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Sensors Without Batteries

In the future, the environment could be pervaded by sensors using the same power-scavenging techniques as RFID tags.

By Kate Greene

Some technologists believe that in the future, seemingly invisible computers will be embedded everywhere, collecting data about the environment and making it useful to decision makers. One way to achieve this sort of ubiquitous computing is to disperse tiny sensors that measure, for instance, light, temperature, or motion.

But without a persistent power source, such sensors would need their batteries replaced every few months. In other words, ubiquitous sensors could also mean "ubiquitous dead batteries," says Josh Smith, a researcher at Intel Research in Seattle.

Smith and his team are addressing this problem not by working on longer-lasting batteries but by trying to eliminate the need for batteries altogether. Instead, their prototype devices employ the same power-scavenging technique used by battery-free radio frequency identification (RFID) tags.

The concept of throwing out the sensor battery is not new. Researchers have proposed capturing energy from environmental vibrations or ambient light to power a sensor (see "Free Electricity from Nano Generators"). But it is unclear whether technology that captures ambient energy can be inexpensively integrated into a sensing device.

By contrast, the technology used in RFID tags, which transmit a few bits of information when scanned by an RFID reader, is cheap enough to integrate into sensors and be mass produced; they're already widely used to track livestock and cargo, as well as cars passing through "easy pass" lanes on highways.

Smith explains that Intel's sensor devices use off-the-shelf components: an antenna to send and receive data and collect energy from a reader, and a sensor-containing microcontroller -- a tiny computer that requires only a couple hundred microwatts of power to collect and process data.

The antenna harvests this power directly from the radio waves emitted by an RFID reader. When a tag comes within range of a reader, the reader's radio signal passes through the antenna, generating a voltage that activates the tag. The tag is then able to send information to the reader through a process called backscattering, in which the antenna essentially reflects a data-encoded variation of the received radio signal.

The microcontroller that Smith's team added to the RFID antenna includes a 16-bit microprocessor, 8 kilobytes of flash storage, and 256 bytes of random-access memory.

One of the microcontroller's main jobs is to ensure that information is transmitted to the reader error-free, which requires more computation than a conventional RFID tag can handle. In a typical tag, the error-checking information is precomputed and stored on the chip; but for a sensor, Smith says, this information needs to be computed in real-time as data is gathered.

Just like RFID tags, the battery-free sensors turn on only when they encounter a reader. As long as the RFID reader is within range of the device, Smith says, it can collect data and send it to the reader.

Battery-free sensors could be useful in many areas, including medicine, says Zeke Mejia, chief technology officer of St. Paul-based Digital Angel, an RFID tag maker. They could "check the status and certain conditions in the body" at any moment, Mejia says, from glucose levels in people with diabetes to the pH of blood and other body fluids.

In their current form, Intel's sensors need to be within about a meter of a reader to be activated. That's closer than would be ideal for some applications, such as measuring the temperature of foods packed in large crates or vibrations in thick walls. The problem is that while the microcontroller needs only a milliwatt of power to run, it needs three volts of electricity to turn on, and the sensor has to be within a meter of an industry-standard RFID reader to generate that much energy. But with minor changes to the way the microcontroller processes data, Smith says, the group could reduce the voltage requirement to 1.8 volts, thus extending the range to about five meters.

The team's latest prototype incorporates a light sensor, temperature sensor, and even a tilt sensor into one battery-free device. The researchers are working on ways to integrate the microcontroller and antenna into a single chip that would be easier to install in the field. In the meantime, they have developed a visual demonstration of just how much energy an RFID antenna can garner from a reader: they've used it to power the second hand on a wristwatch.

"It's surprising to people that this invisible form of energy –- radio waves -– can actually make a watch hand move," Smith says. And a single tick of a second hand, Smith says, takes about as much energy as sending one bit of data from his sensor.