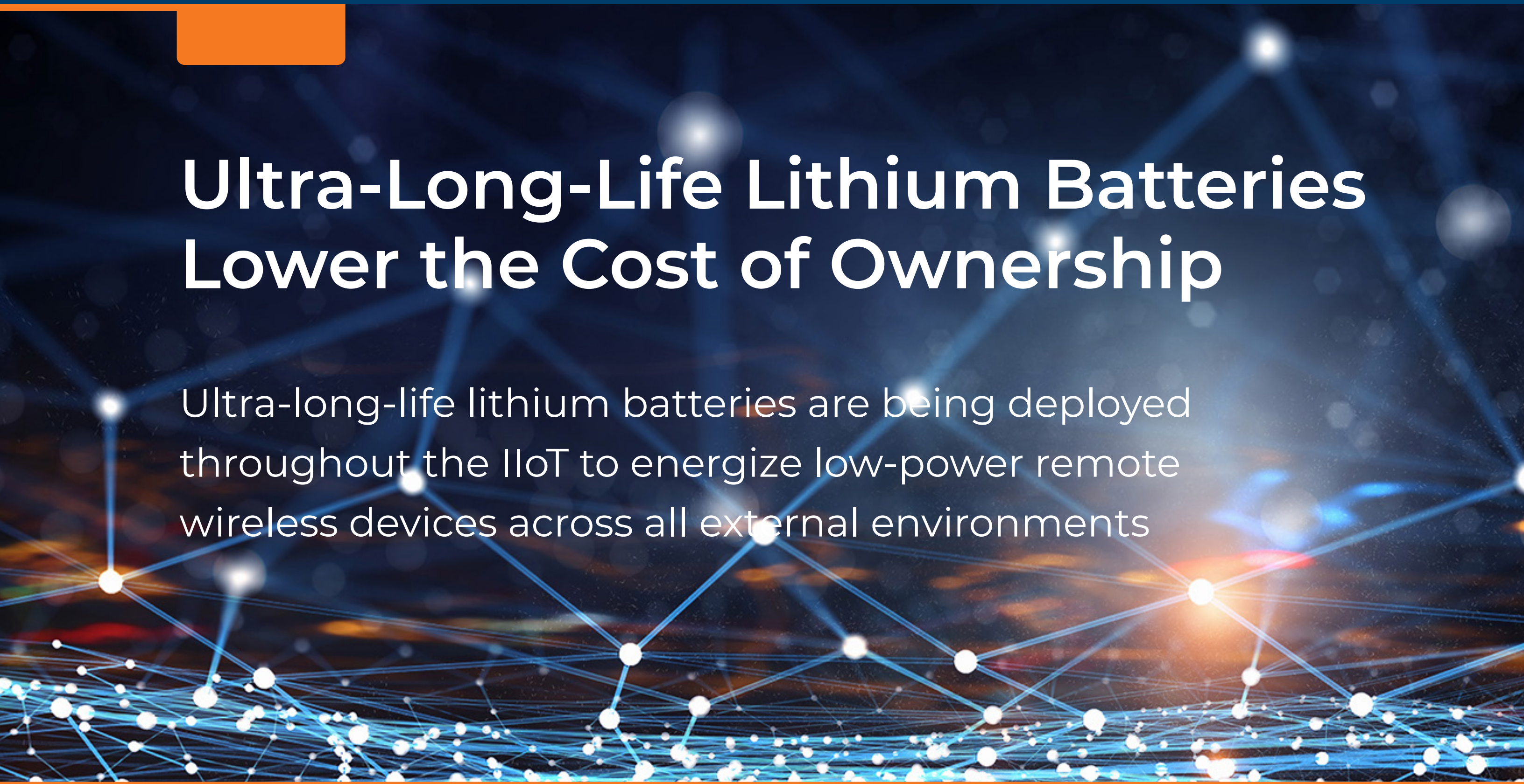


Ultra-Long-Life Lithium Batteries Lower the Cost of Ownership

Ultra-long-life lithium batteries are being deployed throughout the IIoT to energize low-power remote wireless devices across all external environments

