Consumer Technology Association™

ANSI/CTA Standard

Modular Communications Interface for Energy Management

ANSI/CTA-2045-B

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(Formulated under the cognizance of the CTA **R7.8 Modular Communication Interface for Energy Management Subcommittee**)

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FOREWORD

This document was developed by the Consumer Technology Association's R7.8 Modular Communications Interface for Energy Management subcommittee.

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FIGURES

TABLES

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Modular Communications Interface for Energy Management

1 INTRODUCTION

Utilities worldwide are investing heavily in smart grid infrastructure that extends to homes and businesses, with the goal of improving grid reliability and efficiency through increased consumer awareness and participation. High hopes abound for grid connected homes and buildings to be better prepared and more willing to react to changing grid conditions. But, how do we enable grid connectivity today and into the future, in the midst of an evolutionary wave of standards competition and innovation?

This standard provides a solution to this problem through a modular communications interface (MCI) enabling any product to connect to any type of demand response system (Advanced Meter Reading (AMI), Smart Energy Profile (SEP), OpenADR), and/or home or building network. The concept is simple; encourage manufacturers to build an MCI interface into their products that can accept a simple communications module. Consumers and program managers are then free to select whatever communication solution works best for their particular environment.

The concept is relatively straightforward. Utilizing the RS-485 and Serial Peripheral Interface (SPI)1 supported by most silicon chips today, the MCI protocol is capable of simply passing through standard protocols including Internet Protocol (IP), OpenADR, and SEP from the communications module to the end-device. Network security is supported through the selected transport protocol, such as Wi-Fi, ZigBee, HomePlug, Z-Wave, LonWorks, etc., in addition to network or application layer security.

Communications messaging supported by this MCI standard supports direct load control, TOU, CPP, RTP, peak time rebates, all kinds of block rates, and a range of ancillary services. The functionality of the removable 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.

The CTA-2045-B Modular Communications Interface for Energy Management standard will enable a new generation of “smart grid ready” products that limit risks and constraints of proprietary communications technologies and evolving standards. This approach simplifies Home Area Network (HAN) device and network interoperability, fosters program and product innovation, and opens DR programs to a broader range of consumer products while respecting customer choice and a competitive market landscape.

1 See http://www.rs485.com/rs485spec.html and
http://en.wikipedia.org/wiki/Serial_Peripheral_Interface_Bus

2 SCOPE

This standard specifies a modular communications interface (MCI) to facilitate communications with residential devices for applications such as energy management. The MCI provides a standard interface for energy management signals and messages to reach devices. Such devices 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.

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.

The MCI specifies a physical connection from a communication module to residential Smart Grid Devices and a communications protocol with OSI (Open System Interconnection) layer specifications including application layer messaging. An optional translation function is specified for connection to another communications medium. Examples include power line carrier or radio (RF), depending on the home area network installed or the connection to an energy management system access-network supplied by a service provider. This second medium is outside the scope of this standard. The MCI also specifies a pass-through mechanism to allow for an alternate architecture in which the Smart Grid Device terminates the passed-through protocol (e.g., SEP, OpenADR, etc.).

CTA-2045-B details the mechanical, electrical, and logical characteristics of a socket interface that allows communication devices (hereafter referred-to as UCMs – universal communication modules) to be separated from end devices (hereafter referred-to as SGDs – Smart Grid Devices). Although the potential applications of this technology are wide-ranging, it is intended at a minimum to provide a means by which residential products may be able to work with any load management system through user installable plug-in communication modules. Figure 2-1 illustrates the general concept.

Figure 2-1 – Illustrations of the Modular Communications Concept on a controlled device (left) or Energy Management Console (right)

CTA-2045-B identifies the physical and data-link characteristics of the interface, along with certain higher-layer and application layer elements as needed to assure interoperability over a broad range of device capabilities. In addition, it defines a mechanism through which network, transport and application layer messages (pass-through; defined in other standards) may be passed across the interface.

The scope of this standard is limited to the socket interface between the UCM and the SGD. It does not address the technology or protocol associated with the communications system of which the UCM is part.

The scope of this specification 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 noted in Informative Appendix E.

2.1 References

2.2 Normative References

The following specifications and documents contain provisions that, through reference in this text, constitute normative provisions of this standard. At the time of publication, the editions indicated were valid. All specifications and documents are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the specifications and documents listed here.

2.2.1 Normative References List

1. TIA-485-A R-2012, *Electrical Characteristics of Generators and* Receivers *for Use in Balanced Digital Multipoint Systems*, March 1998 (Reaffirmed December 2012), https://tiaonline.org/products-and-services/buy-standards/

2.3 Informative References

The following documents contain provisions that, through reference in this text, constitute informative provisions of this document. At the time of publication, the editions indicated were valid. All documents are subject to revision, and parties to agreements based on this document are encouraged to investigate the possibility of applying the most recent editions of the documents listed here.

2.4 Informative References List

1. ClimateTalk 2.0 (Document revision 01, June 2013), http://www.climatetalkalliance.org/ClimateTalkTechnology/SpecDownload.aspx
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3. IEEE 2030.5-2013, *IEEE Adoption of Smart Energy Profile 2.0 Application Protocol Standard* (2013), https://standards.ieee.org/
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15. ANSI/CTA-2045.3 R-2019, *MCI for Thermostat Message Set*, August 2014, www.cta.tech
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17. ASHRAE 135-2016 Standard 135-2016 -- BACnet-A Data Communication Protocol for Building Automation and Control Networks (ANSI Approved); or ISO 16484-5:2014 Building automation and control systems (BACS) -- Part 5: Data communication protocol, https://www.ashrae.org
18. ASSE 1017 -- American Society of Sanitary Engineering (ASSE) 1017 -- Performance Requirements for Temperature Actuated Mixing Valves for Hot Water Distribution Systems
19. ASSE 1082 -- Performance Requirements for Water Heaters with Integral Temperature Control Devices for Hot Water Distribution Systems
20. ASSE 1084 -- Performance Requirements for Water Heaters with Temperature Limiting Capacity
21. UL 60730-1 -- Automatic Electrical Controls - Part 1: General Requirements

3 COMPLIANCE

CTA defines the following compliance terms for use in its documents:

shall	This word indicates specific provisions that are to be followed strictly (no deviation is permitted).
shall not	This phrase indicates specific provisions that are absolutely prohibited.
should	This word indicates that a certain course of action is preferred but not necessarily required.
should not	This phrase means a certain possibility or course of action is undesirable but not prohibited.
may	This phrase indicates that a certain course of action is optional.

4 DEFINITIONS, SYMBOLS AND ABBREVIATIONS

4.1 Symbols and Abbreviations

AMI Advanced Metering Infrastructure

AMR Automated Meter Reading

AP Average price

CPP Critical Peak Price

ESD Electrostatic Discharge

GND Electrical Ground

HAN Home Area Network

IP Internet Protocol

DR Demand Response

LS Abbreviation for Least Significant

MCI Modular Communication Interface

MS Abbreviation for Most Significant

OpenADR 2.0 Open Automated Demand Response standard version 2.0

OSI Open System Interconnection

PCB Printed Circuit Board

PLC Power line communications

RF Radio frequency

RTP Real-time prices

SEP Smart Energy Profile

SDO Standards developing organization

SGD Smart Grid Device

SPI Serial Peripheral Interface

TOU Time-of-Use

TVC Time varying charges

UCM Universal Communications Module

UTC Coordinated Universal Time

5 PHYSICAL/ELECTRICAL INTERFACE

Two physical form factors are presently defined. 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 described in detail in Appendix A – Low Voltage DC Form Factor (normative) of this document. 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 (100 to 240V) and an RS-485 based serial interface. This form factor is described in detail in Appendix B – AC Form Factor (normative) of this document. 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.

5.1 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.

5.2 Block Diagram

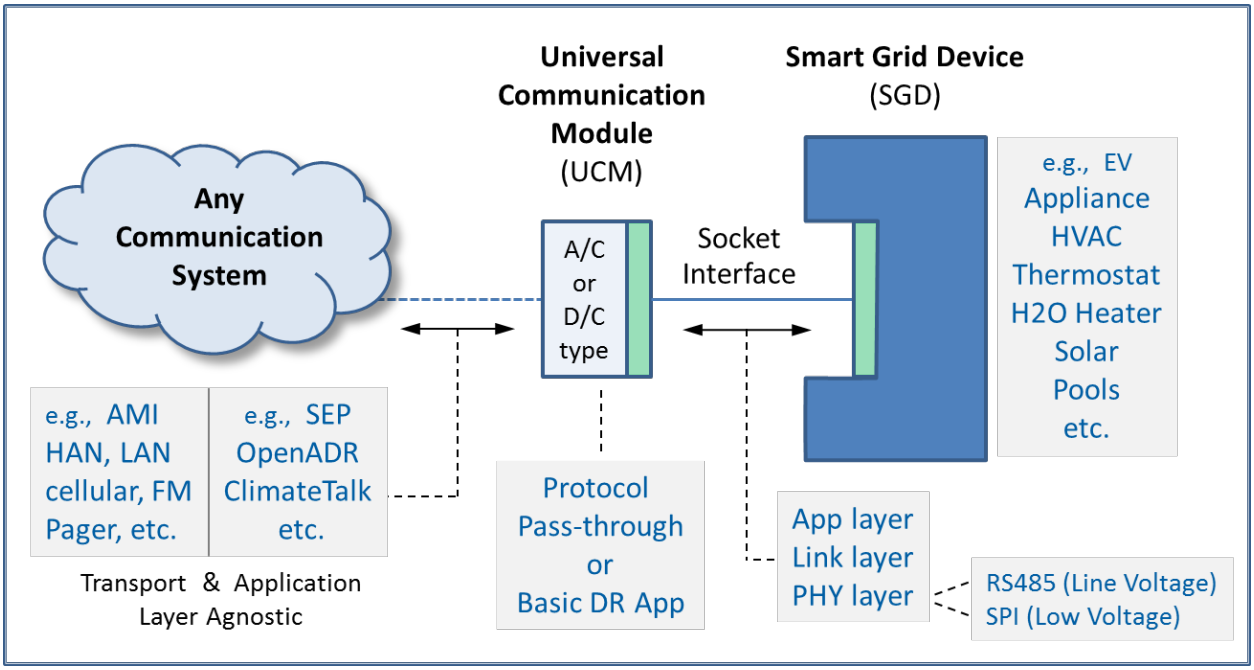


Figure 5-1 – Modular Interface - Block Diagram

6 SERIAL PROTOCOL

In this document, hex notation is used to describe binary numbers: 0x00 – 0xFF One or Two digit (8 bit) hexadecimal numbers ranging from 0 to 255 decimal.

Related to binary values, b0, b1 .. b15 are bit values within a hexadecimal number. b0 is least significant bit.

CTA-2045-B defines an extensible serial protocol data unit that is manageable by the simplest of devices and is also capable of being extended to accommodate the more complex. The general message format is shown in Table 6-1.

Message Type	Reserved Must be '0x0'	Payload Length	Payload	Checksum
2 Bytes	3 Bits	13 Bits	Variable	2 Bytes

Table 6-1 – Protocol Data Unit Format

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 to assure link layer data integrity. There are 3 bits at the top of the 3 byte that are reserved for future work. These must be held at 0 to keep 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 protocols one another support.

6.1.1 Message Type Field

The "Message Type" bytes indicate the type of message, essentially indicating which communications protocol is represented in the payload. The following "Message Type" values are specified in Table 6-2.

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	OpenADR1.0 over IP, Pass-Through
0x09	0x06	OpenADR2.0 over IP, Pass-Through
0x09	0x07	Generic IP Pass-Through (IP packets self-identify version so both IPV4 and IPV6 are covered)
0x09	0x08	ECHONET Lite Pass-Through
0x09	0x09	KNX Pass-Through
0x09	0x0A	LonTalk Pass-Through
0x09	0x0B	SunSpec Modbus Pass-Through
0x09	0x0C	BACnet Pass-Through
0x09	0x0D 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

Table 6-2 – Message Type Assignments

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. Notionally, this would be done in coordination with the organization(s) responsible for the management of the domain-area or protocol that is to be passed through.

Section 8, Data-Link Messages, describes 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.

6.1.2 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 defined by the other protocols.

6.1.3 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 detailed in Appendix C.

6.1.4 Bit and Byte Order

All bytes are transmitted most significant bit first for the DC Form Factor and least significant bit first for the AC Form Factor. 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:

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

6.1.5 Message Synchronization and Timing

All communication on the CTA-2045-B interface shall be half-duplex. This applies to both the low voltage DC interface using SPI and the high voltage AC interface using RS-485. The nature of the two-wire RS-485 interface fundamentally allows only one side to transmit successfully at any time.

CTA-2045-B allows either the communications module or the end device to initiate communication. As a result, bus contention is possible on the AC interface and must 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 described in Section 6.1.5.2.

6.1.5.1 Link Layer Timing

Required link layer timing is illustrated in Figure 6-1 – Data-Link Timing and specified in Table 6-3 – Message Timing Requirements.

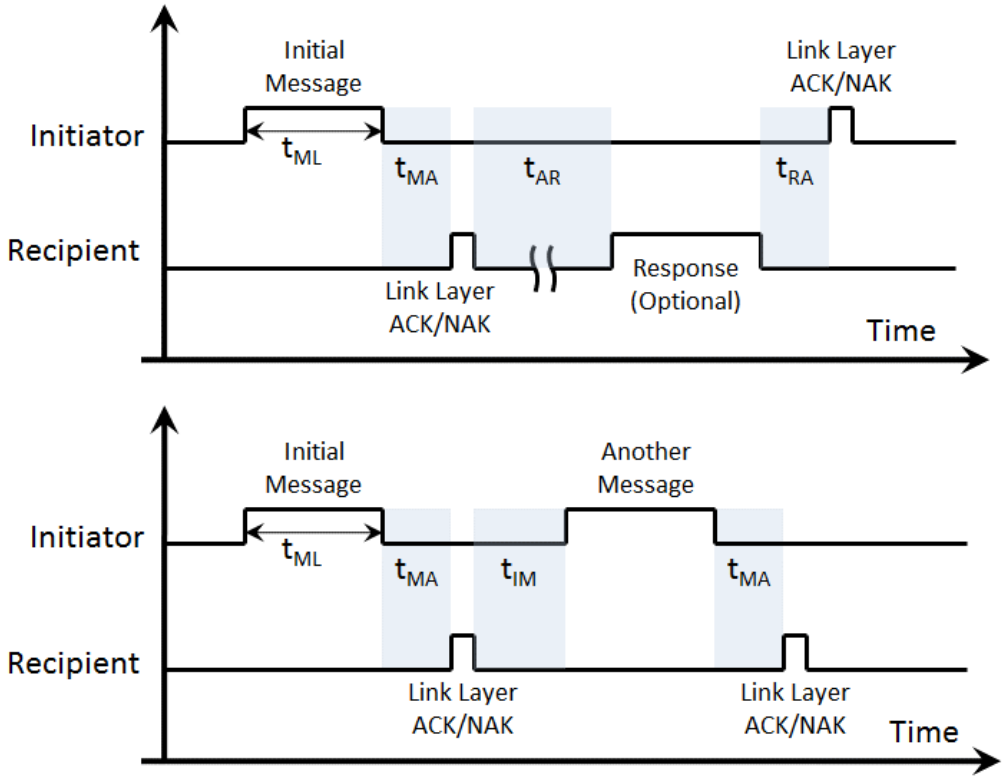


Figure 6-1 – Data-Link Timing

Note that the existence of an application-layer response is optional. The Basic DR and "Intermediate DR" applications defined herein always result in a response, but other pass-through applications may not.

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 requirements of

Parameter	Minimum	Maximum	Description
			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 ≤ 500mS)

Table 6-3 – Message Timing Requirements

6.1.5.2 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 data-link layer, with a randomized delay between each retry of 100 to 2000[mS]. Additional error recovery may exist at the application layer but the specific handling of such is outside the scope of this specification.

6.1.5.3 Application Layer Timing

Application layer timing shall not violate any of the link layer requirements identified above. For pass-through application protocols, the application layer timing is outside the scope of CTA-2045-B.

For the Basic DR and "Intermediate DR" messages defined in CTA-2045-B, the timing parameters are illustrated in Figure 6-2 and specified in Table 6-4.

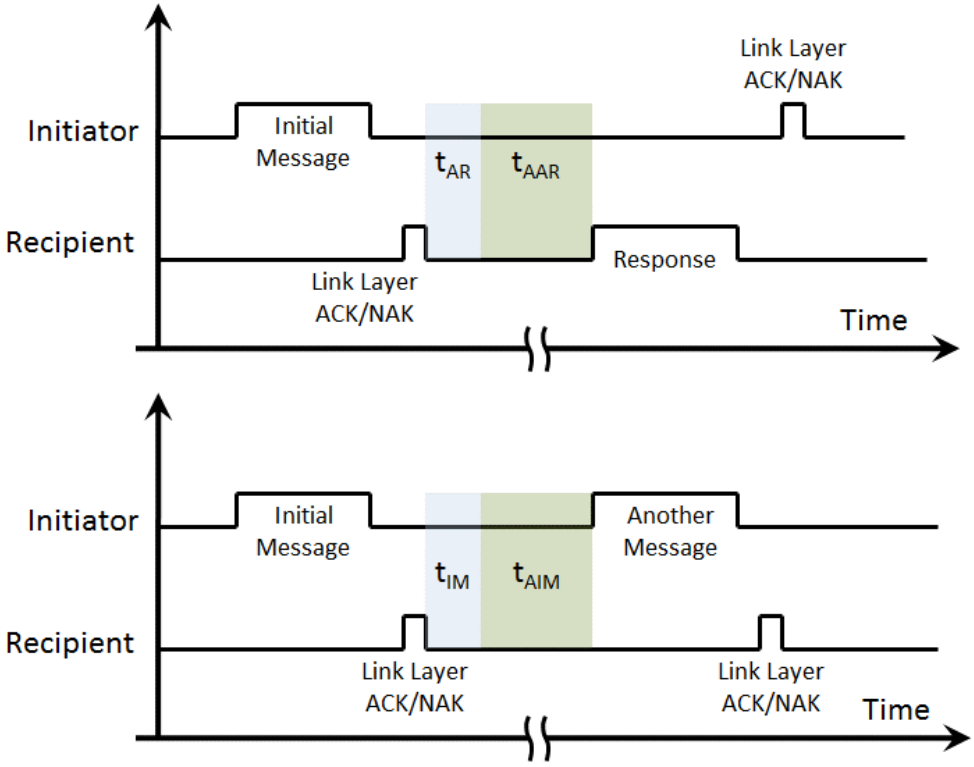


Figure 6-2 –Application Layer Timing

Parameter	Minimum	Maximum	Description
t_{AAR}	0[mS]	3000[mS]	For all application messages from alternating sides of the interface: Additional time 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 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.

Table 6-4 – Basic/Intermediate DR Application Layer Timing Parameters

6.1.6 SGD Handling of Conflicting Messages

CTA-2045-B supports multiple possible application layer protocols, including the basic and intermediate DR commands defined herein in addition to the pass-through of other industry 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 (Section 10) and Intermediate DR (Section 10 - Intermediate DR Application (Message Type = 0x08, 0x02)) applications are indicated in the “Priority:” sub-row of the “Usage” column in Table 10-2 and Table 11-2. If the curtailment mode triggered by a command of priority "High" is currently active, only another command of priority "High" will 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" will 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 will be acted upon as soon as received.

7 SIMPLE IMPLEMENTATION (NORMATIVE)

Compliance with CTA-2045-B is described in detail in Appendix F - Certification Levels (normative), which supersedes and adds different levels of support to the requirements of this section. Tests and certification procedures for CTA-2045-B shall consider all sections and appendices in this document marked (normative). Level 1 of Appendix F is considered to be the replacement to the simple implementation in this section.

CTA-2045-B identifies 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 CTA-2045-B systems for demand response applications, UCMs and SGDs shall support the messages listed in Table 7-1, each of which is limited to 8 bytes length. Devices may optionally support additional messages as desired.

Different minimum requirements may be established in the future for applications of the CTA-2045 interface other than demand response.

Mandatory Message	Layer	Description

Shed	Basic DR Application	Fixed, 8 byte
End Shed	Basic DR Application	Fixed, 8 byte
Application ACK/NAK	Basic DR Application	Fixed, 8 byte
Outside Communication Connection Status	Basic DR Application	Fixed, 8 byte
Link Layer ACK/NAK	Link Layer	Fixed, 2 bytes See Section 8.1
Message Type Supported Query	Link Layer	Fixed, 6 byte See Section 8.2

Table 7-1 – Mandatory Message Summary

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

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, defined in Section 8.2 is also required.

8.1 Link Layer ACK/NAK

All packets shall result in a link layer ACK or NAK as shown in **Figure 6-1**. ACKs and NAKs are both two byte packets as shown in **Table 8-1** below.

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

Table 8-1 ACK/NAK Packet

NAKs are used to indicate that the packet was not accepted or understood. **Table 8-2** below lists the NAK codes and their use.

Link NAK Error Code	Priority	Description	Usage
0x00		No Reason	Not used.

Link NAK Error Code	Priority	Description	Usage
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	NA
0x05	5	Message Timeout	Indicates that more than t_{ML} (defined in Table 6-3) 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 Appendix 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.

Table 8-2 Link Layer NAK Codes

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

8.2 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 6-2** for the defined message type values) with a 0 length payload. If the receiver supports that message type, it will 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 8-2**).

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

Table 8-3 – Message Type Supported Query

Example 1 - SGD Supports Intermediate Message Type:

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

SGD sends 06 00 - Link Layer ACK

Example 2 - UCM does not support Network Message Type:

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

UCM sends 15 06 - Link Layer NAK, Unsupported Message Type

9 DATA-LINK MESSAGES

The data-link messages identified in this section 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 indicated in **Table 9-1**, with message type = (0x08, 0x03) and the payload field used as defined here in Table 9-2.

Message Type = 0x08, 0x03	Reserved, Must be '0'	Payload Length = 0x00, 0x02	Opcode1	Opcode2	Checksum
2 Bytes	3 Bits	13 Bits	1 Byte	1 Byte	2 Bytes

Table 9-1 – Data-Link Message Format

Description	Format	Usage
Request Different Power Mode	(8 bytes total, see **Table 9-1**) Opcode1 =0x16 Opcode2 = Power Level Indicator	Sent from the UCM to the SGD to request permission to draw higher power than the default. See Section 9.1.1 for "Power Level Indicator" details.
Request Different Bit Rate	(8 bytes total, see **Table 9-1**) 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 Section 9.1.2 for "Bit Rate Indicator" details.
Query: Maximum payload length?	(8 bytes total, see **Table 9-1**) Opcode1 = 0x18 Opcode2 = 0x00	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 are supported.

Description	Format	Usage
Response: Maximum payload length	(8 bytes total, see **Table 9-1**) 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 9-1**) 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 9-1**) 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 will be contained in the upper 3 bits.

Description	Format	Usage
Query: Get Available Slot Numbers	(8 bytes total, see **Table 9-1**) Opcode1 = 0x1C Opcode2 = 0x00	UCM asking the SGD what slot numbers exist and which are used.
Response: Available Slot Numbers	(8 bytes total, see **Table 9-1**) 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 9-1**) 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.

Table 9-2 – Data-Link Command Set

9.1.1 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:

Power Level Indicator	DC Form Factor		AC Form Factor		
	Maximum Continuous Average	Maximum Peak	Maximum Continuous Average	Maximum Peak	Maximum Instantaneous
0x00 (default)	50[mA]	300[mA]	50 [mA,rms]	300 [mA,rms]	10 [Amps]
0x01	150[mA]	2[Amp]	N/A	N/A	N/A
0x02	250[mA]	2[Amp]	N/A	N/A	N/A
0x03	500[mA]	2[Amp]	N/A	N/A	N/A
0x04	750[mA]	2[Amp]	N/A	N/A	N/A
0x05 5 V Power Option (See Section 17.2.1)	1[Amp]	1.5[Amp]	N/A	N/A	N/A
0x06 to 0xFF (Reserved)					

Table 9-3 – Interface Power Level Indicator Codes

Where:

- "Maximum Peak" = allowed for a 100 milliseconds maximum duration, with a 10% maximum duty cycle in any given second.
- "Maximum Instantaneous" = allowed for 1 millisecond maximum duration, with a 10% maximum duty cycle in any given 10millisecond period and a 1% maximum duty cycle in any given 10 second 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 described in the respective physical layer appendices.

All UCMs must 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) 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 Section 8.2. 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 must 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.

Example 1 - SGD does not support “Request Different Power Mode” message at all:

UCM sends 08 03 00 00 76 D3 – Message Type Supported Query for Data-Link Messages (0x08 0x03)

SGD sends 06 00 - Link Layer ACK

SGD sends 08 03 00 00 76 D3 – Message Type Supported Query symmetrical response

UCM sends 06 00 - Link Layer ACK

UCM sends 08 03 00 02 16 00 C0 71 - Power Level Indicator 0x00 (default) Request message

SGD sends 15 07 - Link Layer NAK, Request Not Supported Error

Example 2 - SGD supports Request Different Power Mode, up to level 0x02 (DC form factor only):

UCM sends 08 03 00 00 76 D3 – Message Type Supported Query for Data-Link Messages (0x08 0x03)

SGD sends 06 00 - Link Layer ACK

SGD sends 08 03 00 00 76 D3 – Message Type Supported Query symmetrical response

UCM sends 06 00 - Link Layer ACK

SGD sends 08 03 00 02 16 00 C0 71 - Power Level Indicator 0x00 (default) Request message

UCM sends 06 00 - Link Layer ACK, default power mode and Request message supported

SGD sends 08 03 00 02 16 01 BE 72 - Power Level Indicator 0x01 Request message

UCM sends 06 00 - Link Layer ACK, Power Level Indicator 0x01 supported

SGD sends 08 03 00 02 16 02 BC 73 - Power Level Indicator 0x02 Request message

UCM sends 06 00 - Link Layer ACK, Power Level Indicator 0x02 supported

SGD sends 08 03 00 02 16 03 BA 74 - Power Level Indicator 0x03 Request message

SGD sends 15 07 - Link Layer NAK, Request Not Supported Error, therefore highest power level support is 0x02

9.1.2 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 must 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.

