SILICON LABS

Battery Size Matters

Five fundamental considerations for a battery-powered, wireless IoT sensor product.

The Internet of Things (IoT) is upon us. Gartner recently reported a typical family home may contain more than 500 smart devices by 2022 (Gartner news, Sep 8, 2015). The promise is that every day home automation products will be smarter through the introduction of low-cost IoT technology including wireless transceivers and innovative sensors. But these features take energy, and a majority of these devices will be powered by batteries.

This presents an interesting challenge. To successfully design a product for the connected home, designers must generally build a small form-factor product, with the cheapest bill of materials (BOM), and reliable operation over several years without battery replacement.

IoT Home Automation Challenge: Designers Must Create...

"small form factor products,"

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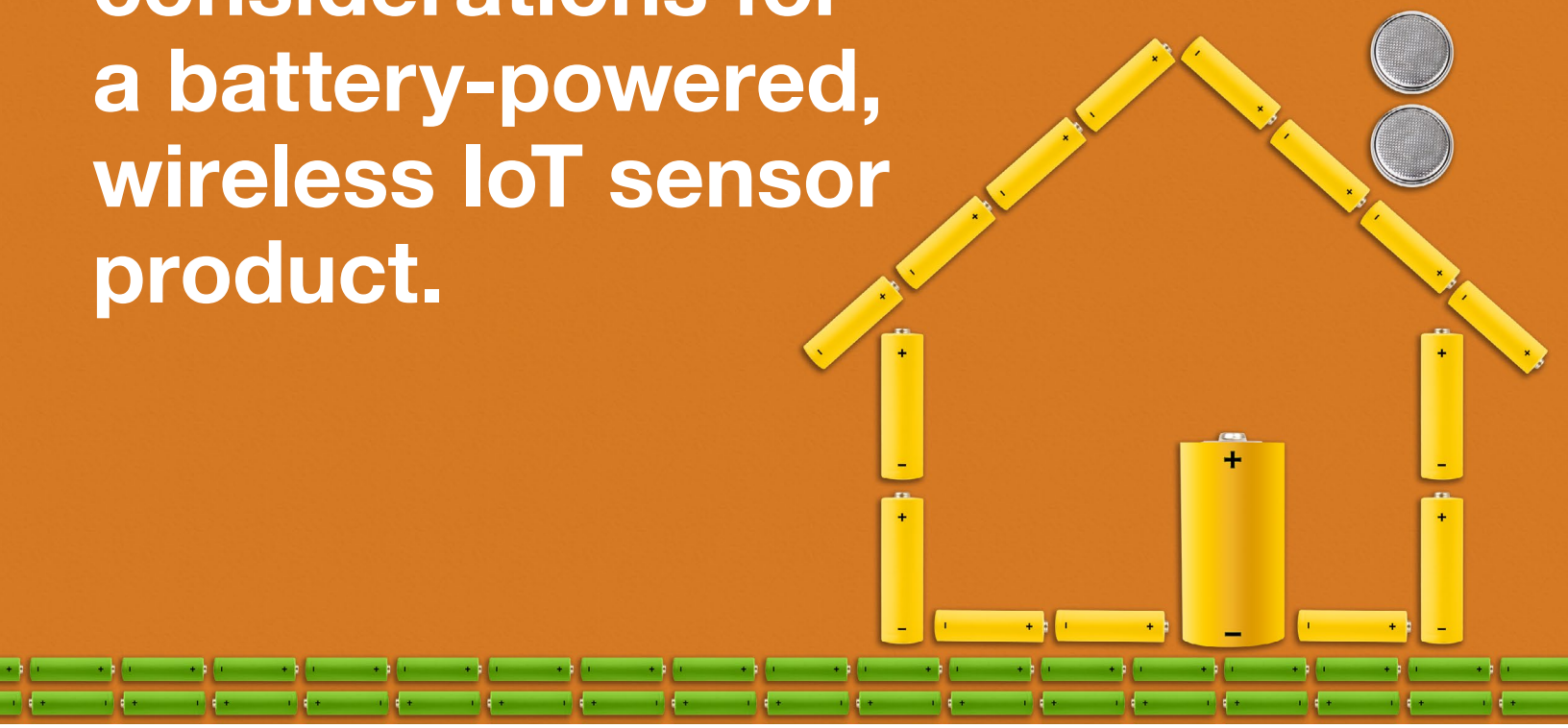
Five fundamental considerations for a battery-powered, wireless IoT sensor product.



