

Joint Appendix JA5

Appendix JA5 - Technical Specifications For Upgradeable Setback Thermostats

JA5.1 Introduction

This document provides a high level technical specification for an upgradeable setback thermostat (UST). All USTs shall comply with the specifications set forth in this document or specification approved by the Executive Director. This specification focuses on four interfaces that the CEC has determined must be supported by all USTs:

1. HVAC System Interface
2. Communications Interface
3. Expansion Interface
4. Human-Machine Interface

Sections within this document address each interface in terms of its hardware and software characteristics. In general and unless otherwise specified, this specification is compatible with NEMA Standards Publication DC 3-2008 – “Residential Controls – Electrical Wall-Mounted Thermostats”.

The Communications Interface is defined as a set of logical services that may be performed over a physical network interface connected to either the Expansion Interface, or in some cases an internal communications device.

The communications interface is designed to permit a variety of intended uses for USTs that have been defined in other publications (see references in Annex D). Those uses included remote energy management services to the extent that UST users voluntarily enable such services. To the extent possible, this document strives to be upward compatible with related efforts underway (e.g. NIST, the Smart Grid Interoperability Panel, Open Smart Grid, etc.). Upward compatibility will be facilitated by not specifying any capability or feature that can be foreseen to contradict or impede the clear direction of those related efforts.

UST Vendors should use Title 24 code language, this document, and the documents they reference to make early design decisions on physical design (e.g. mold plastic to support connectors), processing power, code space, working memory, and code licensing. These documents provide enough information to make these decisions. The following elements are addressed in this document and are considered the key requirements that gate early design and decision making:

- Support for the Basic HVAC terminal interface specification
- Support for an expansion port that will allow for the installation of a removable module to enable communications with the thermostat

The following sections describe these and other elements of the specification in more detail.

JA5.1.1 Required Functional Resources

The following UST functional resources are required by Section 122(c) of the Standards:

a) An Expansion/Communication Port

This port is available to be used by a module supporting one-way or two-way communications supporting standards based communication protocols, including but not limited to Z-wave, Zigbee, WiFi, Radio Data Broadcasting System (RDBS,)/ Radio Data System (RDS), and Bluetooth. Refer to Section 3 for more information.

The module shall also enable standards based messaging protocols (Smart Energy Profile (SEP), OpenADR and/or others defined in the Smart Grid Interoperability Panel (SGIP) Catalog of Standards (CoS)).

When the Expansion/Communication port is unpopulated, the thermostat is referred to herein as Non-Upgraded. Section 112(c) refers to this mode as a Programmable Setback Thermostat. When the Expansion/Communication port is populated with a module that provides communications, it is referred to as Upgraded. Section 112(c) refers to this as a Communicating Setback Thermostat.

b) An Display Facility that shall be used to display the following:

The current communications status, indicating whether status is normal (ie connective, active) or abnormal (ie disconnected or inactive)(always displayed).

The type of event in progress: Demand Response Period, price event, or no event (always displayed).

Thermostat Maintenance-related information: Icons and/or error codes.

The currently sensed temperature (always displayed)

Current Set Point

One or more setting mechanism(s) that allow a customer to change the following thermostat settings at any time:

A temperature setpoint and associated starting time used during normal operation.

The UST shall provide a separate pair of parameters for at least four operating periods that collectively govern thermostat operation during the 24-hour day.

Temperature offsets that, unless overridden by users or modified by an energy management system or service, may be triggered by price signals or demand response signals:

The UST shall provide one offset for price signals and one offset for demand response signals. The offset may be common for both types of events.

The UST shall be shipped with a default value of -4oF when operating in the heating mode.

The UST shall be shipped with a default value of +4oF when operating in the cooling mode.

A clock mechanism that allows the UST to execute temperature setpoints scheduled by the customer.

JA5.1.2 Required Functional Behavior

The following describes how the UST needs to behave and use the functional resources specified above to comply with Load Management Standards requirements.

a) Clock Operation

The clock mechanism enables the UST to execute temperature setpoints scheduled by the customer. It also supports other timing functions such as start-time, end-time and duration for time coordination of Demand Response Periods and price signal response.

Accuracy to a precision of one minute is acceptable for this operating environment and the applications being considered.

The clock in an Upgraded UST may be set or resynchronized by three means: (1) through system communications messages sent by the customer's selected demand response event provider (2) by a customer-authorized energy management system or service, and (3) by the customer, using the UST's human interface. Such action by any source will override a prior setting, regardless of which source set it. In practice they may override each other, an approach that serves the needs of the system and the customer in a balanced way. One possible system update time could be 2 AM, as that is frequently the official time used for changes to and from daylight-savings time.