Bit Rate Indicator	Bit Rate [Kbps]
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

Table 9-4 – Bit Rate Indicator

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 described at the end of Section 9.1.1 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 bitrates 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[Kbps].

9.1.3 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) must be renegotiated following a power cycle.

The "Outside Communication Connection Status" message defined in Section 10 requires that a message be sent at least once every 1-5 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.

9.1.4 Security

If present, security shall be handled above the link layer (network, transport, application) and is outside the scope of this specification.

The Basic and Intermediate DR applications' messages identified in CTA-2045-B do not employ any security mechanisms.

9.2 Setting Slot Numbering

During initialization, the UCMs in a multiple module system do not have an assigned slot. Each UCM that supports slot numbering will 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)

This section defines a set of Basic DR application commands and explains how they are supported by the CTA-2045-B interface. 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 Critical Peak Event 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 follows, with the message type being a "0x08, 0x01" and the payload being a 1 byte Opcode1 and a 1 byte Opcode2.

Message Type = 0x08, 0x01	Reserved, Must be '0'	Payload Length = 0x00, 0x02	Opcode1	Opcode2	Checksum
2 Bytes	3 Bits	13 Bits	1 Byte	1 Byte	2 Bytes

Table 10-1 – Basic Application Data Format

The Basic DR message payloads are defined as follows:

				Mandatory?	
Description	**Opcode1**	**Opcode2**	**Usage**	**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 must fall back to this Opcode. Event Duration: See Section 10.1.2 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"	✓	✓

				Mandatory?	
Description	**Opcode1**	**Opcode2**	**Usage**	**for SGDs**	**for UCMs**
End Shed/Run Normal	0x02	0x00 (Not Used)	This command must 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. This command also terminates the effect of any other command in this document that is listed as Priority: "High", including Intermediate DR commands like Set Offset, Set SetPoint, Start Autonomous Cycling and Advanced Load Up. **Priority:** "High"	✓	✓
Basic Application ACK	0x03	ACK'ed Opcode1	Acknowledge successful receipt and support of previous command. This message does not imply that the SGD will alter its state according to the command sent by the UCM. The UCM should query the operational state to determine whether the command has taken effect. 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"	✓	✓

				Mandatory?	
Description	**Opcode1**	**Opcode2**	**Usage**	**for SGDs**	**for UCMs**
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 = Customer Override is in effect 0x06 to 0xFF Reserved **Priority:** "Not Applicable"	✓	✓
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 Section 10.2.1. **Priority:** "High"		

				Mandatory?	
Description	**Opcode1**	**Opcode2**	**Usage**	**for SGDs**	**for UCMs**
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 Section 10.2.2 for description and usage. If NAK'ed, UCM must 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 Section 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 Section 10.1.2 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 program) 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 Section 10.1.2 for description and usage. **Priority:** "High"		

				Mandatory?	
Description	**Opcode1**	**Opcode2**	**Usage**	**for SGDs**	**for UCMs**
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 Section 10.1.2 for description and usage. **Priority:** "High"		
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 to 5 minutes so that SGD's 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 must be shared
Customer Override	0x11	0 = No Override, 1 = Override	Sent from either the SGD or 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 set to override.		

				Mandatory?	
Description	**Opcode1**	**Opcode2**	**Usage**	**for SGDs**	**for UCMs**
			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. In some cases, as determined by the SGD, this message may be sent spontaneously not in response to Opcode 0x12. If SGD sends this message, the UCM should respond with a Basic Application ACK. Operating State Codes: See Section 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 will be 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"		
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. UCM's 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"		

				Mandatory?	
Description	**Opcode1**	**Opcode2**	**Usage**	**for SGDs**	**for UCMs**
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. **Priority:** "Not Applicable"		
Load Up	0x17	Event Duration	This command is the opposite (complement) of the "Shed" command. It requests that the end device run now, and continue as possible. The assumption of this command is that energy is not wasted, but rather that things like 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 Section 10.1.2 for description and usage. **Priority:** "High"		
Pending Event Time	0x18	Time Until Event	Used to inform the SGD (and possibly the user) that a DR event will occur in the near future. Time Until Event See Section 10.1.2 for description and usage.		

				Mandatory?	
Description	**Opcode1**	**Opcode2**	**Usage**	**for SGDs**	**for UCMs**
			Priority: "Not Applicable"		
Pending Event Type	0x19	Opcode 1 of the Pending Event	Used to inform the SGD (and possibly the user) of the type of DR event will occur in the near future. Note: To Cancel a previously notified pending event, send this message with Opcode2 set to 0x02 (End Shed/Run Normal)	Pending Event Type	0x19
			Priority: "Not Applicable"		
Reboot	0x1A	Type of reset	Request made by either UCM or SGD for the other device to perform a reboot Opcode 2 0x00 = Soft reboot 0x01 = Reset to factory defaults (restore factory default configuration and then reboot) 0x02 to 0xFF Reserved After this command is acknowledged, both UCM and SGD must return to startup conditions, see Section 9.1.3 Power-Up and State Reset		
			Priority: "Not Applicable"		

Table 10-2 – Basic DR Application Command Set

10.1.1 Basic Message Fixed Length

The "Basic DR Application" messages are fixed at 8 bytes total length, because the payload always consists of 2 bytes. This makes message parsing simple because processors can shift over a known number of bytes and always find the field of interest.

10.1.2 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 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 defined by a square function of the byte value:

Time in Seconds = 2 * (Byte Value)^2

This results in the ability to represent a range of Event Durations between 2 and 129032 seconds (approximately 35.8 hours) as indicated in **Figure 10-1**.

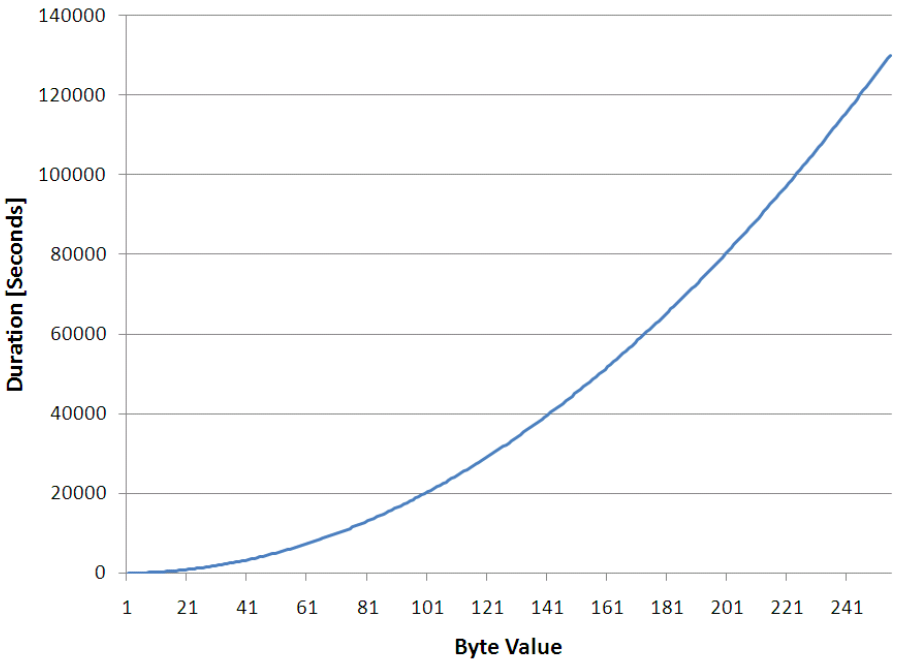


Figure 10-1 – Non-Linear Event Duration Scaling

10.1.3 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, UCM's that provide the Basic DR price look-ahead capability enabled by messages 0x08 and 0x09 must send these messages along with the 0x07 message within the timing t_{IM} specified in **Table 6-3 – Message Timing Requirements**. 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., analog 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 4500 watts, could be managed at certain times of day to operate at 900 watt (20%). This setting could be modified rapidly 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 will operate at approximately the requested average Power Level shall ACK this command; under all other conditions a NAK shall be provided. A device for all sorts of 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 **Table 10-2**, the Opcode2 field of these messages (Opcode1 = 0x07 or 0x08) provides the relative price indictor.

Relative_Price_Indicator = Present_Price / Average_Price

Where "Average_Price" is calculated as defined in Appendix D.

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 defined by a nonlinear function of the byte value:

Relative_Price_Indicator = (Byte Value-1) * (Byte Value + 63) / 8192

This equation results in the scale indicated in **Figure 10-2**.

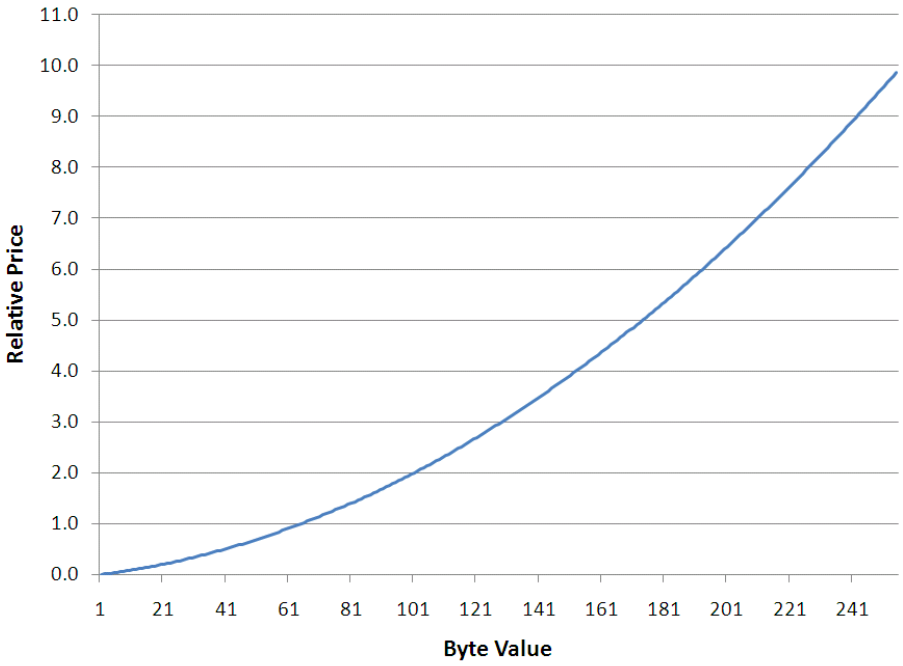


Figure 10-2 – Non-Linear Relative Price Scaling

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 must obey the priority as set out in Section 10 - Basic DR Application (Message Type = 0x08, 0x01) and in **Table 10-2**.

Note: Actual price information is supported through the use of more advanced commands as described in Section 10 - Basic DR Application (Message Type = 0x08, 0x01).

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 must 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. The following may be extended in future versions of CTA-2045. Up to 255 states may be defined.

Op State Code	Name	Description
0	Idle Normal	Indicates that no demand response event is in effect and the SGD has no/insignificant energy consumption.
1	Running Normal	Indicates that no demand response event is in effect and the SGD has significant energy consumption.
2	Running Curtailed	Indicates that a curtailment type demand response event is in effect and the SGD has significant energy consumption.
3	Running Heightened	Indicates that a heightened-operation type of demand response event is in effect and the SGD has significant energy consumption.
4	Idle Curtailed	Indicates that a curtailment type demand response event is in effect and the SGD has no/insignificant energy consumption.
5	SGD Error Condition	Indicates that the SGD is not operating because it needs maintenance support or is in some way disabled (i.e. no response to the grid).
6	Idle Heightened	Indicates that a heightened-operation type of demand response event is in effect and the SGD has no/insignificant energy consumption.
7	Cycling On	Indicates that a cycling type of demand response event is in effect and the SGD has significant energy consumption (i.e. cycled on).
8	Cycling Off	Indicates that a cycling type of demand response event is in effect and the SGD has no/insignificant energy consumption (i.e. cycled off).
9	Variable Following	Indicates that a variable-setting type of demand response event is in effect and the SGD is presently following the specified setting.
10	Variable Not Following	Indicates that a variable-setting type demand response event is in effect and the SGD is presently not following

Op State Code	Name	Description
		the specified setting (e.g. has no/insignificant energy consumption.
11	Idle, Opted Out	Indicates that the SGD is presently opted out of any demand response events and the SGD has no/insignificant energy consumption.
12	Running, Opted Out	Indicates that the SGD is presently opted out of any demand response events and the SGD has significant energy consumption.
13	Running, Price Stream	Indicates that the SGD is responding to the price stream and the SGD has significant energy consumption.
14	Idle, Price Stream	Indicates that the SGD is responding to the price stream and the SGD has no/insignificant energy consumption.
15-125	Not Used	Future use
126-255	Reserved	Reserved for manufacturer use.

Note: Op State Codes 13 and 14 are new to this version of the standard, revision B. To determine if the latest set of Op State Codes are supported, devices should use the GetInformation message, see Section 11.1.1 to discover what version of the CTA-2045 standard is implemented.

The following table include an example use of the operational state codes.

		SGD Energy Use at the Moment of the Request	
		Operating / in Use (Significant consumption)	Idle / Not in Use (Insignificant consumption)
Demand Response Event in Effect	None, End Shed / Run Normal	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
	Grid Emergency	Op State Code 2	Op State Code 4
	High Relative Price	Op State Code 2	Op State Code 4
	Low Relative Price	Op State Code 3	Op State Code 6
	Load Up	Op State Code 3	Op State Code 6

	Price Stream	Op State Code 13	Op State Code 14
	Advanced Load Up	Op State Code 3	Op State Code 6
	Cycling	Op State Code 7	Op State Code 8
	Variable Control	Op State Code 9	Op State Code 10
	Any, Device Opted Out	Op State Code 12	Op State Code 11

Table 10-3 – Operating State Codes

11 INTERMEDIATE DR APPLICATION (MESSAGE TYPE = 0X08, 0X02)

This section identifies 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 which causes the length of the packet to be content specific.

Prior to sending any of the messages defined in this section, the device must negotiate the maximum payload size using the "Query: Maximum payload length?" and "Response: Maximum payload length" messages defined in **Table 9-2**. CTA-2045-B 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 this section, they refer only to the requirement for inclusion of those fields within the message being described. Where multiple fields are labeled as “optional”, the sender must include all elements up to the last “optional” value transmitted. When the sender must send an “optional” value and does not have a valid value, it will send the highest positive value for that field. For 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 Intermediate DR commands follow the protocol data unit format indicated in Table 6-1, with the “Payload” field used as defined in Table 11-2 – Intermediate DR Application Command Set.

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 11-1 – Intermediate DR Application Command Set (Command Byte Description) provides a list of the categories for the messages defined in this section. The Opcode1 column refers to the first byte (most significant byte) of the payload section as described in **Table 6-1** (Protocol Data Unit Format).

Opcode1	Usage Categories
0x00	Reserved
0x01	Device Information and Efficiency Level (Mode)

0x02	Time & Date
0x03	Tier & Temperature
0x04	Demand Reduction
0x05	Demand Response Event Schedules
0x06	Consumption/Production
0x07	See external document ANSI/CTA-2045.3 Thermostat Specific commands
0x08	See external document ANSI/CTA-2045.2 Generic Display commands
0x09	See external document ANSI/CTA-2045.1 OTA Firmware commands
0x0A	Device Activation/Deactivation
0x0B	User Preference Level
0x0C	Advanced Load Up
0x0D	Price Stream
0x0E-0xEF	Future Use
0xF0-0xFF	Manufacturer Specific

Table 11-1 – Intermediate DR Application Command Set (Command Byte Description)

Table 11-2 provides a more granular list of the messages defined in this section.

	Payload			
Description	**Opcode1**	**Opcode2**	**Additional Payload Definitions**	**Usage**
Info Request	0x01	0x01	Defined in Section 11.1.1	Request device information **Priority:** "Not Applicable"
Get/Set SGD Efficiency Level	0x01	0x02	Defined in Section 11.7	Set or recommend the SGD efficiency level. This is related to the mode the SGD is operating in. **Priority:** "Not Applicable"
Set Capability Bitmap	0x01	0x03	Defined in Section 11.1.1.3	Set Device Capabilities on the SGD from the UCM **Priority:** "Not Applicable"

	Payload			
Description	**Opcode1**	**Opcode2**	**Additional Payload Definitions**	**Usage**
Get/Set UTC Time	0x02	0x00	Defined in Section 11.1.2	Set or request Time **Priority:** "Not Applicable"
Get/Set Energy Price	0x03	0x00	Defined in Section 11.1.3	Set or request the current price of energy **Priority:** "Low"
Get/Set Tier	0x03	0x01	Defined in Section 11.1.4	Set or request the current tier value **Priority:** "Low"
Get/Set Temperature Offset	0x03	0x02	Defined in Section 11.1.5	Set or request the current temperature offset value **Priority:** "High"
Get/Set SetPoint	0x03	0x03	Defined in Section 11.1.6	Set or request the current temperature set point value(s) **Priority:** "High"
Get Present Temperature	0x03	0x04	Defined in Section 11.1.7	Request the current physical temperature reading **Priority:** "Not Applicable"
Start Autonomous Cycling	0x04	0x00	Defined in Section 11.1.8	Start a Demand Reduction cycling event per the parameters passed in the command **Priority:** "High"
Terminate Autonomous Cycling	0x04	0x01	Defined in Section 11.1.8.3	Terminate a Demand Reduction cycling event **Priority:** "High"
Demand Response Event Schedules	0x05	0x00	Defined in Section 11.2.1	Send Scheduled Events Request **Priority:** "Not Applicable"

	Payload			
Description	**Opcode1**	**Opcode2**	**Additional Payload Definitions**	**Usage**
Get/Set Commodity Read	0x06	0x00	Defined in Section 11.3.1	Get or Set(Publish) Energy Consumption Values **Priority:** "Not Applicable"
Get/Set Commodity Subscription	0x06	0x01	Defined in Section 11.3.2	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"
Thermostat Specific Commands	0x07	*	Defined in ANSI / CTA-2045.3	See the external document for this command set **Priority:** "Not Applicable"
Generic Display Commands	0x08	*	Defined in ANSI / CTA-2045.2	See the external document for this command set **Priority:** "Not Applicable"
OTA Firmware Commands	0x09	*	Defined in ANSI / CTA-2045.1	See the external document for this command set **Priority:** "Not Applicable"
Get/Set Activation Status	0x0A	0x00	Defined in Section 11.4.1	Set or read the "Activation" Status. This message has been identified as a marketplace requirement for certain end-device types and its use is restricted. See description in Section Device Activation. **Priority:** "Not Applicable"
Get/Set User Preference Level	0x0B	0x00	Defined in Section 11.5	Set or read user preference level. This message is intended to provide a mechanism to convey user preferences. **Priority:** "Not Applicable"
Get/Set Advanced Load Up	0x0C	0x00	Defined in Section 11.6	Sent by the UCM to absorb energy above the amount of energy absorbed during a Basic DR Load Up command. **Priority: "High"**
Price Stream: Static Tariff	0x0D	0x00	Defined in Section 11.8.1	Provide static information about the Tariff that is being streamed using Price Stream **Priority:** "Not Applicable"

	Payload			
Description	**Opcode1**	**Opcode2**	**Additional Payload Definitions**	**Usage**
Price Stream: Accepted Pairs	0x0D	0x01	Defined in Section 11.8.2	Allows the SGD to provide the total number of time+price pairs that it can accept and store for a complete price stream and whether it supports export prices.
				Priority: "Not Applicable"
Price Stream	0x0D	0x02	Defined in Section 11.8.3	Provide a stream of current and future prices
				Priority: "Not Applicable"
Export Price Stream	0x0D	0x03	Defined in Section 11.8.4	Provide a stream of current and future prices to be used for exporting energy (selling to the grid or microgrid)
				Priority: "Not Applicable"

Table 11-2 – Intermediate DR Application Command Set

Intermediate DR Message responses include a response code byte.+ **Table 11-3** provides a list of the defined response codes.

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
0x07	Customer Override is in effect
0x08	Command not enabled
0x09-0xFF	Reserved

Table 11-3 – Response Code Values

11.1 Usage and Details of Intermediate DR Application Messages

11.1.1 Info Request

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.

11.1.1.1 Format GetInformation() – Request

Byte	Hex value	Comments	Mandatory/ Optional
1	0x01	Opcode1	M
2	0x01	Opcode2	M

11.1.1.2 Format GetInformation() - Reply

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
4-5		CTA-2045 Version – ASCII*	M
6-7		Vendor ID	M
8-9		Device Type	M
10-11		Device Revision	M
12-15		Capability Bitmap	M
16		Reserved	M
17-32		Model Number – ASCII	O
33-48		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

* Value is 0x42, 0x00 (ASCII null-terminated string "B") for this revision B of this standard

Device Information included here is read-only and will 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 CTA-2045 version (0x41, 0x00 for initial version) that the unit was designed for, firmware information, Serial Number and Model Number.

Vendor ID

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

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 (e.g., ZigBee)
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 (BPL)
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

SGD Device Types		UCM Device Types (Phy/MAC)	
Device Type	**Description**	**Device Type**	**Description**
0x0012	Microwave Oven		
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		
0x001A	Central AC – Heat Pump Variable Capacity		
0x001B	Water Heater – Heat Pump Variable Capacity/Speed		
0x001C	Water Heater - Phase Change Material		
0x0020	Fan		
0x0030	Pool Pump – Single Speed		
0x0031	Pool Pump – Variable Speed		
0x0032	Electric Hot Tub		
0x0040	Irrigation Pump		
0x0041	Clothes Dryer – Heat Pump		
0x1000	Electric Vehicle		
0x1001	Hybrid Vehicle		
0x1100	Electric Vehicle Supply Equipment – general (SAE J1772)		
0x1101	Electric Vehicle Supply Equipment – Level 1 (SAE J1772)		

SGD Device Types		UCM Device Types (Phy/MAC)	
Device Type	**Description**	**Device Type**	**Description**
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		
0x7000	Distributed Energy Resources		
0x7001	Solar Inverter		
0x7002	Battery Storage		
0x8000 – 0xFFFF	Manufacturer Defined Device Types		

Capability Bitmap

Bit (2^n)	Description
0	Cycling supported
1	Tier mode supported
2	Price mode supported
3	Temperature Offset supported
4	Continuously variable power
5	Discretely variable power
6	Advanced Load Up supported
7	Price Stream supported
8	SGD Efficiency Level supported
9-31	Reserved

Continuously variable power

Equipment capable of varying its power

Discreetly variable power

Equipment capable of varying its power in one or more discrete steps

Device Revision

16-bit integer that defines the device revision. all zeros = not supported

Model Number

Device model number, all zeros = not supported

Serial Number

Device serial number, all zeros = not supported

Firmware Year

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

Firmware Month

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

Firmware Day

1 - 31

11.1.1.3 Set Capability Bitmap

If the manufacturer intends to support Advanced Load Up and would like set or unset the corresponding bit in the Capability Bitmap using the CTA-2045-B port, the following optional command may be used by the UCM.

In order for a third-party UCM manufacturer to request the bit be set to enable the Advanced Load Up functionality on the SGD, the third-party UCM shall disclose and get a positive response from the consumer through a user-interface on the third-party module or through an application that:

1. The Advanced Load Up functionality allows the customer's utility to increase the tank temperature above the customer's setpoint. This functionality could result in hotter temperatures in your water heater.;

2. A thermostatic mixing valve conforming to ASSE 1017 must be installed on the hot water supply line following all manufacturer installation instructions or the water heater conforms to UL 60730-1, ASSE 1082, or ASSE 1084 in order to reduce the risk that water substantially hotter than the temperature set point will be delivered to taps; and
3. The thermostatic mixing valve's temperature setting has been adjusted to at or below the heat pump water heater's temperature set point.

The command is also flexible and allows other bits to be set or unset as needed and only if the SGD supports the proposed bit to be set or unset. The SGD should respond with "Bad Value – one or more values in the message are invalid" if setting or unsetting as specific bit is not supported.

11.1.1.3.1 Format SetCapabilityBitmap() - Request

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x01	Opcode1	M
2	0x03	Opcode2	M
3		Capability Bit Number	M
4		Set or Unset	M

11.1.1.3.2 Format SetCapabilityBitmap() – Reply

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x01	Opcode1	M
2	0x83	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M

Capability Bit Number

The bit number in the capability bitmap that will be altered by this command (see section 11.1.1.2).

Set or Unset

If 0x01, the bit number above in the capability bitmap shall be set to 1
If 0x00, the bit number above in the capability bitmap shall be set to 0
Values 0x02 - 0xFF are RESERVED and not to be used

Example 1 - After a qualified professional installs a mixing valve meeting ASSE 1017 on the hot water output line of a water heater (SGD), and after the approval of the local inspection authority, the end

user wishes to activate the Advanced Load Up feature in the water heater's internal control electronics. An app or cloud service is used to send a message via the UCM to set bit 6 in the Capability Bitmap to 1.

UCM sends: 08 02 00 04 01 03 06 01 CRC1 CRC2

08 02 - Intermediate DR

00 04 - length

01 03 - Set Capability Bitmap Opcodes

06 - bit 6 in the Capability Bitmap for Advanced Load Up

01 - set the bit (change it to 1)

CRC1 CRC2

SGD sends 06 00 - Link Layer ACK

SGD sends 08 02 00 03 01 83 **00** CRC1 CRC2 - SGD responds (0x01 0x83) with success (**0x00**) in receiving the command.

UCM sends 06 00 - Link Layer ACK

11.1.2 Get/Set UTC Time

Set the time on the device.