1

Different Markets, Different Requirements?

Before you can begin designing it is important to understand the target market, as each present different requirements on cost, reliability and battery life. Below are two extreme examples of how market requirements force designers to make trade-offs.

Subscription-based Service Providers

A subscription-based service provider (e.g., cable or satellite internet service) places greater importance on long-term, reliable operation than achieving the lowest BOM cost or attaining the smallest form-factor.

These companies weigh product cost versus the cost of sending a technician on-site for trouble shooting, which costs between $200 and $2,000 per trip, according to various sources. Of course, if the issue is merely a drained battery, the cost trade-off is obviously to put a bigger battery or a lower-power design in place.

Do-it-Yourself Home Automation

While this segment values reliability, these consumers often select products based on cost, size and appearance. This market is where batteries are typically small to accommodate an aesthetically pleasing enclosure. Additionally, the product cost must be low to achieve a low shelf price. If the do-it-yourselfer gets the product home only to have it fail, the replacement cost of a defective consumer product is much lower than the professional service provider market; therefore, product designers are willing to make these kinds of trade-offs.

2

Battery Efficiency and Wireless – Not Always an Obvious Choice

When a product needs wireless connectivity, the choice of which protocol to use will be a major factor affecting battery life. There are several wireless choices to consider, some of which may be preferred or even required by the target market.

Wi-Fi is a commonly used protocol in consumer wireless products. Wi-Fi accommodates large streams of data at high throughput rates and is more power-hungry compared to other wireless protocols. Wi-Fi products are often plugged into power outlets or frequently recharged as they are not optimal for a product running off a battery compared to products that use very low throughput rates.

For example, most home automation sensors such as magnetic door and window sensors and passive infrared (PIR) motion detectors, are static for long periods of time and would not benefit from large data stream Wi-Fi offers. These sensors can utilize battery-friendly wireless standard such as Bluetooth® Smart (also known as “BLE”) or ZigBee®. Bluetooth Smart targets direct point-to-point communication, while ZigBee targets multi-node mesh-networking.

As a point-to-point technology, Bluetooth Smart or “BLE” might be best suited for querying a smart device in the home such as a door lock. For mesh networking,

Wireless Eats Energy

Transmitting and receiving streams of wireless data consumes milliamps of energy per hour, well beyond what can normally be supported with two low-cost AAA batteries.

ZigBee might be best suited for multiple smart devices such as thermostats, door sensors and even window shades that can be configured to communicate autonomously with very little user interaction. A mesh network also has built-in redundancy that can eliminate single points of failure, making it more reliable than point-to-point technology.

	ZigBee	Wi-Fi	Bluetooth Smart
Standards-based	Yes (802.15.4)	Yes (802.11)	Yes
Standards Body	ZigBee Alliance	Wi-Fi Alliance	Bluetooth SIG
Application Focus	Monitoring & Control	Web, Email, Video	Sensors
Type of Battery	Coin-cell	Rechargeable (Li-ION)	Coin-cell
Number of Nodes	<10 to 1,000+	<10 to 250	<10
Required Throughput (Kbps)	<250	>500	<250
Typical Range (Meters)	1 to 100	1 to 100	1 to 70
Network Topology	Self-healing Mesh, Star, Point-to-Point	Star, Point-to-Point	Star, Point-to-Point

3

Duty Cycle – How Often Does the Device Communicate?

Sleep-state power numbers within the electrical specifications of a wireless transceiver should not be the sole input when examining a device's wireless power budget.

