Batteries FOR LIFE

Lithium power sources can last 20 years, just the thing for embedded sensors that must work reliably for long periods.

Sol Jacobs
Tadiran Batteries
Port Washington, N.Y.

The world is going wireless. Currently, there are approximately 80 million wireless-monitoring systems in use worldwide, serving applications ranging from building automation to vibration-monitoring systems and mesh networks.

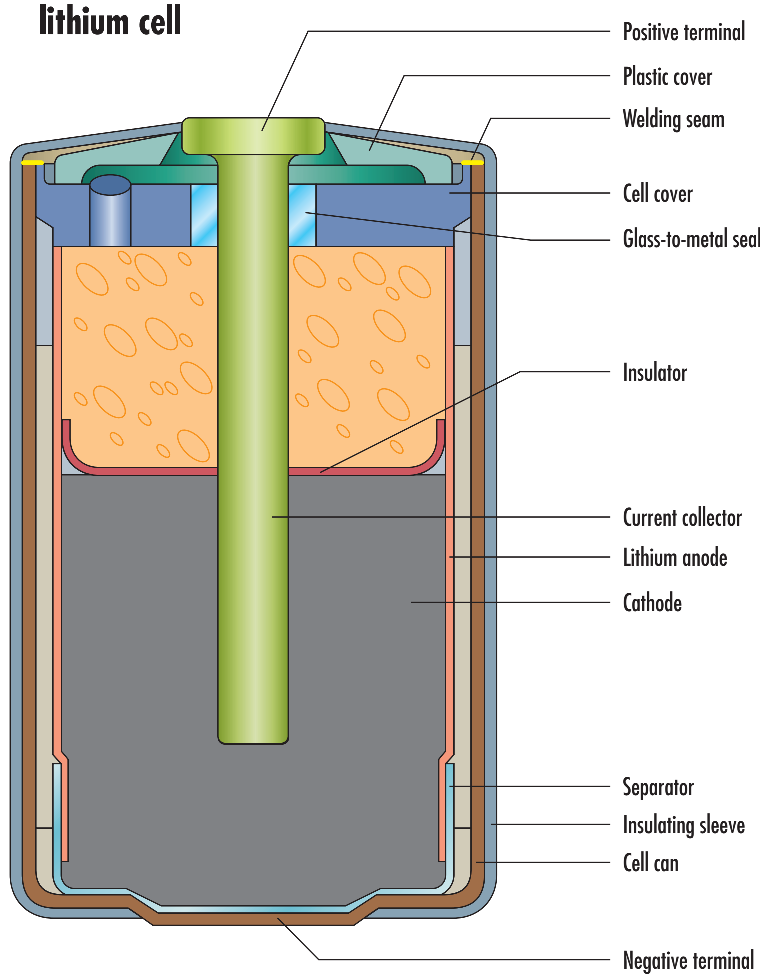
Oak Ridge National Laboratory recently outlined 12 top requirements for an ideal wireless sensor. Researchers there concluded that the number-one criterion was the need for an adequate battery life, followed by the need to be self-powered and small. This study makes clear how important battery technology is for practical wireless sensors.

Of all battery technologies currently available, lithium is considered the best choice for remote wireless sensors. Household alkaline batteries have low initial voltages and high self-discharge. In contrast, lithium chemistries feature the highest energy density (energy per unit weight and energy per unit volume) of all battery types.

To conserve power, wireless devices can be designed to remain in a sleep mode, which requires little background current (usually on the order of hundreds of microamps or less). These devices then wake up to transmit or receive data.

The power dissipation qualities of some wireless sensors are that of low power consumption in sleep mode, followed by a large spike when active.

