Wireless detection

Embedded system technologies in wireless motion detectors

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Motion detectors have become ubiquitous in homes and workplaces across the globe as a form of protection, and as a means of triggering light sources indoors and out. However, these detectors need wires to function, making their installation laborious as well as costly. The good news is that this is all about to change. ABB, in cooperation with one of its partners, has recently developed a new wireless motion detector. Using embedded system technologies, not only have the wires disappeared but engineers have produced a flexible, reliable, compact and inexpensive device that can operate for at least five years using just standard alkaline batteries!

Busch-Jaeger, an ABB company, offers a broad range of motion detectors for use in homes, offices and outdoor environments. These *Busch Watchdogs* are characterized by their high reliability and innovative design. However, in some cases the installation effort required, especially in existing buildings where no extra cabling has been placed, can be quite high. Therefore, to reduce this effort as well as allowing for additional placing freedom, Busch-Jaeger, working together with ABB's Corporate Research Center and another company MEMS Inc.[1)], has developed a new wireless motion detector 1.

1 The new wireless motion detector excels through its high reliability and innovative design

Low power consumption was one of the fundamental demands of the new wireless motion detector, and it had to be provided without compromising reliability. This demand was met using low power-consuming components and embedded system technologies. Electromagnetic susceptibility, which increases with a rise in system impedance, had also to be addressed. To avoid this, all sensitive signal lines were kept short. So, not only have the cables disappeared making installation easier, but the end result is a reliable and inexpensive motion sensor that consumes, on average, less than 20 µA of current! In addition, it allows for seamless integration into the existing Busch-Jaeger product portfolio in terms of cost, design and performance.

ABB's wireless motion detector uses embedded system technologies, is flexible, reliable, compact and inexpensive.

Detector design

To carry out the different functions of the detector, three interconnected modules have been developed – the sensor, radio and controller modules.

The sensor module

This is the most delicate part of the system as it contains the passive pyroelectric infrared sensor (PIR) 2a that captures the monitored movements, and transforms them into infinitesimal electrical signals. Because small signals are particularly prone to electromagnetic interferences, they need to be amplified as close to their source as possible. Therefore, an ultra-low power amplifier 2b has been mounted directly beside the PIR sensor connections. The sensor has been taken from the Busch Watchdog Professional product series and adapted to the stringent power consumption requirements of the new device.

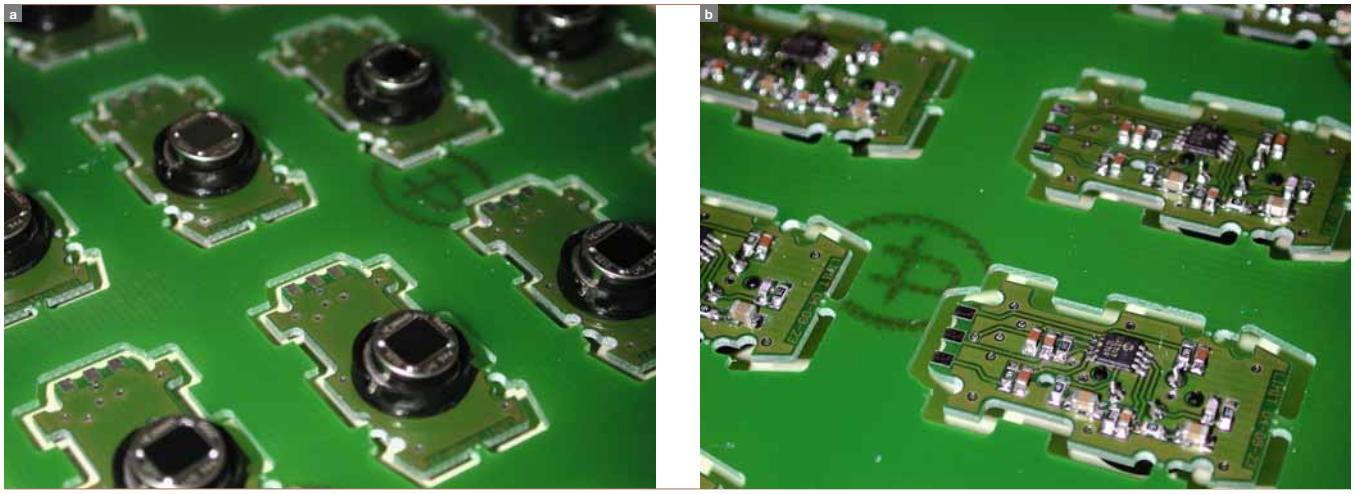
The radio module

The radio module ensures communication between the wireless motion detector, and one or several actuators (ie, radio-controlled light switches). To fulfill the low power consumption requirements in this module, only one-way communication from the motion detector to the actuator is used to avoid permanent reception readiness. A typical transmission takes place in the ISM-Band (industrial,

Footnote

[1)] MEMS Inc. is an engineering company whose founding members are former ABB research engineers. For further information see www.memsag.ch (September 2007).

