Building Self-Powered IoT Devices

The internet of things (IoT) has grown incredibly in the past decade. Devices across a wide range of industries, geographies, and terrains are now connected to central systems and generate valuable data-based insights for businesses. While continuous power for devices at the edge of the IoT network is usually available, a large swath of industrial and commercial applications warrant the use of battery power or other mechanisms as the cost of supplying continuous power is prohibitive. Refineries, transmission lines, power generation, etc. have devices/sensors in rugged environments that are far away from power sources. New technology is emerging that can make these devices self-powered. In this article, we examine energy harvesting mechanisms available for IoT edge devices.

Energy Harvesting

Energy harvesting is the capture and conversion of small amounts of readily available energy in the environment into usable electrical energy. The harvested electrical energy is conditioned for either direct use or accumulated and stored for later use. Applications in locations where there is no grid power and where it is inefficient to obtain wind or solar power can utilize energy harvesting as an alternative power source.

There are many sources for energy harvesting. Outdoor/indoor light, mechanical movement, dissipated heat from industrial processes, human body temperature and radio frequency are all potential sources for energy harvesting. While the magnitude of power generated varies by the source (a few $\mu W/cm^3$ when human body powered and hundreds of $\mu W/cm^3$ when powered from machinery), the energy harvested can be more than adequate for certain applications. Applications can vary from wristwatches to transceivers. The figure below shows the amount of power generated by various sources and the type of devices that can be powered by energy harvesting.