11.1.2.1 Format GetUTCTime() - Request

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x02	Opcode1	M
2	0x00	Opcode2	M

11.1.2.2 Format GetUTCTime() - Example 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
4-7		UTC Seconds	M
8		Time zone offset in ¼ hours (e.g., EST = -20)	M
9		DST Offset in ¼ hours	M

11.1.2.3 Format SetUTCTime() - Request

Payload Byte	Hex value	Comments	Mandatory/ Optional
1	0x02	Opcode1	M
2	0x00	Opcode2	M
3-6		UTC Seconds	M
7		Time zone offset in ¼ hours (e.g., EST = -20)	M
8		DST Offset in ¼ hours	M

11.1.2.4 Format SetUTCTime() - Example 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. **Note**: UTC time includes leap seconds and they should be correctly represented in any value sent in this field (the UTC time should be retrieved from a source that accounts for leap seconds).

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

11.1.3 Get/Set Energy Price

This section is deprecated and will be removed in the next revision of the standard. Please refer to section 11.8 for the messages that will replace this section.

If the SGD supports the Energy Price messages and it supports the Get Information Reply message, then the "Price Mode" bit should be set (1) in the "Capability Bitmap" field of the Get Information Reply (11.1.1.2) from the SGD to the UCM. This allows for better interoperability and functional discovery by the UCM.

11.1.3.1 Format GetEnergyPrice() - Request

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x03	Opcode1	M
2	0x00	Opcode2	M

11.1.3.2 Format GetEnergyPrice() - Example 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
4-7		Current Price	M
8-9		Currency Code	M
10		Digits After Decimal Point	M
11-14		Expiration Time/Date in UTC seconds	O
15-18		Next Price	O

11.1.3.3 Format SetEnergyPrice() - Request

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x03	Opcode1	M
2	0x00	Opcode2	M
3-6		Current Price	M
7-8		Currency Code	M
9		Digits After Decimal Point	M
10-13		Expiration Time/Date in UTC seconds	O
14-17		Next Price	O
18-19		Commodity Code	O

11.1.3.4 Format SetEnergyPrice() - Example 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 16 bit value, see ISO 4271, US Dollar = 840, Euro = 978, Mexican Peso = 484, Canadian Dollar = 124. The codes can be found on the Web site of the ISO 4217 Maintenance agency, SNV - SIX Interbank Clearing (https://www.currency-iso.org/en/home/tables/table-a1.html).

Digits After Decimal Point

Unsigned, the number of digits after the decimal point (e.g. 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

Commodity Code

The commodity that the price in the message applies to. This field should be a code from section 11.3.1. For example: a device that uses both electricity and natural gas like a gas water heater may be interested in both electricity price and natural gas price. Similarly, a home energy management system would be interested in all applicable commodity prices for the home, if it is managing devices that used different commodities.

11.1.4 Get/Set Tier

If the SGD supports the Tier messages and it supports the Get Information Reply message, then the "Tier Mode" bit should be set (1) in the "Capability Bitmap" field of the Get Information Reply (11.1.1.2) from the SGD to the UCM. This allows for better interoperability and functional discovery by the UCM.

11.1.4.1 Format GetTier() - Request

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x03	Opcode1	M
2	0x01	Opcode2	M

11.1.4.2 Format GetTier() - Example 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 – 6, 255 = no tier)	M
5-8		Expiration Time/Date in UTC seconds	O
9		Next Tier	O

11.1.4.3 Format SetTier() - Request

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

11.1.4.4 Format SetTier() - Example 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

11.1.5 Get/Set Temperature Offset

If the SGD supports the Temperature Offset messages and it supports the Get Information Reply message, then the "Temperature Offset" bit should be set (1) in the "Capability Bitmap" field of the Get Information Reply (11.1.1.2) from the SGD to the UCM. This allows for better interoperability and functional discovery by the UCM.

This message, in its default mandatory form (without Basic DR Code), is intended as an immediate request that the SGD curtail significant energy usage by applying the temperate offset at the time the message is received.

To set the temperature offset to be applied to the current set point when receiving Basic DR curtailment messages like Shed, Critical Peak, etc., the optional parameter "For Basic DR Code" must be used in section 11.1.5.1 to section 11.1.5.3 below.

Note: Any temperature offset applied with this message should *not* be included in the reported setpoint using the GetSetPoint message in section 11.1.6.

11.1.5.1 Format GetTemperatureOffset() - Request

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x03	Opcode1	M
2	0x02	Opcode2	M
3		For Basic DR Code	O

11.1.5.2 Format GetTemperatureOffset() - Example 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

6		For Basic DR Code	O

11.1.5.3 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
5		For Basic DR Code	O

11.1.5.4 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

For Basic DR Code

Used to get/set the temperature offset that will/should be used when a Basic DR Curtailment message of a certain type is received. This field should be set to the Basic DR Opcode1 that the offset applies to.

Example 1 - Set the temperature offset of 4 (0x04) degrees F (0x00) be used when a Basic DR Shed (0x01) is received:

UCM sends 08 02 00 05 03 02 04 00 01 CRC1 CRC2 - UCM attempts to set the offset

SGD sends 06 00 - Link Layer ACK

SGD sends 08 02 00 03 03 82 00 CRC1 CRC2 - SGD responds with success (0x82 0x00) in setting the offset

UCM sends 06 00 - Link Layer ACK

Example 2 - Request the current offset used for Critical Peak Event (0x0A), SGD responds 6 deg F

UCM sends 08 02 00 03 03 02 0A CRC1 CRC2 - UCM requests/ gets the offset for 0x0A

SGD sends 06 00 - Link Layer ACK

SGD sends 08 02 00 06 03 82 00 06 00 0A CRC1 CRC2 - SGD responds with success (0x82 0x00) and the offset 0x06 in units deg F 0x00 for Basic DR 0x0A

UCM sends 06 00 - Link Layer ACK

11.1.6 Get/Set SetPoint

These messages are used to read and write the present setpoint of the SGD. Any TemperatureOffset that may be in effect is not reflected in the returned value. For example, if the temperature setpoint is presently 72 degrees and the present offset is 4 degrees, the "GetSetPoint" will return 72 degrees and will **not** return 76 degrees.

11.1.6.1 Format GetSetPoint() – Request

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x03	Opcode1	M
2	0x03	Opcode2	M

11.1.6.2 Format GetSetPoint() - Example 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
4-5		Device Type	M
6		Units	M
7-8		Set Point 1	M
9-10		Set Point 2	O

11.1.6.3 Format SetSetPoint() – Request

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

11.1.6.4 Format SetSetPoint() - Example 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 (Section 11.1.1) for Device Type table (Section 11.1.1.2). 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). For Water Heaters, Top Element set point. For Thermostats, Heat set point. For Refrigerator/Freezer, Refrigerator set point.

Set Point 2

Signed 16 bit value. Second temperature value, 0x8000 = don't change (set)/not supported (get). For Water Heaters, Bottom Element set point. For Thermostats, Cool set point. For Refrigerator/Freezer, Freezer set point.

Example 1 - Context: The user has entered a cooling set point to the device (device type 0x0007) of 72 deg F using a method like the user interface buttons and screen of the thermostat. Then a temperature offset of 4 deg F was successfully sent using this standard (see Get/Set Temperature Offset) using a UCM, previous to the messages shown below. The messages below show that device will still report 72 deg F as the cooling set point and not include the 4 deg F offset.

UCM sends 08 02 00 02 03 03 CRC1 CRC2 - UCM requests the set point

SGD sends 06 00 - Link Layer ACK

SGD sends 08 02 00 0A 03 83 00 00 07 00 80 00 00 48 CRC1 CRC2 - SGD responds with success (0x83 0x00) and device type (0x00 0x07), units deg F (0x00) no heat setpoint (0x80 0x00) and cool set point of 72 (0x00 0x48).

UCM sends 06 00 - Link Layer ACK

11.1.7 GetPresentTemperature

These messages are used to read the present temperature from the SGD. This is the actual temperature of the controlled environment, not the set point. For example, if a thermostat is presently set to 72 degrees, but the room temperature is presently 69 degrees, this message will return 69.

11.1.7.1 Format GetPresentTemperature() – Request

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x03	Opcode1	M
2	0x04	Opcode2	M

11.1.7.2 Format GetPresentTemperature() - Example reply

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x03	Opcode1	M
2	0x84	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M
4-5		Device Type	M
6		Units	M
7-8		Present Temperature	M

Device Type

See Info Request (Section 11.1.1) for Device Type (Section 11.1.1.2). 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

Present Temperature

Signed 16 bit value. The present temperature value in hundredths ($1/100^{th}$) of one degree, giving a range of -327.68 to 327.67 degrees. Example, Thermostats should report zone temperature. For water heaters, the average tank temperature should be used.

11.1.8 Autonomous Cycling

The commands described in this section are used to initiate and terminate autonomous cycling. As described herein, the commands need only be used once when 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.

If the SGD supports the Start Autonomous Cycling or Terminate Cycling messages and it supports the Get Information Reply message, then the "Cycling" bit should be set (1) in the "Capability Bitmap" field of the Get Information Reply (11.1.1.2) from the SGD to the UCM. This allows for better interoperability and functional discovery by the UCM.

11.1.8.1 Format StartCycling() – Request

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

11.1.8.2 Format StartCycling() - Example 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 = Now (i.e. upon receipt of command, unless delayed by Start Randomization)

Event Duration

Duration of the control event in minutes

Duty Cycle

% reduction of the load (e.g., 75 means that the device will be off ¾ of the time)

Start Randomization

The start of the control will be delayed by this randomized value in minutes. The default value is 0 minutes, but, e.g., a value of 2 minutes means the SGD will randomly add zero to 120 seconds to the start time defined in Bytes 7-10. The start randomization does not change the duration of the event.

End Randomization

The event duration will be lengthened by this random value. The default value is 0 minutes, but, e.g., a value of 60 minutes means the SGD will randomly add zero to 3,600 seconds to the event duration time defined in Bytes 11-12.

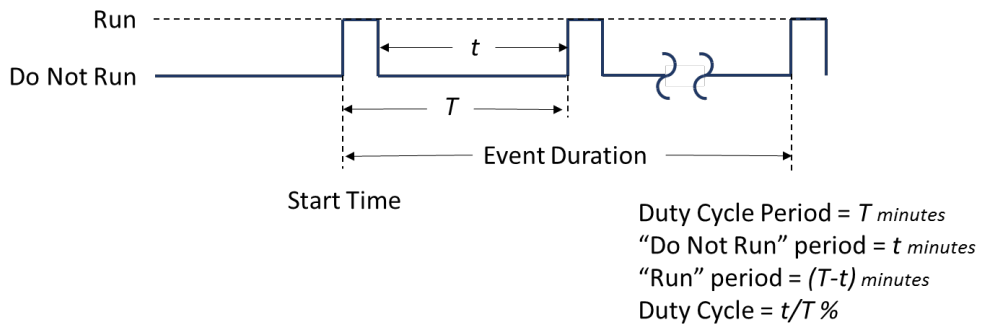
Criticality

Reserved for future use.

Duty Cycle Period

Defines the total duration (in minutes) of one cycle. Default value shall be 60 minutes.

The following figure depicts the intended use of some of the fields for this command.



11.1.8.3 Format TerminateCycling() – Request

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

11.1.8.4 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

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

11.2 Demand Response Event Schedules

Allows for displaying information about demand response events duration, %shed, etc.

11.2.1 Send Scheduled Events Request

11.2.1.1 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

11.2.1.2 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

11.3 Energy Consumption

This allows an In Home Display or Energy Management System to provide an estimate of consumption to a consumer. By transmitting price, a dollar 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. It could be a connection to an AMI Meter, an AMR meter reader, or a reader for an aftermarket optical device attached to a meter. It could also be connected to a backhaul system that sums multiple meters for a property. If a more detailed understanding of where this information is coming from 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 device.

This section enables the sharing of instantaneous or cumulative usage, delivery or generation of electricity and other utilities.

11.3.1 Commodity Read

This is the command used to exchange information on the consumption. Use the commands in Section 11.3.2 to determine the types and reporting frequency of data available, or to subscribe to data.

When the Get CommodityRead Request (Section 11.3.1.1) 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 (Section 11.3.1.2) 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. A sender using the Requested Commodity Code byte should first use the messages in Section 11.3.2 to determine valid commodity codes to use.

11.3.1.1 Format Get CommodityRead Request

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

11.3.1.2 Format Get CommodityRead Reply

Payload Byte	Hex value	Comments	Mandatory/ Optional
1	0x06	Opcode1	M
2	0x80	Opcode2(Response has 1st bit set)	M
3		Response Code	M
4		Commodity Code	M
5-10		Instantaneous Rate	M
11-16		Cumulative Amount	M
17		2nd Commodity Code	O
18-23		2nd Instantaneous Rate	O
24-29		2nd Cumulative Amount	O
		Continue as needed.	O

11.3.1.3 Format Set CommodityRead Request

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

11.3.1.4 Format Set CommodityRead Reply

Payload Byte	Hex value	Comments	Mandatory/ Optional
1	0x06	Opcode1	M
2	0x80	Opcode2(Response has 1st bit set)	M
3		Response Code	M

Commodity Code

*Lower 7-bits	Description	Units
0	Electricity Consumed	W & W-hr
1	Electricity Produced	W & W-hr
2	Natural gas	cu-ft/hr & cu-ft
3	Water	Gal/hr & Gallons
4	Natural gas	cubic meters/hour (m^3) & cubic meters (m^3)
5	Water	liters/hr & liters
6	Total Energy Storage/Take Capacity (see Figure 11-1)	W-hr Note: Instantaneous field in CommodityRead is not used.
7	Present Energy Storage/Take Capacity (see Figure 11-1	W-hr Note: Instantaneous field in CommodityRead is not used.

8	Rated Max Consumption Level Electricity	W Note: Cumulative field in CommodityRead is not used.
9	Rated Max Production Level Electricity	W Note: Cumulative field in CommodityRead is not used.
10	Advanced Load Up Total Energy Storage/Take Capacity (see Figure 11-1)	W-hr of **total** energy take capacity when considering the extra capacity for **Advanced Load Up** Note: Instantaneous field in CommodityRead is not used.
11	Advanced Load Up Present Energy Storage/Take Capacity (see Figure 11-1)	W-hr of **present** energy take capacity when considering the extra capacity for **Advanced Load Up** Note: Instantaneous field in CommodityRead is not used.
11-127	Reserved	

*MSBit

MSBit = 1, Measured, (Instrumentation is used to derive commodity values)

MSBit = 0, Estimated, (Calculated based on Operating States or other data, Instrumentation is NOT used to derive commodity values)

Instantaneous Rate

48 bit unsigned value

Cumulative Amount

48 bit unsigned value

Commodity Code Requirements

Cumulative amount is necessary to provide an accurate indication of cumulative energy consumption. This could be used by 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.

If instantaneous consumption is not supported, report 0xFFFF FFFF FFFF.

The set command shall be used to push metering data that the SGD/UCM has subscribed to.

Total Energy Storage/Take Capacity is the total amount of energy storage that the end device represents. For example, the energy capacity of a water heater would be the total amount of energy (W-hr) 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 Basic DR "Load-Up" before shutting off). Similarly, for a thermostat/HVAC system, this would be the total energy (W-hr) to move the temperature of the conditioned space from its curtailed state (at the temp offset for example), back to its max cooled/heated state.

Present Energy Storage/Take Capacity is the amount of energy that the end device can take now. This parameter is also represented in (W-hr) and would normally be some portion of the Total Energy Storage Capacity as illustrated in Figure 11-1. It is recognized that under some extraordinary circumstances, the Present Energy Storage/Take Capacity could exceed the Total. For example, if a water heater temperature has fallen well below the normal minimum regulation range.

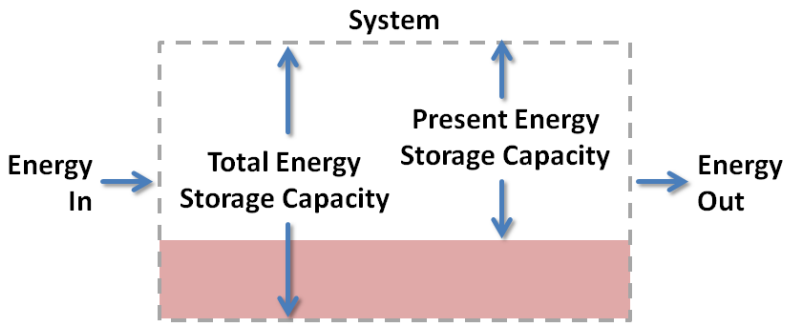


Figure 11-1 - Example Use of Total Energy Storage Capacity (Code 6) and Present Energy Storage Capacity (Code 7)

Advanced Load Up Total Energy Storage/Take Capacity

The regular **total** energy take capacity is defined in terms of the Basic Dr Load Up command. The intent of the Advance Load Up (section 11.6) is for the SGD to take more energy than normal, which results in extra capacity to absorb energy. When reporting this commodity value, the extra capacity should be included in this total take capacity.

Advanced Load Up Present Energy Storage/Take Capacity

The regular **present** energy take capacity is defined in terms of the Basic Dr Load Up command. The intent of the Advance Load Up (section 11.6) is for the SGD to take more energy than normal, which results in extra capacity to absorb energy. When reporting this commodity value, the extra capacity should be included in this present energy take capacity

Rated Max Consumption Level Electricity

Maximum rated load of the equipment, reported in W. Use Instantaneous field.

Rated Max Production Level Electricity

Maximum rated production level of the equipment, as reported in W. Use Instantaneous field.

11.3.2 Get/Set CommodityType

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 on by a device. Commodity code refers to tables in Section 11.3.1. 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.

11.3.2.1 Format GetCommoditySubscription Request

Payload Byte	Hex value	Comments	Mandatory/ Optional
1	0x06	Opcode1	M
2	0x01	Opcode2	M

11.3.2.2 Format GetCommoditySubscription Reply

Payload Byte	Hex value	Comments	Mandatory/ Optional
1	0x06	Opcode1	M

2	0x81	Opcode2 (Response has 1st bit set)	M
3		Response Code	M
4		Commodity Type Supported	M
5-6		Commodity Update Frequency	M
7		2nd Commodity Type Supported	O
8-9		2nd Commodity Update Frequency	O
		Continue as needed	

11.3.2.3 Format SetCommoditySubscription Request

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

11.3.2.4 Format SetCommoditySubscription Reply

Payload Byte	Hex value	Comments	Mandatory/ Optional
1	0x06	Opcode1	M
2	0x81	Opcode2 (Response has 1st bit set)	M
3		Response Code	M

Commodity Type Supported / Commodity Type Subscription requested

Use Commodity Types defined in Section 11.3.1.

Update Frequency/Subscription Frequency

Available/Desired update frequency in seconds.

Notes:

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 sec 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.
    a. Exception if rate reported as 0xFFFF, a time value may be selected to gather data in a periodic manner.

11.4 Device Activation

Device “activation” in this context refers to scenarios in which a product’s operation is limited or enhanced based on the state of the settings identified herein. In some cases, utilization of this message may be restricted.

For example, the US Energy Efficiency Improvement Act of 2015 requires that certain types of water heaters be shipped in a limited state of operation (reduced water heating capability) unless it is enrolled in a demand-response program. In this example, use of this “activation” message is restricted to authorized demand response service providers.

11.4.1 Get/Set Activation Status

11.4.1.1 Format Get Activation Status Request

Payload Byte	Hex value	Comments	Mandatory/ Optional
1	0x0A	Opcode1	M
2	0x00	Opcode2	M
3		Activation Index (see description below)	M

11.4.1.2 Format Get Activation Status Reply

Payload Byte	Hex value	Comments	Mandatory/ Optional
1	0x0A	Opcode1	M
2	0x80	Opcode2(Response has 1st bit set)	M
3		Activation Index	M
4		Activation Status (see description below)	M

11.4.1.3 Format Set Activation Status Request

Payload Byte	Hex value	Comments	Mandatory/ Optional
1	0x0A	Opcode1	M
2	0x01	Opcode2	M
3		Activation Index	M
4		Activation Status	M
5-x		Device Activation Key (variable-length, 1 to 32 bytes)	O

11.4.1.4 Format Set Activation Status Reply

Payload Byte	Hex value	Comments	Mandatory/ Optional
1	0x0A	Opcode1	M
2	0x81	Opcode2(Response has 1st bit set)	M
3		Activation Index	M
4		Activation Response Code (see description below)	M

Activation Index

This field (0-255) allows for an end-device to have more than one aspects that are activated/deactivated. For example, a manufacturer could use higher-index values of this message as "softkeys" to remotely unlock additional product features as an added service.

Activation Index	Description
0	Used for activating end-device functionality is association with enrollment in an approved demand response program.
1-127	Reserved for future standardized functions to be specified by this standard
128-255	Reserved for manufacturer-specific uses

Activation Status

This field is used in both "get" and "set" messages to indicate the status.

Activation Status	Description
0	Device Deactivated – not enrolled in a demand response program, operation is limited
1	Device Activated – device is enrolled in a demand response program, operation is not limited
2-127	Reserved for other "activation status" codes to be specified by this standard
128-255	Reserved for manufacturer-specific uses

Activation Response Code

This field is used in replies to Activation Status "set" messages.

Activation Response Code	Description
0	Activate request accepted, the specified "Activation Index" is now activated
1	Activate request rejected, the specified "Activation Index" was already activated
2	Activate request rejected, Activation Key incorrect for the specified index
3	Activate request rejected, temporary lockout - too many unsuccessful attempts
4	Deactivate request accepted, the specified "Activation Index" is now deactivated

5 Deactivate request rejected, the specified “Activation Index” cannot be deactivated

6 Deactivate request rejected, the specified “Activation Index” was already deactivated

7 Deactivate request rejected, Activation Key incorrect for the specified index

8-127 Reserved for other “Activation Response Codes” to be specified by this standard

128-255 Reserved for manufacturer-specific uses

11.5 Get/Set User Preference Level

The user preference level message is intended to provide a mechanism to convey user preferences.

11.5.1 Get/Set User Preference Level

11.5.1.1 Format Get Preference Level Request

Payload Byte	Hex value	Comments	Mandatory/ Optional
1	0x0B	Opcode1	M
2	0x00	Opcode2	M
3		Preference Type	M

11.5.1.2 Format Get User Preference Level Reply

Payload Byte	Hex value	Comments	Mandatory/ Optional
1	0x0B	Opcode1	M
2	0x80	Opcode2(Response has 1st bit set)	M
3		Preference Type	M
4		Preference Level Value	M

11.5.1.3 Format Set User Preference Level Request

Payload Byte	Hex value	Comments	Mandatory/ Optional
1	0x0B	Opcode1	M
2	0x01	Opcode2	M
3		Preference Type	M
4		Preference Level	M

11.5.1.4 Format Set User Preference Level Reply

Payload Byte	Hex value	Comments	Mandatory/ Optional
1	0x0B	Opcode1	M
2	0x81	Opcode2(Response has 1st bit set)	M
3		Preference Type	M
4		Preference Level	M

Preference Type

This field (0-255) allows for multiple user preferences types.

Preference Type	Description
0	Demand Reduction
1	Energy Reduction
2-127	Reserved
128-255	Reserved for manufacturer-specific uses

Preference Level

This field (0-255) allows for multiple user preference levels, dependent on preference type.

For both preference types 0 and 1, the preference level is defined as follows:

Preference Level	Description
0 through 10	Reduction Aggressiveness Scale 0 = Low to 10 = High
11-255	Reserved

For manufacturer-specified preference types 128-255, the preference level may take any value from 0-255, as defined by the manufacturer:

Preference Level	Description
0-255	Reserved for manufacturer-specific uses

11.6 Advanced Load Up

If the SGD supports Advanced Load Up messages and the necessary safety equipment is installed and all liability issues have been settled, then the "Advanced Load Up supported" bit 6 should be set (1) in the "Capability Bitmap" field of the Get Information Reply (11.1.1.2) from the SGD to the UCM. This allows for the UCM to detect when this message is available for use.

This message is sent by the UCM to request that the SGD absorb more energy than the amount of energy absorbed during a Basic DR Load Up command.

One concrete example of advanced load up is specified by the California “Building Energy Efficiency Standards (Title 24 Part 6) Joint Appendix 13. [JA13.3.3 (b) 2.] describes advanced load up for water heaters as:

Advanced Load Up: The System stores extra thermal energy, where some or all of the tank may exceed the set point temperature chosen by the user, within safe operating conditions. Advanced Load Up must only be enabled after agreement by the user and utility as defined below. It will avoid use of electric resistance elements unless user needs cannot be met. Advanced Load Up will only be available in Advanced Demand Response Control mode as defined in JA13.3.3.2;

While basic “Load Up” can only bring the water heater to set point, this command can increase the storage temperature above set point increasing the amount of energy the water heater can absorb. This command is only allowed if it is supported by the end device.

There is no barrier to using this command and capability on other device types if they are capable of efficiently storing more energy than they would in normal operation. Other temperature set point controlled devices like refrigerators, freezers, air conditioners or space heaters may be able to use some extra energy to benefit the grid. Electric vehicles and other battery-based systems may have extra battery capacity that is not normally used, but could be used a limited number of times to assist the grid.

The energy values specified by this command are expected to result in the SGD attempting to store the extra amount of energy if it can, though operational contraints at the time the message is received may prevent the SGD from doing so. In that case the SGD can still respond with Success in receiving the command and then store as much energy as possible during the duration of the event.

Manufacturers should note that certification bodies like those testing for JA13 compliance may require that at least the full energy amount specified can be stored under the lab conditions during testing.

If the UCM sends an AdvancedLoadUp and the SGD has not had that functionality enabled and activated (see Capability Bit 6), the SGD should respond with Intermediate DR response code 0x08.

The End Shed/Run normal message will end this event at any time. The SGD should internally end the AdvancedLoadUp after the number of minutes in the Event Duration have passed from the Start Time or from the command receive time if the Start Time is absent.

