ELECTRIC POWER RESEARCH INSTITUTE

Introduction to the ANSI/CEA-2045 Standard

3002004020

Introduction to the ANSI/CEA-2045 Standard

3002004020

Technical Update, May 2014

EPRI Project Manager

C. Thomas

ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1338 ▪ PO Box 10412, Palo Alto, California 94303-0813 ▪ USA
800.313.3774 ▪ 650.855.2121 ▪ askepri@epri.com ▪ www.epri.com

THE PRIMARY CONTRIBUTOR TO THIS REPORT WAS EPRI, WITH SECONDARY CONTRIBUTIONS PROVIDED BY WORKSHOP PARTICIPANTS.

This is an EPRI Technical Update report. A Technical Update report is intended as an informal report of continuing research, a meeting, or a topical study. It is not a final EPRI technical report.

NOTE

For further information about EPRI, call the EPRI Customer Assistance Center at 800.313.3774 or e-mail askepri@epri.com.

ACKNOWLEDGMENTS

The Electric Power Research Institute (EPRI) prepared this report:

EPRI
942 Corridor Park Boulevard
Knoxville, TN 37932

Principle Investigators
B. Seal

This report describes research sponsored by EPRI.

ABSTRACT

The Consumer Electronics Association (CEA) is an American National Standards Institute (ANSI) standards-development organization. Within the CEA R07 Home Networks Committee, Subcommittee 8 (R7.8) is titled "Modular Communication Interface for Energy Management." This subcommittee was created in 2012, following a period in which the National Institute of Standards and Technology (NIST) Home-to-Grid Domain Expert Working Group (H2G DEWG) had developed a concept design of a modular communication interface. The NIST design incorporated elements from prior EPRI research, the USNAP Alliance, and other modular interfaces from around the world.

In February 2013, the CEA released the ANSI/CEA-2045 standard. This standard defines a "port" or "plug" interface that could be incorporated into off-the-shelf appliances during manufacture in order to make appliances ready to receive and respond to utility demand-response signals. ANSI/CEA-2045 standard includes the mechanical, electrical, and logical features that are required to enable communication modules of any type to be plugged into the appliance.

This report provides a general overview of this standard. It explains the background of its development, the technical characteristics of the interface, and the capabilities that it supports. The present status is described, including continued developments of the standard, vendor engagement, field testing, and applications beyond load management.

Keywords
Demand Response
Load Management
Modular
Communication Interface
CEA-2045

CONTENTS

1
WHAT IS THE ANSI/CEA-2045 STANDARD?

The ANSI/CEA-2045 standard (hereafter referred to as the *CEA-2045 standard* for brevity) is a standard developed by the Consumer Electronics Association (CEA) for demand-response (DR) applications of electric utilities. As illustrated in Figure 1-1, CEA-2045 defines a modular communication interface, or port, into which communication modules of any kind can be plugged.

Figure 1-1
Concept of the CEA-2045 modular communication interface

The CEA-2045 does not define the technology of the communication module or how it communicates to the outside world, but only the interface between the appliance and the communication module. It defines the mechanical, electrical, and logical aspects of this interface with the vision that:

1. A maker of an appliance could produce one model with an CEA-2045 communication interface that would be compatible with *any* communication system, even those not yet invented.
2. A provider of a communication system could make a module compatible both with their system and the CEA-2045 standard.
3. When plugged into one another, information can be shared between the communication network and the end device.

In the language of the CEA-2045 standard, end devices are referred to as *Smart Grid Devices* (SGDs), and communication modules are referred to as *Universal Communication Modules*

(UCMs). The CEA-2045 port is intended for use on residential and commercial electrical products.

As described later in this document, the CEA-2045 interface could be used to exchange any kind of information, but it was initially designed specifically to support demand-response applications, including regular load control/curtailment, critical peak, price-based programs, and ancillary services such as up/down regulation.