A DEMAND RESPONSE SIGNAL may also include an update to the UST clock.

The clock in a Non-Upgraded UST may be set by the customer.

b) Normal Operation

Normal operation of an Upgraded or a Non-Upgraded UST is defined to be the UST's prevailing mode of operation as determined by the customer's prior settings and use of features¹ provided by the UST vendor's design or the mode of operation of the energy management system, if any, that a customer has elected to connect to the Upgraded UST. Aspects of normal operation of an Upgraded UST may be modified or interrupted in response to customer subscribed price signals or Demand Response Periods are in progress, but only to the extent specified by customers or their representatives.

Customers shall always have the right to change UST settings or use other features of a UST vendor's design during an event. Those changes may alter what is considered to be the prevailing mode of operation when an Demand Response Period is terminated and the UST returns to normal operation.

Unless a customer has elected to connect the UST to an energy management system or service that provides for alternate strategies, the UST shall, whether Upgraded or Non-Upgraded, provide a mode of operation whereby it controls temperature by following the scheduled temperature setpoints.

c) DEMAND RESPONSIVE CONTROL

Upon receiving a price signal or a Demand Response Signal, Upgraded USTs shall have the ability to adjust the currently applicable temperature setpoint by the number of degrees indicated in the temperature offset (heating or cooling, as appropriate). Unless a customer shall (i) have elected to connect the Upgraded UST to an energy management system or service that provides for alternate strategies, or (ii) have selected a different default response or no response, Upgraded USTs shall default to price event offsets of +4°F for cooling and -4°F for heating when a price signal triggers a response or a Demand Response Signal is received. Occupants or their representative shall be able to change the current and default offsets and thermostat settings at any time. The UST shall also have the capability to allow occupants to define setpoints for cooling and heating in response to DEMAND RESPONSE SIGNALS and pricing signals as an alternative to temperature-offsetting response.

Non-Upgraded USTs need not respond to price events.

Override: Upgraded USTs shall allow a customer to alter or eliminate the default response to price signals and/or Demand Response Signals, and to override any individual price response or Demand Responsive Control through use of up/down temperature adjustment buttons, allowing the customer to choose any temperature during the Demand Response Period.

When the price signal changes to a non-response level or the Demand Response Period is concluded, Upgraded USTs shall return to normal operation.

1 The specific design of such features (e.g. HOLD, OVERRIDE) is defined by individual vendors and not by this document.

The UST shall also be equipped with the capability to allow customers to define setpoints for heating and cooling in response to price signals and/or Demand Response Signals as an alternative to temperature-offsetting response as follows:

1. The default price response or event setpoint in the cooling mode for Upgraded USTs shall be 8xoF. The UST shall allow the user to change the default event setpoint to any other value.
2. The default price response or event setpoint in the heating mode for Upgraded USTs shall be 6xoF. The UST shall allow the user to change the default event setpoint to any other value.
3. The UST shall ignore a price event temperature setpoint lower (in cooling mode) or higher (in heating mode) than the customer selected prevailing setpoint temperature just before the price event.
4. Additionally, thermostats shall not be remotely set above 8xoF or below 6xoF. This measure protects customer premises from extreme temperatures that might otherwise be imposed using emergency offsets, should the customer already have a very high or low temperature setpoint in effect.

Demand response control signals may also include a temperature setpoint or a setpoint offset that Upgraded USTs will accept as the setpoint for the Demand Response Period. The customer may still override or change the setpoint during these Demand Response Periods.

Summarizing, price signal response and Demand Responsive Control only modify the operating range of the thermostat. They do not otherwise affect the operation and use of features provided by the vendor's design.

JA5.2 The HVAC System Interface

The physical connector on the UST to be presented to the HVAC system shall be one or two screw terminal block headers (of a type chosen by the manufacturer) for direct control applications. The following sections describe each interface. Alternatively, a UST may present a digital interface in a vendor dependent manner and is not described in this document.

JA5.2.1 Minimal Direct Control Interface

The UST is required to support at least one 6 terminal connector for basic HVAC and heat pump systems. The terminal numbering and definitions for this connector is shown in Table 5.2-1. The terminal designations are from NEMA DC 3-20082.

