Low-Cost Occupancy Sensor Saves Energy

By: Markus Levy, Convergence Promotions

Advances in technology make it easier for us to save energy and help our environment. One example where technology has a significant role is in occupancy sensors to control lighting, heating and cooling according to motion detected within an intermittently occupied area. Occupancy sensors can save up to 80% of the lighting and HVAC energy when properly applied. Modern sensors, with the aid of leading-edge microcontrollers, have many sophisticated features such as the ability to self-adjust to occupancy data collected in a prescribed “learning period”. These sensors also reduce false-on and -off conditions. Another useful feature is a “lights-out warning” in the form of an audible or visible (lights flicker) indicator that lights will be turning off in one minute (time should be adjustable).

Defining the Project Goals

To effectively implement an intelligent occupancy sensor, there are several key factors to consider. These factors include a reduced bill of materials, lower power consumption, and reduced time-to-market. Ideally, you should also consider ways to reduce the finished goods inventory.

As with every new generation of products, the most logical evolutionary design step is to determine how to reduce the bill of materials. Continuous advances in semiconductor technology make it possible to shrink chip sizes while simultaneously integrating more features, all at a lower cost. For example, the cost of the electronic components in the occupancy sensor that we’ll be discussing dropped from $6.60 (for the previous generation product) down to $4.00. The biggest cost savings comes from not having to use external analog-to-digital converters (ADC), brown-out detection circuitry, and a crystal. In addition to the cost savings, higher levels of integration also leads to reduced system board size, higher reliability, and typically more functionality of the end product.

Building a Better Sensor

The increased functionality of an occupancy sensor is represented with features such as signature analysis, adaptive time out, adaptive occupancy sensing, and audible and visual alerts. One of the toughest challenges for a motion sensor is to be able to reject unwanted signals such as those caused by pets or wind-based motion of curtains, papers, or plants. In complex surveillance systems this is accomplished using a video camera and a high-performance digital signal processor. On the other hand, in an inexpensive occupancy sensor, movement in a room is captured and processed by an ADC and the resulting conversion is stored in SRAM. When the signature of the room is analyzed, the microcontroller compares this with values stored in a flash memory look-up table.

In addition to using a motion sensor to determine room activity, an infrared sensor combined with an ADC channel scans the room and identifies small changes in the thermal environment. The PYRO technique is one algorithm used in conjunction with the infrared sensor. This technique divides the room into segments and continuously compares the samples of these segments (Figure 1). Another ADC channel measures the ambient light level. Based on information from the I/R sensor, the amount of ambient light will be used to determine if the light switch should be triggered.

An infrared sensor can be used with the PYRO technique to segment a room and compare the infrared value to a control database stored in flash memory. The occupancy sensor can also be fitted with an adaptive time out mechanism to determine when to shut off the switch.

Using the microcontroller’s on-chip real-time clock, the microcontroller can calculate the time out based...
on how the space is used. The system can begin to develop usage patterns and log data every 15 minutes over the previous week (also known as learning) to build a database and understand how the space is used.

Another important feature is the ability to warn people prior to the switch turning off. (How many times have you been motionlessly working in a conference room and the lights automatically turn off, leaving you in solid darkness?) You can take advantage of the microcontroller’s PWM channel and its compare and capture feature, combined with an external piezo speaker element to generate different sounds for different user settings. Alternatively, the system can generate a warning by flashing the room’s lights on and off. Additional user feedback can be communicated with a flashing LED built into the sensor. This LED can be connected to the microcontroller’s I/O ports that can sink or source 20mA without the need for external circuits or current limiting resistors. The high boundary mark of 20mA allows a direct connection of an LED to the AVR microcontroller without a resistor.

Pulling Out the Stops

The microcontroller that can make this sophisticated occupancy sensor a reality is Atmel’s AVR 8-bit RISC microcontroller called the ATmega88 (Figure 2). This microcontroller integrates a wide variety of peripherals, but the peripherals specifically valuable to the sensor include a very accurate 10-bit ADC with up to 8 differential channels, 8K of self-programming flash, 512 bytes of EEPROM, 1K SRAM, and an internal RC oscillator. This oscillator can go from sleep to wake up and stabilization in 6 cycles, 10x faster than competitive solutions. This fast wake up time has a major impact on power consumption. The ATmega88’s I/O ports with internal pull-up resistors on every pin can be turned on or off individually as required and the timer/counters have compare, capture and PWM outputs.

The ATmega88 integrates many useful peripherals to facilitate the design of a cost-effective occupancy sensor.

The performance of the ATmega88, along with its variety of peripherals allows designers to build one occupancy sensor to serve multiple markets. The microcontroller’s in system Flash program memory enables simplified inventory management, just-in-time delivery, and eliminates wasted product due to code patches.