New Smart Energy Technology Boosts Battery Life for IoT Devices

Around 2012, I remember attending an energy-harvesting conference. What a great technique for smart energy! Harvesting unused energy from the environment, people, machines, etc. and using it to power valuable devices, for free. The premise, at the time, was that four key technologies had converged to enable mass adoption of energy harvesting: namely, low-power microcontrollers, low-power sensors, efficient harvesting devices, and efficient voltage converters. Applications spanned a large range, from ultra-tiny photovoltaics harvesting light energy to large-scale piezo elements embedded in sidewalks to harvest the energy of people's footsteps.

While some applications in energy harvesting have taken off, much of the vision from that 2012 conference has not been fulfilled. Despite the fact that energy harvesting operates for free, the investment in the systems is not free. Ultimately, energy harvesting may not be the right technique for powering so many smart energy applications.

Today, we've also got more devices to power than ever before. Fueling this growth in number of devices are sophisticated sensors, more pervasive connectivity, and secure, low-power microcontrollers that are providing an underlying foundation for smart....everything. While the internet of things (IoT) term elicits a fair amount of eye-rolling, we are nonetheless expected to have 20 billion smart, connected devices by 2020. We've already got smart tea infusers, doorbells, thermostats, TVs, medical devices, and a host of other connected gadgets. Many of these things are small and battery-powered, which means that energy efficiency and long battery life will continue to be big demands—and challenges—for design engineers.

How Taking Coffee "Offline" is a Smart Energy Example

Earlier visions of a smart energy/IoT build-up led us to believe that by now, we'd be extracting and analyzing data at a certain level of granularity. But we're not. For example, we're not measuring energy consumption of individual light bulbs, perhaps because of the high cost of such systems compared to the energy cost to run a lamp. Plus, we now have many low-energy-consuming light sources at our disposal. But even though one particular vision of smart energy hasn't materialized, many wonderful advancements have made possible a new vision.

A great analogy for all of this is coffee. Remember the days when most people, at least in North America, made coffee in a glass or ceramic pot that then sat on a burner? That burner consumed energy as it slowly cooked the coffee, ruining its taste. The "smart energy/IoT" solution to this problem might be to monitor the coffee with a few sensors, and shut off or control the heating mechanism as the coffee degrades. However, someone had the much better idea of keeping the coffee hot in a thermos. This step took coffee "offline" after it was brewed. Now, coffee-making consumes less energy and results in a much better-tasting drink. How's that for an example of smart energy?!

The coffee example relates to the idea behind the development of engineering systems that both maximize performance and save energy. Many IoT devices spend a fair amount of their time in sleep or hibernate modes, making quiescent current (when a part is neither operating nor completely shut down) more impactful on battery life. In fact, a power supply's quiescent current has become the biggest contributor to a system's standby power consumption. One great advancement to maximize performance and save energy is nanoPower technology. nanoPower technology applies to current consumption of certain parts in their quiescent state. Newer products that take advantage of advanced analog CMOS process technology operate with nanoamp currents that are almost immeasurable. You get energy-saving benefits from these products first by duty-cycling these systems, and secondly, by decentralizing the power-consumption architecture.

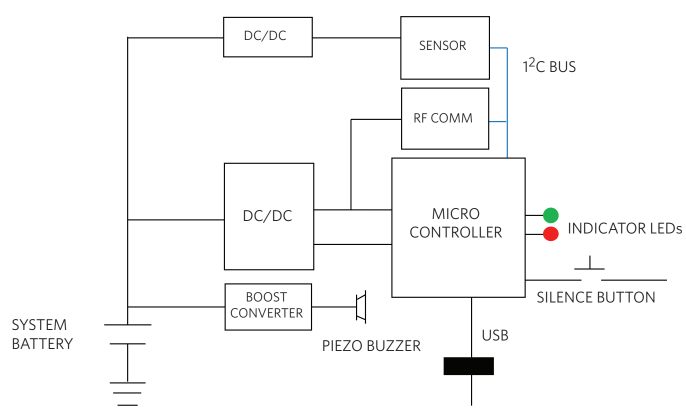

Figure 1. Smoke detector block diagram

Component	Typical Operational Circuit	Typical Quiescent Current
Microcontroller	10mA	2.5µA
Sensor	1mA	2.5µA
DC-DC*	1.6mA	500nA

Table 1. Example values of current consumption for smoke detector.

**DC/DC power consumption based on an output current of 15mA with an efficiency of ~90%.*

Smoke detectors can be considered an early IoT device. These detectors typically need to last for 10 years, running on a battery that is changed infrequently and operating even during power outages. See Figure 1 for a block diagram of a typical, modern smoke alarm, with a battery, multiple DC/DC converters, a microcontroller, RF communication, a sensor (which may be a variety of architectures), and a piezo buzzer. Table 1 provides example values of current consumption for each block, based on modern components. With optical smoke sensors, peak currents to run LEDs will be in the mA range, but the average current drops as the LEDs are typically cycled fairly infrequently. In most alarms, the active circuitry may sample the air only 0.05% of the time, so for 99.95% of the time the system runs in quiescent mode. Discounting the RF circuit, which may have a completely different duty cycle, the main circuits in full power mode would consume 12.6mA. During quiescent periods, the main circuit would consume 5.5µA. Therefore, the average current per second consumption by the active circuit is 12.6mA X 0.0005 = 6.3µA, resulting in an average current consumption of 11.8µA. Now, any quiescent currents above one µA start to impact system battery life. So in the ~10µA current consumption range, each additional µA of current impacts a 1500mAhr battery life by a single year.

