New chip captures power from multiple sources: light, heat and vibrations

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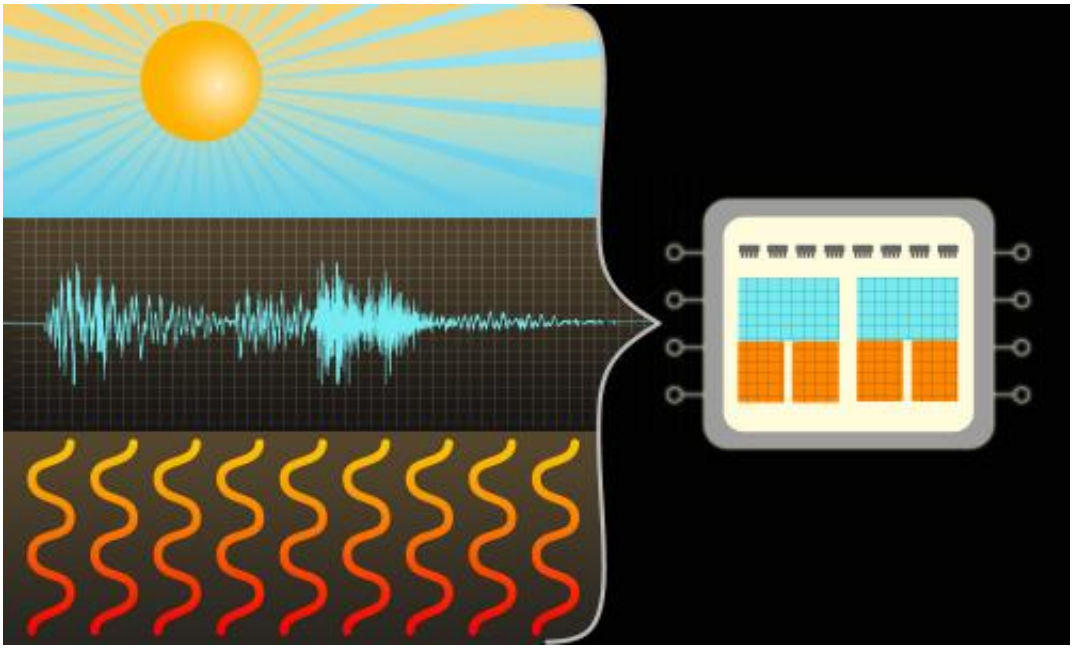

Graphic: Christine Daniloff

Researchers at MIT have taken a significant step toward battery-free monitoring systems — which could ultimately be used in biomedical devices, environmental sensors in remote locations and gauges in hard-to-reach spots, among other applications.

Previous work from the lab of MIT professor Anantha Chandrakasan has focused on the development of computer and wireless-communication chips that can operate at extremely low power levels,

and on a variety of devices that can harness power from natural light, heat and vibrations in the environment. The latest development, carried out with doctoral student Saurav Bandyopadhyay, is a chip that could harness all three of these ambient power sources at once, optimizing power delivery.

The energy-combining circuit is described in a paper being published this summer in the *IEEE Journal of Solid-State Circuits.*

“Energy harvesting is becoming a reality,” says Chandrakasan, the Keithley Professor of Electrical Engineering and head of MIT’s Department of Electrical Engineering and Computer Science. Low-power chips that can collect data and relay it to a central facility are under development, as are systems to harness power from environmental sources. But the new design achieves efficient use of multiple power sources in a single device, a big advantage since many of these sources are intermittent and unpredictable.

“The key here is the circuit that efficiently combines many sources of energy into one,” Chandrakasan says. The individual devices needed to harness these tiny sources of energy — such as the difference between body temperature and outside air, or the motions and vibrations of anything from a person walking to a bridge vibrating as traffic passes over it — have already been developed, many of them in Chandrakasan’s lab.

Combining the power from these variable sources requires a sophisticated control system, Bandyopadhyay explains: Typically each energy source requires its own control circuit to meet its specific requirements. For example, circuits to harvest thermal differences typically produce only 0.02 to 0.15 volts, while low-power photovoltaic cells can generate 0.2 to 0.7 volts and vibration-harvesting systems can produce up to 5 volts. Coordinating these disparate sources of energy in

real time to produce a constant output is a tricky process.

So far, most efforts to harness multiple energy sources have simply switched among them, taking advantage of whichever one is generating the most energy at a given moment, Bandyopadhyay says, but that can waste the energy being delivered by the other sources. “Instead of that, we extract power from all the sources,” he says, by switching rapidly between them. “At one particular instant, energy is extracted from one source by our chip, but the energy from other sources is stored in capacitors” and later picked up, so none goes to waste.

Another challenge for the researchers was to minimize the power consumed by the control circuit itself, to leave as much as possible for the actual devices it’s powering — such as sensors to monitor heartbeat, blood sugar, or the stresses on a bridge or a pipeline. The control circuits optimize the amount of energy extracted from each source.

The system uses an innovative dual-path architecture. Typically, power sources would be used to charge up a storage device, such as a battery or a supercapacitor, which would then power an actual sensor or other circuit. But in this control system, the sensor can either be powered from a storage device or directly from the source, bypassing the storage system altogether. “That makes it more efficient,” Bandyopadhyay says. The chip uses a single time-shared inductor, a crucial component to support the multiple converters needed in this design, rather than three separate ones.

David Freeman, chief technologist for power-supply solutions at Texas Instruments, who was not involved in this work, says, “The work being done at MIT is very important to enabling energy harvesting in various environments. The ability to extract energy from multiple different sources helps maximize the power for more functionality from systems like wireless sensor nodes.”

Only recently, Freeman says, have companies such as Texas Instruments developed very low-power microcontrollers and wireless transceivers that could be powered by such sources. “With innovations like these that combine multiple sources of energy, these systems can now start to increase functionality,” he says. “The benefits from operating from multiple sources not only include maximizing peak energy, but also help when only one source of energy may be available.”

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More information: ieeexplore.ieee.org/xpl/articl … jsp?arnumber=6225400

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