By Sol Jacobs, Tadiran Batteries

Extended-life lithium batteries are supporting the Industrial Internet of Things (IIoT) by powering advanced functions that include supervisory control and data acquisition (SCADA), automated process control, and machine learning, to name a few. These technologies monitor structural stress, environmental quality, asset tracking, tank level and flow monitoring, energy usage, and more. Ultra-long-life lithium batteries are essential to powering these applications to reduce the cost of ownership by increasing system reliability, ensuring continuous data flow, and eliminating battery change-outs.

Primary batteries predominate

There are two types of low-power devices: Those that operate mainly in a “stand-by” state while periodically drawing pulses in the multi-amp range for an average current measurable in micro-amps, typically requiring an industrial-grade primary (non-rechargeable) lithium battery; and those that draw average energy (background current and pulses) measurable in milli-amps, typically requiring an energy harvesting device in combination with an industrial grade Lithium-ion (Li-ion) rechargeable battery.

Remote wireless devices are typically powered by primary (non-rechargeable) battery chemistries including alkaline, iron disulfate ($LiFeS_2$), lithium manganese dioxide ($LiMnO_2$), lithium thionyl chloride ($LiSOCl_2$), and lithium metal-oxide (see Table 1).

Primary Cell (AA-size)	**$LiSOCL_2$** Bobbin-type with Hybrid Layer Capacitor	**$LiSOCL_2$** Bobbin-type	**Li Metal Oxide** Modified for high capacity	**Li Metal Oxide** Modified for high power	**Alkaline**	**$LiFeS_2$** Lithium Iron Disulfate (AA-size)	**$LiMnO_2$** Lithium Manganese Oxide
Energy density (Wh/Kg)	700	730	370	185	90	335	330
Power	Very high	Low	Very high	Very high	Low	High	Moderate
Voltage	3.6 to 3.9 V	3.6 V	4.1 V	4.1 V	1.5 V	1.5 V	3.0 V
Pulse amplitude	Excellent	Small	High	Very high	Low	Moderate	Moderate
Passivation	None	High	Very low	None	N/A	Fair	Moderate
Performance at elevated temp.	Excellent	Fair	Excellent	Excellent	Low	Moderate	Fair
Performance at low temp.	Excellent	Fair	Moderate	Excellent	Low	Moderate	Poor
Operating life	Excellent	Excellent	Excellent	Excellent	Moderate	Moderate	Fair
Self-discharge rate	Very low	Very low	Very low	Very low	Very high	Moderate	High
Operating temp.	–55°C to 85°C, can be extended to 105°C for a short time	–80°C to 125°C	–45°C to 85°C	–45°C to 85°C	0°C to 60°C	–20°C to 60°C	0°C to 60°C

Table 1. Comparison of primary lithium cells

Among lithium chemistries, bobbin-type $LiSOCl_2$ is overwhelmingly preferred for long-term deployments because it delivers the highest capacity and energy density, the widest temperature range, and the lowest annual self-discharge of all, especially well-suited for extreme environments (Figure 1).

Figure 1: Bobbin-type $LiSOCl_2$ batteries are preferred for remote wireless applications, delivering high energy density, up to 40-year service life, and the widest possible temperature range, making them ideal for use in inaccessible locations and extreme environments.
Courtesy: Tadiran Batteries

Keeping self-discharge low

IIoT-connected devices, especially those that expend additional energy to power two-way wireless communications, need to conserve energy wherever possible. Energy-saving strategies include the use of a low power communications protocol (WirelessHART, ZigBee, Lora, etc.), low-power chipsets, and proprietary techniques to minimize power consumption during “active” mode. While useful, these schemes are typically dwarfed by energy losses resulting from self-discharge.

