Meeting the low-power challenge for building automation applications

TEXAS INSTRUMENTS

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Introduction

Today's building automation developers face many challenges. Building automation equipment commonly employs one or more sensors to monitor environmental conditions and irregular events. These devices are used for safety (heat, fire and gas detectors), HVAC (thermostats, environmental sensors and fault detectors) and security (motion and glass break detectors). Devices can also be fairly complex, such as electronic locks that require keypads, digital readers and mechanical functionality.

As with many applications, the challenge for developers designing building automation equipment is to improve power efficiency while increasing node intelligence and integrating additional functionality. The need for wireless connectivity to enable the Internet of Things (IoT) so devices can be controlled and managed remotely puts a further burden on developers to maintain low-power operation. Finally, developers must drive down manufacturing cost without compromising robustness or fail-safe mechanisms.

The low-power challenge

Low power is an essential design consideration for many building automation applications. For example, occupancy sensors and motion detectors use infra-red, ultrasound, acoustics and image recognition to detect activity in spaces like offices, classrooms, conference rooms, restrooms, storage areas and corridors (see Figure 1). These sensors primarily operate in a deep sleep, ultra-low power-operating mode as they do not need full functionality until activity is sensed. Once an event is detected, these systems wake-up, process sensor data
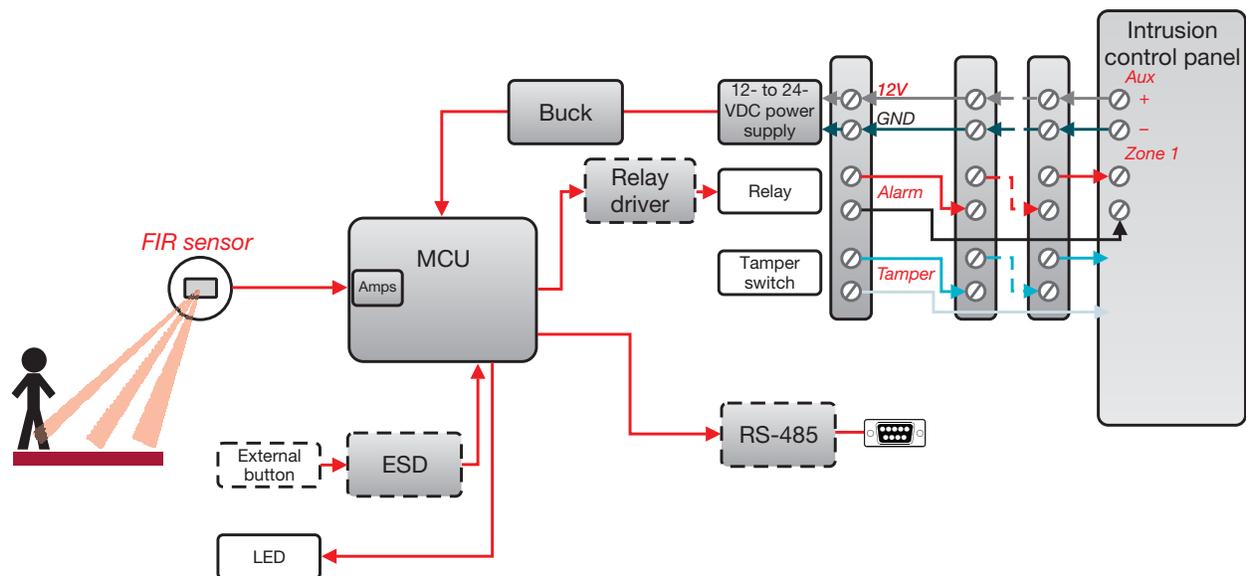