The Environmental Protection Agency, in a continuation of the Energy Star program, has been developing “connected criteria” for a number of appliance types. These criteria describe a range of requirements, including the architectures or ways in which connectivity can be established, the degree to which open standards are recommended or required, and the types of reporting and control functions that must be supported.

2
WHY WAS CEA-2045 DEVELOPED?

Many utility projects and pilots have been conducted involving the concept of demand-responsive appliances, which requires communicating intelligently with an appliance instead of simply cutting off its power. These projects have been successful in terms of demonstrating the benefits of intelligent responses but have not translated into mainstream retail availability due to a number of factors. The CEA-2045 standard was developed to address these issues.

Minimizing Upfront Product Cost

The vision of CEA-2045 is that products that are purchased and installed every day have demand-responsive capabilities. The existence of a high-end model product that few would buy does not satisfy the intent of the standard. In order to be practical for mainstream retail, the incremental upfront cost must be very low. A modular interface defers the cost of communication electronics and associated power supplies until the time of actual DR program enrollment. At present, only a small percentage of target products are ever enrolled in any energy-related program, making it a necessity to minimize or eliminate up front costs.

Allowing for Diversity of Communication Technologies

A wide range of communication technologies are in use for DR purposes throughout North America and worldwide. The diversity is not just a matter of lack of agreement but is rooted in fundamental differences in terrain, customer density, and availability of existing communication infrastructure. Differing regulatory views have led to a wide range of utility-owned systems, and potential third-party aggregators—such as cable operators, security companies, and providers of home automation systems —have deployed a number of communication systems that they would like to utilize for DR purposes.

Differences also exist in the protocols being used over these communication systems. Until recently, there were no standards for demand response, and many companies and organizations, such as the KNX and Z-Wave Alliances, built out systems that used proprietary or licensed protocols. More recently, application-layer protocols such as OpenADR, EchoNet Lite, and Smart Energy Profile 1.0 and 2.0 have been developed. These differences have made it impossible for manufacturers of end-use devices to produce products that can be mass-produced, sold through mainstream retail channels, and relocated with people when they move and yet are compatible with DR systems everywhere.

Accommodating Rapid Evolution of Communication Technologies

Appliances have long service lives, sometimes as much as 20 to 30 years. This is particularly true for the big-load types that are involved in DR programs such as HVAC systems, water heaters, and electric vehicle chargers. In contrast, communication technologies are evolving rapidly. Improvements in highly integrated mixed-signal semiconductor technology are driving constant changes in communication systems. This is primarily driven by the cellular and computer networking industries, where the devices involved (such as cellular telephones and laptops) are short-lived or even disposable. Whereas a laptop manufacturer may have no hesitation building-in a certain version of Wi-Fi, an appliance maker may be concerned today with communication connectivity in the year 2044. The CEA-2045 modular communication interface is intended to address these challenges.

3
HOW DOES CEA-2045 WORK?

The CEA-2045 standard is described in layers, including, mechanical, electrical, and logical aspects as presented in the following sections.

Simple yet Extensible

The design of the interface was produced by a large number of end-device manufacturers and providers of communication technologies working together over several years. In both of these stakeholder groups, there were providers who required a very simple interface. This included end-device manufacturers whose products were simple in nature, perhaps having only *on* and *off* states of operation and operated by microprocessors with very limited processing capability. It also included providers of communication systems whose networks by nature could only convey a few bits or bytes of information. These stakeholders required an interface definition that could provide maximum capability with a minimum level of complexity. Many utility stakeholders also advocated simplicity, having failed to achieve interoperability of products with more complicated protocols.

At the other extreme were makers of advanced products and high-performance communication systems. This group represented the Internet-of-Things (IoT), including the idea that an end-use device might provide a browser-link interface through which a customer could use the Internet. From a DR perspective, these products and systems might be those that provide a wider range of responses (such as variable up/down regulation) and fast two-way communication for state and response monitoring.

