

IEEE Standard for Universal Power Adapter for Mobile Devices

IEEE Computer Society

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Microprocessor Standards Committee

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IEEE Std 1823™-2015

IEEE Standard for Universal Power Adapter for Mobile Devices

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Microprocessor Standards Committee
of the
IEEE Computer Society

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Abstract: A power delivery connection between a power adapter and a power using device greater than 10 W and up to, but less than 240 W, is defined in this standard. A communications link between the power adapter and the mobile power-using device is also defined. The communications may be used to coordinate the power delivery and provide identification between the power adapter and the power-using device. While intended for portable computing and entertainment devices, power adapters conforming to this standard may also be used with other devices (including simple devices, with no communications capabilities, up to 20 W).

Keywords: communications controlled power, IEEE 1823™, low-energy connect and disconnect, mobile power, power delivery, smart power, universal power, Universal Power Adapter for Mobile Devices, UPAMD

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Introduction

This introduction is not part of IEEE Std 1823™-2015, IEEE Standard for Universal Power Adapter for Mobile Devices.

This standard focuses on a generic power adapter designed for reuse across brands, models, and years. A compliant adapter will supply a nominal 21 V at up to 130 W and may negotiate voltages up to 60 V at power levels up to, but less than, 240 W. Each power adapter will have one or more power ports to service load devices with control of each port via a serial communications link, an electrical variant of the CAN bus standard. Input power may be ac or dc depending on the market being served.

A group of laptop, notebook, and other computing device, entertainment, and gaming system manufacturers approached the Microprocessor Standards Committee to define a common connector configuration, a power specification, and a communications protocol for a reusable durable power adapter system. This standard is the result of the foresight of that group.

IEEE Std 1823-2015 defines a power delivery and communication connection between a power adapter and a power-using device greater than 10 W up to, but less than, 240 W range. The communications are used to coordinate the power delivery and provide identification between the power adapter and the power-using device. While primarily intended for portable computing and entertainment devices, this standard applies to adapters serving other mobile devices in use around the office, home, or vehicle. To enable the powering of a wider class of low-cost devices, low-power devices with no communications capabilities are also supported under this standard.

*To Bob Davis, for his leadership, contribution, and dedication
to better the standards and computing practice.*

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1. Overview

Historical design practice for laptops, notebooks, and other computing devices with external power adapters is to design a power adapter for each device. The adapter design is optimized for the device design to be powered but is not generally usable with other devices. The rationale for this standard is to greatly reduce the electronic waste caused by the inability to reuse a power adapter with changing mobile devices.

Adoption of a single standard will encourage better, more efficient, design of each adapter. With a known adapter standard, each portable device design can optimize for the standard. This common adapter can also promote portable power ports being available for public use in hotels and conference centers and other facilities. It can enable travelers to carry a single adapter to power multiple devices.

Most highly portable systems, such as laptops, are being served by more than one power adapter for the convenience of the user. The inability to reuse existing power adapters with new devices leads to disposal of hundreds of millions of working power adapters due to the failure or obsolescence of the device they are intended to supply. This Universal Power Adapter for Multiple Devices (UPAMD) will also help reduce user costs for power adapters.

1.1 Scope

IEEE Std 1823-2015 defines a power delivery connection between a power adapter and a power using device greater than 10 W and up to, but less than 240 W.¹ A communications link between the power adapter and the mobile power-using device is also defined. The communications may be used to coordinate

¹ IEEE Std 1823-2015 is also referred to here as the “UPAMD standard.”

the power delivery and provide identification between the power adapter and the power-using device. While intended for portable computing and entertainment devices, power adapters conforming to this standard may also be used with other devices.

1.2 Purpose

IEEE Std 1823-2015 creates a common interconnect for power delivery greater than 10 W and up to, but less than, 240 W to portable and fixed devices. This standard supports more universal use and reuse of power adapters replacing brand specific and model specific power adapters. The IEEE 1823 adapter system may be usable in portable computing and entertainment systems, security, household, and office equipment within the power range. Universality and reuse are among the primary driving factors. Communications may support the adaption of the powered device performance to the power available.

1.3 Goals for the standard

The following adopted goals were used as a basis for the development of the standard:

- a) Life expectancy for standard of a minimum of *10 years*, hopefully much more
- b) Same connector for *all* device and adapter connections
- c) Power range *10 W < UPAMD < 240 W* delivered to device; is brand, model, and year agnostic
- d) First adapter shall work with last device designed and last adapter with first device designed. Standard compatibility.
- e) Adapter ↔ mobile device communications required for higher power safety
- f) Continuous communications growth to support growth of UPAMD capability
- g) Shall support devices with, and without, internal battery power.
 - 1) Basic power delivery mechanism—external power supply (EPS)
 - 2) Make independent of rapidly changing technology
- h) Standard designed to support *certification* testing of adapter and device
- i) Connector design to consider future mobile device design options
 - 1) Smaller profiles, headed for *10 mm to 5 mm*? Different shape devices, non-edge usage.
- j) No significant power without communications
 - 1) Maximum energy at cable connect and disconnect < 15 uJ
 - 2) Maximum exposed power on unconnected power source connector is <100 uW
 - 3) Maximum mute device power, connection detection only, is 20 W
- k) Any device may be capable of being a source or sink of power, or both.
- l) Able to share power for mission critical or business critical applications
- m) Connector shall not mate with any current designs—product safety issue—no confusion
- n) Environmentally friendly to eventual disposal

These goals and the rationale behind them are explained in Annex B.

1.4 Basic operation

A universal power supply compliant with this specification may be as simple as an ac-in, dc-out one-port adapter or as complex as a multi-port hub with each port capable of being either a power source or sink. In order to make this possible, messaging between source and sink devices are defined in this standard.

When initially detected and connected, a smart device receives a nominal 12 V with a maximum current of 25 mA to provide sufficient power to enable communication while maintaining a very low stored energy profile. Once mute devices are detected, a limited power may be supplied at a level of 20 W or below based on the passively detected power request. Communication uses Bosch/ISO CAN Specification Version 2.0B (the CAN 2.0 standard) for messaging.² All messages use the Extended Format with the 29-bit identifier as specified in the CAN standard.

Through a comprehensive set of messages the standard enables both simple power adapters and sophisticated hubs with power sinks negotiating for priority of power provision. Messages also support a reversing of roles. A notebook PC, for example, may use the same port to be charged, or to charge another device from the PC battery. Thus a truly universal power supply/provision matrix can be established.

In addition to defining the negotiation process for a device receiving power, the standard includes mechanical and electrical specifications so that users can use standard cables with any UPAMD-compliant device and expect everything to plug and play.

Clauses in this standard define the CAN 2.0 extended format messages in detail, the negotiation logic flow, and the mechanical and electrical aspects of the specification. The CAN physical layer for UPAMD uses 3.3 V signaling protocols. For this version of the standard the signaling speed is set to 1.0 Mb/s, thus providing room for future requirements and allowing for the possibility of higher communications speeds in future versions.

1.4.1 UPAMD communications

All power control, identity, and inter-device communications in the UPAMD system use the CAN bus. Header information in the CAN bus protocol defines the Logical Channel, Application Priority, Request Priority, and Sender Class information for the originator of the message. Header information is described in Clause 6.

Communications are point to point, with the exception of a test node. Maximum signaling distance is expected to be 10 m.

Three forms of communications are used to connect a Source of power, (adapter) to a Sink (load). These include a basic load detection mechanism, a power control communications format using the CAN bus protocol and an extended inter-device messaging system using the Data Channel protocols through the CAN bus.

The lowest level is the basic termination load applied to the center tap of the communications line signal termination resistors. This form is used to detect the presence of a load and the determination if the load is a smart—communicating—load, or a mute load with limited power options.

Power control messages use normal message channel to transfer RPMs, Available Power messages, and Device Identification messages. This set of messages governs the power delivery for the system. Without the capability to send and receive these messages, the power delivery is restricted to 20 W or less using the Mute device protocols.

² Information on references can be found in Clause 2.

Data Channel messages are used for system management, such as system configuration, extended messaging between system components, higher level message traffic, and power optimization and control. Enhanced system management, multi-device power flow, and system power optimization are available through this messaging system.

1.4.1.1 Basic device detection and signaling

No action is started until a device is detected upon being attached to a port. The UPAMD cable, specified in Clause 11, contains the power delivery pins and the CAN bus signaling pins. Detection occurs when the CAN signaling pins are terminated in their characteristic impedance of $120\ \Omega$, with a resistive load from the center tap of the termination to the Negative power rail. Attached device type is determined by the voltage at the center tap of the common-mode node.

Common-mode voltages of approximately one-half of the probe voltage indicate that the attached device is a smart device and communications is initiated. Lower voltages signal a mute device with no communication capability, which is then supplied with up to 20 W of power at 21 V. The exact value of the common-mode voltage is used to further restrict the amount of power delivered to the mute device. Clause 12 describes this operation in detail.

At any time the common-mode voltage exceed power delivery values, the power delivery shall cease within about 2 ms to remove the energy in the power delivery pins, to below the 15 uJ level, prior to pin separation. Refer to Annex A and Clause 12 for details of this operation.