Once a wireless technology is chosen, the next factor facing the designer is determining the required transmission strength, duration and duty-cycle between active and sleep states.

Most modern wireless transceivers offer sleep modes when not in use to save power. The longer a device is in sleep state the less power it uses, which extends battery life. However, the sleep-state power numbers within the electrical specifications of a wireless transceiver should not be the sole input when examining a device's wireless power budget. The wireless transceiver's wake-up times and pre-processing algorithms prior to transmission and return to sleep also affect power and should be included when calculating the total wireless power budget.

The frequency, or duty-cycle, of wireless transmissions will directly affect the battery life of the product. Duty-cycle is determined in-part by the wireless standard requirements, the software algorithm and how the device is normally used. For example, a door sensor with an open/close event will cause a wireless data transmission to occur; however, this sensor may also send and receive periodic wireless polling events to and from other mesh network nodes for status updates. Figure 1 provides an overview of this process.

Sensibly Designing-in Sensor

In general, each application requires a certain type of sensor; a carbon monoxide detector needs a CO sensor, a smoke detector needs an ionization or photoelectric sensor, a motion detector needs a PIR sensor, and so on. Once the type of sensor is selected, how it is designed and what MCU is selected can save power and cost. The reference designs below provide some insights.

The Silicon Labs RD-0030-0201 ZigBee Contact Sensor Reference Design monitors entry points such as doors and windows. The main sensor is a reed switch to detect the presence of a nearby magnet and determine if an entry point is open or closed. Once a magnetic field reaches a certain threshold, the sensor assumes the entry point status has changed and a wireless notification cycle is initiated.

When it comes to the number of entry events, while it has an effect on battery life, the number itself is a small factor when measured across multiple entry events, as seen in Figure 2.

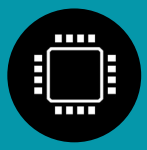
However if the reed switch is held static in a specific state (open or closed) for long periods of time, it can affect battery life if the state creates a very low series impedance circuit across the battery supply. To avoid this situation, Silicon Labs developed a reference design with kilo-ohms of impedance across the battery supply when the reed switch is opened or closed so the state of the reed switch is negligible on the chosen battery. In other words, a door can remain open or closed for many days with very little effect on the battery.

MCU choice can also make a difference in the sensor node's power. The RD-0039-0201 ZigBee Capacitive-Sense Dimmer Switch Reference Design is used to control ZigBee-based LED lighting nodes. This design is battery-powered and uses ZigBee so it can be placed anywhere on a flat surface, fully wireless from the switch to the lights. It also employs capacitive sensors to detect the user's physical touch to correspond to particular lighting commands.

This reference design uses a small, low-storage CR2032 battery. To conserve energy, the design uses a Silicon Labs low-cost, energy-efficient 8-bit EFM8SB1 MCU for touch sensing capability. This circuit is designed to operate below 1uA to detect multiple touch points and gestures for light commands, such as on or off or level control.

Further, these capacitive events are monitored in a relatively slow, millisecond duty cycle rate since people are accustomed to relatively slow human interface responses compared to most MCU capabilities. This saves battery power without sacrificing usability.

All of these factors should be considered when designing for the targeted battery life of a product.



Adjusting MCU Polling Frequency Saves Power with No User Impact

MCU capacitive events are monitored in a relatively slow, milli-second duty cycle rate since people are accustomed to relatively slow human interface responses compared to most MCU capabilities. This saves battery power without sacrificing usability.