2 On the sensor module, the amplifier and the PIR sensor have been mounted in a way that avoids electromagnetic interferences
- a Front fitted with PIR sensor
- b Back with electronics and amplifier (these pictures taken during production show several sensors)



scientific and medical) at 868 MHz (KNX-RF protocol), and a range of up to 300 meters is possible out in the open.

The controller module

The radio and sensor modules are mounted on the controller module 3. This module also contains a power supply and provides the means for background illumination sensing and parametrization. Its core component is a mixed-signal microcontroller that processes all sensor signals and system parameters, finally generating the binary presence signal that is transmitted to the actuator by the radio module. The microcontroller supports several power down modes that allow the temporary shutdown of individual processor functions, and their subsequent recovery within a few microseconds. By operating only the necessary circuitry needed to perform a particular function, additional – in fact substantial – power savings are achieved.

Finding an appropriate power supply

Ultimately, the success of a wireless appliance depends as much on its innovative design as it does on the choice and availability of an appropriate power supply. Users demand energy sources that are cheap and compact, and which function for a very long time. Therefore, a variety of power supply solutions were investigated as to their suitability in a wireless motion detector. Some of the criteria that had to be met included:

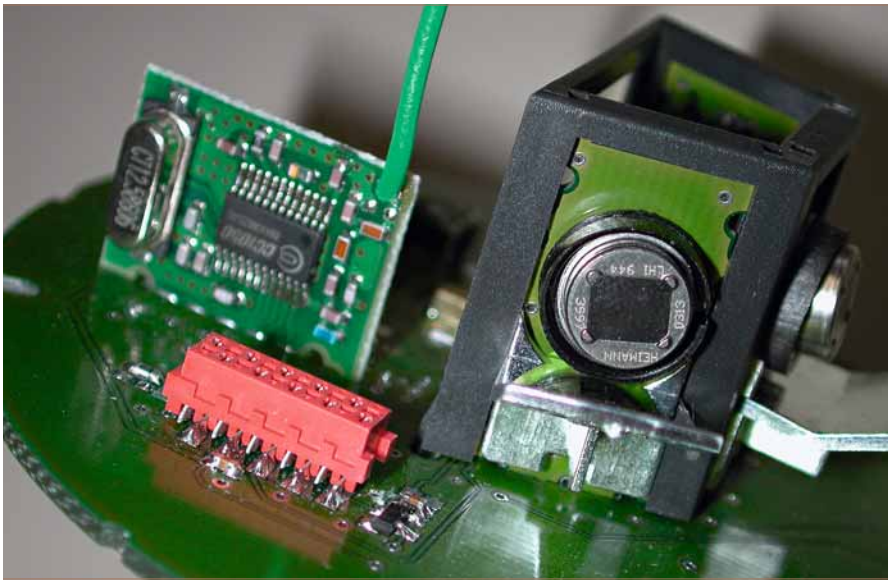
- A potential source should function uninterrupted for at least ten years.
- It must be able to deliver an average current of 20 µA and sustain current peaks of 25 mA. These typically occur during radio communications.
- The temperature range should extend from at least –20 to +60°C.

Six possible candidates are listed in the Factbox.

Factbox Power supply possibilities for the wireless motion detector

Power supply	Source of energy	Suitability
Batteries	Electrochemical	Suitable
Solar cell	Sun	Suitable
Thermoelectric generator	Temperature difference	Possibly suitable – Low performance
Fuel cell	Electrochemical	Not suitable – Expensive, limited long-term stability
Piezoelectricity	Wind (von Karman effect)	Not suitable – Very low performance
Wireless energy transfer	Power supply system	Not suitable – Expensive, acceptance issues

3 Controller module fitted with three sensor modules and one radio module



Batteries

Batteries constitute the most obvious solution. Four 1.5 V alkaline cells ensure a lifespan of five to seven years, just a little short of the ten year goal. Moreover, this option is very cheap and batteries can be acquired virtually anywhere. The downside, however, is their limited temperature range[2)] and self-discharge rate, which happens to be quite significant. To overcome these disadvantages, the more expensive but longer lasting lithium iron disulphide cells (Li-FeS2) could be used instead.

Users demand energy sources that are cheap and compact, and which function for a very long time. Therefore, the success of a wireless appliance also depends on the power supply used.