1.4.1.2 Normal channel power operation messaging

Power control and Identity messaging is transmitted over the normal logical channel of the CAN bus.

Basic power control information is transferred using the following messages:

- Initialization message
- Available Power Message
- Requested Power Message (RPM)

Power flow is controlled through the use of these messages; they define the capabilities of the source and the requirements of the sink. Negotiations for power delivery are through these messages and the priorities contained in the message header.

For a single-port power adapter, these messages simply set up the power delivery up to the limit of the power available in the source adapter. In multi-port adapter devices and hubs, more complex power delivery is possible to optimize the overall operation of the system of devices. Operation of the power control messages is defined in 7.3.

Identity messages convey device dependent information for identification, certification and security purposes. These messages include:

- Device Certification Reference Number
- EUI-64—Extended Unique Identifier 64 bits in length from a block assigned by the IEEE Registration Authority—Vendor Identification message—Vendor name
- Model Identification (MID) message—device model

- Device Serial Number (SER) message
- Date of Manufacturer (DOM) message
- Software Version message
- Firmware Version message

Identification of the attached devices supports configuration identification, diagnostic support, certification tracking, and updating of the software and firmware for the device. This information is used in configuration analysis and compatibility testing. Each device is uniquely identified through the EUI-64 identifier.

1.4.1.3 Data channel system messaging

Data channel messaging supports discovery of all devices attached to a system of UPAMD devices. This channel enables a logical mesh network of the connected devices and supports the retrieval of the configuration of these devices. Creation of the State Table for each device enumerates the attached devices and builds the communication to allow more effective power control over the entire power system. This supports system monitoring to:

- Determine the version of the UPAMD standard being used by each device.
- Determine if this is a tested, certified, legitimate, product.
- Determine the location of stored power and monitor its state.
- For high availability devices, determine that the multiple sources are truly independent.
- Create a map of all devices and the interconnect paths between them, and power level of those paths.
- Find loops, and other misconnections, in the system connections and warn user.
- Find and determine priority of mute devices.
- Maintain a profile on power usage by device.
- Other uses to be developed by users.

Maximum data packet size on the CAN 2.0 bus is 8 bytes. Data channel messaging supports longer message sizes up to 64 K bytes in length between devices using the wormhole message source routing scheme identified in the discovery phase of the data channel operations. This channel supports sending IPv6 messages among the component devices. A connected device that is also connected with the Internet could then forward these messages as needed.

The discovery process builds the State Table for each device. This information is needed to support the monitoring of the system. It also identifies where power is stored and would support power routing if the appropriate bi-directional ports are available. Expected future use not covered by this version of the standard (partially due to security concerns) could include the following:

- Reconfigure power flow when needed over power source availability changes
- Enable slaved power operation based on a primary device, both on and off
- Supervise the recharging of power storage devices by rerouting power if appropriate
- Report power system status to local and possible remote users
- Lights-out system management

Data channel operations are fully described in Clause 8.

1.5 Priorities

Communications priority is enforced by the Logical Channel being used and CAN 2.0 design choices. Priority Channel has the highest priority followed by the Normal Channel and the Data Channel. This message priority system places power control operations at a high priority, avoiding these from being blocked by normal messages or lengthy data channel message traffic.

Device priorities within the UPAMD system are determined by three priority indicators and the state of the device. Transferred on each power request and power available message are the Application Priority and the Request Priority of the sending device. The tie-breaking priority in a multi-port device is the port number with the lowest port number winning the arbitration if the other priorities are at the same level.

Application Priority is a 2-bit field defining Low, Routine, Priority, and Critical conditions. Normal operations are expected to be in the Routine category. Elevation to Priority or Critical would be based on operation with mission or business critical devices to meet the specific needs of such usage. If simply an idle background operation, the device can downgrade its priority to low to allow other device on the multi-port adapter to have power diverted to their use ahead of its own needs, should there be insufficient available power for all connected devices. Application Priority forms the two MSBs of the 5-bit combined priority field sent on every message header.

Request Priority has a default setting in the middle of the 3-bit, 8-level range. The sink device can elevate its current request as needed to show a change in its status, such as more power being needed to meet a higher processing power requirement, or lower it to allow power to be diverted when its current needs are satisfied. Request Priority forms the three least significant bits in the 5-bit combined priority field sent on each message in every message header.

Application Priority and Request Priority are set by the device and can be identical in value. A port number is assigned to each port with a range of 1 to 255; the device itself is addressed as Port 0. The lower port number has the higher priority and port numbering is the deciding factor with all other factors being equal. This again allows the user to influence the priority for a device by connecting the device to a specific port.

Power priorities, in multi-port adapters, are determined by both the power source and attached sinks. The source can determine the condition of the sinks devices attached to it through the status information. It will allocate power among the devices based on the indicated priorities and the indicated minimum power requirements and locally stored energy. Vendor energy distribution strategies should take all available information into account to best serve the overall system needs.

1.6 Connector and cables

Cables may be attached to the source or sink or be fully detachable. Each unattached cable shall have identical connectors on its ends. It is expected that cables will be available from many vendors in lengths from 0.5 m to possibly 10 m long. Each cable has four conductors: two power conductors and two signaling conductors for the CAN bus. Power conductors are restricted to having a total resistance from connector contact to connector contact of 50 m Ω . CAN bus signal lines are a twisted pair with characteristic impedance of 120 Ω . Different construction techniques have been proposed for the cable. Details of the cable are specified in Clause 11.

All connectors in the system are identical. The device connector is specified as a low-profile connector surface that can be mounted flush into a device containing the contact pads for the power and signal lines and a retention latch element. The connector is orientation-independent to support easy connection. Two

latching retention settings are specified: one for low-retention mode to allow the contact to be broken with less force to prevent tripping someone with the cable and another high-retention position that is specific to assure firm mounting for high acceleration environments and for locations not easily accessible. Spring pin contacts are rated for very long service life under very high connect and disconnect cycles. Clause 10 details the connector specifications.

1.7 Conformance levels

Several keywords are used in this standard to differentiate between different levels of requirements and optionally, as follows:

shall: Indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (“shall” means “is required to”).

should: Indicates that among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain course of action is deprecated but not prohibited (“should” means “is recommended to”).

may: Indicates a course of action permissible within the limits of the standard with no implied preference (“may” means “is permitted to”).

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

Bosch/ISO CAN Specification Version 2.0B.³

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁴

Application Priority: A 2-bit application priority for the current message in Controller Area Network (CAN) Header. Universal Power Adapter for Mobile Devices (UPAMD) resolves competition for available power using several inputs, Application Priority being one input.

architecture: The organizational structure of a system or component, their relationships, and the principles and guidelines governing their design and evolution over time.

³ Available at http://www.bosch-semiconductors.de/media/pdf_1/canliteratur/can2spec.pdf.

⁴ *IEEE Standards Dictionary Online* subscription is available at:
http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.

Bidirectional Port (or Device): A port on a device capable of acting as a *sink* or a *source* of power; or a device with such port.

bit rate (BR): Number of bits per time during transmission, independent of bit representation.

bit stuffing: Filling using bits to provide bus state changes required for periodic resynchronization when using a non-return-to-zero (NRZ) bit representation.

NOTE—Whenever the transmitting logic encounters a certain number (stuff width) of consecutive bits of equal value in the data, it automatically stuffs a bit of complementary value—a *stuff bit*—into the outgoing bit stream. Receivers destuff the frame, i.e., the inverse procedure is carried out.⁵

bit time: Duration of one bit.

bus: Topology of a communication network where all nodes are reached by passive links that allow transmission in both directions.

bus comparator: Device converting physical signals used for transfer across the communication medium back into logical information or data signals.

bus driver: Device converting information or data signals into physical signals so that these signals can be transferred across the communication medium.

bus failure: Failures caused by a malfunction of the physical bus such as interruption or short circuits.

bus state: One of two complementary logical states: dominant or recessive.

NOTE—The dominant state represents the logical 0, and the recessive state represents the logical 1. During simultaneous transmission of dominant and recessive bits, the resulting bus state is dominant. When no transmission is in progress, the bus is idle. During that time it is in the recessive state.

bus voltage: Voltage of the bus line wires CAN_L and CAN_H relative to ground of each individual Controller Area Network (CAN) bus node.

NOTE— $VCAN_L$ and $VCAN_H$ denote the *bus voltage*.

CAN Bus: The power communications system for Universal Power Adapter for Mobile Devices (UPAMD) based on Bosch/ISO CAN Specification Version 2.0B.

CAN Header: Twenty-nine data bits sent at the beginning of every Bosch/ISO CAN 2.0B message.

common-mode bus voltage range: Boundary voltage levels of $VCAN_L$ and $VCAN_H$, for which proper operation is expected if up to the maximum number of CAN nodes are connected to the bus.

contention-based arbitration: Arbitration procedure where simultaneous access of multiple nodes results in a contention.

Controller Area Network (CAN): Denotes the Bosch/ISO CAN Specification Version 2.0B.

data flow: Application-level communications from a producer of data to a consumer of the data.

data link: A physical communication connection (wire, fiber, wireless, etc.) from a source to a destination.