Typical lithium cell



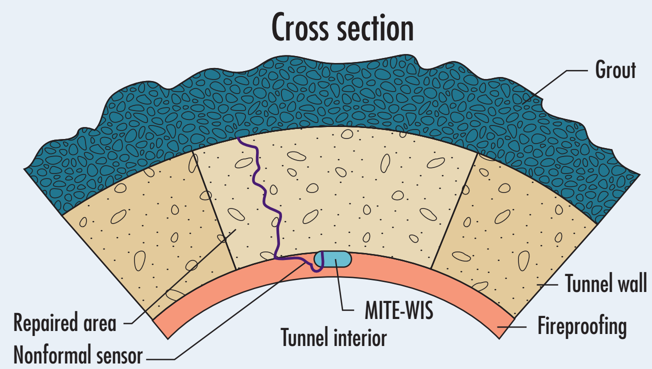
The cross section of a typical bobbin-type lithium cell reveals details of their construction. The anode is typically lithium foil pressed onto the inner surface of the cell. The separator between the anode and cathode is nonwoven glass that allows ions to move between the electrodes. The cathode is porous Teflon-bonded carbon powder. Thyonyl chloride cathodic reduction takes place on the cathode surface when a load is connected. The electrolyte is a solution of lithium aluminum tetrachloride in thionyl chloride. The current collector makes an electrical connection between the porous carbon cathode and the positive terminal of the battery. The can and cover are typically nickel-plated cold-rolled steel. The cell cover is welded to the cell can by a laser seam-welding process.

LITHIUM BATTERIES IN ACTION

Invocon Inc. in Conroe, Tex. (*invocon.com*), manufactures Multiple-Input, Tiny, Enhanced Wireless Instrumentation Systems (MITE-WIS) devices used to monitor repaired concrete sections of the Westerschelde River Tunnel in the Netherlands. A MITE-WIS unit is embedded into the concrete repair patch each time a concrete repair is made. Fireproofing maintains its integrity and there is no need for large cables to pass through the concrete, which would otherwise create weak points for heat to reach the primary tunnel wall.

MITE-WIS units identify potential structural failures by sensing strain variations across the boundaries of concrete patches. Lithium batteries provide up to two years of service life for a sampling rate of three separate channels per minute. Each unit can store up to three months of data, which downloads during monthly maintenance procedures.

American Millennium Corp. (AMCi) in Golden, Colo. (*amc-wireless.com*) manufactures devices that interact with GPS/GEO satellites to monitor a variety of applications, including pipelines and gas compressors. Alkaline batteries are problematic here because the SatAlarm-Sentry systems would need 20 D-sized alkaline cells. Temperature range is also an issue because the capacity of an alkaline cell drops by 60% at –10°C.



A wireless MITE-WIS unit embedded in a concrete repair patch enables fireproofing material to maintain its integrity by eliminating the need for large cables to pass through tunnel-wall concrete, which would otherwise create weak points for heat infiltration.

Instead, four D-sized lithium-thionyl-chloride cells plus four hybrid-layer capacitors (HLCs) supply power. SatAlarm devices deliver high-current pulses for short intervals and otherwise remain in a power-save stand-by mode. The hybrid lithium's extended temperature range of –40 to 85°C lets the monitoring devices perform continuously in severe climates.

Hexagram Inc., Cleveland (*hexagram.com*), manufactures automatic meter-reading (AMR) systems that handle gas, electric, and water meter reading remotely. STAR meter-transmitter units use narrow-band radio signals to communicate with a network of data-collection units mounted on buildings or utility poles. To conserve energy, a timer powers up the unit and transmits data at programmed intervals. Over 2 million units are now in the field powered by lithium-thionyl-chloride batteries. Units installed 20 years ago are still operating with over 75% of their original capacity. Low self-discharge gives the batteries a proven 20-year life in this application, and their extended temperature range is compatible with outdoor installations.

Hexagram STAR meter-transmitter units contain lithium cells that are still operating after 20 years in the field.

Oceantronics Inc. in Honolulu (*oceantronics.net*), manufactures GPS tracking/sensing devices. One of the applications for these tracking devices are in ice buoys used to track global climate change on ice floating on the Arctic Ocean. The first such buoys carried battery packs made from 380 alkaline D cells. The batteries weighed 54 kg and operated for about a year. These have since been replaced by battery packs containing 32 lithium-thionyl-chloride D cells and four hybrid layer capacitors. The new batteries weigh about 90% less than the old ones. The logistics of shipping a much smaller and lighter unit are also simplified, which is extremely important to technicians working in frigid Arctic waters. Several smaller lithium packs can be used in sequence to extend the operational life of the system.

