Solving battery-free devices' short-term memory loss

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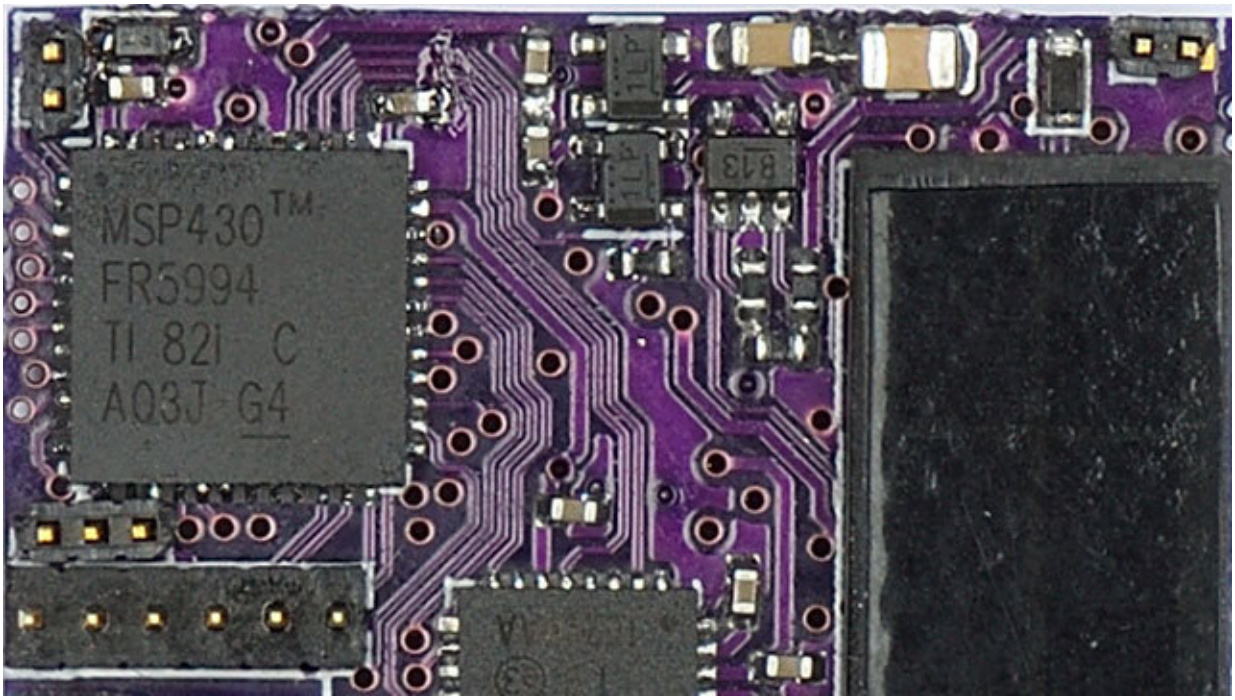

Novel timekeeping circuit enables battery-free devices to quickly restart quickly after losing power. Credit: Northwestern University

For decades, researchers have been searching for a better battery. Now an international team presents a bold new solution: ditch the battery altogether.

Led by Northwestern University and Delft University of Technology

(TU Delft) in The Netherlands, the researchers have designed and developed a new system that enables battery-free devices to keep time during intermittent power outages, solving a critical problem that has curbed research in the field.

Many small, battery-free Internet of Things (IoT) devices could work by harvesting ambient energy, such as solar, kinetic and thermal power. If fully adopted, using these devices would prevent trillions of used batteries from entering landfills. But because they switch between power sources, battery-free devices notoriously experience frequent, short losses of power.

"Naturally, removing batteries has consequences," said TU Delft's Przemyslaw Pawelczak, who co-led the research. "It means having lower storage capacity and lower reliability. Energy harvested from the environment is not always predictable."

"We have embraced this and built a system that strings together fragmented periods of execution," said Northwestern's Josiah Hester, who co-led the research. "We built a custom system that reliably keeps track of time despite numerous power failures and interruptions for any IoT device."

Hester and Pawelczak presented their work virtually this spring at the Architectural Support for Programming Languages and Operating Systems (ASPLOS) 2020 annual meeting. The team presented two papers: One that outlines hardware for the novel timekeeping circuit and another that demonstrates that the circuit can be used to convert battery-powered devices into battery-free devices.

Hester is an assistant professor of computer science and electrical and computer engineering in Northwestern's McCormick School of Engineering. Pawelczak is an assistant professor in TU Delft's

Embedded Software Lab.

Time is on our side

Timekeeping is one of the most vital resources for any computing system. Underlying almost all system services and security features, timekeeping helps the computer keep track of running applications. Most people, however, only notice the timekeeping function when it stops working.

If you have ever lost power while working at your computer, for example, then you know the agony of trying to restart the system. The computer can take several minutes to restart as it has to remember where you left off and run through a list of operations. And then, even when the computer is up and running again, any unsaved work could be lost.

If this happened every time a small IoT device—such as a smart watch, fitness tracker, security camera, smart thermostat or medical sensor—briefly lost power, these devices would be essentially useless.

That's the beauty of Hester and Pawelczak's system. A small device might briefly lose power, but it never loses its sense of time. That means it can restart so quickly that you might not even notice that the device lost power in the first place.

"Our device enables fast reconstruction of time and state from 'breadcrumbs' we left behind we leave behind before a power failure," Hester said.

Bypassing batteries

Hester and Pawelczak are motivated by their overarching goal to reduce the number of lithium-ion batteries entering the environment every year.

Not only is lithium mining incredibly energy and water intensive, lithium is a flammable, toxic material that can even catch fire in recycling plants.

Major tech companies now estimate that we could see trillions more IoT devices within the next 50 years. That's a lot of used and eventually discarded batteries.

"Working on battery-free energy-harvesting systems is self-evident, given the environmental impact that accompanies batteries," Pawelczak said. "We don't know the exact number of new devices that will emerge, but nobody doubts that the sheer volume of devices is massive and more and more consumer electronics will be powered by batteries. These batteries have to be replaced and later recycled, so we need to develop a system that reduces the carbon footprint of electronics."

"If we hope to have a vision of computing that is sustainable, then we have to rethink how we design these systems," Hester added. "Our technology will inform the design of the next trillion devices and enable IoT that is practical, scalable and useful."

Provided by Northwestern University