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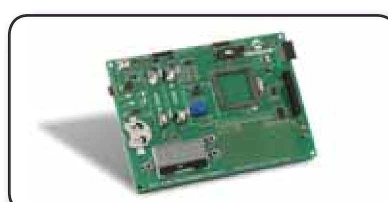

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Welcome to the 2012 Engineers' Guide to 8/16-bit Technologies

Analysts from the VDC Research embedded hardware team left this year's Embedded World conference with the impression that 2012 is the Year of the Microcontroller based on the level of technology activity in this area. And there's certainly a lot going on.Ultra-low-power advances are revolutionizing new applications, as our roundtable panel discusses in "How Low Can You Go?"

In this issue, we give you the information you need to make the right microcontroller, hardware, software and tools decision for your 8-bit and 16-bit applications, with plenty of inside scoop on innovative approaches to low-power designs. Anders Guldahl of Energy Micro helps you predict how well an MCU will perform over its lifetime on a single battery charge, and make intelligent architecture choices based on those demands. Ross Bannatyne of Silicon Labs talks about enabling technologies for wireless sensor networks, including cost-effective energy-harvesting devices, small and efficient energy-storage devices, and single-chip, ultra-low-power wireless MCUs.

We hope you enjoy this EECatalog Resource Guide. As always, we'd love to hear your feedback, thoughts and comments. Send them to info@extensionmedia.com.

Cheryl Berglund Coupé

Editor
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Cover Image: Test board of imec and Holst Centre's 8 bit, 30fJ/conversion step ADC. This extreme low-power ADC is applicable in ultra-low power radios, usable in a wide range of applications from healthcare to industrial (©imec, 2010)

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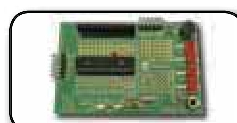

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How Low Can You Go?

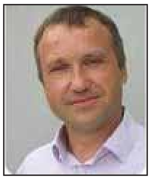
Ultra-low-power microcontroller technologies may revolutionize new designs.

By Cheryl Coupé, Editor

VDC Research embedded hardware team analysts left Embedded World 2012 with the impression that this is the Year of the Microcontroller based on the level of technology activity in this area. Our panelists provide insight into a range of exciting microcontroller innovations, from wireless connectivity to MEMS integration to ultra-low-power advances that may revolutionize new wearable technologies. See what Ralf Brederlow, MSP430 research and development manager and distinguished member of the Texas Instruments technical staff; Jacko Wilbrink, Atmel product marketing director; and Mike Salas, general manager for MCU products at Silicon Labs have to say.

EECatalog: Mobile design requirements continue to drive demands for smaller, lower-power devices. What technologies are microcontroller vendors implementing to keep up with this evolution?

Ralf Brederlow, Texas Instruments: Form factors are driven by both the silicon area needs of the microcontroller and by the package. One of the benefits of CMOS technology scaling is that cost and form factor come together nicely when moving to a smaller, sub-micron CMOS technology. TI has been investing in wafer scale packaging technology for its MCU products, which will match the package size to the silicon size. The remaining challenge is to keep low power (namely leakage currents) in advanced CMOS process nodes at a reasonable level. To address this challenge, TI has been investing in an ultra-low-power, advanced CMOS process technology for its next generation of microcontroller products.



Jacko Wilbrink, Atmel: System-level integration continues to push microcontroller manufacturers to look beyond the established standards like flash memory and power management. The integration of new technologies in the areas of communication and user interface, such as capacitive touch technology, wireless and power-line communication, might require acquisitions. Several companies have been acquired in the past years, including Quantum and ADD Semiconductor, by market-leading microcontroller vendors. Another technology step towards smaller devices is the use of wafer-level scale packaging.

And, with the migration towards smaller geometry technologies, controlling the impact of the higher leakage current while preserving high performance and fast wake-up from low-power modes is going to be the main challenge for low-power MCUs. Implementation of multiple power domains, low-power retention memories and flip-flops and voltage scaling are becoming standards. On the smaller geometry processes, the cost of functionality is going down and performance up, but the impact on power consumption can be significant. Finding the right balance will make the difference.

Mike Salas, Silicon Labs: Through a combination of innovative mixed-signal circuitry and thoughtfully designed peripherals, there are many different methods for reducing both size and power in microcontroller (MCU) designs. One of the best-known ways commonly used to reduce power is to minimize the internal operating voltage of the MCU. To accomplish this, many MCUs on the market today integrate internal low drop-out regulators (LDOs) on-chip. An LDO, for example, can take a 3.6 V input and regulate the internal voltage of the chip to a lower value, typically 1.8 V or less. In other words, taking a 3.6 V input using a linear regulator with a 1.8 V output results in a 50-percent conversion efficiency.

More advanced 8-bit embedded controllers, contain integrated switching regulators with much higher efficiency than their LDO counterparts. In many cases, these devices can have switching efficiencies as high as 85 percent. This high efficiency has the effect of reducing the total current sourced from the battery and greatly extending battery life for mobile systems.

Other examples for reducing power include "intelligent" analog peripherals that can operate autonomously without the need to interrupt the processor; fast-switching phase-locked loops (PLLs) that allow a designer to dynamically reduce clock speeds to reduce power; extensive wake-up circuitry that can enable a processor to go into extreme deep sleep modes without the need for a real-time clock (RTC), as well as many other similar mixed-signal methods specifically designed to reduce overall device power.

EECatalog: What trends are you seeing in the integration of micro-electromechanical systems (MEMS) with micro-controllers in embedded designs?

Brederlow, Texas Instruments: There is definitely a trend toward the integration of MEMS with silicon ICs. The first step is to combine the micromechanical device with an analog front end and, possibly, a digital interface. These functions naturally come together due to their voltage and area requirements either in a single piece of silicon or in a total system package. Combining these chips with a micro-controller is technically feasible as well, but removes some of the flexibility to integrate other functions to the system. A microcontroller can be re-used in the same system for many other functions including sleep control, non-MEMS-related sensing functions, interfacing and bridging between multiple other devices – just to name a few. Keeping the microcontroller separate can provide smaller and more flexible systems.

Wilbrink, Atmel: The compatibility in technology between MEMS and microcontrollers will determine if it is feasible and cost-effective to go for a single die. Alternatively, multiple dies can be put in the same package to increase system-level integration.

Salas, Silicon Labs: MEMS technology can be used to create different types of sensors such as accelerometers and pressure sensors. These MEMS-based sensors can be combined with MCUs in multichip modules (MCMs) optimized for specific applications, such as tire-pressure monitoring systems (TPMS), which integrate a MEMS pressure sensor, MCU and RF transceiver in a small-footprint module. To that end, it makes sense to develop more integrated solutions that combine MEMS technology with standard CMOS structures.

New developments in MEMS process technology underway today can enable the fabrication of MEMS resonators and sensor structures directly on top of standard CMOS wafers. This approach eliminates the need for boutique semiconductor processing technologies and enables new levels of performance, integration, and size by eliminating the electrical parasitics and packaging issues associated with traditional solutions that co-package a standalone MEMS device with a CMOS-based IC, such as an MCU, on the same monolithic die. Future MCUs that integrate a MEMS-based oscillator as a standard CMOS layer will eliminate the need for external crystal oscillators, thereby reducing system cost, complexity and size while enhancing reliability. Forthcoming MCUs with on-chip MEMS oscillators will provide ideal solutions for a wide range of cost-sensitive, high-volume consumer and embedded applications.

EECatalog: What are some of the challenges in integrating wireless connectivity with low-power microcontrollers?

Brederlow, Texas Instruments: CMOS technology fits well with RF design and small form factor microcontrollers – especially for low-power applications – so there is no technical boundary. The biggest challenge is to reduce RF transmission energy to the absolute minimum needed for the application. Range, and therefore RF output power, is given by the needs of the wireless link and the application. Understanding design needs is necessary, but integrating RF with a microcontroller can help developers optimize their application.

Salas, Silicon Labs: A relatively new class of device in the embedded market is the wireless microcontroller, which combines an MCU with an RF transceiver. Building a monolithic CMOS IC that integrates the MCU and radio functions in a single die poses several challenges. A critical design challenge is finding an optimum process technology that is suitable for both the flash memory and processing functions of an MCU as well as RF operation. A single-chip solution may drive an IC designer to pick a process optimized for one of the functions while taking a cost and/or performance hit on the other. Another significant challenge is the impact of the processor's digital blocks on the transceiver's RF performance.

On the smaller geometry processes, the cost of functionality is going down and performance up, but the impact on power consumption can be significant.

In a multichip module (MCM) approach, the impact of noise from the MCU's digital circuits on the RF frequency spectrum is minimized. Physical distances within the MCM ensure that the MCU's clock frequencies do not cause spurs and/or blocked channels on the radio. The impact on critical RF specifications such as sensitivity and range is also minimized, ensuring interoperability without compromising radio performance. An MCM approach also provides numerous benefits for hybrid wireless MCU solution including lower power consumption and reduced cost, complexity and BOM count – all achieved while ensuring exceptional RF performance.

EECatalog: What new microcontroller technologies will help developers address ultra-low power application requirements?

Brederlow, Texas Instruments: Ferroelectric random access memory (FRAM). This game-changing technology significantly reduces the most energy-consuming function in a microcontroller – accessing memory data. For example, embedded FRAM technology gives developers up to 100x power savings when writing memory data. This enables not only dramatic power savings, but for example, may make software upgrades completely transparent to the end user.

Embedded FRAM technology gives developers up to 100x power savings when writing memory data.

Wilbrink, Atmel: DMAs, sleep walking and the event system allow peripherals to operate without CPU intervention. Hardware provides lower power than software implementations but takes out some of the flexibility, so is well-suited for established peripherals or high-volume ASSPs. Power-analysis tools will assist the developers to optimize their code for lower power operation.

Salas, Silicon Labs: MCU suppliers can employ three strategies to address ultra-low power applications: Maximize energy transfer efficiency (an approach that is essential for battery-operated systems), reduce time in active mode and minimize power in sleep mode.

Greater efficiency in transferring energy from the battery results in less energy lost as heat dissipation, which reduces system-level power consumption and extends battery life. Some state-of-the-art, ultra-low-power MCUs integrate an on-chip dc-dc buck converter that enables significantly higher efficiency in voltage conversion compared to a linear regulator, resulting in energy transfer efficiencies of up to 85 percent. An on-chip buck converter can supply power not only for the MCU itself but also for other circuits in the system such as an RF transceiver, resulting in not only superior energy efficiency but also lower component count and BOM cost.

Since MCUs use maximum power in active mode, many ultra-low-power MCUs incorporate advanced technologies designed to reduce the time spent in active mode. For example, an on-chip dedicated packet processing engine with hardware acceleration blocks can enable more than a fivefold increase in RF message processing speed, allowing the CPU to remain idle during transactions, thereby reducing active time and the current load on the battery.

Cheryl Berglund Coupé is editor of EECatalog.com. Her articles have appeared in EE Times, Electronic Business, Microsoft Embedded Review and Windows Developer's Journal and she has developed presentations for the Embedded Systems Conference and ICSPAT. She has held a variety of production, technical marketing and writing positions within technology companies and agencies in the Northwest.