This is because they draw a high current in active mode, perhaps on the order of amps for periods ranging from a fraction of a second to a few minutes.

Such behavior is particularly true for devices transmitting signals to receivers located some distance away. One example is that of GPS-enabled buoys. Buoys may periodically read their position from GPS satellites, then report back via a burst radio transmission to a receiving station miles away. Current draw can reach several amperes for as much as a few seconds in such cases. But the delivery of these pulses presents technical challenges even to some kinds of lithium cells.

These challenges are most applicable to bobbin-type lithium cells. Such cells are particularly well suited for remote use thanks to their high capacity, small size, and an ability to withstand broad fluctuations in pressure, temperature, and shock. Bobbin cells, for example, are well suited for wireless applications fielded under the Zigbee standard. Wireless sensors following the Zigbee format can use single-chip transceiver chips that operate from under 20 mA in both transmit and receive modes.

Nevertheless, the low-rate design that gives bobbin-type lithium cells a long life impedes their ability to deliver the large currents that some kinds of remote applications demand. Contributing to this problem is a build-up of solid electrolyte interface (SEI) on the lithium anode, which is part of the internal battery. This reduction becomes even more significant when the cells are stored at elevated temperatures.

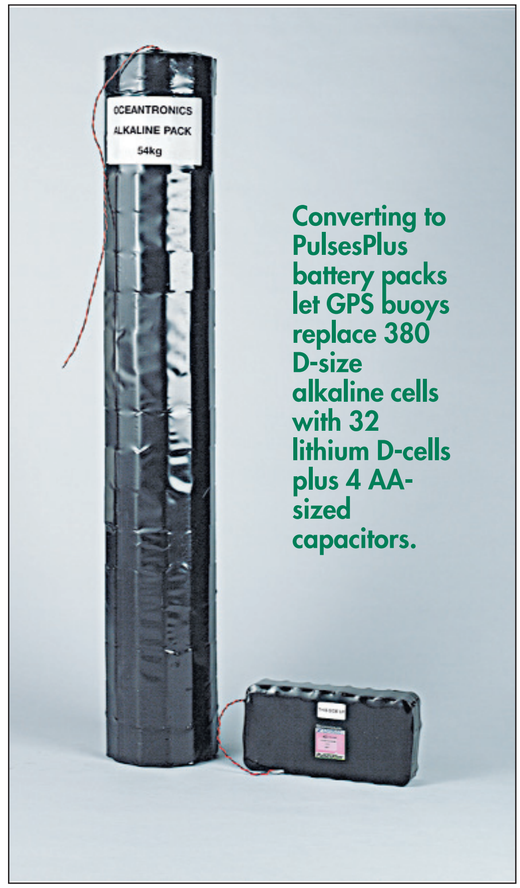
A few years ago, Tadiran developed a hybrid battery called PulsesPlus. It combines a bobbin-type cell with a patented high-rate, low-impedance HLC (hybrid layer capacitor). This hybrid system delivers extremely high currents with a generous safety margin. The HLC can supply a continuous current of up to 2A with maximum pulses of up to 5A.

INSIDE THE CELL

It is useful to review how lithium cells are constructed. All lithium cells use a nonaqueous electrolyte. Their nominal open-circuit voltages (OCVs) range between 2.1 and 3.9 V. Lithium cells also feature extended operating temperature ranges, with some lithium-based cells capable of operating at up to 150°C.

However, lithium batteries are not all alike. Primary cells can employ a variety of lithium chemistries including: Li/CFx (lithium poly carbon monofluoride); Li/MnO_2 (lithium manganese dioxide); Li/SO_2 (lithium sulfur dioxide); and $Li/SOCL_2$ (lithium thionyl chloride).