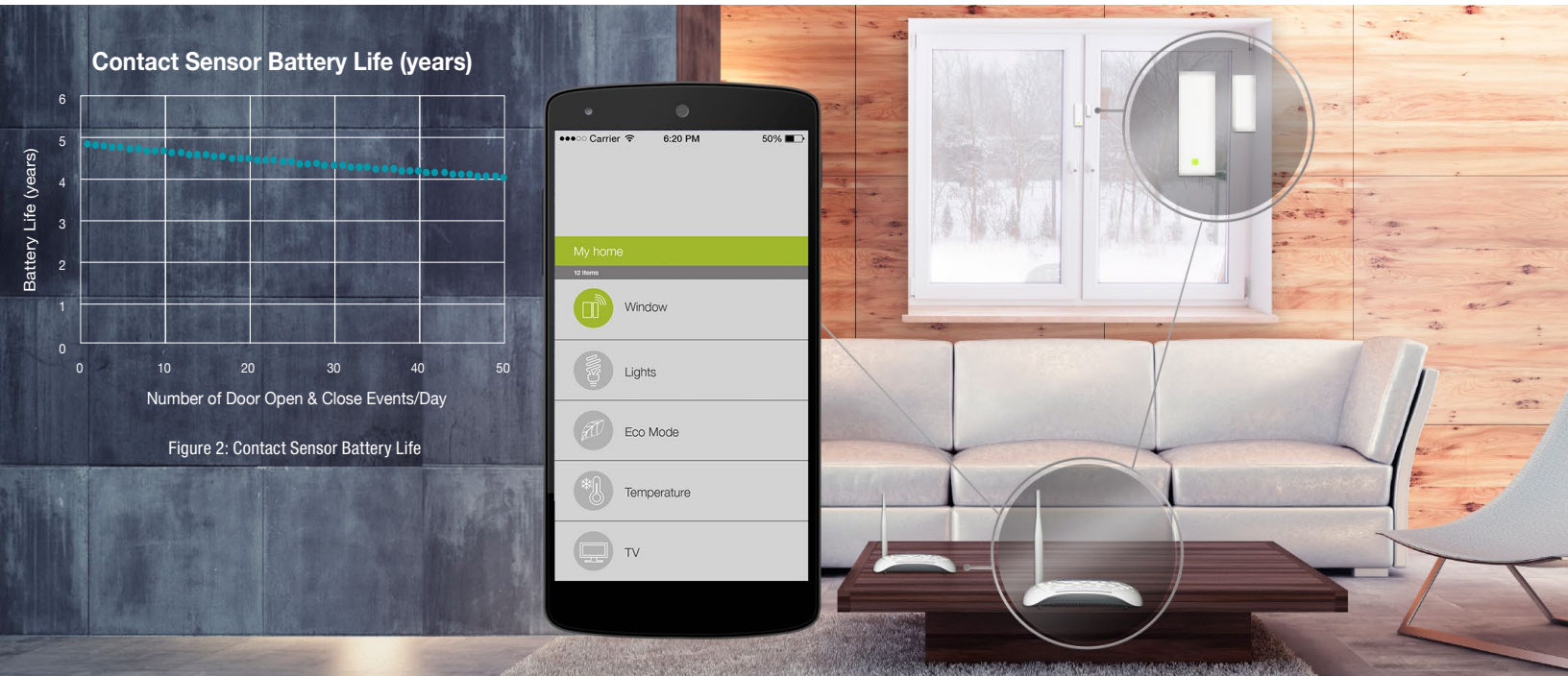


Figure 2: Contact Sensor Battery Life

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Space Constraints and Stored Power in the Design

