Power from motion and vibrations

February 16 2010, by David L. Chandler

The Trans-Alaska Pipeline System, which traverses hundreds of miles of some of the most inhospitable terrain on Earth, must be monitored almost constantly for potential problems like corrosion or cracking. Humans do some of this work -- surveying the pipeline from the air and inspecting it more closely in the areas that can be easily accessed by roads -- but the bulk of it is done by mechanical "pigs," sensor-laden robots that travel inside the pipeline looking for flaws.

A simpler process might involve outfitting remote stretches of the pipeline with sensors that would automatically radio a warning of impending problems. But the need to periodically change the batteries on such sensors lessens the appeal of that option. For electronic devices in remote or inaccessible situations like this, including environmental or mechanical monitoring sensors as well as some kinds of biomedical monitors, it can be inconvenient or even impossible to replace batteries.

This is the second of a series about MIT research on harnessing micro-sources of power (part one can be read here).

But what if batteries weren't necessary?

Systems that could provide power for such sensors just by harvesting the normal vibrations of the pipeline (or bridges or industrial machinery and so on), eliminating or reducing the need for a battery, are being developed by Anantha Chandrakasan, MIT's Joseph F. and Nancy P. Keithley professor of electrical engineering and director of the MIT Microsystems Technology Laboratories, and his former student Yogesh Ramadass SM '06, PhD '09.

They have been working for years on the development of ways to harness small amounts of power from ambient vibrations. A paper describing their latest work on a new control circuit for such systems, which can quadruple the amount of power they produce, appeared last month in the *IEEE Journal of Solid-State Circuits*.

Big steps toward tiny power

There are a number of different approaches to harnessing vibrational energy, some using magnetic or electric fields. But the new control circuit Ramadass and Chandrakasan developed is designed to work with piezoelectric systems — ones that use voltage generated by stress in a crystalline material, such as lead-zirconate-titanate.

It has been known for well over a century that some materials, including some crystals and ceramics, will produce an electrical current when subjected to stress by squeezing or bending. To harness the energy of motion or vibration, such a material is coupled to a spring, pendulum or other mechanism that converts the motion into pressure.

Chandrakasan and Ramadass envision applications in such things as implantable medical diagnostic or treatment devices that could be powered indefinitely by the person's own natural movements, or distributed sensors to monitor structural elements on bridges or the pressure in truck tires and transmit the data to a central receiver, powered by the vibrations of ordinary traffic.

Existing devices for harvesting energy from vibrations tend to be tuned to very specific frequencies, Chandrakasan says, but "in many practical applications, we need something more general. That's still a technical question to be addressed."

For now, such systems can't deliver enough power to run consumer devices such as cell phones, Ramadass explains. "The power levels for a cell phone are way up from what we can generate now" from a person's natural movements, he says, although some simpler devices, such as an mp3 music player, might be within the available range. He is currently working with semiconductor leader Texas Instruments to develop commercial applications of ultra-low power systems and solutions.

David Lamb, chief operating officer of Camgian Microsystems, a company that produces a variety of low-power, lightweight semiconductor chips, says enabling new, low-power distributed sensor and security systems will depend on improving the efficiency of energy-harvesting techniques, including the power-producing system as well as control and storage systems. Because low-power systems are still a relatively new area of research, he says, "typical power management approaches are not well suited to energy harvesters, and there are still a lot of unsolved challenges," But devices such as the company's remote surveillance system are designed to operate on very low power, he says, and "if efficient interface and control circuits can be developed, this microsystem can be continuously powered by energy harvesting."

The U.S. Defense Advanced Research Projects Agency (DARPA) has provided support for this research, which also holds promise for monitoring military equipment in remote locations.

The team has also been developing systems to derive small amounts of power from temperature differences (as described in part one of this series), and Chandrakasan says that in the future, some applications might make use of systems that combine both the heat- and vibration-harvesting devices to produce more power, or to work in situations where these energy sources are variable and one or the other might not always be available.

Some parts of such a system, such as the electronic control circuits and transmitters for relaying the collected data, could be connected to both the heat and vibration generating systems (as well as additional sources of power, such as a solar cell), Ramadass says. "You could have one set of electronics that interfaces" with multiple inputs, he says.

For the future, the researchers are working on ways to improve the integration of the various components, and on making the systems as versatile as possible. "We want to make them adaptable over a broad range" of operating conditions, Chandrakasan says. In addition, they are working on improving the devices' overall efficiency. "We want to get to the maximum theoretically possible achievable energy," Ramadass says.

More information: *This is the second of a series about MIT research on harnessing micro-sources of power (part one can be read here).*

Provided by Massachusetts Institute of Technology