“Never Need Batteries Again”

By Ken Gilleo

The battery is very old technology that converts chemical energy to electricity. The earliest electrical experimenters used homemade batteries. A battery delivers electrical energy using electrochemical reactions and there are literally hundreds that can produce electricity. Over the years, a few have become standards like, carbon-zinc (general purpose dry cell), lead-sulfuric (automotive) and now, various lithium (dry, rechargeable) batteries. You can even use mud for the electrolyte according to microbiologists at the University of Massachusetts who built a battery using ocean silt, graphite and glass jars.

Fuel cells are close kin to batteries since stored chemical energy (a hydrogen-containing fuel) is converted directly to electricity by oxidizing the fuel into water. But say we want to power a remote wireless system and there is no convenient electrical service. The battery or fuel cell would eventually run out of “fuel”. So is there any alternative? We might use an “energy extractor”. Never heard of one? How about a *wind generator*? In the early 1900’s, farms and rural residences used small windmills directly connected to electrical generators to charge radio batteries. Windmills, hydroelectric generators and all the other systems for converting waste energy to useful forms may be classified as energy extractors. But the early machinery and most modern versions are macro-scale. Could we build a micro-size energy extractor and use it to power small electronic devices like a “monitor module”?

It’s time to enter the world of MicroElectroMechanical Systems, or MEMS, for the solution. Can this technology build a tiny chip that extracts energy? The MEMS teams at Sandia have built just about everything including a micro stream engine, so the extractor should be quite feasible. What energy form could we mine? There’s always solar and wind, but they may not be too dependable, especially indoors. How about mechanical vibrations? In a sense, everything vibrates unless it’s at absolute zero. Heat, or thermal energy, is vibrating molecules. We certainly will also want to consider waste heat. But macro vibrations occur in just about every machine. So why not convert these vibrations into electrical power?

MIT, under DARPA funding, has studied the feasibility of extracting energy from vibrating equipment, although the professors prefer the term “energy harvesting”. One MIT MEMS group has designed chips that convert vibrations to electrical output using movable capacitor plates. They have found that the 1 to 5 KHz range is rich in energy and have therefore optimized their harvesters for this part of the vibrational spectrum. There are other mechanisms that could be used, but the capacitor plate, common in MEMS motion detectors, is easy to design and fabricate.

We may also want to tap into thermal energy using some of the new thermoelectric materials though most are being focused on macro applications. A nanotechnology solid-state heat pump substrate could do the trick. Clemson University, MIT's Lincoln Labs and a few other research groups have reported progress. While they may be targeting large sources, like automobile engines, the principles can work on a smaller scale. Inductors could also extract electricity from the magnetic field near an electric motor.

Assuming that we can build practical chip-size energy extractors, what should we use them for? How about equipment monitoring? The US Navy has hundreds of ships and each has thousands of motors and mechanical devices. The present method of having a sailor check them is imprecise and has elements of danger depending on the situation. What if we place an energy extractor on the motor and use it to power a MEMS vibration analyzer? This is what the Navy needs and the DoD is funding several related programs. When the vibration signature changes, the logic circuit could send an alarm that something is amiss. Now let's add the equivalent of an RFID (Radio Frequency Identification Tag) circuit. A single-chip transceiver could report back data when queried by an electronic "reader". We already have a lot of RFID technology and even commercial products to draw from. When the RF chip receives a wireless query signal, it sends back stored coded information. "I'm motor M-235, experiencing level 4 abnormal vibration, time & date, etc". The reader next logs the collected data into the ship's master maintenance computer so that necessary action can be planned in a timely, preemptive manner. Some estimates suggest as many as 500,000 monitors per ship will be needed. If that number were anywhere close, wired in power would be impractical, as would batteries needing periodic replacement. Sounds like a good fit for *MEMS Energy Extractors*. Since the entire ship structure vibrates with "the throb of the engines", any location might work.

Of course, the same technology and strategy can be applied to a factory environment. The tiny *MEMS Monitor Modules* could be affixed to equipment. Maybe even incorporate GPS so that monitors can be moved at will. Now, a quick walk-through each day, with a hand- or belt-held reader, would measure the "health" of the equipment. There are all kinds of possible scenarios, so go ahead and imagine. The limits of MEMS and Nanotechnology are only those of human imagination.