September/October 2005 www.BatteryPowerOnline.com Volume 9, Issue 5

BATTERY POWER PRODUCTS & TECHNOLOGY

Solutions for OEM Design Engineers, Integrators & Specifiers of Power Management Products

Power Management for Portable Applications

Juan Alvarez
Texas Instruments

Achieving a long battery life in portable applications is challenging. Designers have multiple aspects that need to be considered to minimize power consumption, which include managing multiple low power operating modes, power supply design and component selection.

Managing Multiple Low Power Operating Modes

Optimizing resources will help conserve battery life. The following five-step process illustrates how to minimize power consumption by adequately using multiple power operating modes.

As an example, we will use a smoke detector with a ten year battery life to illustrate each step of the process. The smoke detection is implemented with an optical smoke chamber. Inside the chamber, there is an IR transmitter and IR receiver, both of which are purposely not in line of sight. When a fire occurs, the smoke particles enter the chamber. The smoke particles reflect the IR transmission so that the IR receiver will pick up the IR transmitter signal. The IR receiver signal received is extremely small, between 20 nA to 200 nA. The signal is detected with a comparator and an operational amplifier. The comparator is used to compare the signal coming from the IR receiver against a voltage reference that will determine if smoke is present in the chamber. The op-amp amplifies the IR receiver signal by 10^7. The smoke detector wakes-up every five seconds to check if there is a fire. A bright LED lights when either is detected; for some smoke detectors an audible alarm is implemented, but will not be considered for this example. Figure 1. illustrates the block diagram of the system.

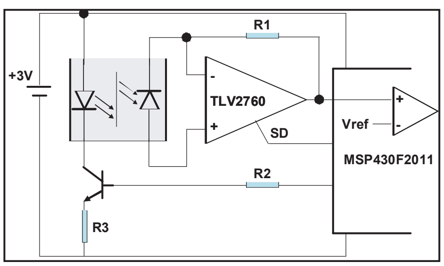

Figure 1.

Step 1: Determine the Maximum Average Current Consumption

The easiest method to determine the power budget of your application is to establish the battery's maximum average current consumption. This calculation will depend on battery life and on battery selection. A 220 mAh inexpensive CR2032 lithium battery is selected for the example. The resulting average current consumption for the CR2032 with a 10-year battery life is as follows:

220 mAh x (1000 uA/mA) / (10 years) /
(8760 hr / year) = 2.5 uA

Step 2: Focus First on Your Stand-By Mode Of Operation

Many battery-operated applications are asleep or inactive for more than 99 percent of the time. While the application sleeps, the central processor unit (CPU) is not active. During the sleep mode, either the application runs a real time clock operation using an internal timer or the clock system is completely shut-down waiting for an external event. To save power consumption, it is critical to select a microcontroller (MCU) that will provide extremely low power consumption while the system is asleep. The sleep mode current consumption strongly influences the average current consumption.

For the example, the smoke detector needs to wake-up every five seconds to detect a fire, meaning that the application requires a real time clock operation while it sleeps. A MSP430F2011 will be used as the MCU of choice given the requirement of an extremely low current consumption during sleep mode. This MCU offers the lowest stand by current consumption in the 8- or 16-bit MCU space. In stand-by mode at 3 V, it will draw a maximum power consumption of 1.2 uA including brown-out reset protection (BOR) using a 32 kHz crystal. The current consumption can be reduced further by utilizing the very low power oscillator (VLO). The VLO is an internal oscillator than requires no external components. It will run at a frequency of 12 kHz and provide a typical current consumption of less than 500 nA. The external crystal will be used for this example. The MSP430F2011 has 2KB Flash, 128 BRAM, a timer with two capture and compare registers, 10 general purpose I/O (GPIO) and a multiplexed comparator which will satisfy the minimum requirements of the application.

Step 3: Plan for the Highest Level of Integration Possible

Integration enables faster communication and better control of analog peripherals by using registers instead of using slow serial communication ports. Avoiding adding external components will minimize leakage current. The internal comparator will be used for the smoke detector; an external op-amp is also required.

Step 4: Shut Down External Analog Components During Stand-By

Low quiescent current components are highly regarded as the components are 'always' on, and there is no settling time associated with them. For portable applications, settling time is negligible given the long stand-by periods. Consider using external components that have shut-down capability. For components that do not have a shut-down pin, try to power the component itself directly from a GPIO as long as the current draw on the component does not exceed the port pin specification.

For some components, like digital signal processors (DSP), even the shut-down mode will drain significant amount of current consumption. For these components, consider using an external switch. The MCU controls the switch using a GPIO and disable it to remove the power source when the component is not being utilized.

For our example, an op-amp is required to amplify the signal given that the IR receiver varies between 10 nV to 200nV. The TLV2760 will be used as it has a shut-down mode feature that has a maximum power consumption of 50 nA in shut-down mode. The settling time of the op-amp is 13.5 uSec, which is negligible.

