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INTERNATIONAL STANDARD

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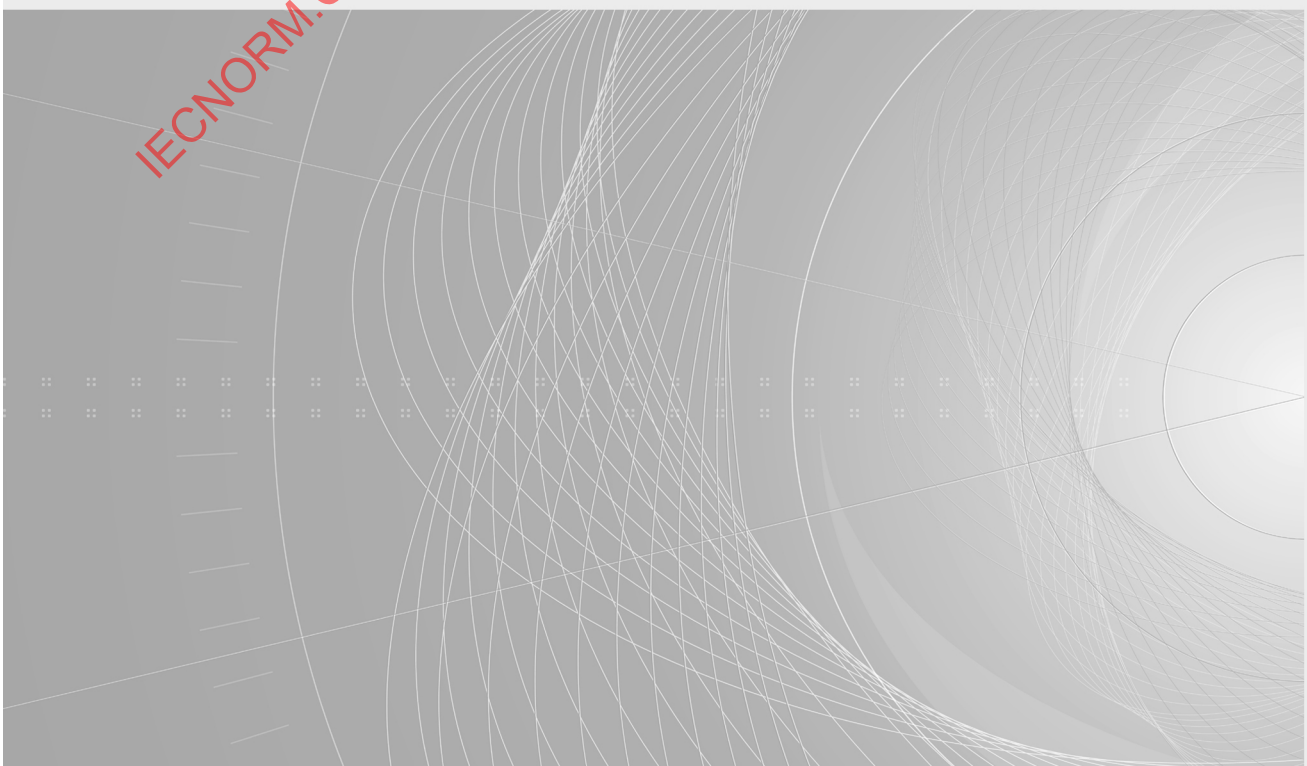
Information technology – Home electronic system (HES) interfaces – Part 3: Modular communications interface for energy management



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Information technology – Home electronic system (HES) interfaces – Part 3: Modular communications interface for energy management

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INFORMATION TECHNOLOGY – HOME ELECTRONIC SYSTEM (HES) INTERFACES –

Part 3: Modular communications interface for energy management

FOREWORD

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International Standard ISO/IEC 10192-3 was prepared by subcommittee 25: Interconnection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology.

This International Standard has been approved by vote of the member bodies, and the voting results may be obtained from the address given on the second title page.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the ISO/IEC 10192 series, published under the general title *Information technology – Home electronic system (HES) interfaces*, can be found on the IEC and ISO websites.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours, which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Utilities world-wide are investing heavily in smart grid infrastructures for energy that extend to homes and businesses with the goal of improving grid reliability and efficiency through increased consumer awareness and participation. This document provides a solution for grid connections within the home through a modular communications interface (MCI) enabling any product to connect to a variety of demand-response systems. Such systems may include Advanced Metering Infrastructure (AMI), Smart Energy Profile (SEP), IEC PAS 62746-10-1:2014 (OpenADR 2.0) and/or home or building networks such as protocols specified in the ISO/IEC 14543 series. The concept is simple: encourage manufacturers to build an MCI into their products that can accept a simple communications module. Consumers and programme managers are then free to select whatever communications solution works best for their particular environment.

The MCI is based on the ISO/IEC 8482 interface (commonly referenced as RS-485) and the Serial Peripheral Interface (SPI) supported by most silicon chips. The messages conveyed through the MCI to the end-device use either an externally specified command set (called the “Pass-Through mode”) or the demand response (DR) application command set specified in this document as the Simple Protocol. The DR command set is intended for devices that cannot process one of the “pass-through” command sets. This document specifies options for the Pass-Through mode based on protocols commonly used in grid applications such as Internet Protocol (IP), IEC PAS 62746-10-1:2014 (OpenADR 2.0), SEP, and ISO/IEC 14543 series protocols. Network security is supported at the application layer in the Pass-Through mode in addition to network or application layer security.

The MCI specified in this document may use either of the following connectors:

- an AC powered form, which uses the ISO/IEC 8482 interface over a physical connector defined in this document;
- a DC powered form, which uses the Serial Peripheral Interface over a connector defined in ISO/IEC 24739-3. The use of this connector is discussed in Annex A and Annex B.

The MCI applies to devices that may include an energy management hub, an energy management controller, an energy management agent, a residential gateway, an energy services interface, a sensor, a thermostat, an appliance or other consumer products. A physical connection from a communication module to residential smart grid devices and options for a communications protocol including application messages are specified. The specific residential devices to use an MCI are not specified. For energy management the choice depends on the system and the network topology. If a hub topology is chosen, the MCI may be located on the hub. The connection between the hub and end-devices such as appliances is not specified.

Communication messages specified in this document for the DR command set support direct load control, time-of-use (TOU), critical-peak-pricing (CPP), real-time pricing (RTP), peak time rebates, various types of block rates, and a range of ancillary services. The functionality of the removable MCI modules can be tailored by utilities or other load managing entities to provide support for the unique needs in a given region or service territory without impacting the end-devices. Figure 1 illustrates the general concept of the MCI.

a) MCI on a controlled device **b) MCI on an energy management console**

Figure 1 – Illustrations of the modular communications interface (MCI) concept

This document enables a new generation of “smart grid ready” products that limit risks and constraints of proprietary communication technologies and evolving standards. This approach simplifies home area network (HAN) device and network interoperability, fosters programme and product innovation and opens DR programmes to a broader range of consumer products, while facilitating customer choice and a competitive market landscape.

INFORMATION TECHNOLOGY – HOME ELECTRONIC SYSTEM (HES) INTERFACES –

Part 3: Modular communications interface for energy management

1 Scope

This part of IEC 10192 specifies a UCM (Universal Communications Module) that transfers energy management data via a home network between an end-device and an energy management agent (specified in ISO/IEC 15067-3) or an energy service provider. This document specifies the mechanical, electrical and logical characteristics of the interfaces of UCM to an end-device (hereafter referred to as an SGD – Smart Grid Device) and a choice of interfaces to a home communications network.

This document specifies the physical and data-link characteristics of the interface between the UCM and the SGD, along with certain higher-layer and application layer elements as needed to assure interoperability over a broad range of device capabilities. It specifies a mechanism through which network, transport and application layer messages specified in other documents listed in this document may be passed through the interface. For those end-devices that cannot process one of the "pass-through" command sets, a Simple Protocol is specified according to the OSI (Open System Interconnect) reference model (ISO/IEC 7498-1) including application layer messaging for energy management.

The UCM specified in this document is intended to be installable by the purchaser, home occupant or professional installer. The connectors are integrated in a way that allows for easy, plug-in installation. However, the manufacturer may choose to pre-install a module during production or have installation handled by a manufacturer representative or professional installer.

The scope of this document does not include safety related construction, performance, marking or instruction requirements. UCM products should additionally comply with applicable product safety standard(s). Examples of such standards are presented in Annex G.

NOTE Some regulatory authorities require that appliances intended for participation in energy management, such as thermostats, be user installable.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 8482, *Information technology – Telecommunications and information exchange between systems – Twisted pair multipoint interconnections*

ISO/IEC 14543-3-1, *Information technology – Home electronic system (HES) architecture – Part 3-1: Communication layers – Application layer for network based control of HES Class 1*

ISO/IEC 14543-4-3, *Information technology – Home electronic system (HES) architecture – Part 4-3: Application layer interface to lower communications layers for network enhanced control devices of HES Class 1*

ISO/IEC 14908-1, *Information technology – Control network protocol – Part 1: Protocol stack*

ISO/IEC 24739-3, *Information technology – AT attachment with packet interface-7 – Part 3: Serial transport protocols and physical interconnect (ATA/ATAPI-7 V3)*

ISO 4217, *Codes for the representation of currencies*

IEC PAS 62746-10-1:2014, *Systems interface between customer energy management system and the power management system – Part 10-1: Open Automated Demand Response (OpenADR 2.0b Profile Specification)*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

3.1.1
average price
equivalent constant price for electricity as determined by the energy service provider

3.1.2
hot-swappable
connected and removed under load

3.1.3
Pass-Through mode
use of one of the following application layer protocols: Advanced Metering Infrastructure (AMI), Smart Energy Profile (SEP), IEC PAS 62746-10-1:2014 (OpenADR 2.0) and/or home or building networks specified in the ISO/IEC 14543 series

3.1.4
relative price
ratio of the current price to the average price, where “Average_Price” is calculated as specified in Annex F

3.1.5
smart grid device
end-device that is being informed of energy grid conditions

3.1.6
universal communications module
communications device that provides communication connectivity to a smart grid device

3.2 Abbreviated terms

AMI	Advanced Metering Infrastructure
AP	Average Price
ATA	Advanced Technology Attachment
CPP	Critical Peak Price
DR	Demand Response
HVAC	Heating, Ventilation and Air Conditioning
IP	Internet Protocol
LS	Least Significant
MS	Most Significant
OpenADR	Automated Demand Response specification from the OpenADR Alliance
PCB	Printed Circuit Board
PLC	Power Line Carrier

PoE	Power over Ethernet
RBDS	Radio Broadcast Data System
RDS	Radio Data System
SEP	Smart Energy Profile
SGD	Smart Grid Device
SPI	Serial Peripheral Interface (data transfer standard originally specified by Motorola (Freescale))
TVC	Time Varying Charges
UCM	Universal Communications Module
UTC	Universal Coordinated Time
0x00 to 0xFF	Two digit (8 bit) hexadecimal numbers ranging from 0 to 255 decimal
b0, b1 .. b15	Bit values within a hexadecimal number. b0 is the least significant bit.

4 Conformance

In order to conform to this document a UCM shall transfer energy management data between an end-device and an energy management agent or an energy service provider via a home network, provide an interface to the device (as specified in Clause 5 with a DC interface as specified in Annex A or an AC interface as specified in Annex C) and provide an interface to a home network as specified in Clause 6.

The messaging format shall be one of the protocols referenced in Clause 13 or the Simple Protocol specified in Clauses 7, 8, 9, 10, 11 and 12.

5 Physical/electrical Interface

5.1 Form factors

Two physical form factors are specified. End-device manufacturers may choose either, and communications module providers who wish to cover all products may offer two module versions. For both form factors, the communications protocol across the socket interface is the same, as described herein. Also in both cases, the power for the UCM is provided by the SGD. One form factor provides a low voltage DC supply and an SPI serial data interface. This form factor is specified in Annex A. This option might be attractive in cases where the end-device has no AC power source or when smaller socket size is required.

The second form factor provides AC service voltage for a single phase (typically 120 V or 240 V depending on the country and the appliance) and an ISO/IEC 8482-based serial interface. This form factor is specified in Annex C. This option might be attractive in cases where the end-device does not provide a DC power supply, where compatibility with PLC communications modules is desired or where communications module access to line frequency is needed.

NOTE 1 ISO/IEC 8482 was originally developed as RS-485 and TIA-485.

5.2 Removal and exchange of a UCM

It is assumed that UCMs will be removed or exchanged without turning off the SGD. Therefore, the UCM shall be hot-swappable.

5.3 Block diagram

Figure 2 shows the block diagram of the MCI.

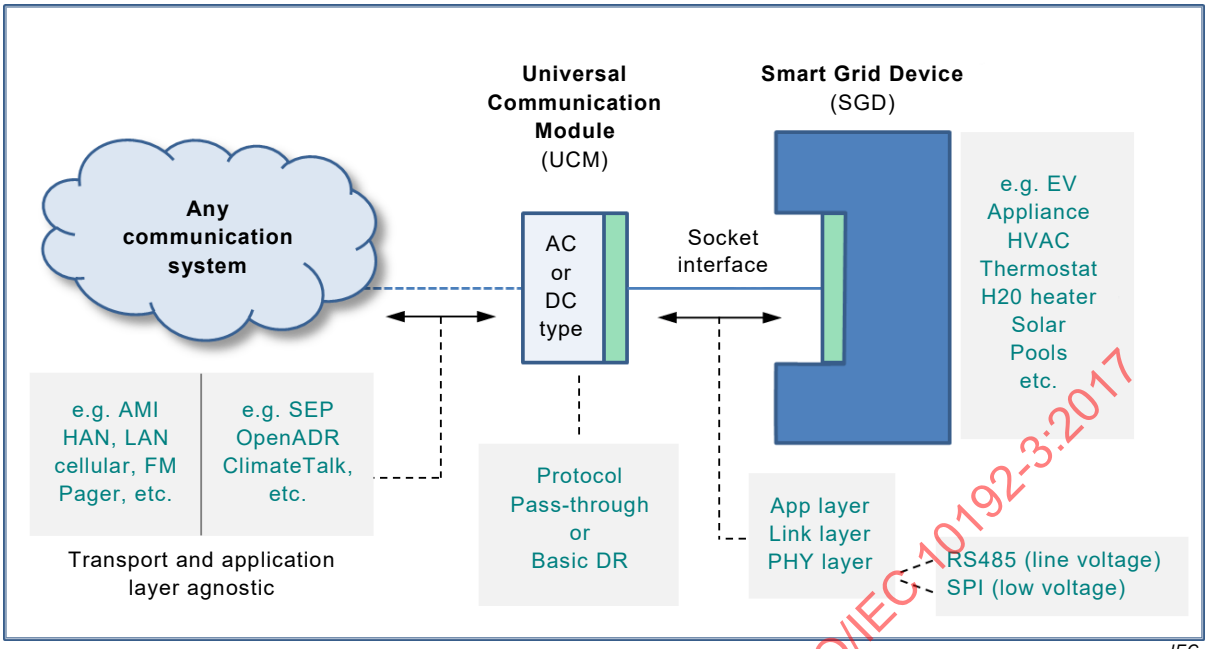


Figure 2 – Modular communications interface (MCI) block diagram

6 Serial protocol

6.1 Protocol data unit

This document defines an extensible serial protocol data unit that is manageable by the simplest of devices and also capable of being extended to accommodate more complex devices. The general message format is shown in Table 1.

Table 1 – Protocol data unit format

Message Type	Reserved shall be '0x0'	Payload length	Payload	Checksum
2 bytes	3 bits	13 bits	Variable	2 bytes

Conceptually the "payload" portion of the message can transport a range of protocols, with the "Message Type" field indicating which protocol and the checksum included ensuring link layer data integrity. There are 3 bits at the start of the third byte that are reserved for future work. These shall be held at 0 for compatibility with future revisions. This scheme provides a high level of flexibility and extensibility. A simple means is provided for SGDs and UCMs to discover which protocol each supports.

6.2 Message Type field

The "Message Type" bytes indicate the type of message, essentially indicating which communications protocol is represented in the payload. The "Message Type" values are specified in Table 2. Typical communication exchanges are presented in Clause 14.

Table 2 – Message type assignments

Message Type MS byte	Message Type LS byte	Description
0x00 to 0x05	0x00 to 0xFF	Reserved for vendor proprietary use
0x06	0x00 to 0xFF	Reserved to avoid confusion with link layer ACK
0x07	0x00 to 0xFF	For Future Assignment
0x08	0x01	Basic DR Application (at least partially supported by all devices)
0x08	0x02	Intermediate DR Application
0x08	0x03	Data-Link Messages
0x08	0x04	Commissioning and Network Support Messages
0x08	0x05 to 0xFF	For Future Assignment
0x09	0x01	USNAP 1.0, Pass-Through
0x09	0x02	ClimateTalk, Pass-Through
0x09	0x03	Smart Energy Profile 1.0, Pass-Through
0x09	0x04	Smart Energy Profile 2.0 over IP, Pass-Through
0x09	0x05	OpenADR 1.0 over IP, Pass-Through
0x09	0x06	IEC PAS 62746-10-1, Pass-Through
0x09	0x07	Generic IP Pass-Through (IP packets self-identify version so both IPv4 and IPv6 are covered)
0x09	0x08	ISO/IEC 14543-4-3 Pass-Through
0x09	0x09	ISO/IEC 14543-3-1 Pass-Through
0x09	0x0A	ISO/IEC 14908-1 Pass-Through
0x09	0x0B	Sunspec Modbus Pass-Through
0x09	0x0C to 0xFF	For Future Assignment
0x0A to 0x14	0x00 to 0xFF	For Future Assignment
0x15	0x00 to 0xFF	Reserved to avoid confusion with link layer NAK
0x16 to 0xEF	0x00 to 0xFF	For Future Assignment
0xF0 to 0xFF	0x00 to 0xFF	Reserved for vendor proprietary use

The “Vendor Proprietary” message types allow for device makers to make use of the serial interface for any purpose they wish. This includes manufacturing processes, field diagnostics, etc. Once a message begins with an address in these vendor-proprietary ranges, the remainder of the message may be formatted and used as desired by the manufacturer. In cases where the device has multiple internal subsystems sharing the serial bus, further addressing might be handled using the second byte.

New Message Types are to be assigned by the respective interface standard or specification. Usually this would be done in co-ordination with the organization(s) responsible for the management of the domain-area or protocol that is to be passed through.

Clause 9 specifies the query used to determine if a device supports a specific message type. Support of the basic message type 0x08 0x01 is required and need not be queried.

6.3 Payload length field

The “Payload Length” is a 13-bit representation of the number of bytes in the Payload field. For the Basic DR messages, this is always a 2. Other message types may have variable payload lengths and may also include additional length bytes somewhere in the message payload as specified by the other protocols.

A device, either UCM or SGD, shall not send a payload greater than 2 bytes unless it has first determined the Maximum Payload of the receiving device by sending a Maximum Payload Length Query (see Table 14) to the receiving device.

6.4 Checksum field

The checksum is calculated starting with the first Message Type byte through to the end of the payload. Checksum calculation and encoding is according to a Fletcher checksum as specified in Annex D.

6.5 Bit and byte order

6.5.1 Bit order within a byte

Bytes are transmitted most significant bit first for the DC form factor and least significant bit first for the AC form factor.

6.5.2 Byte order for multi-byte messages

For both the AC and DC form factor interfaces, multi-byte numbers, such as the Message Type and Length, are transmitted most significant byte first (Big Endian).