11.6.1 Format GetAdvancedLoadUp() – Request

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x0C	Opcode1	M
2	0x00	Opcode2	M

11.6.2 Format GetAdvancedLoadUp() - Reply

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x0C	Opcode1	M
2	0x80	Opcode2	M
3		Response Code	M
4-5		Event Duration in minutes	M
6-7		Value	M
8		Units	M
9		Suggested Load Up Efficiency	O
10-13		Event ID	O
14-17		Start Time UTC seconds since 1/1/2000	O
18		Start Randomization in minutes	O
19		End Randomization in minutes	O

11.6.3 Format SetAdvancedLoadUp() - Request

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x0C	Opcode1	M
2	0x00	Opcode2	M
3-4		Event Duration in minutes	M
5-6		Value	M
7		Units	M
8		Suggested Load Up Efficiency	O
9-12		Event ID	O
13-16		Start Time UTC seconds since 1/1/2000	O

Payload Byte	Hex value	Comments	Mandatory /Optional
17		Start Randomization in minutes	O
18		End Randomization in minutes	O

11.6.4 Format SetAdvancedLoadUp()–Reply

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x0C	Opcode1	M
2	0x80	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M

Note: If the optional Start Time UTC field is not included, the Advanced Load Up is intended to begin immediately upon receipt of the message.

Event Duration

See section 11.1.8 for the definition of this field. If the optional Start Time UTC field is not included, the advanced load up is intended to begin immediately upon receipt of the message and continue for the duration specified.

Value

Unsigned 16 bit

0x0000 - No Effect on the SGD, but the SGD should respond with Response Code = Success if this Advanced Load Up command is implemented and the necessary mixing valve or other safety precautions are in place. (See Capability Bit **Table 11-3 – Response Code Values**)

In the case of sending this value, the units shall be set to 0xFF

0x0001 to 0xFFFE - This quantity of **Units** specifies the minimum amount of energy that the SGD should store ***above*** the amount that would be stored during normal operation.

For SetAdvancedLoadUp, Response Code = Success from the SGD means the message was received and the device is trying to store the specified amount of energy. There is no guarantee that the SGD can achieve the full amount.

For GetAdvancedLoadUp, the SGD should respond with the currently active value (the Event Duration is not over) that it is trying to store. The value returned in the Get is **not** the amount of energy already stored. If the SGD is **not currently performing Advanced Load Up**, then the response should set event duration = 0, value = 0x0000 and units = 0xFF.

0xFFFF - Store as much energy as possible above the normal amount, while maintaining the safety and efficiency of the SGD and any temperature limiting device (one example: a Water Heater Mixing Valve)

Units

Unsigned 8 bit unit code

0x00 - 1 watt-hour (Wh)
0x01 - 10 Wh
0x02 - 100 Wh
0x03 - 1000 Wh (1 kWh)
0x04 to 0xFE Reserved for future use - Do not use
0xFF - Used in response to the GetAdvancedLoadUp, to indicate that advanced load up is not currently active in the SGD. Used by the UCM when sending value 0x0000 to check for AdvancedLoadUp support in the SGD.

Suggested Load Up Efficiency

Unsigned 8 bit code

Same values as defined in section 11.7 field **Efficiency Level**

Interpretation:

Suggests (does not require) the SGD Efficiency Level that should be used during the advanced load up. Since this parameter is a suggestion, the SGD may respond with Success to AdvancedLoadUp even it does not follow the suggestion, but still loads up.

In cases where a fast load up is desired by the larger grid or local microgrid, especially during times of plentiful renewable energy production that can be highly variable, the message may suggest using the lowest efficiency / high power (Example: water heaters using electric resistance mode section 11.7 low values 0-3) to load up faster with this parameter.

In cases where renewable generation is expected to be available for a long period of time, the message can suggest using a more efficient / lower power and slower load up (Example: heat pump water heaters using heat pump only mode section 11.7 higher values 7-9). **Note:** Some regulations like California Title 24 JA13 may require only high efficiency mode be used.

If an SGD has only one mode or efficiency level, it can accept any value and return Success, then perform the AdvancedLoadUp in its normal mode.

For SGD types other than water heaters, this parameter may still be supported and used if multiple modes (with different efficiency levels) are available.

This does not affect the permanent efficiency level setting of the SGD, which the SGD should return to after the AdvancedLoadUp event ends.

Event ID

Start Time

Start Randomization
End Randomization

In this message, all these fields are optional. See section 11.1.8 for the definition of the above fields.

Example 1: One way to comply with California's JA13 specification of Advanced Load Up, to meet the performance standards of California Title 24, Part 6, Sections 150.1(b).

"For a water heater sized in accordance with JA13.3.2(b) and with the default set point as shipped from the manufacturer, the System shall be able to shift:

- A minimum of 0.5 kWh of user electrical energy per (Basic Load Up + Light Shed) event; and
- A minimum of 1 kWh of user electrical energy per (Advanced Load Up + Light Shed) event, including at least 0.5 kWh on Advanced Load Up. "

To activate an Advanced Load Up meeting the above requirements, starting immediately. Different units may be used to achieve the same effect, in this example 100 Wh was chosen as the largest unit not resulting in a fractional value (Optional fields omitted):

UCM sends: 08 02 00 07 0C 00 00 3C 00 05 02 CRC1 CRC2

08 02 - Intermediate DR

00 07 - length

0C 00 - Advanced Load Up Opcodes

00 3C - Event Duration (60 minutes)

00 05 - Value (5)

02 - Units (100 Wh)

5 x Units of 100Wh = 500 Wh / 0.5 kWh of JA13

CRC1 CRC2

SGD sends 06 00 - Link Layer ACK

SGD sends 08 02 00 03 0C 80 **00** CRC1 CRC2 - SGD responds (0x0C 0x80) with success (**0x00**) in receiving the command and will immediately take action to use energy in order to load up.

UCM sends 06 00 - Link Layer ACK

Example 2: Request a fast advanced load up (low efficiency/high power) of 1.0 kWh for 30 in minutes. If all conditions are favorable and enough energy storage is available, a device could operate on average at 2kW over 30 minutes to achieve this.

UCM sends: 08 02 00 08 0C 00 00 1E 00 01 03 00 CRC1 CRC2

08 02 - Intermediate DR

00 08 - length

0C 00 - Advanced Load Up Opcodes

00 1E - Event Duration (30 minutes)

00 01 - Value (1)

03 - Units (1000 Wh)

1 x Units of 1000Wh = 1000 Wh / 1.0 kWh

00 - Suggested Load Up Efficiency of 0, which is (low efficiency/high power see section 11.7)

CRC1 CRC2

SGD sends 06 00 - Link Layer ACK

SGD sends 08 02 00 03 0C 80 **00** CRC1 CRC2 - SGD responds (0x0C 0x80) with success (**0x00**) in receiving the command and will immediately take action to use energy in order to load up.

UCM sends 06 00 - Link Layer ACK

11.7 SGD Efficiency Level

If the SGD supports the SGD Efficiency Level messages and it supports the Get Information Reply message, then the "SGD Efficiency Level supported" bit 8 should be set (1) in the "Capability Bitmap" field of the Get Information Reply (11.1.1.2) from the SGD to the UCM. This allows for better interoperability and functional discovery by the UCM.

These messages are used to read (Get) and write (Set) the current SGD Efficiency Level (related to the operating mode) on the SGD. Manufacturers may choose to support only the Get versions of the messages and respond with "Command not implemented" to the Set version of the command if setting is not supported via this standard. If the manufacturer supports the Set versions, then they must support Get versions.

11.7.1 Format GetSGDEfficiencyLevel () – Request

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x01	Opcode1	M
2	0x02	Opcode2	M

11.7.2 Format GetSGDEfficiencyLevel () - Reply

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x01	Opcode1	M
2	0x82	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M
4		Efficiency Level	M

11.7.3 Format SetSGDEfficiencyLevel () - Request

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x01	Opcode1	M
2	0x02	Opcode2 (Reply always has bit 7 high)	M
3		Efficiency Level	M

11.7.4 Format SetSGDEfficiencyLevel () – Reply

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x01	Opcode1	M
2	0x82	Opcode2	M
3		Response Code	M

Efficiency Level

Unsigned 8 bit value

The value is from 0-10. Values above 10 are reserved.

0 is considered to be "off". It is optional for SGDs to support this value, though if this value is supported it should mean using only enough energy to maintain UCM and SGD CTA-2045 bus communication and UCM outside communication.

1 is considered the least energy efficient mode of operation. However, this standard does not prescribe any correspondence to particular mode, which is left to the SGD manufacturer to decide and share as needed.

2 to 8 varying levels of efficiency between lowest efficiency (0) to highest efficiency (9)

9 is considered the most energy efficient mode of operation. As above, the correspondence to real SGD modes is up to the SGD manufacturer.

10 is considered to be "vacation mode". It is optional for SGDs to support this value.

11.8 Price Stream Communication

This feature is to enable the module to send a sequence of time/price pairs to the SGD. Common uses will be for providing Time-of-Use (TOU) or Real-time (RTP) prices. The times may be fixed periods apart (e.g. hourly) but there is no requirement that the periods have equal lengths. A common forecast period is 24 hours, but more or less can be sent. The forecast may be binding (guaranteed) prices, or may be a best effort forecast.

To support Price Stream Communication and have the capability bitmap set (Get Information Reply (11.1.1.2) bit 7: Price Stream supported set to 1), the SGD shall support at least the SetPriceStream message. The Accepted Pairs and Static Tariff and Export Price Stream are optional.

If the UCM and SGD supports different prices for buying and exporting (selling) energy (ie. battery systems, central energy managements, or other), then the extra optional message SetExportPriceStream can be used. If the UCM has export prices available to send, it shall first use the messages in the Accepted Pairs section to determine if the SGD supports export prices as well.

11.8.1 Static Tariff

Streaming prices involves a number of static data elements. These are not necessary for the SGD to use the prices (except the currency), and the UCM may or may not have them. That said, the SGD may want them, including to display the information on a user interface, particularly the name of the electricity retailer and the name of the rate/tariff.

Note that the currency is static data, but it is included in dynamic data for CTA-2045 so that the price can be used even if the Static Tariff information has not been sent or if the StaticTariff commands are not even supported by the SGD.

11.8.1.1 Format SetStaticTariff() - Request

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x0D	Opcode1	M
2	0x00	Opcode2	M
3-4		Country Code	M
5-6		Principal Subdivision Code	M
7-12		Retailer Short [6]	M
13-18		Rate Name Short [6]	M
19		Binding Prices	O
20		Local Price	O
21		Export Price Available	O
22-51		Retailer Long [30]	O
51-81		Rate Name Long [30]	O
82-89		Date Announced [8]	O
90-97		Date Effective [8]	O
98-157		URL [60]	O

11.8.1.2 Format SetStaticTariff() – Reply

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x0D	Opcode1	M
2	0x80	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M

Country Code

ASCII text string, 2 bytes. Normative Reference: ISO 3166-1 alpha-2.

Principal Subdivision Code

ASCII text string, 2 bytes. Normative Reference: ISO 3166-2. Note: In the US, this code is the two character state, district or outlying area code.

Retailer Short

ASCII text string, 6 bytes maximum. The retailer's abbreviation, e.g. "PGE". This field is fixed length, so shall be padded with 0x00 up the maximum bytes.

The string “PGE” would be 6 bytes (with 0x00 padding): 0x50 47 45 00 00 00

Rate Name Short

ASCII text string, 6 bytes maximum. The rate name, e.g. “TOUA”. This to be unique to each retailer. This field is fixed length, so shall be padded with 0x00 up the maximum bytes.

The string “TOUA” would be (with 0x00 padding): 0x54 4F 55 41 00 00

Binding Prices

Optional. Unsigned 8 bit: false = 0x00, true=0x01, and if unknown = 0xFF

True if prices are fixed once transmitted. If not available the SGD default is to assume false.

Local Price

Optional. Unsigned 8 bit: false = 0x00, true=0x01, and if unknown = 0xFF

True if the price has been adapted from a grid price by a building entity, or created entirely locally (within the building).

False if a grid price has been passed through unchanged.

If not available, the default is false.

Export Price Available

Optional. Unsigned 8 bit: false = 0x00, true=0x01, and if unknown = 0xFF

True indicates that Export price messages (SetExportPriceStream) could be sent by the UCM to provide a stream of current and future prices used by the SGD when producing energy(sell), rather than consuming (buy).

False indicates that there is no separate export price.

Retailer Long

Optional. ASCII text string, 30 bytes maximum. The text string of the retailer full name, e.g. “Pacific Gas and Electric”. This field is fixed length, so shall be padded with 0x00 up the maximum bytes.

Rate Name Long

Optional. ASCII text string, 30 bytes maximum. The text string of the rate name, e.g. “Residential Time of Use-A”. This to be unique to each retailer. This field is fixed length, so shall be padded with 0x00 up the maximum bytes.

Date Announced

Optional. ASCII text string, 8 bytes numeric format YYYMMDD, this the ‘publishing date’, particularly helpful if there is an update to the rate after initial announcement. This embodies a version number.

Date Effective

Optional. ASCII text string, 8 bytes numeric format YYYMMDD, This is the first date that the rate is planned to be available. No end date is specified.

URL

Optional. ASCII text string, 60 bytes maximum. The URL for a web page with a description of the tariff in machine and human readable form. Should contain the current/correct tariff if there are multiple versions over time. This field is fixed length, so shall be padded with 0x00 up the maximum bytes. Normative reference: The URL should conform to https://tools.ietf.org/html/rfc3986 with scheme 'https'.

Example 1:

Send the static data about a “buy” price tariff from the UCM to the SGD for the utility “PGE” and tariff name “TOUA”, where the prices are binding (TOU) and are not local prices.

UCM sends: 0x 08 02 00 10 0D 00 50 47 45 00 00 00 54 4F 55 41 00 00 01 00 CRC1 CRC2

0x 08 02 - Intermediate DR

00 10 - length 16

0D 00 - Static Tariff Opcodes

50 47 45 00 00 00 - Retailer Short “PGE” plus fill with null 0x00

54 4F 55 41 00 00 - Rate Name Short “TOUA” plus fill with null 0x00

01 - Binding Prices

00 - Local Price

CRC1 CRC2

SGD sends 06 00 - Link Layer ACK

SGD sends 08 02 00 03 0D 80 **00** CRC1 CRC2 - SGD responds (0x0D 0x80) with success (**0x00**) in receiving the command and will store the static tariff information internally.

UCM sends 06 00 - Link Layer ACK

11.8.2 Accepted Pairs

If this message is not supported, then by default all devices (UCM and SGD) that support PriceStream must support at least 8 time+price pairs.

In some cases, a mechanism is needed for the SGD to inform the UCM of the maximum number of time/price pairs that the SGD can take in. The UCM does not need to have a mechanism to communicate to the SGD its maximum number of pairs that it supports. The required maximum number of pairs required by the SGD is determined by the certification level it supports supported in Appendix F.

If the SGD and UCM wish to support export prices (selling energy to the grid or microgrid), then this message shall be supported.

11.8.2.1 Format GetAcceptedPairs() – Request

Payload Byte	Hex value	Comments	Mandatory/Optional
1	0x0D	Opcode1	M
2	0x01	Opcode2 (Reply always has bit 7 high)	M

11.8.2.2 Format GetAcceptedPairs() - Reply

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x0D	Opcode1	M
2	0x81	Opcode2	M
3		Response Code	M
4		Maximum number of time+price pairs in a sequence for SetPriceStream	M
5		Export Price Supported	O

Maximum number of time+price pairs in a sequence for SetPriceStream

Unsigned 8 bit. To inform the UCM of the maximum number of time/price pairs that the SGD can take for a sequence of prices that comprise a single Tariff.

Export Price Supported

Unsigned 8 bit: false = 0x00, true=0x01

True 0x01 indicates that Export price message SetExportPriceStream is supported by the SGD when producing energy (selling to the grid or microgrid). In this case, the maximum number of time/price pairs field applies to both normal (buy) prices **SetPriceStream (buy)** and the number for **SetExportPriceStream (sell)**. Two sets of storage of this size shall be present in the SGD, if they support buy and export prices.

If False or if this field is omitted, it indicates that the SGD does not support receiving a Export price.

Example 1:

The UCM requests the number of accepted pairs of time+price streaming from the UCM, which responds that it can support 16 pairs. In this case the Export Price Supported field is omitted, indicating the SGD does not support separate export prices.

UCM sends: 0x 08 02 00 02 0D 01 CRC1 CRC2

0x 08 02 - Intermediate DR

00 02 - length 2

0D 01 - Static Tariff Opcodes

CRC1 CRC2

SGD sends 06 00 - Link Layer ACK

SGD sends 0x 08 02 00 04 0D 81 **00 10** CRC1 CRC2

SGD responds (0x0D 0x81) with success (**0x00**) in receiving the command and 16 (**0x10**) pairs are supported for Price Stream. No optional fields are used.

UCM sends 06 00 - Link Layer ACK

11.8.3 Price Stream

Prior to sending any of the messages defined in this section, the device must negotiate the maximum payload size using the "Query: Maximum payload length?" and "Response: Maximum payload length" messages defined in **Table 9-2 – Data-Link Command Set**. CTA-2045-B prohibits transfer of serial messages that would overflow buffers of the recipient.

If the GetAcceptedPairs message is not supported, by default all devices (UCM and SGD) that support PriceStream must support at least 8 time+price pairs for a full sequence.

11.8.3.1 Format SetPriceStream() - Request

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x0D	Opcode1	M
2	0x02	Opcode2	M
3-4		Currency Code	M
5		Digits After Decimal Point	M
6		Number of pairs in sequence	M
7		Message Index	M
8-11		First time	M

12-15		First price	M
16-19		Second time	O
20-23		Second price	O
...		Further time+price pairs as needed, as long as the total payload size does not exceed the previously negotiated SGD Maximum Payload Length	O

11.8.3.2 Format SetPriceStream()– Reply

Payload Byte	Hex value	Comments	Mandatory/Optional
1	0x0D	Opcode1	M
2	0x82	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M

Currency Code

Unsigned 16 bit value, see ISO 4271, US Dollar = 840, Euro = 978, Mexican Peso = 484, Canadian Dollar = 124. The codes can be found on the Web site of the ISO 4217 Maintenance agency, SNV - SIX Interbank Clearing (https://www.currency-iso.org/en/home/tables/table-a1.html).

Digits After Decimal Point

Unsigned 8 bit value, the number of digits after the decimal point (e.g. 22¢ = 0.22 dollars so the Digits after decimal point value would be 2)

Number of pairs in sequence

Unsigned 8 bit - The sequence is defined as all the pairs that make up the complete set of current and future prices for the given tariff.

Price sequences will in some cases require multiple payloads, as each entry requires 8 bytes (4 for time, 4 for price), this can add up and could exceed the Maximum payload capability of UCM or SGD if all pairs were sent in a single message. Therefore, the sequence may be sent in chunks using several SetPriceStream messages, each with an increasing **Message Index**.

The intention is that once all the SetPriceStream messages for a tariff are received with no gaps in the **Message Index** and the SGD has received a total number of time+price pairs equal to the value in this field, then the current price sequence is complete.

Message Index

Unsigned 8 bit - The index (0 based) of this message in the series of SetPriceStream messages that are used to deliver the time + price pairs that make up the entire price sequence for the given tariff.

First time

Unsigned 32 bit value of seconds since 1/1/2000 00:00:00 UTC. It is intended that the UCM send the SetPriceStream message sequence so that the **First time** of the message with **Message Index** = 0 should be equal to or prior to the current time. This provides clarity to the SGD about when to clear any previously stored sequence of prices. Note: UTC time implies that the number of seconds has been adjusted for leap seconds and they are included in this value.

First price

Unsigned 32 bit value. This value must be interpreted using **Digits After Decimal Point** to get a usable price in **Currency Code** per kWh.

Second time, Second price and further pairs

Each payload is to have only integral sets of time/price pairs. All pairs from the second onward shall have the same format as the First Time and First Price

11.8.3.3 UCM Indicating No Valid Prices

It is intended that the SetPriceStream message is sent often as the current price and future prices change over time, giving the most recent and accurate forecast or binding prices. However, if communication is interrupted or for some other reason the UCM cannot provide accurate and valid prices to the SGD, then the UCM may notify the SGD of this by sending all 0x00 for the bytes in the Mandatory fields of SetPriceStream, starting at Currency Code, up to and including First Price. By sending this, the UCM implies that the currently stored forecast prices could change without the SGD being informed.

11.8.3.4 Price Stream Examples

Example 1:

Send all the time+price pairs for a tariff, assuming that the Maximum payload Negotiation determined the lowest common maf payload size to be 128 bytes, so all time+price pairs fit in one message. The rate is sent at real clock time Wed, 19 Aug 2020 00:00:00 Pacific Daylight Time and corresponds to the rate:

Pacific Gas & Electric Co

E-TOU-C3 Residential Time of Use Baseline Region Z *(as of 19 Aug 2020)*

Summer, Weekday

UCM sends: 0x 08 02 00 1F 0d 02 03 48 05 03 00 26 cf 8a 70 00 00 5d 4a 26 d0 5d 60 00 00 75 4a 26 d0 b1 c0 00 00 5d 4a CRC CRC

Bytes 0x	**Explanation of Bytes**
08 02	Intermediate DR
00 1F	payload length = 31 bytes
0d 02	Price Stream Opcodes
03 48	Currency Code decimal = decimal 840 = USD
05	Digits After Decimal Point = 5
03	Number of pairs in sequence = 3 (TOU)
00	Message Index = 0
26 cf 8a 70	time 0 Wed, 19 Aug 2020 00:00:00 -0700
00 00 5d 4a	price 0 value 23882 with 5 digits is 0.23882
26 d0 5d 60	time 1 Wed, 19 Aug 2020 15:00:00 -0700
00 00 75 4a	price 1 value 30026 with 5 digits is 0.30026
26 d0 b1 c0	time 2 Wed, 19 Aug 2020 21:00:00 -0700
00 00 5d 4a	price 2 value 23882 with 5 digits is 0.23882
CRC1 CRC2	CRC bytes

SGD sends 06 00 - Link Layer ACK

SGD sends 08 02 00 03 0D 82 **00** CRC1 CRC2 - SGD responds (0x0C 0x80) with success (**0x00**) in receiving the command and will store the tariff's time+price pairs internally to allow modifying energy usage in relation to pricing

UCM sends 06 00 - Link Layer ACK

11.8.4 Export Price Stream

Prior to sending any of the messages defined in this section, the device must negotiate the maximum payload size using the "Query: Maximum payload length?" and "Response: Maximum payload length" messages defined in **Table 9-2**. CTA-2045-B prohibits transfer of serial messages that would overflow buffers of the recipient.

11.8.4.1 Format SetExportPriceStream() - Request

Payload Byte	Hex value	Comments	Mandatory /Optional
1	0x0D	Opcode1	M
2	0x03	Opcode2	M
3-4		Currency Code	M
5		Digits After Decimal Point	M
6		Number of pairs in sequence	M
7		Message Index	M
8-11		First time	M
12-15		First price	M
16-19		Second time	O
20-23		Second price	O
...		Further time+price pairs as needed, as long as the total payload size does not exceed the previously negotiated SGD Maximum Payload Length	O

11.8.4.2 Format SetExportPriceStream()– Reply

Payload Byte	Hex value	Comments	Mandatory/Optional
1	0x0D	Opcode1	M
2	0x83	Opcode2 (Reply always has bit 7 high)	M
3		Response Code	M

The fields in the messages above have the same definition as in section 11.8.3.1 and section 11.8.3.2.

The difference in SetExportPriceStream is that the prices in the pairs only apply to energy produced by the SGD or devices under control of the SGD, ie. They are only for exporting energy (selling energy back to the grid or microgrid).

12 COMMISSIONING AND NETWORK MESSAGES (MESSAGE TYPE = 0X08, 0X04)

These commands are all optional. The format for these messages is as identified in Table 6-1, with the payload as identified in Table 12-1. For those messages identified in this section that are longer than 8 bytes, it is required that the "Maximum Data Unit Length" query defined in the data-link section be used first. In other words, CTA-2045-B prohibits transfer of serial messages that could overflow buffers of the recipient. Unless indicated otherwise, when referenced in this section, "ACK" and "NAK" refer to the Basic DR Application ACK and NAK.

	Payload			
Description	**Opcode1**	**Opcode2**	**Additional Payload**	**Usage**
Set Network ID	0x01	0x00 = LAN 0x01 = WAN	Network ID String	Sent to the UCM, from either the SGD of any other configuration/commissioning tool to which it is connected Network ID String: 1 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 of any other configuration/commissioning tool to which it is connected. User ID String: 1 to 120 Bytes, ASCII encoded NAK means that the UCM does not accept User IDs.

	Payload			
Description	**Opcode1**	**Opcode2**	**Additional Payload**	**Usage**
Set Password	0x03	0x00 = LAN 0x01 = WAN	Password String	Sent to the UCM, from either the SGD of any other configuration/commissioning tool to which it is connected. Password String: 1 to 120 Bytes, ASCII encode 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
Set Transmission Mode	0x06	Mode		Sent from the SGD to request the UCM to use a specific transmission mode. Opcode 2 Usage Codes: Individual = 0x00 Broadcast = 0x01 Future Use= 0x02 to 0xFF
Get Transmission Mode Query	0x07	Not used		Sent from the SGD to the UCM to determine the present transmission mode.

	Payload			
Description	**Opcode1**	**Opcode2**	**Additional Payload**	**Usage**
Get Transmission Mode Response	0x08	Transmission Mode Code		Sent from the UCM to SGD in response to an opcode 0x02 query. Opcode 2 Transmission Mode Codes: Individual = 0x00 Broadcast = 0x01 Future Use = 0x02 to 0xFF

Table 12-1 – Commissioning and Network Messages

13 PASS-THROUGH OF STANDARD PROTOCOLS

In its simplest mode of operation, this modular communications interface provides for 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 must be capable of accepting and understanding the protocol that is passed through.

CTA-2045-B provides support for any number of such pass-through protocols through the following mechanisms:

Full Encapsulation in the Message Payload – As illustrated in Figure 13-1, other protocols are inserted in the message payload without any modification. As described below, the organizations that own and manage each protocol will define how their messaging is placed into the payload field.

Message Type	Reserved Must be '0x0'	Payload Length	Payload = Pass-Through Message	Checksum
2 Bytes	3 Bits	13 Bits	Variable	2 Bytes

Figure 13-1 – Pass-Through Message

Message Type Field – As described in Table 6-2, each pass-through protocol is assigned a "Message Type" code. This code is placed in the "Message Type" field indicated in Figure 13-1

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.

