TECHNICAL VIEW

PIR sensor alarms get the picture

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FUTURE ELECTRONICS

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- Ideas for adding value to simple intruder alarm systems
- New image sensor, alarm enhancer and radio components to enable enhanced intruder detection designs

Traditionally, the function of the Pyroelectric Infrared (PIR) sensor in an intruder detection system (commonly known as a burglar alarm) is simply to switch an output to an alarm, which activates a siren and/or auto-dials a police or security company control centre. Paul Silcock, Technical Solutions Manager, Future Electronics (UK) explains how to add functionality by adding image capture without increasing size or the power budget.

Recent improvements in component technologies mean that it is now possible to design a camera, flash and wireless transmitter into the PIR sensor with only a small increase in the size of the end product. By taking still or moving pictures of the intruder, compressing them and then uploading the images to a central server, the sensor greatly strengthens its deterrent effect against intruders by providing evidence, which can be used against the perpetrator. This adds a large amount of value to the end product, but without a correspondingly large increase in the bill of materials.

The chief challenges involved in implementing such a design are, first, to keep the physical size of the product to a minimum; and second, to limit power consumption so that it can run for extended periods on battery power. As this article will show, both of these challenges can be met by using the latest generation of components. The main principles of the design approach taken here are:

- To use highly integrated ICs, eliminating peripheral components and thus reducing footprint

- To keep large sections of the system in sleep mode except when an intruder is detected. This means that the power-hungry elements of the system, such as the short-range radio and image processing, only operate at full power in short, infrequent bursts.

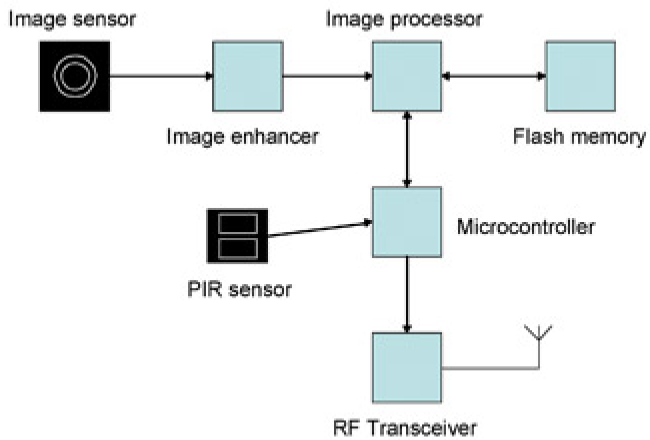

Fig. 1: Block diagram of enhanced PIR sensor system

The basic architecture of this enhanced intruder detection system is simple (see Figure 1). When the PIR sensor detects a moving body in its field of view, it wakes up the microcontroller.

The controller activates the camera flash and image sensor to capture images of the intruder, and also activates a siren; the images are processed, enhanced and compressed before being transmitted by the short-range radio transceiver to a local control panel. The control panel (not described in this article) will then dial out to a security control centre, sending the images and an alert.

The first challenge for the designer is to find a way to implement this considerable additional functionality, of capturing and wirelessly sending images, without requiring a large amount of extra board space. The answer is integration.

The output from a PIR sensor requires signal conditioning before it can be processed by the controller (see Figure 2). Most intruder detectors on the market today implement this signal conditioning with a large number of discrete analogue components. Since the controller functions required for this essentially dumb device are so limited, such designs only need an extremely simple, very low-cost 8-bit microcontroller. No such microcontroller will offer the sophisticated analogue functionality required to implement PIR sensor signal conditioning. This is why these designs use a large number of discrete analogue components.

Clearly, bolting on camera and radio functionality to such an architecture would dramatically increase the size and cost of the end product. There is an alternative, however: using a specialist mixed-signal controller, the designer can absorb both signal-conditioning and system-control functions into one device. This will eliminate a large number of discrete analogue components while providing the capability to control the additional camera and radio functions.

The effect of this integrated approach can be seen clearly in Figure 3, an implementation using the new ePIR controller from ZiLOG.

The ePIR solution uses a software algorithm for signal conditioning, running on a microcontroller from ZiLOG's Z8 Encore! XP family. In this intruder alarm design, the 8-pin Z8F042ASB020SG device would be suitable. No external gain or filtering circuitry is required, which dramatically reduces component count. At the same time, an ePIR design will offer excellent immunity to false alarms and noise, high reliability and integrated compensation for environmental effects.

Because there is no filter, there is no loss of signal, which results in improved range and coverage. The total cost of an ePIR-based circuit is cheaper than a traditional all-analogue PIR sensor circuit, while offering better performance than high-end digital PIR sensor systems are able to provide.

