Perpetual Power for Wireless Sensors

Autonomously Monitoring Industrial Manufacturing Equipment

Few things frustrate industrial plant managers more than the ongoing maintenance required to power structure-wide monitoring systems. As the industry moves away from overly cumbersome wired networks, wireless solutions provide a new and different set of problems, namely surrounding the issue of power. Maintenance work is still labor-intensive, though now it requires workers to access sometimes inaccessible locations multiple times a year using the right tools and accessories to replace short-lived batteries.

Regardless of the maintenance hassle, wireless sensor networks have become an essential solution for permanent monitoring applications. As the adoption rate of wireless sensor networks grows, though, so does the need for networks that can be powered indefinitely without requiring a battery.

APPLICATION OVERVIEW

Industry: Industrial Manufacturing

Partner: Marlow Industries

Market: Equipment Health Monitoring for Industrial Manufacturing

Products: Energy Harvesters, EH-Link®, Wireless Sensor Network

Measured: Temperature, Vibration

Growing Demand

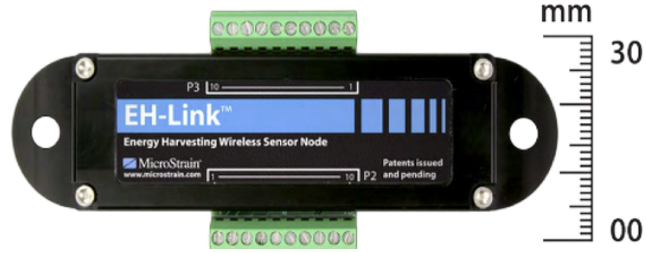
According to ON World Inc, "Wireless sensor network R&D spending will reach $1.3 billion by 2012, up from $522 million in 2007." Because of the new spotlight on wireless power, the implementation of these networks is expected to rise significantly. Manufacturers are more readily accommodating alternative energy sources as hundreds of thousands of sensors are deployed in less-than-accessible environments.

Not to mention that the sky seems to be the limit. Currently, wireless sensor networks are active in a range of industries across many monitoring applications. Machine, structural, environmental, vehicle, rotating machinery, and data center health monitoring are just a few of the areas that have a manifest need to employ alternatively powered wireless sensors. Clearly, customers view wireless sensor networks as an effective means to monitor systems, but most networks rely upon batteries with limited life that require ongoing and costly replacement, thereby limiting broad acceptance.

Kirsten West, Principal Analyst at West Technology Research Solutions, acknowledges that most of the explosive growth "in 2011 will be due to market demand for solutions to overall network connectivity and battery-free operational constraints." In harvesting ambient energy sources, including strain, vibration, solar energy, and thermal energy, wireless sensors are able to collect, store, and transmit data without the need for batteries. The introduction of thermal energy harvesting to power wireless sensor networks eliminates the need for batteries, a critical step in overcoming adoption-rate barriers.

Industrial Plant "Smart" Monitoring

An industrial plant offers a real world scenario for this technology. A compact, thermal energy harvester can power temperature and vibration sensors that monitor motors anywhere inside the plant, alerting managers of excessive wear and allowing them to perform preventative maintenance to avoid factory downtime. Without these intelligent monitoring systems, plant managers would need to rely upon regular maintenance schedules and often perform costly and unnecessary repairs simply to avoid a failure. With advanced alert systems, conditions that would normally result in failure can be managed as an isolated issue, increasing productivity and reducing maintenance cost.



MicroStrain's energy harvesting wireless node supports external strain gauges, bridge sensors, onboard relative humidity, temperature and triaxial acceleration

More specifically, a motor exterior surface warms to approximately 46°C in a 22°C ambient. As the bearings begin to fail, the motor temperature increases because of the added friction in the bearings and the vibration spectrum changes. In order to measure and transmit temperature readings at five-second intervals with an additional one second, single axis acceleration burst to collect 4,000 data points in two minute intervals, a plant managerneeds an energy harvester to provide an average of 400 uW of continuous power at 3V.

Integrated Energy Harvesters

A solid-to-air miniature harvester consisting of a thermoelectric device positioned between an aluminum interface plate and small, finned natural convection heat sink sustains requirement. With the harvester, thermal energy transfers from the motor onto the mounting plate, then moves through the thermoelectric device and exhausts to the air through a heat sink. The movement of heat through the thermoelectric module (TEM) causes current to flow in the special p and n type semiconductor materials used in the thermoelectric device, thus producing the DC electrical energy to power the sensor and provide feedback regarding system performance.

Achieving the required voltage output requires a balance between interrelated and often conflicting electrical and thermal design characteristics. For example, the open circuit voltage (V_{oc}) output is a function of the number of thermocouples (N) inside a thermoelectric device, the thermoelectric material Seebeck coefficient (α)and the temperature difference (ΔT):

$V_{oc} = 2N(\alpha \Delta T)$.

Consequently, with a given temperature difference, increasing the number of thermocouples will increase voltage output. However, increasing thermocouples also lowers thermal resistance. If thermal resistance is low, relative to the heat sink thermal resistance, most of the available temperature difference ends up across the heat sink instead of the thermoelectric device. Because the efficiency of a thermoelectric device is a function of the temperature difference across the device, thisresults in lower voltage and power output. A 17 thermocouple TEM coupled with a small cubic 10 mm finned heat sink provides the desired thermal and electrical optimization in the smallest footprint possible.

Augmenting the typical low voltage output of a thermoelectric device with a step-up circuit produces the 3Vrequired to power the sensors, charges the small battery and transmits the data. With this added feature, an energy harvester can produce DC power with as little as 8-10°C temperature difference between the motor and surrounding ambient. The resulting solution produces 400 uW of continuous power output from a thermoelectric energy harvesting source contained in 1 cubic inch volume, a persuasive casefor eliminating batteries in wireless sensors.

Long-Term, Low-Maintenance

As more wireless sensor systems integrate thermal energy harvesting to power networks, the elimination of battery maintenance and replacement costs will enable further adoption of wireless sensor technology. End users will be able to monitor high value assets for the long term, eliminating critical failures and optimizing process operations. Moreover, it will open the door for creative exploration of new sensor applications.

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