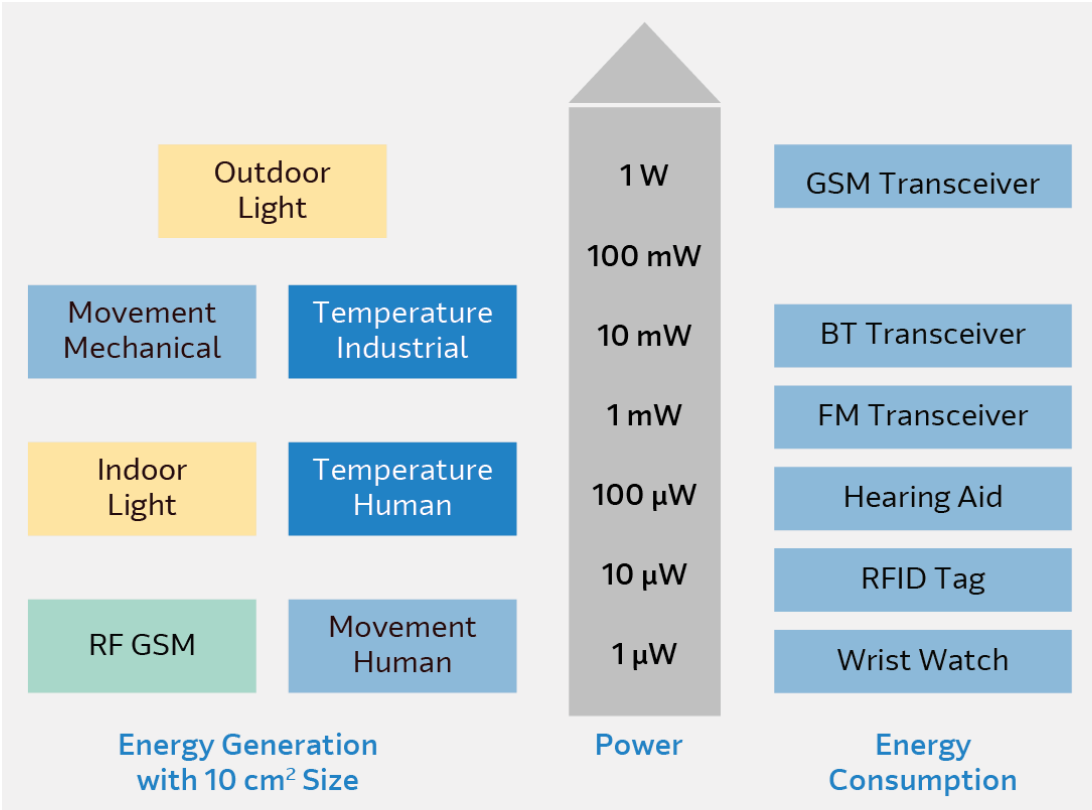

Figure: Power generated from various sources

Even when the harvested energy is low and incapable of powering a device, it can still be used to extend the life of a battery. In industrial, commercial, and medical applications, energy harvesting powers installations of standalone sensors in hard-to-reach and/or remote locations. These sensors can be used to monitor and alert stakeholders in a wide range of applications including air quality, condition-based maintenance, forest fires, load monitoring in bridges, and more. Typical applications that can benefit from energy harvesting include remote corrosion monitoring systems, implantable devices and remote patient monitoring, structural monitoring, RFID, and equipment monitoring.

Energy Harvesting Device Capabilities

Typical energy harvesting systems rely on three functional components:

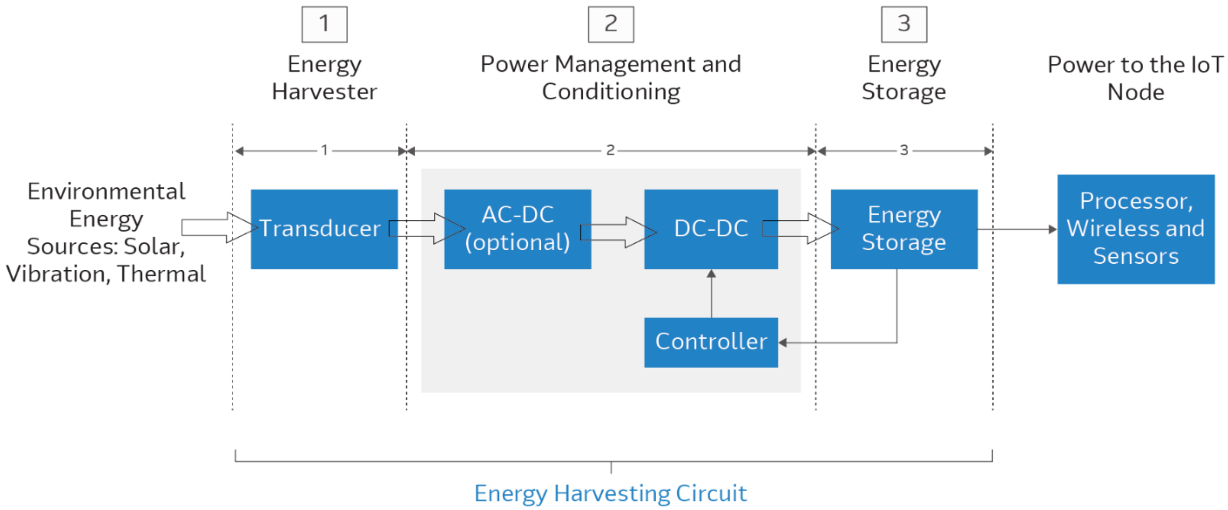

Figure: Energy harvesting solution components

Energy Harvester: Transducers - which convert the energy harvested from an ambient source. Energy can be harvested to power small autonomous sensors such as those developed using MEMS technology. These systems are often very small and require little power, but their applications are limited by the reliance on battery power. Scavenging energy from ambient vibrations, wind, heat or light could enable these smart sensors to be functional indefinitely.

Power Management: Interface circuits - which extract energy from the transducers – are generally the core of modern energy harvesting systems. These circuits condition the electrical energy into a suitable form for the application. Electronic systems powered by harvesting cannot directly use the generated energy due to the following reasons:

- The harvester output voltage is rarely at or near common Vdd levels due to a universal requirement to operate oscillating vibrational harvesters in resonance. Voltage and power drop off dramatically when operating away from resonance.
- The impedance from a harvester tends to be high relative to standard battery characteristics.
- The output voltage is low, sometimes less than 1 V.