As an example, the 16-bit hexadecimal value 0x102F would be transmitted as follows.

Byte	Contents	Comments
1	0x10	First byte transmitted
2	0x2F	Last byte transmitted

6.6 Message synchronization and timing

6.6.1 Message sequencing

All communication on the MCI shall be half-duplex. This applies to both the low-voltage DC interface using SPI and the high-voltage AC interface using ISO/IEC 8284. The nature of the two-wire ISO/IEC 8284 interface fundamentally allows only one side to transmit successfully at any time.

This document allows either the communications module or the end-device to initiate communication. As a result, bus contention is possible on the AC interface and shall be electrically tolerated by the devices on both sides without damage. Recognition of contention is to be achieved by the absence of an appropriate link layer response and recovery by the randomized data-link retry process specified in 6.6.3.

6.6.2 Link layer timing

Required link layer timing is illustrated in Figure 3 and specified in Table 3.

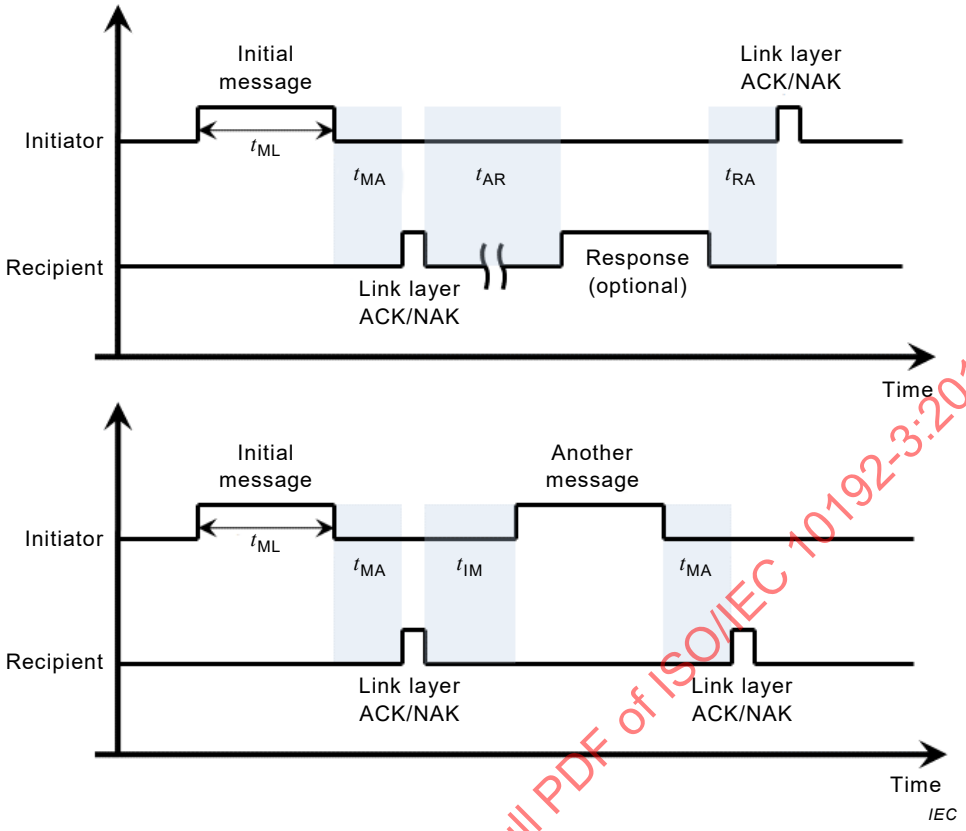


Figure 3 – Link layer timing

The existence of an application-layer response is optional. The Basic DR and Intermediate DR applications specified always result in a response, but other pass-through applications may not.

Table 3 – Message timing requirements

Parameter	Minimum	Maximum	Description
t_{MA}	40 ms	200 ms	Time from the end of a message until the beginning of an associated link layer ACK or NAK.
t_{AR}	100 ms	Maximum determined at application layer	Time from the end of a link layer ACK until the beginning of an application response (if used) from the same device.
t_{RA}	40 ms	200 ms	Time from the end of a response message until the beginning of an associated link layer ACK or NAK.
t_{IM}	100 ms	Maximum determined at application layer	Time from the end of a link layer ACK or NAK until the beginning of another message sent in the same direction. This parameter applies to applications that may send multiple messages in the same direction with no response in between. The requirement of 1 second applies only to “grouped” Basic DR messages that are intended to be processed collectively. Otherwise there is no maximum.
T_{ML}	N/A	500 ms	Maximum message duration, from beginning of first byte to end of last byte. NOTE Manufacturer needs to verify that any chosen payload/bitrate combination supports this requirement. (payload length / bitrate ≤ 500 ms)

6.6.3 Randomized link layer retries

The link layer may determine failure from either lack of a response within the allowed time or from a link layer NAK with an error code indicating that the message was corrupted. Three retries are recommended at the link layer, with a randomized delay between each retry of 100 ms to 2 000 ms. Additional error recovery may exist at the application layer but the specific handling of such is outside the scope of this document.

6.6.4 Application layer timing

Application layer timing shall not violate any of the link layer requirements specified in Table 3. For pass-through application protocols, the application layer timing is outside the scope of this document.

For the Basic DR and Intermediate DR messages specified is this document, the timing parameters are illustrated in Figure 4 and specified in Table 4.

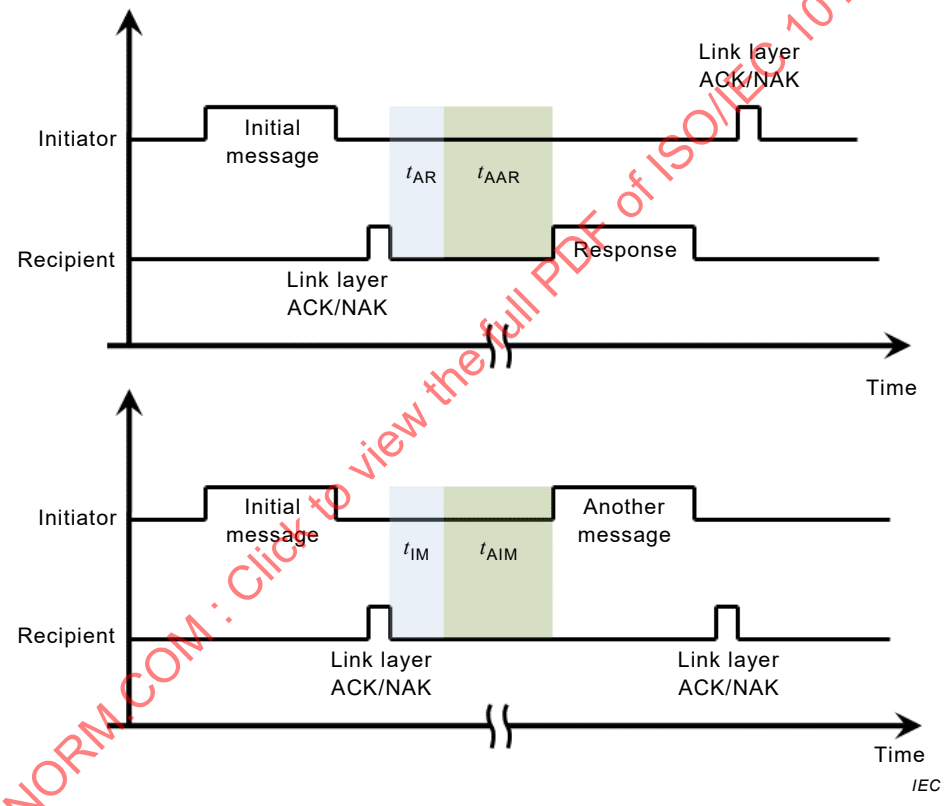


Figure 4 – Application layer timing

Table 4 – Basic/Intermediate DR application layer timing parameters

Parameter	Minimum	Maximum	Description
t_{AAR}	0 ms	3000 ms	For all application messages from alternating sides of the interface: Additional time, as shown in Figure 4, following a link layer ACK, and associated link layer delay, until the beginning of an application response.
t_{AIM}	0 ms	1000 ms for grouped messages, unlimited otherwise	For all application messages from the same side of the interface: Additional time, as shown in Figure 4, following a link layer ACK or NAK, and associated link layer delay, until the beginning of another message or retry from the same sending device.

6.7 SGD handling of conflicting messages

This document supports multiple possible application layer protocols, including the Basic and Intermediate DR commands specified herein in addition to the pass-through of other industry and standard protocols. Among these varied protocols are many different commands related to demand response. It is the responsibility of the UCM, and the system in which it participates, to provide SGDs with single, clear indications of the conditions at any time.

In the event that an SGD is presented with conflicting curtailment mode actions, the curtailment mode triggered by the last command received of equal or greater priority shall take precedence. For example, a cost triggered load change should not override a shed command.

The priority of commands in the Basic DR (Clause 10) and Intermediate DR (Clause 11) applications are indicated in the “Priority:” sub-row of the “Usage” column in Table 14. If the curtailment mode triggered by a command of priority "High" is currently active, only another command of priority "High" shall be acted on by the SGD and replace the current curtailment mode. If the curtailment mode triggered by a command of priority "Low" is currently active, then the most recently received command of either priority "Low" or "High" shall be acted on by the SGD and replace the current curtailment mode. For the special case of commands with priority "Low" where the information is being used for display purposes only (such as displaying the current price) then it may be displayed by the SGD during an active priority "High" command, but not affect the curtailment mode caused by the “High” command. Commands with priority "Not Applicable" are not related to curtailment and shall be acted upon as soon as received.

7 Simple Protocol

If a pass-through protocol from Clause 13 is not implemented, the Simple Protocol shall be implemented. The Simple Protocol includes many message types and commands, but very few are mandatory. The messages are grouped into several types, including a set of data-link messages, Basic and Intermediate DR application messages, and advanced protocol pass-through messages. To assure compatibility between systems for demand response applications that are compliant with the document, UCMs and SGDs shall support the messages below, each of which is limited to 8 bytes length. Devices may optionally support additional messages as desired.

These messages are defined in Clause 10. The mandatory messages are shown in Table 5.

Table 5 – Mandatory message summary

Mandatory message	Layer	Description
Shed	Basic DR Application	Fixed, 8 bytes
End Shed	Basic DR Application	Fixed, 8 bytes
Application ACK/NAK	Basic DR Application	Fixed, 8 bytes
Outside Communication Connection Status	Basic DR Application	Fixed, 8 bytes
Link Layer ACK/NAK	Link Layer	Fixed, 2 bytes See 8.2
Message Type Supported Query	Link Layer	Fixed, 6 bytes See 8.3

The establishment of mandatory messages is necessary in order to guarantee that any DR communications system, when connected to any end-device, may still provide basic demand responsiveness. The mandatory list has been minimized in recognition that many present demand response systems provide only on/off control information and many end-devices have only on/off response capabilities.

8 Link layer

8.1 Use of link layer messages

Link Layer ACK and NAK messages shall be supported and used in response to all messages except other link layer ACKs and NAKs (i.e. do not ACK an ACK). The Message Type "supported query", specified in 8.3, is also required.

8.2 Link layer ACK/NAK

All packets shall result in a link layer ACK or NAK as shown in Figure 3. ACKs and NAKs are both two byte packets as shown in Table 6. NAKs are used to indicate that the packet was not accepted or understood.

Table 6 – ACK/NAK Packet

Type	Byte 1	Byte 2
ACK	0x06	0x00
NAK	0x15	NAK Code

Table 7 lists the NAK codes and uses.

Table 7 – Link layer NAK codes

Link NAK error code	Priority	Description	Usage
0x00		No Reason	Not used.
0x01	1	Invalid Byte	Indicates that a byte framing or other invalid byte error has occurred (e.g. missing stop-bit on the AC RS-485 interface).
0x02	2	Invalid Length	Used to indicate that the length indicated in the PDU length field is out of range.
0x03	3	Checksum Error	The bytes in the checksum field at the end of the message did not agree with the computed checksum.
0x04	4	Reserved	N/A
0x05	5	Message Timeout	Indicates that more than t_{ML} (specified in Table 3) elapsed between receipt of the first byte and receipt of the last byte in a message transmission. t_{ML} was selected to allow any combination of data rate and payload. As additional speeds and payloads are added some combinations may be invalid. This error code is not used by the DC form factor, as noted in Annex A.
0x06	6	Unsupported Message Type	Indicates that the "Message Type" is not supported.
0x07	7	Request Not Supported	Indicates that the requested setting is not supported (e.g. a requested Power Mode or Bit Rate is not supported). This error code is used only in regards to link layer requests, not in regards to lack of support for application layer requests.

In the event that multiple errors are detected, the Link NAK Error Code with the lowest priority number shall be returned.

8.3 Message Type "supported query"

Support of the message type "supported query" is mandatory. After power-up, communications modules and end-devices shall begin communication assuming only that the mandatory functions of the Basic DR application are supported. This requires the ability to handle only 8 byte messages, parsing of only a short list of payloads (two required commands), and allows NAK'ing of any unsupported commands.

To determine what message types are supported, the originator (can be either the UCM or the SGD) sends a packet of the message type in question (see Table 2 for the specified message type values) with a 0 length payload as shown in Table 8. If the receiver supports that message type, it shall respond with a Link Layer ACK. If the receiving device does not support the requested message type, it responds with an Unsupported Message Type NAK (see Table 7).

Table 8 – Message type "supported query"

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6
		Reserved	Payload length		
Desired Message Type		0x00	0x00	Checksum	

Case 1 – SGD supports intermediate Message Type:

a) UCM sends 08 02 00 00 7A D0 – Intermediate DR Message Type (0x08 0x02) Supported Query

b) SGD sends 06 00 – Link Layer ACK

Case 2 – UCM does not support NETWORK Message Type:

a) SGD sends 08 04 00 00 72 D6 – Network Message Type (0x08 0x04) Supported Query

b) UCM sends 15 06 – Link Layer NAK, Unsupported Message Type

9 Data-link messages

9.1 Message format

The data-link messages specified in 9.1 are employed to manage link layer optional features. Use and/or support of the data-link messages are all optional, with a lack of support indicating that only the link layer defaults are supported. The data-link commands follow the protocol-data-unit format specified in Table 9, with message type = (0x08, 0x03) and the payload field used as specified in Table 10.

Table 9 – Data-link message format

Message Type = 0x08, 0x03	Reserved, shall be '0'	Payload length = 0x00, 0x02	Opcode1	Opcode2	Checksum
2 bytes	3 bits	13 bits	1 byte	1 byte	2 bytes

Table 10 – Data-link command set

Description	Format	Usage
Request Different Power Mode	(8 bytes total, see Table 9) Opcode1 =0x16 Opcode2 = Power Level Indicator	Sent from the UCM to the SGD to request permission to draw higher power than the default. See 9.2 for “Power Level Indicator” details.
Request Different Bit Rate	(8 bytes total, see Table 9) Opcode1 =0x17 Opcode2 = Bit Rate Indicator	Sent from either the UCM or the SGD to the other to request a shift to a higher Bit Rate. See 9.3 for “Bit Rate Indicator” details.
Query: Maximum payload length?	(8 bytes total, see Table 9) Opcode1 = 0x18 Opcode2 = Default: 0x00, Optional: Max Payload Length Indicator	A query sent from either the UCM or the SGD to the other to ask how long message payloads can be. “Link NAK” means that only the default of 2 payload bytes is supported. If Opcode2 is not 0x00, then it indicates the max payload length code of the sender as described in the Response below. If the Opcode2 is 0x00, then the receiver shall perform a separate query to determine it.
Response: Maximum payload length	(8 bytes total, see Table 9) Opcode1 = 0x19 Opcode2 = Max Payload Length Indicator	Response to an Opcode 0x16 query. Max Payload Length Indicator: 0x00 = 2 (default) 0x01 = 4 0x02 = 8 0x03 = 16 0x04 = 32 0x05 = 64 0x06 = 128 0x07 = 256 0x08 = 512 0x09 = 1024 0x0A = 1280 0x0B = 1500 0x0C = 2048 0x0D = 4096 0x0E to 0xFF reserved
Query: Get SGD Slot Number	(8 bytes total, see Table 9) Opcode1 = 0x1A Opcode2 = 0x00	Query sent from the UCM to the SGD to determine which slot the UCM is installed in.
Response: Slot Number	(8 bytes total, see Table 9) Opcode1 = 0x1B Opcode2 = Slot Number in upper 3 bits	Response to Opcode 0x1A. Slot Number = a value from 0x0n to 0xEn indicating the slot number in which the UCM is installed. The slot number is contained in the upper 3 bits.
Query: Get Available Slot Numbers	(8 bytes total, see Table 9) Opcode1 = 0x1C Opcode2 = 0x00	UCM asking the SGD what slot numbers exist and which are used.

Description	Format	Usage
Response: Available Slot Numbers	(8 bytes total, see Table 9) Opcode1 = 0x1D Opcode2 = Slot Number Detail	Response to Opcode 0x1C. Slot Number Detail = Bit-field: 0 = Slot does not exist or is not occupied 1 = Slot is occupied Bit 0 (LSbit) = Slot Number 0 … Bit 7 (MSbit) = Slot Number 7
Send Next Command to Slot	(8 bytes total, see Table 9) Opcode1 = 0x1E Opcode2 = Slot Number	Instructs the SGD to forward the next message to the indicated Slot Number. Slot Number = a value from 0x00 to 0x07 indicating the slot number to which the message is to be sent.

9.2 Interface power limit negotiation

UCMs may optionally use this data-link function to request that the power consumption limits be changed to the level indicated by the request. The Opcode2 field, Power Level Indicator, is an enumeration as shown in Table 11.

Table 11 – Interface power level indicator codes

Power level indicator	DC form factor		AC form factor		
	Maximum continuous average	Maximum peak [a]	Maximum continuous average	Maximum peak [a]	Maximum instantaneous [b]
0x00 (default)	50 mA	300 mA	50 mA,rms	300 mA,rms	10 A
0x01	150 mA	2 A	N/A	N/A	N/A
0x02	250[mA	2 A	N/A	N/A	N/A
0x03	500 mA	2 A	N/A	N/A	N/A
0x04	750 mA	2 A	N/A	N/A	N/A
0x05 to 0xFF (Reserved)					

[a] The maximum peak value is allowed for a 100 ms maximum duration, with a 10 % maximum duty cycle in any given second.

[b] The maximum instantaneous value is allowed for 1 ms maximum duration, with a 10 % maximum duty cycle in any given 10-ms period and a 1 % maximum duty cycle in any given 10-s period.

For the DC Form Factor interface, power is supplied at low voltage DC and for the AC Form Factor interface, at the AC line voltage, as specified in the respective physical layer annexes.

All UCMs shall operate within the default power limits until negotiating a higher power with SGD. It is recognized that wired media UCMs may draw power from their media (PoE, PLC, telephone, etc.) if additional power is required from a separate power supply or interface dongle.

This function always results in either a “Link ACK or a “Link NAK” response. “Link ACK” means that the requested power mode is approved. However, in order to request a new power level, the following procedure should be followed to determine support for power mode changes. Any negotiation involving optional message types starts with sending a Message Type Supported Query, the details of which are covered in 8.3. After that initial negotiation, UCMs first send a request for the Power Level Indicator 0x00 (default) and:

- If the SGD responds with “Link NAK” and error code 0x07, then the Request Different Power Mode message is not supported at all. This follows because Power Level Indicator 0x00 is the default and shall be supported if the Request Different Power Mode message is supported.
- If the SGD ACKs the Power Level Indicator 0x00 (default), then the Request Different Power Mode message is supported. Subsequently, the UCM can request higher power levels (non-default) in succession to determine the power level supported by the SGD.

