Using Nanotimers to Reduce IoT System Power Consumption by an Order of Magnitude

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Reducing power and cost are often two of the most crucial factors when designing a battery-powered system. Reducing power consumption plays an in important role to extend system life by reducing overall system current. Hence, as a result, power reduction paves the way to cut down system cost by reducing the required battery capacity.

This concept readily applies to Internet of Things (IoT) systems and connected products such as wearables, wireless sensors and building automation systems. The life of the growing number of wireless sensor end-nodes in the system all are constrained by one thing: power consumption of the end-node. Such sensor end nodes are typically powered by batteries, which last from several months to several years, depending on the power consumption of each end node. Here the "shelf-life" of a given sensor node is purely dependent on the lifetime of the battery. Though it is possible to simply replace the battery towards the end of the node's life, it is not always practical to do so as the replacement itself can become an expensive "total cost of ownership." Figure 1 shows the network topology of a typical IoT system.

Each sensor node typically consists of the following architecture:

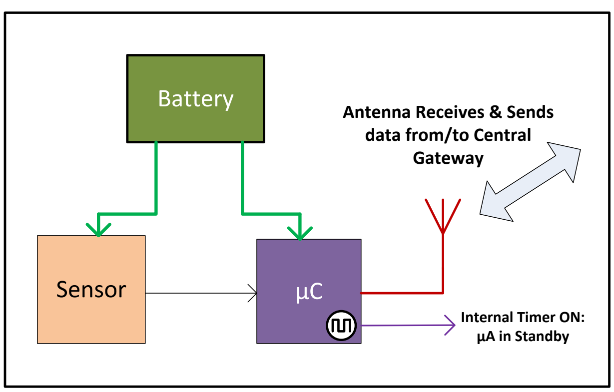

Figure 1. A Typical Sensor Node

Such simple IoT nodes collect and transmit data to a central gateway which is linked to the Internet and the cloud. Most IoT applications operate in burst mode, where the system is asleep most of its lifetime and is only woken up when it requires data from the sensor few times a day or to simply transmit and receive data during a specified time interval. Because of the duty-cycled nature of the system, the microcontroller operates in a low-power sleep mode most of the system's lifetime. Here, with the assumption that overall system low-power sleep or standby mode duration becomes significantly greater than the active state duration, the critical factor that begins to determine battery life is microcontroller sleep and system leakage currents during the low-power mode. For example, even in microcontroller's low power mode with a running internal oscillator, which duty-cycles the peripherals in the sensor node, off-state currents can still reach microamps.

In systems where the IoT application is configured as a star network as in Figure 1, where it is not important for the microcontroller to retain state or have control when it is in low power mode, a low-power system timer could be extremely beneficial to instead fully duty cycle the entire system end-node. TI's TPL5110 and TPL5111 nano-power system timers, with power consumption of only 35nA in active mode, can not only fully replace the power hungry internal timer of a microcontroller, but can also be used to power cycle the entire system to reduce power consumption by at least an order of magnitude than the microcontroller!

To further exemplify such as system and its current saving benefit, let's replace the system in Figure 1 with an integrated nanotimer:

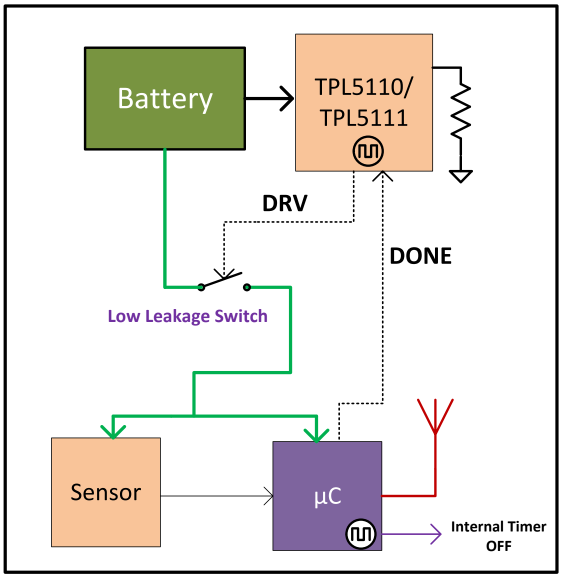

Figure 2. A Sensor Node with an Integrated Power-gating System Nanotimer

Figure 2 introduces both a power-gating nanotimer and a low leakage switch in a typical sensor node system. The nanotimer now takes control over power to all remaining circuitry in the system instead of the battery which provided constant, direct power to the system. The nanotimer will switch on power to the system at a programmed interval, such as once a minute or hour when the microcontroller needs to transmit sensor data, via a control signal (DRV) to the switch. When the microcontroller has finished reading and transmitting the sensor data, a DONE signal will be sent to the timer indicating the timer to shut down the entire system. By doing this, as shown in figure 2, the nanotimer and the switch are the only blocks that remain always powered on in the system. Then, overall battery life will solely be dependent on the system off-state duration and determined by the nanotimer operation current, the off-state leakage currents of the switch and any supply capacitor charging and discharging currents!