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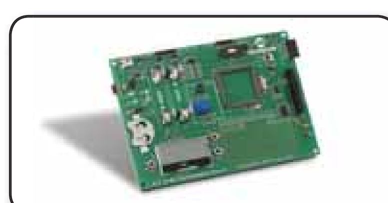

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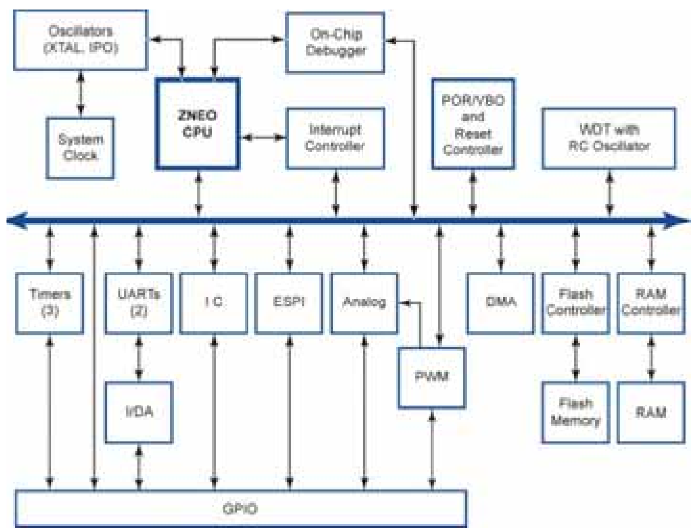
Efficient Brushless DC Motor Control with Zilog® Products

By Zilog

Many different types of induction motors have been available on the market for decades, including AC induction, brushed DC and brushless DC motors. Each type of motor has different advantages and disadvantages. The DC Brushed motors are easier to operate, however, tend to require more maintenance due to the additional wear and tear caused from the multiple contacts to the rotating shaft. The AC induction motor and the DC Brushed motors tend to not be as efficient under certain operating conditions. The brushless DC (BLDC) motor requires more intelligence to operate but tend to be virtually maintenance free. The control intelligence provides the ability to operate the BLDC motor using sophisticated control schemes to run at optimum efficiency.

World-wide, industries are growing more demanding on efficiency and sophistication for BLDC motor drives. BLDC motors are found in industries such as white goods, automotive, cooling, aero space, medical, and Industrial automation. Each of these implementations within the different industries, have specialized operational requirements. To meet these requirements, microcontrollers are a natural choice as they offer the flexibility and ease of implementation to meet the most stringent design requirements demanded by the industry.

There are many microcontroller based solutions available on the market today, ranging from low cost 8-bit devices to higher performance 16 and 32-bit microcontrollers. Zilog provides both 8-bit and 16-bit microcontrollers that are designed to provide outstanding motor control. These parts promote cost sensitive and fast time-to marked designs. Zilog's microcontroller architecture, combined with the implementation of efficient firmware algorithms allow for reliable three-phase BLDC motor control at a relative low MIPS rate, which is important because if design constraints allow it, running a micro-controller at the lowest possible clock frequency allows for less MCU power consumption and less linear switching power losses, and in most cases, it helps to avoid EMI related problems.



The demand for efficiency, reliability and low cost are accelerating the BLDC motor usage.

The versatility combined with sophisticated control schemes requires an intelligent controller to optimize efficiency. Zilog motor control solutions step up to help developers implement these controls.

Zilog products provide the tools necessary to lower the cost, reduce electrical noise, and reduce the learning curve while achieving a faster time to market. Further product information on Zilog microcontrollers and development tools can be obtained at www.zilog.com.

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Energy Harvesting Comes of Age for Wireless Sensor Networks

Enabling technologies include cost-effective energy-harvesting devices, small and efficient energy-storage devices and single-chip, ultra-low-power wireless MCUs.

By Ross Bannatyne, Silicon Labs

As wireless sensor nodes become commonplace in building automation, security systems, embedded controls, agricultural technology, infrastructure monitoring, asset management and medical monitoring systems, it makes sense to power these sensor networks with reliable, economical and sustainable sources of energy. In many cases, a primary battery cell provides a simple, low-cost power source for a wireless sensor node.

However, there are numerous examples in which an energy-harvesting system can provide a cost-effective alternative for wireless sensor nodes, eliminating the need for batteries or mains power supplies. Running mains power to wireless sensors is often neither possible nor convenient, and since wireless sensor nodes are often placed in hard-to-reach locations, changing batteries regularly can be costly and inconvenient.

In some applications, battery replacement cost can be orders of magnitude greater than the cost of the battery itself or even the cost of a self-sustaining energy-harvesting system. For example, a simple service call to replace a battery in a wireless utility meter may cost hundreds of dollars. Wireless, sensor-based infrastructure-monitoring systems also pose challenges for battery operation. Sensors buried inside suspension bridges and highway overpasses provide access to a tremendous amount of mechanical energy through the constant vibration of passing vehicles. This can make energy harvesting much more attractive than traditional batteries in these applications, given the challenging physical environments and the cost of servicing the sensor nodes.

In recent years, advances in energy-storage technologies such as supercapacitors and thin-film batteries (TFBs) have provided cost-effective building blocks for energy-harvesting systems. Mixed-signal microcontrollers (MCUs) that can perform useful functions, such as algorithmic control and wireless communications, also have become more cost-effective and exceptionally power-efficient. These technology innovations are driving the evolution of energy-harvesting-based systems from today's niche products,such as calculators and wrist watches, to their widespread deployment in wireless sensor nodes.

Although systems powered by harvested energy sources have existed for many years, developers have found it challenging to implement wireless sensor nodes within very low power budgets. The off-the-shelf availability of ultra-low-power wireless MCUs and transceivers, coupled with thin-film battery and solar-cell technologies, has made it feasible to design self-sustaining wireless sensor nodes powered by harvested energy sources.

Optimizing Wireless Systems for Ultra-Low Power

Low-power modes on MCUs and wireless transceivers have been optimized in recent years to enable effective power management in wireless sensor applications. Figure 1 illustrates a typical wireless sensor node power cycle.

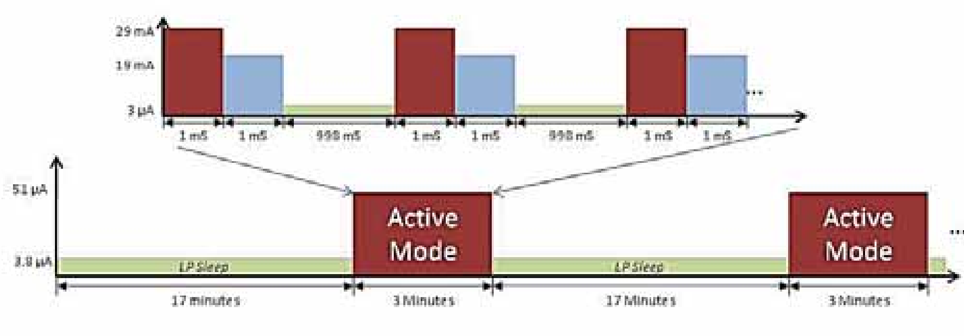


Figure 1: Wireless sensor node power cycle

The wireless sensor node designer's goal is to minimize power consumption by optimizing the relative amount of time spent in low-power sleep mode and reducing the active mode time, as shown in Figure 1. A fast processing core enables the MCU to execute the control algorithm very quickly, enabling a rapid return to low-power sleep mode and thereby minimizing the power-hungry active mode.

Wireless sensor nodes spend most of their time in sleep mode. The only subsystem that stays awake is the real-time clock (RTC). The RTC keeps time and wakes up the wireless sensor node to measure a sensor input. Low-power RTCs typically integrated onto microcontrollers consume only a few hundred nanoamps. It is important to minimize the system's wake-up time because power is consumed during this time. An RTC uses a free-running counter in the MCU timer subsystem. When the free-running counter rolls over, it generates an interrupt that wakes up the MCU often. If a 32.768 kHz crystal is used, a 16-bit free-running counter rolls over every two seconds and wakes up the MCU. If a wider free-running counter, such as a 32-bit counter, is used, the periodic interrupt occurs less often, and additional power may be conserved.

When a wireless sensor node wakes up, it is usually intended to measure a sensor signal using the analog-to-digital converter (ADC). It is important to note the wake-up time of the ADC as well as the digital wake-up time since there is little point in waking up the CPU very quickly if the ADC takes an order of magnitude longer to wake up. A low-power MCU should wake up both the CPU and the ADC in a couple of microseconds. When the sensor node is awake, the MCU current is typically approximately 160 µA/MHz. When the sensor data has been measured, the algorithm running in the MCU decides whether the data should be transmitted by the radio. To send the data, a low-power ISM band radio consumes somewhat less than 30mA for only a millisecond or so. When this peak current is averaged out, the overall average current consumption of the wireless sensor node is in the low microampere range.

The radio transmission consumes most of the current in the system. Minimizing the amount of time the radio is on is essential to conserving energy. One way to achieve this is to avoid complicated communications protocols that require the transmission of many bits of data. Steering clear of standards with large protocol overhead is desirable when power is at a premium. It is also important to consider the desired range. Wireless range can be traded for power consumption. An interesting approach to balancing this trade-off is to use dynamic ranging, which allows full-power transmissions when maximum energy is available but reduces the output power level when harvested energy is limited.

Another way to reduce the wireless sensor node's power consumption is to minimize the number of chips used in the system. Fewer chips on the printed circuit board (PCB) result in lower leakage current losses. Using an MCU that integrates as many functions as possible ultimately helps reduce overall current consumption. If a dc-dc converter is integrated onto the MCU, it can be switched off when the MCU is sleeping. Silicon Labs' Si10xx wireless MCU, for example, contains an integrated dc-dc converter that allows the system to be powered by a single AAA alkaline battery and still achieve 13dB output power at the antenna. Because of its high level of integration and ultra-low power consumption, the Si10xx wireless MCUs have been used successfully in energy harvesting wireless sensor nodes.

Managing Harvested Energy

An important consideration in the development of an energy harvesting sensor node is to ensure that there is always enough energy available to power the system, as shown in Figure 2.

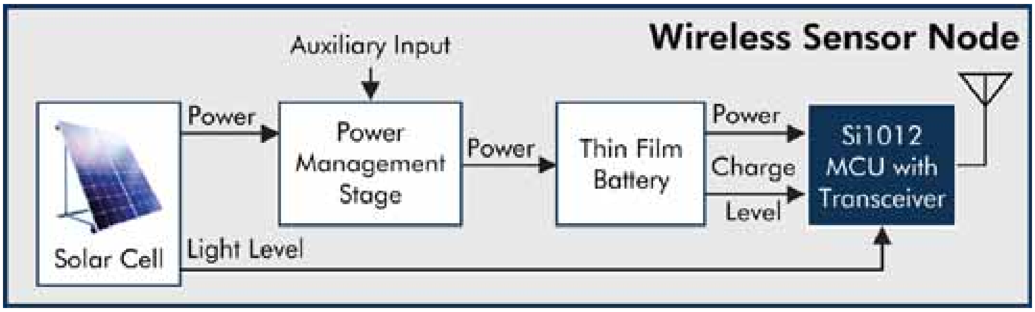


Figure 2: Typical energy harvesting system

This energy harvesting system uses a solar cell array to harvest energy. A solar cell unit, such as a Sanyo AM-1815, delivers approximately 40 µA when a 200Lx light level is available. It is reasonable to expect this level of light in an office with a window but no direct sunlight on the cell. The 40 µA of current that the array generates is fed into a power management circuit and trickle-charged into a thin-film battery (TFB). When selecting power management chips, it is necessary to pay attention to the leakage current characteristics, which are normally only a few microamperes. However, with only 40 µA coming into the TFB, this tiny amount of leakage must be understood and accounted for. A thin-film battery, such as the Infinite Power Solutions MEC101-7SES, provides a 0.7mAh capacity, which is a reasonable amount of energy for a wireless sensor node system. At a 200Lx level of light, this TFB charges up fully in around 17.5 hours.

This combination of solar cell, power management and storage technologies provides an adequate level of energy for a wireless sensor node. The next important decision in the design process is the selection of a low-power MCU and wireless transceiver combination that can operate effectively from a limited energy source. A Silicon Labs

Si1012 wireless MCU is an ideal choice because of its extremely low power consumption and high-performance radio characteristics. This wireless MCU uses a programmable sub-GHz ISM radio in a single-chip configuration with an ultra-low-power MCU; the highly integrated device, which also includes an on-chip temperature sensor, is essentially a wireless sensor node on a chip.

