Engineers invent smart microchip that can self-start and operate when battery runs out

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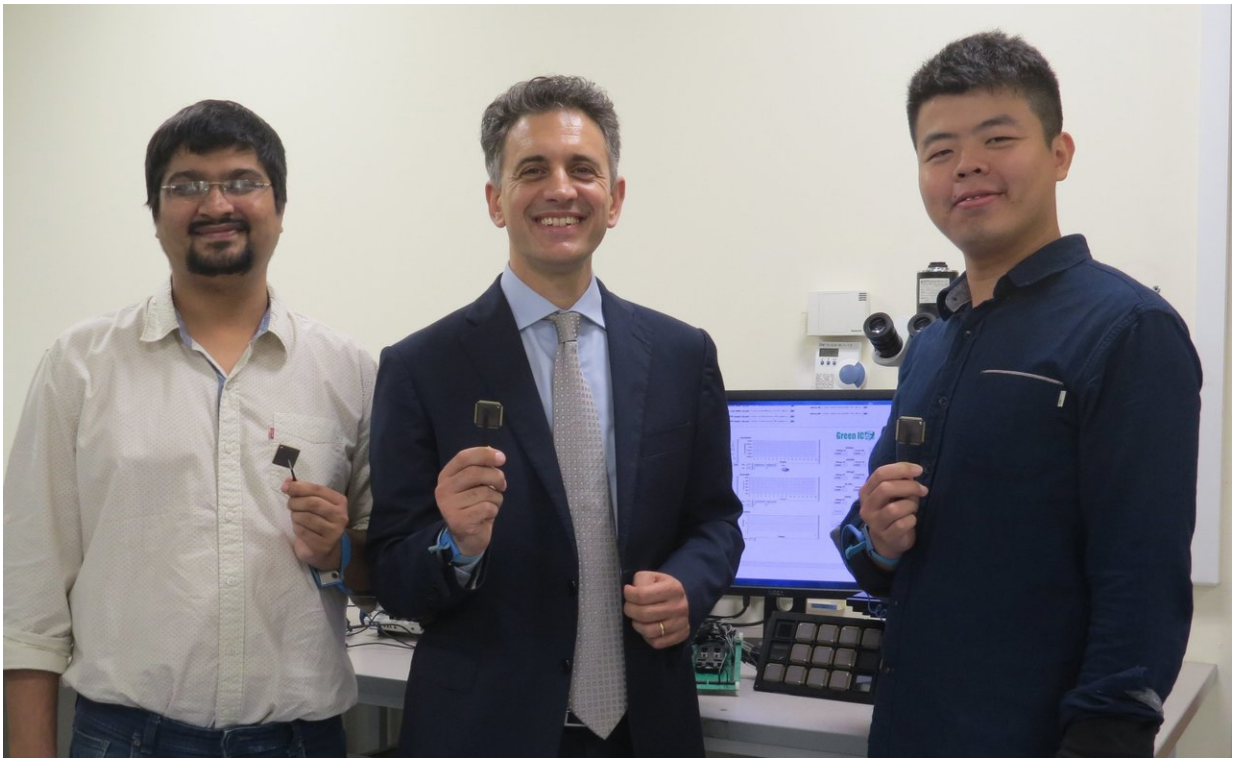

BATLESS, a smart microchip developed by a team of researchers led by Associate Professor Massimo Alioto (center) from National University of Singapore's Faculty of Engineering, can self-start and continue to operate even when the battery runs out of energy. This novel technology could enable smaller and cheaper Internet of Things (IoT) devices. Credit: National University of Singapore

The Internet of Things (IoT), while still in its infancy, is shaping the future of many industries and will also impact daily life in significant ways. One of the key challenges of moving IoT devices from concept to reality is to have long-lasting operation with tightly constrained energy sources, and thus extreme power efficiency. IoT devices such as sensors are often deployed on a massive scale and in places that are usually remote and difficult to service regularly, thus making their self-sufficiency essential.