Message Type Supported Query – As indicated in Section 8.2 Message Type Supported Query, a query must 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.

Maximum Message Length Negotiation – Devices must 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 described in **Table 9-2**.

Pass-Through Handling Instructions by the SDO – For each protocol to be passed through in this way, the standards organization that owns and manages the protocol shall produce an application note describing how that protocol is to be mapped into the payload field. Such an application note will define, for example, the byte or field to begin with and the byte or field to end with when passing through the protocol.

13.1 Example Pass-Through Handling Instructions

13.1.1 USNAP 1.0 Protocol Pass-Through

This section shows how the USNAP1.0 protocol is supported by the interface. The messages will be formatted as follows, with the message type being a 0x09, 0x01, and the payload being defined in the USNAP1.0 specification.

Message Type = 0x09, 0x01	Reserved Must be '0x0'	Payload Length	USNAP1.0 Message	Checksum
2 Bytes	3 Bits	13 Bits	Variable	2 Bytes

Figure 13-2– USNAP1.0 over Serial

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 identified in the USNAP1.0 specification.

13.1.2 SEP1.0 Pass-Through

This section shows how the SEP1.0 protocol is supported by the interface. The messages would look as follows, with the message type being a 0x09, 0x05, and the payload being defined entirely by the ZigBee SEP organization.

Message Type = 0x09, 0x05	Reserved Must be '0x0'	Payload Length	SEP1.0 Message	Checksum
2 Bytes	3 Bits	13 Bits	Variable	2 Bytes

Figure 13-3 – SEP1.0 over Serial

13.1.3 ClimateTalk Pass-Through

This section shows how the ClimateTalk protocol is supported by the interface. The messages would look as follows, with the message type being a 0x09, 0x02, and the payload being defined entirely by the ClimateTalk organization.

Message Type = 0x09,0x02	Reserved Must be '0x0'	Payload Length	ClimateTalk Message	Checksum
2 Bytes	3 Bits	13 Bits	Variable	2 Bytes

Figure 13-4 – ClimateTalk Over Serial

13.1.4 General Internet Protocol Pass-Through

This section shows how the interface is used to support pass-through of applications over IP. This might be of interest for many purposes, including communications systems and SGDs that are capable of web access. This IP pass-through mechanism supports both IPV4 and IPV6, with the self-describing Version field of the IP packet distinguishing between the two.

Using the previously defined 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 (0x09,0x07) and 2byte Length field; and a trailing checksum as illustrated in Figure 13-5 (IPV6 example shown, IPv4 handled in similar fashion).

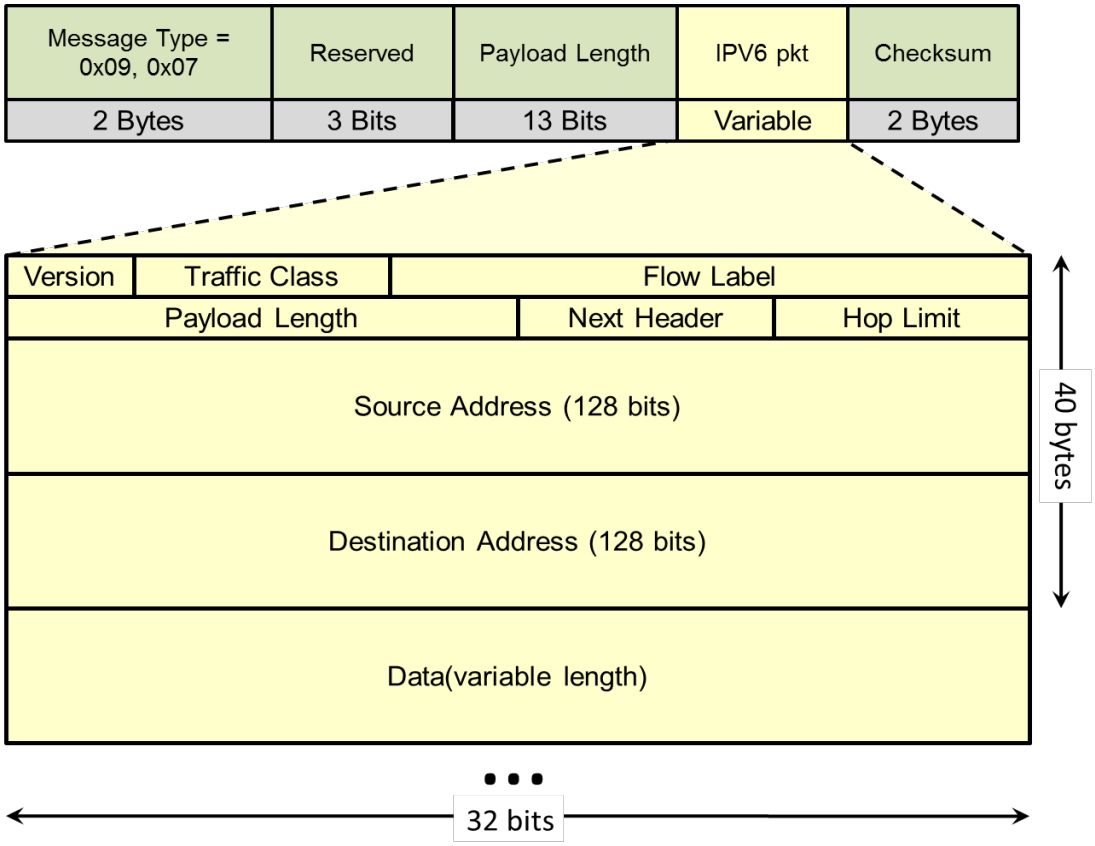


Figure 13-5 – Internet Protocol Pass-Through (IPV6 Example)

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 must be negotiated after power up or reset using the link layer "Maximum Payload Length" negotiation described in **Table 9-2**. IP pass-through packets may NOT be fragmented by the UCM.

13.1.5 ECHONET Lite Pass-Through

This section shows how the ECHONET Lite 1.1 protocol is supported by the CTA-2045-B interface. The messages will be formatted as follows, with the message type being a 0x09 0x08, and the payload being defined entirely by the ECHONET Consortium.

Message Type = 0x09, 0x08	Reserved Must be '0x0'	Payload Length	ECHONET Lite Message	Checksum
2 Bytes	3 Bits	13 Bits	Variable	2 Bytes

Figure 13-6 ECHONET Lite Over Serial

The bit order of the payload is to be the same as that specified for the DC and AC form factors in Section 6.1.4 of this document. Byte order of multi-byte quantities within the ECHONET Lite payload is per the ECHONET Lite specification.

13.1.6 KNX Pass-Through

This section shows how the KNX protocol is supported by the CTA-2045-B interface. The messages will be formatted as follows, with the message type being a 0x09 0x09.

Message Type = 0x09, 0x09	Reserved Must be '0x0'	Payload Length	KNX Message	Checksum
2 Bytes	3 Bits	13 Bits	Variable	2 Bytes

Figure 13-7 KNX Over Serial

The bit order of the payload is to be the same as that specified for the DC and AC form factors in Section 6.1.4 of this document.

13.1.7 LonTalk Pass-Through

This section shows how the LonTalk protocol is supported by the CTA-2045-B interface. The messages will be formatted as follows, with the message type being a 0x09 0x0A, and the payload being defined entirely by the LonMark Association.

Message Type = 0x09, 0x0A	Reserved Must be '0x0'	Payload Length	LonTalk Message	Checksum
2 Bytes	3 Bits	13 Bits	Variable	2 Bytes

Figure 13-8 LonTalk Over Serial

The bit order of the payload is to be the same as that specified for the DC and AC form factors in Section 6.1.4 of this document.

13.1.8 SunSpec Pass-Through

This section shows how the SunSpec protocol is supported by the CTA-2045-B interface. The messages will be formatted as follows, with the message type being a 0x09 0x0B, and the payload being defined entirely by the SunSpec Alliance.

Message Type = 0x09, 0x0B	Reserved Must be '0x0'	Payload Length	SunSpec Message	Checksum
2 Bytes	3 Bits	13 Bits	Variable	2 Bytes

Figure 13-9 SunSpec Over Serial

The bit order of the payload is to be the same as that specified for the DC and AC form factors in Section 6.1.4 of this document.

13.1.9 BACnet Pass-Through

This section shows how the BACnet protocol is supported by the CTA-2045-B interface. The messages will be formatted as follows, with the message type being a 0x09 0x0C, and the payload defined in the BACnet protocol.

Message Type = 0x09, 0x0C	Reserved Must be '0x0'	Payload Length	BACnet Message	Checksum
2 Bytes	3 Bits	13 Bits	Variable	2 Bytes

Figure 13-10 SunSpec Over Serial

The bit order of the payload is to be the same as that specified for the DC and AC form factors in Section 6.1.4 of this document.

14 EXAMPLE 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 prev. msg.

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 prev. msg.

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 prev. msg.

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 prev. msg.

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 prev. msg.

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 prev. msg.

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

End Device to Comm Module ← 06 00 Link Layer Acknowledge of prev. msg.

Comm Module to End Device → 09 04 01 3D <SEP msg> CS CS SEP2/IP msg, length only an example

End Device to Comm Module ← 06 00 Link Layer Acknowledge of prev. msg.

* Note that 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 that 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 or ZigBee 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. For 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 6-1, 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 Comm Module would only know whether or not the SGD is accepting or NAK’ing the messages.

16 LOAD MANAGEMENT EVENT RANDOMIZATION

It is noted that if large numbers of end devices turn on or off simultaneously there may be 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 identified in the application layer command (e.g., the Intermediate cycling command), CTA-2045-B does not require SGDs to perform event randomization. In fact, such behavior 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. The advantage of this approach is that it allows a single SGD to be sold nationwide without assuming to know what timings are needed by the local utility. Figure 16-1 illustrates this concept.

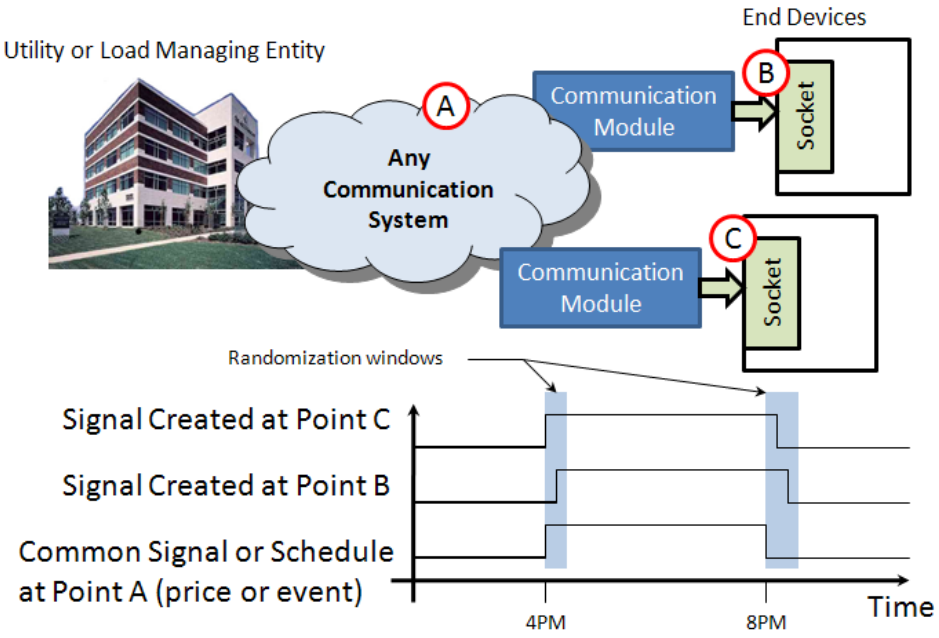


Figure 16-1 – Example of Randomization of Events by Communications Modules

17 APPENDIX A – LOW VOLTAGE DC FORM FACTOR (NORMATIVE)

17.1 Overview

17.1.1 Limitations

- The transport speed is limited by SGD and UCM processor bandwidth. The data-link defaults to a slow data rate (19.2k) 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.
- CTA-2045-B does not include device reliability requirements. There are also no requirements for handling, dropping, ESD resistance, etc.

17.2 Physical Layer

17.2.1 Power for UCM

Power for UCM is provided by SGD. Power is supplied at 3.3 +/- 0.3V DC. Optionally, the power from the SGD could be supplied at 5v +/- 0.3v DC. If the UCM requests 5v *Power Level Indicator* of 0x05 (see Section 9.1.1), then the SGD shall make this power level available only after successful negotiation. Also note that the optional 5v power uses Pins that have been assigned to the discretion of the UCM and SGD manufacturer, so both sides will need to make appropriate accommodations. The power consumption limits are described in Section 9.1.1. Power for the UCM shall be provided by a Class 2 (or equivalent) power supply within the SGD.

17.2.2 Mechanical Interface

17.2.2.1 DC Form Factor Board Layout

The DC UCM device must conform to one of the physical layouts identified in Figure 17-2 and Figure 17-3. 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 47.6mm (width or Y) dimension as well as the 12.3mm (height or Z) dimension once the module exits the SGD after the 60mm minimum in the X direction in Figure 17-3. Similarly, the extended size PCB of Figure 17-1 – DC Form Factor PCB Dimensions 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 must be met.

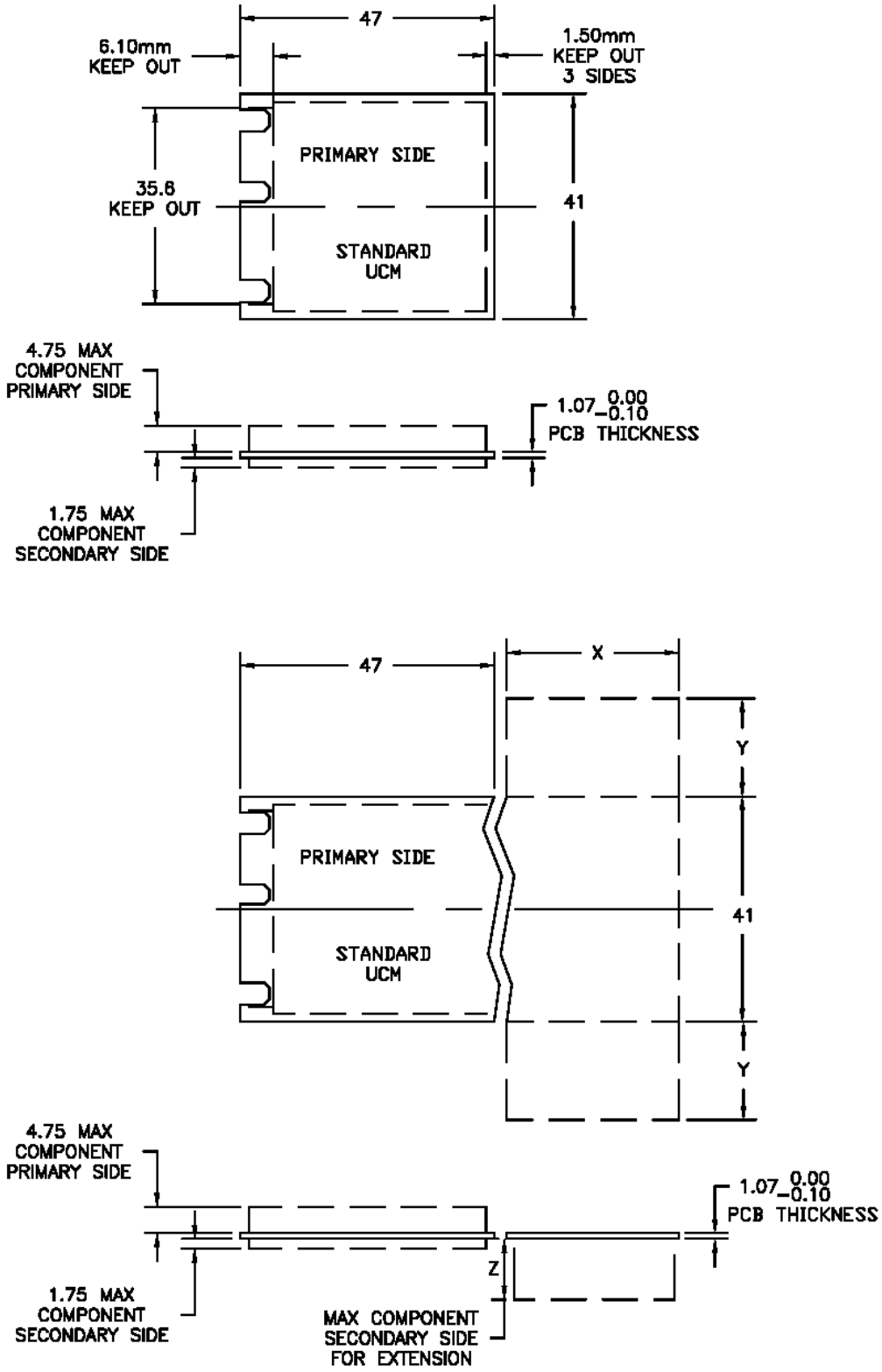


Figure 17-1 – DC Form Factor PCB Dimensions

17.2.2.2 Module Configuration

The DC Form Factor UCM module is defined for the standard layout. Extended size UCMs will have extended housings which shall have all the features and meet all the dimensions of the standard module until after the module exits the SGD past the 60mm minimum in the X direction in Figure 17-3. At that point, the 47.6mm (width or Y) dimension and the 12.3mm (height or Z) dimension which may grow in addition to the X dimension.

A special case of extended length is defined 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.

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 RJ45 receptacle. Specific implementations are left to the discretion of the communication provider.

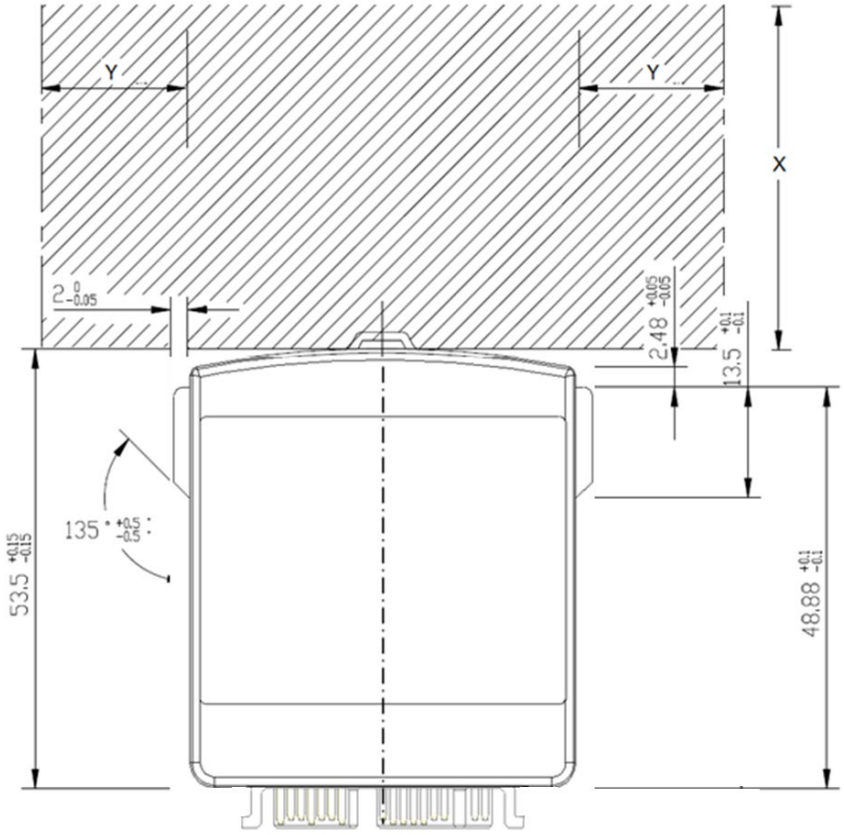


Figure 17-2 – DC Form Factor Housing Dimensions – Top View

* Hatched Area Dimensions for connectors, antennas, or large components

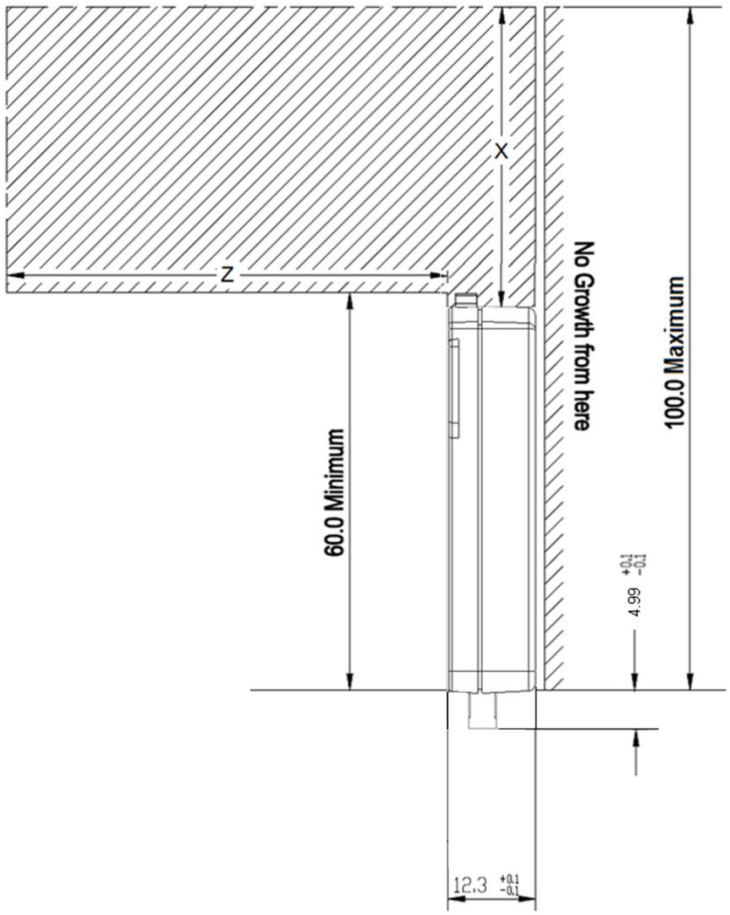


Figure 17-3 – DC Form Factor Housing Dimensions – Side View

* Hatched Area Dimensions for connectors, antennas, or large components

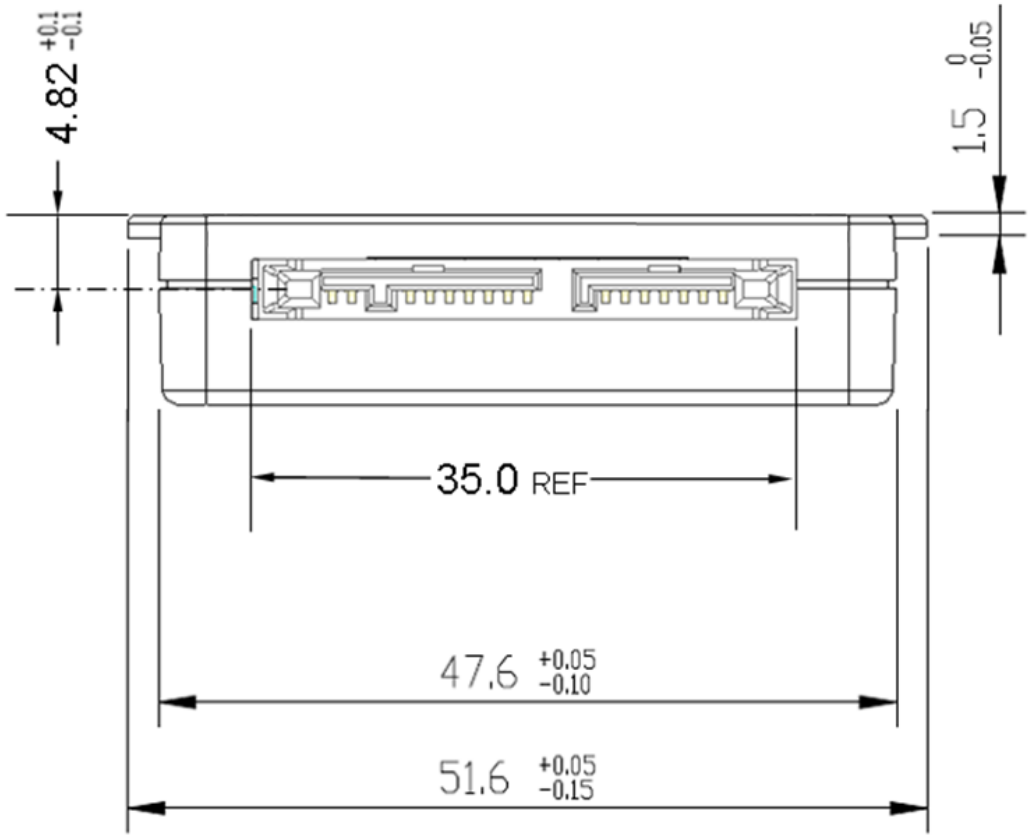


Figure 15-4 DC Form Factor Housing Dimensions – End View

Figure 17-4 – DC Form Factor Housing Dimensions – End View

Note: The connector is centered in the width of the module. All dimensions are provided in millimeters.

17.2.2.3 Weight

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

17.2.2.4 Housing Materials

UCM housing materials must be appropriate for the technology contained within 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 supply, 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 stadards.

17.2.2.5 Connector Type

The interface connectors on SGD and UCM are standard Micro Serial ATA connectors as defined by the Serial ATA International Organization2. (Also refer to ISO/IEC 24739)

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

17.2.2.6 Pin Assignments

The pin assignments of the connector are defined as follows.