An alternative approach to integrating the analogue signal-conditioning circuitry is to use a member of the PSoC (Programmable System-on-Chip) family of devices from Cypress Semiconductor. PSoC devices are mixed-signal arrays of configurable digital and analogue blocks, controlled by an on-chip 8-bit core. The blocks can be configured to fulfil standard peripheral functions such as analogue-to-digital converter, timer and UART. But the value of PSoC is its ability to also integrate sophisticated analogue functions such as filters and amplifiers.

The analogue functions of the conditioning circuit outlined in Figure 2 can be integrated in the PSoC, meaning that a complete solution comprising the PIR sensor, PSoC and a handful of tiny passive components can be realised (see Figure 4). Furthermore, like the ePIR implementation, the solution can be streamlined to fit into an 8-pin device.

Such an implementation leaves processing bandwidth to spare to control the downstream system functions: activating the image sensor, power LED and image processor, and operating the short range radio.

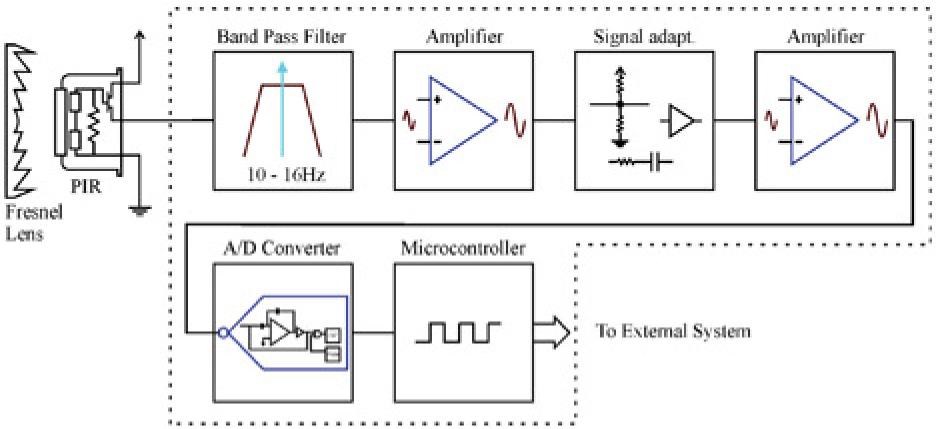

Fig. 2: Typical PIR sensor signal-conditioning circuit.

Enhancing and compressing images of an intruder

By integrating signal-conditioning functions in the motion-detection section of the system, the board space that is released can now be populated with devices to realise additional functionality. For instance, capturing an image will require an image sensor, an image processor and a small light-source.

The past few years have seen a proliferation of small, cheap image sensors, thanks largely to the enormous volumes of such devices consumed by the mobile phone industry. For this intruder detection application, the MLX75007 camera-on-a-chip from Melexis would be suitable. The device offers panoramic VGA resolution at 750x400 pixels, in black-and-white or colour. Originally developed for the automotive industry, it is very competitively priced, while offering high dynamic range and image quality that is good enough to allow identification of an intruder, without being of the high quality required by consumers in a camera phone. The device has a Stand-by mode for reduced power-consumption.

The images produced by this camera will result in the creation of, typically, several hundred kilobytes of data. This data cannot be permanently stored locally, otherwise the intruder could simply remove the sensor to get rid of the evidence of the crime. So the images have to be transmitted to a safe location. Wireless transmission is preferred, as it reduces installation costs and eliminates any risk of a cable being cut by an intruder. But transmitting large data files wirelessly consumes a lot of power and takes a lot of time. The answer to this problem is to use an image-processor to compress the data before transmission.

As shown above, when designing the motion-sensing function, integration allowed a big reduction in component-count.

The same principle can be applied to the image-processor. A useful device here is the tiny, 8mm2, BU6569GVW from Rohm: it offers interfaces for a 2 Megapixel camera, NAND Flash and SD/MMC cards. Crucially it also provides adaptive differential pulse-code modulation and JPEG codecs for image compression.

It is worth bearing in mind the requirements of this application: the subject of the image does not want to be photographed and could be moving, the pictures could need to be taken at night, and yet to be useful they must allow the subject to be clearly identified. The design therefore requires two additional functions: flash lighting and image enhancement. A power LED provides a bright burst of light from a low-voltage source while occupying a small area. The LXCL-PWF3 Flash LED from Philips Lumileds measures just 2mm x 1.6mm. A single device can illuminate up to a distance of 2m with a 1A pulse.

Unmodified, the signal from an image sensor under the harsh lighting conditions experienced by typical security applications will often be unusable. Areas of excessive brightness or darkness will cause the image sensor to bleach or black-out the image.