Each of these points of view represents valid needs, and the resulting CEA-2045 specification seeks to address both. Upon power-up, UCMs and SGDs assume that the other is limited to the most basic of functionality. At this level, each is required to support a small set of interactions that are sufficient to enable basic load management. From there, either can negotiate for more, asking the other whether messages can be longer, bit rates faster, or protocols more advanced. This includes an option for transparent pass-through of Internet Protocol (IP).

Physical Form Factors

CEA-2045 defines two physical form factors. The messaging/protocol is the same for both, but they differ mechanically and electrically. The smaller of the two is referred-to as the "DC Form Factor." This defines a communication module that is roughly 1.9" by 1.9" by 0.5". The module slides in and is retained by friction. The electrical connector is a micro-SATA, which involves a card-edge connector on the communication module and a mating socket inside the SGD. The power for the communication module is provided by the SGD at 3.3 V_{DC}. The communication interface is a synchronous SPI *serial peripheral interface*, always clocked by the SGD.

The other form factor is referred to as the "AC Form Factor." This defines a communication module that cannot exceed 2.875" by 4.8" by 1.625". The communication modules are retained by two thumbscrews, which are near the electrical connector. The electrical connector is a standard pin-and-socket plug with spacing and clearances sufficient for safety and the voltages involved. Power for the UCM is provided by the SGD at AC line voltage. UCMs must accommodate from 120 to 240 V_{AC}. The communication interface is RS-485, operating differentially in the range of 3 to 5 V.

The DC form factor is a necessity for small end devices, such as thermostats and in-home displays, where size prohibits the larger form factor and only low-voltage DC exists.

The AC form factor is a necessity for communication technologies that require higher power, larger components (such as antennas), or direct line access for PLC *power-line carrier* networks. It may also be necessary for large end-use devices that have longer wires and electrically noisy environments, where the RS-485 interface is a necessity.

It is possible to have an adapter device that allows a DC module to plug into an AC socket.

Link Layer

The link layer establishes the basic message structure, message integrity, and a set of services that are used to negotiate link performance. The basic message structure is presented in Table 3-1.

Table 3-1
Typical CEA-2045 protocol data unit

Message Type	Reserved Must Be "0x0"	Payload Length	Payload	CRC
2 Bytes	3 Bits	13 Bits	Variable	2 Bytes

This structure adds 6 bytes of overhead to the payload. These overhead bytes allow the identification of the message type and simple message integrity checking through a provided message length and cyclic redundancy check. The specification includes a link-layer acknowledge (ACK) and rejection (NAK) that allow the sending device to know whether each data transfer was bit- and byte-wise successful or not. Actual support of the exchanged message is a function of the application layer and is handled separately. Any link-layer NAK includes a "reason" code that provides the sending device with insight into what problem occurred with the data transfer.

The link-layer includes a set of messages for managing the link. These include:

- Negotiation of allowable payload size (the default/mandatory level is 2 bytes)
- Negotiation of the bit rate for the AC/asynchronous interface (the default/mandatory speed is 19.2 kbps)
- Negotiation of allowed power consumption for the DC form factor

Network Layer

The payload can, optionally, include network, transport, and/or other layers as defined by the OSI stack. CEA-2045 includes a defined "message type" that identifies the use of IP messages.

Application Layer

The application layer defines the functional messaging: status of the monitoring device, behavior of the managing device, or any number of other actions. At the application layer, CEA-2045 is designed to support the transparent pass-through of any relevant application layer protocol. It is in this regard that the goal of being “simple yet extensible” is addressed. Some protocols for the application layer for demand response are complex, and their security mechanisms are even more complex. For some end-use devices, this complexity is supportable, but for others, it is not. To address the more limited devices, the CEA-2045 standard defines a set of simple application layer messages that are only a few bytes in length.

CEA-2045 seeks to achieve interoperability of any end-use device, meaning that any UCM plugged into any SGD will work, at least to the level at which both are capable. This recognizes that some end-use devices will be very simplistic, supporting only an *on* and *off* state of operation and having only very limited computational and communication capabilities. It recognizes that other end-use devices might be very capable, including Internet browsing capabilities and having high performance capabilities. Likewise, it recognizes that communication systems vary. Some may be one-way in nature, others two-way. Some may support only a few bits per second, others megabits or gigabits per second.