Case 1 – SGD does not support “Request Different Power Mode” message at all:

a) UCM sends 08 03 00 00 76 D3 – Message Type Supported Query for Data-Link Messages (0x08 0x03)
b) SGD sends 06 00 – Link Layer ACK
c) SGD sends 08 03 00 00 76 D3 – Message Type Supported Query symmetrical response
d) UCM sends 06 00 – Link Layer ACK
e) UCM sends 08 03 00 02 16 00 C0 71 – Power Level Indicator 0x00 (default) Request message
f) SGD sends 15 07 – Link Layer NAK, Request Not Supported Error

Case 2 – SGD supports “Request Different Power Mode” up to level 0x02 (DC form factor only):

a) UCM sends 08 03 00 00 76 D3 – Message Type Supported Query for Data-Link Messages (0x08 0x03)
b) SGD sends 06 00 – Link Layer ACK
c) SGD sends 08 03 00 00 76 D3 – Message Type Supported Query symmetrical response
d) UCM sends 06 00 – Link Layer ACK
e) SGD sends 08 03 00 02 16 00 C0 71 – Power Level Indicator 0x00 (default) Request message
f) UCM sends 06 00 – Link Layer ACK, default power mode and Request message supported
g) SGD sends 08 03 00 02 16 01 BE 72 – Power Level Indicator 0x01 Request message
h) UCM sends 06 00 – Link Layer ACK, Power Level Indicator 0x01 supported
i) SGD sends 08 03 00 02 16 02 BC 73 – Power Level Indicator 0x02 Request message
j) UCM sends 06 00 – Link Layer ACK, Power Level Indicator 0x02 supported
k) SGD sends 08 03 00 02 16 03 BA 74 – Power Level Indicator 0x03 Request message
l) SGD sends 15 07 – Link Layer NAK, Request Not Supported Error, therefore highest power level support is 0x02

9.3 Bit rate negotiation

For the DC Form Factor, this link layer function establishes the maximum rate at which the SGD may clock the SPI interface. For the AC Form Factor with the asynchronous RS-485 serial interface, it establishes the Bit Rate that both the UCM and the SGD shall use in order to communicate with one another. Either UCM or SGD may optionally use this data-link function to request a different Bit Rate than the default or current rate as shown in Table 12.

Table 12 – Bit rate indicator

Bit rate indicator	**Bit rate** [kbit/s]
0x00	19,2 (default)
0x01	38,4
0x02	57,6
0x03	115,2
0x04	256
0x05	460,8
0x06	921,6
0x07	1843,2
0x08	3686,4
0x09 to 0xFF	Reserved

If the requested Bit Rate is supported, “Link ACK” is immediately returned at the original Bit Rate. Future communication is at the new requested Bit Rate until such time as the units revert to default or a different Bit Rate is requested. “Link NAK” with Error Code 0x07 means that the requested Bit Rate is not supported.

Similar to procedure specified at the end of 9.2, the default Bit Rate Indicator 0x00 should be sent first by the UCM to determine support for the Request Different Bit Rate message. Upon success (Link Layer ACK), the UCM can request higher bit rates using the other indicators.

If no valid communication is exchanged for more than 15 minutes, both SGD and UCM shall return to the default of 19,2 kbit/s as specified in 9.4.

9.4 Power-up and state reset

Upon power cycle, all operational settings shall return to defaults. Any non-default settings (e.g. Bit Rate, Power Level) shall be renegotiated following a power cycle.

The “Outside Communication Connection Status” message specified in Clause 10 requires that a message be sent at least once every 1 minute to 5 minutes. If no valid communication is exchanged for more than 15 minutes, both SGD and UCM shall return to defaults. This includes returning to the default bit rate and UCM’s limiting power consumption to the default levels.

9.5 Security

If present, security shall be handled above the link layer (network, transport and/or application) as specified in Clause 15.

The Basic and Intermediate DR applications’ messages specified in this document do not employ any security mechanisms.

9.6 Setting slot numbering

During initialization, the UCMs in a multiple module system do not have an assigned slot. Each UCM that supports slot numbering shall send a “Get SGD Slot Number” message.

Slot number 0 is reserved for universal communications and for communications in a system that does not support slot numbering.

The mechanism of assigning slot numbers is completely within the domain of the SGD.

10 Basic DR application (Message Type = 0x08, 0x01)

10.1 Basic DR application commands

10.1.1 Message format

10.1 specifies a set of Basic DR application commands and explains how they are supported by the MCI. Understanding the Basic DR commands is important because even advanced communications modules and devices that may normally use more complex demand response protocols are required to be able to fall back to a few required Basic DR messages in the event that the device to which they are connected is not capable of the same advanced functionality.

There is no nesting of commands, and no requirement for history keeping by the SGD. As noted previously, the last received command of equal or greater priority shall be effective. Because the SGD acts upon the most recently received command, if the device is in Shed state and then receives a CPP or Grid Emergency, the SGD shall understand that the intent is to transition directly into the new event without passing through an “End Shed” state.

Each Basic DR message shall be formatted as shown in Table 13, with the message type being a “0x08, 0x01” and the payload being a 1-byte Opcode1 and a 1-byte Opcode2.

Table 13 – Basic application data format

Message Type = 0x08, 0x01	Reserved, shall be ‘0’	Payload length = 0x00, 0x02	Opcode1	Opcode2	Checksum
2 bytes	3 bits	13 bits	1 byte	1 byte	2 bytes

The Basic DR message payloads are specified in Table 14. High priority messages are noted in red-coloured blocks.

Table 14 – Basic DR application command set

Description	Opcode1	Opcode2	Usage	Mandatory?	
				for SGDs	for UCMs
Shed	0x01	Event Duration	Sent from the UCM to the SGD when a load-shed event begins. If other load management commands are attempted but not accepted by the SGD, then the UCM shall fall back to this Opcode. See 10.1.3 for description and usage. NOTE Event Durations of 10 minutes or less relate to “spinning reserve” uses. Event Durations greater than 10 minutes relate to “shift” uses. **Priority**: “High”	✓	✓
End Shed/Run Normal	0x02	0x00 (Not Used)	This command shall be sent once from the UCM to the SGD when a load shed or other curtailment event ends, regardless of whether the Event Duration is provided for informational purposes. Curtailment event commands that are terminated by this End Shed include: Shed 0x01, Request for Power Level 0x06, Critical Peak Event 0x0A, Grid Emergency 0x0B, and Load Up 0x17. **Priority**: “High”	✓	✓
Basic Application ACK	0x03	ACK’ed Opcode1	Acknowledge successful receipt and support of previous command. Returned for all supported Opcodes except 0x03 (do not “Application ACK” an “Application ACK”) and those that are queries and have a natural response, such as 0x12. **Priority:** “Not Applicable”	✓	✓
Basic Application NAK	0x04	Reason	Reject previous command. Sent from either SGD or UCM to the other when any of the following reasons occur. Reason: 0x00 = No reason given 0x01 = Opcode1 not supported 0x02 = Opcode2 invalid 0x03 = Busy 0x04 = Length Invalid 0x05 to 0xFF Reserved **Priority:** “Not Applicable”	✓	✓

Description	Opcode1	Opcode2	Usage	Mandatory?	
				for SGDs	for UCMs
Request for Power Level	0x06	Percent Setting	Sent from the UCM to the SGD to request that its average Power Level (relative to the full rating of the device) be reduced to a level between 0 and 100 % of full value on a 7 bit precision scale. Percent Setting: MSbit = 0, Least significant 7 bits: 0x00 to 0x7F = 0 to 100% power absorbed MSbit = 1, Least significant 7 bits: 0x00 to 0x7F = 0 to 100 % power produced Details regarding the use of this command are provided in 10.2.1. **Priority**: "High"		
Present Relative Price	0x07	Relative Price Indicator	Sent from the UCM to the SGD when a change in relative price occurs to inform of the new relative price. Relative Price Indicator: See 10.2.2 for description and usage. If NAK'ed, UCM shall use Opcodes 0x01 and 0x02 to inform SGDs. **Priority:** "Low"		
Next Period Relative Price	0x08	Relative Price Indicator	Sent from the UCM to the SGD when a change in relative price occurs to inform of the relative price in the next future period. Relative Price Indicator: See 10.2.2 for description and usage. **Priority:** "Low"		
Time Remaining in Present Price Period	0x09	Event Duration	Sent from the UCM to the SGD when a change in price occurs to inform of the duration of the present price period. Event Duration: See 10.1.3 for description and usage. **Priority**: "Low"		
Critical Peak Event	0x0A	Event Duration	Critical Peak Event is in Effect (Critical Peak Events are intended to represent events that occur only a few times per year, on system peak days, for a maximum duration determined by the terms of the programme) Sent once from the UCM to the SGD when a critical peak price event goes into effect. If NAK'ed, send Opcode 0x01. Event Duration: See 10.1.3 for description and usage. **Priority:** "High"		
Grid Emergency	0x0B	Event Duration	A Grid Emergency is occurring. Sent once from the UCM to the SGD when a grid emergency event goes into effect. If NAK'ed, send Opcode 0x01. Event Duration: See 10.1.3 for description and usage. **Priority**: "High"		

Description	Opcode1	Opcode2	Usage	Mandatory?	
				for SGDs	for UCMs
Grid Guidance	0x0C	Guidance Indicator	Sent from the UCM to the SGD to provide an arbitrary indication of whether energy consumption is preferred or not. Guidance Indicator: 0x00 = Bad Time to Use Energy 0x01 = Neutral 0x02 = Good / Preferred Time to Use Energy 0x03 to 0xFF = Reserved Priority: “Low”		
Outside Comm Connection Status	0x0E	Connect Status Code	Sent from the UCM to the SGD when outside communication status is gained or lost. When in the “communicating” state, this command is resent every 1 minute to 5 minutes so that SGDs may know that the UCM is still attached and working. Connect Status Code: 0x00 = No / Lost Connection 0x01 = Found / Good Connection 0x02 = Poor/Unreliable Connection 0x03 to 0xFF = Reserved **Priority:** “Not Applicable”	✓	✓ If known, it shall be shared
Customer Override	0x11	0 = No Override, 1 = Override	Sent from the SGD to the UCM anytime a customer chooses to change its override state. Also sent immediately after acknowledging receipt of any load reduction message if the customer’s preference is permanently set to override. **Priority:** “Not Applicable”		
Query: What is your operational state?	0x12	0x00 (Not Used)	Sent from the UCM to the SGD. **Priority:** “Not Applicable”		
State Query Response	0x13	Operating State Code	Sent from the SGD to the UCM in response to an Opcode 0x12 query Operating State Codes: See 10.2.4 for description and usage. **Priority:** “Not Applicable”		
Sleep	0x14	0x00	Sent from the SGD to the UCM to inform it that the SGD is idle, that information from the UCM is not needed, and that the UCM may shift into a low power state, if exists. This command assumes that the UCM is provided with a “Wake” command before it will be expected to operate. Usage assumes the UCM can hear “Wake” messages while in “Sleep” mode. **Priority:** “Not Applicable”		

Description	Opcode1	Opcode2	Usage	Mandatory?	
				for SGDs	for UCMs
Wake / Refresh Request	0x15	0x00	Sent from the SGD to the UCM to end a "Sleep" period and to request that all messages related to currently valid connection status, price, time and/or load curtailment be sent. UCMs that previously received a "Sleep" message shall provide up-to-date grid information within 10 seconds of receipt of a "Wake" signal. How UCMs function internally during Sleep periods in order to be able to support this capability is up to the UCM provider. **Priority:** "Not Applicable"		
Simple Time Sync	0x16	Time Value	When supported, this command is sent from the UCM to the SGD on the hour. Time Value: Bits 7..5 = Weekday (0 = Sunday, 6 = Saturday) Bits 4..0 = Hour* of Day (0 to 23) * This is the local hour, including DST where applicable, for display on the SGD clock as-is.		
Load Up	0x17	Event Duration	This command is the opposite (complement) of the "Shed" command. It requests that the end-device runs now, and continues as possible. The assumption of this command is that energy is not wasted, but that products such as thermal devices will cycle on and operate until the maximum stored energy state is reached. Sent from the UCM to SGD at the beginning of the event. The End Shed/Run Normal message will end this event. Event Duration See 11.2.7 for description and usage **Priority**: "High"		
Pending Event Warning	0x18	Warning Duration	Used to provide a warning to the SGD and possibly user that a DR event will occur soon. Warning Duration See 11.2.7 for description and usage See 10.1.3 for usage to cancel a previously notified event. **Priority:** "Not Applicable"		

10.1.2 Basic message fixed length

The Basic DR Application messages are fixed at 8 bytes total length, because the payload always consists of 2 bytes. Since the Basic DR Application message has a fixed structure and each field has a fixed length, it is easy to parse to a field of interest.

10.1.3 Event Duration field

Basic DR Opcode1s 0x01, 0x09, 0x0A and 0x0B include a secondary Opcode2 that is an Event Duration indicator. This indicator is a single byte that defines the duration (or remaining

duration) of the present event or price period. The duration field is limited to a single byte in order to accommodate the capabilities of controllers in some smart-grid devices. As the duration of events increases, the precision may be reduced while achieving the same energy management goal. The value of 0x00 is reserved to indicate that the Event Duration is unknown and the value of 0xFF indicates that the duration is longer than what can be represented. For values from 0x01 to 0xFE, the indicated time is specified by a square function of the Opcode2 byte value:

$$\text{Time in seconds} = 2 \times (\text{byte value})^2$$

This results in the ability to represent a range of Event Durations between 2 and 129 032 seconds (approximately 35,8 hours) as indicated in Figure 5. When used in conjunction with the "Pending Event Warning" command (0x18), an "Event Duration" field value of 0xFF shall cancel any previously notified event.

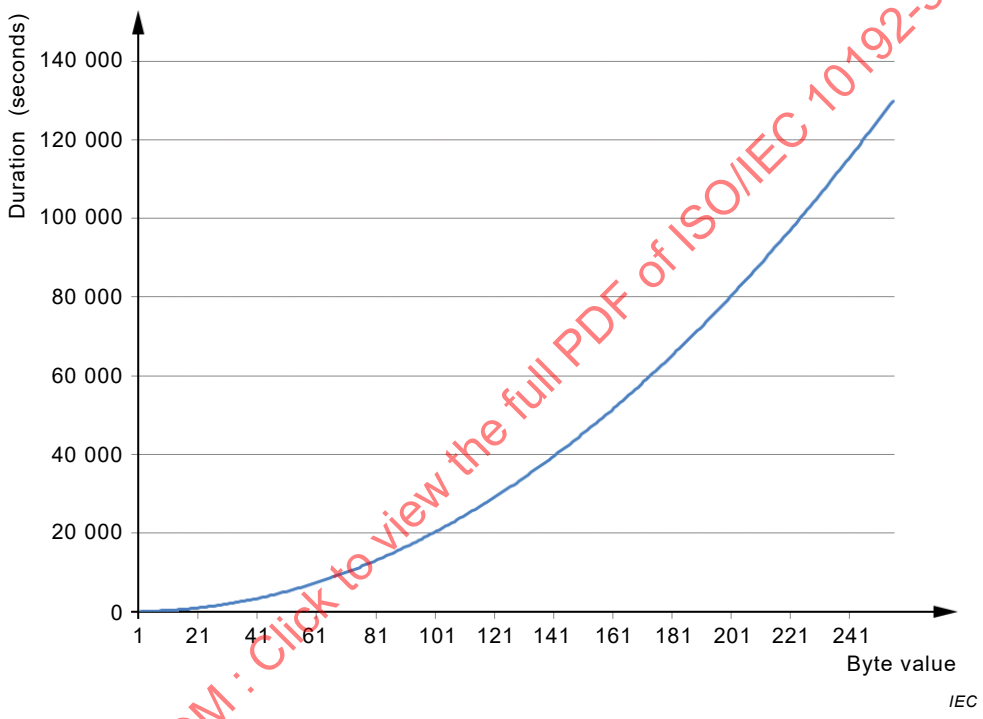


Figure 5 – Non-linear event duration scaling

10.1.4 Grouped messages

The Basic DR messages with Opcodes 0x07, 0x08 and 0x09 are considered a grouped set, sent from the UCM to the SGD to represent relative price information. As a requirement, UCMs that provide the Basic DR price look-ahead capability enabled by messages 0x08 and 0x09 shall send these messages along with the 0x07 message within the timing t_{IM} specified in Table 3. The 0x07 message may be used alone if the UCM intends only to provide current price information.

As a recommendation to avoid incorrect responses, SGDs that receive any of these messages may delay action until it is determined whether or not others in the group are immediately following.

10.2 Usage and details of basic DR application messages

10.2.1 Request for power level (Opcode 0x06)

Used by the service provider to ask suitable loads to provide ancillary service to the grid such as frequency support, in-hour load following, etc. Typical signal changes could occur as often

as every 5 minutes in some scenarios or every few seconds in others. The mechanism used by the end-device to respond (e.g. analogue variability, adjustable regulator, or PWM duty cycling) is up to the manufacturer of the SGD and is not specified by this request.

EXAMPLE A water heater's bottom heating element, instead of operating at 4 500 W, could be managed at certain times of day to operate at 900 W (20 %). This setting could be modified rapidly in order to compensate for variable generation sources such as wind power.

During usage, the UCM relays the command to SGD; Application ACKs and NAKs from SGD may be conveyed upstream to Service Provider, if applicable.

For SGDs, loads that operate at approximately the requested average Power Level shall ACK this command; under all other conditions a NAK shall be provided. A device for various reasons might be able to comply at some times and not at others, e.g. exceeding the number of design relays cycles permitted per day. ACKs shall be reserved for those instances where the target setting is actually applied.

10.2.2 Relative price commands (Opcode 0x07 and 0x08)

The relative price commands are intended for use in variable-price systems wherein the UCM is able to provide to the SGD with an indication of the ratio of the current price to the average price. As indicated in Figure 6, the Opcode2 field of these messages (Opcode1 = 0x07 or 0x08) provides the relative price indicator.

Relative_Price_Indicator = Present_Price / Average_Price

NOTE 1 See Annex F for an explanation of how Average Price may be determined.

The value of 0x00 is reserved to indicate that the Relative Price is unknown and the value of 0xFF indicates that the Relative Price is higher than what can be represented. For values from 0x01 to 0xFE, the indicated Relative Price Indicator is specified by a non-linear function of the byte value:

Relative_Price_Indicator = (Byte Value-1) × (Byte Value + 63) / 8 192

This equation results in the scale indicated in Figure 6.

