Powering wirelessly via batteries, energy harvesting

Lithium batteries and energy-harvesting devices offer a variety of choices to identify the ideal power management solution

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While lithium thionyl chloride ($LiSOCl_2$) chemistry remains the leading choice for remote wireless devices in extreme environmental conditions, there are also numerous applications for which energy-harvesting devices can provide a logical alternative, requiring more informed decisions based on application-specific parameters.

$LiSOCl_2$ chemistry is ideal for remote, inaccessible locations due to its proven track record for delivering reliable, long-term performance, with certain brands capable of delivering up to 40 years of maintenance-free service life. $LiSOCl_2$ chemistry can also be modified to deliver the high-current pulses required to meet the rapidly growing need for advanced two-way communications and remote shut-off capabilities.

Meanwhile, energy-harvesting devices are garnering increased media attention. Energy-harvesting technology encompasses a variety of complex options, often involving certain tradeoffs, so it is important to understand the fundamentals of this technology as well.

The basics of energy harvesting

There are two basic types of energy-harvesting devices: those that create trickle charges, including solar cells and Peltier devices; and those that create 'bursts' of energy, including dynamos and piezo devices.

The most common type of trickle-charge device is the photovoltaic system or solar cell, which converts sunlight into electrical energy. Use of this technology is mainly limited to larger industrial applications due to expense, bulkiness, long-term maintenance issues, and reliance on dependable sunlight. Solar cells typically require rechargeable batteries to store captured energy. Relatively inexpensive photovoltaic coatings are being developed, but this technology is still years away from commercialization.

Another interesting form of trickle-charge device captures small amounts of RF energy from short-range transmitters and/or broadcast signals within the ISM (industrial/scientific/medical) band, storing these small amounts of energy in supercapacitors or rechargeable batteries. This technology is best suited for certain low-power applications.

Peltier devices create electrical charges by tapping into the energy stream that occurs when two sides of an object have a temperature difference of at least 5°C. By nature, these systems are reliant on their surrounding environment as a reliable source of energy and typically require rechargeable batteries or supercapacitors to store captured energy.

Dynamos create bursts of energy by working as a reverse step engine, using motion to create electrical energy. If crudely designed, these devices can generate excess energy than is required, which needs to be burned off.

Piezo devices create electrical energy by producing mechanical tension. As a result, piezo devices must be ruggedly constructed to avoid failure over time caused by wear and tear.

Fig. 1: Tadiran TLI Series rechargeable LI-ion batteries.

Energy harvesters need to store energy

Energy-harvesting devices are not designed to provide power for pulses needed by remote sensors for data collection or transmission. In most cases, these devices use rechargeable batteries to store the energy and supply short bursts of power.

The most popular rechargeable battery used in conjunction with energy harvesters are lithium-ion cells. This technology is mature and readily available, but has many drawbacks. Li-ion cells cannot be used in temperatures below 0° or above +60°C. They also have very high self-discharge rates (about 60% a year), and their operating lives are limited to 5 years or 1,000 charge cycles. Li-ion .cells were designed mainly for use in portable commercial applications and not for remote, M2M industrial devices.

Tadiran has responded to the power storage requirements of energy harvesters by developing a new Li-ion technology called the TLI Series, which offers the following improvements over conventional Li-ion cells:

- Wider operating temperature (–40° to 85°C, with storage up to 90°C)
- Ability to deliver high-current pulses (up to 5 A for a AA-size cell)
- Low annual self-discharge rate (less than 5%)
- Up to five times more life cycles (5,000 full cycles)

- Longer operating life (10 years)
- Charging possible at extreme temperatures (10-hour rate)
- Glass-to-metal seal (others use crimped seals that are prone to leakage)

The basics of $LiSOCl_2$ chemistry

Among the different battery chemistries available for long-term use in remote wireless devices, bobbin-type $LiSOCl_2$ is overwhelmingly preferred due to its high energy density, wide temperature range, and low annual self-discharge rate.