With the hardware configured as shown in Figure 2, the control problem to be considered is how to operate the wireless sensor node at a duty ratio that does not deplete the TFB capacity that is itself being trickle-charged by the solar cell. Using the low-power design techniques discussed earlier, it is possible to reduce the average current of the wireless sensor node to around 51 μA (including power management leakage) while transmitting sensor data every second for three minutes. That is low enough to allow the system to operate and stay fully charged in minimal lighting conditions.

In some applications, battery replacement cost can be orders of magnitude greater than the cost of the battery itself or even the cost of a self-sustaining energy-harvesting system.

If the light input is reduced to 0Lx, the wireless sensor node continues to operate and transmit for 64 hours before the TFB capacity is exhausted (assuming the three-minute transmit period is repeated every 20 minutes). A simple spreadsheet detailing expected input energy (i.e., how much light is available) versus output energy (how often the node is required to transmit) is the only tool that a designer needs to optimize the system. If more than adequate light is expected, this energy can be used to increase the range of the transmitter. This type of system allows a range up to 300 feet, depending on the exact conditions.

Many different types of energy harvesting sources can be used to power a wireless sensor node instead of using a solar cell (or even in combination with solar energy). If a wireless sensor node is placed in a location without ready access to a light source, the node can be powered by thermal, vibration (piezoelectric) or radio wave energy harvesting sources. The power management, storage and wireless sensor node circuits are essentially the same as those used in the solar cell example. Regardless of the harvested energy source, the system design principles are the same: a limited source of energy is captured and stored in a TFB and then used to power an ultra-low-power wireless sensor node.

Enabling "Green" Wireless Sensor Nodes

The ability to power wireless sensor nodes from harvested energy sources enables embedded designers to develop wireless networking systems that offer significantly reduced cost of ownership for the end-user as well as green benefits for the environment such as fewer batteries ending up in landfills. The cost of replacing batteries housed in out-of-the-way sensor node locations can be quite significant. Some wireless sensor nodes, for example, can be embedded in structures, such as buildings or bridges, or even buried underground.

The three key enabling technologies needed to create self-sustaining wireless sensor nodes are readily available today: cost-effective energy harvesting devices, small and efficient energy storage devices and single-chip ultra-low-power wireless MCUs. Wireless sensor nodes powered by harvested energy sources will soon become commercially viable and commonplace technologies used in our homes, offices, factories and infrastructure.

Ross Bannatyne serves as an MCU marketing manager for Silicon Laboratories' Embedded Mixed-Signal division. Mr. Bannatyne is the author of numerous technical articles as well as two textbooks: Using Microprocessors and Microcomputers (Prentice-Hall) and Electronic Control Systems (SAE). Mr. Bannatyne holds a master's degree in business administration from the University of Texas at Austin and a bachelor's degree in electrical engineering with honors from the University of Edinburgh in Scotland.

Capacitive Proximity Sensing

Remote interaction with user interface offers new opportunities for product differentiation.

By Patrick Hanley, Atmel

Capacitive touch technology is still all the rave in the user-interface space, as it rightfully should be. It is becoming rarer that someone wouldn't have a smartphone with a touchscreen on it today. And the thought of carrying a paper planner or even a notepad around is almost archaic as your capacitive touchscreen tablet can do all of that, plus enable you to surf the web, read a book, look at pictures and chat with friends – all through one device. The interface to these products helps to make the appeal associated with them, the ease of use and the fun they are to interact with. Capacitive interfaces enable all this, with no moving components which would break down over time, no gaps or creases which can get containments in them which are really tough to clean, low power to make it so your battery life is longer and the ability to reliably detect and reject a finger press when it is supposed to, even in noisy conditions. Since they already offer so much, how could you make them better? What if there was a way you could interact with your phone, remote control, thermostat, etc. without actually touching a surface? Almost as if the electrical device knows what you are going to do before you actually do it? That remote know-how is called proximity detection.

> ***What if there was a way you could interact with your phone, remote control, thermostat, etc. without actually touching a surface?***

Imagine as you arrive home from a long day at work, open the door and move your hand over the area where you know your home control panel is located; this home control panel then lights up and comes alive through capacitive proximity detection. It provides you with options to turn the lights on, open the blinds and listen to music simply by touching it. There are many other potentially revolutionary applications that could be driven by proximity sensing. Although the FCC has regulations in place around specific absorption rates (SAR), which specify how much WiFi and RF signals that electronics are allowed to emit in the close presence of a human being, many tablets are implementing capacitive proximity detection within these allowable limits. For example, some mobile phones are upgrading their infrared sensor in order to avoid problems such as direct sunlight turning your screen off or on unexpectedly. A wireless mouse is yet another example, where the user can immediately move the cursor with the mouse instead of having to shake-it to wake it up. Automotive applications include car handles, center consoles, light fixtures and even the trunk so you can open it with both hands full of groceries! As you can see, proximity detection can take an already great technology based on capacitive sensing and make it even more interactive.

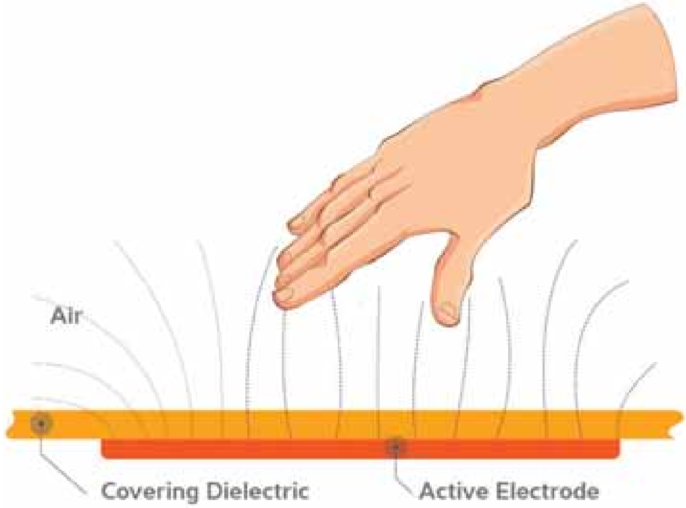
Not only does this interface technology add a "cool" element to your device, but this can also improve many other aspects of your product:

1. Power – Power increases the length of time that your device can run on one set of batteries since the power consumption is actually less. Let's say there are 16 - buttons on a panel; instead of all 16 - capacitive buttons having to continuously wake up, determine if there is a finger press and then go back to sleep, over and over, now the buttons can stay in sleep mode until after the proximity detection has been triggered. This will save upwards of 16x the power.

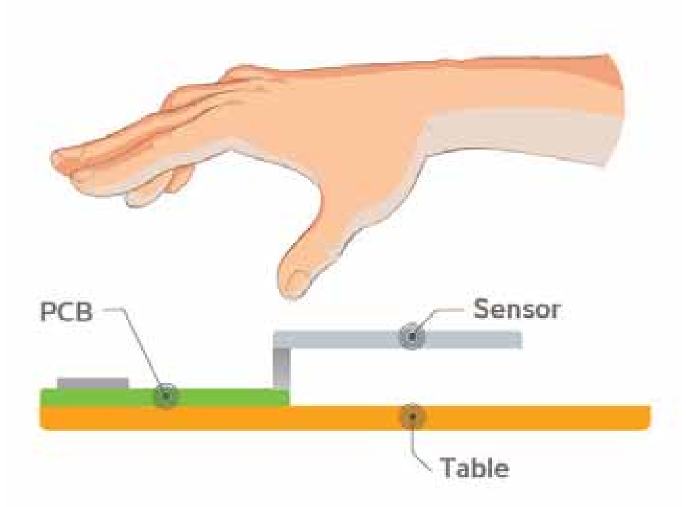
2. 3D Gesturing – With proximity ranges as far as 10" (25cm), it is possible to implement 3D gestures so that users can simply wave their hand in front of the sensors and increase the volume of the TV or turn the page of their book, etc. There are no limits to what could potentially be unlocked taking this technology from two dimensions to three.

3. Replacing IR – Today's most common method of doing proximity detection in electronics is infrared (IR). There are many downsides to IR, though, that capacitive proximity detection can overcome. IR needs a lot of power to drive the LED and can be very expensive, unlike capacitive. IR has to have visible windows on the screen; also not needed with capacitive. IR can be fooled by changing lighting conditions like direct sunlight; this will not happen with capacitive.

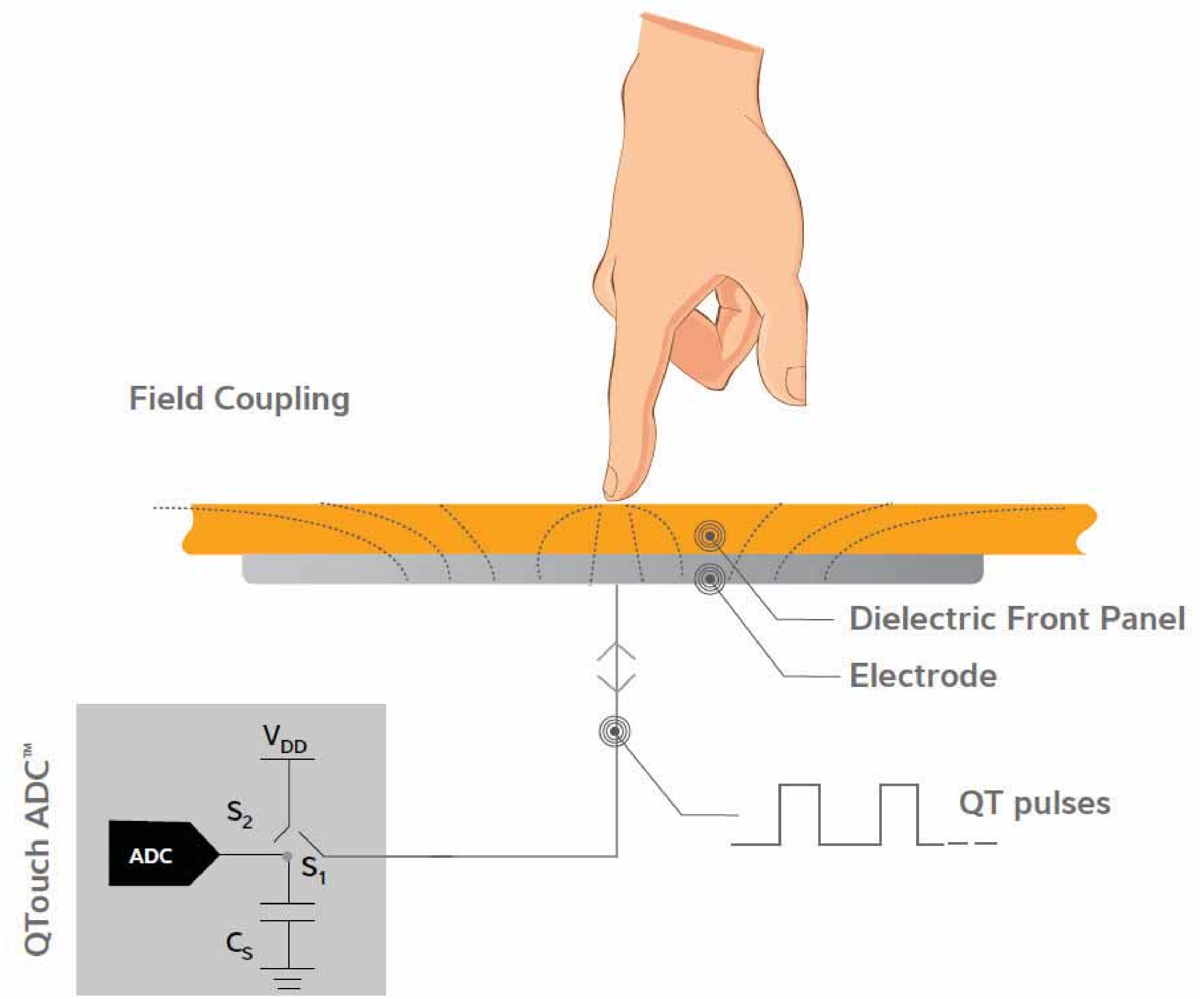
There are two primary implementations of capacitive sensing: self capacitance, where you are measuring the capacitance delta between one electrode and earth ground (your hand); and mutual capacitance, where you are measuring the capacitance change between two electrodes. There are many variations of each of these (software,



Self-capacitance proximity detection shows hand coupling with the electricfield.