Typical image enhancers work on the principle of adjusting the balance of the whole image. For this application, however, a better choice would be the BU1570KN adaptive image enhancer from Rohm. This device uses hardware-based image-processing technology to raise or lower the brightness of only selected portions of the image which are too bright or too dark. This approach achieves much better image clarity under extreme lighting conditions. The BU1570KN also offers motion detection, colour correction and brightness determination. In a PIR sensor application, the motion detection hardware can verify inputs from the PIR sensor.

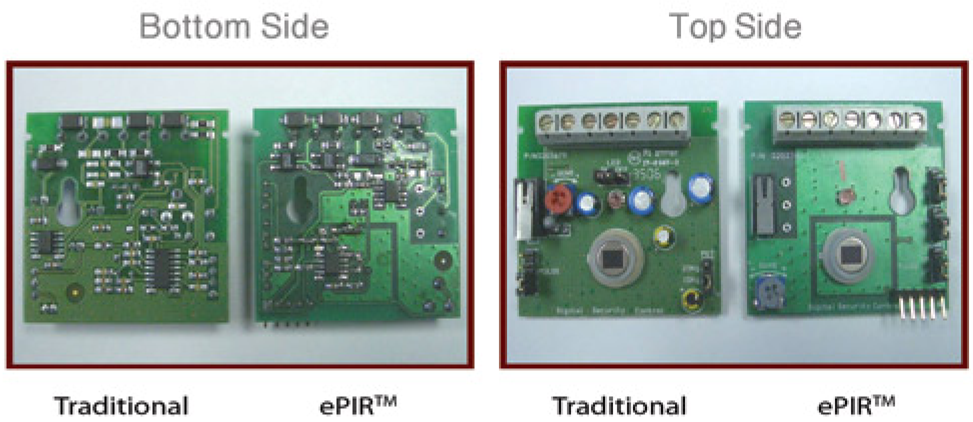

Fig. 3: Board space saving achieved by use of a highly-integrated ePIR controller from ZiLOG to replace a traditional analogue PIR sensor design.

Transmitting images for secure storage

The enhanced, compressed images now need to be sent to a central server for secure storage, where they cannot be tampered with by an intruder. The main design challenge is, again, to provide this functionality with a miniature, power-efficient device.

The data rate requirement is quite moderate. JPEG typically achieves a 10:1 compression ratio with little perceivable loss in image quality. This means that a typical 500kB image file could be compressed to 50kB, and transmitted in 2s at 250kbit/s, even with a prudent allowance for overhead.

A sensible approach would be to buffer images in a small Flash memory on activation of the sensor, bringing the NAND Flash interface in the BU6569GVW into play, and then stream them to the server.

Operating in Europe's unlicensed 433MHz and 868MHz bands, Micrel's MICRF505/6 transceiver comes in a 5mm2 MLF package. It provides a data-rate up to 200kbaud and draws 28mA in transmit mode.

The use of just a transmitter would give a small saving in board space and power, whilst a transceiver would allow for confirmation of receipt of transmitted images. Bearing in mind the application, the risk of failed transmission is not worth taking: the system might only ever be called on to operate once – when it does, the user will expect it to work flawlessly.

For end products that are to be marketed worldwide, the 2.4GHz frequency is more suitable. Here, Freescale's MC13202 is compatible with the IEEE 802.15.4 standard and has an over-the-air data rate of 250kbps using Direct Sequence Spread Spectrum (DSSS) coding for interference immunity.

