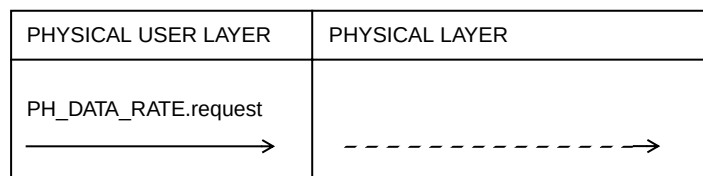


Figure 3—Timing sequence for data rate designation primitive

7.2.5 PH_ACTIVATE.request

7.2.5.1 Function

This primitive is the service request primitive for activation of a BCC port’s or DCC’s transmit circuitry and deactivation of the respective receive circuitry at the local media attachment.

7.2.5.2 Semantics of the service primitive

The primitive shall provide the following parameter:

```
PH_ACTIVATE.request (
    )
```

7.2.5.3 When generated

This primitive is passed from the PhS_user to the Physical layer when the physical user entity wishes to disable the receiver and enable the transmitter for Physical layer protocol data unit (PhPDU) transfer.

7.2.5.4 Effects on receipt

The receipt of this primitive by the Physical layer causes the local physical entity to initiate the establishment of a transmit connection to the physical media. For the low-speed version of the Physical layer, PH_ACTIVATE.request causes the Physical layer entity to initiate transmission of a frame. For the high-speed version of the Physical layer, PH_ACTIVATE.request causes a start delimiter to be transmitted prior to the first Manchester-encoded bit of the first transmitted byte.

7.2.5.5 Additional comments

A possible logical sequence of primitives associated with network connection is shown in Figure 4.