Step 5: Minimize Power Consumption During Active Mode Operation

Even though the stand by current significantly impacts your average current consumption, it is important to minimize power consumption during active mode operation as well. To optimize power consumption, consider the following recommendations:

- Minimize the active time for components that will consume the most amount of current.
- Shut down the CPU as frequently as possible. In many cases, the CPU is waiting for a peripheral or an external component to finish a task before it can do any further processing. Use a MCU that will allow you to operate peripherals while the CPU is shut-down. Make sure that the CPU wakes-up quickly to avoid wasting time or battery life.
- Avoid polling GPIOs and peripherals. During active mode, CPU over-head and time are wasted by checking GPIOs for user interaction. Instead, consider using interrupt driven architectures that will interrupt the CPU if there is any user input or any critical events that need to be served immediately.

Figure 2. describes a rough estimate of the power consumption profile of the CPU and external components during the active operation of the smoke detector. Notice that the CPU has been purposely shut-down while the comparator and op-

Task	t	Icc	Icc x t / t-total	Power Profile (max @ 3V)			
				CPU	op-amp	Comparator	IR-Tx
	mSec	*mA*	*uA*	*400 uA*	*30 uA*	*60 uA*	*200 mA*
Turn on op-amp	0.015	0.400	0.00120	X			
Turn on comparator	0.015	0.430	0.00129	X	X		
Wait for stabilization	0.090	0.090	0.00162		X	X	
Wake-up	0.002	0.490	0.00020	X	X	X	
Turn on IR-Transmitter	0.003	200.490	0.12029	X	X	X	X
Read the comparator signal	0.003	200.490	0.12029	X	X	X	X
Turn off IR-transmitter	0.003	200.490	0.12029	X	X	X	X
Turn off comparator	0.015	0.490	0.00147	X	X	X	
Turn off op-amp	0.015	0.430	0.00129	X	X		
Calculate algorithm	0.150	0.400	0.01200	X			
Sleep (stand by)	4999.689	0.001	0.99994	1.2 uA			
Total	5000.000		1.37989				

Figure 2.

amp were stabilizing. The highest power consumption was driven by the IR transmitter. Hence, the IR transmitter was turned-on and off efficiently to minimize on time. The total average current consumption for standby and active operation is 1.38 uA, extremely close to the maximum stand by current consumption, which is 1.2 uA. The maximum average current consumption of 2.5 uA was required for the ten-year life smoke detector; with a total average current consumption of 1.38 uA, we've met our goal.

Power Supply Design

Another aspect of achieving long battery life in portable applications has to do with the power supply system design, including battery and regulators selection. The following section will provide a couple of design tips to extend battery life by designing more efficiently.

Tip 1: Use a Single Voltage Source

Having multiple voltage sources in a system is power hungry and expensive. Multiple voltage sources add the need for regulators; because these regulators continuously drain current, they will shorten battery life. Adding multiple voltage sources will increase cost because level shifters and regulators will be required in the design. 3V power supply is quite popular for portable applications as most of the components today are in this voltage realm and provide an adequate voltage range for effective analog performance.

Tip 2: Use Lithium Cell Batteries Whenever Possible

Compared to other battery technologies, lithium cell batteries have the most stable voltage source output, which extends battery life. One limitation of a commercially available lithium cell is its lower peak current capacity. When long high peak currents are needed, alkaline batteries are better suited for the task at hand.

Tip 3: Use Components with Wide Operating Voltages

To maximize the life of your battery, use components that will support wide operating voltages. Voltage for all battery technologies will drop in time; for example, alkaline battery drops linearly. Components that support a wide operating voltage range will help maximize battery life. Supporting a voltage range of 2.2 versus 2.7 V will double the battery life of 2 AA batteries.

Tip 4: Power Manage Multiple Voltage Sources

In some cases, multiple voltage sources are required. As an example, consider a system that is based on a DSP or a 32-bit MCU. This type of system typically has a very high stand-by current consumption and also has multiple voltage rails, such as 3.0 V and 1.8 V, to support input-outputs (I/O) and the core CPU. Adding a low-cost, small MCU helps shut-down voltage rails when these are not being utilized.

Component Selection

There are many components available in the market today. As you may have noticed in the previous sections, component selection is a critical factor towards extending battery life.

The following questionnaire will help benchmark different MCU options:

- *Questions that will impact the stand by mode of operation:*
  - o What is the maximum current consumption for the standby mode used most frequently in the application?
  - o What is the brown out reset (BOR) protection's maximum current consumption?
  - o What is the maximum pin leakage current?
- *Questions that will impact the active mode of operation:*
  - o How fast can the MCU wake-up and provide a fast stable internal oscillator?
  - o What is the interrupt capability of the MCU so that polling can be avoided?
  - o Can the peripherals be pre-configured and driven by external events so that the CPU can be shut down while it is not being utilized?

Answering the following set of questions will help benchmark different analog components:

- o Does the component have a shut down option?
- o How fast does the component settle?
- o Can the functionality be integrated in a MCU?

The steps described above for managing multiple low power modes, power supply design, and component selection are not bulletproof, but hopefully they can provides some sound guidelines to keep in mind when trying to maximize the battery life of your next portable application.

Contact Texas Instruments at www.ti.com.

Reprinted from the September/October 2005 issue of *Battery Power Products & Technology* magazine. ©2005 Webcom Communications Corp.
7355 E. Orchard Rd., Ste. 100, Greenwood Village, CO 80111 USA Phone 720-528-3770. Fax 720-528-3771. wwwinfowebcom.com