Figure 1: Sensors like **occupancy and motion detectors** operate primarily in a deep sleep, ultra-low power operating mode as they do not need to function until activity is sensed. Once an event is detected, these systems need to wake, process sensor data efficiently, act on the data and drop back into sleep or standby mode as quickly as possible to minimize energy consumption.
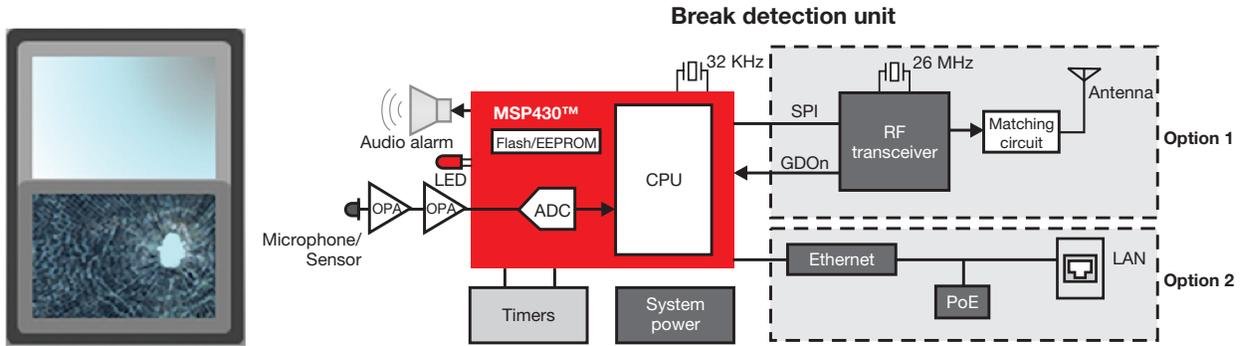
Break detection unit

Figure 2: Sensors like glass-break detectors can be simple in implementation or utilize a more complex design requiring more processing capacity to increase detection accuracy.

efficiently, act on the data and drop back into sleep or standby mode as quickly as possible.

Sensors can be simple or complex. For example, glass-break detectors can use narrowband microphones tuned to the frequencies typical of a glass-shattering alarm to trigger a detection event when these sounds rise above a certain threshold (see Figure 2). Alternatively, a more complex design might compare sound events to glass-break profiles using signal transforms to more accurately detect breaches.

Similarly, equipment that employs a combination of mechanical and electronics, such as a lock, also requires low-power operation (see Figure 3). Such equipment needs to be built on a flexible platform that can support different technologies, such as keypads, fingerprint readers, RFID cards and security tokens.

Building automation equipment often needs to operate independently on battery power for long periods of time. Using a low-power MCU enables sensors to conserve energy, leading to a longer effective battery life (10+ years). This results in lower maintenance costs by eliminating the need for manual management of end equipment.
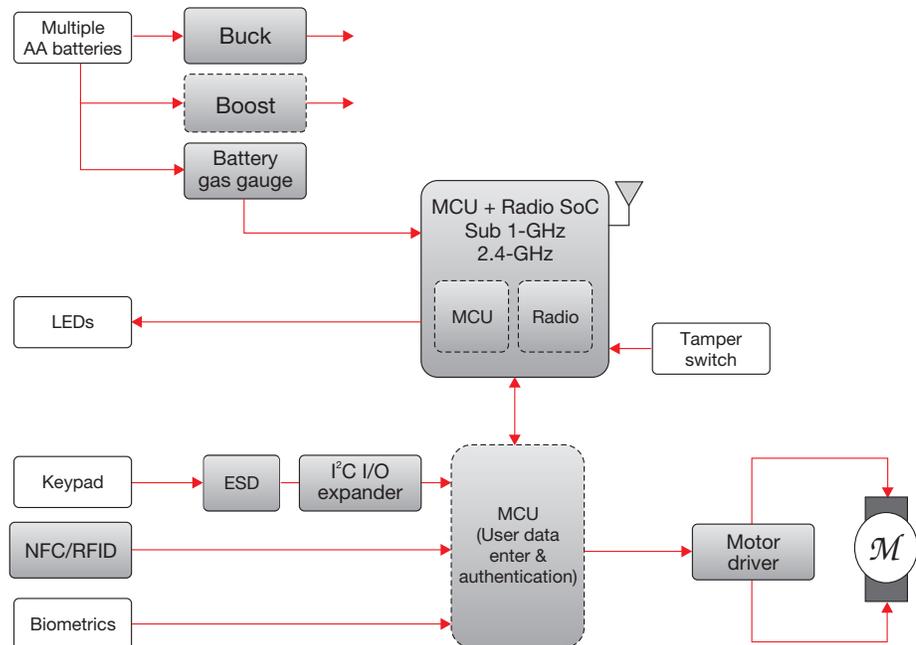

Figure 3: Some building automation equipment, like an electronic lock, employs a combination of mechanical and electronics. These designs require a low-power, flexible platform that can support different technologies, such as keypads, fingerprint readers, RFID cards and security tokens.