The above reasons necessitate the use of conditioners which include regulators and complex control circuits to manage the power available to suit the application. Energy harvesting power management ICs perform key functions:

- Receive the intermittent, very low- energy from the energy harvesting device (EHD) and transform that extracted power into energy for the storage device. Depending on the type of EHD, the power management IC offers buck, boost, or linear DC/DC conversion.
- Manage the outflow of power from the storage device, while ensuring that power is not drawn when the stored energy is below a threshold value.
- Manages its own start-up sequence when sufficient energy is present.

Although it is desirable to have a harvesting source that can be useful in a wide range of applications, a one-size-fits-all "battery replacement" energy harvester/conditioner is unrealistic. Every application's unique environment and the different sources of energy at play make a universal EHD impractical. In most cases, both the energy harvester and its power-conditioning circuit must be uniquely optimized for the application.

Power Storage: Energy storage – device which stores the extracted energy for use by power-consuming devices. Energy can be stored in a capacitor, super capacitor, or battery. Capacitors are used when the application needs to provide huge energy spikes. Batteries leak less energy and are therefore used when the device needs to provide a steady flow of energy. A common type of battery that is used for this purpose is the lead-acid or lithium-ion battery although older types such as nickel-metal hydride are still widely used today. Compared to batteries, super-capacitors have virtually unlimited charge-discharge cycles and can therefore operate forever enabling a maintenance-free operation in IoT and wireless sensor devices.

Ideal characteristics of energy harvesting design

Good energy harvesting device design needs to balance the capabilities of the three main components – energy harvester, power management, and power storage. Optimal designs ensure that the harvesting circuit and the application circuit of the device are designed to match.

Harvesting circuit **Energy management system components should have:**	**Application Circuit** **Circuits receiving harvested energy for application should:**
• High energy efficiency in capturing, accumulating, and storing small energy packets. • High energy retention with minimal leakage or losses in energy storage. • Energy conditioning to ensure the output meets power requirements for the application or desired task.	• Consume the lowest amount of electrical power possible when active. • Consume the lowest standby current. • Be capable of turning on and off with minimal delay. • Operate at the low-voltage range. • Cost and scaling capability

• Tolerance of a wide range of voltages, currents, and other irregular input conditions.	

Use of the Harvested Energy
A majority of the current interest in low power energy harvesting is for independent sensor networks that are crucial elements of some IoT installations. In these applications, an energy harvesting scheme puts power stored into a capacitor then boosted/regulated to a second storage capacitor or battery for use in the microprocessor or data transmission. The power is usually used in a sensor data storage application or is employed in transmitting collected data wirelessly.

Arrow Energy Harvesting Solutions

From individual components to modules and integrated sensing and RF solutions, Arrow's broad portfolio of energy harvesting solutions includes leading technologies from industry leaders. For those building solutions from the ground up, we offer all the individual components required to build complete energy harvesting solutions – energy harvesting power management ICs, ultra-low-power wireless and sensing devices, switches, actuators, and controllers.

Arrow also offers fully integrated solutions that are easy to deploy. For example, EnOcean's self-powered wireless sensor solutions combine miniaturized energy converters, ultra-low-power electronics, and robust radio technology using open standards. Together with an efficient energy management system, the energy-harvesting technology facilitates communication between maintenance-free IoT devices.

Figure: EnOcean's ready to deploy energy harvesting solutions

Summary

Energy harvesting is an important emerging technology. IoT devices that are battery-powered and do not have easy access to continuous power sources can rely on energy harvesting technology to continue operation for a long time. Energy harvesting devices operate by capturing and converting small amounts of readily available energy in the environment into usable electrical energy. The harvested electrical energy is conditioned for either direct use or accumulated and stored for later use. While all energy harvesting devices constitute three main components – energy harvester, power manager, and power storage, it is not practical to have one energy harvesting device design for multiple situations. The sources of power and the specific application that needs to be powered govern the design of energy harvesting circuits. Arrow has a broad range of harvesting solutions for customers to choose from when trying to solving device power issues in IoT sensor networks.

References

Energy Harvesting towards Self-Powered IoT Devices
The How and Why of Energy Harvesting for Low-Power Applications