Figure 3 presents the timing of this behavior for the TPL5111 (where an NMOS switch is driven):

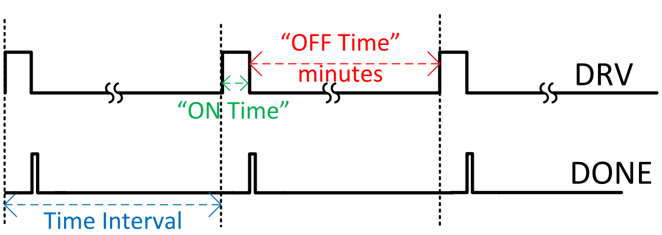

Figure 3. TPL5111 Timing

The TPL5111/5110 provide selectable timing intervals for duty cycling, from 100ms to 7200s, with a typical time base accuracy of 1%, through an external resistor connected between one of its pins and ground. For a given time interval, the system cycles between two states: an on-state and an off-state through the behavior of the DRV signal. The interval begins with the on-state, where the DRV signal goes high, resulting in the switch connecting the battery to the rest of the system. Here the microcontroller receives power, communicates with the sensor, transmits the data and sends a DONE signal to the nanotimer to signal the nanotimer to shut down the entire system. Upon registration of the DONE signal, the nanotimer transitions the system to the off-state. The DRV signal goes low, which disconnects the battery from rest of the system, for the remaining length of the selected time interval.

To understand the impact of this phenomenon on battery life, let's assume that system on-state current and duration remain fixed. Then, by varying the wakeup interval of the nanotimer and hence modifying the off-state duration time, we can begin to understand its direct effect on battery life. It also must be noted that current savings from this external nanotimer-integrated system topology (Figure 2) in the off-state is being directly compared to a topology without a nanotimer (as in Figure 1, which instead relies on the standby mode of the microcontroller and other peripherals to determine off-state currents).

Figure 4 shows the impact of modifying the off-state duration (system wake up interval) on estimated battery life using with and without a power-cycled system.

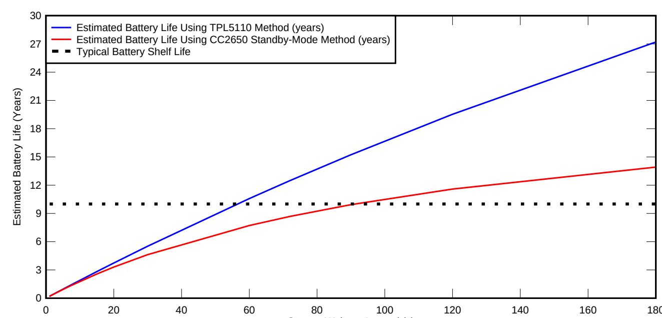

Figure 4. Estimated Battery Life Comparison: Nanotimer vs. MCU Standby Mode

In Figure 4, it's noted that the system using the nanotimer to duty cycle the system will always have a better estimated coin-cell battery life than a system using the microcontroller's standby mode. As a result battery life can easily be extended greater than ten years.

Alternative Device Recommendations

The TPL5110 and TPL5111, are specifically designed to power gate a system with or without an inverted output. For applications where switching off the entire system is not preferred, the TPL5010 can be used. The TPL5010, which also has a typical operating current of 35nA, can be used for system wake-up functionality replacing the functionality of the integrated microcontroller oscillator, which has high sleep currents, allowing the microcontroller to be placed in much lower power mode for added current savings.

Table 1. Alternative Device Recommendations

Device	Features	Implementation
TPL5110	Inverted DRV Polarity from TPL5111	Power-Gating System
TPL5010	WAKE Signal to Microcontroller, with watchdog functionality	Microcontroller Wake-Up

Table 2. Related TI Designs

Device	Reference Design
TPL5110	TIDA-00374
TPL5111	TIDA-00484
TPL5111	TIDA-00756

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