The low-power MSP microcontroller

The MSP MCU family of low-power microcontrollers from TI is optimized to address the challenges of building automation design. With efficient energy consumption as its foundation, these MCUs provide extensive processing capabilities, including floating-point and security functionality. Operating at up to 48 MHz, MSP MCUs can implement analysis and intelligent decision-making capabilities in building automation systems. For example, sensors can implement advanced data analytics to improve safety and security within the areas they monitor.

Building automation applications need a wide range of capabilities and the highly integrated architecture of the MSP MCU enables developers to implement complete systems with a single-chip design. With integrated ADCs, op amps and comparators, the MSP MCU simplifies the design and operation of sensor-based functionality. Pulse Width Modulation (PWM) outputs enable the MSP MCU to control motors efficiently and LCD drivers can support up to 320-segment display. For applications where size is important, the MSP MCU comes in small packages, starting at 8 pins and 2×2.2 mm^2.

FRAM for low-power operation

Traditional embedded systems utilize both SRAM and Flash memory. SRAM provides fast access speed but constantly draws power and loses data when the system is powered off or experiences a power failure. As a non-volatile memory technology, Flash can retain data without consuming energy. However, because of its relatively slow access speed, typically only critical data like program code

and system configuration parameters that need to be retained when the system is powered down are stored to Flash.

A key feature of the MSP MCU architecture is its use of **Ferroelectric Random Access Memory (FRAM)** technology, also known as FeRAM or F-RAM. FRAM combines the speed of SRAM with the non-volatility of Flash to provide robustness with flexibility and efficiency in a single memory technology.

The flexibility of FRAM starts with its functionality as a universal memory—it can be used for program code and data storage. It can also be written in a bit-wise fashion, providing programmers an efficient data management solution. FRAM has virtually unlimited write endurance (on the order of 1015 cycles) with no signs of degradation, enabling developers to use it just like they would SRAM.

FRAM changes the way firmware is designed. FRAM offers superior **write speed**, read access and energy efficiency. With FRAM-based MSP MCU devices, developers have the flexibility to partition how much memory is allocated for program code and how much for data storage. Because this partition is user-defined, it can be adjusted to make the best possible use of memory depending upon the application and any specification changes that arise during the development cycle. For example, developers can trade off between data and code size to optimize program performance without having to specify a new processor with a different memory configuration.

TI's FRAM technology also offers many advanced features. An integrated Memory Protection Unit (MPU) prevents accidental modification of program code. Developers can also make use of IP Encapsulation functionality to protect program code against authorized write and read accesses. FRAM

also offers higher write speeds (100× faster than Flash), lower power operation, higher endurance and better security aspects.

Optimizing energy consumption at the application level

Many sensors used in building automation applications are in standby most of the time. By maximizing standby time and minimizing standby current, developers can optimize power consumption. However, traditional debugging tools are limited in their ability to accurately assess energy usage across a system's various use cases.

The **MSP430™ MCU** family supports **EnergyTrace™**, which enables developers to maximize power optimization by profiling processor operation in real-time. For building automation applications, the MSP430FRx and MSP430FR6x support EnergyTrace++ technology. This enables power monitoring of individual peripherals in addition to visibility into CPU energy utilization.

The ability to monitor individual peripherals makes it possible to measure more than just overall energy usage over time. This level of granularity in monitoring enables developers to verify that the operating state of peripherals is as expected. For example, the ADC or FPU may be left powered on when it is not being used. With EnergyTrace++, developers can profile when each peripheral is on and determine that it should indeed be powered.

Similarly, Energy Trace++ technology can be used to verify that the CPU is in the correct low-power mode. Each low-power mode has dependencies, and the CPU may not be able to drop into a lower power mode if it hasn't been initialized correctly. For example, the system clock may need to run

at a specific frequency to enter a lower power mode. If the clock is configured incorrectly, the system will not be able to enter this power mode and consequently will draw substantially more power than expected. This is not a bug that can be detected using a debugger alone.

To further aid developers in optimizing energy efficiency, TI offers its Ultra-Low Power (ULP) Advisor. ULP Advisor™ is a tool that scans through application and firmware code and makes recommendations for ways developers can lower power consumption. ULP Advisor is much more than just a list of best practices. The tool identifies specific ways to optimize a system's code for energy efficiency and where these methods should be implemented.

Increasing robustness with compute through power loss

One challenge for designers is to minimize the effort required to maintain a building automation network. For example, when a device unexpectedly loses power, it loses not only the data in its volatile memory but also its current operating state. When power returns, the device must completely reset itself, and whatever operations it was in the middle of will be lost. In addition, some equipment might require manual reconfiguration.