Table 5.2-1: Terminal Block 1 - Basic Thermostat Terminal Mapping (Required)

<u>Term #</u>	<u>Signal Name</u>	<u>Normal Color</u>	<u>Notes</u>
<u>1</u>	<u>(Conventional) Y or Y1: Cooling</u> <u>(Heat Pump) Y: Compressor</u>	<u>Yellow</u>	<u>Conventional - First stage cooling</u> <u>Heat Pump - First stage compressor. Will heat and cool based on the output of terminal 2 - O/B</u>

2 NEMA DC 3-2008 - <http://www.nema.org/stds/dc3.cfm#download>

<u>Term #</u>	<u>Signal Name</u>	<u>Normal Color</u>	<u>Notes</u>
<u>2</u>	<u>(Conventional) W or W1: Heating</u> <u>(Heat Pump) O/B: Compressor</u>	<u>White</u>	<u>Conventional - First stage heating</u> <u>Heat Pump – Configurable option to energize the terminal for cooling (O option) or heating (B option)</u>
<u>3</u>	<u>G: Fan</u>	<u>Green</u>	<u>Fan switch on thermostat or on a call for cooling or heat pump</u>
<u>4</u>	<u>C: 24 Vac Common</u>	<u>Black</u>	<u>24Vac transformer neutral</u>
<u>5</u>	<u>R: 24 Vac Power</u>	<u>Red</u>	<u>24Vac transformer power. In a two source transformer installation, this terminal becomes Rh.</u>
<u>6</u>	<u>Rc: 24 Vac Power</u>	<u>Red</u>	<u>Cooling transformer power for two source transformer installations. This terminal can be tied to terminal #2 in single transformer installations.</u>

JA5.2.2 Advanced Thermostat Direct Control Interface

Thermostats designed to support advanced HVAC systems such as multi-stage configurations can support a second terminal block. The terminal numbering and definitions for this connector are shown in Table 5.2-2. Note that the terminal numbering starts with 7 to minimize confusion with the mandatory terminal block. This will also facilitate use of a single, standardized connector in the future.

<u>Term #</u>	<u>Signal Name</u>	<u>Normal Color</u>	<u>Notes</u>
<u>7</u>	<u>(Conventional) W2: Second Stage Heating</u> <u>(Heat Pump) Aux/E: Auxiliary Heating</u>	<u>Various</u>	<u>Conventional - Second stage heating</u> <u>Heat Pump – Auxiliary and emergency heating control relay.</u>
<u>8</u>	<u>Y2: Second Stage Cooling</u>	<u>Blue or Orange</u>	<u>Second stage cooling for both Conventional and Heat Pump configurations</u>
<u>9</u>	<u>L: Equipment Fault</u>	<u>Various</u>	<u>Installed as an input based on equipment type. When configured as in input, activation of the external generated signal informs the user via icon or LED enunciation, that the heat pump system is not available.</u> <u>Installed as an output based on equipment type. This output is used to “inform” zoning equipment that the system is in emergency heat mode. In this situation the secondary</u>

<u>Term #</u>	<u>Signal Name</u>	<u>Normal Color</u>	<u>Notes</u>
			<u>piece of equipment (zoning panel) will disable a call for heat pump.</u>
10	<u>(Conventional) W3: Third Stage Heating</u>	<u>Various</u>	<u>Conventional - Third stage heating</u> <u>Heat Pump – Second stage auxiliary heating</u>
	<u>(Heat Pump) Aux2: Second Stage Auxiliary Heating</u>		

Table 5.2.2-1 Terminal Block 2 - Advanced Thermostat Terminal Mapping (Optional)

Note that the optional connector may be extended in a vendor-dependent manner to support additional functionality. These terminals should use industry standardized designations, if appropriate, from those defined in Tables 5.2-3 and 5.2-4 below.

Table 5.2.2-2 Terminal Markings for Low-Voltage Class 2 Controls⁷

Heating	
1 st Stage	W1 or W
2 nd Stage	W2 or Aux, or Aux1
3 rd Stage	W3 or Aux2.
Cooling	
1 st Stage	Y, or Y1
2 nd Stage	Y2
3 rd Stage	Y3
Fan	G
Switched Side, Class 2 Power (Single Source)	R
Switched Side, Class 2 Power, Heating	RH
Switched Side, Class 2 Power, Cooling Side	RC
Unswitched Side, Class 2 Power (Number Sequentially)	C <input type="checkbox"/>
Damper (heat); Reversing Solenoid (heat)	B
Damper (cool); Reversing Solenoid (cool)	O
Configurable for Reversing Solenoid (cool) or Reversing solenoid (heat)	O/B
General Purpose (Any Number)	
	A
Lockout Reset	X
One Side, Class 2 Circuit Switch-Heat	TT
Other Side, Class 2 Circuit Switch-Heat	TT
Indicator Circuits; System Monitors (Number Sequentially)	L <input type="checkbox"/>
Switched Side, Second Source-Class 2 Power	K1
Unswitched Side, Second Source-Class 2 Power	K2
Defrost	DF
Emergency Heat Relay	E
Outdoor Thermistor	T