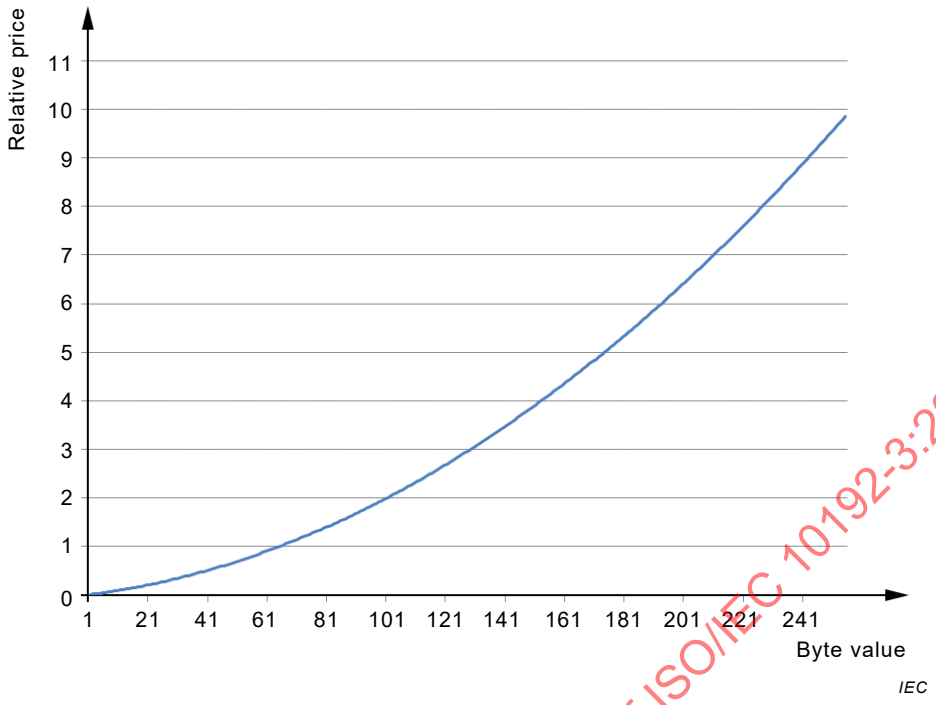


Figure 6 – Non-linear relative price scaling

For SGDs the “Relative_Price_Indicator” may be simply used directly as an indication of how high or low the energy price for the period is relative to normal. As a simple ratio, it may be directly converted to percentages for customer presentation or preference settings.

The intent of the Opcode 0x07 is that it be sent from the UCM to the SGD at the beginning of each new price period. It reflects the price that has just become effective. The intent of the Opcode 0x08 is to provide a forward-looking indication of the relative price in the next future period. If available and supported, UCMs shall attempt to provide SGDs with both the present (0x07) and next (0x08) indicators. SGDs may support neither, one, or both, at their discretion.

The pricing related commands can be used for curtailment or load shedding purposes or they may be used only for the purpose of display to the end user. In either case, the usage shall obey the priority as set out in Clause 9 and in Table 10.

NOTE 2 Actual price information is supported through the use of more advanced commands as specified in 10.1.1.

10.2.3 Time remaining in present price period (Opcode 0x09)

This command is related to the Relative Price Messages and provides an indication of the time remaining until the next price change. When supported, this command shall be sent once from the UCM to the SGD when a new relative price becomes effective or when a refresh is requested by the SGD. This “Time Remaining in Present Period” message may be of most value when used in conjunction with the “Next Period Relative Price” message so that end-devices know whether the price is increasing or decreasing at the end of this period.

10.2.4 Operating state monitoring (Opcodes 0x12 and 0x13)

Opcode 0x12 requests the operational state of the SGD and Opcode 0x13 provides the response. The Opcode 0x13 response includes a single byte Opcode2 that describes the state of the device as explained in Table 16. As shown in Table 15 the operating state codes may be extended in future versions of ISO/IEC 10192-3. Up to 255 states may be specified.

Table 15 – Operating state codes

Operating state code	Meaning
0	Idle Normal
1	Running Normal
2	Running Curtailed Grid
3	Running Heightened Grid
4	Idle Grid
5	SGD Error Condition
6 to 255	Unused

Op State Code 0 "Idle Normal" indicates that the SGD is not presently carrying out any demand response function and is in a "normal" operational state, albeit idle. This code indicates a low power state, including user-operated devices that are not presently being used and automatically operated devices that are in a standby state.

EXAMPLE 1 A clothes dryer that is not operating, a refrigerator in idle mode (any time the compressor is not running), a water heater without a heating element energized, a TV in off/standby mode, etc.

Op State Code 1 "Running Normal" means the SGD is operating in any normal mode or process. This includes user-operated devices that are presently being used (a washing machine that is in any cycle of the washing process including "soak", an oven that is maintaining a set temperature even if the element is off at the moment, etc.), as well as automatically-operated equipment that is currently active (an HVAC unit that is presently running, a water heater with heating element energized, etc.).

Op State Code 2 "Running Curtailed Grid" means the SGD is running, but has responded to some grid signal and has reduced average power relative to normal or unrestricted operation. An SGD may respond to an emergency curtailment for only one minute; if the state-query comes during this minute then the response would be state code 2. If the state query comes after the normal control method resumes then the state code response would be 1.

EXAMPLE 2 A dryer may cycle the heating element in some way to reduce average power, or a refrigerator may stop the compressor or raise the temperature setting, etc.

Op State Code 3 "Running Heightened Grid" means the SGD has responded to a grid signal and has increased average power relative to normal or unrestricted operation.

EXAMPLE 3 An HVAC or refrigerator consuming more average power (putting additional heat or cold into building, tank, or other thermal mass) in response to lower price or a more specific control command.

EXAMPLE 4 SGD operating in a grid friendly mode and using more average power. Grid friendly mode applies to SGDs that have flexibility to operate over a wide range of average Power Levels at times not constrained by customer demands, (e.g. a water heater maximizing water temperature at night, or an EV charging its battery at night).

Op State Code 4 "Idle Grid" means the SGD has stopped (reduction to lowest consumption state) or is deferring consumption to a later time, in response to a grid signal. This state is different from Op State Code 1 because Op State Code 4 implies that the SGD would be operating were it not for the grid signal. Whereas Op State Code 2 is used to

indicate some level of partial reduced consumption, Op State Code 4 indicates full reduction to Idle level.

Op State Code 5 "SGD Error Condition" means the SGD is not operating because it needs maintenance support or is in some way disabled (i.e. no response to the grid).

Table 16 – Operating-state codes for usage conditions

Demand response event in effect	SGD energy use at the moment of the request	
	Operating / in Use (significant consumption)	Idle / not in use (insignificant consumption)
Run Normal / End Shed	Op State Code 1	Op State Code 0
Shed	Op State Code 2	Op State Code 4
Critical Peak Event	Op State Code 2	Op State Code 4
High Price	Op State Code 2	Op State Code 4
Low Price	Op State Code 3	Op State Code 3
Load Up	Op State Code 3	Op State Code 3

11 Intermediate DR application (Message Type = 0x08, 0x02)

11.1 Intermediate DR message set

11.1 specifies intermediate commands to support more advanced functions. Unlike the Basic DR Application message set, which is fixed at 8 bytes total message length, Intermediate DR application messages have variable lengths. Some message definitions include Null terminated strings that cause the length of the packet to be content specific.

Prior to sending any of the messages specified in 11.1, the device shall negotiate the maximum payload size using the "Query: Maximum payload length?" and "Response: Maximum payload length" messages specified in Table 10. This document prohibits transfer of serial messages that would overflow buffers of the recipient.

Intermediate DR commands are all optional. Where the terms "optional" and "mandatory" are used in the tables in 11.1, they refer only to the requirement for those fields within the message being described. Where multiple fields are labelled as "optional", the sender shall include all elements up to the last "optional" value transmitted. When the sender includes an "optional" value and does not have a valid value, it shall send the highest positive value for that field. Intermediate DR commands use the protocol-data-unit format shown in Table 1 with the "Payload" field as specified in Table 18.

EXAMPLE A single byte value would be set to 0xFF, an unsigned two-byte value would be set to 0xFFFF and a signed two-byte value would be set to 0x7FFF.

Fields designated as Signed values use Two's Complement format. The signed 8-bit value −5 would be encoded as 0xFB. The signed 16-bit value −1 would be encoded as 0xFFFF.

Table 17 provides a list of the categories for the messages specified in 11.1. The Opcode1 column refers to the first byte (most significant byte) of the payload section as specified in Table 1.

Table 17 – Intermediate DR application command set (command byte description)

Opcode1	Usage categories
0x00	Reserved
0x01	Device Information
0x02	Time & Date
0x03	Tier & Price
0x04	Demand Reduction
0x05	Demand Response Event Schedules
0x06	Consumption/Production
0xF0 to 0xFF	Manufacturer Specific

Table 18 provides a more granular list of the messages specified in 11.1. High priority messages are noted in red-coloured blocks.

Table 18 – Intermediate DR application command set

Description	Payload			Usage
	Opcode1	Opcode2	Additional payload DEFINITIONS	
Info Request	0x01	0x01	Defined in 11.2.1	Request device information
				Priority: "Not Applicable"
Get/Set UTC Time	0x02	0x00	Defined in 11.2.2	Set or request Time
				Priority: "Not Applicable"
Get/Set Energy Price	0x03	0x00	Defined in 11.2.3	Set or request the current price of energy
				Priority: "Low"
Get/Set Tier	0x03	0x01	Defined in 11.2.4	Set or request the current tier value
				Priority: "Low"
Get/Set Temperature Offset	0x03	0x02	Defined in 11.2.5	Set or request the current temperature offset value
				Priority: "High"
Get/Set Set Point	0x03	0x03	Defined in 11.2.6	Set or request the current temperature set point value(s)
				Priority: "High"
Start Autonomous Cycling	0x04	0x00	Defined in 11.2.7	Start a Demand Reduction cycling event per the parameters passed in the command
				Priority: "High"
Terminate Autonomous Cycling	0x04	0x01	Defined in 11.2.8	Terminate a Demand Reduction cycling event
				Priority: "High"
Demand Response Event Schedules	0x05	0x00	Defined in 11.3.2	Send Scheduled Events Request
				Priority: "Not Applicable"
Get/Set Commodity Read	0x06	0x00	Defined in 11.4.2	Get or Set(Publish) Energy Consumption Values
				Priority: "Not Applicable"
Get/Set Commodity Subscription	0x06	0x01	Defined in 11.4.3	Gets the Commodity Types supported by a metering device/system and the update frequency. Sets the types that are being subscribed to.
				Priority: "Not Applicable"

Intermediate DR Message responses include a response code byte. Table 19 provides a list of the defined response codes.

Table 19 – Response code values

Response code	Description
0x00	Success
0x01	Command not implemented
0x02	Bad Value – one or more values in the message are invalid
0x03	Command Length Error – command is too long
0x04	Response Length Error – response is too long
0x05	Busy
0x06	Other Error

11.2 Usage and details of Intermediate DR application messages

11.2.1 Info request

11.2.1.1 Purpose

This command may be optionally used by the UCM to determine information about the SGD and by the SGD to determine information about the UCM.

11.2.1.2 Format GetInformation() – Request

Payload byte	Hex value	Comments	Mandatory/optional
1	0x01	Opcode1	M
2	0x01	Opcode2	M

11.2.1.3 Format GetInformation() – Reply

11.2.1.3.1 Payload

Payload byte	Hex value	Comments	Mandatory/optional
1	0x01	Opcode1	M
2	0x81	Opcode2 (Reply always has bit 7 high)	M
3	0x00	Response Code	M
4 to 5		Version of ISO/IEC 10192-3 – ASCII [a]	M
6 to 7		Vendor ID	M
8 to 9		Device Type	M
10 to 11		Device Revision	M
12 to 15		Capability Bitmap	M
16		Reserved	M
17 to 32		Model Number – ASCII	O
33 to 48		Serial Number – ASCII	O
49		Firmware Year – 20YY	O
50		Firmware Month	O
51		Firmware Day	O
52		Firmware Major	O
53		Firmware Minor	O
[a] Value is 0x00, 0x00 for the first edition of ISO/IEC 10192-3.			

Device Information included here is read-only and shall not change after the device has been powered on (i.e. this value may be read once at power-on with confidence that there is no need to read it again until a subsequent reset or power cycle). Typical values included in the device information command include the version of this standard (0x00, 0x00 for initial version) that the unit was designed for, firmware information, Serial Number and Model Number.

11.2.1.3.2 Vendor ID

Vendors who support this command shall request a unique vendor ID provided by the standard development organization or users alliance.

11.2.1.3.3 Device Type

SGD device types		UCM device types (Phy/MAC)	
Device type	**Description**	**Device type**	**Description**
0x0000	Unspecified Type	0x4000	Wireless (other, non-standard)
0x0001	Water Heater – Gas	0x4001	PLC (other, non-standard)
0x0002	Water Heater – Electric	0x4002	Wired (other, non-standard)
0x0003	Water Heater – Heat Pump	0x4003	IEEE 802.15.4
0x0004	Central AC – Heat Pump	0x4004	IEEE 802.11 (e.g. Wi-Fi)
0x0005	Central AC – Fossil Fuel Heat	0x4005	IEEE 802.16 (e.g. WiMAX)
0x0006	Central AC – Resistance Heat	0x4006	VHF/UHF Pager
0x0007	Central AC (only)	0x4007	FM (RDS / RBDS)
0x0008	Evaporative Cooler	0x4008	Wired Ethernet
0x0009	Baseboard Electric Heat	0x4009	Coaxial Networking
0x000A	Window AC	0x400A	Telephone Line
0x000B	Portable Electric Heater	0x400B	IEEE 1901 (Broadband power line)
0x000C	Clothes Washer	0x400C	IEEE 1901.2 (Narrowband-PLC)
0x000D	Clothes Dryer – Gas	0x400D	ITU-T G.hn
0x000E	Clothes Dryer – Electric	0x400E	ITU-T G.hnem (Narrowband-PLC)
0x000F	Refrigerator/Freezer	0x400F	Cellular (3g, 4g (LTE), Mobile, any)
0x0010	Freezer	0x4010	Utility AMI, Wireless
0x0011	Dishwasher	0x4011	Utility AMI, PLC
0x0012	Microwave Oven	0x4012	ISO/IEC 12139-1, High speed PLC
0x0013	Oven – Electric		
0x0014	Oven – Gas	All others	Available for Assignment
0x0015	Cook Top – Electric		
0x0016	Cook Top – Gas		
0x0017	Stove – Electric		
0x0018	Stove – Gas		
0x0019	Dehumidifier		
0x0020	Fan		
0x0030	Pool Pump – Single Speed		
0x0031	Pool Pump – Variable Speed		
0x0032	Electric Hot Tub		
0x0040	Irrigation Pump		
0x1000	Electric Vehicle		
0x1001	Hybrid Vehicle		
0x1100	Electric Vehicle Supply Equipment – general (SAE J1772)		
0x1101	Electric Vehicle Supply Equipment – Level 1 (SAE J1772)		
0x1102	Electric Vehicle Supply Equipment – Level 2 (SAE J1772)		
0x1103	Electric Vehicle Supply Equipment – Level 3 (SAE J1772)		
0x2000	In Premises Display		
0x5000	Energy Manager		
0x6000	Gateway Device		
0x8000 to 0xFFFF	Manufacturer Defined Device Types		

11.2.1.3.4 Capability bitmap

Bit (2^n)	Description
0	Cycling supported
1	Tier mode supported
2	Price mode supported
3	Temperature Offset supported
4 to 15	Reserved

11.2.1.3.5 Model number

Device model number, all zeros = not supported

11.2.1.3.6 Serial number

Device serial number, all zeros = not supported

11.2.1.3.7 Firmware year

Year − 2000 (e.g. Firmware Year = 11 (0x0B) for 2011)

11.2.1.3.8 Firmware month

0 (0x00) = January, 11 (0x0B) = December

11.2.1.3.9 Firmware day

1 to 31

11.2.2 Get/Set UTC time

11.2.2.1 Function

Set the time on the device.

11.2.2.2 Format GetUTCTime() – Request

Payload byte	Hex value	Comments	Mandatory/optional
1	0x02	Opcode1	M
2	0x00	Opcode2	M

11.2.2.3 Format GetUTCTime() – Reply

Payload byte	Hex value	Comments	Mandatory/optional
1	0x02	Opcode1	M
2	0x80	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M
4 to 7		UTC Seconds	M
8		Time zone offset in quarter hours (e.g. EST = −20)	M
9		DST Offset in quarter hours	M

11.2.2.4 Format SetUTCTime() – Request

Payload byte	Hex value	Comments	Mandatory/optional
1	0x02	Opcode1	M
2	0x00	Opcode2	M
3 to 6		UTC Seconds	M
7		Time zone offset in quarter hours (e.g. EST = −20)	M
8		DST Offset in quarter hours	M

11.2.2.5 Format SetUTCTime() – Reply

Payload byte	Hex value	Comments	Mandatory/optional
1	0x02	Opcode1	M
2	0x80	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M

UTC Seconds

Unsigned 32 bit value of seconds since 1/1/2000 00:00:00 UTC

Time Zone Offset

Signed 8 bit value, offset from UTC in 15 minute intervals (e.g. EST would be −20 (0xEC))

DST Offset

Unsigned, if non-zero, add value in 15 minute intervals to UTC seconds for local time conversion

11.2.3 Get/Set energy price

11.2.3.1 Overview of Get/Set energy price

If the SGD supports the Energy Price messages and it supports the GetInformation Reply message, then the "Price Mode" bit should be set (1) in the "Capability bitmap" field of the GetInformation Reply (11.2.1.3.4) from the SGD to the UCM. This facilitates interoperability and functional discovery by the UCM.

11.2.3.2 Format GetEnergyPrice() – Request

Payload byte	Hex value	Comments	Mandatory/optional
1	0x03	Opcode1	M
2	0x00	Opcode2	M

11.2.3.3 Format GetEnergyPrice() – Reply from UCM

Payload byte	Hex value	Comments	Mandatory/optional
1	0x03	Opcode1	M
2	0x80	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M
4 to 5		Current Price	M
6 to 7		Currency Code	M
8		Digits After Decimal Point	M
9 to 12		Expiration Time/Date in UTC seconds	O
13 to 16		Next Price	O

11.2.3.4 Format SetEnergyPrice() – Request

Payload byte	Hex value	Comments	Mandatory/optional
1	0x03	Opcode1	M
2	0x00	Opcode2	M
3 to 4		Current Price	M
5 to 6		Currency Code	M
7		Digits After Decimal Point	M
8 to 11		Expiration Time/Date in UTC seconds	O
12 to 15		Next Price	O

11.2.3.5 Format SetEnergyPrice() – Reply from SGD

Payload byte	Hex value	Comments	Mandatory/optional
1	0x03	Opcode1	M
2	0x80	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M

Current Price

Unsigned 32 bit value

Currency Code

Unsigned 32 bit value, in accordance with ISO 4217.

NOTE The codes can be found at http://www.iso.org/iso/home/standards/currency_codes.htm.

Digits After Decimal Point

Unsigned, the number of digits after the decimal point

EXAMPLE 22¢ = 0.22 dollars so the Digits After Decimal Point value would be 2.

Expiration Time/Date

Unsigned 32 bit value of seconds since 1/1/2000 00:00:00 UTC

Next Price

The price that takes affect when the current time reaches the Expiration Time/Date

11.2.4 Get/Set tier

11.2.4.1 Overview of Get/Set Tier

If the SGD supports the Tier messages and it supports the GetInformation Reply message, then the "Tier Mode" bit should be set (1) in the "Capability bitmap" field of the GetInformation Reply (11.2.1.3.4) from the SGD to the UCM. This allows for better interoperability and functional discovery by the UCM.