Lithium thionyl chloride is the chemistry found in the bobbin-type cells often employed with wireless applications. These 3.6-V cells feature the highest energy density and voltage of all lithium chemistries, with up to 20 years of service life. Bobbin-type lithium thionyl chloride cells offer extended temperature ranges of –55 to 85°C, with some models going to 150°C. While the theoretical service life of a lithium thionyl chloride cell can exceed 20 years, the actual service life varies depending on the manufacturer.



Converting to PulsesPlus battery packs let GPS buoys replace 380 D-size alkaline cells with 32 lithium D-cells plus 4 AA-sized capacitors.

The combination of an HLC with a bobbin cell enables the PulsesPlus to exhibit qualities of both a battery and a capacitor. Specifically, the capacitor portion of the PulsesPlus cell eliminates the voltage drop that would otherwise take place when loads draw significant pulse current. The battery portion of the cell supplies long-term, relatively low currents. Pulsed loads initially draw current from the capacitor rather than the battery. The capacitor and the battery are electrically in parallel.

An alternative to using a PulsesPlus cell would be to synthesize this behavior by using a discreet capacitor with a separate primary cell. The problem with using conventional capacitors in such a role is that they are necessarily bulky; it takes a large capacitor to supply enough energy for time periods that can extend to minutes, as with some pulse-type loads. Moreover, the larger the capacitor, the larger the rate of charge leakage. So the

Bobbin-type $Li/SOCl_2$ cells combined with a Hybrid Layer Capacitor together form PulsesPlus batteries that can handle applications drawing ampere-level current pulses.

capacitor is constantly discharging the cell, albeit at a low rate.

Some designs also try handling pulses through use of what are often dubbed supercapacitors in parallel with the primary cell. Supercapacitors are electrochemical capacitors. They store charge in a bulk electrolyte rather than on plates. This construction lets them be physically smaller than conventional plate-type caps. The problem with such devices is that they generally exhibit high impedance, which may limit the magnitude of the instantaneous current they can supply for a pulse. Supercapacitors are made up of individual 2.3-V units which have balancing problems when placed in series for higher voltages. Leakage current can be a problem as well.

In contrast, the HLC uses a special structure that eliminates the usual difficulties associated with supercapacitors. HLCs are made specifically to work in the 3.6 to 3.9-V nominal range and are made with only one unit.

CELL QUALITIES

Service life mainly depends on the cell's self-discharge rate, which is governed by the chemical composition of the electrolyte, manufacturing processes, as well as mechanical and environmental considerations. Self-discharge can be made worse by high levels of impurities in the electrolyte. Extreme temperatures can also reduce battery performance, affecting both voltage and self-discharge rate.

Lithium battery performance can also be hindered by the cell's internal impedance. This internal resistance is developed by the electrolyte, the anode, and the cathode. Experienced battery manufacturers know how to effectively control impedance by blending special additives with the electrolyte.

There are several other lithium chemistries that are useful as primary cells and may be candidates for specific kinds of uses. Li/CFx cells have an OCV of 3.0 V and moderate energy density. Cylindrical types use a spiral cathode for higher rate capability and have crimped plastic seals. Though generally safe, the elastomer seal can break under conditions of extremely high temperature and humidity, causing cell failure.

$LiMnO_2$ cells are 3.0-V devices that resemble Li/CFx cells both in construction as well as performance related to high temperatures and humidity. Their energy density and voltage is slightly better than Li/CFx cells, especially at cold temperatures.

Li/SO_2 cells are also 3.0-V devices that deliver high current, especially at cold temperatures. Their main drawback, for wireless devices, is high self-discharge and reduced capacity. The service life and energy density of Li/SO_2 cells are typically half that of lithium-thionyl-chloride cells. ■

MAKE CONTACT:

Tadiran, (516) 621-4500, Fax: (516) 621-4517, *www.tadiranbat.com*

We want your feedback.

Did you find this material interesting?	Circle 701
Do you want more information of this type?	Circle 702

Comment via e-mail to mdeditor@penton.com

What related topics would you like to see covered? What additional information on this topic would you find useful?