Table 5.2.2-1 Terminal Markings by System Type

Heat Pump Systems	
Function	Terminal Marking
Power	R
Common	C
1 st stage cool	Y or Y1
2 nd stage cool	Y2
1 st stage heat	Y or Y1
2 nd stage heat	W2, Y2 or Aux
3 rd stage heat	W3 or Aux
4 th stage heat	W4 or Aux2
Fan	G
Reversing valve or damper (heat)	B
Reversing valve or damper (cool)	O
Emergency Heat	E
System monitor or lockout reset	L

Heat Pump Systems	
Function	Terminal Marking
Power	R
Common	C
1 st stage cool	Y or Y1
2 nd stage cool	Y2
1 st stage heat	Y or Y1
2 nd stage heat	W2, Y2 or Aux
3 rd stage heat	W3 or Aux
4 th stage heat	W4 or Aux2
Fan	G
Reversing valve or damper (heat)	B
Reversing valve or damper (cool)	O
Emergency Heat	E
System monitor or lockout reset	L

Heat/Cool Systems (non-heat pump)	
Function	Terminal Marking
Power	R
Heat transformer power	Rh
Cool transformer power	Rc
Common	C
1 st stage cool	Y or Y1
2 nd stage cool	Y2
1 st stage heat	W or W1
2 nd stage heat	W2
3 rd stage heat	W3
Fan	G
Active in heat (i.e., damper, etc.)	B, or O/B
Active in cool (i.e., damper, etc.)	O, or O/B

Heat/Cool Systems (non-heat pump)	
Function	Terminal Marking
Power	R
Heat transformer power	Rh
Cool transformer power	Rc
Common	C
1 st stage cool	Y or Y1
2 nd stage cool	Y2
1 st stage heat	W or W1
2 nd stage heat	W2
3 rd stage heat	W3
Fan	G
Active in heat (i.e., damper, etc.)	B, or O/B
Active in cool (i.e., damper, etc.)	O, or O/B

JA5.3 Expansion Interface

USTs shall include an expansion port and interface to enable communication capabilities by the addition of a removable module. The removable module may also provide a means of memory storage, logging, and firmware upgrade. The requirements associated with the expansion interface are:

1. The expansion/communication port shall be readily accessible to the occupant for installing and removing the communication module. The occupant shall be able to insert or remove the communications module without the need to use tools or hardware.
2. Installation of the module shall upgrade the programmable setback thermostat to a communicating setback thermostat.
- 3. After the communication module is installed and the occupant has enrolled in a program or subscribed to a messaging service, the UST shall be capable of both receiving and responding to demand response signals.

The UST's expansion port interface has no mandated specification. Potential physical interfaces include vendor specific or proprietary connections, USNAP, Multi-Media Card (MMC) format, and Universal Serial Bus (USB).

JA5.4 Communications Interface

The communications interface has two aspects – the physical interface and the logical interface.

The physical communications interface includes a one- or two-way communications interface connected through the Expansion Interface as selected and specified by the customer's messaging service or Demand Response service provider. There is no mandated specification for the physical communications. However, Section 112(c) specifies that the communications module shall utilize standards based communications including but not limited to ZigBee, (IEEE 802.15.4), WiFi". (IEEE 802.11), etc..

The logical interface consists of the information model used to represent messages sent to the Upgraded UST. Similar to the physical communications interface, no specific standard is mandated, but direction is provided as "standards based messaging protocols (Smart Energy Profile (SEP), OpenADR or others defined in the Smart Grid Interoperability Panel (SGIP) Catalog of Standards (CoS))".

JA5.4.1 UST Messages and Attributes

If a DEMAND RESPONSE SIGNAL or price signal is received and validated, but conflicts with a prior message, the newer message shall supersede the previous message and any continuing action for the prior message is automatically terminated by the Upgraded UST (unless the subsequent message attempts to initiate an action that has been disapproved by the consumer).

JA5.4.1.1 Event Modes

The UST specifications recognize the following two basic system event modes:

1. Price signals, with responses that can be overridden by the customer
2. Demand Response Periods, which can also be overridden by the customer.