11.2.4.2 Format GetTier() – Request

Payload byte	Hex value	Comments	Mandatory/optional
1	0x03	Opcode1	M
2	0x01	Opcode2	M

11.2.4.3 Format GetTier() – Reply from SGD

Payload byte	Hex value	Comments	Mandatory/optional
1	0x03	Opcode1	M
2	0x81	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M
4		Current Tier (0 to 6, 255 = no tier)	M
5 to 8		Expiration Time/Date in UTC seconds	O
9		Next Tier	O

11.2.4.4 Format SetTier() – Request

Payload byte	Hex value	Comments	Mandatory/optional
1	0x03	Opcode1	M
2	0x01	Opcode2	M
3 to 4		Current Tier (0 to 6, 255 = no tier)	M
5 to 8		Expiration Time/Date in UTC seconds	O
9 to 10		Next Tier	O

11.2.4.5 Format SetTier() – Reply from UCM

Payload byte	Hex value	Comments	Mandatory/optional
1	0x03	Opcode1	M
2	0x81	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M

Current Tier

0 to 6, 255 = no active tier

Expiration Time/Date

Unsigned 32 bit value of seconds since 1/1/2000 00:00:00 UTC

Next Tier

Tier that takes effect when the expiration time/date is reached

11.2.5 Get/Set temperature offset

11.2.5.1 Overview of Get/Set temperature offset

If the SGD supports the Temperature Offset messages and it supports the GetInformation Reply message, then the "Temperature Offset" bit should be set (1) in the "Capability bitmap" field of the GetInformation Reply (11.2.1.3.4) from the SGD to the UCM. This allows for better interoperability and functional discovery by the UCM.

11.2.5.2 Format GetTemperatureOffset() – Request

Payload byte	Hex value	Comments	Mandatory/optional
1	0x03	Opcode1	M
2	0x02	Opcode2	M

11.2.5.3 Format GetTemperatureOffset() – Reply from SGD

Payload byte	Hex value	Comments	Mandatory/optional
1	0x03	Opcode1	M
2	0x82	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M
4		Current Offset	M
5		Units	M

11.2.5.4 Format SetTemperatureOffset() – Request

Payload byte	Hex value	Comments	Mandatory/optional
1	0x03	Opcode1	M
2	0x02	Opcode2	M
3		Current Offset	M
4		Units	O

11.2.5.5 Format SetTemperatureOffset() – Example reply from UCM

Payload byte	Hex value	Comments	Mandatory/optional
1	0x03	Opcode1	M
2	0x82	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M

Current Offset

Unsigned 8-bit value. Offset to apply to the normal operating temperature in degrees.

Units

0 = degrees F, 1 = degrees C

11.2.6 Get/Set set point

11.2.6.1 Format GetSetPoint() – Request

Payload byte	Hex value	Comments	Mandatory/optional
1	0x03	Opcode1	M
2	0x03	Opcode2	M

11.2.6.2 Format GetSetPoint() – Reply

Payload byte	Hex value	Comments	Mandatory/optional
1	0x03	Opcode1	M
2	0x83	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M
4 to 5		Device Type	M
6		Units	M
7 to 8		Set Point 1	M
9 to 10		Set Point 2	O

11.2.6.3 Format SetSetPoint() – Request

Payload byte	Hex value	Comments	Mandatory/optional
1	0x03	Opcode1	M
2	0x03	Opcode2	M
3 to 4		Device Type	M
5		Units	M
6 to 7		Set Point 1	M
8 to 9		Set Point 2	O

11.2.6.4 Format SetSetPoint() – Reply

Payload byte	Hex value	Comments	Mandatory/optional
1	0x03	Opcode1	M
2	0x83	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M

Device Type

See Info Request (11.2.1) for Device Type table (11.2.1.3.3). For Set command, packet is ignored if the device type doesn't match the SGD's device type.

Units

0 = degrees F, 1 = degrees C

Set Point 1

Signed 16-bit value. First temperature value, 0x8000 (-32768) = don't change (set)/not supported (get).

NOTE 1 For water heaters, Set Point 1 is the top element set point. For thermostats, Set Point 1 is the heat set point. For refrigerator/freezer, Set Point 1 is the refrigerator set point.

Set Point 2

Signed 16-bit value. Second temperature value, 0x8000 = don't change (set)/not supported (get).

NOTE 2 For water heaters, Set Point 2 is the bottom element set point. For thermostats, Set Point 2 is the cool set point. For refrigerator/freezer, Set Point 2 is the freezer set point.

11.2.7 Autonomous cycling

11.2.7.1 Overview of Autonomous cycling

If the SGD supports the StartCycling or TerminateCycling messages and it supports the GetInformation Reply message, then the "Cycling" bit should be set (1) in the "Capability bitmap" field of the GetInformation Reply (11.2.1.3.4) from the SGD to the UCM. This allows for better interoperability and functional discovery by the UCM.

11.2.7.2 Format StartCycling() – Request

The application of randomized start and end times for load management is specified in Clause 16.

Payload byte	Hex value	Comments	Mandatory/optional
1	0x04	Opcode1	M
2	0x00	Opcode2	M
3 to 6		Event ID	M
7 to 10		Start Time UTC seconds since 1/1/2000	M
11 to 12		Duration in minutes	M
13		Duty Cycle	M
14		Start Randomization in minutes	O
15		End Randomization in minutes	O
16		Criticality	O

11.2.7.3 Format StartCycling() – Reply from SGD

Payload byte	Hex value	Comments	Mandatory/optional
1	0x04	Opcode1	M
2	0x80	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M

Event ID

Unsigned 32 bit value control event identifier

Start Time

Unsigned 32 bit value of seconds since 1/1/2000 00:00:00 UTC, 0 = NowDuration

Duration of the control event in minutes

Duty Cycle

Percentage reduction of the load (e.g. 75 means that the device will be off three quarters of the time)

Start Randomization

The start of the control will be delayed by this randomized value in minutes. The start randomization does not change the duration of the event.

End Randomization

The event duration will be lengthened by this random value.

Criticality

Reserved for future use.

11.2.8 Demand reduction – terminate cycling

11.2.8.1 Overview of Demand reduction – terminate cycling

The commands described in 11.2.8 are used to initiate and terminate autonomous cycling. These commands are needed only once when the cycling process first begins and once when the process ends. During the time between these commands, the SGD cycles itself according to the parameters provided in the command.

11.2.8.2 Format TerminateCycling() – Request

Payload byte	Hex value	Comments	Mandatory/optional
1	0x04	Opcode1	M
2	0x01	Opcode2	M
3 to 6		Event ID	M
4		End Randomization in minutes	O

11.2.8.3 Format TerminateCycling() – Example reply from SGD

Payload byte	Hex value	Comments	Mandatory/optional
1	0x04	Opcode1	M
2	0x81	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M

Event ID

Unsigned 32 bit value control event identifier

End Randomization

Continue the control for random value time to prevent large groups from turning on at the same time.

11.3 Demand response event schedules

11.3.1 Function

Allows for displaying information about demand response event duration, percentage shed, etc.

11.3.2 Send scheduled events request

11.3.2.1 Format SendScheduledEvents Request (from SGD)

Payload byte	Hex value	Comments	Mandatory/optional
1	0x05	Opcode1	M
2	0x01	Opcode2	M
3		MSB Start Time (UTC)	M
4		…	M
5		…	M
6		LSB Start Time (UTC)	M
7		UINT8 Number of Events	M

11.3.2.2 Format SendScheduledEvents Reply (from UCM)

Payload byte	Hex value	Comments	Mandatory/optional
1	0x05	Opcode1	M
2	0x81	Opcode2 (Reply bit always has bit 7 high)	M
3		Response Code	M

11.4 Energy consumption

11.4.1 Function

This allows an In Home Display or Energy Management System to provide an estimate of consumption to a consumer. By transmitting price, a value estimate of the commodity consumed can be created.

The system is set up to allow an SGD to poll a UCM for “Whole Home Consumption”. How the UCM gets this information is out of scope.

NOTE If a more detailed understanding of where this information originates is required, then a pass through of an advanced language would be more appropriate.

The command is symmetric, in that a UCM can ask an SGD for its consumption. In that case the consumption is for the SGD.

11.4.2 Commodity read

11.4.2.1 Commodity read functions

This is the command used to exchange information on the consumption. Use the commands in 11.4.3 to determine the types and reporting frequency of data available or to subscribe to data.

When the Get CommodityRead Request is sent without the Requested Commodity Code byte from one side (sender), then the other side (receiver) shall reply with a single Get CommodityRead Reply message with the rates and amounts for all the commodity codes supported by the receiver, subject to the condition that the maximum payload length of the sender is not exceeded.

If the Requested Commodity Code byte is used in the Get CommodityRead Request by the sender, the receiver shall respond with a single Get CommodityRead Reply with one rate and amount for the commodity code specified. In this case if the commodity code is not supported,

the receiver shall reply with Response Code 0x02 (BAD Value) and 0xFFFF FFFF FFFF in the Rate and Amount fields.

11.4.2.2 Format Get CommodityRead Request

Payload byte	Hex value	Comments	Mandatory/optional
1	0x06	Opcode1	M
2	0x00	Opcode2	M
3		Requested Commodity Code	O

11.4.2.3 Format Get CommodityRead Reply

Payload byte	Hex value	Comments	Mandatory/optional
1	0x06	Opcode1	M
2	0x80	Opcode2(Response has first bit set)	M
3		Response Code	M
4		Commodity Code	M
5 to 10		Instantaneous Rate	M
11 to 16		Cumulative Amount	M
17		Second Commodity Code	O
18 to 23		Second Instantaneous Rate	O
24 to 29		Second Cumulative Amount	O
		Continue as needed	O

11.4.2.4 Format Set CommodityRead Request

Payload byte	Hex value	Comments	Mandatory/optional
1	0x06	Opcode1	M
2	0x00	Opcode2	M
3		Commodity Code	M
4 to 9		Instantaneous Rate	M
10 to 15		Cumulative Amount	M

11.4.2.5 Format Set CommodityRead Reply

Payload byte	Hex value	Comments	Mandatory/optional
1	0x06	Opcode1	M
2	0x80	Opcode2(Response has first bit set)	M
3		Response Code	M

Commodity Code

Lower 7 bits[a]	Description	Units
0	Electricity Consumed	W & W·h
1	Electricity Produced	W & W·h
2	Natural gas	cubic feet per hour (ft^3/h) & ft^3
3	Water	gallons per hour (gal/h) & gallons (US)
4	Natural gas	cubic metres per hour (m^3/h) & cubic metres (m^3)
5	Water	litres per hour (l/h) & litres
6	Total Energy Storage/Take Capacity (see Figure 7)	W·h NOTE Instantaneous field in CommodityRead is not used.
7	Present Energy Storage/Take Capacity (see Figure 7)	W·h NOTE Instantaneous field in CommodityRead is not used.
8 to 127	Reserved	
[a] MSBit = 1, Measured (Instrumentation is used to derive commodity values) MSBit = 0, Estimated (Calculated based on Operating States, Instrumentation is not used to derive commodity values)		

Instantaneous Rate

48 bit unsigned value

Cumulative Amount

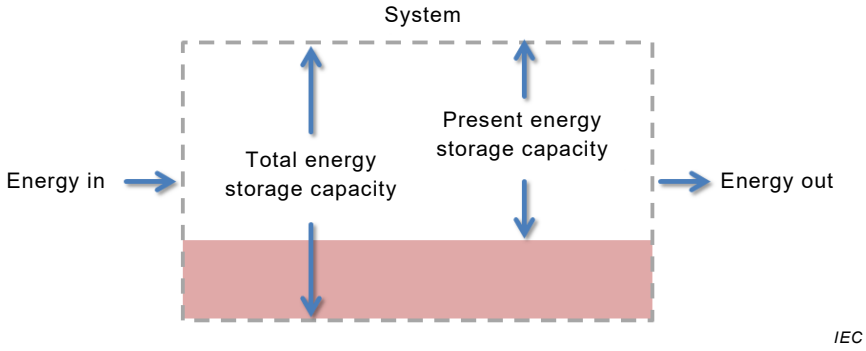
48 bit unsigned value

Commodity Code Requirements

1) Cumulative amount is necessary to provide an accurate indication of cumulative energy consumption. This could be used by a back-end or local system to manage aggregate demand of a building or to generate charts of the energy consumption profile. Manufacturers should strive to submit this data. This quantity increments for the life of the product and the exact time of zeroing is not specified. When interpreting the data, rely on the difference between any two data reads, and not the actual value. 0xFFFF FFFF FFFF indicates this measurement is not supported.
2) If instantaneous consumption is not supported, report 0xFFFF FFFF FFFF.
3) The set command shall be used to push metering data that the SGD/UCM has subscribed to.
4) Total Energy Storage/Take Capacity is the total amount of energy storage that the end-device represents.

   EXAMPLE The energy capacity of a water heater would be the total amount of energy (Wh) to move the tank from its minimum operating temperature (e.g. what it would allow itself to drop to during a curtailment event) to its maximum operating temperature (e.g. what it could run up to when asked to “Load-Up” before shutting off). Similarly, for a thermostat/HVAC system, this would be the total energy (Wh) to move the temperature of the conditioned space from its curtailed state (at the temperature offset for example), back to its maximum cooled/heated state.
5) Present Energy Storage/Take Capacity is the amount of energy that the end-device can take at the present time. This parameter is also represented in (Wh) and would normally be some portion of the Total Energy Storage Capacity as illustrated in Figure 7. It is recognized that under some extraordinary circumstances, the Present Energy Storage/Take Capacity could exceed the Total Energy Storage/Take Capacity.

NOTE For example, if a water heater temperature has fallen well below the normal minimum regulation range.



The Total Energy Storage Capacity is Code 6 and the Present Energy Storage Capacity is Code 7.

Figure 7 – Illustration of energy storage capacity

11.4.3 Get/Set CommodityType

11.4.3.1 CommodityType options

This command determines the type of consumption reporting available, and the associated update frequency. The length of the get reply or set may be variable as more than one commodity may be reported by a device. Commodity code refers to the table in 11.4.2.5. Setting a commodity code shall be interpreted as subscribing to that commodity of the ones supported, not changing the types of commodities that a device is capable of reporting on; assume that subscription ends with a power loss and re-subscribe following a power restoration.

11.4.3.2 Format GetCommoditySubscription Request

Payload byte	Hex value	Comments	Mandatory/optional
1	0x06	Opcode1	M
2	0x01	Opcode2	M

11.4.3.3 Format GetCommoditySubscription Reply

Payload byte	Hex value	Comments	Mandatory/optional
1	0x06	Opcode1	M
2	0x81	Opcode2 (Response has first bit set)	M
3		Response Code	M
4		Commodity Type Supported	M
5 to 6		Commodity Update Frequency	M
7		Second Commodity Type Supported	O
8 to 9		Second Commodity Update Frequency	O
		Continue as needed	

11.4.3.4 Format SetCommoditySubscription Request

Payload byte	Hex value	Comments	Mandatory/optional
1	0x06	Opcode1	M
2	0x01	Opcode2	M
3		Commodity Type Subscription Requested	M
4 to 5		Commodity Subscription Frequency (seconds)	M
6		Second Commodity Type Subscription Requested	O
7 to 8		Second Commodity Subscription Frequency (seconds)	O
		Continue as needed	O

11.4.3.5 Format SetCommoditySubscription Reply

Payload byte	Hex value	Comments	Mandatory/optional
1	0x06	Opcode1	M
2	0x81	Opcode2 (Response has first bit set)	M
3		Response Code	M

Commodity Type Supported / Commodity Type Subscription requested

Use Commodity Types specified in 11.4.2.

Update Frequency/Subscription Frequency

Available/Desired update frequency in seconds.

Requirements:

1) If a UCM cannot support a specific commodity read, it shall use response code 0x02 (BAD Value) to the request for the scheduled read.
2) This command can be used to request multiple subscriptions. If only capable of supporting one subscription, use response code 0x02 (BAD Value) to the request for a multiple subscription, and continue to report the one (if any) that was already subscribed to.
3) If receiving a request for a commodity subscription that is already being reported, change the reporting time to the new time. If the time is the same, report response code 0x00 (Success).
4) Since update time for instantaneous and cumulative values are reported as one number, they shall be reported as the lowest value (fastest update rate). This assumes that the actual physical representation value could change that frequency, and does not guarantee that the actual consumption will change that frequently.
5) Time = 0x0000 is a special case that means < 1 s update rate in a GET reply and cancel a repetitive subscription in a SET.
6) Time = 0xFFFF is a special case that means “unknown or unpredictable update rate” in a GET reply, and cancel subscription in a SET.
7) Do not request a subscription rate faster than the update rate, and SGDs/UCMs are permitted to report a response code of 0x02 BAD Value, for too rapid update rates. Exception: if rate reported as 0xFFFF, a time value may be selected to gather data in a periodic manner.

12 Commissioning and network messages (Message Type = 0x08, 0x04)

These commands are all optional. The format for these messages is as specified in Table 1 with the payload as specified in Table 20. For those messages specified in Clause 12 that are longer than 8 bytes, it is required that the “Maximum payload length” query specified in 9.1 be used first. In other words, this document prohibits transfer of serial messages that could overflow buffers of the recipient. Unless indicated otherwise, when referenced in Clause 12, “ACK” and “NAK” refer to the Basic DR Application ACK and NAK.

Table 20 – Commissioning and network messages

Description	Payload			Usage
	Opcode1	Opcode2	Additional payload	
Set Network ID	0x01	0x00 = LAN 0x01 = WAN	Network ID String	Sent to the UCM, from either the SGD or any other configuration/commissioning tool to which it is connected Network ID String: 1 byte to 120 bytes, ASCII encoded NAK means that the UCM does not accept Network IDs.
Set User ID	0x02	0x00 = LAN 0x01 = WAN	User ID String	Sent to the UCM, from either the SGD or any other configuration/commissioning tool to which it is connected. User ID String: 1 byte to 120 bytes, ASCII encoded NAK means that the UCM does not accept User IDs.
Set Password	0x03	0x00 = LAN 0x01 = WAN	Password String	Sent to the UCM, from either the SGD or any other configuration/commissioning tool to which it is connected. Password String: 1 byte to 120 bytes, ASCII encoded NAK means that the UCM does not accept Passwords.
Join Network	0x04	0x00	None	Set to the UCM to instruct it to join the network for which it is configured
Leave Network	0x05	0x00	None	Set to the UCM to instruct it to leave the network to which it is currently connected

13 Pass-Through Mode

13.1 Pass-Through method

13.1.1 General

In its simplest mode of operation, this document specifies physical layer diversity and allows application layer (and network layer) protocols that are used in the communications system to pass-through directly to the end-device. In such a mode of operation, the UCM need not understand the content of the messages or parse them in any way. In order for this to work, the end-device shall be capable of accepting and understanding the protocol that is passed through. Typical communication exchanges are presented in Clause 14.

This document provides support for a number of such pass-through protocols with the mechanisms described in 13.1.2 to 13.1.6.

13.1.2 Full Encapsulation in the Message Payload

As illustrated in Table 21, other protocols are inserted in the message payload without any modification. As described below, the organizations that own and manage each protocol specify how their messaging is placed into the payload field.

Table 21 – Pass-Through message

Message Type	Reserved shall be '0x0'	Payload length	Payload = Pass-Through message	Checksum
2 bytes	3 bits	13 bits	Variable	2 bytes

13.1.3 Message Type Field

As shown in Table 2, each pass-through protocol is assigned a "Message Type" code. This code is placed in the "Message Type" field indicated in Table 21 whenever pass-through of that protocol is occurring. This field allows end-devices that might support multiple protocols to recognize which is being used and to parse accordingly.

13.1.4 Message Type Support Query

As indicated in 8.3, a query shall be sent to determine if the other device (UCM or SGD) supports the pass-through of a particular protocol before a pass-through is attempted. In this way, the support of the protocol to be passed through is known.

13.1.5 Maximum Message Length Negotiation

Devices shall assure that the maximum message length associated with the protocol to be passed-through is supportable by the device on the other side of the interface. This is to be achieved by using the link layer maximum message length query shown in Table 10.