Solar cells

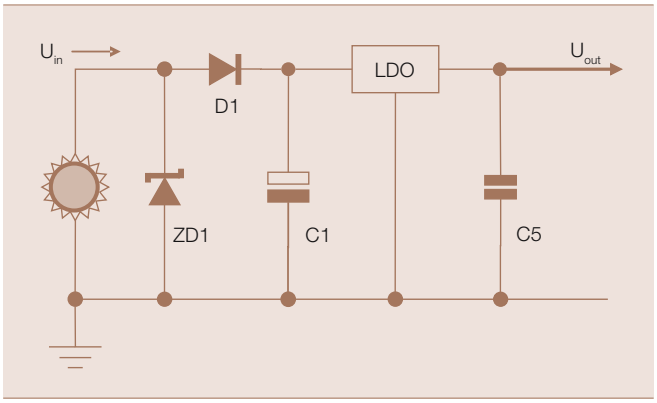
A power supply based on solar cells is ideal for the wireless motion sensor. Solar cells constitute an ecological alternative to a battery supply. They require no maintenance or replacement and are particularly suited for

Footnote

[2)] The typical temperature range for alkaline batteries extends from –10 to +50°C, while it can range from –40 to +85°C for Li-FeS2 cells.

self-sufficient working. In fact, a solar cell-based power supply prototype for the wireless motion detector has already been designed by ABB engineers. Photovoltaic cells produce most of their energy during daylight, and therefore some energy storage is required for night operation. This principle is illustrated in 4: The electric double layer capacitor (EDLC), C1, stores the energy generated by the solar cell during the day. These capacitors, also known as Gold Caps, deliver energy densities that are 300 times that of conventional capacitors. They can be recharged hundreds of thousands of times, unlike conventional batteries which last for only a few hundred, or at most a thousand, recharge cycles. However, loading the EDLC can take several hours. Therefore, another smaller capacitor, C5, is normally connected in parallel to reduce the initial start-up time of the powered device.

4 Principle of the solar cell supply. Solar cells produce power during daylight, and additional energy storage for night operation is provided by C1 and C5



The solar cells consist of amorphous silicon. This type is much cheaper than crystalline cells, and its effectiveness does not depend on even illumination. This is important because motion sensors are often operated in partially shaded locations. With the above solution, a cell of size 57 × 50 mm suffices to reliably power the wireless motion detector.

Thermoelectric generators

Thermoelectric generators use the Seebeck Effect to create power from temperature differentials. The Seebeck Effect is defined as the open circuit voltage produced between two points on a conductor, where a uniform temperature difference exists between those points. This effect is usually very small, but recent generators have achieved as much as 20 µW on a single chip with a temperature difference of 5°C. In order to apply the thermoelectric principle to the wireless motion detector, a sufficient temperature gradient must be attained inside the device. While solar energy could be used to this end, thermoelectric generators are not yet suitable for indoor applications.

Fuel cell

A fuel cell is an electrochemical device similar to a battery, but it is designed to continuously replenish the reactants consumed. In other words, while a battery has limited internal energy storage capacity, the fuel cell produces electricity from an external fuel supply of hydrogen and oxygen. Research has shown that the development of fuel cells for portable computers and cellular phones is possible, but high costs and a limited lifespan currently prevents their use in wireless motion detectors.

The wireless motion detector combines the well-established reliability of Busch Watchdogs with ultra-low power consumption, and it can be placed anywhere and is easy to install.

Piezoelectricity

With piezoelectricity, certain crystals generate a voltage in response to an applied mechanical stress, for example one generated by wind or by any other form of thermal airflow with the aid of the von Karman effect. This principle, which notably describes the flapping of a flag, states that flow around a bluff body will generate vortices on alternate sides of the body. The effectiveness of this method however is insufficient for powering the wireless motion detector.

Wireless energy transfer

Wireless energy transfer works by transmitting electromagnetic energy from an external power source to the receiver. This would require the mounting of an expensive and space-consuming emitter coil in the actuator. In any case, customer acceptance of such technology is still low.

Where customers benefit

The wireless motion detector developed by ABB combines the well-established reliability of Busch Watchdogs with ultra-low power consumption. It can be placed anywhere and is easy to install. Normal off-the-shelf alkaline batteries ensure a lifespan of at least five years, and this is extended to more than ten years when lithium iron disulphide cells are used. The detector complies with all current EMC regulations.

The wireless Busch Watchdog[3)] was successfully presented at the "Elektrotechnik" fair in Dortmund, Germany in September 2007.

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Footnote

[3)] More detailed product information can be found at http://www.busch-jaeger.de/de/bewegung-smelder/1836.htm (September 2007)