JA5.4.1.1.1 Price Signals

Price signals allow the utility or another entity selected by the customer to send a signal or message providing pricing information to the customer to initiate Demand Responsive Control for the Demand Response Period utilizing a Demand Response Signal.

Price Signal attributes and requirements shall be specified within the messaging protocol utilized by the utility or other entity selected by the customer.

JA5.4.1.1.2 Demand Response Periods

This event class allows the utility or another entity selected by the customer to initiate Demand Responsive Control for the Demand Response Period utilizing a Demand Response Signal.

Demand Response Signal attributes and requirements shall be specified within the messaging protocol utilized by the utility or other entity selected by the customer.

JA5.4.2 Security

The UST communications system must be secure from a variety of cyber attacks. A thorough discussion of security issues may be found at: <http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/CyberSecurityCTG>.

Demand Response Signal security attributes and requirements shall be specified within both the communications standard and the messaging protocol utilized by the utility or other entity selected by the customer.

JA5.4.2.1 Business Logic

Thermostats shall have hard-coded limits on what set points will be accepted via remote commands, to prevent unsafe set points.

Unless the messaging protocol contains randomization or restoration delay logic, Upgraded USTs shall randomly delay for up to 30 minutes after being instructed to conclude or cancel a Demand Response Period, thereby avoiding sudden increases in load on the grid. The display of the thermostat shall not indicate the end of the event until after the random delay.

Time synchronization commands received via the customer's selected demand response provider shall update and override any previous set time.

JA5.5 Human-Machine Interface

This section discusses the interface between humans and the UST. All core functional requirements for the Human-Machine Interface are defined in Load Management Standards. The following section addresses requirements for terminology.

JA5.5.1 Terminology

The only human-machine interface standardization required to support the Load Management Standards requirements is a clear definition of terminology. All other standard features of the UST are up to the discretion and innovative talents of the thermostat manufacturers.

UST user interface and documentation shall use the following terminology.

<u>Demand Response</u>	<u>Short-term changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.</u>
<u>Demand Response Period</u>	<u>A period of time during which electricity loads are curtailed in response to demand response signal.</u>
<u>Demand Response Signal</u>	<u>A signal sent by the local utility, Independent System Operator (ISO), or designated curtailment service provider or aggregator indicating a price or a request to their customers to curtail electricity consumption for a limited time period.</u>
<u>Demand Responsive Control</u>	<u>A control that is capable of receiving and automatically responding to a demand response signal sent via a third-party network or device.</u>
<u>Energy Management System</u>	<u>ENERGY MANAGEMENT CONTROL SYSTEM (EMCS) is often a computerized control system designed to regulate the energy consumption of a building by controlling the operation of energy consuming systems, such as the heating, ventilation and air conditioning (HVAC), lighting and water heating systems. The EMCS is also capable of monitoring environmental and system loads, and adjusting HVAC operations in order to optimize energy usage and respond to demand response signals.</u>
<u>Energy Management Services</u>	
<u>Price Event</u>	<u>Refers to a change in pricing sent to the UST from the utility or the customer's selected demand response provider.</u>
<u>Critical Peak Pricing Event (CPP)</u>	<u>A type of price event. When a CPP is received by the UST, the device should take appropriate behavior as defined by the settings configured by the customer.</u>
<u>Override</u>	<u>Refers to a person adjusting the functional behavior of the UST to ignore a demand response or price message.</u>
<u>Provision</u>	<u>Describes the commissioning or binding process of connecting a UST to an in-premise network or the communications network of the customer's selected demand response provider.</u>
	<u>NOTE: This process depends critically on the data security solution chosen.</u>
<u>Pending Event</u>	<u>Refers to a price event or Demand Response Period that is scheduled but has not yet happened.</u>
<u>Active Event</u>	<u>Refers to a price event or Demand Response Period that is underway.</u>

JA5.6 Restoring Temperature Offsets and Setpoints

The UST shall include the capability to allow the occupant to restore the default temperature offsets and set points to the defaults specified in 112(c)2.a.i and Reference Joint Appendix JA5 (factory installed setpoints). Removing and re-inserting the removable communication module shall also restore all temperature offsets and setpoints to factory installed default setpoints.

JA5.7 Onboard Communications Devices

Exception 3 to Section 112(c) allows onboard communication devices under certain conditions. When onboard communication devices are present, the UST shall:

- a) Meet all other technical requirements specified in Sections 5.1 through 5.7 of this document.
- b) Be equipped with a physical on/off switch that will enable to occupant to cutoff power to the onboard communication device, rendering it inoperative.