Device Classes: A set of bits defining the class characteristics of the sending device.

⁵ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

differential voltage (of CAN bus) (V_{diff}): Differential voltage of the two-wire CAN bus:
 $V_{\text{diff}} = V_{\text{CAN}_H} - V_{\text{CAN}_L}$.

EUI-64: Extended Unique Identifier (EUI) 64-bits in length from a block assigned by the IEEE Registration Authority.

external power supply (EPS): Power supply external to the unit being powered.

fault-free communication: Mode of operation without loss of information.

frame: Data-link bit-stream structure specifying the arrangement and meaning of bits or bit fields in the sequence of transfer across the transmission medium.

information transfer time: The interval beginning when the information is issued from the source application and ending when the information has been completely delivered to the receiving application (i.e., first byte sent by source application to last byte received by destination application).

interoperability: The capability of two or more networks, systems, devices, applications, or components to externally exchange and readily use information securely and effectively or for a device to operate as an equivalent substitute for some other device.

latency: Channel access delay plus the propagation delay (first byte transmitted on the medium to first byte received at the destination).

Logical Channels: The four logical channels for messages in the Universal Power Adapter for Mobile Devices (UPAMD) protocol.

low-energy connection: Stored energy in the interface and cable maintain a value below 15 μJ as the connection is made.

low-energy disconnection: Stored energy in the interface and cable maintain a value below 15 μJ as the connection is disconnected.

Microprocessor Standards Committee: IEEE Computer Society Standards Committee.

Mute device or Mute sink: A device connected to a Universal Power Adapter for Mobile Devices (UPAMD) source that does not have CAN communications capability. A Mute device can only be a sink of power.

Node: Assembly, connected to the communication line, capable of communicating across the network according to the given communication protocol specification.

non-return-to-zero (NRZ): Method of representing binary signals, i.e., within one and the same bit time the signal level does not change, where a stream of bits having the same logical value provides no edges.

physical layer: Electrical circuit realization (bus comparator and bus driver) that connects a CAN node to a bus, consisting of analog circuitry and digital circuitry, interfacing between the analog signals on the CAN bus and the digital signals inside the CAN node.

physical medium (of the bus): Pair of parallel wires, shielded or unshielded, dependent on electromagnetic compatibility (EMC) requirements.

NOTE—The individual wires are designated as CAN_L and CAN_H . The names of the corresponding pins of CAN nodes are also denoted by CAN_L and CAN_H , respectively. In dominant state, CAN_L has a lower voltage level than in recessive state and CAN_H has a higher voltage level than in recessive state.

Port Priority: Lowest level priority mechanism. Lower port numbers have priority over higher port numbers.

Power Available Message interval: Maximum time between Power Available messages.

Power Available Message timeout: Maximum time for Power Available Message response.

receiver: Device that transforms physical signals used for the transmission back into logical information or data signals. Node is either a receiver or transmitter when bus is not idle.

Request Priority: A 3-bit priority field that can change on each request.

Requested Power Message timeout: Maximum time for Requested Power Message (RPM) to response.

Requested Power timeout interval: Maximum time between Requested Power Messages (RPMs).

Sink Dominant Bidirectional ports: Port that normally acts as a sink but can change to a source when needed. An example would be a mission critical device that normally receives power but in mission critical application it can also become a source of power.

Sink Initialization Message timeout interval: Time allowed for Sink to respond with *Sink Initialization Message*.

Smart: As applied to sinks or sources, denotes a device that has built-in resources that allow it to communicate and react to interface conditions. It mostly implies that the device contains a microcontroller attached to the Universal Power Adapter for Mobile Devices (UPAMD) interface.

Smart Sink/Smart Source: Denotes a device that sinks or sources power, and that has built-in resources that allow it to communicate and react to interface conditions. It mostly implies that the device contains a microcontroller attached to the Universal Power Adapter for Mobile Devices (UPAMD) interface.

Sockets: Message groups allocated to different communications functions.

Source Dominant Bidirectional Ports: Ports that normally act as a source of power but can change to a power sink when needed. An example of this would be a power port supplying a storage device with power (*not* charging the device) that can reverse the power flow and take the power from the power storage device to feed the other power ports on the hub.

Source Initialization Message Timeout interval: Time allowed for Source to respond with *Source Initialization Message*.

transmitter: Device that transforms logical information or data signals to electrical signals so that these signals can be transmitted via the physical medium.

Universal Power Adapter for Mobile Devices (UPAMD) Port: A connection point in the UPAMD system device.

XX_h: A subscript “h” following a number denotes that that number is expressed in hexadecimal.

3.2 Acronyms and abbreviations

ac	alternating current
ACK	acknowledgement

AP	Allocated Power
AV	Allocated Voltage
AWH	Available watthours
BCD	Binary-coded decimal data format
BR	bit rate
CAN	controller area network, Bosch/ISO CAN Specification Version 2.0B
CAN _x	One of the two differential CAN communications wires (will become CAN _H or CAN _L)
CAN _y	The other wire in the CAN communications differential pair (can be CAN _L or CAN _H)
CAP	Current Available Power
CDC	Current Device Class
CPR	Current Power Request
CRC	cyclic redundancy check
CRGS	Local Storage Charge State
CRP	Current Requested Power
CS	Current Source Status
CVR	Current Voltage Request
dc	direct current
DLL	data link layer
DOM	Date of Manufacture
DPP	Device Power Priority
DTM	Data Transfer message
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EOF	end of frame
ESD	electrostatic discharge
EUI	Extended Unique Identifier (for the purposes of this standard, refers to EUI-64)
EUI-64	64-bit Extended Unique Identifier
FVM	Firmware Version Number
GUI	graphical user interface
IC	integrated circuit
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
LOA	Letter of Assurance
LPN	Local Port Number
LSB	least significant bit
MAP	Maximum Available Power from this port 0 to <240 W
MAV	Maximum Available Voltage

MDP	Maximum Device Power
MID	Model Identification
MP	Maximum Power device will ever request
MPR	Maximum Power Request
MPV	Maximum Port Voltage
MRP	Minimum Required Power
MRV	Minimum Required Voltage
MSB	most significant bit
MSG	Data Transfer message (DTM) descriptor
MSP	Maximum Storable Power
MWH	Maximum Stored Watthours
NIST	U.S. National Institute of Standards and Technology
NRZ	Non-Return-to-Zero
NTP	Network Time Protocol
NV	Nominal Voltage 21 V out 20V in
OUI	Organizationally Unique Identifier
RF	radio frequency
RPM	Requested Power Message
SAW	Stored Available watthours
SCA	Stored Capacity Available
SDO	Standards Developing Organization
SER	Serial Number
SOF	start of frame
SVN	Software Version Number
UPAMD	Universal Power Adapter for Mobile Devices
VID	Vendor Identification
VR	Voltage Request

4. Architecture

UPAMD architecture consists of a set of UPAMD ports connected with UPAMD cables. The ports may be sources of power or sinks of power, or capable of being either a source or sink of power. Cables between devices may be detachable or permanently attached to a device. Figure 1 shows some of the potential topologies available to the UPAMD architecture.

Devices may have one or more ports; each port may be an input, output, or bidirectional—capable of changing function, for power flow. Normally, at least one port attaches to nominal ac or dc power source using a connector appropriate to that power source.

All smart devices shall communicate via a version of the CAN bus protocol. Mute (passive) devices shall provide a termination for the CAN bus only and will be restricted in power available.