Currently, batteries in IoT devices are much larger and up to three times more expensive than the single chip they power. Their size is determined by the sensor node lifetime, which directly affects how often they need to be changed. This has an important bearing on maintenance cost and impact on the environment when batteries are disposed. To extend the overall lifetime, the battery is usually recharged slowly by harvesting some limited power from the environment, such as using a solar cell. However, existing IoT devices cannot operate without battery, and small batteries are fully discharged more frequently. Hence, battery miniaturisation often results in highly discontinuous operation of IoT devices, as they stop functioning every time the battery runs out of energy.

To address this technology gap, a team of engineers from the National University of Singapore (NUS) has developed an innovative microchip, named BATLESS, that can continue to operate even when the battery runs out of energy. BATLESS is designed with a novel power management technique that allows it to self-start and continue to function under dim light without any battery assistance, using a very small on-chip solar cell. This research breakthrough substantially reduces the size of batteries required to power IoT sensor nodes, making them 10 times smaller and cheaper to produce. The breakthrough has been presented at the International Solid-State Circuits Conference (ISSCC) 2018 conference in San Francisco, the premier global forum for

presenting advances in solid-state circuits and systems-on-a-chip.

The leader of the NUS research team, Associate Professor Massimo Alioto at the NUS Faculty of Engineering, said, "We have demonstrated that batteries used for IoT devices can be shrunk substantially, as they do not always need to be available to maintain continuous operation. Tackling this fundamental problem is a major advancement towards the ultimate vision of IoT sensor nodes without the use of batteries, and will pave the way for a world with a trillion IoT devices."

Battery indifference is the ability for IoT devices to continue operations even when the battery is exhausted. It is achieved by operating in two modes—minimum energy and minimum power. When the battery energy is available, the chip runs in minimum-energy mode to maximise the battery lifetime. However, when the battery is exhausted, the chip switches to the minimum-power mode and operates with very low power consumption of about half a nano-Watt—this is about a billion times lower than the power consumption of a smartphone during a phone call. Power can be provided by a very small on-chip solar cell that is about half a square millimetre in area, or other forms of energy available from the environment, such as vibration or heat.

The chip's ability to switch between minimum energy and minimum power mode translates into aggressive miniaturisation of batteries from centimetres down to a few millimetres. The BATLESS microchip enables the uncommon capability to uninterruptedly sense, process, capture and timestamp events of interest, and for such valuable data to be wirelessly transmitted to the cloud when the battery becomes available again. Despite being in minimum-power mode when battery is not available, the reduced speed of the microchip is still adequate for numerous IoT applications that need to sense parameters that vary slowly in time, including temperature, humidity, light, and pressure. Among many other applications, BATLESS is very well suited for smart

buildings, environmental monitoring, energy management, and adaptation of living spaces to occupants' needs.

Assoc Prof Alioto added, "BATLESS is the first example of a new class of chips that are indifferent to battery charge availability. In minimum-power mode, it uses 1,000 to 100,000 times less power, compared to the best existing microcontrollers designed for fixed minimum-energy operation. At the same time, our 16-bit microcontroller can also operate 100,000 times faster than others that have been recently designed for fixed minimum-power operation. In short, the BATLESS microchip covers a very wide range of possible energy, power, and speed trade-offs, as allowed by the flexibility offered through the two different modes."

BATLESS is also equipped with a new power management technique that enables self-starting operations while powered directly by the tiny on-chip solar cell, with no battery assistance. The team demonstrated this at 50-lux indoor light intensity, which is equivalent to the dim light available at twilight, and corresponds to nano-Watts of power. This makes BATLESS indifferent to battery availability, addressing a previously unsolved challenge in battery-less chips.

The NUS Engineering team is now exploring new solutions to build complete battery-indifferent systems that cover the entire signal chain from sensor to wireless communications, thus expanding the current work on microcontrollers and power management. The research team aims to demonstrate a solution that shrinks the battery to millimetre scale, with the long-term goal of completely eliminating the need for it. This will be a major step toward the realisation of the IoT vision worldwide, and also make the planet greener and smarter.

More information: Longyang Lin et al, A 595pW 14pJ/Cycle microcontroller with dual-mode standard cells and self-startup for

battery-indifferent distributed sensing, *2018 IEEE International Solid - State Circuits Conference - (ISSCC)* (2018). DOI: 10.1109/ISSCC.2018.8310175