A hand over a table that has a PCB and sensor resting on it to detect proximity.



QTouchADC sensing algorithm is based on standard self-capacitance; the SAR ADC is over-sampled.

hardware blocks, ADC, etc.), but the same overarching concept reigns true throughout. Today, the self-capacitance implementation seems to serve best for longer range proximity distances. The device charges a sense electrode of unknown capacitance to a known potential. The electrode is typically a copper area on a PCB (could be any conductive material, including ITO). The sensor layout can be done in a variety of ways, but the most effective and efficient is the loop sensor (or commonly called loop antenna). This is just a copper trace of approx 10mm thick around the outside area that is to be proximity enabled. For a thermostat this would likely be a loop around the outside of the entire box, completely invisible to the user, but able to drive long-range detection. The larger the loop, the longer the total range (diminishing returns at a certain size). As with all technologies, there are trade-offs associated with power, response rate and noise immunity. If you can increase the acquisition rate with shorter burst lengths, this will result in lower power consumption and increased proximity range. The total reliable range you can achieve will depend on all of these factors, plus your particular application, packaging and environmental conditions.

An animation of a hand approaching a dead-fronted thermostat and it waking-up.

All capacitive proximity can be setup to do physical touch sensing (where the finger makes contact with the sensor) or tuned to do proximity sensing (where the hand only needs to couple with the sensor's e-field). Ideally, the same IC can drive both proximity sensing and standard button, slider and wheel implementations, while minimizing the number of external components required.

There are other forms of proximity detection. As discussed earlier, the most commonly used today is IR / PIR, but it has its trade-offs. There are also magnetic, optical, ultrasonic and others. Each has their respective pros and cons associated with them. Capacitive proximity detection, in most applications and environmental conditions, offers the most advantages (product differentiation, low power, low cost, no visible sensors, etc.), from physically touching a surface to a distance away of 6" or 15cms reliably (capacitive proximity is capable of much longer ranges, just with all the outside factors and trade-offs associated with them). This revolutionary technology can make all of the above benefits happen so that you are able to differentiate your end product.

Patrick Hanley joined Atmel Corporation in August 2010 as the marketing manager for the touch technology team focusing on buttons, sliders and wheels (BSW). Mr. Hanley's responsibility includes defining new products, pricing, channel management, and many other functions for the success of the BSW product line within the Touch Business Unit at Atmel. Mr. Hanley holds a bachelor of science degree in electrical engineering (BSEE) and a minor in business administration from Marquette University in Milwaukee, WI.

Real-Time Clock Adds Accurate Timekeeping to Microcontroller System

How to add an RTC that supports the 1-Wire protocol to a microcontroller-based system.

By Aaron Minor, Maxim Integrated Products Inc.

Introduction

Many microcontrollers include timer circuits, but only a few include a battery-backed real-time clock (RTC). Yet many applications require an RTC, which you can easily add by using a 1-Wire® network. This article explains how to add an RTC that supports the 1-Wire protocol to a microcontroller-based system. The necessary code is included. It explains principles and techniques that apply equally well to any microcontroller whose general-purpose I/O (GPIO) pins are capable of driving the 1-Wire communications protocol.

Design Goals

This demonstration shows how to implement methods for performing the following operations using the 1-Wire interface:

- Read the 64-bit ROM ID of the selected RTC
- Start and stop the RTC
- Read the current value of the RTC
- Set the RTC to a new value

The demo will also display the current RTC value in a readable format, i.e., convert from raw seconds to a year/month/day/time format. It will allow the user to modify the clock value by incrementing the various converted values (e.g., year, month, day) rather than calculating and entering a new value for the seconds.

As for any application that stores a count of seconds for the date/time value, we must choose a zero baseline. For this application, that baseline is January 1, 2000, at 12:00:00 AM, for which the raw seconds count is zero (00000000h).

System Setup

The 1-Wire interface is fundamental to this article. It lets you add an RTC that supports the 1-Wire protocol to any microcontroller. The DS1904 RTC iButton® will be used in this example. This application uses the MAXQ610 microcontroller because it can easily communicate with an RTC, set clock and control values, and convert between raw seconds and the corresponding calendar date, even when using assembly language.

The low-power MAXQ610 is well-suited for portable applications, but it lacks a battery-backed RTC. You can, however, connect this microcontroller to a dedicated RTC by using one of its GPIO pins. Demonstration code for the microcontroller has been written using the assembly-based MAX-IDE environment. It is designed to run on the Maxim® evaluation (EV) kit, MAXQ610-KIT. Source code, project files, and additional documentation are all available for download here: *www.maxim-ic.com/an4641-software*.

Running the Application

You need the following hardware to run the demonstration code:

- MAXQ610-KIT EV kit
- 5VDC power supply
- Serial-to-JTAG or USB-to-JTAG interface board
- JTAG programming cable (2 × 5 ribbon cable with 0.100in. pin connectors)
- Straight-through DB9 serial-interface cable
- PC with available COM port or USB-to-serial adapter
- DS1904L-F5# RTC iButton
- DS9094F+ through-hole-mount iButton clip

The code runs on the MAXQ610 EV kit. An iButton clip (DS9094F+) is installed in the prototyping area and a DS1904L-F5# RTC iButton inserted in the iButton clip. Connections are then made from the iButton clip:

- Connect the GROUND pin of the iButton clip (the pin labeled "+" on the top side of the clip that contacts the back/unlabeled side of the DS1904) to one of the GND test points on the MAXQ610 EV kit.
- Connect the DATA pin of the iButton clip (the pin on the inside of the clip that contacts the front/labeled side of the DS1904) to port pin P2.0 (header pin P3.1) on the MAXQ610 EV kit.

You also need the following software:

- MAX-IDE assembly language development environment for a MAXQ® microcontroller

- Microcontroller Tool Kit (MTK) or other terminal emulator with "dumb terminal" mode

The latest installation package and documentation for the MAX-IDE environment are available at MAXQ Microcontroller.

Data for the RTC is transferred serially over the 1-Wire protocol; only a single data lead and a ground return are required. This RTC contains a unique 64-bit ID, factory-lasered in ROM and an RTC/calendar implemented as a binary counter. It resides in a durable MicroCan package that resists dirt, moisture, and shock. This package can be mounted on almost any surface, including printed circuit boards (PCBs) and plastic key fobs. When operating, the RTC adds a calendar date, time and date stamp, stopwatch, hour meter, interval timer, and logbook function to any electronic device or embedded application that uses a microcontroller.

The RTC contains a 32-bit counter with 1-second resolution, which provides a range of approximately 136 years. All the hardware needed to keep the clock running, including the 32kHz crystal and a battery, are sealed inside. The resulting device has an operating life greater than 10 years, with clock accuracy of approximately ±2 minutes per month at a room temperature of +25°C. Operating mode (halted or running) and the value of the clock counter can be read or written using the 1-Wire interface.

Driving the 1-Wire Network

The 1-Wire interface provides power and communications over a single wire plus a single ground return. This means that a single port pin enables a microcontroller to communicate with a 1-Wire sensor.

A 1-Wire network operates with a single master and multiple slaves in multidrop configurations. Timing requirements are flexible, allowing all slaves to synchronize with the master at communication speeds up to 16kbps. Each 1-Wire sensor has a globally unique 64-bit ROM ID, so the 1-Wire master selects slaves individually and precisely, regardless of their physical position on the network.

The 1-Wire line operates in an open-drain mode: the master (and also the slaves, when their output is requested) indicates "zero" by pulling the line to ground, or "one" by letting it float high. This operation is normally implemented with a discrete pullup resistor attached between the line and VCC. Microcontrollers with a weak pullup mode on their port pins (like the MAXQ610) can simply switch the port pin back to that mode and let the line float high; no external resistor is required. Because the master and slaves pull the line low and never actively pull it high, the 1-Wire network operates in a wired-OR configuration. This approach prevents line conflict when multiple slaves attempt to transmit on the 1-Wire bus simultaneously.

To drive the 1-Wire network, the microcontroller uses software to generate time slots on a single pin. All time slots are initiated by the 1-Wire master, so the microcontroller does not need to monitor the 1-Wire line when it is not communicating with a slave device.[1]

- **Reset** time slots are approximately 1ms wide. For the first half of the time slot, the master (MAXQ610) holds the 1-Wire line low. Halfway through the time slot, it releases the 1-Wire line and lets it float high. Any 1-Wire slaves present on the line respond by resetting themselves and pulling the line down during the second half of the time slot. The slaves then generate a presence pulse, which indicates to the master that one or more slaves are present and ready to communicate.

- **Write** time slots are 60µs to 120µs wide, and used by the master to transmit bits (0 or 1) to one or more slaves. Both types of write time slots start with the master pulling the line low for at least one microsecond. To transmit a 1, the master then releases the line (lets it float high) for the rest of the time slot. To transmit a 0, the master holds the line low until the end of the timeslot.

- **Read** time slots are 60µs to 120µs wide, and used by the master to read bits (0 or 1) from a slave device. The time slot starts with the master pulling the line low for at least one microsecond. The master then releases the line, allowing the slave to either hold it low (0) or let it float high (1). Midway through the time slot, the master samples the line to read the bit value from the slave.

The MAXQ610 runs at about 12 instruction cycles per microsecond at 12MHz, so it easily executes the standard 1-Wire protocol in software using a port pin (P2.0). It implements read time slots in a similar manner. Note that all data bytes on the 1-Wire bus are transmitted least significant bit (LSB) first.

The value of the pullup resistor on the 1-Wire bus varies according to the number of devices on the network, but is typically specified at 4kΩ to 5kΩ. In contrast, the weak pullup resistor on the MAXQ610 port pin varies from 15kΩ to 40kΩ, depending on the operating voltage. To avoid an excessive time interval on the 1-Wire bus as it floats high from the low state, the code briefly drives the bus (via P2.0) with a normal high state that "snaps" the bus to the high state before setting P2.0 to the normal weak-pullup mode. This action causes no disruption on the 1-Wire bus if, that is, you avoid those time intervals in which the slave might attempt to pull the bus low. As an alternative, you can put a physical external pullup resistor on the 1-Wire bus, and then drive the port pin in standard low mode for a zero state and to the tristate mode for a high state.

Starting, Stopping, and Setting the Clock

Because more than one 1-Wire device may be present on the 1-Wire bus, communication with these devices proceeds in two stages. The bus master first selects a 1-Wire device with which to communicate, and then issues the communication.[2] After the bus master transmits a reset pulse, all slave devices on the 1-Wire bus return to the default unselected state. Several commands are then available to the bus master for selecting the device with which it will communicate in the second stage. The following commands use the 64-bit ROM ID associated with each slave device. The commands are supported by all 1-Wire devices.

Skip ROM [CCh]

This single-byte command activates all slave devices on the bus. It is useful if only a single 1-Wire device is present, or if the bus master needs to send the same command to all 1-Wire devices on the bus. The application above has only one device on the bus (e.g., the DS1904 RTC), so the bus master (e.g., the MAXQ610 microcontroller) uses this command throughout to activate the RTC before reading from or writing to it.

Read ROM [33h]

This single-byte command activates all slave devices on the bus and causes them to transmit their 64-bit ROM ID values back to the bus master. Since it activates all slave devices, it can only be used for single-slave systems. Otherwise, multiple slave devices will cause data collisions as they attempt to transmit their ROM IDs simultaneously. Because only one device (DS1904) is present on the bus in our application, the MAXQ610 uses this command at the beginning to read the ROM ID of the DS1904.