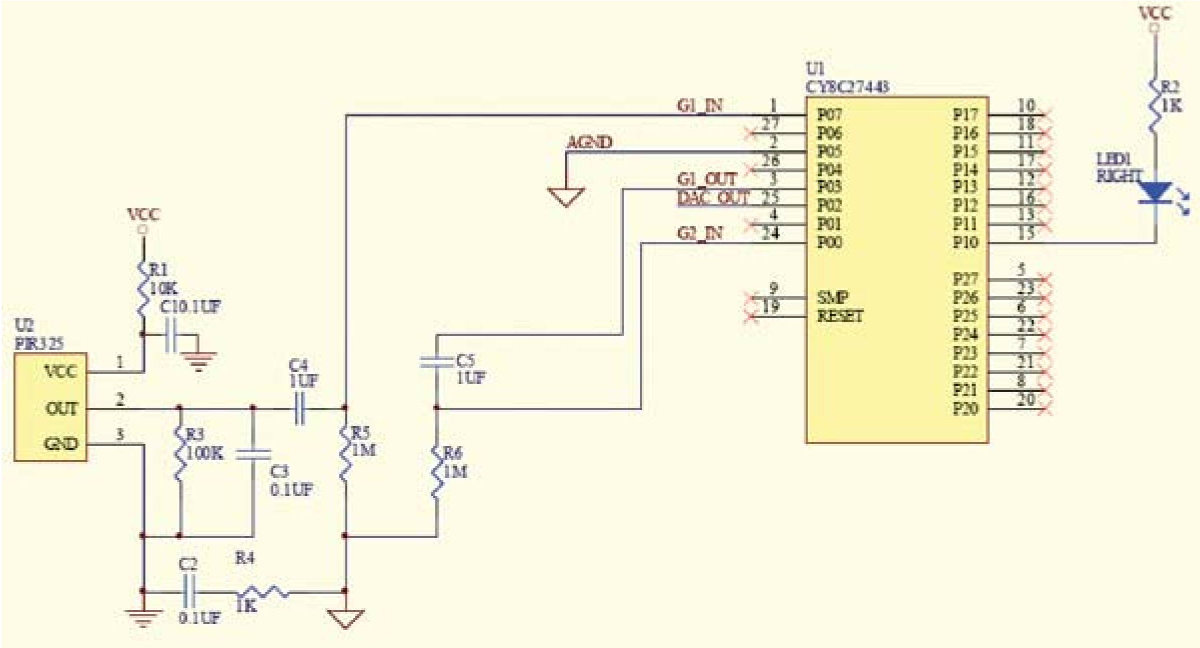

Fig. 4: PIR sensor signal-conditioning circuit implemented in a CY8C27443 PSoC.

Optimising this design for low-power operation

It is inevitable that, as devices are added to a design in order to add functionality, so more power is consumed. But the enhanced marketability of the improved PIR design would be negated if an expensive and bulky power supply were also required.

Fortunately, however, recent advances in DC-DC conversion technology come to the design's rescue. New, highly efficient synchronous buck regulators with integrated FETs, and in some cases inductors, provide considerable savings in battery-powered applications.

For instance, the SupIRBuck family of Point-of-Load (PoL) voltage regulators from International Rectifier integrates high performance synchronous buck control ICs and HEXFET trench-technology MOSFETs in a compact 5mm x 6mm Power QFN package. The IR3812MPbF, for example, can supply up to 4A from a wide-input range of 2.5V to 21V, with efficiency exceeding 90%.

Fairchild Semiconductor's TinyBuck™ family of synchronous buck regulators would also be very suitable for PIR sensor applications. The FAN2103, for example, supplies up to 3A from a 3V-24V input in a 5mm x 6mm 25-pin MLP package. Efficiency can be in excess of 95%.

Improvements in the efficiency of power ICs are not the only way for this design to hit its power budget. In this application, most of the system is active very infrequently, and when it is active it is in a short burst. The key to long battery life, therefore, is to use the controller to put most of the system into sleep mode while waiting to be activated by the PIR sensor.

On activation of the PIR sensor, the microcontroller will supply power to the camera, LED flash light, image processor and Flash memory to enable capture, compression and storage of images. With the exception of the Flash memory, these devices will all be switched off before the radio transceiver is powered up and the streaming of image data can be initiated. Finally, the system will return to its inert state awaiting the next activation.

The average current drawn by this system, of an estimated 6mA as opposed to around 0.25mA for a traditional dumb PIR sensor, is moderate, and so ensuring long battery-life should not be technically challenging. In fact, the more important calculation is whether the chosen battery can support the peak load, when the system is fully active. To be sure of this, the design engineer must carefully work out current consumption at each stage of operation.

Traditional design		Enhanced design	
PIR sensor	$2.00	SMT PIR sensor	$3.00
Microcontroller	$0.60	Mixed-signal microcontroller	$1.20
Filter	$0.50	Power supply	$3.00
Amplifiers	$1.00	Miniature image sensor	$8.00
Power supply	$2.00	Image processor	$1.60
		Image enhancer	$3.00
		LED Flash module	$1.50
		NAND Flash	$2.00
		RF transceiver	$2.20
TOTAL (estimated)	$6.10	TOTAL (estimated)	$39.90

Table 1: Estimated bill of materials comparison between a traditional dumb PIR sensor and the enhanced camera/sensor with radio.

Conclusion

Improvements in a range of components recently brought to market have, in combination, enabled a valuable enhancement to traditional dumb PIR sensors without sacrificing battery life and without increasing significantly the size of the end product. For designers prepared to consider non-traditional controllers such as the ePIR from ZiLOG or the PSoC from Cypress, such a design is relatively easy to implement.

Table 1 compares the component costs of the traditional solution and the enhanced system. While the cost of materials is higher in the improved design, the extra value it provides, derived from the ability not just to detect but also to identify an intruder, should support a much higher selling-price.

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