WHITE PAPER

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# 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.

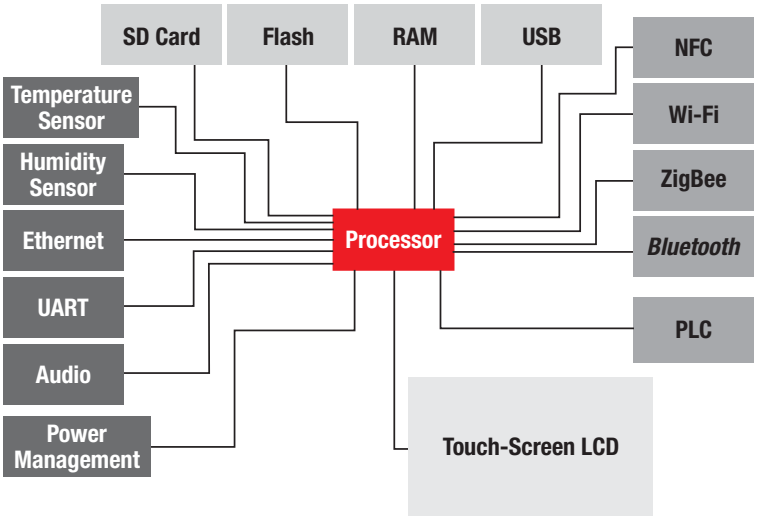


*Figure 1. Smart thermostat architecture*

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**.

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