Match ROM [55h]

This command selects one slave among multiple slaves on the 1-Wire bus. After the bus master transmits this command, it follows up by transmitting the 64-bit ROM ID of the slave device to be selected. The device with matching ROM ID responds by going to an active state, while all other devices on the bus go inactive and await the next 1-Wire reset from the bus master. (This command is not used in the application described here.)

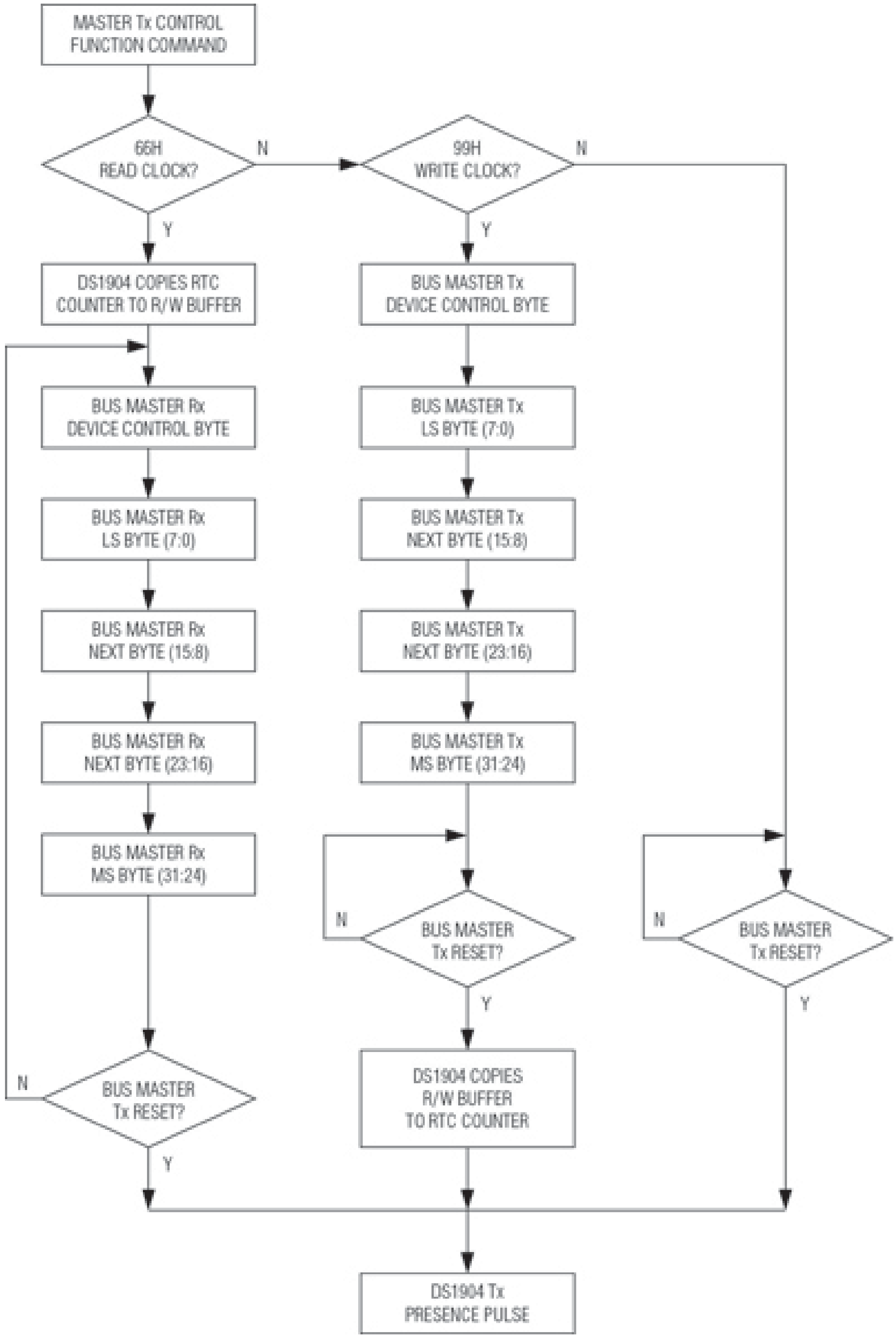


Figure 1: These DS1904 clock-function commands are taken from the data sheet.

Search ROM [F0h]
This command lets the bus master use an iterative discovery process to determine the ROM ID values of one or more slave devices on the 1-Wire bus.[3] (This command is not used in the application described here.)

Reading and Writing the Clock and Control values
When the bus master has selected the 1-Wire slave device (i.e., the RTC, DS1904) using the Skip ROM or Read ROM command, that device is ready to accept 1-Wire commands specific to it. These commands (Figure 1) are detailed below:

Read Clock [66h]
This command allows the bus master to read both the device control byte from the DS1904 and the 4-byte (32-bit) RTC value. The device control byte determines whether the 32kHz oscillator that drives the RTC is running or stopped. As shown by the code below, only one command reads both the device control byte and the clock value. Even if both values are not needed, you must read the device control byte before the device will output the clock data.

Write Clock [99h]
As the complement to Read Clock, this command allows the bus master to set new values for the device control byte and the DS1904 4-byte clock counter. Note that you must write all 5 bytes and transmit a 1-Wire reset pulse before the new values take effect. The application code above includes routines that set the device control byte and clock value individually, by first reading the 5 bytes of data from the DS1904 (1 byte of device control plus 4 bytes of the clock counter), and then writing back the data with the appropriate changes.

Converting Time and Date Values
To convert the raw seconds count into printable form, the application determines the value of each date and time field (year, month, day, hour, minute, and second) individually, beginning with the largest field (the year) and working downward:

1. While Seconds ≥ (seconds per year), subtract (seconds per year) from Seconds and increment Year.
2. While Seconds ≥ (seconds per month), subtract (seconds per month) from Seconds and increment Month.
3. While Seconds ≥ (seconds per day), subtract (seconds per day) from Seconds and increment Day.
4. While Seconds ≥ (seconds per hour), subtract (seconds per hour) from Seconds and increment Hour.
5. While Seconds ≥ 60, subtract 60 from Seconds and increment Minute.
6. The remaining value of seconds is the Second field.

Even if the bus master provides hardware support for division, a simple division operation is not enough to calculate the first two field values (years and months). This is because the number of seconds per field unit changes due to the effect of leap years (which affects the value for years and months) and the number of days per month (which affects months only). As an example, start with the year 2000 (a leap year):

- Seconds per year in 2000) = 366 (days) × 24 (hours/day) × 60 (min/hour) × 60 (sec/min) = 31,622,400 seconds.
- Standard years have one less day (365 days), which changes the seconds/year to (31,622,400 - 86,400) = 31,536,000.

Because every fourth year is a leap year, we calculate Year as follows (note that items 2, 3, and 4 in this pseudocode are identical.):

1. If Seconds ≥ (seconds per leap year), subtract (seconds per leap year) from Seconds and increment Year, otherwise stop.
2. If Seconds ≥ (seconds per year), subtract (seconds per year) from Seconds and increment Year, otherwise stop.
3. If Seconds ≥ (seconds per year), subtract (seconds per year) from Seconds and increment Year, otherwise stop.
4. If Seconds ≥ (seconds per year), subtract (seconds per year) from Seconds and increment Year, otherwise stop.
5. Go back to line 1.

The value of the months field is calculated in a similar manner:

1. If Seconds ≥ (seconds in January), subtract (seconds in January) from Seconds and increment Month, otherwise stop.
2. If Seconds ≥ (seconds in February), subtract (seconds in February) from Seconds and increment Month, otherwise stop.
3. If Seconds ≥ (seconds in March), subtract (seconds in March) from Seconds and increment Month, otherwise stop.
4. Proceed through the remaining months.

Running the Demo

To run the demo, load and run the application. Then use the DB9 serial cable to connect the MAXQ610 EV kit from J1 SKT to COM1 on the PC. Start MTK (or another terminal emulator) and open COM1 at 38400 baud. The initial output should be similar to the following:

@

ID: 24B91231000000B2 AC 18F83065

\+ 18F83065 Apr 10 2013, 02:15:01 pm

\+ 18F83066 Apr 10 2013, 02:15:02 pm

\+ 18F83067 Apr 10 2013, 02:15:03 pm

\+ 18F83068 Apr 10 2013, 02:15:04 pm

\+ 18F83069 Apr 10 2013, 02:15:05 pm

The second line of code contains the DS1904 ROM ID value (24B91231000000B2), the device control byte (AC), and the current clock value (18F83065). The "+" value in subsequent lines indicates that the clock is running. The time value is refreshed and displayed as often as it changes, which should be once per second. Press "-" to stop the clock. At that point you can alter the clock values by pressing additional keys:

\+ Start the clock and begin auto-updating again.

Y Increment the year value, and reset month and day to 01/01.

M Increment the month value, and reset the day to 01.

D Increment the day value (wraps around, depending on the current month).

h Increment the hour value.

m Increment the minute value.

s Reset the seconds counter to 00.

Z Zero the seconds counter, resetting the time to Jan 01 2001, 12:00:00 am.

References

[1] Refer to the DS1904 RTC data sheet for more details on 1-Wire timing requirements. Go to www.maxim-ic.com/DS1904 .

[2] For more details on the following commands, please refer to the DS1904 data sheet. www.maxim-ic.com/DS1904 .

[3] Ibid., www.maxim-ic.com/DS1904.

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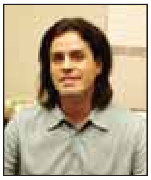
Aaron Minor is an applications engineer and technical writer in the microcontroller group at Maxim Integrated Products.



Make the Most of MCU Sleep Modes

Predict how well an MCU will perform over its lifetime on a single battery charge, and make intelligent architecture choices.

By Anders Guldahl, Energy Micro

The advent of inexpensive, energy-efficient embedded processors and smart-object technologies has fueled the growth of intelligent distributed networks for applications for smart buildings, the smart grid and environmental monitoring. The same technologies are also being used to add intelligence to existing products such as utility meters and health-monitoring and portable-medical equipment. While the operational and design requirements vary widely, all these applications must operate reliably for years using the limited energy resources available from their batteries or energy-harvesting systems.

Many of these applications, such as smart wireless water and gas meters, which are buried or otherwise difficult to access, present the engineer with significant design challenges. To achieve service lives of 10 to 20 years, they use batteries with specialized low-leakage chemistries that can cost $0.75/Wh or more. As a result, the meter's energy budget must be aggressively trimmed to maintain pricing that's competitive in the global marketplace. Even when a system is accessible – it may be the condition-monitoring system for a shipping container – it is not realistic to expect it to be maintained more than a few times during a 20-year service life, if at all.

Time is the enemy in any battery-powered application; even apparently small power consumption values become significant over long periods.

It is therefore not unusual to see microcontroller power budgets, averaged over the device's lifetime, of 5-20µA. A typical design might have an energy budget that allocates 20 percent of the available capacity to transmit activities, 30 percent for receiving commands and 20 percent for data collection and system maintenance. This leaves a mere 30 percent of the battery's capacity to support the system's idle mode. At first glance, this may seem a high proportion of the total battery life dedicated to doing no useful work. The problem is that the device will spend more than 99.9 percent of its life in this mode.

If a power-constrained application is properly implemented, most energy-intensive subsystems, such as radio-frequency (RF) transceivers and displays, will be designed to spend only as much time in their active state as they need to. A wireless sensor node will have a tight transmit-and-receive window – the system will attempt to send and receive only at predefined times to minimize the energy needed to listen for incoming packets. Similarly, most sensor inputs need only be sampled at intermittent intervals. So it's likely that the MCU will be idling for much of its time in between these events. The key to low-power design is not to simply let the MCU run in an idle loop, but to put it into an appropriate sleep mode.

Time is the enemy in any battery-powered application; even apparently small power consumption values become significant over long periods. During periods of activity, the power consumption of any logic is given by the formula CV^2f where C is the total capacitance of the circuit paths within the device, V is the supply voltage and f is the operating frequency. The situation is slightly complicated by the widespread use of clock gating in most modern processor cores, which limits switching activity in unused logic by temporarily disabling the clock signal to those circuits. However, the formula provides a good approximation to active power consumption. The fewer transistors that are powered during a given period, the lower the power consumption will be.