Pin	Mating	Designation
S1	2nd	Spare
S2	3rd	ATTENTION*
S3	3rd	SCLK
S4	2nd	SELECT*
S5	3rd	MOSI
S6	3rd	MISO
S7	2nd	RESET*
P1	3rd	+3.3 Power
P2	2nd	+3.3 Power
P3	1st	Signal Ground
P4	1st	Signal Ground
P5	2nd	SGD Reserved – Optionally +5 Power (see Section 17.2.1
P6	3rd	SGD Reserved
P7	3rd	Module Detect (connected to Signal Ground on UCM)
P8	3rd	UCM Reserved – Optionally +5 Power (see Section 17.2.1
P9	3rd	UCM Reserved

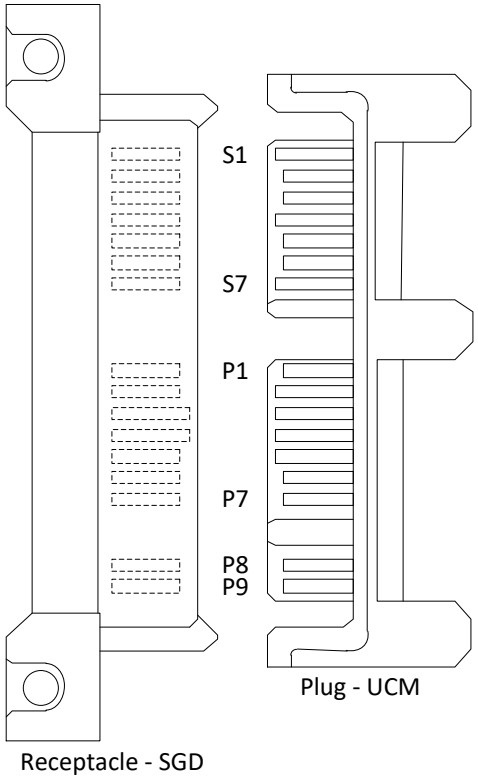


Figure 17-5 – Pin Assignment

2 http://www.sata-io.org/

17.2.2.7 Electrical Interface Levels

All signals are 3.3V Logic Levels. Logic '0' is defined as less than 0.8V, and Logic '1' as greater than 2.2V.

17.2.2.8 Signal Timing

Representative signal timing is shown for SPI byte transfers:

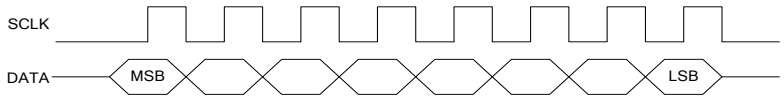


Figure 17-6 – SPI Mode 0 Bit Timing

CTA-2045-B 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.

17.2.2.9 Interface Circuits

Circuit(s)	Direction	active state	Purpose
Spare	*n/a*	*n/a*	Reserved for future use. UCM and SGD must not connect to this pin.
Signal Ground	*n/a*	*n/a*	Establishes a common ground potential
+3.3V Power	From SGD	n/a	Provides +3.3V 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 must not connect to these pins.

			If the optional 5Vdc is negotiated, one of these pins will be dedicated to 5Vdc. See Section 17.2.1
UCM Reserved	N/A	N/A	Two signals for UCM test use at factory only. SGD must not connect to these pins. If the optional 5Vdc is negotiated, one of these pins will be dedicated to +5Vdc. See Section 17.2.1

Table 17-1 – Low Voltage Interface Signal Definitions

17.2.2.10 Data Transfer Protocol

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.

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 must 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).

RESET*

On power-on, the SGD will assert RESET* (drive it low) for a minimum of 100mS. 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.

17.2.2.11 Clock and Data Rate

Data rate is controlled by the SPI SCLK. SCLK is generated by the SGD. Standard data rates are defined in Section 9.1.2.

17.2.2.12 Multiple Slots

SGD's may, but are not required to provide multiple slots.

Independent SELECT*, ATTENTION* and RESET* must 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.

17.3 Link Layer

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.

17.3.1 Messages

17.3.1.1 Frame Structure

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

17.3.1.2 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.

17.3.1.3 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.

17.3.1.4 Command/Response Encoding

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

17.3.1.5 Checksum Calculation

The checksum calculation is defined in Appendix C.

17.3.1.6 Master/Slave

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

17.3.1.7 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.

17.3.1.8 Error Detection and Recovery

17.3.1.9 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 milliseconds, 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 milliseconds, 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.

17.3.1.10 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 milliseconds, 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 milliseconds , 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 milliseconds, 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.

17.3.2 Operation

17.3.2.1 Transaction Sequence

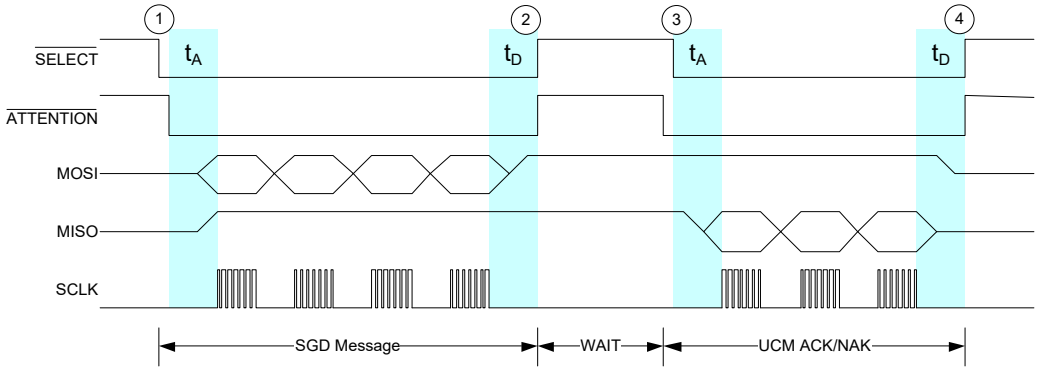


Figure 17-7 – SPI Transaction Sequence: SGD-initiated message to the UCM

Figure 17-7 describes 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 must respond with an ACK or NAK. In addition to the physical timing requirements t_A and t_D in Table 17-2, this transaction is also governed by data-link timing in Table 6-3.

Transaction Sequence

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 6-3 – Message Timing Requirements**), 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 17-8, where the roles of SGD and UCM are swapped. Figure 17-8 would take place after a time meeting the requirements of Table 6-3. 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.

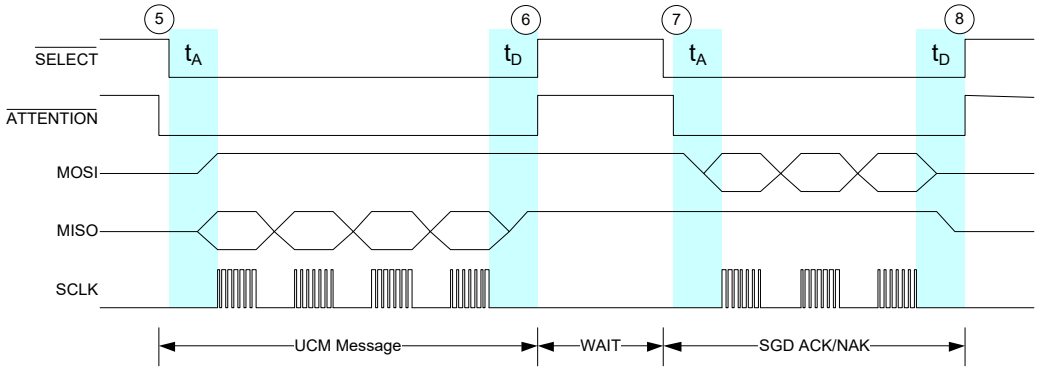


Figure 17-8 – SPI Transaction Sequence: UCM-initiated message to the SGD

Figure 17-8 describes 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 must respond with an ACK or NAK. In addition to the physical timing requirements t_A and t_D in Table 17-2, this transaction is also governed by link layer timing in Table 6-3.

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 6-3), 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 17-8 would occur first and Figure 17-7 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.

Parameter	Minimum	Maximum	Description
t_A	20 [µS]	NA	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]	NA	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*)

Table 17-2 – SPI Physical Timing Requirements

17.3.2.2 SPI Data Transfer State Machine

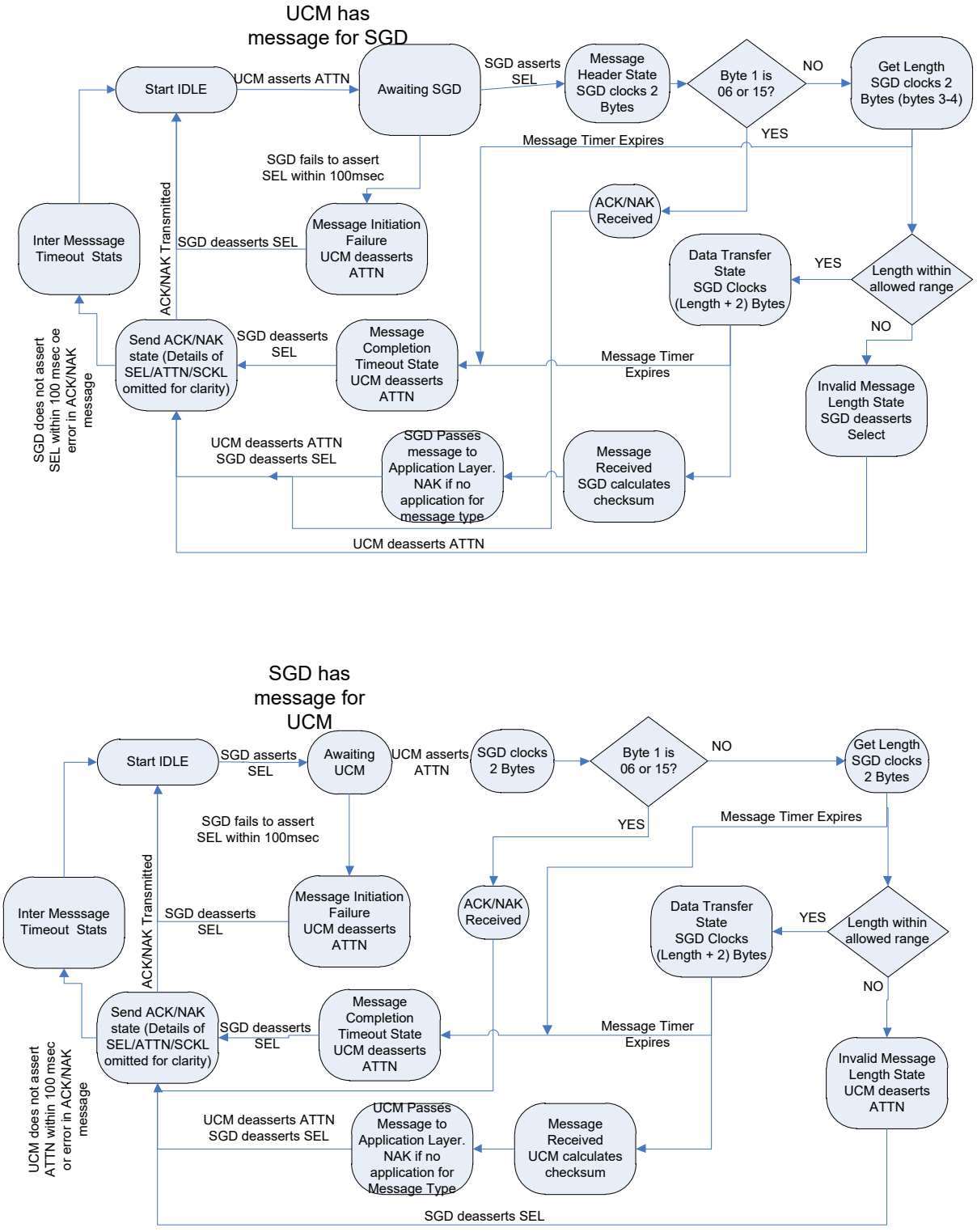


Figure 17-9 – SPI Data Transfer State Machine

This state machine diagram describes the behavior 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 signaling line, ATTENTION* for the UCM and SELECT* for the SGD.

17.3.2.3 SGD Transmitter Operation

The SGD device transmitter must 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 transmitted notify 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.

17.3.2.4 SGD Device Receiver Operation

The SGD Device receiver must 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 check sum 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-assertion 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.

17.3.2.5 UCM Operations

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

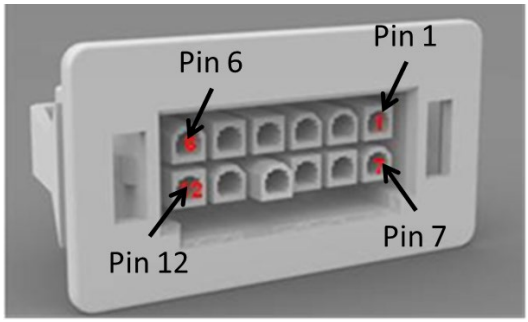
- The actions of SELECT* and Attention* are reversed.
- The UCM has to monitor for Message Timeout.
- The UCM relies on the SGD to clock the bytes.

18 APPENDIX B – AC FORM FACTOR (NORMATIVE)

18.1 Physical Form

18.1.1 AC SGD and AC UCM Connector

The AC SGD connector shown in Figure 18-1 provides sufficient clearance for the 240Vac signals. In the case of 120V devices, pin 12 (Line 1) shall be the hot connection and pin 5 (Line 2) shall be the neutral connection. In the case of 208/240V three-wire devices, pin 12 (Line 1) shall be one service phase and pin 5 (Line 2) shall be another. The connector includes protective sleeves to cover the energized pins, has some circuits removed to increase clearance around the AC power, and is polarized so that the mating device can only be plugged-in one way. The connector part that would go on the SGD is available from connector manufacturers in various types.



1	Data- (RS-485)	7	Data+ (RS-485)
2	No connection	8	Signal Ground
3	Reserved for vendor-specific use	9	No connection
4	No connection	10	Earth Ground
5	AC Line 2	11	No connection
6	No connection	12	AC Line 1

Note: AC power pins utilize 18AWG wires. All others utilize 22AWG.

Figure 18-1 – Panel Mount AC Connector Form Factor (Device Side Shown) and Pin-Out

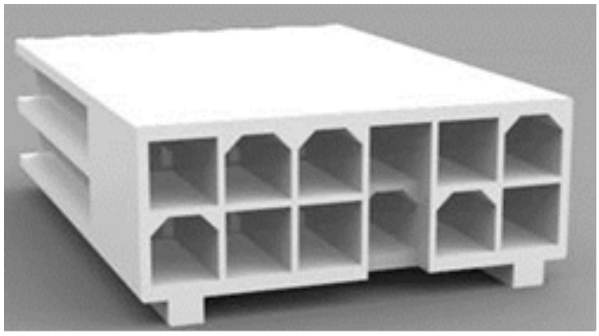


Figure 18-2 – PCB-mount AC UCM connector (housing)

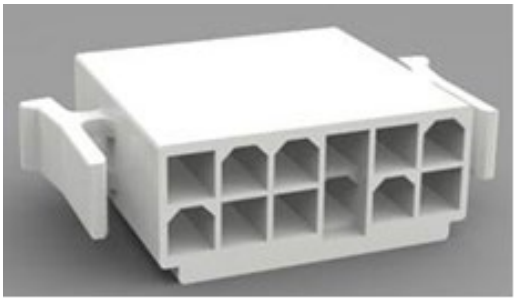
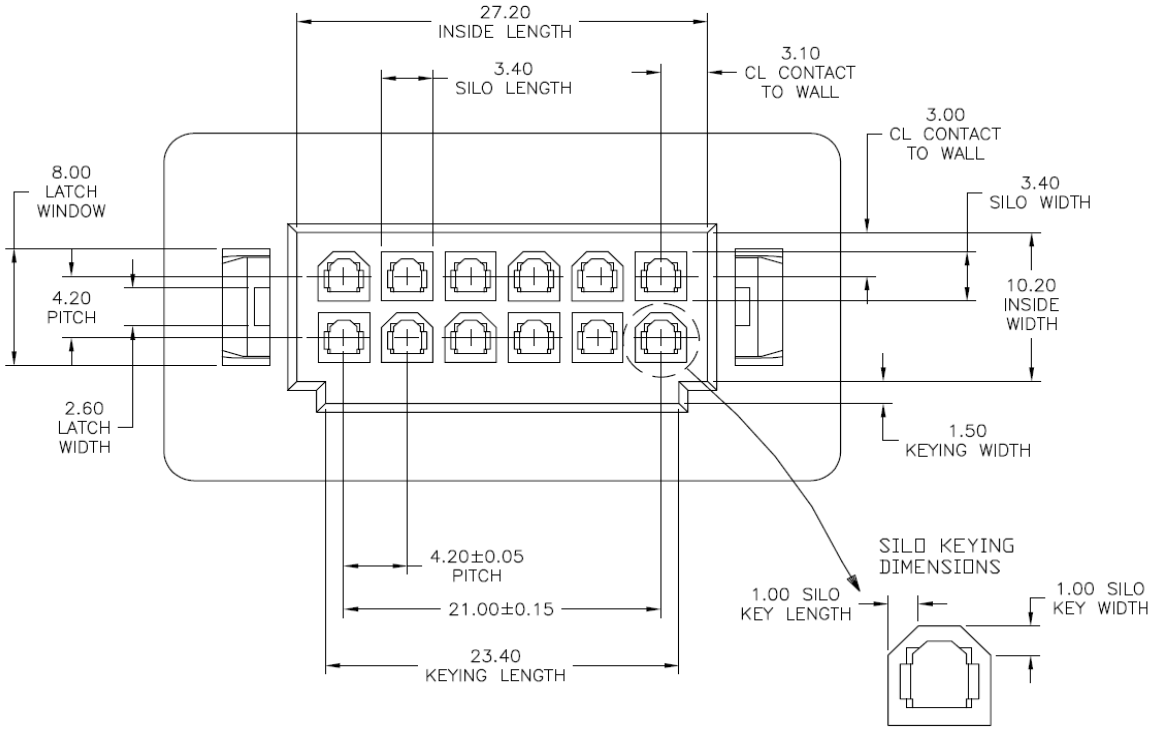


Figure 18-3 – Cable AC UCM Connector (housing)

The interface details for these connectors are shown below as Figure 18-4 through Figure 18-7. These will allow any manufacturer to produce connectors that will intermate.



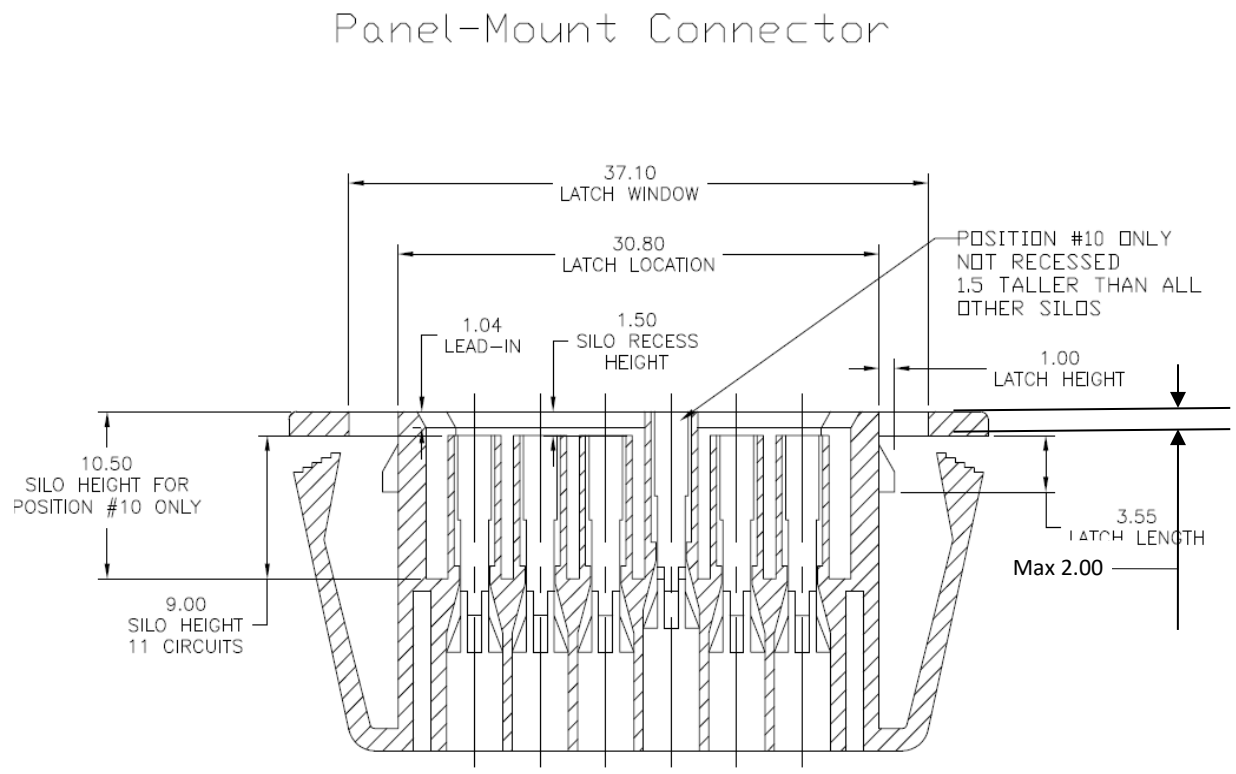


Figure 18-4 – Panel Mount AC SGD Connector Form Factor dimensions

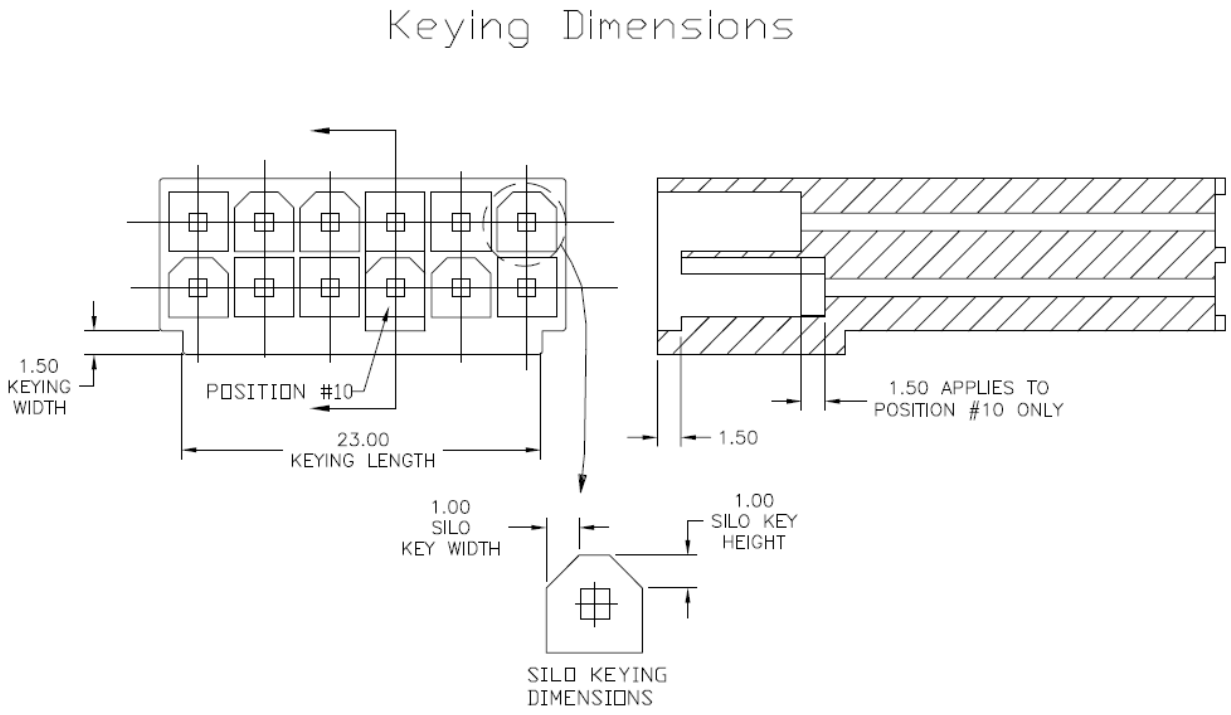


Figure 18-5 – PCB Mount Connector dimensions

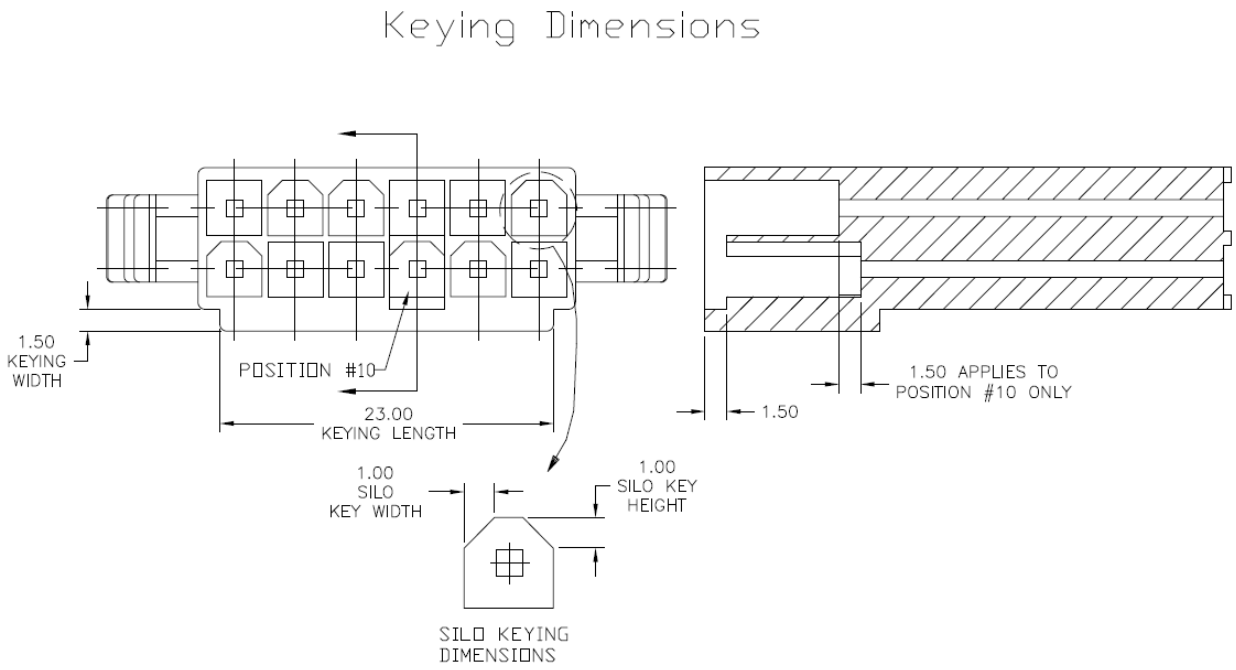


Figure 18-6 – Cable Connector dimensions

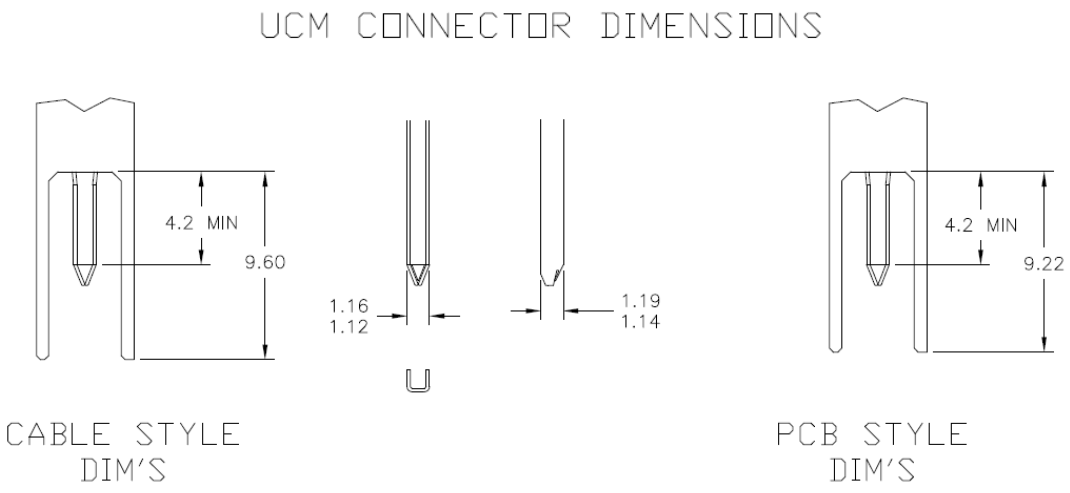


Figure 18-7 – Contact dimensions for Cable Connector and PCB mount connector

18.1.2 AC Enclosure requirements

It is anticipated that the AC Form Factor will have a variety of enclosure types, shapes, and dimensions. In order to ensure interoperability between different implementations, minimum and maximum dimensions are defined as follows.