13.1.6 Pass-Through mode protocols

For each protocol to be passed through in this way, the insertion of the payload is specified in 13.2.

13.2 Pass-Through mode protocols

13.2.1 USNAP 1.0 protocol Pass-Through

13.2.1 shows how the USNAP1.0 protocol is supported by the interface. The messages shall be formatted as shown in Table 22, with the message type being a 0x09, 0x01, and the payload specified in the USNAP1.0 protocol.

Table 22 – USNAP1.0 over serial

Message Type = 0x09, 0x01	Reserved shall be '0x0'	Payload length	USNAP1.0 message	Checksum
2 bytes	3 bits	13 bits	Variable	2 bytes

The USNAP1.0 message in the payload shall begin with the first byte of the USNAP message, called "CommandByte1", and shall end with the last byte before the "Checksum" as specified in USNAP1.0.

13.2.2 SEP1.0 or 1.1 Pass-Through

13.2.2 shows how the SEP1.0 and 1.1 protocols are supported by the interface. The messages shall be formatted as shown in Table 23, with the message type being a 0x09, 0x05, and the payload specified in the SEP1.0 or 1.1 protocol.

Table 23 – SEP1.0 or 1.1 over serial

Message Type = 0x09, 0x05	Reserved shall be 0x0'	Payload length	SEP1.0 Message	Checksum
2 bytes	3 bits	13 bits	Variable	2 bytes

13.2.3 ClimateTalk Pass-Through

13.2.3 shows how the ClimateTalk protocol is supported by the interface. The messages shall be formatted as shown in Table 24, with the message type being a 0x09, 0x02, and the payload specified in the ClimateTalk protocol.

Table 24 – ClimateTalk over serial

Message Type = 0x09,0x02	Reserved shall be '0x0'	Payload length	ClimateTalk message	Checksum
2 bytes	3 bits	13 bits	Variable	2 bytes

13.2.4 General Internet Protocol Pass-Through

13.2.4 specifies the data format for supporting pass-through of applications over IP. This IP pass-through mechanism supports both IPv4 and IPv6, with the self-describing Version field of the IP packet distinguishing between the two.

NOTE This might be of interest for many purposes, including communications systems and SGDs that are capable of web access.

By using the previously specified data-link commands, either the SGD or the UCM may probe the other to determine what Message types it supports. Whenever a UCM and SGD that both support pass-through of IP are connected together, the two can recognize this fact and pass-through communication can commence. When passing an IP packet over the serial interface, the UCM or SGD shall add:

- a leading Message Type field according to Table 2:
  - 0x09, 0x04 for Smart Energy Profile 2 (SEP2), or
  - 0x09, 0x05 for OpenADR 1.0, or
  - 0x09, 0x06 for IEC PAS 62746-10-1:2014 (OpenADR 2.0), or
  - 0x09, 0x07 for generic IP,
- a 2-byte Length field, and
- a trailing checksum.

This packet format is illustrated in Figure 8 (IPv6 shown, IPv4 handled in similar fashion).

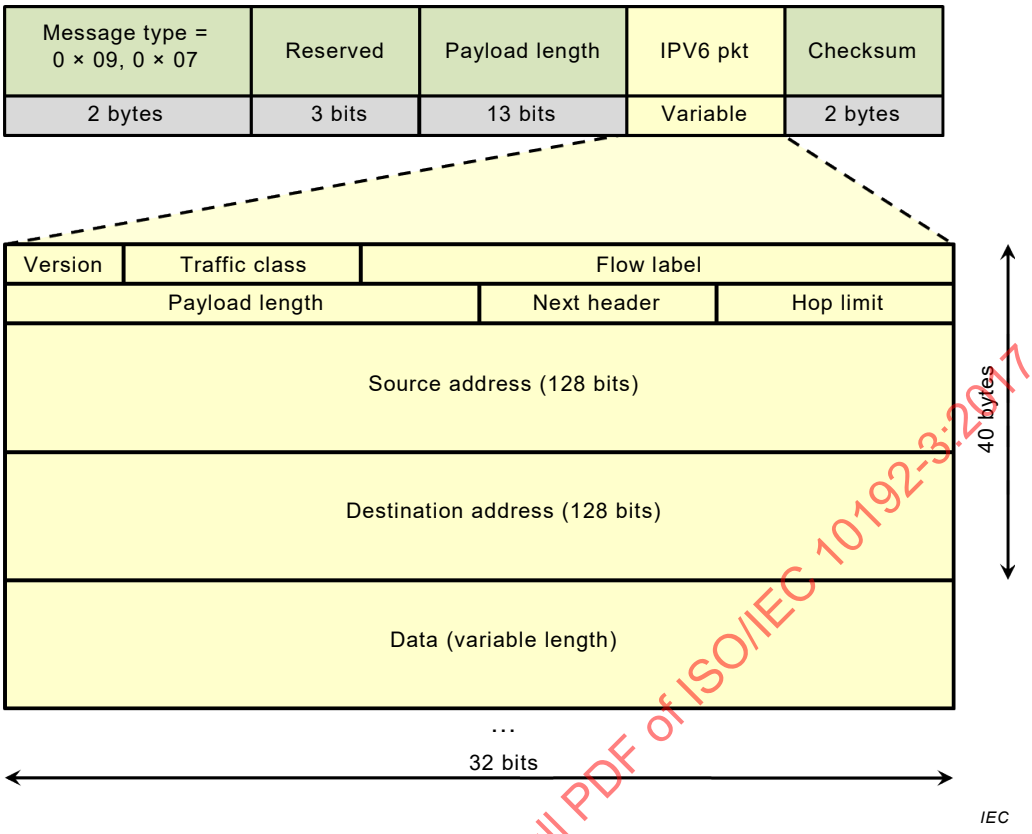


Figure 8 – Internet Protocol Pass-Through (IPv6)

Use of any IP pass-through requires that the UCM and SGD negotiate the maximum payload length needed to support the type of pass-through messages to be used. This length shall be negotiated after power up or reset using the link layer "Maximum Payload Length" negotiation specified in Clause 8. IP pass-through packets may not be fragmented by the UCM.

13.2.5 ISO/IEC 14543-4-3 Pass-Through

13.2.5 shows how the ISO/IEC 14543-4-3 protocol is supported by the MCI. The messages shall be formatted as shown in Table 25, with the message type being a 0x09 0x08, and the payload specified in the ISO/IEC 14543-4-3 protocol.

Table 25 – ISO/IEC 14543-4-3 over serial

Message Type = 0x09, 0x08	Reserved shall be '0x0'	Payload length	ISO/IEC 14543-4-3 message	Checksum
2 bytes	3 bits	13 bits	Variable	2 bytes

The bit order of the payload is to be the same as that specified for the DC and AC form factors in 5.1. The byte order of multi-byte quantities is specified in the ISO/IEC 14543-4-3 payload.

13.2.6 ISO/IEC 14543-3-1 Pass-Through

13.2.6 shows how the ISO/IEC 14543-3-1 protocol is supported by the MCI. The messages shall be formatted as shown in Table 26, with the message type being a 0x09 0x09.

Table 26 – ISO/IEC 14543-3-1 over serial

Message Type = 0x09, 0x09	Reserved shall be '0x0'	Payload length	ISO/IEC 14543-3-1 message	Checksum
2 bytes	3 bits	13 bits	Variable	2 bytes

The bit order of the payload is to be the same as that specified for the DC and AC form factors in 5.1.

13.2.7 ISO/IEC 14908-1 Pass-Through

13.2.7 shows how the ISO/IEC 14908-1 protocol is supported by the MCI. The messages shall be formatted as shown in Table 27, with the message type being a 0x09 0x0A, and the payload being specified in ISO/IEC 14908-1.

Table 27 – ISO/IEC 14908-1 over serial

Message Type = 0x09, 0x0A	Reserved shall be '0x0'	Payload length	ISO/IEC 14908-1 message	Checksum
2 bytes	3 bits	13 bits	Variable	2 bytes

The bit order of the payload is to be the same as that specified for the DC and AC form factors in 5.1.

13.2.8 SunSpec Pass-Through

13.2.8 shows how the SunSpec protocol is supported by the MCI. The messages shall be formatted as shown in Table 28, with the message type being a 0x09 0x0B, and the payload being defined entirely by the SunSpec Alliance.

Table 28 – SunSpec over serial

Message Type = 0x09, 0x0B	Reserved shall be '0x0'	Payload length	SunSpec message	Checksum
2 bytes	3 bits	13 bits	Variable	2 bytes

The bit order of the payload is to be the same as that specified for the DC and AC form factors in 5.1.

14 Typical communication exchanges

- Simple Serial, Request Operating State
  Comm Module to End-Device → 08 01 00 02 12 00 D8 5F
  Opcode 0x12, what is your state?
  End-Device to Comm Module ← 06 00 Link Layer Acknowledge of previous message.
  End-Device to Comm Module ← 08 01 00 02 13 02 D1 63
  Opcode 0x13, End-device is curtailed
  Comm Module to End-Device → 06 00 Link Layer Acknowledge of previous message.
- Simple Serial, Unsupported Message Followed by Shed Message
  Comm Module to End-Device → 08 01 00 02 07 40 79 89
  Opcode 0x07, Relative Price

End-Device to Comm Module ← 06 00 Link Layer Acknowledge of previous message.

End-Device to Comm Module ← 08 01 00 02 04 01 01 44

Opcode 0x04, App NAK, Bad Opcode

Comm Module to End-Device → 06 00 Link Layer Acknowledge of previous message.

Comm Module to End-Device → 08 01 00 02 01 00 0C 3D

Opcode 0x01, Shed

End-Device to Comm Module ← 06 00 Link Layer Acknowledge of previous message.

End-Device to Comm Module ← 08 01 00 02 03 01 04 42

Opcode 0x03, App ACK of Opcode 0x01

Comm Module to End-Device → 06 00 Link Layer Acknowledge of previous message.

- Query, Then Use, of Smart Energy Profile 2.0 over IP

  Comm Module to End-Device → 09 04 00 00 CS CS Link Query, Do you support SEP2/IP? (CS = checksum bye)

  End-Device to Comm Module ← 06 00 Link Layer Acknowledge of previous message.

  Comm Module to End-Device → 09 04 01 3D <SEP msg> CS CS

  SEP2/IP message, length only an example

  End-Device to Comm Module ← 06 00 Link Layer Acknowledge of previous message.

NOTE 1 The Basic DR application ACK (Opcode 0x03) is only used in response to Basic DR commands (message type 0x08, 0x01). Once SEP2/IP is used (message type 0x09, 0x04), then the application layer acknowledge, if any, is up to the SEP2 specification.

NOTE 2 The UCM does not have to initiate communications. For example, an SGD can initiate an IP-based exchange of information.

15 General security principles

The serial interface between a UCM and an SGD supports end-to-end security at the application layer and/or at the IP / network layer. It is not encrypted at the link layer. For certain application protocols, such as the Basic DR, it is not encrypted. In this case, the socket interface is treated as a protected local interface like any other wired connection between circuit boards inside a product. If the communication on the communications network (PLC, wireless, etc.) is encrypted, as it may be in a secured Wi-Fi HAN for example, the decryption may occur in the communications module or be passed through to the SGD, if supported.

In the case of more advanced protocols, like Internet pass-though, encryption may exist within the IP packet embedded in the serial message.

EXAMPLE If the communications network is Wi-Fi, then a Wi-Fi communications module may receive an IP packet wirelessly, strip-off any 802.11 phy/mac part, insert the IP packet as the “Payload” in the message structure shown in Table 1 and send it on through to the SGD. In this case, the communications module would be serving as a phy/mac translator and would know nothing of the packet’s content, which may or may not be encrypted. The communications module would only know whether or not the SGD is accepting or NAK’ing the messages.

16 Load management event randomization

The purpose of randomization is to prevent a large number of end-devices from turning on or off simultaneously. Such simultaneous actions may cause an undesirable sudden change in load on the power system. This unnatural synchronization could result in voltage problems on distribution systems. This type of situation could occur in a broadcast-type communications system (pager, FM, PLC) where a real-time request to shed load is sent to a large number of devices at once. Another scenario that would cause similar alignment is that of a scheduled event where a large number of devices are all responding to a common schedule, such as a high price period that begins or ends at a specific time.

Unless explicitly specified in the application layer command (e.g. the Intermediate cycling command), this document does not require SGDs to perform event randomization. In fact, such behaviour could prevent the device from being used for certain time-sensitive services, such as compensation for intermittent renewable generation. Rather, the utility, communications system, or UCMs, shall perform randomization, if desired. Figure 9 illustrates this concept.

NOTE The advantage of this approach is that it allows a single SGD to be sold world-wide without assuming to know what timings are needed by the local utility system.

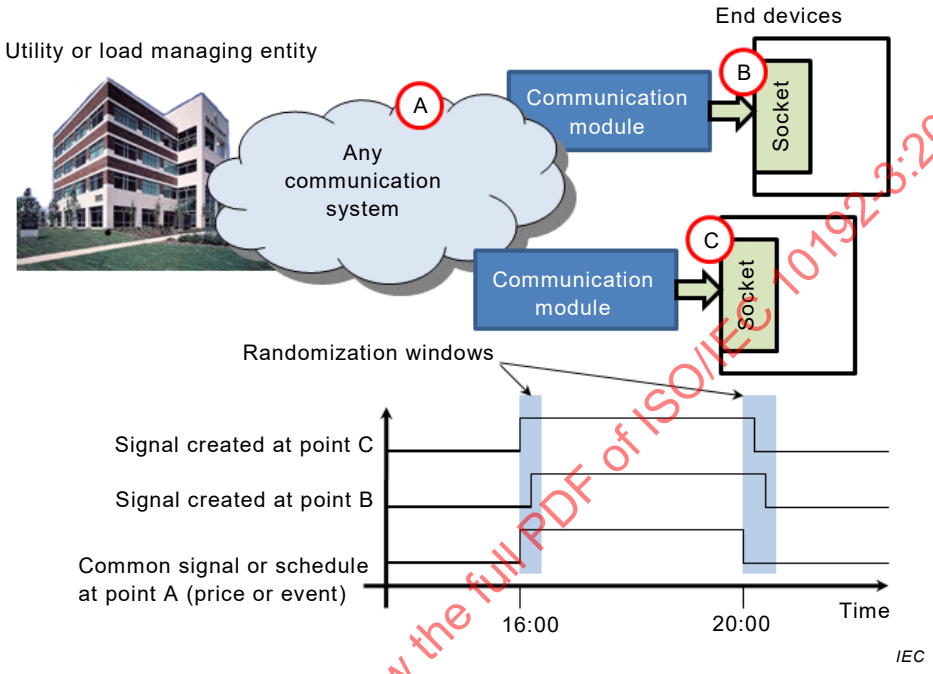


Figure 9 – Illustration of randomization of events by communications modules

Annex A
(normative)

Low voltage DC form factor

NOTE Annex A will be replaced by reference to appropriate IEC specifications when and if available.

A.1 General

Annex A specifies the DC form factor UCM and SGD interface.

NOTE Following are the requirements that led to the selection of this connector, which is based on ISO/IEC 24739-3, with the changes specified in Annex A:

1) Require at least 11 conductors for low voltage communications. The specification is a 16-position Advanced Technology Attachment (ATA) connector. Connectors shall not be pins. This is a card-edge connector.
2) Ability to double up conductors for guaranteed connection 3,3 V, signal ground). Customer defines the uses of the conductors.
3) Have a small number of spare pins for future functionalities: 16 positions available with 11 positions used.
4) Require a make-first/break-last pin for signal ground. This is accommodated on the header.
5) Require keying so that the connector cannot be mated backwards. Module keying will prevent other devices from being plugged in.
6) Connector should have a common form factor (use of existing connector), which is consistent with ISO/IEC 24739-3.
7) Require a flat PCB mount header on the appliance side. This connector is a surface mount (SMT) header.
8) Require a PCB-mount header on the communication module side using card-edge style connector.
9) Require that the connector header on the communication module fit the DC communication module designs.

A.2 Limitations

- The transport speed is limited by SGD and UCM processor bandwidth. The data-link defaults to a slow data rate (19,2 kbit/s) and small payload (2 bytes). Data-link layer commands allow negotiating the speeds and payloads for more capable devices. Process for reverting to default settings is also documented at the application layer.
- This document does not include device reliability requirements. There are also no requirements for handling, dropping, ESD resistance, etc.

A.3 Power for UCM

Power for UCM is provided by SGD. Power is supplied at 3,3 V ± 0,3 V DC. The power consumption limits are specified in 9.2. Power for the UCM shall be provided by a Class 2 (or equivalent) power supply within the SGD.

A.4 Mechanical interface

A.4.1 DC form factor board layout

The DC UCM device shall conform to one of the physical layouts specified in Figure A.7 and Figure A.2. These physical layouts were chosen to provide as large a volume as possible, consistent with application to thermostats and in-home displays. The Standard DC UCM layout is designed to fit inside the SGD while the Extended Size DC UCM may protrude outside the SGD. It includes an extended segment where larger components and external connectors may be included. The extended size DC UCM casing allows growth of the 47,6 mm (width or Y) dimension as well as the 12,3 mm (height or Z) dimension once the module exits the SGD after the 60-mm minimum in the X direction in Figure A.3. Similarly, the extended size PCB of Figure A.1 may grow in the Y dimension as well as the Z dimension

once outside the SGD. All dimensions within the envelope of the standard size UCM shall be met.