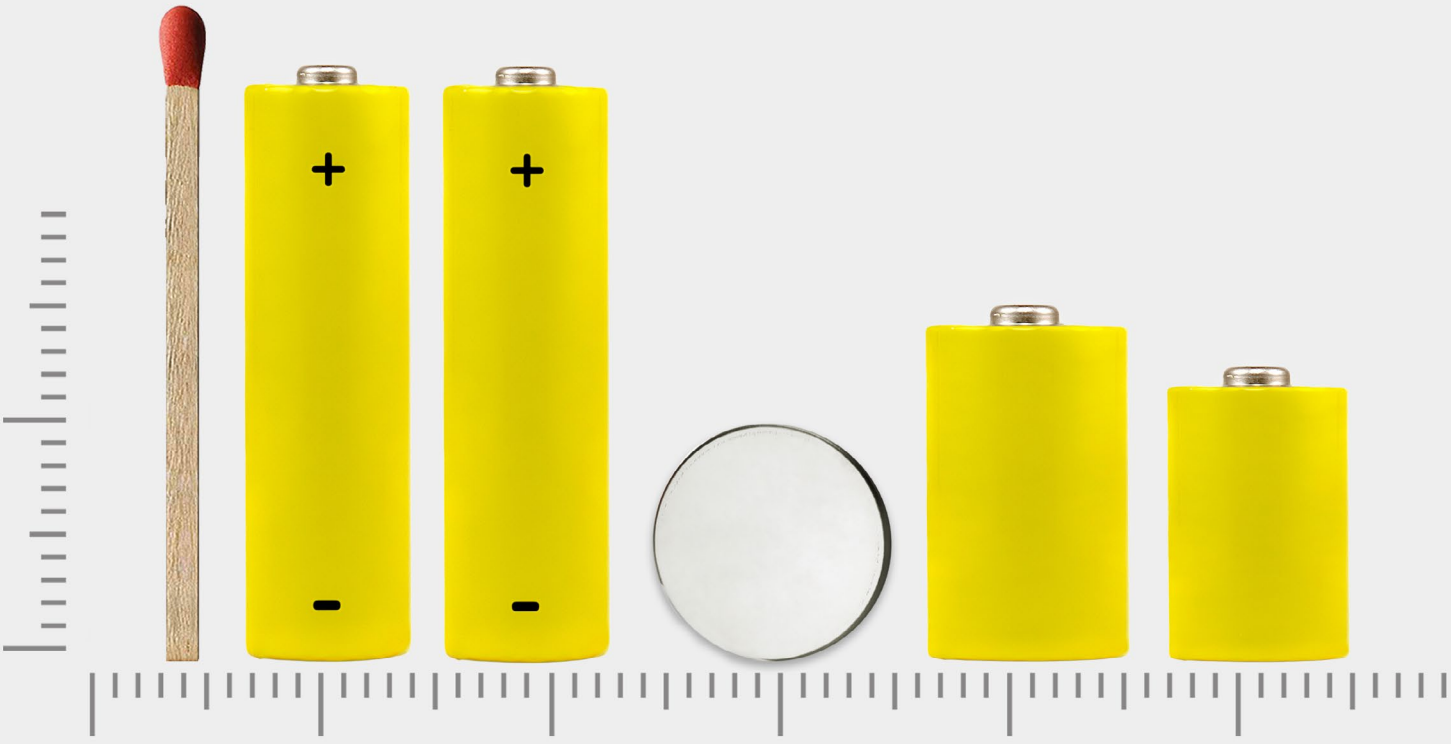
Once the target market and electronic components that affect battery life are considered, one must look at different battery options. In general, smaller batteries have less storage capability than larger ones and are described in milliamp-hours (mAh). In addition, a battery's chemical composition plays into its cost as well as its storage effectiveness.

Alkaline batteries, such as 1.5 volt AA and AAA, are very low-cost and possess high storage capabilities; however, they are large in size, prone to high leakage and are typically limited to handheld devices such as television remote controls. Also, two Alkaline batteries are commonly used to achieve a minimum three volt supply required in many consumer products.

Lithium batteries, such as CR2 or CR123A are smaller in size and weigh less than Alkaline, but have higher costs; therefore these batteries are favored in designs which benefit from small size and low leakage such as security sensors.

Even smaller coin-cell sized batteries, such as the CR2032 are efficient when it comes to storage versus size, and have better leakage rates in comparison to Alkaline. However given they possess less than one-fourth the storage to two AAA batteries, these coin-cell batteries are mainly used in designs optimized for very low power use. Table 2 provides an overview of these differences between these batteries.