18.1.2.1 AC Form Factor - SGD mounting space

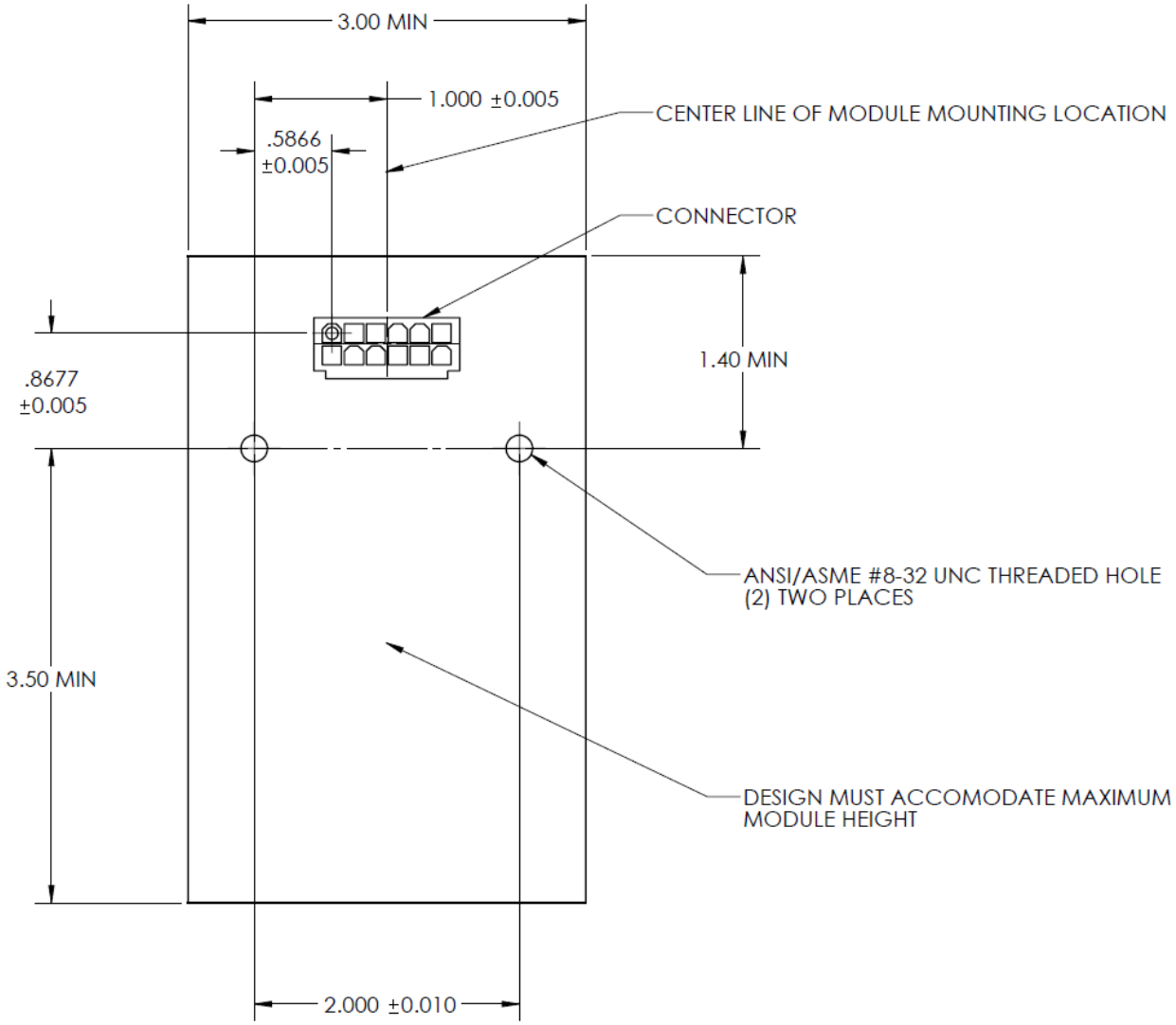


Figure 18-8 – Reserved area and dimensions on SGD (receptacle)

Notes:

1) Access area for module must be free of obstructions.
2) If module is to be recessed into a pocket, there must be clearance provided for insertion and removal of the module around the sides.

18.1.2.2 AC Form Factor – UCM dimensions

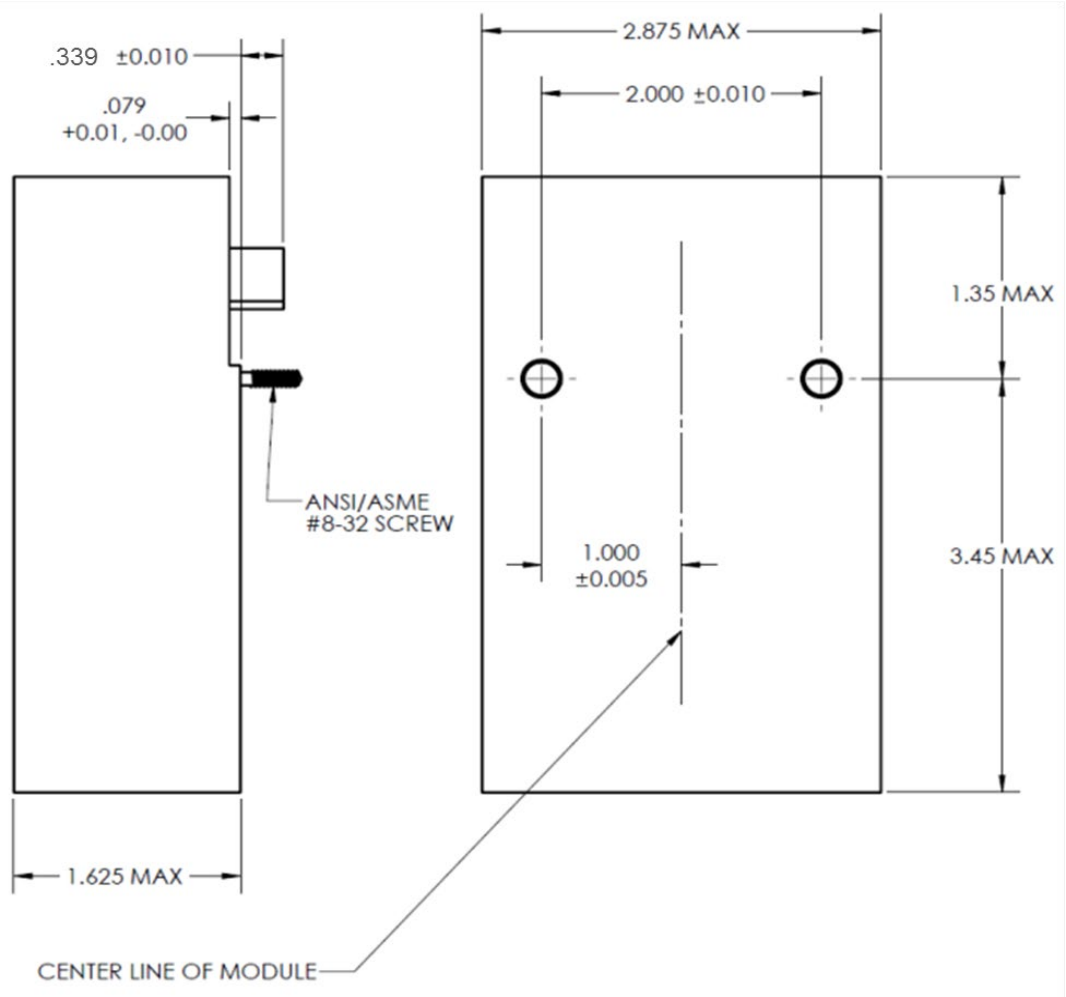


Figure 18-9 – Right side and top view of maximum UCM dimensions

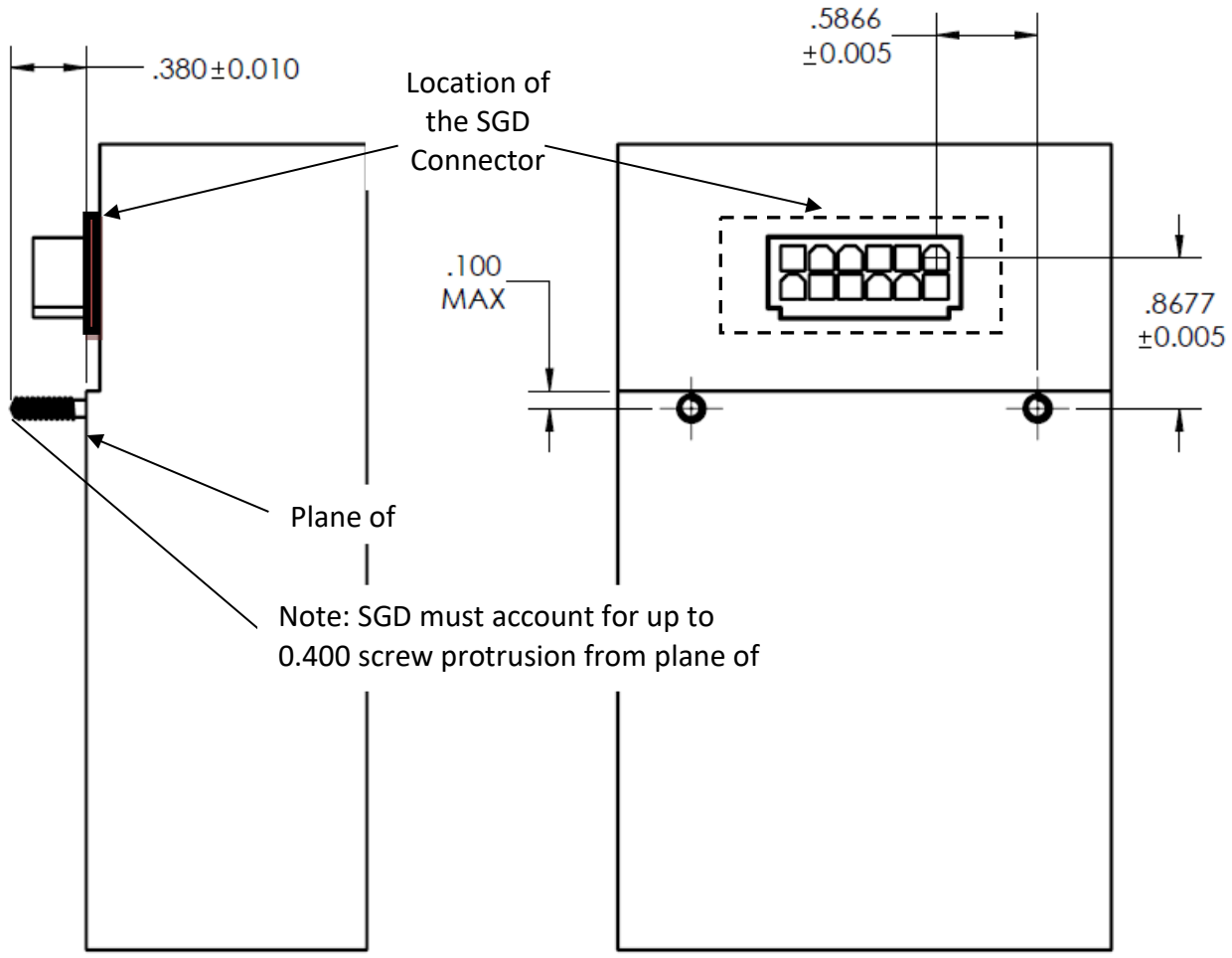


Figure 18-10 – Left side and bottom view of maximum UCM dimensions

Notes:

1) The connector position in relation to the screws must be adhered to.
2) The purpose of the 0.079” step in the package design is intended to accommodate a flange which may exist around the panel-mount connector on the SGD as illustrated in Figure 18-4. The UCM connector is designed to correctly mate to the SGD connector whether the flange is present or not. UCM designs must provide a bearing surface in the vicinity of the mounting screws that is 0.079" above the housing surface at the base of the UCM connector to provide for proper engagement of the UCM connector into the SGD connector as the two mounting screws are tightened.
3) All dimensions above are in inches.

18.2 AC Power

UCMs must be designed to operate normally over a voltage range from 10% under the nominal service voltage to 20% over the nominal voltage. This equates to 90 to 288VAC for 100 to 240V systems. UCMs must be auto-ranging. Current consumption on the AC lines may not exceed the limits indicated in Table 9-3. SGDs providing this connection may optionally choose to limit the current to these levels.

The serial communications link (Data-, Data+, Signal Ground) shall have at least 1500 VAC isolation from the AC Power connections (Earth Ground, Line 2, Line 1) through the power supply Serial Electrical Interface to assure good communication.

This is an RS-485 2-wire connection on pins 7 (Data+) and 1 (Data-), operating at a nominal voltage of 3 to 5V as illustrated in Figure 18-11.

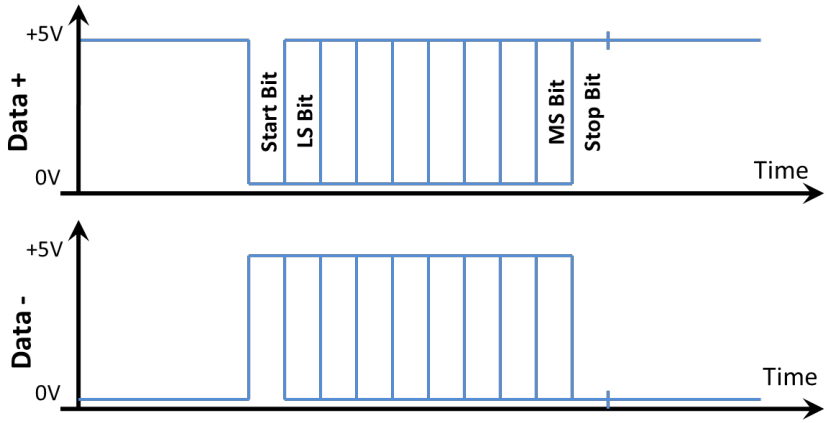


Figure 18-11 – Typical RS-485 Polarity and Byte Transfer

The RS-485 interface is anticipated to employ a driver IC. The use of such a driver provides protection against ESD and other transients and potential noise problems. RS-485 is multi-drop capable, allowing the serial port going into the device to connect to multiple sub-systems inside the device if desired. The default state for this bus is a logic “1”, with the bias provided by the SGD via a 1K ohm pull-up resistor on the Data+ line to +5V and a 1K pull-down resistor to GND on Data- provided by the SGD as illustrated in Figure 18-12.

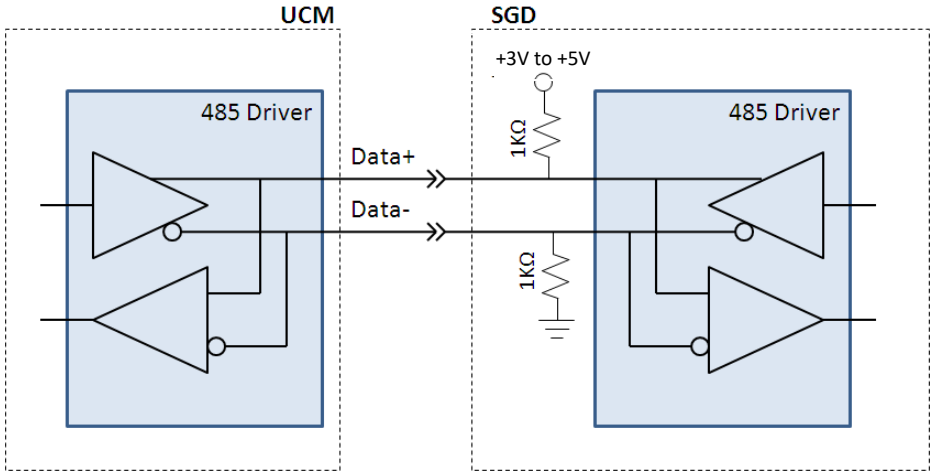


Figure 18-12 – RS-485 Connections

The default baud rate on the interface is 19.2KBaud with one start bit (0), eight data bits, no parity, and one stop bit (1). Transmitters must send one stop bit; receivers must tolerate one or more.

18.3 Obtaining Message Sync

Because the serial message structure does not employ a special start character, bus idle (logic "1" state) for 20[mS] or more shall indicate the end of message. During a packet transfer, transmitters must assure that the inter-character delay is less than this time. Receivers are only required to report time-outs at the message level, per the T_{ML} parameter in Table 6-3. Receivers are not required to measure inter-byte delay, other than when searching for the start of a new message. There is no LINK NAK error code associated with inter-byte delay.

19 APPENDIX C – FLETCHER CHECKSUM (NORMATIVE)

The checksum method for this protocol shall be a “Fletcher’s 16-bit 1’s complement checksum”. The two bytes are coded and decoded as follows:

19.1 Calculating the Checksum

Initialize checksum1 to 0xAA and checksum2 to 0x00

Loop through the message (this example uses variable “I”) from the first ‘Message Type’ byte to end of payload, to calculate the 2-byte checksum. This loop excludes the checksum bytes as they are not yet created.

checksum1 = (checksum1 + sendData[I]) Mod 255

checksum2 = (checksum2 + checksum1) Mod 255

Find the bytes to append in the following manner:

mscheckbyte = 255 - ((checksum1 + checksum2) Mod 255) (the MSB of the new checksum)

lscheckbyte = 255 - ((checksum1 + mscheckbyte) Mod 255) (the LSB of the new checksum)

19.2 Decoding the Checksum

As shown in the example below, calculate the checksum exactly as it is done for creating the checksum bytes, from the first ‘Message Type’ byte to end of the payload not including the checksum bytes. The calculated checksum should equal the following two checksum bytes in the received message.

Alternatively, loop through the incoming message from the first byte to the end, including the two checksum bytes. Once the entire message including the two checksum bytes have been analyzed, checksum1 and checksum2 should equal 0x00.

19.3 Example VB Code

Creating Checksum:

```
Public Sub CalcChksum(ByRef senddata() As Byte, ByVal chrCount As Integer)
    'Calculates the Fletcher Checksum (16-bit 1's complement) on chrCount number of bytes in the
    'senddata array then modifies the array, appending the checksum to the consecutive 2 indexes.
    'Be sure array is dimensioned at least 2 larger than message.
    'Arguments:
    'senddata() byte array, ByRef, contains message
    'chrCount is number of bytes in the message not including the checksum
    Dim checksum1 As Int16 = 170     '0xaa
    Dim checksum2 As Int16 = 0
    Dim mscheckbyte As Int16

    For I = 0 To (chrCount - 1) Step 1
        checksum1 += senddata(I)
        checksum1 = checksum1 Mod 255
        checksum2 += checksum1
        checksum2 = checksum2 Mod 255
    Next I
    mscheckbyte = 255 - ((checksum1 + checksum2) Mod 255)

    senddata(chrCount) = mscheckbyte 'add 16 bit checksum
    senddata(chrCount + 1) = 255 - ((checksum1 + mscheckbyte) Mod 255)
End Sub
```

Decoding Checksum

```
Public Function verifyChecksum(ByVal receivedData() As Byte, ByVal chrCount As Integer) As Boolean
    'Calculates the Fletcher Checksum (16-bit 1's complement) on chrCount number of bytes in the
    'receivedData array then compares that to the checksum stored in the following 2 indexes.
    'Arguments:
    'receivedData() byte array contains message and 2-byte checksum
    'chrCount is number of bytes in the message not including the checksum
    'Returns True if checksum is correct else returns False
    Dim checksum1 As Int16 = 170     '0xaa
    Dim checksum2 As Int16 = 0
    Dim mscheckbyte, lscheckbyte As Int16

    For I = 0 To (chrCount - 1) Step 1
        checksum1 += receivedData(I)
        checksum1 = checksum1 Mod 255
        checksum2 += checksum1
        checksum2 = checksum2 Mod 255
    Next I
    mscheckbyte = 255 - ((checksum1 + checksum2) Mod 255)
    lscheckbyte = 255 - ((checksum1 + mscheckbyte) Mod 255)

    verifyChecksum = False
    If (mscheckbyte = receivedData(chrCount) And lscheckbyte = receivedData(chrCount + 1)) Then
        verifyChecksum = True
    End If
End Function
```

20 APPENDIX D – GUIDELINE FOR COMPUTING AVERAGE PRICE (INFORMATIVE)

This appendix explains the calculation of the Average Price (AP) from which the relative price is computed.

Electric rates structures, today, are very complex and vary in every jurisdiction. Common elements of rate design consist of components like fixed charges per month (including customer charge, flat tax or levy fees), a unchanging prices per kWh (often to recovery fixed costs charge on a per kWh basis), peak kW demand charges, a percent tax (or tax equivalent) adder on certain charges, and worst of all, block rates that cause a higher (or lower) rate kWh

when usage during a billing period moves above a certain quantity of use. (Some rates even have multiple blocks).

Note:

Average price by state and sector are available at:
http://www.eia.gov/cneaf/electricity/epm/table5_6_b.html.

However, these average prices are inclusive of all fixed and flat rate charges. AP based on more than TVC is desirable from a customer perspective but there is no way to reconcile block rate designs with average price since two customers can have significantly different average prices from a monthly bill perspective. Also observe that averaged at the state level, the total price per kWh varies between 8 and 28 cents per kWh; this should emphasize the problem of trying to communicate actual price and have anything but a complex application make sense of it. Everyone can understand price relative to the expected monthly bill.

The relative price command only applies to the bill components that relate to price changes as a function of time during a day or hour ("Time Varying Charges, TVC"). Most commonly TVC charges apply to the cost of energy generation, but in some rate designs charges for the fixed cost of distribution may also be time varying. TVC exclude kW, demand charges if any. The purpose of command 0x07 is to convey the bundled price of all TVC, which affect the retail customer's bill. Thus the service provider responsible for conveying price signals via the UCM combines all TVC even if the service provider only provides energy or distribution services. The following instructions assume that block rate price increase or decreases have no relationship to time only the usage in a billing cycle. (This is the most common outcome. It has the effect of say the flat price per kWh is $X/kWh for the first Q use and then $Y/kWh for the next block of usage. Depending on the time varying price structure the bill calculation add or subtracts dollars depending on the block rate structure, but not dependent on when in a day usage was consumed.)

The following explanation gives examples with prices quoted in mills per kWh. (This is numerically equal to $ per MWh the unit of price in wholesale markets. Retail customers are commonly quoted prices in cents per kWh; cents per kWh equals mills per kWh divided by ten.)

A utility or service provider using this command should be willing (or regulated) to provide to their customer a basis for the average price ("AP") per kWh that pertains to TVC; relative prices equals current price divided by AP. The intent of the AP is to convey the price per kWh, pertaining to TVC, which produces an average bill amount. Example let's say a bill consists of 3 components, a fixed charge per month of $11 (including flat taxes), a flat rate of 41.2 mills (40 mills per kWh plus a 3% tax) and an AP of TVC equal to 82.4 mills (80 mills plus 3% tax). If the customer uses 800 kWh per month, the intent of AP is to convey that the customer on the rate would receive a bill of $65.92 for TVC, IF the customer's usage pattern matches the statistical average load shape with respect to time. ($65.92 = $82.4/MWh times 0.8 MWh). Note the customer's total bill would be $109.88 = $11 + $32.96 + $65.92. Thus if the customer uses more energy in higher-priced hours than the average customer, they would expect a higher bill being on this time varying rate design.