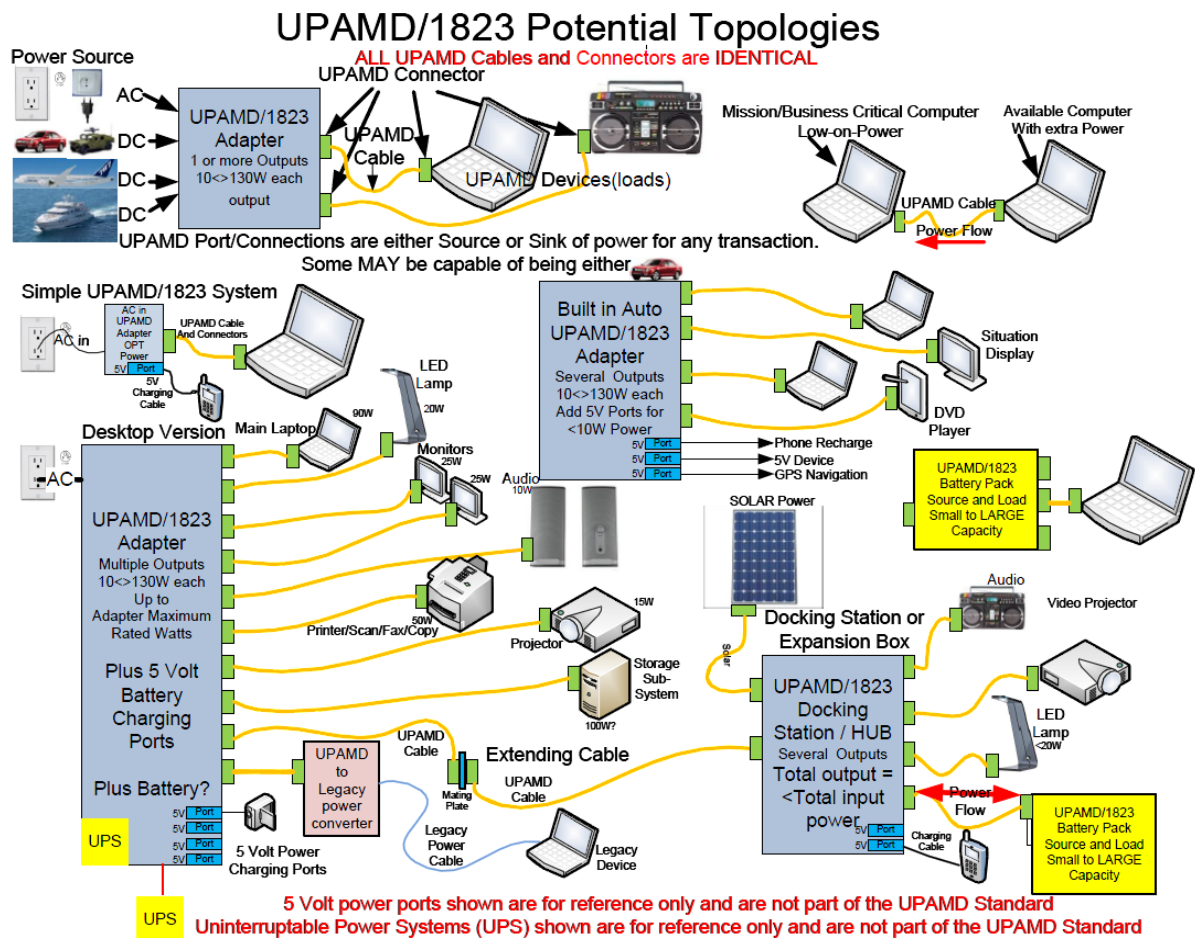


Figure 1—UPAMD potential topologies

4.1 Communications

Power shall only be delivered when communications are established between a source port and a sink port. Communications take place on two levels, first is the physical connection between the source port and the sink port through the UPAMD cable and the termination of the CAN signaling lines and secondly through the messages sent between the source and the sink over the CAN bus.

Connectivity through the cable assumes that one end is connected to a source port or a bidirectional device that will assume the role of a source or a sink port. Probing from the source port determines the type of sink attached, smart or mute, and if mute, what power is expected to be delivered. A mute device does not have the capability to send messages on the CAN bus.

Once powered and initialized, smart sinks will start sending an Initiation Message and continue with power negotiations as needed.

Extended communications on the data channel will allow exploration of any larger configuration attached to the devices using the established link. For the minimum UPAMD power system, consisting of one source and one sink, this first link will be the only link established.

Secure communication through the data channel is enabled for devices that choose to enable the ability to exchange a public key encryption capability. This is optional for this version of the standard.

4.2 UPAMD ports

A port is a connection point in a UPAMD system. A port may be a source of power or a sink of power. In the case of bidirectional devices the port may switch function from sink to source or from source to sink based on the priority of the ports and the negotiations between the ports.

All ports from adapters shall be enumerated. This enumeration forms the final arbitration element if all other priority items are identical. Within a multi-port adapter, and all other factors being equal, the lowest numbered port has the priority.

Each port shall be logically identified by a bit pattern consisting of the EUI-64:PortNumber pair.

Each communicating device shall be logically identified by the EUI-64 assigned identifier and as port 00_h.

Each port on an adapter shall be labeled, adjacent to the port, with the maximum power (MP) capability, input and output, of that port. Each label shall be preceded with an “O” for output or an “I” for input. Each port will be designed to handle the specified power values. Example, a port capable of 120 W output power shall have an O-120 text permanently displayed next to that port connector or cable. Input ports shall have a number representing the maximum input power labeled next to the port, preceded by an “I” for input. Example input port label “I-65” indicates a port with 65 W input capability. Watts are the assumed measurement increment.

Each bidirectional port on an adapter shall have a label next to the physical connector indicating both the input and output capabilities. Labels shall list the inputs and output power for each port such as “O-240/I-120.” Bidirectional ports that have symmetrical capabilities may label the ports with IO leading characters such as “IO-150.”

4.3 CAN 2.0B 29b ID frame

The base of data communications in this standard, IEEE Std 1823-2015, is the Bosch/ISO CAN Specification Version 2.0B. CAN bus was chosen because of its ubiquitous usage, reliability, and inexpensive implementation in modern embedded microprocessors. This standard allows for different physical layers as long as recessive and dominant symbols can be represented; where a dominant symbol overrides any recessive symbols in the communications line. Given the dominant/recessive definition at the wire level, CAN has a built-in message prioritization that is carried on to the implementation of CAN hardware itself. A header with a dominant bit (0) on an early position will win arbitration over a header with a recessive bit (1) in that position. This means that packets with lower-numbered headers will be sent before packets with higher-numbered headers.

The CAN 2.0B data packet consists of a 29-bit header followed with up to 8 bytes of data payload and a 15-bit cyclic redundancy check (CRC). Given its use of non-return-to-zero (NRZ) coding with bit stuffing and recessive symbols, CAN is able to notify the sender of a transmission error at the end of the packet via error or overload frames (violations of the bit stuffing definition). Although the Bosch/ISO CAN 2.0B standard allows for multiple devices in a CAN bus, IEEE Std 1823-2015 uses it as a point-to-point communications standard.

4.4 Interconnect configuration

Interconnections within a UPAMD configuration can be simple or complex. This subclause covers the exploration of the extended interconnects to resolve the actual data and power flow. The following is an example of a connectivity diagram, which serves to highlight the possible variety of connections in a complex UPAMD system. Even a simple, single-port power adapter may be connected to a power expander serving multiple loads.

The connectivity diagram shown in Figure 2 was created to show a complex system for the purpose of developing the details needed in the message routing and State Table generation. Using this diagram, the State Table for the system is shown in Figure 3. For this example, sequential EUI-64 values were assigned to the devices in the diagram.

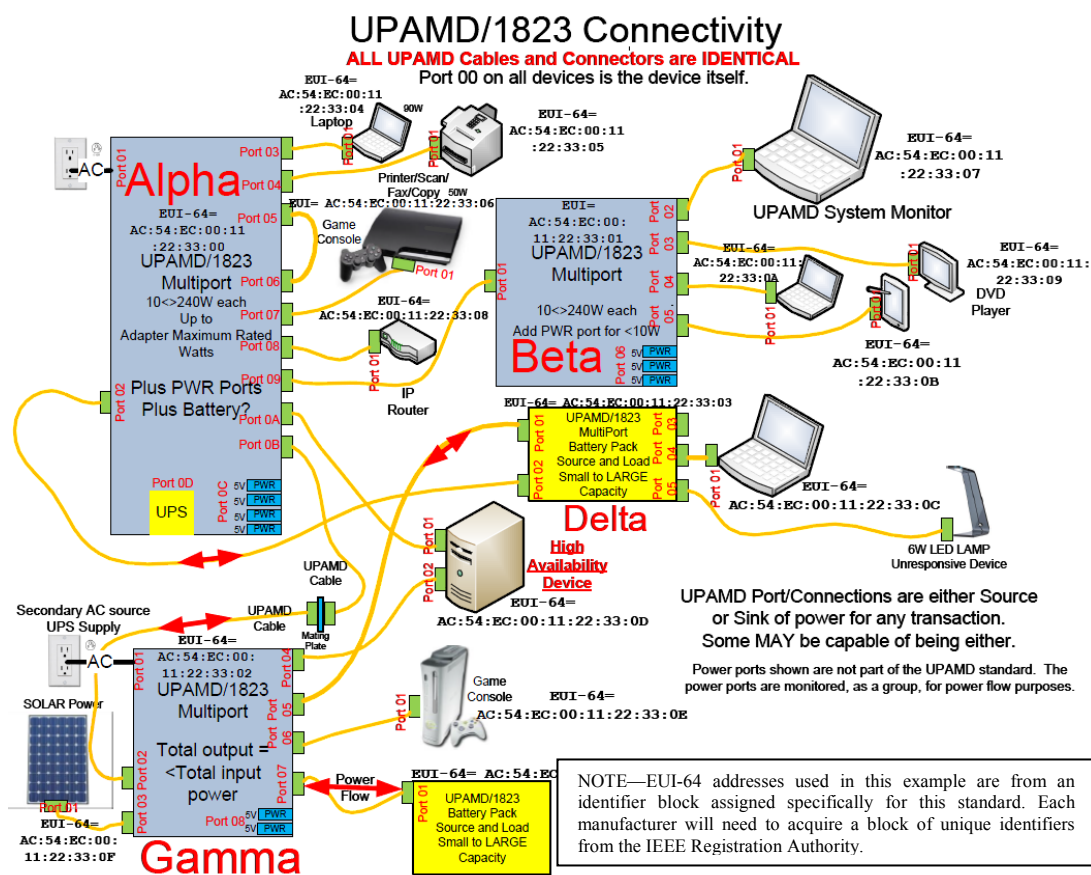


Figure 2—Connectivity example for extended illustrative system

There can be multiple purposes for the gathering of device connectivity data and pathways along with the device State Table information for each of the devices. Use of this connectivity and state information can range from the cursory gathering of basic information, to the enabling of supervision by one or more monitoring devices, to:

- Determine the version of IEEE Std 1823 (UPAMD version) being used by each device.
- Determine the manufacturer's information about the product.
- Determine the location of stored power and monitor its state.