	2x AAA	CR2032	CR123A	CR2
Material	Alkaline	LiMnO2*	Lithium	Lithium
Voltage	3 V	3 V	3 V	3 V
Capacity	1000 mAh	225 mAh	1500 mAh	800 mAh
Diameter	10.5 mm (x2)	20 mm	17 mm	15.6 mm
Height	45 mm	3.2 mm	34 mm	27 mm
Weight	24 g	3 g	17 g	11 g

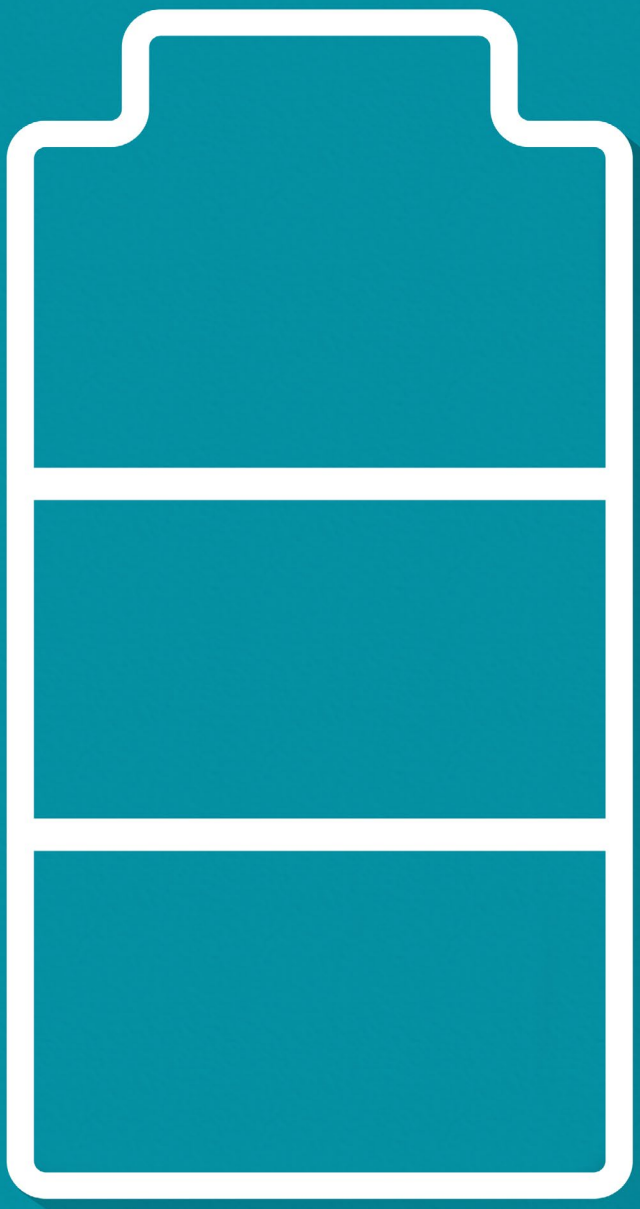


Results

When these design considerations are employed, the benefit is a lower-cost IoT sensor that is capable of achieving an increased battery life for a given target market.

For example the RD-0030-0201 ZigBee Contact Sensor Reference Design runs up to five years on a single CR2032. And the RD-0039-0201 ZigBee Capacitive-Sense Dimmer Switch Reference Design operates longer than typical battery-powered consumer remotes.

Some of the main contributors to this long battery life are the low-sleep current on the EM3587 ZigBee Pro transceiver as well as its ability to efficiently wake up and transmit data. This particular design is configured to provide non-entry status updates approximately once per minute, which also minimizes its battery use.



Jump Start Your Power Savings with Reference Designs

By carefully assessing the design considerations outlined in this article, a product designer can effectively achieve a small-form factor product able to reliably operate with a low-cost battery.

Silicon Labs offers an array of IoT reference designs that eliminate many of these design complexities and optimize battery use for particular applications such as a door/window sensor (RD-0030-0201) and capacitive-sense dimmer switch (RD-0039-0201). For more information or to evaluate one of these reference designs, please visit silabs.com/iot.