Self-discharge is common to all batteries as chemical reactions exhaust energy even when a cell is disconnected or in storage. The rate of annual self-discharge is affected by the cell’s current discharge potential, the quality of the raw materials, and, most importantly, the passivation effect.

Passivation is unique to $LiSOCl_2$ batteries, as a thin film of lithium chloride (LiCl) forms on the surface of the lithium anode to limit reactivity. Bobbin-type cells are better able to harness the passivation effect than spiral wound cells that allow for greater energy flow.

"**Bobbin-type cells** are better able to harness the passivation effect than spiral wound cells that allow for greater energy flow."

Whenever a load is placed on the cell, the passivation layer causes initial high resistance and a temporary dip in voltage until the discharge reaction begins to dissipate the LiCl layer—a process that keeps repeating each time the load is removed. Passivation can be affected by the cell's current capacity, length of storage, storage temperature, discharge temperature, and prior discharge conditions, as removing the load from a partially discharged cell increases the level of passivation relative to when it was new.

Passivation is essential to limiting annual self-discharge. However, too much of it can be problematic if it overly-restricts energy flow. Experienced battery manufacturers know how to optimize the passivation effect using higher quality raw materials and proprietary manufacturing processes.

Powering two-way wireless communications

Standard bobbin-type $LiSOCl_2$ cells are unrivaled for harnessing the passivation effect. However, the tradeoff is the inability to generate the high pulses required for two-way wireless communications due to their low-rate design. This challenge can be overcome with a hybrid battery that combines a standard bobbin-type $LiSOCl_2$ cell that delivers nominal background current in combination with a hybrid layer capacitor (HLC) that delivers periodic high pulses (Figure 2).

Figure 2: Bobbin-type $LiSOCl_2$ batteries can be combined with a patented hybrid layer capacitor (HLC) to deliver up to 40-year service life along with the high pulses required for two-way wireless communications. *Courtesy: Tadiran Batteries*

Other design considerations include the amount of current consumed in active mode (along with the size, duration, and pulse frequency); energy consumed while in "standby" mode (the base current); storage time (as normal self-discharge diminishes capacity); extreme temperatures during storage and in-field operation; equipment cut-off voltage — as battery capacity is exhausted, or in extreme temperatures, voltage can drop to a point too low for the device to operate (Figure 3).

Figure 3: Bobbin-type $LiSOCl_2$ feature the widest possible temperature range, modifiable for use in the cold chain, where temperatures can dip below -80°C. These batteries can also be modified to handle +125°C heat for specialty applications such as the autoclave sterilization of medical devices.
: Courtesy: Tadiran Batteries and Awarepoint

Battery quality

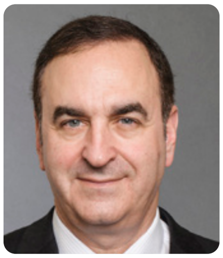
Major differences exist between seemingly identical bobbin-type $LiSOCl_2$ cells. For example, a superior quality bobbin-type $LiSOCl_2$ battery can feature a self-discharge rate as low as 0.7% per year versus an inferior quality cell with a higher self-discharge rate of up to 3% per year, losing 30% of its capacity every 10 years to make 40-year battery life unachievable. By contrast, the higher quality cell can retain more than 70% of its original capacity, even after 40 years.

Specifying an ultra-long-life lithium battery can be difficult because the impact of higher self-discharge can take years to discover, and predictive models often underestimate the effects of passivation as well as long-term exposure to extreme temperatures. Where extended battery life is essential, it pays to perform added due diligence by demanding fully documented long-term test results along with historical in-field test data involving comparable devices under similar loads and environmental conditions (Figure 4).

Pay more attention when comparing batteries and pay less over the operating life of remote wireless devices.

Figure 4: Resensys structural stress sensors mounted beneath bridge trusses require extended life bobbin-type $LiSOCl_2$ batteries to reduce the need for costly and dangerous work to replace batteries in such hard-to-access locations. *Courtesy: Resensys*

ABOUT THE AUTHOR



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