- d) For high availability devices, determine that the multiple sources are independent.
- e) Create a map of all devices and the interconnect paths between them, and power level of those paths.
- f) Find loops and other misconnections, in the system connections and warn user
- g) Find and determine priority of non-communicative devices.
- h) Maintain a profile on power usage by device.
- i) Other uses to be developed by users.
- j) Control functions, not covered by this version of IEEE Std 1823
 - 1) Reconfigure power flow when needed over power source availability changes.
 - 2) Enable slaved power operation based on a primary device, both on and off.
 - 3) Supervise the recharging of power storage devices by rerouting power if appropriate.
 - 4) Report power system status to local and possible remote user. Lights-out maintenance system management.

4.4.1 Device state table definition

The state table of a device serves to represent all the relevant information that this device has about its directly connected neighbors as well as itself. The State Table for a device shall enumerate all connected devices and the path to those devices. All of the information is collected in the course of operations via direct messages to the attached devices as well as the information contained in header messages. The entirety of a device's state table can be requested via a data register request (see Clause 8).

Each device state table contains a list of entries for each connected device, arranged in rows, ordered by port number. Port numbers are in the range of 0 to 255 and reported as a hexadecimal byte. Port 00_h is the device itself and contains information on the basic device such as its EUI-64, certification number, and UPAMD version (which version of IEEE Std 1823) the device is supporting. All other ports are listed on subsequent rows starting with the port number.

An example state table for a large, intentionally complex, hypothetical system is Figure 2. Each node was given a name Alpha, Beta, Gamma, etc., for ease of discussion. Each device was also given a sequential EUI-64 identifier for use in the example. These EUI-64 identifiers are taken from a unique identifier block assigned to this standards project. Each vendor will need to obtain a unique identifier assignment for their organization from the IEEE Registration Authority. This block of unique identifiers is then used to assign a globally unique EUI-64 identifier to each UPAMD device. This unique identifier is then used to assign the globally unique EUI-64 identifiers to each UPAMD device. See the IEEE Registration Authority website.⁶

State Table entries message:

⁶ Available at <http://standards.ieee.org/develop/regauth/oui/index.html>.

Address+0 00 01 02 03 04 05 06 07	Address+1 08 09 10 11 12 13 14 15				Address+2 16 17 18 19 20 21 22 23				Address+3 24 25 26 27 28 29 30 31				Address+4 32 33 34 35 36 37 38 39				Address+5 40 41 42 43 44 45 46 47				Address+6 48 49 50 51 52 53 54 55				Address+7 56 57 58 59 60 61 62 63				
Port Num(7:0)		EUI-64(64:8)																											
EUI-64(7:0)		Attached Port Number(7:0)				L Sink L Redefine L Bidirect L Cont Pwr L Inter Pwr Reserved L Multiport L SecureCap	R Sink R Redefine R Bidirect R Cont Pwr R Inter Pwr Reserved R Multiport R SecureCap	Local APP Pri		Local REQ Pri		Remote APP Pri		Remote REQ Pri		Stored Maximum Capacity (15:0)													
Percentage Full (7:0)		UPAMD VER		UPAMD REV		MAX OUTPUT Watts(7:0)				MAX OUTPUT Volts (7:0)				MIN INPUT Power(7:0)				Maximum INPUT Power(7:0)				Maximum INPUT Voltage (7:0)				Current Voltage (7:0)			
Current POWER (15:0)						STATUS (7:0)				RESERVED (7:0)				CERTIFICATION Number (63:32)															
CERTIFICATION Number (31:0)																													

Figure 3—State Table row entry, as transmitted

a) Device port number—1 byte

With the exception of the first row of the State Table, the first entry in each row is the port number to which the device is connected. Each device shall have at least one port making the minimum State Table a two row table.

The first row of the State Table is for the device itself with the first byte specifying the version number of the state table format with the major and minor number stored in this byte. For State Table version 1.0 this shall be stored as a high nibble of 1_h and low nibble as 0_h. Version number information, instead of port 00_h shall be the first byte in the first row as this special row in the table is assumed to refer to port 00_h, the device itself.

b) EUI-64—8 bytes

This is the globally unique identifier for the device. This 64-bit number is also used as the lower 8 bytes of the IPv6 address for the device. Each manufacturer will assign a globally unique EUI-64 identifier from a unique identifier block obtained from the IEEE Registration Authority.⁷ For port 00, it is the EUI-64 of this device. For all other port entries it is either all 0's for no attached device or the 64-bit EUI-64 of the device attached to that port. If two ports on a multiport adapter are connected together, the EUI-64 reported on each of those ports would be the EUI of the device itself, indicating the connection to self.

The EUI-64 for this device is stored internally in the EUI register. The EUI-64 for the attached device is read via the EUI request message detailed in Extended Unique Identifier (EUI) message.

c) Attached port number—1 byte

This port number is the port number on the attached device to which this local device is connected. For the first entry, the attached port number is 00 as it is the device itself. For all other ports entries this is the port on the attached device. For example, a laptop with one input power port, port 01, could be attached to port 05 on a power adapter. For the same configuration, port 05 on the power adapter would report that it is connected to port 01 on a device. If there is no attachment to this port the value 0 (0_h) will be reported.

The attached port number is obtained for devices acting as sources, through the port number in the Initialization Message. For devices acting as sink devices, the port number on the source is located in the Available Power Message.

⁷ See <http://standards.ieee.org/develop/regauth/oui/> for information on obtaining a unique identifier.

d) Local port status—1 byte

Each entry in the table will record both the device status of this port and the attached device, if any. Device status is condensed into 1 byte. The following are the bit definitions, extracted from the messages between the different devices or, if not connected, from the local device capabilities.

- 1) Bit 0—Is local port serving as a sink?—1 for yes, 0 for source or none.
- 2) Bit 1—Is this base status *or* redefined bits?—1 for base, 0 for redefined.
- 3) Bit 2—Is port capable of bidirectional operation?—1 for yes, 0 for not capable.
- 4) Bit 3—Is this device capable of continuous power?—1 for yes, 0 for intermittent power source.
- 5) Bit 4—Is there internal stored power in device?—1 for yes, 0 for no stored power.
- 6) Bit 5—Reserved for future use—undefined, set to 0.
- 7) Bit 6—Is this a multiport device?—1 for yes, 0 for no.
- 8) Bit 7—Are secure communications available?—1 for yes, 0 for no.

Bit 1 is a switch to allow the redefinition of the later bits in a future version of this standard.

Bit 7 indicates the device has encryption capabilities.

e) Connected port status—1 byte

Each entry in the table will record the device status of the attached device, if any. The device status is condensed into 1 byte. The following are the bit definitions, extracted from the messages between the different devices or, if not connected, set to FF_h.

- 1) Bit 0—Is connected device serving as a sink?—1 for yes, 0 for source or none.
- 2) Bit 1—Is this base status *or* redefined bits?—1 for base, 0 for redefined.
- 3) Bit 2—Is port capable of bidirectional operation?—1 for yes, 0 for not capable.
- 4) Bit 3—Is this device capable of continuous power?—1 for yes, 0 for intermittent power source
- 5) Bit 4—Is there internal stored power in device?—1 for yes, 0 for no stored power.
- 6) Bit 5—Reserved for future use—undefined. Set to 0 for this version 1.0 of the standard.
- 7) Bit 6—Is this a multiport device?—1 for yes, 0 for no.
- 8) Bit 7—Are Secure Communications available?—1 for yes, 0 for no.

Connected port status is obtained from the header information in the CAN header for bits 0 through 6. Bit 7, secure communication capability is captured from the initializing message indicating that the device has the capability of encrypted communications with the ability to handle public key encryption, 7.5.

f) Local priority application and request—1 byte

Local device priority is stored in two nibbles. The upper nibble is the 4-level application priority and the lower nibble is the 3-bit request priority. Application priority upper two bits of the 4-bit field shall be set to 0. If the application priority was normal, level 2, and the request priority was at level 4, the field would be 24_h. If there is no established priority the priority is stored as FF_h, an illegal value for the byte.

This information is gathered from the internal source that generates the outgoing CAN header.

g) Connected priority application and request—1 byte

Connected device priority is stored as two nibbles. The upper nibble is the 4 level application priority and the lower nibble is the 3-bit request priority stored in a 4-bit field. The upper two bits of the Application priority field and the most significant bit (MSB) of the Request priority field shall be set to 0_h. If the application priority was normal, level 2, and the request priority was at level 4, the field would be 24_h. If there is no established priority the priority is stored as FF_h, an illegal value for the byte.