For any UCM/SGD combination, the simpler of the two naturally dictates the level of capability of the complete system. The CEA-2045 standard allows for variable degrees of capability, mandating only that a few basic messages are supported—sufficient to enable basic demand responsiveness.

CEA-2045-Defined Simple Messages

“Basic” and “Intermediate” messages defined by the CEA-2045 standard are a simple set of messages that are intended to be supportable by all devices, even those with most limited capabilities. The basic messages are 2 bytes in length. Intermediate messages have a few more bytes and add capabilities that are not possible in 2 bytes.

The “shed” and “end shed” basic messages are mandatory for all devices in order to achieve interoperability. The simple messages defined in the CEA-2045 standard including examples of their use are shown in Table 3-2.

Table 3-2
Examples of CEA-2045-defined simple messages

Message Name	Description
Shed/End Shed	A curtailment message sent from the UCM to SGD. Upon the receipt of this command the SGD could reduce demand while minimizing customer discomfort.
End Shed / Run Normal	A message that informs the SGD that a curtailment event has ended.
Critical Peak	A curtailment message for use on critical peak days. The SGD may respond to more aggressively due to the infrequency of this type of event.
Grid Emergency	Reserved for use to avoid blackouts and during restoration activities.
Load-Up	Opposite of “shed”. Instructs SGD to use energy now, if practical without wasting energy.

Message Name	Description
Override	Message to indicate if/when the consumer has overridden an event response.
Price & Relative Price	For various rate-based programs.
Go to Power Level	-100 to +100% variable power level setting for variable devices.
Go to Duty Cycle	0 to 100% setting for the duty cycle.
Operational State Query/Status	Monitoring of the SGDs present operating mode and status.
Device Identification	Information such as device type, brand, and model. This information could originate from either the SGD or UCM.

Pass-Through

A number of application-layer protocols related to demand response exist, including OpenADR and Smart Energy Profile, each in multiple versions. In the event that the SGD and the UCM both support the same application-layer protocol, the application layer messages (sometimes including network and transport layers also) can pass transparently through the UCM into the end-use device. The up side of this approach is that the messaging is end-to-end with no mapping or translation, and the action of the UCM is simpler. The challenge of this approach is that end-use devices must support the passed-through protocol—including security, if any—in a consistent and interoperable way. In addition, in order to achieve broad market interoperability, the same application-layer protocol must be supported by all end-use devices.

4
WHAT APPLICATIONS DOES CEA-2045 SUPPORT?

CEA-2045 is intended as a general communication interface for energy management, with provisions made for other uses, as identified in the following sections.

Residential and Commercial Demand Response

The CEA-2045 messages and identified pass-through protocols support known DR use cases, including cases in which the control originates from the utility, grid/system operator, aggregator, distribution operator, or facility manager. The CEA-2045 standard is intended for use on both residential and commercial equipment.

Home/Building Automation

The CEA-2045 messages are applicable to home and building automation. Common capabilities—such as the discovery of the device type, status monitoring, and energy management—might apply to many types of end-use devices. Additional message sets are being created to extend the home-automation capabilities of the CEA-2045 interface on a device type-by-type basis. For example, a companion standard called *CEA-2045.3* is a thermostat-specific remote-management message set that supports the full range of thermostat control modes, states, and schedules. Similar message sets are anticipated for devices of many kinds.

Manufacturer-Specific Uses

The CEA-2045 standard reserves a large range of the message type space for manufacturer-specific uses. This means that the standard does not constrain a manufacturer or inhibit innovation. Manufacturers can privately define any range of messages—using any format that they prefer—and pass them through the CEA-2045 interface in a defined way.