When a power outage is considered on the scale of an entire building, power loss becomes a major maintenance issue if every device on the automation network experiences a reset and requires manual configuration. Instead, if each device is able to store its context and data upon power loss, devices can automatically restore themselves to their state before the loss and seamlessly resume operation.

Traditionally, context save and restore through power loss has been implemented using battery backup or a large capacitor that stores enough energy to enable the device to complete information writes to non-volatile memory. This approach requires additional components, board space and switching circuitry. It also increases the cost and complexity of systems, as well as introduces an additional point of failure. With FRAM, compute through power loss can be implemented without larger backup power sources. First, because program data can be stored in FRAM, this data is already protected against power loss. Second, the fast write speed and low energy of the FRAM enables the system to save any contextual information in the short time between detecting a power loss and complete loss of power.

With the MSP430FR5x and MSP430FR6x MCUs, TI supplies **Compute Through Power Loss (CTPL)** software utility that code developers can use to monitor the power supply and detect a degrading voltage drop. When a specific threshold is reached, the system is able to immediately save its current context before the power loss is complete. Upon power restoration, the system can restore its context and then resume operations.

The ability of the MSP MCU to save system state quickly and restore with just as much speed, enables even lower power operation in some use cases. The lower the standby current, the longer it can take the system to wake. When the system needs to be able to respond quickly, such as to a sensor event, the system often needs to utilize a less efficient standby mode.

Because FRAM read speed is so fast, the time to restore context is significantly faster as well. For example, it takes 1 second to save a 13KB block of data using Flash. With FRAM, this same data write will only take 10ms. It is important to note that with

FRAM, much of the application context and data are already stored in a non-volatile manner in FRAM. In some cases, this reduction in the wake-up time may make it possible for a system to drop into a lower power mode, such as from LPM3 (as low as 400nA current) to LPM3.5 (as low as 250nA current), and still be responsive to real-time events. Depending upon the frequency of such use cases, this could result in a substantial reduction in overall standby energy consumption.

Flexibility and choice

Interconnecting devices in a cost-effective and power-efficient manner is essential to good building automation design. Rather than limit developers, the MSP MCU architecture supports most standard communication protocols with drivers and application-level reference software, including KNX, an intelligent buildings communications protocol that runs over UART, and the **SimpleLink™** wireless connectivity portfolio like 2.4 GHz Wi-Fi®, *Bluetooth*® **Smart** and **ZigBee**®. In addition to protocol stacks and software, TI provides an extensive offering of hardware for both wired and wireless connectivity components so designers can choose the communication interface ideal for their application.

TI also offers a complete portfolio of analog components, simplifying procurement for sensor applications of all kinds, including sensors to monitor temperature, light, movement, proximity, flow and many other types of data. To further speed development, TI provides an entire library of sensor-based reference designs.

The MSP microcontroller family is an ideal platform for developing building automation applications, from sensor nodes to access and control systems. Low-power operation is essential for maximizing

battery life and minimizing maintenance costs and, with its architecture designed for low power, the MSP430 enables efficient operation, long battery life and less complex power supplies. Its high level of digital and analog integration optimized for specific applications and end equipment simplifies design, supports multiple sensor inputs, allows for a smaller form factor, and further improves power efficiency.

MSP MCUs support a wide range of communications protocols, enabling a high level of connectivity and IoT-based functionality. With its FRAM-based architecture, the MSP430 reduces the complexity of designing with non-volatile memory technology while at the same time improving overall energy efficiency. Advanced features like IP Encapsulation and integrated AES256 functionality allow developers to provide the enhanced security required for building automation systems.

Developers also have access to an extensive portfolio of MSP devices with varying processing capabilities, peripherals and memory densities tailored to provide the right level of integrated functionality for a particular application.

To address the higher performance and processing needs, TI recently introduced **MSP432™ MCUs** which have been designed with ARM®'s 32-bit Cortex®-M4F core. The MSP432 MCU has advanced mixed-signal features while staying true to **MSP ultra-low-power DNA**. The microcontroller performs better with optimized math libraries, saving developers time and effort. They also offer higher security features like regional secure zones, AES256 and dual-bank memory ideal for remote firmware upgrades.

With the MSP microcontroller portfolio (16 and 32 bit), developers can maximize performance, energy efficiency, security, and cost.

For more information on using TI MSP MCUs in building automation applications, including reference designs and recommended devices, visit the **MSP applications page**.

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