Connected priority application and request priority is collected from the incoming CAN Header from that device.

h) Stored power capacity watthours (Wh) 0 to 65536—2 bytes

Device stored power capacity under fully charged conditions in watthours. This does not define the method of storage, only the maximum potential stored power. For the port 00 line this is the stored power capacity in this device. For all other port lines this is the MP storage capacity in the attached device. Power in the range of 0 to 65535 Wh is stored. If there is no stored power this is set to 0000_h. For bidirectional power ports, this stored energy may be made available if needed to satisfy power demand.

Stored power for this device is read from internal conditions and reported on the first line of the State Table for this device as a total maximum capacity and the percentage of that capacity that is available. For example, if a device held 27% charge of a 2000 Wh maximum capacity, then 2000 Wh would be stored in this field and 27% would be stored in the following field, Percent Stored Power. All other lines report the stored power in the attached device as its total capacity times the percent of the current state of charge. This information is collected from the Requested Power Message (RPM) if the attached device is a sink and from the Power Available Message if the attached device is a source.

i) Percent stored power (percent/0.4)—1 byte

This field is used in conjunction with the Stored Power Capacity field to determine available power. This is reported as the percentage of (power stored/ total capacity) divided by 0.4 (multiplied by 2.5) to produce a number between 0 and 250. Ten percent capacity would be represented as 25 decimal or 19_h.

This information will be gathered from an attached sink via a Power Request message through the Fill State 3-bit field in increments of 12.5%. For sources, the information will be gathered from the PercentFull byte in the Power Available Message (in increments of 0.4%).

j) UPAMD Version—1 byte

Specifies which version of UPAMD is being used in the local device and the attached devices. This information is needed to understand messages received and to create messages that will be understood by the attached device. The port 00 line reports the UPAMD version of this device, with the upper nibble representing the major version of the standard and the lower nibble reporting the revision or level of the implementation. For each physical port, the attached device's UPAMD version is reported. This will facilitate communications at the proper level. For devices supporting this version of the standard a major version 1, revision level 0 shall be reported, i.e., the field shall be set to 10_h.

The remote UPAMD version and revision information is communicated from an attached sink during the first byte of the Initialization message. For an attached source the information is requested through the Version—Initialization message.

k) Maximum OUTPUT watts 0 to 240—when output—1 byte

Physical design of the port power defines the MP output from this port. This is the maximum any attached device can expect to receive from this specific port. It is expected that different ports may have different power handling capabilities. Likewise, internal ports such as USB ports and other non-UPAMD ports, if any, would report the MP available to such ports if used to the maximum capacity. Battery charging for an internal power storage system will also be listed with the MP that can be applied to recharging the internal storage. For external ports this value is up to but less than 240 W.

Maximum output watts is derived from the design of this device and port. It is the maximum value that this device will advertise, in source mode, through the first byte of the Power Availability Message.

l) Maximum OUTPUT volts 0 to 60 (0.25 V steps) (when output)—1 byte

Power output circuitry design will define the voltage output capability of the port. This defines which connections can be supported from this port. This will include the basic 12 V communications voltage and a higher voltage, 21 V for non-communicative devices and possibly a higher voltage to support higher power levels. Defined as what the port is capable of in output mode. Voltage is measured in 0.25 V steps with 12 V = 30_h, 21 V = 54_h, and 60 V = F0_h for example. A value of FF_h is out of allowed voltage range and is treated as an unknown value.

This value depends on the design of the output stage and is an internal number for this device's output. This is the value that will be shown in the Source Initialization Message when this port is used as a source.

m) Minimum INPUT power—0 to 255 (when input)—1 byte

When this port is used as an input power port, this field specifies what the minimum power that is needed to keep this device operating.

This is the value that would be reported as Minimum Power in the RPM.

n) Maximum INPUT power capacity—0 to 255 (when input)—1 byte

When this port is used as an input port, this field specifies the MP that this port is capable of accepting. This is the electrical capacity of the input components.

This is a design criterion of the physical port and is a design specification for this physical port.

o) Maximum INPUT voltage accepted 0 to 60 (0.25 V steps) (when input)—1 byte

When this port is used as a power input port, this field specifies the maximum voltage it will accept. This voltage is specified in the number of 0.25 V steps. Values from 0 to 60 V are represented as counts from 0 to 240 (F0_h). A value of FF_h is defined as unknown.

This is a design criterion of the physical port and is a design specification for this physical port.

p) Current voltage on connection 0 to 60 (0.25 V steps) in use—1 byte

This reports the voltage present on the port at this time. This voltage is measured by the port. This is reported in 0.25 V steps from 0 to 60 V and reported as a hexadecimal value of 0 to F0_h.

If the port is a source, this is the currently delivered voltage. If this port is a sink it is the voltage specified in the RPM—Current Voltage Request (CVR).

- q) Current power through this port: 0 to 65 536 W on connection—2 byte

Current power flow through this port is reported as a power value of 0 to 65 536 W. Direction of power flow is determined by which end is acting as a source. If there is no acting Source this is reported as 0 W. This port may be the power input port for an adapter supplying multiple output ports of up to 240 W and requires the larger power range.

- r) STATUS—1 byte—Status byte reflects the condition of the reporting device.

Bits 0, 1—	00—Normal operation
	01—Reduced capability operation
	10—Power failure
	11—Device failure
Bit 2—Power limited operation	1 for yes, 0 for no
Bit 3—Thermal stress	1 for yes, 0 for no
Bit 4—Voltage deviation	1 for yes, 0 for no
Bit 5—Shutting down	1 for yes, 0 for no
Bit 6—Communications power only	1 for yes, 0 for no
Bit 7—Secure communications capable	1 for yes, 0 for no

- s) Reserved byte—1 byte for data alignment purposes. Use is not defined in this version of the standard. For this version of the standard this byte shall be set to 00_h.

- t) Device certification number—8 bytes. (Reserved for future use.)

This is the 8-byte identifier for the Device Certification Reference Number. More than one device model, or brand name, may be reported on a single certification statement. This number shall be used to retrieve the certification documentation from a database for certification documents when available.

The Device Certification Number shall be set to 00-00-00-00-00-00-00-00_h if there is no value assigned.

The certification number for this device is retrieved from internal certification number storage. Certification numbers for the attached device is retrieved through Device Certification Reference Number as defined in Identity Messages. See 7.4.1.