Explanation for non-regulated utilities

The above task is a straight-forward exercise today for any regulated utility (public or private); ratemaking 101 if you will. However, in a smart grid world with multiple rates and multiple providers, the best we are likely to do is set AP at a value close to the average TVC, more importantly at a level the make the relative prices (dynamic prices divided by the AP) as indicative of the correct relative price to the consumer.

For regulated utilities most customer are a flat rate price per kWh that represents the sum of fixed and TVC (to the utility). In the creation of a time varying rate the first step is to be explicit about how much of the flat rate will remain at flat price per kWh and how much will be collected through time a time varying rate. Through load research, for customers of a given class, say residential, a known load shape for the average customer is known. Load shape is the percent of total energy use per hour for each hour of the year. This shape can be based on all customers or just customers on a flat rate design. Expected revenue from a given time varying rate is calculated using this model. Consider a two price time-of-day rate. Low rate period is 10p to 6a every day and high price 6a to 10p every day. By looking at the load shape you would determine that 25% of the energy is use in the low rate period. If flat rate price is 120 mills and 80 mills are to be collected in TVC, then to achieve and AP of 80 mills in TVC and the low price is 50 mills, then the high price is 91.67 mills. Relative price when the low price is in effect is 0.563. Relative price when high price is in effect is 1.146. Note when a 3% tax is added the relative prices remain unchanged. This example is the simplest type of design. Introducing a third price period allows much more flexibility in designing the behavior desired from the customer and also the rates marketability. Critical peak pricing and real time pricing introduce a new variable in that the specific period when a price will be available is not known ahead of time. Rate design is based on expected pricing outcomes.

AP for TVC was assumed at 80 mills. This type of rate designed is called "revenue neutral" because both the flat rate and time-varying rate collect are designed to collect 120 mills per kWh for the average customer. It is expected that the customer with time varying rates will shift some loads to the low price period thus creating a net billing savings to the customer. However there are economists would argue time varying-rates should be lower than revenue neutral to reflect that customers that don't wish to deal with peak supply cost problems should pay a premium for the risk burden they put on the energy supplier relative to someone who faces time-varying pricing. Critical peak pricing and real time pricing introduce a new variable in that the specific period when a price will be available is not known ahead of time. Rate design is based on expected pricing outcomes.

The complexity of rate designs in the last paragraph raises a number of issues about how to determine AP. For example, is AP based on all customers: 1) in a given region; 2) of a given provider; 3) on a specific rate, before or after shifting is accounted for? If the rate is based on real time rates what index or forecast is used to determine average rates?

Summary

With regard to CTA-2045-B and Average Price there are no absolute rules that can be workable against all the future outcomes of regulation and market forces. Imagine coming with a relative

price of for a coach round trip airline seat between Washington DC and Tampa Florida in 1977 before deregulation in October 1978. Average price would have been fairly easy to determine. Relative prices for the Wednesday before Thanksgiving would have been relatively easy to determine also. Today we might guess the price at $250, and feel that $200 would be a great price and $500 a very high price. We would feel fortunate if someone even gave us a relative constant metric of average price.

This analogy is only mentioned to show how pricing models to improve asset utilization can change dramatically over time. However unlike airplane flights which are expensive, relatively infrequent transactions, electricity use is like a leaky faucet-- continuous use with small cost incurred during most periods. This command only works, a machine to machine interface, if the consumer can use the signal to manage the size of their electric bill. A service provider that games the signal will eventually be found out, if a large risk of damage to market credibility.

Thus the rules for determining AP can be summarized as follows:

1. AP shall be based on TVC only.
2. AP price is set to indicate the price that will produce the average bill for TVC.
3. In the near term, AP should be calculated in a manner similar to rate designs for regulated entities.
4. In the future, AP should be set (ideally held constant for at least a quarter if not a year) at a level that provides intuitive messages via the relative price signals to customers.

21 APPENDIX E – PRODUCT SAFETY CONSIDERATIONS (INFORMATIVE)

UCM products may interface between a variety of products and systems, including home appliances, energy management systems, and smart grid gateways. Safety requirements applicable to a UCM will depend on the specific application and installation, and may include compliance with safety standards such as:

- UL 244A – Solid State Controls for Appliances
- UL 60730-1 – Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements
- UL 916 – Energy Management Equipment
- UL 60950-1 - Information Technology Equipment Safety - Part 1: General Requirements

22 APPENDIX F - CERTIFICATION LEVELS (NORMATIVE)

22.1 General Requirements

Level 1 is included to describe section 7 of this standard and Level 1 requirements must be met by all devices (both UCM and SGD) that are considered to comply with CTA-2045-B.

Levels other than 1 are specific to device type and are described below.

Compliance to this standard that meets a certain level shall be described as "Compliant to CTA-2045-B Level N" where N is a level number from below.

Example: "Compliant to CTA-2045-B Level 2" indicates that a water heater (implied) meets all the requirements of Level 1 and Level 2.

The phrase "Compliant to CTA-2045-B" shall not be used, but is equivalent to "Compliant to CTA-2045-B Level 1".

22.2 Common Levels

22.2.1 Level 1

Low Voltage / DC Form Factor devices (UCM and SGD) shall meet all requirements in Appendix A

AC Form Factor devices (UCM and SGD) shall meet all requirements in Appendix B

All devices shall perform message checksums according to Appendix C.

All devices shall not ignore messages and shall respond with the appropriate NAK (Link, Basic Dr, Int DR as appropriate) if the message is not valid or the action specified by the message cannot be taken.

Summary table of required message support for Level 1

	Data Link Messages (Message Type 0x08, 0x03):	**Any Device**
		CTA-2045-B Mandatory for Level 1
Section 8.1	Link ACK	Required
Section 8.1	Link NAK	Required
Table 9-2	Maximum Payload Length	Required (2 bytes)
Section 8.2	Message Type Supported	Required
	Basic DR Application (Message Type = 0x08, 0x01)	

	Basic Application ACK	Required
Table 10-2	Basic Application NAK	Required
Table 10-2	Shed	Required
Table 10-2	End Shed	Required
Table 10-2	Outside Comm Connection Status	Required

Table 22-1 Certification Level 1 Message Summary

The following sections outline the specific requirements for each required message.

22.2.1.1.1 Title 24 JA 13 Functions

The SGD shall, if supporting Title 24 JA 13 in addition to CTA-2045-B, use the following correspondence table to map CTA-2045-B messages to Title 24 JA 13 function names.

CTA-2045-B	Title 24 JA 13
Shed	Light Shed
Critical Peak Event	Deep Shed
Grid Emergency	Full Shed
Load Up	Load Up
Advanced Load Up - The SGD shall accept SetAdvancedLoadUp with value = 0x05 and units = 0x02 (100 Wh) to indicate 0.5 kWh.	Advanced Load Up

22.2.1.1.2 Link ACK

The SGD shall respond with link ACK within the specified time limits when the UCM sends messages in accordance with requirements of Section 8.1 Link Layer ACK/NAK and:

For DC form SGDs in conjunction with Appendix A Link Layer Requirements

For AC form SGDs in conjunction with Appendix B Link Layer Requirements

22.2.1.1.3 Link NAK

The SGD shall respond with link NAK with the following NAK Error Codes supported:

For DC form SGDs 0x00 - 0x04 and 0x06

For AC form SGDs 0x00 - 0x06

22.2.1.1.4 Maximum Payload Length

If the SGD shall support a payload length of at least 2 bytes.

22.2.1.1.5 Message Type Supported

The SGD shall support all requirements in Section 8.2 Message Type Supported Query.

The SGD shall respond with Link Layer ACK if it receives Message Type 0x08 0x01.

The SGD may respond with Link Layer ACK to other message types it supports.

22.2.1.1.6 General Basic DR Requirements

22.2.1.1.7 Basic Application ACK

The SGD shall respond with Basic DR ACK if it receives a properly formatted message with the following Opcode1:

Shed, End Shed

22.2.1.1.8 Basic Application NAK

The SGD shall respond with Basic DR NAK to messages in the Basic DR set that it does not support and for any other reason given in the Basic DR NAK opcode2 "Reason". The SGD shall support responding with all Reason codes 0x00 - 0x05.

22.2.1.1.9 Shed

The SGD shall support the Basic DR Shed message.

22.2.1.1.10 End Shed

The SGD shall support the Basic DR End/Shed Normal to end all curtailment events and any message labeled Priority: High.
The SGD shall internally return to normal operation upon receiving this command.

22.2.1.1.11 Outside Comm Connection Status

The SGD shall support receiving this message.

22.3 SGD Certification Levels

22.3.1 Water Heaters

22.3.1.1 Level 2

Water Heaters compliant with Level 2 shall meet all Level 1 requirements.

	Data Link Messages (Message Type 0x08, 0x03):	Water Heater
		CTA-2045-B Requirements for Level 2
Section 8.1	Link ACK	Required
Section 8.1	Link NAK	Required
Table 9-2	Query Maximum Payload Length	Required
Table 9-2	Maximum Payload Length	Required (256 bytes)
Section 8.2	Message Type Supported	Required
	Basic DR Application (Message Type = 0x08, 0x01)	
Table 10-2	Basic Application ACK	Required
Table 10-2	Basic Application NAK	Required
Table 10-2	Shed	Required
Table 10-2	End Shed	Required
Table 10-2	Outside Comm Connection Status	Required
Table 10-2	Critical Peak Event	Required
Table 10-2	Grid Emergency	Required
Table 10-2	Customer Override	Required
Table 10-2	Operational State Query	Required
Table 10-2 & Section 10.2.4	State Query Response	Required
Table 10-2	Load Up	Required
	Intermediate DR Application (Message Type 0x08, 0x02):	
Section 11.1.1	Device Information Request	Required
Section 11.1.2	Get/Set UTC Time	Required
Section 11.3.1	Get Commodity Read	Required Get (UCM to SGD) only
Section 11.6	Advanced Load Up	Required

Section 11.7	Get/Set Efficiency Level	Get Required, Set Optional
Section 11.8.3	Set Price Stream	Required (64 pairs minimum, 24hr)
Section 11.5	Get/Set User Preference Level	Get Required, Set Optional

Table 22-2 Certification Level 2 Message Summary

The following sections outline the specific requirements for each required message.

22.3.1.1.1 Link ACK

The SGD shall respond with link ACK within the specified time limits when the UCM sends messages in accordance with requirements of Section 8.1 and:

For DC form SGDs in conjunction with Appendix A Link Layer Requirements

For AC form SGDs in conjunction with Appendix B Link Layer Requirements

22.3.1.1.2 Link NAK

The SGD shall respond with link NAK with the following NAK Error Codes supported:

For DC form SGDs 0x00 - 0x04 and 0x06

For AC form SGDs 0x00 - 0x06

22.3.1.1.3 Query Maximum Payload Length

The SGD shall send link ACK when receiving this message, which will trigger the response with Maximum Payload Length below.

22.3.1.1.4 Maximum Payload Length

If the SGD has received Query Maximum Payload Length, the SGD shall respond with at least code 0x07 (256 bytes payload).

22.3.1.1.5 Message Type Supported

The SGD shall support all requirements in Section 8.2

The SGD shall respond with Link Layer ACK if it receives Message Type 0x08 0x01.

The SGD shall respond with Link Layer ACK if it receives Message Type 0x08 0x02.

The SGD shall respond with Link Layer ACK if it receives Message Type 0x08 0x03.

The SGD may respond with Link Layer ACK to other message types it supports.

22.3.1.1.6 General Basic DR Requirements

22.3.1.1.7 Basic Application ACK

The SGD shall respond with Basic DR ACK if it receives a properly formatted message with the following Opcode1:

Shed, End Shed, Critical Peak Event, Grid Emergency, Load Up

22.3.1.1.8 Basic Application NAK

The SGD shall respond with Basic DR NAK to messages in the Basic DR set that it does not support and for any other reason given in the Basic DR NAK opcode2 "Reason". The SGD shall support responding with all Reason codes 0x00 - 0x05.

22.3.1.1.9 Shed

The SGD shall support receiving this message.

See section 22.2.1.1.1 Title 24 JA 13 Functions.

22.3.1.1.10 End Shed

The SGD shall support the Basic DR End/Shed Normal to end all curtailment events and any message labeled Priority: High.
The SGD controls shall return to normal operation upon receiving this command.

22.3.1.1.11 Outside Comm Connection Status

The SGD shall support receiving this message.

22.3.1.1.12 Critical Peak Event

The SGD shall support receiving this message.

See section 22.2.1.1.1 Title 24 JA 13 Functions.

22.3.1.1.13 Grid Emergency

The SGD shall support receiving this message.

See section 22.2.1.1.1 Title 24 JA 13 Functions.

22.3.1.1.14 Customer Override

The SGD shall be capable of sending a Customer Override message to the UCM.

The SGD shall be capable of sending the Override Operational State codes in Section 10.2.4 and **Table 10-3** – Operating State Codes.

22.3.1.1.15 Operational State Query

The SGD shall receive this message, and send Link ACK. This shall be followed by the State Query Response, according to the specified timings.

22.3.1.1.16 Operational State Query Response

The SGD shall be capable of responding with all codes specified in section 10.2.4 and **Table 10-3 – Operating State Codes**, except: Variable Following, Not Following.

22.3.1.1.17 Load Up

The SGD shall use the most efficient mode of operation to perform the Load Up, unless user hot water needs deem a change in mode.

See section 22.2.1.1.1 Title 24 JA 13 Functions.

22.3.1.1.18 General Intermediate DR Requirements

22.3.1.1.19 Device Information Request

The SGD shall support and send all of the following fields in the GetInformation() - Reply:

CTA-2045 Version – ASCII* - shall be set to 0x42, 0x00 for this revision 'B' of the standard.

Vendor ID - shall be a valid ID, obtained from the certification program administrator.

Device Type - shall be accurately set according to the SGD Device Types column of the table in section 11.1.1.2

Valid Device Types are:

0x0001	Water Heater - Gas
0x0002	Water Heater - Electric
0x0003	Water Heater – Heat Pump
0x001B	Water Heater – Heat Pump Variable Capacity/Speed
0x001C	Water Heater – Phase Change Material
0x8000 – 0xFFFF	Manufacturer Defined Device Types - Only if the device type description and capabilities are made available by the SGD manufacturer to properly indicate the type is a Water Heater

Device Revision - shall be provided and must change any time functionality of a given Model Number changes

Capability Bitmap - must have this field and support the following bits:

The SGD shall have bit 7 set to 1 to indicate Price Stream is supported

The SGD shall have bit 8 set to 1 to indicate Get SGD Efficiency Level is supported

Advanced Load Up Capability Bitmap support

The SGD shall support reading bit 6 (Advanced Load Up support) by the UCM

The SGD shall only internally set the bit to 1 (Advanced Load Up enabled) after safety measures like a mixing valve are in place, and all necessary liability issues have been resolved.

The resolution of the liability issues is outside the scope of CTA-2045, however, the SGD shall have a way to set the bit to 1 and support enabling Advanced Load Up support in the field during or after installation:

The SGD may use the CTA-2045 SetCapabilityBit message

The SGD may use some other method to enable Advanced Load Up, which then still allows the UCM to send the Advanced Load Up message successfully using the CTA-2045 port

Model Number – ASCII - Shall have, allows determining different functionalities and manufacturer specific code mappings in combination with Vendor ID, Device Revision, Device Type

For determination of supported feature levels and sometimes for workarounds for older firmware versions, the SGD shall support either:

Firmware Year – 20YY

and Firmware Month

and Firmware Day

OR

Firmware Major

Firmware Minor

22.3.1.1.20 Get/Set UTC Time

The SGD shall support receiving the Set UTC Time message from the UCM. Note: UTC time includes leap seconds and the UCM shall provide the correct UTC value with leap seconds "built in" to the field.

The SGD shall support responding with its current internal time value using the Get UTC Time reply after receiving the Get UTC Time Request.

22.3.1.1.21 Get Commodity Read (UCM->SGD only)

The SGD shall be able to respond with Get CommodityRead Reply when receiving Get CommodityRead Request.

The SGD shall support estimated values but may support measured values as defined for Commodity Code "MSBit".

The SGD shall send the following Commodity Codes in each Get CommodityRead Reply:

0 Electricity Consumed both instantaneous W & and cumulative W-hr

6 Total Energy Storage/Take Capacity Cumulative field / W-hr only (Basic Dr Load Up)

7 Present Energy Storage/Take Capacity Cumulative field / W-hr only (Basic Dr Load Up)

Only when the SGD has Advance Load Up enabled (see section 22.3.1.1.19 Advanced Load Up Capability Bitmap support), the SGD shall send the following Commodity Codes in each Get CommodityRead Reply, in addition to the above codes:

10 Advanced Load Up Total Energy Storage/Take Capacity in Cumulative field / W-hr only

11 Advanced Load Up Present Energy Storage/Take Capacity in Cumulative field / W-hr only

22.3.1.1.22 Advanced Load Up

See section 22.2.1.1.1 Title 24 JA 13 Functions.

The SGD shall support receiving the SetAdvancedLoadUp message

The SGD shall support all requirements of section 20.3.1.1.19 **Advanced Load Up Capability Bitmap support.**

The SGD shall respond with Int DR Success and begin Advanced Load Up mode when the conditions of **Advanced Load Up Capability Bitmap support** are met and Advanced Load Up is enabled and the SetAdvancedLoadUp message is sent.

22.3.1.1.23 Get/Set Efficiency Level

The SGD shall support the GetEfficiencyLevel message with any mapping of Efficiency Level of 1-9.

If the SGD has an "off" mode where it no longer heats water, but still supports communication, it shall support responding with Efficiency Level 0 when in that mode.

If the SGD has an "vacation" mode, it shall support responding with Efficiency Level 10 when in that mode.

If the SGD supports SetEfficiencyLevel (optional) then it shall not remain permanently in any low efficiency mode for longer than 1 week (72 hours is recommended)

22.3.1.1.24 Set Price Stream

The SGD shall support a minimum 64 time+price pairs for the SetPriceStream message

The SGD shall be able to accept a price stream spanning at least 24 hours

The SGD shall support receiving the SetPriceStream message according to section 11.8.3.3 in order to know when the UCM has lost access to accurate pricing.

The SGD may evaluate this information and use it in any way, though this message implies that future forecast prices could change without the SGD being informed by the UCM

22.3.1.1.25 Get/Set User Preference Level

The SGD shall support the Get User Preference Level message with Preference type = 1 (Energy Reduction).

The SGD shall support a range of Preference Level field from 0 = Low to 10 = High.

22.4 UCM Certification Levels

UCMs may support several levels if they support all the requirements of each level.

22.4.1 All UCMs

22.4.1.1 Level 2

UCMs compliant with Level 2 shall meet all Level 1 requirements.

	Data Link Messages (Message Type 0x08, 0x03):	**UCM**
		CTA-2045-B Requirements for Level 2
Section 8.1	Link ACK	Required
Section 8.1	Link NAK	Required
Table 9-2	Query Maximum Payload Length	Required
Table 9-2	Maximum Payload Length	Required (256 bytes)
Section 8.2	Message Type Supported	Required
	Basic DR Application (Message Type = 0x08, 0x01)	
Table 10-2	Basic Application ACK	Required
Table 10-2	Basic Application NAK	Required
Table 10-2	Shed	Required
Table 10-2	End Shed	Required
Table 10-2	Outside Comm Connection Status	Required
Table 10-2	Critical Peak Event	Required
Table 10-2	Grid Emergency	Required
Table 10-2	Customer Override	Required

Table 10-2	Operational State Query	Required
Table 10-2& Section 10.2.4	State Query Response	Required
Table 10-2	Load Up	Required
	Intermediate DR Application (Message Type 0x08, 0x02):	
Section 11.1.1	Device Information Request	Required
Section 11.1.2	Get/Set UTC Time	Required
Section 11.3.1	Get Commodity Read	Required Get (UCM to SGD) only
Section 11.6	Advanced Load Up	Required
Section 11.7	Get/Set Efficiency Level	Get Required, Set Optional
Section 11.8.3	Set Price Stream	Required (64 pairs minimum, 24hr)
Section 11.5	Get/Set User Preference Level	Get Required, Set Optional

Table 22-3 UCM Certification Level 2 Message Summary

The following sections outline the specific requirements for each required message.

22.4.1.1.1 Link ACK

The UCM shall respond with link ACK within the specified time limits when the SGD sends messages in accordance with requirements of Section 8.1 and:

For DC form UCMs in conjunction with Appendix A Link Layer Requirements

For AC form UCMs in conjunction with Appendix B Link Layer Requirements

22.4.1.1.2 Link NAK

The UCM shall respond with link NAK with the following NAK Error Codes supported:

For DC form UCMs 0x00 - 0x04 and 0x06

For AC form UCMs 0x00 - 0x06

22.4.1.1.3 Query Maximum Payload Length

The UCM shall send link ACK when receiving this message, which will trigger the response with Maximum Payload Length below.

22.4.1.1.4 Maximum Payload Length

If the UCM has received Query Maximum Payload Length, the UCM shall respond with at least code 0x07 (256 bytes payload).

22.4.1.1.5 Message Type Supported

The UCM shall support all requirements in Section 8.2.

The UCM shall respond with Link Layer ACK if it receives Message Type 0x08 0x01.

The UCM shall respond with Link Layer ACK if it receives Message Type 0x08 0x02.

The UCM shall respond with Link Layer ACK if it receives Message Type 0x08 0x03.

The UCM may respond with Link Layer ACK to other message types it supports.

22.4.1.1.6 General Basic DR Requirements

22.4.1.1.7 Basic Application ACK

The UCM shall respond with Basic DR ACK if it receives a properly formatted message with the following Opcode1:

Customer Override

22.4.1.1.8 Basic Application NAK

The UCM shall respond with Basic DR NAK to messages in the Basic DR set that it does not support and for any other reason given in the Basic DR NAK opcode2 "Reason". The UCM shall support responding with all Reason codes 0x00 - 0x05.

22.4.1.1.9 Shed

The UCM shall support the Basic DR Shed message

22.4.1.1.10 End Shed

The UCM shall support the sending the Basic DR End/Shed Normal to end all curtailment events and any message labeled Priority: High in this document.

22.4.1.1.11 Outside Comm Connection Status

The UCM shall support sending this message.

22.4.1.1.12 Critical Peak Event

The UCM shall support sending this message.

22.4.1.1.13 Grid Emergency

The UCM shall support sending this message.

22.4.1.1.14 Customer Override

The UCM shall support receiving a Customer Override message at any time

22.4.1.1.15 Operational State Query

The UCM shall support sending this message.

22.4.1.1.16 Operational State Query Response

The UCM shall be capable of receiving this message with all codes specified in section 10.2.4 and **Table 10-3** – Operating State Codes, except: Variable Following, Not Following.

22.4.1.1.17 Load Up

The UCM shall support sending this message.

22.4.1.1.18 General Intermediate DR Requirements

22.4.1.1.19 Device Information Request

The UCM shall support sending the GetInformation Request.

The UCM shall send the GetInformation Request at least upon each power up from being off.

The UCM may send the GetInformation Request at any time to determine the current support of features in the SGD.

The UCM shall support reading all of the fields in the GetInformation() - Reply sent back by the SGD.

The UCM shall check the Capability Bitmap of GetInformation() - Reply and further:

If the Capability Bitmap has bit 7 set to 0 to indicate Price Stream is not supported, the UCM shall not send any messages in section 11.8

If the Capability Bitmap has bit 8 set to 0 to indicate Get SGD Efficiency Level is not supported, the UCM shall not send any messages in section 11.7

Advanced Load Up Capability Bitmap support

If the Capability Bitmap has bit 6 set to 0 to indicate Advanced Load Up is not supported, the UCM shall not send any messages in section 11.6

22.4.1.1.20 Get/Set UTC Time

The UCM shall support sending the Set UTC Time message with a valid UTC time that includes leap seconds

The UCM shall support sending the Get UTC Time Request and receiving the Get UTC Time Reply from the SGD to confirm clock synchronization

The UCM shall support responding to the Get UTC Time Request and sending the Get UTC Time Reply to the SGD

The UCM shall send the Set UTC Time message successfully at least once upon powering up

The UCM shall send the Set UTC Time message successfully at least once every 24 hours

22.4.1.1.21 Get Commodity Read (UCM->SGD only)

The UCM shall support sending Get CommodityRead Request message

The UCM shall support the Get CommodityRead Reply from the SGD containing any (or all) of the following Commodity Codes in any order and all in the same Reply message:

0 Electricity Consumed both instantaneous W & and cumulative W-hr

6 Total Energy Storage/Take Capacity Cumulative field / W-hr only (Basic Dr Load Up)

7 Present Energy Storage/Take Capacity Cumulative field / W-hr only (Basic Dr Load Up)

10 Advanced Load Up Total Energy Storage/Take Capacity in Cumulative field / W-hr only

11 Advanced Load Up Present Energy Storage/Take Capacity in Cumulative field / W-hr only

22.4.1.1.22 Advanced Load Up

The UCM shall support sending the SetAdvancedLoadUp message

The UCM shall only send the SetAdvancedLoadUp message when the conditions of section 22.4.1.1.19 **Advanced Load Up Capability Bitmap support** are met.

See section 22.2.1.1.1 Title 24 JA 13 Functions.

22.4.1.1.23 Get/Set Efficiency Level

The UCM shall support sending the GetEfficiencyLevel Request message and receiving and Efficiency Level of 1-9 in the GetEfficiencyLevel Reply message from the SGD.

22.4.1.1.24 Set Price Stream

The UCM shall support sending a minimum 64 time+price pairs for the SetPriceStream message

The UCM shall be able to send a price stream spanning at least 24 hours

The UCM shall support sending the SetPriceStream message according to section 11.8.3.3 to indicated loss of accurate pricing information to the SGD.

22.4.1.1.25 Get/Set User Preference Level

The UCM shall support the Get User Preference Level message with Preference type = 1 (Energy Reduction).

The UCM shall support a range of Preference Level field from 0 = Low to 10 = High.

Consumer Technology Association Document Improvement Proposal

If in the review or use of this document a potential change is made evident for safety, health or technical reasons, please email your reason/rationale for the recommended change to standards@CTA.tech.

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