

Sean Murphy,  
End equipment manager  
Sitara™ ARM® processors

Texas Instruments

---

# Smart thermostats are a cool addition to the connected home

---

## Overview

Over the last several years, the concept of the connected home has become a reality across the world. The morphing of devices like the basic thermostat into a breed of power smart thermostats has shown how the appliances in residences today must adapt, re-imagine and, in some cases, re-invent their role in the connected home of the future or risk being left behind.

Because of the pervasiveness of residential broadband connectivity and the explosion in options, the key to the connected home is – connectivity. In North America, Wi-Fi® networks in the home are practically assumed. In other parts of the world like Europe and Asia, Wi-Fi home networking is supplemented by power line communications (PLC). Moreover, data connectivity over the 3G/4G cellular network has become ubiquitous. Accessing the local network in a home and any device connected to it has become as simple as tapping into the Internet via the wide area cellular network with a smartphone or tablet. The resident never loses touch with their home or the many devices that are now perpetually connected to it by way of connectivity technologies like Wi-Fi, ZigBee®, Bluetooth®, PLC, near field communications (NFC) and others.

## Overview (continued)

With this base level of infrastructure in place, residents are turning to connected home systems for two simple reasons: save time and money. The time-saving appliances and home automation systems that make up a connected home accelerate the time-to-enjoyment for the people living there. And, in addition to saving time, these same systems can save lots of money by reducing utility bills and increasing the overall efficiency of the home. In the end, residents are able to improve their quality of life, decrease their monthly bills, and enjoy their newfound leisure time they have all because of their connected home.

## Not your father's thermostat

Thermostats in particular have come a long way since they were first created. There was a time when the mechanical dial thermostat was the only option. It was simple and intuitive to operate because what you saw was what you got. The user simply set the temperature and walked away. Unfortunately, it was not efficient. Energy and money could be wasted since its settings would only change when someone manually turned the dial to a new temperature.

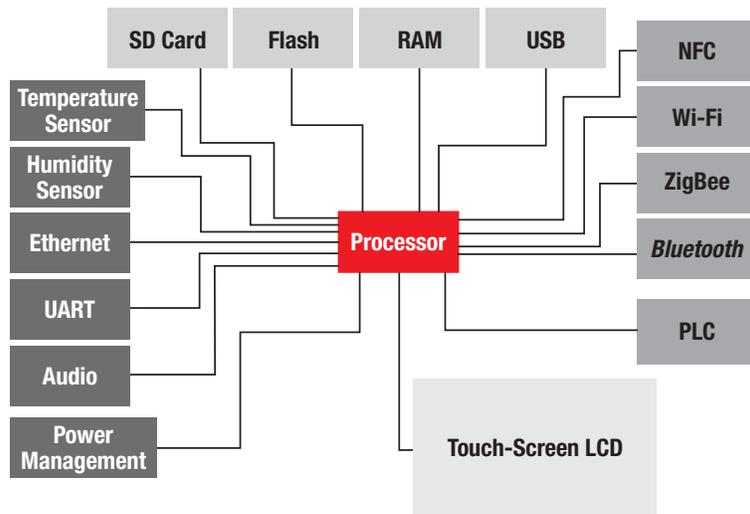
Adding a base level of electronics made thermostats programmable, which meant that the device itself could adjust the temperature according to a schedule defined by the homeowner. Energy consumption and utility bills could be reduced by automatically altering the ambient temperature when residents were away. This could work well as long as residents had a consistent and predictable schedule. If they didn't, they could end up constantly reprogramming the device or simply overriding its preprogrammed schedule to suit their frequent comings and goings. In the end, homeowners might choose to ignore the device's programming capabilities entirely since manually changing the temperature would likely be much easier than frequently reprogramming it.

Two factors were involved in making the jump from a programmable device to a smart thermostat. First, pervasive local and wide area connectivity, not just in thermostats, but in a slew of other devices and systems, has allowed smart thermostats to extend their reach beyond the confines of a particular structure. The interaction also extends beyond the people

who occupy the home to other devices and home automation systems as well. The second factor – more powerful, sophisticated and cost-effective processing capabilities – has enabled smart thermostats to learn from, and adapt to, the habits of users in addition to being able to react to the conditions they find present in their surroundings. Ultimately, the smart thermostat is able to make intelligent decisions.

### **Endless possibilities**

Generally speaking, modern smart thermostats typically are based on an advanced computing architecture (Figure 1). Depending on the price point of the market segment being targeted by the thermostat's processor, a particular smart thermostat can incorporate a powerful microcontroller with digital signal processing capabilities or a sophisticated embedded microprocessor, some of which feature a high-level operating system like Android™. In such an architecture, the processor can be surrounded by a full complement of resources, including sufficient memory, power management to reduce either battery or off-the-grid power consumption, input/output peripherals like USB, interfaces to wireless and wired communications, environmental sensors for temperature and possibly humidity, a user interface subsystem, which often involves audio and a touch-screen display.



*Figure 1. Smart thermostat architecture*

The extensive resources incorporated in such an architecture enable a wide range of new and beneficial activities and services never envisioned for thermostats in the past. For example, interfacing to a smart power meter through a ZigBee wireless connection could form the basis for daily energy usage reports, complete with recommendations on how to reduce energy consumption. Sensors installed in the various rooms of the home could communicate with the smart thermostat which in turn controls a damper system in the ductwork to manipulate heating or cooling on a room-by-room basis. For example, too much heat emanating from the stove in the kitchen would trigger additional cooling to this room.