4.4.2 Example State Tables from Connectivity Diagram 201202251830 (Figure 4)

Port number	EUI - IPv6 Address	Connected Hex Port number	This Device port Sink 1=Yes	This Device port Bidirectional 1=Yes	This Device port Continuous Power 1=Yes	This Device Internal Use - Undefined	This Device Security capable	Connected Port Sink 1=Yes	Connected Port Bidirectional 1=Yes	Connected Port Continuous Power 1=Yes	Connected Port Reserved for Future Use	Connected Device Security capable	Local Application Priority Nibble	Connected Application Priority Nibble	Connected Request Priority Nibble	Stored Maximum Capacity WH 0-65536	Stored Power Percentage (Percent(0.4)	UPAMD Version	Max OUTPUT Watts 0-255 (Two bytes)	Max OUTPUT Volts Byte (in 0.25V increments)	Min Input Power - 0-255	Max Input Power - 0-255	Max input Voltage 0-60 (0.25V steps)	Current Voltage 0-60 (0.25V steps)	Current power 0-255 (two bytes)	Status	Device Certification Number assigned after certification	Description - comment only not part of table.			
"Beta" device in connectivity example																															
0	AC:54:EC:00:11:22:33:01	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	10	239	60	0	0	240	240	0	0	E31779D08B7B3D8B	base device			
1	AC:54:EC:00:11:22:33:00	9	0	0	0	0	0	0	0	0	0	0	0	2	4	1500	138	10	200	60	95	130	240	120	0	0	E2CADB83A256315C	"Alpha" Multiport device			
2	AC:54:EC:00:11:22:33:07	1	0	0	0	0	0	0	0	0	0	0	0	2	4	200	120	10	130	21	25	120	84	84	65	0	0	29CFCA296177C1B5	System monitor laptop		
3	AC:54:EC:00:11:22:33:09	1	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	130	21	15	25	48	48	20	0	0	AA9CD4ACDF21300	DVD Player		
4	AC:54:EC:00:11:22:33:0A	1	0	0	0	0	0	0	0	0	0	0	0	2	4	100	125	10	240	60	25	75	84	84	35	0	0	F6899C7BD308175D	Laptop		
5	AC:54:EC:00:11:22:33:08	1	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	10	130	21	13	20	84	84	15	10	E75C0213CD584573	Med Patient Monitor (critical)			
6		0	0	0	0	0	0	0	0	0	0	0	0	3	7	0	0	0	15	5	0	15	20	20	3	0	NA	USB ports			
For "Alpha" device connectivity example																															
0	AC:54:EC:00:11:22:33:00	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	1500	138	10	239	0	0	0	0	0	0	0	E2CADB83A256315C	Base Device		
1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	800	0	0	NA	AC Power input		
2	AC:54:EC:00:11:22:33:03	2	0	0	0	0	0	0	0	0	0	0	0	2	4	750	210	10	239	240	100	200	220	84	150	0	0	11CB19834FF3201A	Large Battery Pack		
3	AC:54:EC:00:11:22:33:04	1	0	0	0	0	0	0	0	0	0	0	0	2	4	85	240	10	240	84	25	75	84	84	35	0	0	96B5A8E22D1F3FA	Laptop		
4	AC:54:EC:00:11:22:33:05	1	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	240	84	25	75	140	140	50	0	0	BC8A63D3311A9697	Printer FAX Scanner		
5	AC:54:EC:00:11:22:33:00	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	130	84	0	0	0	0	0	0	E2CADB83A256315C	connected to self		
6	AC:54:EC:00:11:22:33:00	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	130	84	0	0	0	0	0	0	E2CADB83A256315C	connected to self		
7	AC:54:EC:00:11:22:33:06	1	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	130	84	25	75	84	84	45	0	0	F52C1C8AD30D4019	Game Console		
8	AC:54:EC:00:11:22:33:08	1	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	130	84	15	75	84	84	20	0	0	9E1E0B4064E3983A	IP router		
9	AC:54:EC:00:11:22:33:01	1	0	0	0	0	0	0	0	0	0	0	0	1	2	120	0	10	240	240	50	240	240	240	220	0	0	E31779D08B7B3D8B	"BETA" MultiPort device		
A	AC:54:EC:00:11:22:33:0D	1	0	0	0	0	0	0	0	0	0	0	0	2	4	120	210	10	240	240	75	240	240	240	175	0	0	2C5CB1D7BC57551	HA Service multi sourced		
B	AC:54:EC:00:11:22:33:02	2	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	130	240	35	110	84	84	10	0	0	57C5C8DB511C153A	Gama Multiport device		
C		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	20	0	0	20	20	6	0	NA	USB Power Ports		
D		0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	1500	138	0	240	240	10	240	192	192	200	0	0	NA	Internal Battery UPS Backup	
For UPAMD System Monitoring Laptop																															
0	AC:54:EC:00:11:22:33:07	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	210	123	10	0	0	53	120	240	84	100	0	0	29CFCA296177C1B5	Monitor Laptop	
1	AC:54:EC:00:11:22:33:01	2	1	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	130	240	53	120	0	80	100	0	0	E31779D08B7B3D8B	Beta Multiport device		
"GAMMA"																															
0	AC:54:EC:00:11:22:33:02	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	239	240	0	0	240	240	0	0	0	0	57C5C8DB511C153A	"Gamma" multiport device	
1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	240	0	0	240	240	450	0	0	NA	AC Power Connection		
2	AC:54:EC:00:11:22:33:00	8	0	0	0	0	0	0	0	0	0	0	0	2	4	1500	138	10	130	84	25	120	84	84	65	0	0	E2CADB83A256315C	"Alpha" multiport device		
3	AC:54:EC:00:11:22:33:0F	1	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	130	240	15	215	48	240	60	0	0	1ADDDB81F9BC3786	Solar Panel		
4	AC:54:EC:00:11:22:33:0D	2	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	240	240	25	75	84	84	35	0	0	2C5CB1D7BC57551	High Availability Server Device		
5	AC:54:EC:00:11:22:33:03	1	0	0	0	0	0	0	0	0	0	0	0	2	4	750	210	10	240	84	13	20	84	84	15	0	0	11CB19834FF3201A	"Delta" Multiport large power source		
6	AC:54:EC:00:11:22:33:0E	1	0	0	0	0	0	0	0	0	0	0	0	3	7	0	0	10	130	240	10	130	84	84	110	0	0	1F03859C18F4534A	Game console		
7	AC:54:EC:00:11:22:33:10	1	0	0	0	0	0	0	0	0	0	0	0	2	4	1500	210	10	239	240	100	200	240	240	150	0	0	BFCB099A7225E719	Energy Storage system single port		
8		0	0	0	0	0	0	0	0	0	0	0	0	3	7	0	0	0	15	5	0	10	20	20	3	0	0	NA	USB ports		
"DELTA"																															
0	AC:54:EC:00:11:22:33:03	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	240	240	0	0	0	0	0	0	0	0	11CB19834FF3201A	Large energy storage Device	
1	AC:54:EC:00:11:22:33:02	5	1	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	240	240	0	240	240	240	200	0	0	0	57C5C8DB511C153A	"Gamma" Multiport device	
2	AC:54:EC:00:11:22:33:00	2	1	0	0	0	0	0	0	0	0	0	0	2	4	1500	138	10	240	240	0	240	240	84	65	0	0	0	E2CADB83A256315C	"Alpha" multiport device	
3		0	0	0	0	0	0	0	0	0	0	0	0	3	7	0	0	10	240	240	0	0	0	48	0	0	0	0	0	Nothing attached	
4	AC:54:EC:00:11:22:33:0C	1	0	0	0	0	0	0	0	0	0	0	0	2	4	100	250	10	240	240	0	240	240	84	35	0	0	EDBA03D220C104C5	Lap top		
5		0	0	0	0	0	0	0	0	0	0	0	0	3	7	0	0	10	240	240	0	20	0	84	6	0	0	0	Led Lamp		
High Availability Server Device																															
0	AC:54:EC:00:11:22:33:0D	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	0	0	85	170	0	0	0	0	0	0	2C5CB1D7BC57551	High Availability Server	
1	AC:54:EC:00:11:22:33:02	5	1	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	130	240	53	170	240	240	140	0	0	0	57C5C8DB511C153A	"Gamma" Multiport device	
2	AC:54:EC:00:11:22:33:00	A	1	0	0	0	0	0	0	0	0	0	0	2	4	1500	138	10	130	240	53	170	248	240	30	0	0	0	E2CADB83A256315C	"Alpha" Multiport device	
Solar Power Panel																															
0	AC:54:EC:00:11:22:33:0F	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	210	240	0	0	0	240	140	0	0	0	1ADDDB81F9BC3786	210 Watt peak Solar Panel	
1	AC:54:EC:00:11:22:33:02	3	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	130	240	53	170	240					0	0	57C5C8DB511C153A	"Gamma" Multiport device
Game Console 2																															
0	AC:54:EC:00:11:22:33:0E	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	0	0	53	120	240	84	110	0	0	0	1F03859C18F4534A	Game console 2	
1	AC:54:EC:00:11:22:33:02	6	1	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	130	240	53	170	240	84	110	0	0	0	57C5C8DB511C153A	"Gamma" Multiport device	
Single port Energy Storage device																															
0	AC:54:EC:00:11:22:33:10	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	210	123	10	0	0	53	120	240	240	100	0	0	BFCB099A7225E719	Energy Storage system	
1	AC:54:EC:00:11:22:33:02	7	1	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	130	240	53	170	240	240	140	0	0	0	57C5C8DB511C153A	"Gamma" Multiport device	
Critical Patient Medical device																															
0	AC:54:EC:00:11:22:33:0B	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	210	123	10	0	0	53	120	240	84	100	0	0	E75C0213CD584573	Critical Patient Monitor	
1	AC:54:EC:00:11:22:33:01	5	0	0	0	0	0	0	0	0	0	0	0	1	2	12	0	10	130	240	53	120	0	80	78	0	0	0	E31779D08B7B3D8B	"Beta" Multiport device	
DVD Player																															
0	AC:54:EC:00:11:22:33:09	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	210	123	10	0	0	53	120	240	84	100	0	0	AA9CD4ACDF21300	DVD Player on "Beta"	
1	AC:54:EC:00:11:22:33:01	3	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	10	130	240	53	120	0	80	78	0	0	0	E31779D08B7B3D8B	"Beta" Multiport device	