Dimensions in millimetres

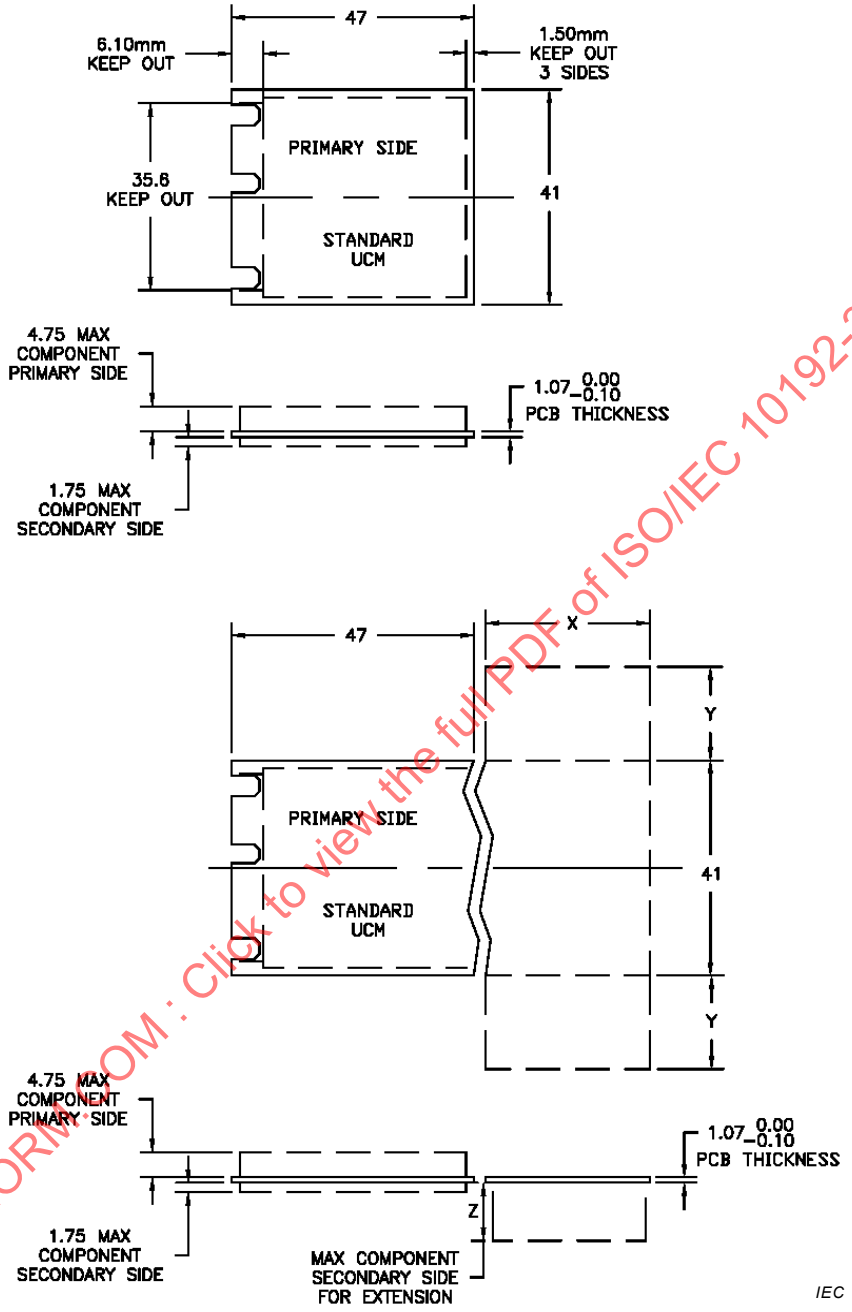


Figure A.1 – DC form factor PCB dimensions

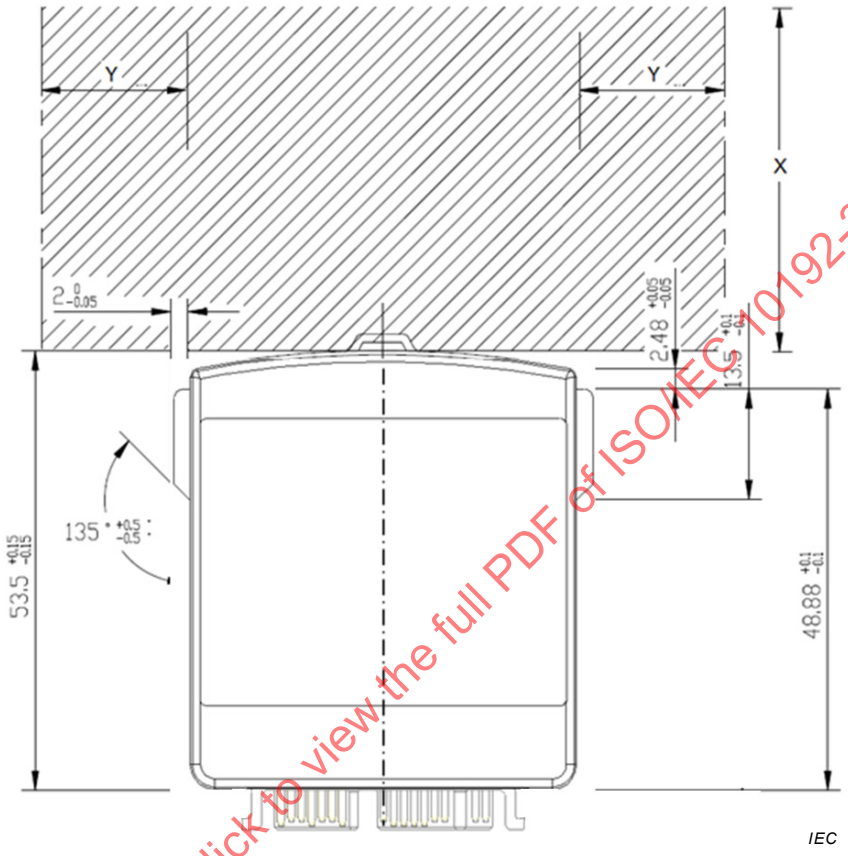
A.4.2 Module configuration

The DC Form Factor UCM module is specified in Figure A.2, Figure A.3 and Figure A.4 for the standard layout. Extended size UCMs shall have extended housings with all the features and meet all the dimensions of the standard module until after the module exits the SGD past the 60 mm minimum in the X direction in Figure A.3. At that point, the 47,6-mm (width or Y) dimension and the 12,3-mm (height or Z) dimension may grow in addition to the X dimension.

A special case of extended length is specified for antennas and wired media. The side of the module opposite of the connector is reserved for extending an antenna or accessing the wired media. Specific implementations are left to the discretion of the communication provider.

NOTE For example, PLC media that need access to the power line or wired media could provide a cord terminated with a NEMA 1-15P plug. Another example could be a wired Ethernet module with an RJ-45 receptacle.

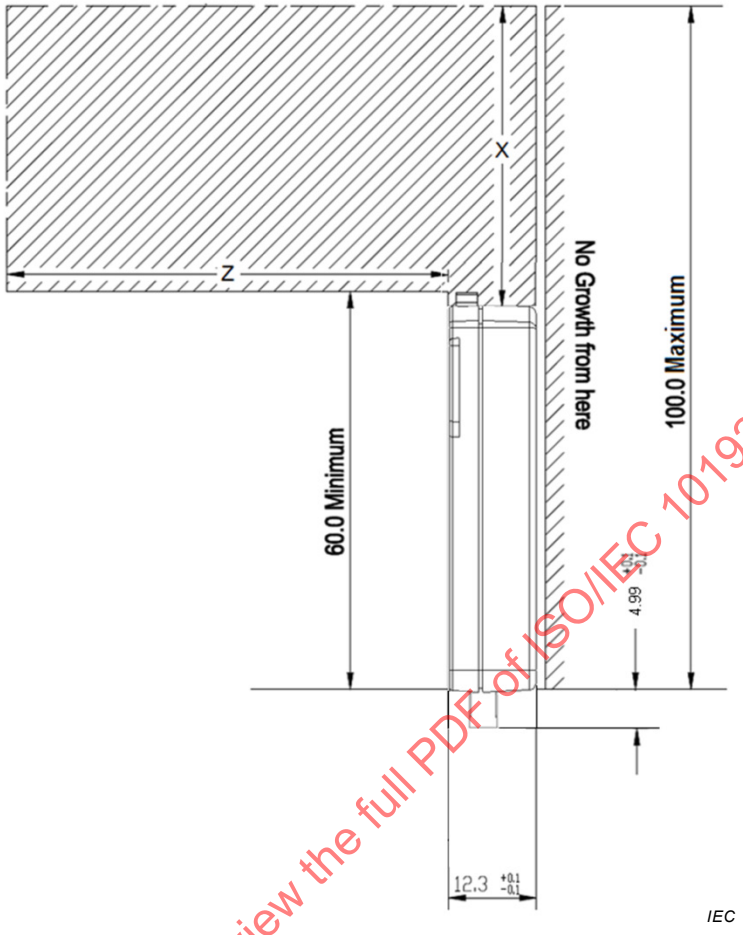
Dimensions in millimetres



Hatched area dimensions are for connectors, antennas, or large components.

Figure A.2 – DC form factor housing dimensions – top view

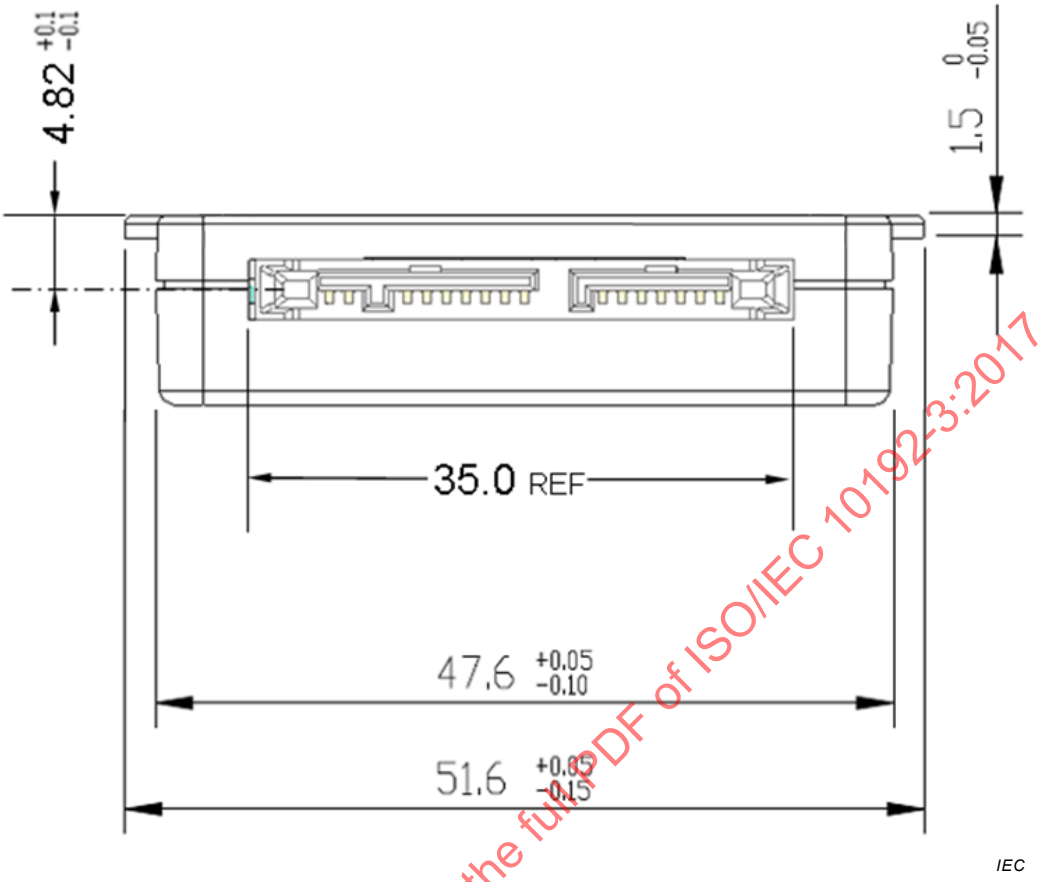
Dimensions in millimetres



Hatched area dimensions are for connectors, antennas, or large components.

Figure A.3 – DC form factor housing dimensions – side view

Dimensions in millimetres



The connector is centred in the width of the module.

Figure A.4 – DC form factor housing dimensions – end view

A.4.3 Form factor

The maximum weight for a DC Form Factor cartridge is 40 grams.

A.4.4 Housing materials

UCM housing materials shall be appropriate for the technology contained within the housing and the environment where the device is expected to operate. UCMs are expected to operate in an indoor environment protected from weather. If SGD operates in a severe environment (i.e. temperatures, UV, chemicals, etc.) it shall provide necessary protection.

If SGDs are UL Recognized Class 2 supplies, then the housing flammability rating of UCMs can be UL94-HB.

These are minimum requirements, and UCMs with internal characteristics that require a higher degree of protection may require higher flammability standards.

A.4.5 Connector type

The interface connectors on SGD and UCM are standard ATA connectors as specified by ISO/IEC 24739-3.

Gold coatings are recommended on UCM to SGD interface for reliability.

A.4.6 Pin assignments

The pin assignments of the connector are specified in Figure A.5.

Pin	Mating	Designation
S1	second	Spare
S2	third	ATTENTION*
S3	third	SCLK
S4	second	SELECT*
S5	third	MOSI
S6	third	MISO
S7	second	RESET*
P1	third	+3,3 Power
P2	second	+3,3 Power
P3	first	Signal Ground
P4	first	Signal Ground
P5	second	SGD Reserved
P6	third	SGD Reserved
P7	third	Module Detect (connected to Signal Ground on UCM)
P8	third	UCM Reserved
P9	third	UCM Reserved

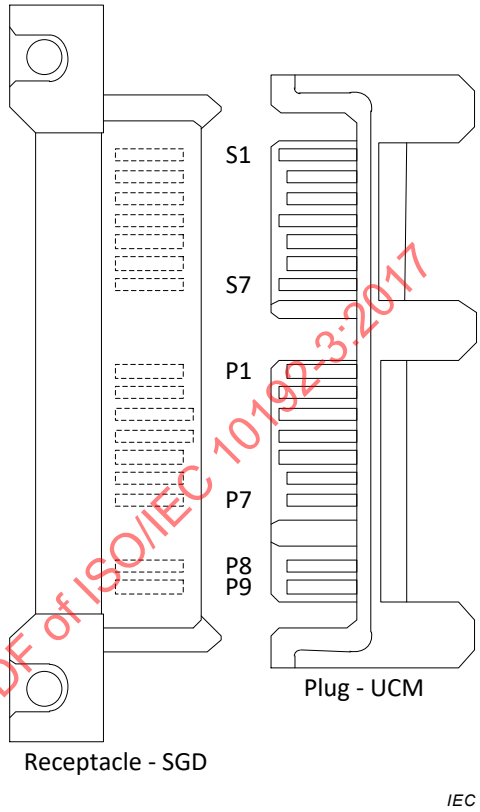


Figure A.5 – Pin assignment

A.5 Electrical interface

A.5.1 Electrical Interface Levels

All signals are 3,3 V Logic Levels. Logic ‘0’ is defined as less than 0,8 V, and Logic ‘1’ as greater than 2,2 V.

A.5.2 Signal timing

Representative signal timing is shown in Figure A.6 for SPI byte transfers.

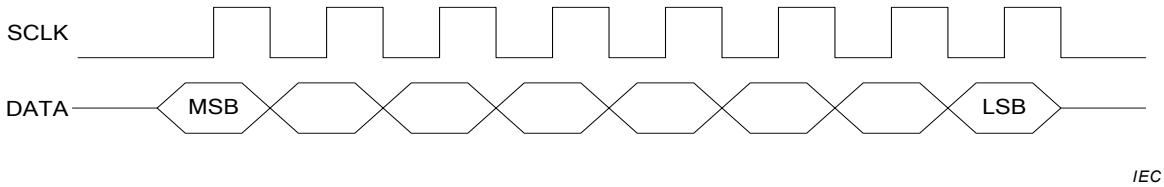


Figure A.6 – SPI Mode 0 bit timing

This document supports SPI Mode 0 only.

Data changes on the falling edge and shall be read on the rising edge.

Data (MISO) from the UCM is high impedance when SELECT is high.

A.5.3 Interface circuits

Table A.1 defines low voltage interface specifications and purposes.

Table A.1 – Low voltage interface signal definitions

Circuit(s)	Direction	Active state	Purpose
Signal Ground	N/A	N/A	Establishes a common ground potential
+3,3V Power	From SGD	N/A	Provides +3,3 V power for radio use
MOSI	from SGD	High	Carries SGD SPI data to UCM
MISO	From UCM	High	Returns UCM SPI data to SGD, High Z when SELECT is high.
SCLK	From SGD	Rising Edge	SPI clock signal from SGD
SELECT*	From SGD	Low	Low during each byte of SPI data transfer. Normally high. SGD can assert (low) to request data transfer with radio.
ATTENTION*	From UCM	Low	Signal from UCM Requesting an SPI data transfer
RESET*	From SGD	Low	Signal from SGD negated after power-on. Open collector/drain output.
Module Detect	From UCM	Low	Pin shall be connected to signal ground on the UCM plug.
SGD Reserved	N/A	N/A	Two signals for SGD test use at factory only. UCM shall not connect to these pins.
UCM Reserved	N/A	N/A	Two signals for UCM test use at factory only. SGD shall not connect to these pins.

A.6 Data transfer protocol

A.6.1 Control signals

A.6.1.1 ATTENTION*

This signal is asserted (driven low) by the UCM whenever it is ready to initiate a data byte transfer across the SPI. In general it is expected that ATTENTION* will be asserted during the entire time of a message from the UCM and the SGD response (if any). Separate ATTENTION* signals are provided to each UCM.

A.6.1.2 SELECT*

This control signal is driven low before each message is transferred via SPI, and driven high after the message transfer is complete. The SGD normally parks this line high. When SELECT* is high, the UCM MISO data line shall be in a high impedance state. Separate SELECT* signals are provided to each UCM.

In a secondary usage, the SGD may initiate data transfer to a UCM (in the course of a data transfer from one UCM to another for instance). In this type of transfer, the SGD can drive the SELECT signal low to request ATTENTION* from the UCM. The UCM can acknowledge this request by asserting (driving low) the ATTENTION* signal (initiating a data transfer).

A.6.1.3 RESET*

On power-on, the SGD will assert RESET* (drive it low) for a minimum of 100 ms. This signal is open-collector (open-drain); it is the responsibility of the UCM to provide any pull-up, if required. Separate RESET* signals are provided to each UCM.

A.6.2 Clock and data rate

Data rate is controlled by the SPI SCLK. SCLK is generated by the SGD. Standard data rates are specified in 9.3.

A.6.3 Multiple slots

SGDs may, but are not required to, provide multiple slots.

Independent SELECT*, ATTENTION* and RESET* shall be provided to each slot.

Power, Signal Ground, SCLK, MOSI, MISO may be common among all slots.

SGD device manufacturers may allocate bandwidth between the slots as necessary.

A.7 Link layer data flow

The SPI is physically capable of transferring data in both directions simultaneously. However, data is only sent in a single direction at a time. The first side to assert the signal line is the sender. The receiver will always send a 0xFF character during data transfer.

If a node is detecting data on the receive line at the same time it is transmitting it has two choices:

1) Ignore it. At end of transmission when the node does not reply with a <ACK> or <NAK>, the sending device will try again.
2) Read the incoming message and buffer it for essentially full duplex communication. Attempt to <ACK> or <NAK> for the message when message is complete and line becomes open. This option requires a more complex state machine that also keeps track of the state of both transfer directions, and is not a requirement.

A.8 Messages

A.8.1 Frame structure

The message frame structure is specified in Clause 6. Message transfer is framed by the SELECT* and ATTENTION* lines.

A.8.2 Message synchronization (frame delimiting)

Synchronization (detection of the start of a message) is achieved by the use of the SELECT* and ATTENTION* lines. Message transfer occurs when the UCM has asserted ATTENTION*, the SGD has asserted SELECT* and the SGD begins to clock data. The order of SELECT* and ATTENTION* depends on which device is initiating the data transfer.

A.8.3 Message filling (inter-message byte filling)

When a device is not sending a message, but SPI transactions are occurring, devices will fill using the special fill byte 0xFF.

A.8.4 Command/Response encoding

Message IDs and responses are encoded as binary bytes. The application layer will define commands to support the application requirements.

A.8.5 Checksum calculation

The checksum calculation is specified in Annex D.

A.8.6 Master/Slave

The SGD is the master of the SPI bus. It generates the SPI clock and drives MOSI.

A.8.7 Flow control

The UCM controls data flow by using the ATTENTION* line. Flow control is achieved by the SGD through its control over the SPI data transfer.

When there are multiple messages queued to send, the SGD or UCM will wait until the prior message has been Acknowledged, Not-acknowledged, or the Inter-Message timeout has expired before initiating the next message.

When a UCM or SGD receives a message to send from its application while it is in the process of receiving a message, it will Acknowledge or Not acknowledge the message it is receiving. Allow SELECT*/ATTENTION* to be de-asserted, and then initiate transfer of new message.

NOTE Supporting separation of layers allows for multi-threading. This does not require an application to support multi-threading, but creates a mechanism to allow it if desired.

A.8.8 Error detection and recovery

A.8.8.1 SGD error detection and recovery

The following errors shall be detected at the SGD device data-link level.