Bobbin-type $LiSOCl_2$ batteries have a proven track record of success in remote wireless applications, first deployed i n the early 1980s by Aclara (formerly Hexagram) to power its first generation of automated meter reading (AMR) devices. While these meters are now being replaced, they continued to operate for over 28 years on their original Tadiran batteries.

Fig. 2: $LiSOCl_2$ batteries were deployed in the early 1980s by Aclara to power its first generation of automated meter readers.

Tadiran bobbin-type $LiSOCl_2$batteries feature an annual self-discharge rate of approximately 0.75%/year, enabling the battery to retain approximately 70% of its initial capacity after 40 years of self-discharge. However, competing brands of bobbin-type $LiSOCl_2$batteries offer significantly higher annual self-discharge rates of 2.5% to 3% per year, allowing only 70% of initial capacity to be retained after 10 years.

Achieving an extremely low annual self-discharge rate is crucial to battery performance, as, in many instances, the total lifetime self-discharge rate of the battery can be greater than the total amount of energy consumed by the device itself.

Powering advanced two-way comms

Increasingly, remote wireless devices are required to provide advanced two-way communications, with increased energy demand for data interrogation and transmission. To conserve energy, these devices typically spend the majority of time in a “dormant” phase, with daily power consumption ranging from nil to a few microamps. These devices are programmed to routinely switch over to an “active” phase during which time high-current pulses of up to several amps are required to energize the device as it reads and communicates data.

Applications that involve dormant periods at elevated temperatures, alternating with periodic high-current pulses, can lead to lower transient voltage readings during the initial phases of battery discharge. This phenomenon, known as transient minimum voltage (TMV), is strongly linked to the make-up of the battery electrolyte, and/or the design of the cathode. Two innovative solutions have been developed by Tadiran: PulsesPlus batteries for high-current pulse applications; and TRR Series batteries for moderate current pulse applications.

PulsesPlus lithium thionyl chloride batteries combine a bobbin-type cell with a patented hybrid layer capacitor (HLC) that stores and generates high-current pulses for brief intervals before returning to an energy-saving “sleep” or “standby” mode that requires nil or nominal energy.

Tadiran Rapid Response TRR series batteries are designed for moderate rate applications that do not require the use of an HLC but still require high capacity and high energy density without experiencing voltage drop or power delay. When a standard $LiSOCl_2$ battery is first subjected to load, voltage can drop temporarily, and then return to its nominal value. TRR Series batteries virtually eliminate this voltage drop as well as voltage drop under pulse (or transient minimum voltage level). The final result is zero delay during the voltage response. These unique attributes enable TRR Series batteries to use available capacity more efficiently, thus extending the operating life of the battery by up to 15% under certain conditions, especially in extremely hot or cold temperatures.

Real-life examples

Powercast Corporation specializes in low-power RF energy harvested from broadcast radio or television signals, and/or RF transmitters located within a 45-ft range. This solution can be ideal alternative for networked wireless sensors that require micro amps of power to operate and which are located in environments where there is access to suitable amounts of RF energy.

Powercast also uses Tadiran PulsesPlus batteries to power its WSN-1101 wall-mounted sensor that measures indoor temperature, humidity and other variables in HVAC, lighting control, energy management, industrial monitoring, and medical applications.

Designed for indoor use in temperatures ranging from -20° to +50°C, the WSN-1101 can transmit data once per minute for more than 25 years to the Powercast WSG-101 wireless gateway, which interfaces with wired building automation systems (BAS) networks via industry-standard protocols. Use of a long-life $LiSOCl_2$ battery enables the Powercast remote sensor to offer a highly cost-effective and reliable 25-year solution that instantly converts buildings into smart buildings. It proves to be an ideal upgrade for older structures with concrete or cinder block walls that cannot be easily retro-fitted for hard-wired solutions.

Fig. 3: The Powercast WSN-1101 wall-mounted sensor measures indoor temperature and humidity and can last 25 years.

These two examples demonstrate how lithium batteries and energy-harvesting devices offer healthy alternatives that lead to more ideal power management solutions. ■