Turning Off Circuits to Save Energy

nanoPower technology is also beneficial via an ability to turn off circuits within the system. In a nanoPower architecture, critical components such as battery monitoring and real-time clocks stay on, while major power consumers, such as the microcontroller and RF circuits, either turn off or go into their lowest power consumption mode. System monitoring ICs can, in many ways, be viewed as good analog insurance. Parts such as comparators, op amps, current sense amplifiers, and supervisory ICs—especially at nanoamp quiescent current levels and in small packages—can help ensure that important things like

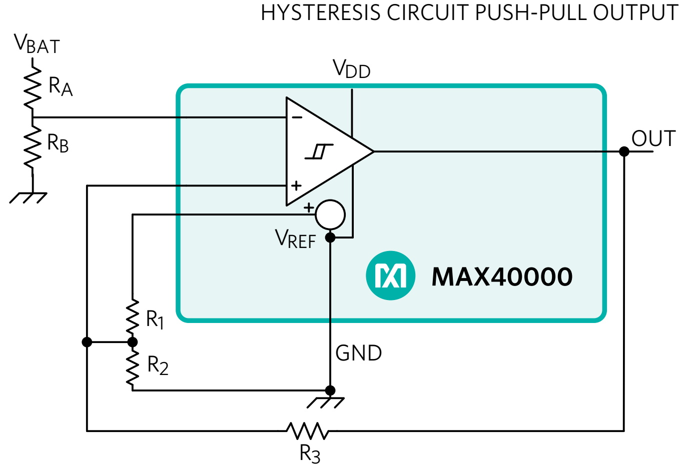

Figure 2. nanoPower window comparator monitoring battery voltage

voltage levels on workhorse components like microcontrollers are at the proper levels without themselves being sources of excessive power consumption. In Figure 2, the circuit shows a nanoPower window comparator monitoring a battery voltage. When the battery goes above or below the allowable voltages, the comparator provides an alert, which is not only a valuable safety function but also helps to extend battery lifespan. So, the system microcontroller doesn't need to operate unless it has received an alarm from the comparator, which runs at a typical current of 900nA. Essentially, this can be viewed as a smart-energy architecture, conserving as much energy as possible, while peeling off specific circuits for functions that must always stay on.

My last example here consists of a power supply from a wall wart or battery, also known as an ORing diode supply. In ORing diode supplies, good designers place a Schottky diode in series with the battery supply to limit the voltage drop. This approach minimizes power loss across the diode, while still protecting the circuit. For example, the new MAX40200 ideal diode (Figure 3) drops as little as 85mV when carrying as much current as 1A, and typically drops 43mV when carrying 500mA. This performance level is up to 10x better than that of a typical Schottky diode, saving tens to hundreds of milliWatts of battery power in a smart way.

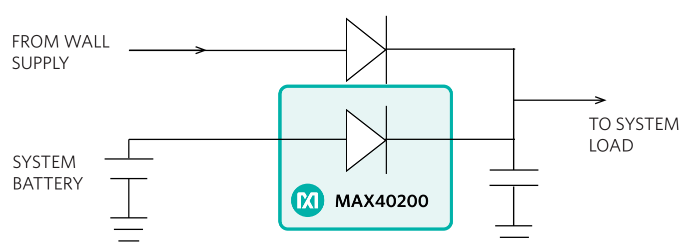

Figure 3: The MAX40200 ideal diode operates with a supply voltage of 1.5V to 5.5V and is available in a tiny, 0.73mm x 0.73mm, 4-bump WLP.

Summary

By now, you might be asking yourself, "Does all of this really relate to energy harvesting or coffee?" Well, as in our coffee example, the architecture is changing. With technology such as nanoPower, various sub-systems essentially disconnect from the central processor and check in periodically, which drastically reduces energy consumption in the process. Unlike energy harvesting, which adds components to a system, these components already exist in function and they now perform much better. Designed with advanced processing and analog architecture, these building blocks consume unprecedentedly low amounts of power. The new smart energy combines intelligent system architecture with advanced components, enhancing system battery life or the life of any power source along with reliability, while also unlocking new applications. For all of those billions of smart, connected products that are on the way, our new model of smart energy bodes well for a better customer experience.

Learn More

- Get more details on MAX40000 nanoPower comparators, including the data sheet, evaluation kits, and parts ordering.
- Get more details on MAX40200 micropower ideal diode current switches, including the data sheet, evaluation kit, and parts ordering.

Maxim Integrated
160 Rio Robles
San Jose, CA 95134 USA
408-601-1000
maximintegrated.com

maxim integrated™