Port number	EUI - IPv6 Address	Connected Hex Port number	This Device port Sink 1=Yes	This Device port Redefined 1=Yes	This Device port Bidirectional 1=Yes	This Device port Continuous Power 1=Yes	This Device Internal power 1=Yes	This Device Security capable	Connected Port Sink 1=Yes	Connected Port Redefined 1=Yes	Connected Port Bidirectional 1=Yes	Connected Port Continuous Power 1=Yes	Connected Port Reserved for Future Use - undefined	Connected Device MultiPort 1=Yes	Connected Device Security capable	Local Application Priority Nibble	Local Request Priority Nibble	Connected Application Priority Nibble	Connected Request Priority Nibble	Stored Maximum Capacity WH 0-65536	Stored Power Percentage (Percent/0.4)	UPAMD Version	Max OUTPUT Watts 0-255 (Two bytes)	Max OUTPUT Volts Byte (in 0.25V increments)	Min Input Power - 0-255	Max Input Power - 0-255	Max input Voltage 0-60 (0.25V steps)	Current Voltage 0-60 (0.25V steps)	Current power 0-255 (two bytes)	Status	Device Certification Number assigned after certification	Description - comment only not part of table.
	Laptop on Beta #2																															
0	AC:54:EC:00:11:22:33:0A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	210	123	10	0	0	53	120	240	84	35	0	F6899C7BD308175D	Second Laptop on "Beta"
1	AC:54:EC:00:11:22:33:01	4	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	1500	138	10	130	240	53	120	0	80	35	0	E31779D08B7B3D8B	"Beta" Multiport device
	Laptop on Alpha																															
0	AC:54:EC:00:11:22:33:04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	210	123	10	0	0	53	120	240	84	35	0	986B5A8E22D1F3FA	Alpha Laptop
1	AC:54:EC:00:11:22:33:00	3	0	0	0	1	0	0	0	0	0	0	0	0	0	2	4	2	4	1500	138	10	130	240	53	120	240	84	35	0	E2CADB83A256315C	"Alpha" Multiport device
	Printer on Alpha																															
0	AC:54:EC:00:11:22:33:05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	210	123	10	0	0	53	120	240	140	50	0	BC8A63D3311A9697	Printer
1	AC:54:EC:00:11:22:33:00	4	0	0	0	1	0	0	0	0	0	0	0	0	0	2	4	2	4	1500	138	10	130	240	53	120	0	140	50	0	E2CADB83A256315C	"Alpha" Multiport device
	Game console on Alpha																															
0	AC:54:EC:00:11:22:33:06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	210	123	10	0	0	53	120	240	84	45	0	F52C1C8AD30D4019	Game console 1
1	AC:54:EC:00:11:22:33:00	7	0	0	0	1	0	0	0	0	0	0	0	0	0	2	4	2	4	1500	138	10	130	240	53	120	84	84	45	0	E2CADB83A256315C	"Alpha" Multiport device
	IP Router on Alpha																															
0	AC:54:EC:00:11:22:33:08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	210	123	10	0	0	53	120	240	84	20	0	9E1E0B4064E3983A	Router
1	AC:54:EC:00:11:22:33:00	8	0	0	0	1	0	0	0	0	0	0	0	0	0	2	4	2	4	1500	138	10	130	240	53	120	0	84	20	0	E2CADB83A256315C	"Alpha" Multiport device

Figure 4—State table example for connectivity example diagram

5. Physical level communication

The physical communication interface of UPAMD is based on a differential current-mode implementation of the CAN bus. The two communication wires provide two separate functions in this system: (1) the detection of device connection and disconnection via the common-mode voltage, and (2) data communication via differential current signaling.

5.1 Device detection

Connection between devices acting as sources and those acting as sinks is determined by the measurement of the CAN bus common-mode voltage. This measurement determines the class of device attached and also detects the disconnection of a device. The detection circuit is a low-energy circuit with maximum connection stored energy of 15 uJ to reduce the spark creation potential.

Determining, through this low-energy probing, what class of devices is attached through the UPAMD cable it the first operation. A power source port will apply a detection and termination voltage of a nominal 3.3 V through a $20\text{ k}\Omega \pm 5\%$ resistor to the center point of the CAN bus termination network on the source side of the connection. (Note that this impedance, in combination with the required nominal $40\text{ k}\Omega$ source impedance to Vneg will produce a Source Thevenin equivalent of approximately $2.2\text{V} @ 13.33\text{ k}\Omega$.) The power sink devices will connect a termination resistor to Vneg at the center point of the CAN bus termination resistance on the sink device. Measurement of this voltage by the source determines the operation of the source for this connection.

Once a device capable of communications is detected, a nominal common-mode voltage of 1.65 V should be present so that communications via the differential lines is possible. This voltage is intrinsic to the selected load and supply side resistors in the connection. This common-mode voltage shall be continuously monitored to detect disconnection or fault conditions. To avoid erroneous detection, while at the same time reacting fast enough, to reduce stored energy of the connection to less than 15 uJ, to a disconnection or fault event, this common-mode voltage shall be filtered with a time constant of no more than 1ms.

5.1.1 Device load resistance values

Load resistances from the center point of the $120\ \Omega \pm 10\ \Omega$ CAN Bus termination resistance, center point to Vneg shall be the following:

- a) Source device = $40\ 000\ \Omega \pm 5\%$
- b) Bi-directional device = $40\ 000\ \Omega \pm 5\%$
- c) Smart Sink device = $40\ 000\ \Omega \pm 5\%$
- d) 20 W Mute device = $15\ 000\ \Omega \pm 5\%$ —allocates the full 20 W to device
- e) Mute Sink with lower power needs—top of range = $13\ 400\ \Omega$ for 1 A maximum current
- f) Mute Sink with lowest power needs—bottom of range = $1700\ \Omega$ for 50 mA maximum current (linear interpolation)
- g) Any value below $1300\ \Omega$ shall be treated as a short circuit by the source

5.1.2 Load detection V_{common} values

For the nominal 3.3 V probe voltage, the load voltage detection values at V_{common} on the source connections are as follows:

- a) Source V_{common} greater than 2.0 V = No device attached
- b) Source V_{common} between 1.25 V and 2.0 V = Smart device attached
- c) Source V_{common} between 1.25 V and 1.1 V = 20 W (1 A) Mute device attached
- d) Source V_{common} between 0.2 V and 1.1 V = Lower power Mute device attached, this value shall determine the maximum sink current from 50 mA up to 1 A.
- e) Source V_{common} less than or equal to 0.2V = No power delivery, No operation, possible short

MP available at the sink or exposed source connector is the 3.3 V power through a $20\ 000\ \Omega$ source resistor or approximately 137 uW (MP transfer at $20\ \text{k}\Omega$ load). The absolute MP would be somewhat less as, assuming an intact source load of $40\ \text{k}\Omega$, only the Source Thevenin equivalent of 2.2 V @ $13.33\ \text{k}\Omega$ would be available at the sink.

Figure 5 shows the detection ranges for the different device classes. The common-mode resistances define the device ranges, with detection values dependent on the design of the detection circuitry. The figure assumes a simple divider from a 3.3 V probe voltage via a $20\ \text{k}\Omega$ probe resistor. Detection should take into account that an active powered source will introduce a measurable load-dependent shift of the common-mode voltage (up to $\pm 350\ \text{mV}$ in worst-case conditions).

	Open	Smart device	20 W mute device	20 W to 1 W lower-power mute device	Short
Resistance	>250 k Ω	40 k Ω	15 k Ω	13.4 k Ω to 1.7 k Ω	<1.3 k Ω
Nominal	2.2 V	1.65 V	1.16 V	1.1 V to 0.25 V	<0.2 V
Detection	>2.0 V	2.0 V ~ 1.25 V	1.25 V ~ 1.1 V	1.1 V ~ 0.2 V	<0.2 V

Figure 5—Detection values for the device classes (probe voltage = 3.3 V)

5.2 CANx and CANy data communication pair

The communication interface is a differential current-mode application of the CAN standard with significant modifications. Summarized as follows:

- a) It is based on a 3.3 V interface voltage (instead of 5 V).
- b) A current-mode definition (instead of voltage-mode), which provides for a maximum current on the interface and allows for future speed improvements.
- c) Polarity-independence connectivity, either wire of the interface can become CAN_H or CAN_L .
- d) Full termination of both sides of a link, allowing for faster communications speed in the future.
- e) The interface components shall be able to withstand a temporary short to 60 V + margin for at least 50 ms, the maximum voltage provided by an UPAMD supply.

5.2.1 Bit representation

Dominant bit, which represents a “0” in CAN2.0B, is asserted by the interface. It shall be represented by a 10 mA nominal current from CAN_L into CAN_H , providing $\pm 5 \text{ mA} \times 60 \text{ } \Omega$ or a $\pm 300 \text{ mV}$ nominal differential deflection from V_{common} , the common-mode voltage (i.e., $CAN_H = V_{\text{common}} + 300 \text{ mV}$, $CAN_L = V_{\text{common}} - 300 \text{ mV}$).

Recessive bit, represents a “1” in CAN2.0B, is the default state of the interface with a 0 V differential ($CAN_H = CAN_L = V_{\text{common}}$ nominally 1.65 V). A recessive bit shall be overridden by a *dominant* symbol.

On the receiver side, the detection of a dominant bit shall be achieved by a differential voltage deviation in excess of 250 mV from V_{common} .

Although the CAN protocol requires a fixed wiring polarity (CAN_H and CAN_L), the interface shall support the interchange of the meaning of these wires after a connection event (on the transmission of the first bit). For this purpose the two communication wires are named CAN_X and CAN_Y , where either can become CAN_H or CAN_L on initial transmission. This can be implemented via two separate differential receivers, with the output of each receiver providing the detection of a dominant symbol for a specific interface polarity.

Once a polarity has been decided, it shall remain in effect for the rest of the connection. Two different polarities shall not become simultaneously active in an interface, as this will turn the combination of two dominant symbols into a recessive one, an illegal condition for CAN. Any device added to an active link should assume the existing polarity of the link.

The CAN symbol speed for this version of UPAMD is 1 MHz; the data rate will be somewhat less due to CAN bit-stuffing and encoding.

5.2.2 Number of connected devices

Although CAN is a bus protocol, for most practical purposes this version of UPAMD defines it as a point-to-point interface, connecting individual ports in Sources and Sinks. Termination of the differential communication lines only happens on such devices.

For testing and other purposes a maximum of two “snooping” devices in the same connection are allowed as long as (1) their power consumption does not exceed 10 mW on communication voltage and 50 mW on active voltage, (2) their communication common-mode impedance is 1 M Ω or greater, and (3) its communication differential impedance is 30 k Ω or greater.