In some cases, a powerful smart thermostat could become the control element for all of the home automation systems in the residence. Solar panels on the roof might provide outdoor temperature information so that the smart thermostat could adjust the home's heating, ventilation and air conditioning (HVAC) equipment accordingly. Based on a light being turned on in a certain room, the home's lighting system could tell the smart thermostat that someone had entered the room. The thermostat might then direct sufficient heat to the room that had been unoccupied. Video security systems might also be monitored and controlled from a smart thermostat.

The variety of communications protocols supported by smart thermostats allows users to interact with the device in the manner that makes the most sense at the moment. Some residents might prefer to control their home automation systems through the thermostat by interacting directly with the device's touch panel. Others might employ their tablet or smartphone connected to the smart thermostat through the home's Wi-Fi network. When away from the home, users could access the device in much the same way via the Internet using Wi-Fi or the 3G/4G cellular network. The possibilities are endless and limited only by the imagination and creativity of smart thermostat designers.

### ***Addressing the challenges***

Emerging markets often have issues that are eventually sorted out by the consumers in the marketplace who make the buying decisions. Price sensitivity, optimized feature sets and ease-of-use/ease-of-installation are three interrelated aspects of the smart thermostat market that designers are coping with.

When a product category has been established for some time, buyers have certain expectations with regards to cost. Even when a new product with innovative and breakthrough features enters the fray, buyers evaluate it based on their previous cost expectations. Previous versions of the product have established what the market will bear. Because the market for smart thermostats is just now emerging and these devices have more electronic content than previous generations, their initial cost can seem higher than expected, especially in comparison to mechanical or simple programmable thermostats. To a degree, suppliers of smart thermostats will be able to overcome this challenge as high-volume manufacturing brings down the cost of components. In addition, consumers will become better educated on the benefits of smart thermostats and will begin to understand how a marginally higher cost will be quickly recovered through lower energy bills. Through feedback from the initial roll-outs, designers of smart thermostats are fine tuning the feature set that consumers want. By eliminating features that are not important to consumers, costs will be reduced further.

To gain consumer acceptance, smart thermostats also must be easy to use and install. Again, the expected way consumers operate a thermostat has been conditioned by previous generations of the device. At a fundamental level, even the smartest thermostat must behave like the legacy generations because this is what users expect. As a result, setting the temperature must be as simple as it was with a mechanical dial or simple programmable thermostat. Of course, smart thermostats will include much greater functionality, but consumers who are not interested in advanced features must be able to interact with the device as they have with mechanical thermostats in the past.

A large portion of the thermostat marketplace is comprised of do-it-yourself consumers. Consequently, smart thermostats must also be extremely easy to install. Replacing a legacy device with a smart thermostat will mean that users must be able to easily implement its connectivity options, like Wi-Fi, PLC, ZigBee or others. Ideally, connecting the device to a network or other devices in the home should be fairly automatic. If extensive technical expertise is required, the smart thermostat might not be a viable product for many of today's non-technical do-it-yourselfers.

### **Texas Instruments (TI) – Connecting the home**

Smart thermostats can certainly function as a central piece to the puzzle that is tomorrow's connected home, but it is only one of many pieces. Greater embedded intelligence and pervasive connectivity are moving home automation beyond the role it has played in the past – where it merely monitored and reported on conditions – to an expanded position where the systems themselves take on a more active and decisive role by controlling and initiating an active response to conditions. For example, a home security system might be able to take actions on its own, like locking a window that was accidentally left unlocked. Home appliances will be able to communicate with each other, interact and share information so that the home operates more efficiently. Based on information from a smart electricity meter, for instance, energy consuming activities could be restricted to certain periods of the day when off-peak utility rates would apply.

The key point is that today's technology is capable of enabling a myriad of new and effective systems and applications for the connected home and TI is one of the leaders in providing these technologies. The company's embedded processors – both microcontrollers (MCU) and microprocessors – support a wide range of capabilities. The versatile and ultra-low-power MSP MCU, for example, could be the basis for a value-priced smart thermostat as well as the control processor in an air conditioning system. Higher-end processors, like the ARM®-based Sitara™ processors, might provide the processing power for sophisticated high-end smart thermostat/home automation systems. In addition, TI produces market-leading support components for smart thermostats, such as the sensors, wireless connectivity chips, power management devices, touch-panel controllers and many others.

For more information on TI's technology for smart thermostats and the connected home, go to

[www.ti.com/connectedhome](http://www.ti.com/connectedhome).

Important Notice: The products and services of Texas Instruments Incorporated and its subsidiaries described herein are sold subject to TI's standard terms and conditions of sale. Customers are advised to obtain the most current and complete information about TI products and services before placing orders. TI assumes no liability for applications assistance, customer's applications or product designs, software performance, or infringement of patents. The publication of information regarding any other company's products or services does not constitute TI's approval, warranty or endorsement thereof.

Sitara is a trademark of Texas Instruments Incorporated. All other trademarks are the property of their respective owners.

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components which meet ISO/TS16949 requirements, mainly for automotive use. Components which have not been so designated are neither designed nor intended for automotive use; and TI will not be responsible for any failure of such components to meet such requirements.

### Products

Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
OMAP Applications Processors	<a href="http://www.ti.com/omap">www.ti.com/omap</a>
Wireless Connectivity	<a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a>

### Applications

Automotive and Transportation	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
Computers and Peripherals	<a href="http://www.ti.com/computers">www.ti.com/computers</a>
Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Space, Avionics and Defense	<a href="http://www.ti.com/space-avionics-defense">www.ti.com/space-avionics-defense</a>
Video and Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>

### TI E2E Community

[e2e.ti.com](http://e2e.ti.com)