Most modern MCUs have more than one low-power mode, ranging from a light-sleep or standby mode, through deep-sleep, to off. Each has a progressively lower level of CPU, memory and I/O functionality as more peripheral blocks are switched off (Figure 1). The specific functionality of each idle, sleep and deep-sleep mode varies from processor to processor but the principles remain basically the same.

Generally, the deeper the sleep, the less power is consumed by the MCU. To provide an example of the difference in power, an Energy Micro EFM32 Tiny Gecko consumes 12.6mW while running fully active at a clock frequency of 28MHz and a supply voltage of 3V. In its lowest-power mode, the same device consumes 60nW – orders of magnitude lower.

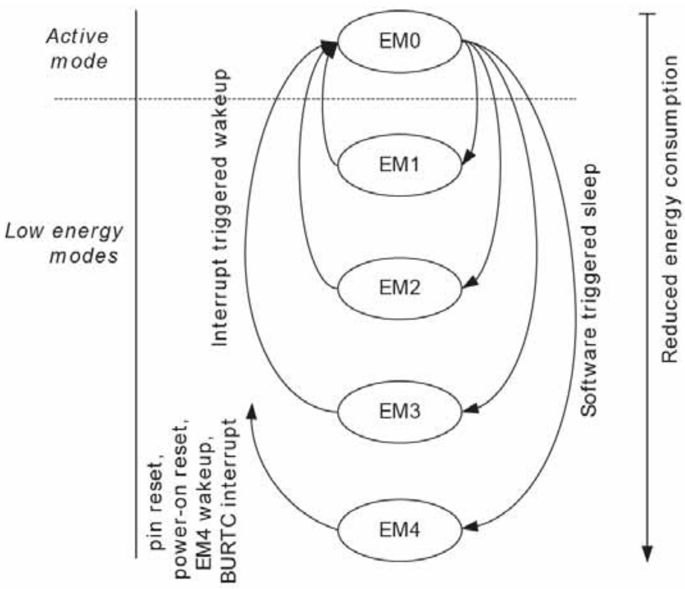


Figure 1: EFM32 family's energy management unit energy mode transitions. Courtesy of Energy Micro.

However, the power savings available from lower-energy sleep modes come at a price: waking from a deeper-sleep mode takes more time due to the time it takes for certain types of circuitry to restart.

For example, analogue circuits such as phase-locked loops (PLLs) that are used to generate the clock used by the processor core and other peripherals are best powered down when the blocks they drive are expected to be inactive. PLLs call for a constant current to maintain a lock. But when starting up, it takes time before the circuit is ready to provide a stable clock signal. When a processor core is fully powered down, its software state must be saved to memory – either battery-backed SRAM or flash. Restoration will take a number of memory cycles as this state data is fetched from the backup memory. A lighter sleep mode may keep the PLLs running and the core registers powered, albeit at a lower voltage to allow them to 'drowse' with a lower power draw than during normal operation. Therefore, the length of this wake-up period is an important consideration in selecting a particular sleep mode, both from the point of view of power consumption and effectiveness of operation.

One of the primary ways to optimize a low-power embedded design is to find the lowest sleep mode that provides an adequate response to real-time events. A good example is a battery-powered module that monitors the conditions experienced by a GPS-enabled cargo-shipping container during transport (Figure 2).

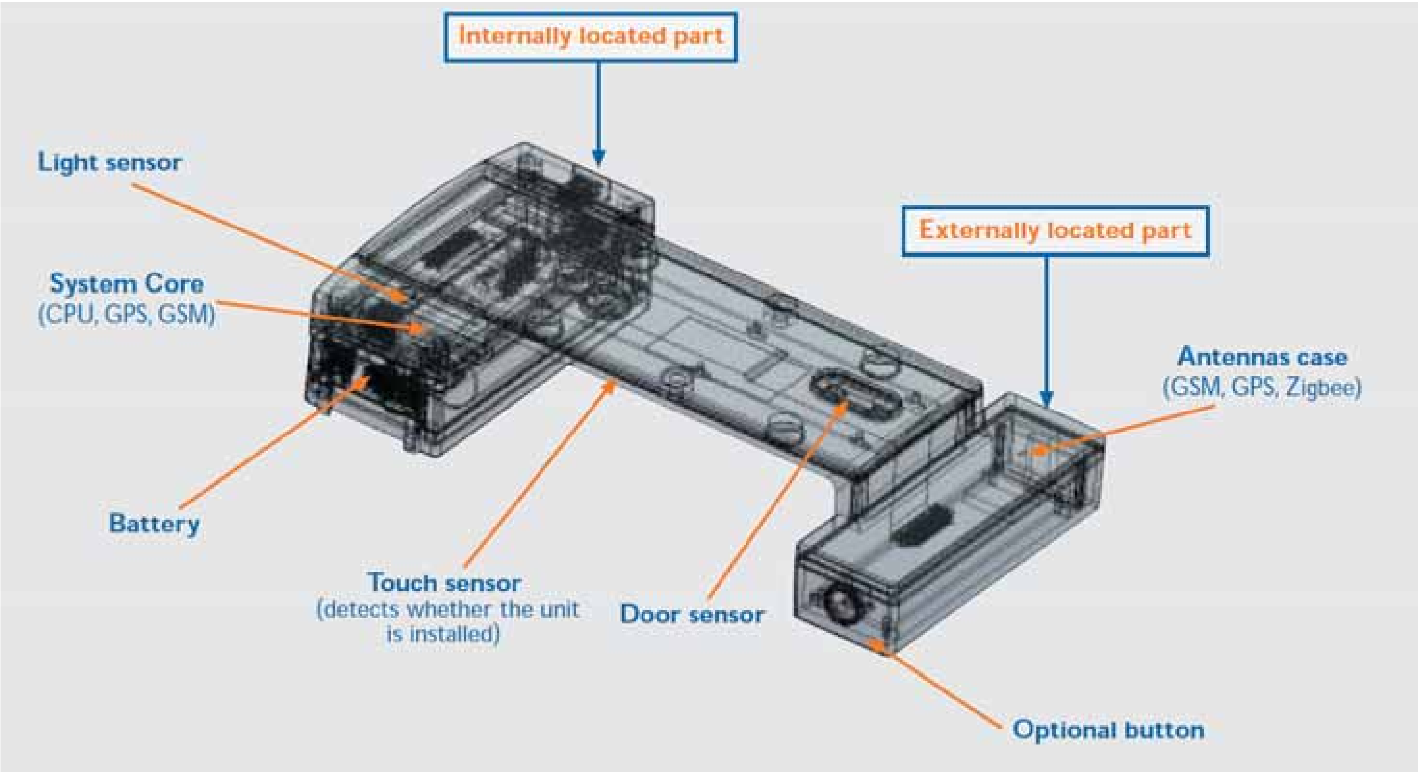


Figure 2: This commercially available cargo container monitor mounts on the container's main door. It uses a low-power MCU to record GPS coordinates, temperature (optional), shock/vibration, door openings and events that might indicate tampering. Courtesy of Starcom Systems.

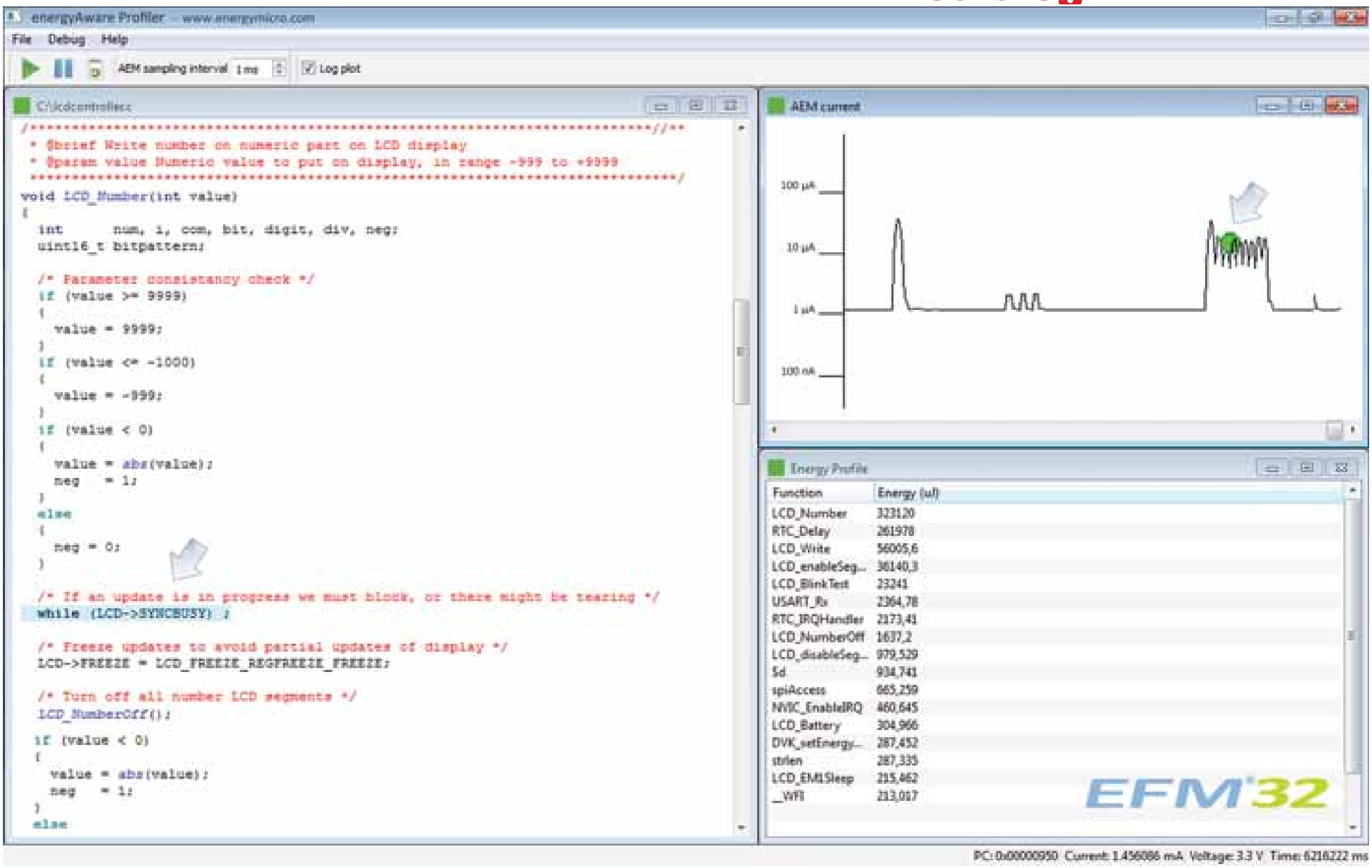


Figure 3: Tools such as the energyAware Battery Estimator allow engineers to simulate total system energy usage.

The first step is to list all the alarm/alert conditions generated by the application and identify the one that can tolerate the shortest time before it is serviced. The container monitor is typically equipped with a GPS receiver, temperature sensors, contact switches to detect tampering and accelerometers to measure the bumps, jolts and shocks that occur along the way. It is also usually equipped with one or more radio interfaces, according to the application's requirements.

Wake-up Time vs. Power Consumption: Evaluating the Trade-off

Designers often need to perform detailed analysis to evaluate the interactions between response time and the savings achievable from different sleep modes. Tools like the energyAware Profiler in Energy Micro's Simplicity Studio provides an effective and inexpensive way of assessing how these interactions will play out.

The energyAware™ Battery Estimator (Figure 3) provides a full simulation of total system energy usage, that takes into account actual battery source, MCU energy modes, peripherals employed and external circuit components.