This could be used, for example, during the manufacturing process to program or configure products on the assembly line, avoiding the need for some other connector or interface. Similarly, it could be used in the field by manufacturer service technicians to connect to products, diagnose their condition, and download updates.

Manufacturer-specific messages could also be shared with strategic partners. For example, an end-use device might perform a limited set of functions in a standard way and a number of additional innovative functions in a proprietary way. The innovative capabilities might be made accessible only when the end-use device is connected in networks that are business partners.

Industry-Group Uses

Any range of groups could work together to define message sets that they hold in common and yet choose not to expose the sets to those outside the group. For example, all the makers of one product type, or all the brands carried through one retailer, could work together to define an additional set of messages for competitive purposes.

From a certification perspective, these proprietary uses do not avoid the requirement to support at least a core set of functions in an open interoperable way. Consumer demand and natural market forces are expected to drive the degree to which proprietary versus open messages are used.

Solar Inverter Integration

The CEA-2045 interface is presently being extended for application on solar inverters. This allows a common communication module to be used for both demand response and the integration of distributed generation. For example, an AMI manufacturer could produce one UCM that is compatible with their system and use it for both.

The application-layer messaging for solar inverter integration may be, at least at the present time, different from what is used for load management. This is because inverter management involves reactive power and a number of curve-based and dynamic settings that are not typically involved in load management. Going forward, standards for application-layer protocols such as OpenADR may increasingly be capable of supporting both load and generation.

5
WHAT IS THE STATUS OF CEA-2045?

Release of the Standard

The Consumer Electronics Association released the CEA-2045 standard in February of 2013. The R07.08 working group continues to meet, managing editorial fixes, correcting bugs, and extending functionality with optional companion parts to the standard.

Certification and the USNAP Alliance

To be effective, any standard must have a certification and compliance test process. Standards, as paper documents, are not sufficient to achieve interoperability. The National Institute of Standards and Technology (NIST) Smart Grid Interoperability Panel (SGIP) describes this as an Interoperability Testing and Certification Authority (ITCA). The USNAP Alliance is an ITCA for the CEA-2045 standard.

The USNAP Alliance is funded by its membership. Ultimately, this would be made up of product manufacturers who are developing compliant products. Additional members are needed presently, including utilities, to accelerate the work of the Alliance, which is presently developing the test framework for certification. EPRI is coordinating with the USNAP Alliance and contributing a suite of tools that could become the basis of a certification test program.

Field Testing

A number of utilities are presently working together to assess the CEA-2045 standard in field environments. This requires manufacturers to invest significantly, producing field-able products that might require new plastic tooling, sheet-metal forms, and printed circuit boards.

In the field environments, these products will be connected to a wide range of existing and planned DR programs. These programs involve different use cases and different communication technologies, yet a common design of the end-use device must be compatible with all programs.

The interoperability of UCMs and SGDs and the self-installability of modules by the consumer (avoiding a truck roll/electrician) are two of the key propositions of the CEA-2045 interface and are the key assessment focus of the EPRI collaborative field demonstration.

Internationalization of the CEA-2045 Standard

In October of 2013, the International Organization for Standardization (ISO) JTC1 (the group responsible for information technology) voted to start the process of making the CEA-2045 an international standard. This required a “yes” vote from a majority of countries and an “I will help work on this” vote from at least five countries. This is the beginning of the process, not the end, and will take some time to complete. International standardization and collaboration is a positive thing as it enhances economies of scale and this ISO action is viewed as a good step toward that end.

Vendor Adoption

The CEA-2045 standard provides local, open access to devices. Such openness is being welcomed by some makers of end-use devices and avoided by others as they develop strategies regarding their offerings of products and systems. Fortunately, the makers of key device types for demand response (such as water heaters, thermostats, and EVSE *electric vehicle service equipment*, etc.) tend to be open to the idea of interoperability and support the CEA-2045 standard.