- Check byte error.
- Invalid Length – Upon receipt of the initial 4 bytes of header, if the length is out of range( ) the SGD will de-assert SELECT*.
- Inter-message time-out – When waiting for an ACK, if no response is received in 100 ms, the SGD times out and returns to IDLE state. SGD may then attempt to transfer message again. This does not generate a <NAK>.
- Message Initiation failure – When SELECT* has been asserted, if no response is received in 100 ms, the SGD times out, de-asserts SELECT* and returns to IDLE state. SGD may then attempt to transfer message again. This does not generate a <NAK>.

Additional error checking shall be performed at the SGD device application level, including data out of range.

A.8.8.2 UCM error detection and recovery

The following receive errors may be detected at the UCM data-link level.

- Invalid byte.
- Check byte error.
- Intra-message time-out error – When a message has been initiated by either device and is ready to send as indicated by both Select and Attention being asserted, and an insufficient number of bytes has been clocked by the SGD (including no bytes). If this does not occur

in 500 ms, the UCM times out, de-asserts ATTENTION* and returns to IDLE state. This does not generate a <NAK>.

- Invalid Length – Upon receipt of the initial four bytes of header, if the length is out of range the UCM will de-assert ATTENTION*.
- Extra Bytes – If the SGD continues to clock beyond where the check-byte was expected, the UCM de-asserts ATTENTION*.
- Inter-message time-out – When waiting for an ACK or when ATTENTION* has been asserted, if no response is received in 100 ms, the UCM times out and returns to IDLE state. UCM may then attempt to transfer message again. This does not generate a <NAK>.
- Message Initiation Failure – When ATTENTION* has been asserted, if no response is received in 100 ms, the UCM times out, de-asserts ATTENTION* and returns to IDLE state. UCM may then attempt to transfer message again. This does not generate a <NAK>.

Additional error checking may be performed at the UCM application level.

A.9 Operation

A.9.1 Transaction sequence

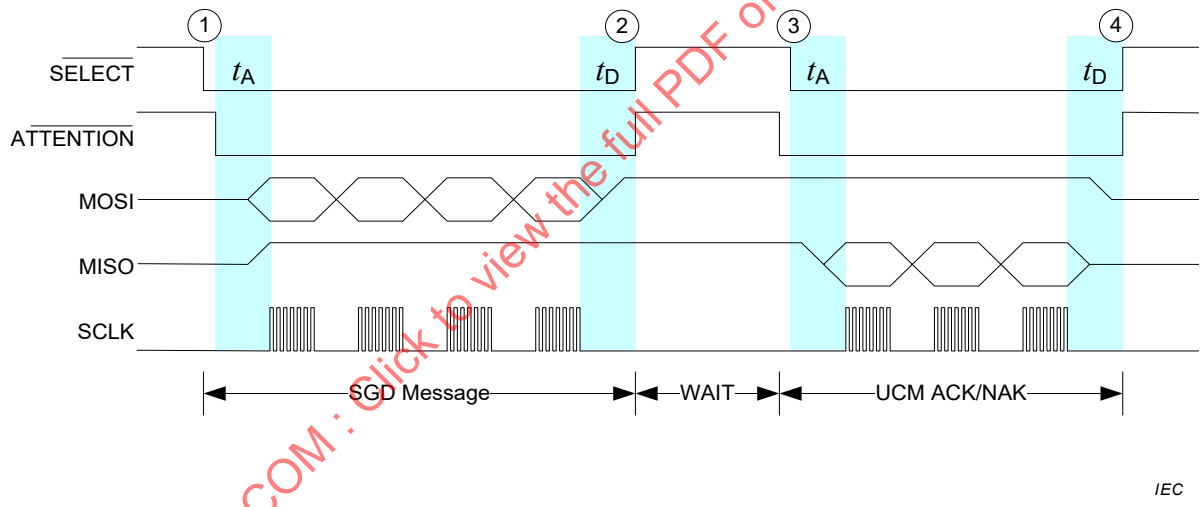


Figure A.7 – SPI transaction sequence: SGD-initiated message to the UCM

Figure A.7 shows a single data-link transaction with the SGD as the data-link transmitter and initiator of the communication of a message. The UCM is the data-link receiver and shall respond with an ACK or NAK. In addition to the physical timing requirements t_A and t_D in Table 22, this transaction is also governed by data-link timing in Table 3.

The transaction sequence is as follows.

1) The SGD begins the data-link transaction by setting SELECT* low (asserted). After detecting the assertion of SELECT*, the UCM then sets ATTENTION* low (asserted). The SGD starts clocking the data after an additional time t_A.
2) After the last message byte is clocked out and an additional time t_D, the SGD sets SELECT* high (de-asserted) and UCM sets ATTENTION* high (de-asserted). The order of these two de-assertions is not defined.
3) When the UCM has an ACK/NAK ready (note the timing requirements in Table 3), it sets ATTENTION* low (asserted). After detecting the assertion of ATTENTION*, the SGD sets SELECT* low (asserted) and after an additional time t_A the SGD starts clocking the data.

4) After the ACK/NAK has completed clocking and an additional time t_D, the UCM sets ATTENTION* high (de-asserted) and the SGD sets SELECT* high (de-asserted). The order of these two de-assertions is not defined.

   If the application message sent successfully by the SGD in this data-link transaction requires a response from the UCM the sequence continues in Figure A.8, where the roles of SGD and UCM are swapped. Figure A.8 would take place after a time meeting the requirements of Table 3. Not all application messages are required to have a response and in these cases an ACK/NAK is sufficient to end the link layer transaction and the application transaction.

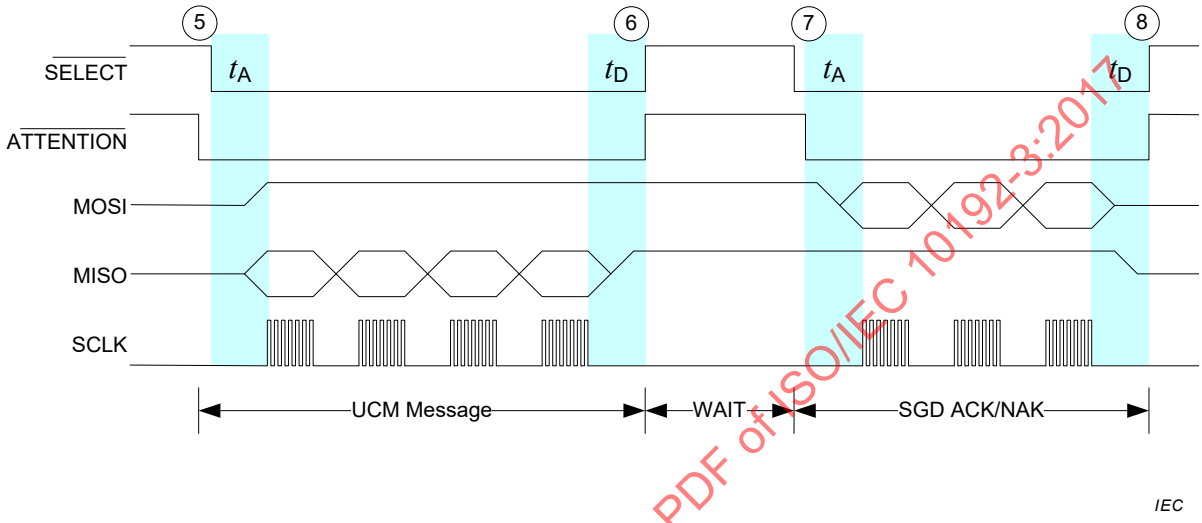


Figure A.8 – SPI transaction sequence: UCM-initiated message to the SGD

Figure A.8 shows a single data-link transaction with the UCM as the data-link transmitter and initiator of the communication of a message. The SGD is the data-link receiver and shall respond with an ACK or NAK. In addition to the physical timing requirements t_A and t_D in Table A.2, this transaction is also governed by link-layer timing in Table 3.

5) The UCM begins the transaction by setting ATTENTION* low (asserted). After detecting the assertion of ATTENTION*, the SGD then sets SELECT* low (asserted). The SGD starts clocking the data after an additional time t_A.

6) After the last message byte is clocked out and an additional time t_D, the UCM sets ATTENTION* high (de-asserted) and SGD sets SELECT* high (de-asserted). The order of these two de-assertions is not defined.

7) When the SGD has an ACK/NAK ready (note the timing requirements in Table 3), it sets SELECT* low (asserted). After detecting the assertion of SELECT*, the UCM sets ATTENTION* low (asserted) and after an additional time t_A the SGD starts clocking the data.

8) After the ACK/NAK has completed clocking and an additional time t_D, the SGD sets SELECT* High (de-asserted) and the UCM sets ATTENTION* High (de-asserted). The order of these two de-assertions is not defined.

In the case where the UCM needs to initiate a message to send to the SGD, Figure A.8 would occur first and Figure A.7 would occur second. Similarly, the sequence of the numbered description points in the case of the UCM initiating would be 5, 6, 7, 8 and then 1, 2, 3, 4.

Table A.2 – SPI physical timing requirements

Parameter	Minimum	Maximum	Description
t_A	20 µs	N/A	Time after both flow control lines (SELECT* and ATTENTION*) have asserted to the start of clocking data on the bus with SCLK
t_D	10 µs	N/A	Time from the end of the last SCLK cycle in the last message byte to the de-assertion of the flow control lines (SELECT* and ATTENTION*)

A.9.2 SPI data transfer state machine

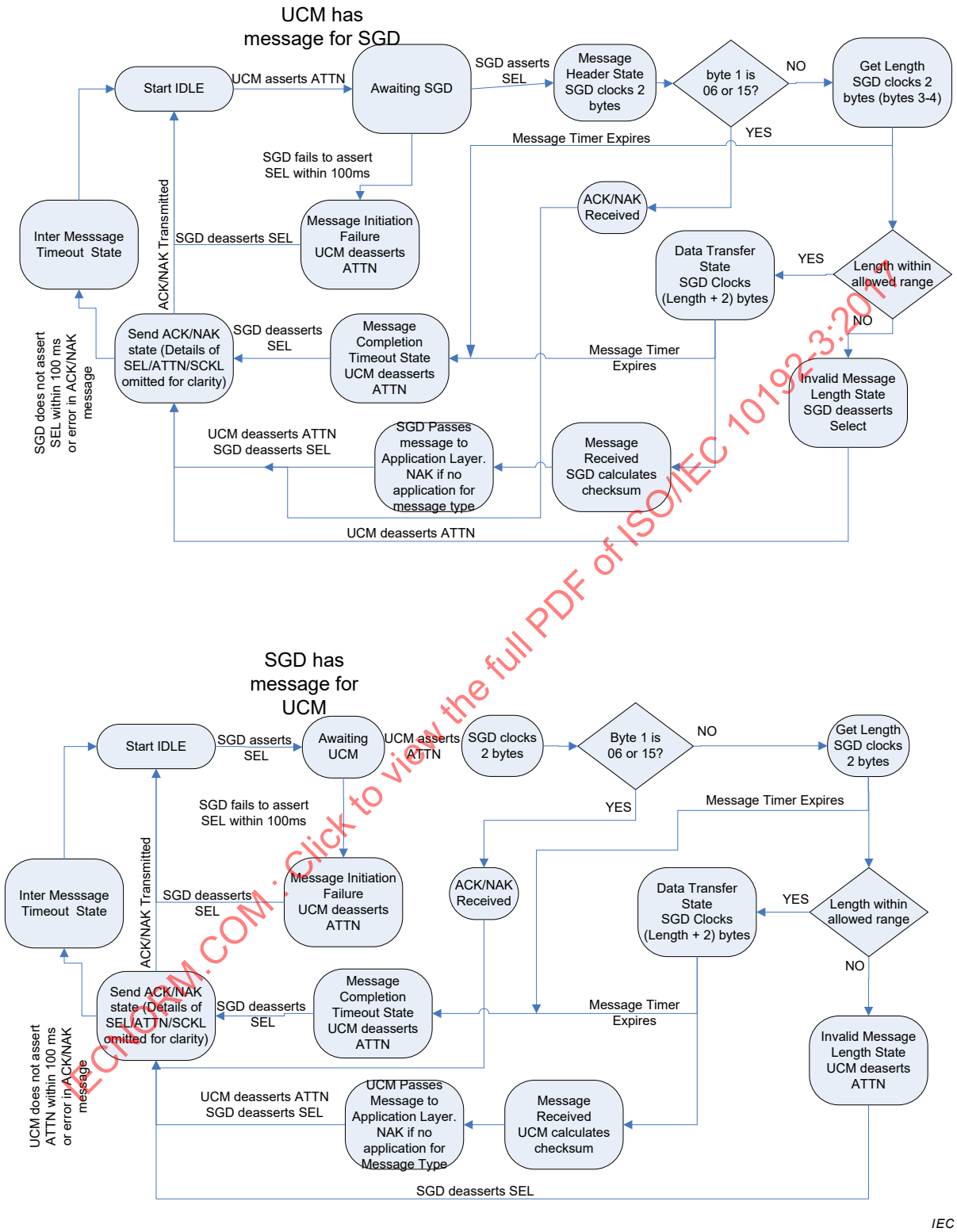


Figure A.9 – SPI data transfer state machine

The state machine diagram in Figure A.9 shows the behaviour of both the UCM and SGD when transferring data over the MCI interface. Data transfer can be initiated on either side by asserting the appropriate signalling line, ATTENTION* for the UCM and SELECT* for the SGD.

A.9.3 SGD transmitter operation

The SGD device transmitter shall perform the calculation of the checksum to be transmitted with each message, encode both the message and the checksum, and queue messages for transmission.

If the SGD has a message to send it will assert SELECT*.

Upon UCM asserting ATTENTION*, the SGD will clock 2 bytes.

If message was ACK or NAK, SGD will de-assert SELECT*.

Otherwise,

- SGD will clock remainder of the message and de-assert SELECT*,
- SGD will then await an ATTENTION* from UCM, to receive the ACK or NAK.

If ACK or NAK received, SGD will de-assert SELECT*, and return to idle.

If a new message is received from UCM,

- SGD notifies application of transmit failure,
- SGD may attempt to transfer again,
- it is recommended that developers put an algorithm in place to handle NAKs/Timeouts. A retry counter, or an increasing delay between attempts, or evaluating the message at the application level to see if it is still valid are options.

A.9.4 SGD device receiver operation

The SGD Device receiver shall perform the following functions:

- detect the request to transfer from UCM,
- detect message length,
- decode the incoming message,
- generate ACK or NAK messages as appropriate, and
- route messages to the appropriate application task.

The SGD initially enters an IDLE state.

If the ATTENTION* line is asserted by the UCM, the SGD asserts the SELECT* line and enters the data transfer state and clocks in two data bytes.

If ACK or NAK received, SGD will de-assert SELECT*, and return to idle. Otherwise, the SGD will clock the third and fourth bytes, which contain the message length value. If this is invalid an error is generated and receipt aborted.

The SGD then clocks in the balance of the message (length plus the two checksum bytes)

When the SGD detects that the last byte has been clocked in, it de-asserts SELECT*.

The SGD then waits for the UCM to de-assert ATTENTION*. Upon de-assertion of ATTENTION*, and after waiting the minimum t_{MA} period, the SGD asserts SELECT* to start the ACK/NAK sequence.

The SGD then forwards the message to the application (if correct) or discards (if incorrect) and returns to IDLE state.

A.9.5 UCM operations

The UCM performs the same functions as the SGD, with the following changes.

- The actions of SELECT* and Attention* are reversed.
- The UCM has to monitor for Message Timeout.
- The UCM relies on the SGD to clock the bytes.

Annex B
(informative)

Description of DC form factor applications

B.1 General

Annex B further describes the use of the ISO/IEC 24739-3 connector for the DC form factor module and compares that use to the use of ISO/IEC 24379-3 in other information technology equipment.

B.2 Applications of ISO/IEC 24379

With regard to the possibility of end-user confusion regarding the DC modules in this document and ISO/IEC 24739-3 (ATA) as used with computer peripherals and equipment, the concern has been raised that it may be possible for an end-user to mistakenly

- insert an ATA hard drive into a Smart Grid Device conforming to this document, and/or
- insert a Universal Communications Module conforming to this document into an ATA hard drive bay.

It has been theorized that such a connection would damage the ATA transceiver circuitry. Whether such damage would indeed occur is not the subject of this discussion. The purpose of this assessment is to determine whether there is an existing physical impediment to such a connection being made.

B.3 Physical Form Factor Review

SATA 3.2 lists a single implementation of the affected connector (see ISO/IEC 24739-3), a disk drive with a 54-mm wide housing, referred to in that document as a “1,8-inch HDD” (see 6.3 in SATA 3.2). (While the same connector is also used in other devices, this analysis is focused here on the “1,8-inch HDD” device, since it appears to be more likely that a mistaken connection might be possible.) The physical dimensions of this device are referenced below:

- Overall Width: 54 mm ± 0,2 mm.
- Overall Height:
  - 5 mm Form Factor – 5 mm ± 0,15 mm;
  - 8 mm Form Factor – 8 mm ± 0,15 mm.
- Height, Case bottom to connector centreline: 1,85 mm (derived from dimensions in Figure 57 of SATA 3.2).
- Insertion Depth: 78,5 mm (distance from exterior surface of equipment to the face of the connector).
- Allowable Vertical misalignment: 1 mm (Figure 62 of SATA 3.2).

This document similarly lists the physical dimensions of a Universal Communications Module (which bears the same gender connector as the SATA 3.2 “1,8-inch HDD”).

- Overall width: $51{,}6^{+0{,}05}_{-0{,}15}$ mm.
- Main body width: $47{,}6^{+0{,}05}_{-0{,}10}$ mm.
- Overall height: 12,3 mm ± 0,1 mm.
- Height, case bottom to connector centreline: 3,85 mm.

- Insertion depth: 60 mm (distance from exterior surface of equipment to the face of the connector).

B.4 Observations with regard to UCM and ATA confusion

B.4.1 General

Based on the measurements discussed in B.3, the following observations can be made.

B.4.2 ATA into Smart Grid Device

- The only identified device with an ATA connector is too wide to fit into a port in this document by a minimum of 2,4 mm (6,4 mm if only the main body is taken into account, excluding the orientation tabs).
- Being too wide, the face of the connector of an ATA device would be 60 mm away from the mating face of the connector in a Smart Grid Device due to the insertion depth.
- Connection is therefore physically impossible without disassembling the Smart Grid Device.

B.4.3 Universal Communication Module into ATA device bay

- A UCM conforming to this document is too thick to fit into an ATA device bay by a minimum of 4,3 mm.
- A UCM conforming to this document has a designed insertion depth 18,5 mm shorter than a 1,8-inch HDD. This means that, even if one were to find a way to make a UCM fit into a 1,8-inch HDD bay (for example, by removing the UCM casing) it would be impossible to apply sufficient pressure to cause the connectors to mate.
- In the event that an ATA bay was not designed for “slide in” installation, connector misalignment between the bay connector and a UCM conforming to this document would exceed the allowed maximum by 1 mm, preventing connection.

B.5 Conclusion

In the typical use of the ISO/IEC 24739-3 connector in ATA applications (i.e. “slide in” installation of a 1,8-inch HDD), end-user confusion between such equipment and applications of the ISO/IEC 24739-3 connector in this document is highly unlikely. In the event that an attempt were made to connect an ATA and equipment conforming to this document together, the connection would be physically impossible without disassembling and/or modifying the respective equipment, or fabricating a cable.