In simulation mode, system battery voltage output is displayed against time (years) in graph format, with the battery capacity rating (mAh), average MCU current consumption (µA) and estimated system operating time (years) shown numerically alongside. An intuitive GUI allows the set-up of a complete system simulation, its energy modes, their related operating times and associated peripheral functions and external component current consumption.

Battery Estimator can today model the performance of the seven most popular battery cell types, arranged in single cell or user-defined multiple cell series- or parallel-connected configurations. The tool allows the selection and analysis of all five energy modes of the EFM32 Gecko MCU used with the complete range of low power peripheral functions available as well as high frequency and low frequency clocks. The facility to factor in the current consumption from any external power hungry components, such as LCDs or speakers, further increases the accuracy of the battery life prediction.

Under normal circumstances, the MCU will remain in sleep mode most of the time, emerging for a few milliseconds every 10 or 15 minutes to record temperature conditions. Activity from the tamper-detect switches does require attention in real time but the window of timely response to that event is measured in hundreds of milliseconds or even seconds. The processor must, however, be able to wake up and begin measuring shock and vibration levels within a millisecond or less of the time its accelerometer inputs exceed a pre-programmed threshold level.

The next step is to add up all the delays involved between the time the alert or alarm condition is generated and the time the MCU is ready to begin attending to it, for each standby, sleep and deep-sleep mode. Continuing with the example of the shipping container monitor, it is safe to assume that the accelerometer sense/comparator circuitry has little or no delay but, depending on the sleep mode it is in, the MCU will experience delays ranging from a few microseconds to hundreds of milliseconds before it can begin paying attention to the alarm event that woke it up.

Adding the execute time of the code required to service the alert or alarm condition gives the total delay between a critical event and the time the MCU responds. The length of this part of the application code will vary widely from application to application. It will also depend on whether the MCU must go through an interrupt service routine (ISR) or jump directly to the code that deals with the event at hand. At that point, the designer can compare these needs with the maximum time of recovery from each sleep mode and identify the lowest-power mode that falls within the application's maximum tolerable delay.

It is also essential to verify that the sleep mode selected has the resources required. For example, if the application requires an RTC, it cannot go below deep sleep, because the RTC will often be disabled in extreme low-energy modes.

Armed with this information, it is possible to accurately predict how well a given MCU will perform over its lifetime on a single battery charge, and to make an intelligent choice on which architecture to progress with.

Anders Guldahl is an application engineer at Energy Micro, supporting customers, developing energy-friendly code examples and writing application notes. Anders also worked in Energy Micro's Simplicity team, designing development kits for the EFM32 Gecko microcontrollers, LESENSE peripherals and capacitive touch. He holds a master's degree in control systems engineering from The Norwegian University of Science and Technology (NTNU) in Trondheim, Norway.

Microchip Technology Inc.

PIC® Microcontrollers for LCD Display

Supported 8-bit & 16-bit Architectures: 8-bit PIC® Microcontrollers

Segmented displays are used in a wide variety of applications, ranging from meters to portable medical devices to thermostats to exercise equipment. PIC® microcontrollers with integrated LCD drivers can directly drive segmented displays with letters, numbers, characters and icons. The main features of Microchip's LCD portfolio include:

- **Flexible LCD segments**
  - 28 pins - up to 72 segments
  - 44 pins - up to 116 segments
  - 64 pins - up to 240 segments
  - 80 pins - up to 368 segments
  - 100 pins - up to 480 segments
- **Variable clock inputs**
- **Integrated voltage bias generation**
- **Direct drive for both 3V and 5V powered displays**
- **Software contrast control for boosting or dimming for different temperature or lighting conditions**
- **Drive LCD while conserving power in Sleep mode**
- **Integrated real time clock and calendar for displaying time and date information**
- **mTouch™ capacitive touch sensing capability**

TECHNICAL SPECS

- **Enhanced Mid-Range Solutions (PIC16F19XX)**
  These LCD MCUs provide excellent Low power capabilities, high LCD pixel count, lots of peripheral and memory integration and a very competitive price point. Features include:
  - 60-184 LCD segments with a low power drive mode to save batteries or lower power consumption
  - 3.5-28 Kbytes Flash program memory (read/write capable)
  - eXtreme Low Power Technology
  - 28/44/64-pin packages
- **Performance PIC18 Solutions (PIC18F8XJ9X and PIC18F8XK90)**
  The PIC18 families of LCD MCUs offer greater memory density and higher pin counts to meet the demands of more complex segmented LCD applications with features including:
  - 128-192 LCD segments
  - eXtreme Low Power Technology
  - mTouch Capacitive Touch Interface
  - 8-128 KB Flash program memory
  - 64 and 80-pin package options
- **16-bit PIC24F Solutions (PIC24FJ128GA3XX)**
  The PIC24F GA3 family provides 16-bit performance and a 60 segment x8 common LCD driver that enables applications with more informative segmented display application.

Features include:

- 240-480 LCD segments
- eXtreme Low Power, VBAT and 150 uA/MHz active current
- mTouch Capacitive Touch Interface
- 64-128 KB Flash program memory
- 64/80/100-pin package options

Learn more at: www.microchip.com/LCDExplorer

AVAILABILITY

All of these PIC Microcontrollers for LCD Display are available today from Microchip.

LCD Explorer Development Board (DM240314)
The LCD Explorer demonstrates the PIC24FJ128GA310 MCU 60 segment x8 common, 480 segment LCD Driver. The board includes a 296 segment LCD glass with a 37 x 7 segment banner display area and 37 additional icons. The board also demonstrates the booster capability for contrast control and dimming as well as a PICtail™ Plus connector.

Learn more at: www.microchip.com/LCDExplorer

APPLICATION AREAS

- **Consumer:** Thermostat, Sprinkler Controller, Baby Alarms, Lawn Mowers
- **Medical:** Thermometer, Pulse Ox Meter, Drug Injector, Medical Pump, Glucose Meter
- **Industrial:** Utility Meters, Instruments, Gas Detection, Gasoline Pumps
- **Appliance:** Refrigerator, Stove/Oven/Microwave, Coffee Maker
- **Automotive:** Dashboard, Tire Pressure Sensor, Battery Vehicle Display, Audio System, Compass

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Microchip Technology Inc.

mTouch™ Sensing Solutions

Supported 8-bit & 16-bit Architectures: PIC® Microcontrollers

Touch sensing has become an alternative to traditional pushbutton switch user interfaces. It requires no mechanical movement and enables modern-looking design. Touch sensing is expanding beyond the consumer market and is taking hold in medical, industrial and automotive applications because of aesthetics, flexibility, maintenance, cost and cleanliness.

Microchip's mTouch technology offers a wide variety of solutions for keys and sliders as well as turnkey touch screen controllers. These are easy to implement, consume extremely low power and are offered in small packages.

mTouch Technology provides a free and easy method for designers to add touch sensing keys to applications utilizing PIC® MCUs. Being a source-code solution further helps engineers quickly integrate touch sensing functionality with their existing application code in a single, standard microcontroller, thus reducing the total system cost associated with current solutions.

FEATURES & BENEFITS

- **PIC MCUs featuring mTouch technology offer several benefits:**
  - Keys, sliders, wheels and proximity detection
  - Lowest power MCUs in the industry offer you longest battery life
  - Integrated peripherals such as USB, segmented and graphical LCD modules for true human interface system-on-a-chip
  - Works through plastic, glass and metal surfaces
  - Water-proof designs for all weather conditions
  - Free software library simplifies implementation and free source code puts you in control
  - High noise robustness

TECHNICAL SPECS

- **mTouch™ solutions offer:**
  - 1 to 32 Capacitive Touch Channels
  - 6-pin to 100-pin devices
  - Up to 512 KB Flash memory
- **Industry's lowest power touch sense solutions**
  - Capacitive sensing in less than 5 uA
  - Proximity sensing down to less than 1 uA

AVAILABILITY

  - Over 150 PIC MCUs featuring mTouch technology are in production today
  - Download the mTouch Capacitive Library from the Microchip Applications Libraries
- **mTouch™ Evaluation Kit (DM183026-2)**
  - Low-cost, flexible and easy way to evaluate mTouch technology
  - Supports PIC16, PIC18F, PIC24F and PIC32 MCU families
  - Variety of keypads and sliders implemented on daughter cards
  - Graphical User Interface (GUI) for easy set up and real time data monitoring

Visit *www.microchip.com/mTouch* to learn more and to download application notes and software.

APPLICATION AREAS

- Battery Applications, Thermostats, Remote Controls, Medical Devices, Cell Phones, Line-powered Applications, Home Appliances, Smart Energy Monitors, Printers

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PIC18F66K80 Family: Low-Cost CAN and General Purpose MCU

Supported 8-bit & 16-bit Architectures: 8-bit PIC® Microcontrollers

PIC18F66K80 is a high performance 8-bit MCU with Integrated ECAN™ featuring eXtreme Low Power consumption. The PIC18F66K80 family is ideal for applications requiring cost-effective, low-power CAN solution with high performance and robust peripheral set. The PIC18F66K80 family features Low power consumption, extended operating voltage up to 5.5V, an on-chip 12-bit Analog-to-Digital Converter (ADC) and a peripheral that enables mTouch™ capacitive touch sensing user interfaces.

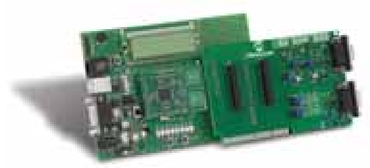
FEATURES & BENEFITS

- Enhanced 16 MIPS performance in PIC18 with integrated CAN
- 16-64 KB of Flash, 4 KB RAM, 1 KB EEPROM
- Temperature range: -40 to 150°C
- 28, 44 and 64-pin packages available
- Battery Friendly via XLP Technology o 1 MHz Run current < 100 µA o Sleep current < 20 nA
- 1.8V to 5.5V operating voltage for automotive, building control, elevator control and industrial application
- 12-bit ADC for higher measurement accuracy
- 12-bit ADC for higher measurement accuracy Timers/ Enhanced Compare/Capture/PWMs for precision timing control
- Charge Time Measurement Unit for capacitive touch sensing enables advanced human machine interfaces
- I²C™, SPI, and UART communication peripherals

AVAILABILITY

More information and samples of the PIC18F66K80 family can be found at *www.microchip.com/pic18f66k80*.

Development tools and application notes for the CAN families can be found at *www.microchip.com/can*



- PIC18 Explorer Board Part # DM183032 with o 64-pin PIC18F66K80 Plug-in Module (PIM) Part # MA180032 (or) o 44-pin PIC18F46K80 PIM Part # MA180031
- For CAN applications, CAN/LIN PICtail™ (Plus) Daughter Board Part # AC164130-2

APPLICATION AREAS

- Automotive: Body control modules, automotive lighting, door/seat/steering/window and HVAC control
- Building automation such as elevators and escalators, lighting and sensors, and air condition control
- Industrial applications such as security systems, alarm control and remote monitors

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Microchip Technology Inc.

PIC24F "GA3" Family

The PIC24F "GA3" family features the industry's lowest active current for 16-bit Flash MCUs along with flexible new low-power sleep modes. The PIC24F GA3 devices feature 150 mA/MHz active current, a new low-power sleep mode with RAM retention down to 330 nA and a dedicated V_{BAT} pin to back up the RTCC function to minimize the power consumed and maximize battery life. As an eXtreme Low Power Microcontroller the GA3 family has typical Deep Sleep currents of 10 nA and can maintain the RTCC with only 400 nA. The PIC24F 'GA3' family is also the first PIC24F to include segment LCD driver providing an expansion path for 8-bit designs requiring additional performance, Flash, RAM, or pins. Six channels of general purpose DMA increase the throughput of the family by offloading much of the data transfer associated with high bandwidth peripherals. Multiple serial channels and timers round out the feature set creating a versatile low power CMU family.