In general, vendor implementation of the CEA-2045 standard is just beginning. With an interface standard, there is a fundamental challenge in market development because SGD makers want to wait to see many UCMs available, and UCM makers want to wait to see many SGDs available. Breaking that cycle of waiting will likely depend on electric utilities, including the messaging and guidance that they provide to manufacturers and the programs that they develop that would take advantage of such an interface if it existed.

6 EPRI PERSPECTIVE

The CEA-2045 is one of several standards that relate to demand response that have been created in the past few years. Prior to these developments, there was no option other than to deploy proprietary systems. These systems often included a degree of undesirable vendor lock-in that reduced competition and value. Now these standards are making it possible, for the first time, to deploy open systems. EPRI views these as positive developments with regard to serving the interests of consumers, improving cost effectiveness and life-cycle manageability, and improving the general capabilities of DR systems.

The CEA-2045 is a modular communication interface. Modularity generally costs something, and it would, in theory, be less expensive to fully integrate communications into end devices. However, the application of modular interfaces at strategically selected locations is a critical part of large system design and has been successful in many cases in breaking down large complicated problems into a set of smaller, more manageable tasks. Modular interfaces provide a point of decoupling, allowing the entities on each side of the interface to evolve independently. Strategic locations for modular interfaces generally include those points where the asset ownership and management responsibility is passing from one entity to another. In this sense, a modular interface on end-use devices is sensible, allowing the end-use devices and the utility (and third-party) communication systems to be managed and updated as business needs dictate. The rapid pace of evolution of communication technologies, when contrasted with the long service life of large-load devices, necessitates flexible architectures, such as might be achieved through a modular interface.

Efforts to coordinate internationally and working with the ISO in this regard are appropriate. The economies of scale that might be achieved and the increase in globally present businesses serving the current market of end-use loads will benefit from such activity, if completed successfully. This will accelerate product availability for consumers and increase choices and competition.

The great challenge in achieving DR-ready devices is not related to a modular approach or any other design particulars. The challenge is incorporating DR-ready capabilities, on everyday mass-produced products, in an environment where the average consumer is not looking for those features and is not willing to pay for them. The vision of modular interface standards, like the CEA-2045, is that products of all types can be inherently DR-ready and that the associated opportunity for demand response will begin to accumulate in consumer homes and businesses, independent of whether or not consumers are looking for it.

To achieve this, methods must exist by which manufacturers can recover their investments in making products DR-ready up front. There are several ways in which this could be handled, each with certain benefits and certain limitations. EPRI is presently facilitating an economics study group that is assessing these options.

Export Control Restrictions

Access to and use of EPRI Intellectual Property is granted with the specific understanding and requirement that responsibility for ensuring full compliance with all applicable U.S. and foreign export laws and regulations is being undertaken by you and your company. This includes an obligation to ensure that any individual receiving access hereunder who is not a U.S. citizen or permanent U.S. resident is permitted access under applicable U.S. and foreign export laws and regulations. In the event you are uncertain whether you or your company may lawfully obtain access to this EPRI Intellectual Property, you acknowledge that it is your obligation to consult with your company's legal counsel to determine whether this access is lawful. Although EPRI may make available on a case-by-case basis an informal assessment of the applicable U.S. export classification for specific EPRI Intellectual Property, you and your company acknowledge that this assessment is solely for informational purposes and not for reliance purposes. You and your company acknowledge that it is still the obligation of you and your company to make your own assessment of the applicable U.S. export classification and ensure compliance accordingly. You and your company understand and acknowledge your obligations to make a prompt report to EPRI and the appropriate authorities regarding any access to or use of EPRI Intellectual Property hereunder that may be in violation of applicable U.S. or foreign export laws or regulations.

The Electric Power Research Institute, Inc. (EPRI, www.epri.com) conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, affordability, health, safety and the environment. EPRI also provides technology, policy and economic analyses to drive long-range research and development planning, and supports research in emerging technologies. EPRI's members represent approximately 90 percent of the electricity generated and delivered in the United States, and international participation extends to more than 30 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass.

Together…Shaping the Future of Electricity

3002004020

Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com