FEATURES & BENEFITS

- Integrated LCD display driver provides the ability to directly drive up to 480 segments, with an eight-common-drive capability, enabling more informative and flexible displays that include descriptive icons and scrolling
- Dedicated V_{BAT} pin for battery backup of the on-chip Real-Time Clock Calendar
- 6 DMA channels increase throughput by reducing CPU intervention required for high bandwidth peripherals
- Includes 24 channels of 12-bit 200 Ksps ADC with threshold detect. Threshold detect will allow the MCU to wake from sleep when the ADC meets a specified threshold

TECHNICAL SPECS

- **Advanced Low Power Features**
  - Reduced Active Current - 150
  - A/MHz
  - Deep Sleep Currents down to 10 nA
  - Watchdog Timer down to 270 nA
  - V_{BAT} Battery Backup and Real–Time Clock/Calendar down to 400 nA
  - Low-Power RAM Retention with 330 nA Current
- Up to 128 KB for Flash Program Memory and 8 KB of Data Memory
- 4 UART, 2 SPI and 2 I²C™ serial channels
- 5 16-bit Timers, 9 IC and 9 OC
- CTMU for mTouch Capacitive Touch sensing

AVAILABILITY

All variants of the PIC24FJ128GA310 family are in production. A PIC24FJ128GA310 General Purpose PIM (MA240029) and the LCD Explorer Development Board (DM240314) are also available to support development with the GA3 family.

APPLICATION AREAS

- Consumer
  - Thermostats
  - Door Locks Industrial
- Security
  - Wired & Wireless Sensors
- Medical
  - Blood Pressure Meter
  - Glucose Meter Metering
  - E-Meters
  - Gas/Water/Heat Meters
  - Automated Meter Reading

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High Performance Motor Control and General Purpose MCUs

Supported 8-bit & 16-bit Architectures: PIC® Microcontrollers

Microchip's dsPIC33E DSCs and PIC24E MCUs for motor control and general purpose MCUs combine a 16-bit, 70 MIPS PIC24E or dsPIC33E core with industry leading peripherals. The dsPIC33E core includes a DSP extension to accelerate math operations. Available in a wide variety of packages and memory sizes, the PIC24E MCUs and dsPIC33E DSCs fit any application needing high performance!

FEATURES & BENEFITS

- High-performance 16-bit, 70 MIPS PIC24E or dsPIC33E Core (DSP instructions included with dsPIC® DSC core)
- 32-512 KB of Flash available
- 28 to 100-pin packages available, including ultra small 5x5 mm 36-pin VTLA package
- Motor control PWM modules simplify generating complex PWM waveforms
- Over 10 motor control application notes and 3 motor control development platforms available
- mTouch™ hardware for capacitive touch sensing enables advanced human machine interfaces
- CAN, I²C™, SPI, and UART communication peripherals

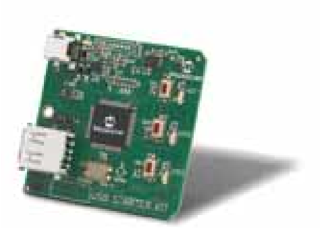
AVAILABILITY

More information and samples of the dsPIC33E and PIC24E families can be found at *www.microchip.com/16bit*.

The dsPIC33E and PIC24E families have 12 products in production and more on the way.

Motor control development tools and application notes can be found at *www.microchip.com/motor*

GET STARTED TODAY!



- dsPIC33E/PIC24E USB starter kit provides an easy way to evaluate dsPIC33E DSCs or PIC24E MCUs.
- $64.99
- Part number DM330012

APPLICATION AREAS

- Home appliances such as washing machines, dishwashers, and refrigerators
- Automotive motor control systems
- Industrial pumps, fans and other motor systems
- Automotive sensors
- Consumer sensor systems

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Microchip Technology Inc.

Low-Cost Motor Control and General Purpose MCUs

Supported 8-bit & 16-bit Architectures: PIC® Microcontrollers

Microchip's 16 MIPS, 16 KB of Flash dsPIC33F and PIC24F family brings the performance of a 16-bit dsPIC33F or PIC24F to cost sensitive applications. The dsPIC33F and PIC24F 16 MIPS family can be tailored for motor control or general purpose applications. dsPIC33F devices include DSP hardware to accelerate math operations. For motor control applications, Microchip offers an ultra low-cost motor control starter kit for sensorless BLDC motor control.

FEATURES & BENEFITS

- High performance 16-bit, 16 MIPS dsPIC33F or PIC24F Core (dsPIC33F includes DSP hardware)
- 16 KB of Flash
- 18 to 36-pin packages available, including SPDIP and ultra small 36-pin 5x5 mm VTLA
- Motor control PWM modules simplify generating complex PWM waveforms
- mTouch™ hardware for capacitive touch sensing enables advanced human machine interfaces
- I^2C™, SPI, and UART communication peripherals

AVAILABILITY

More information and samples of the PIC24F and dsPIC33F families can be found at *www.microchip.com/16bit*.

Motor control development tools and application notes for the PIC24F and dsPIC33F can be found at *www.microchip.com/motor*.

GET STARTED TODAY!

- Motor Control Starter Kit enables easy sensorless BLDC development
- Complete kit with motor for only $99.99
- Part number DM330015

APPLICATION AREAS

- Home appliances such as washing machines, dishwashers, and refrigerators
- Automotive motor control systems
- Industrial pumps, fans and other motor systems
- High end toys including model cars, planes, and helicopters
- Automotive sensors
- Consumer sensor systems

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MICROCHIP

Partner Guide

CCS

CCS provides a complete, integrated tool suite for developing and debugging embedded applications running on Microchip PIC(r) MCU and dsPIC(r) DSCs. Development tools offered by CCS include an optimized C compiler, in-circuit programmers/debuggers, production programmers, complete development kits and embedded Ethernet and Wifi integration modules.

Load-n-Go: Mobile, Handheld ICSP PIC(r) Programmer
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- Includes ICSP cable with RJ-12 or with Tag Connect cable.

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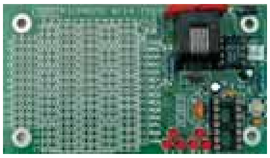

Coast Electronics has been around since 1980 (yes...that long!!). We specialize in Scientific Electronics-based products, mainly gas analyzers, our people offer quality and reliable products and services you can count on. We also have an E-Shop at www.coastelect.eu/shop offerring many exciting products.... Components, Gas Analyzers, including Argon-fill units for the double-glazing industry, Industrial parts, Kits, PICs, Development tools, Valves, Pneumatics, Short-range radio, REPRAP, LED lighting....and more.

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Demmel AG

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MetalLight by Demmel

combines high quality metal surfaces with illuminated symbols including touch switch functionality. A new sputtering method allows etched symbols to be filled with robust plastics. This assures a uniform and bright illumination of even very small symbols. A very special feature of MetalLight is the possible combination of different plastics and LED colors, which offers a infinite variance of illumination!

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- Easy to clean surface, sterile and no moving parts

Demonstration units are available.

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EarthLCD

EarthLCD has introduced the new ezLCD-301 to its lineup of intelligent touch LCD products. Described as "The Character Module Killer", this new "ezLCD" product was developed to give engineers a functional, flexible, and cost effective alternative to buttons, switches, character modules, STN, or more complex graphic touch displays.

FEATURES

- 2.6" Color TFT LCD
- 400 x 240 Resolution, 16 Bit, 65K Colors
- Integrated 4 Wire Resistive Touchscreen
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- USB Interface / Breakout Cable Included
- Engineering Development Kit Available
- 2.6" Reflective; 3.5" and 4.3" LCD Models Available Soon
- store.earthlcd.com/ezLCD-301 or MicrochipDirect.com

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Efficient Computer Systems, LLC

The CandyBar Demo Board is a hardware platform to speed up the design of handheld electronic products and is smaller than a candy bar. It's loaded with features to get you up and running in record time.

FEATURES

- Bluetooth, Wi-Fi
- Dimensions 2″x4.25″
- 3 Axis Accelerometer
- Stereo headphone jack
- Amplified mono speaker
- Serial flash 4MB–16MB
- 2.8″ touchscreen LCD, 320x240
- PIC32 standard, PIC24 optional
- MP3 encode/decode and microphone
- Power efficient switching supplies for long battery life
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Embedded Sense, Inc. (ESI) is a premier technology partner specializing in leveraging embedded processing, interface, sensing and wireless expertise into product solutions for global customers in the military, industrial, commercial and medical markets.

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- Embedded wireless solutions
- Embedded software, FPGA and hardware development
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- Turnkey development and manufacturing solutions
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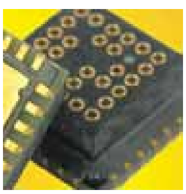
Ironwood Electronics

Connect to SMT Pads



Ironwood's SMT package emulation adapters are often called "surface mount feet". These adapters provide access and interconnections to surface mount lands. Typically, the adapters are soldered to the target board in place of the IC device and provide a pluggable array of pins interface for sockets, probing adapters, package converters, and even board-to-board connections. Many of our PLCC, QFP and SOIC emulation bases use our proprietary shaped solder techniques, replacing expensive, and often fragile, J-lead and Gull Wing leads. Shaped solder parts are easily fluxed and reflowed onto the target system. Our adapters can present either a male or female interface at 1.27mm or 1mm or 0.8mm pitch gold plated array pins for pluggable connection. Hundreds of standard parts for BGA and QFN are online.

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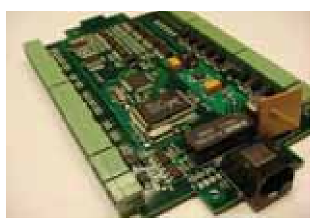
LX Design House



LX is an innovative contract electronics design company specialising in embedded systems and wireless technologies. We offer a professional turnkey experience, taking a new product from concept to production. We focus on fully understanding our clients' requirements (technical and business) and work to ensure these requirements are met.

Our high caliber engineering team has won international awards. We have experience across a wide range of technologies and industries, and work with clients both in Australia and abroad.

We strive to develop long-term relationships with clients through:

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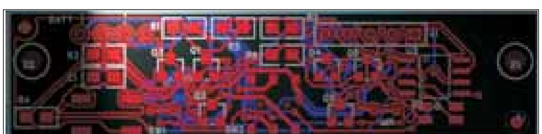

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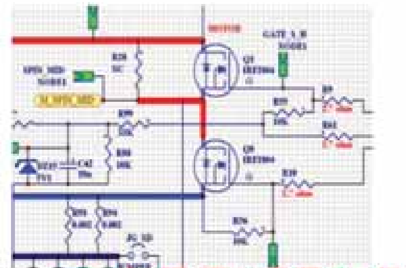

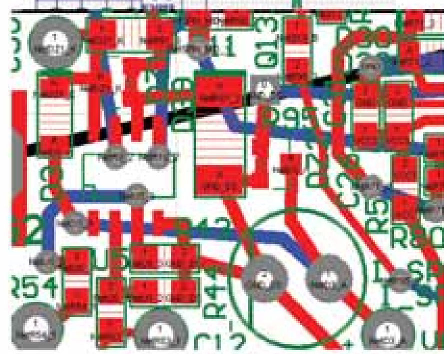

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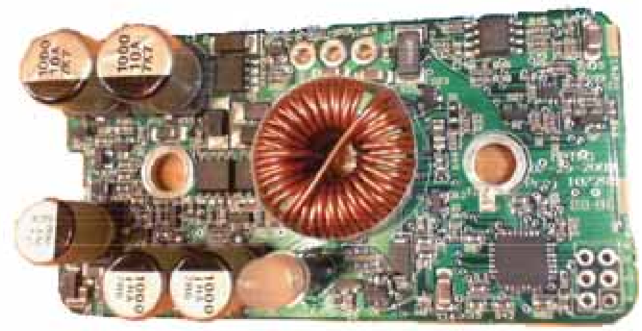

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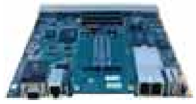

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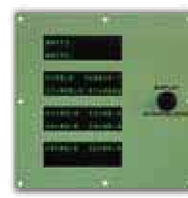

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