Batteries Designed to Run an IIoT Marathon

Remote wireless devices are becoming increasingly essential to virtually all IIoT-connected applications, including asset tracking, supervisory control and data acquisition, environmental monitoring, AI, M2M, and machine learning, to name a few. Battery-powered devices eliminate the need for expensive hardwiring in challenging environments and inaccessible locations. Industrial-grade lithium batteries are preferable to short-lived consumer-grade batteries, as extended battery life can bring higher reliability, greater longevity, improved customer satisfaction, and a lower cost of ownership.

By Sol Jacobs, Tadiran Batteries

Ultra-long-life lithium batteries can overcome the problem of high self-discharge to run for long distances while delivering the high pulses required for two-way wireless communications.

Low-power wireless devices designed for marathons

Low-power devices can run long distances by carefully conserving energy. Two types of low-power wireless devices are available: those that draw an average current in microamps, typically powered by an industrial-grade primary (nonrechargeable) lithium battery; and those that draw average current in milliamps, enough to prematurely exhaust a primary battery. Because these applications involve greater energy consumption, they can require the use of an energy harvesting device in tandem with an industrial-grade rechargeable lithium-ion (Li-ion) battery.

Specifying an ultra-long-life battery involves numerous parameters, including: the amount of current consumed while in active mode (including the size, duration, and frequency of pulses); the amount of energy consumed while in standby mode (the base current); storage time (as normal self-discharge during storage diminishes capacity); thermal environments (including storage and in-field operation); and equipment cut-off voltage, which drops as cell capacity is exhausted or during prolonged exposure to extreme temperatures. Most important is the annual self-discharge of the cell, which often exceeds the amount of current required to operate the device.

Remote wireless devices are predominantly powered by primary (nonrechargeable) chemistries, including iron disulfate ($LiFeS_2$), lithium manganese dioxide ($LiMnO_2$), lithium thionyl chloride ($LiSOCl_2$), alkaline, and lithium metal oxide chemistry (table 1).

Figure 1. Bobbin-type $LiSOCl_2$ batteries are preferred for use in remote wireless applications. These cells deliver higher capacity and energy density, up to 40-year operating life, and the widest possible temperature range, which is ideal for hard-to-access locations and extreme environments.

Primary cell	$LiSOCL_2$	$LiSOCL_2$	Li Metal Oxide	Li Metal Oxide	Alkaline	$LiFeS_2$	$LiMnO_2$
	Bobbin-type with hybrid layer capacitor	Bobbin-type	Modified for high capacity	Modified for high power		Lithium iron disulfate	CR123A
Energy density (Wh/1)	1,420	1,420	370	185	600	650	650
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 temperature	Excellent	Fair	Excellent	Excellent	Low	Moderate	Fair
Performance at low temperature	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 temperature	–55°C to 85°C, can be ex-tended 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.

Lithium stands apart as the lightest nongaseous metal, with a high intrinsic negative potential that exceeds all others, resulting in the highest specific energy (energy per unit weight) and energy density (energy per unit volume) of all commercially available chemistries. Lithium cells operate within a normal operating current voltage range of 2.7 to 3.6 V. These chemistries are also nonaqueous, whereas water-based chemistries can freeze in extremely frigid temperatures.

Lithium thionyl chloride ($LiSOCl_2$) chemistry, which offers the longest operating life, is constructed in two ways: bobbin-type or spiral wound. Spiral wound cells are specified for applications that require higher energy flow. Bobbin-type cells are better suited for low-power applications due to their higher capacity and higher energy density, as well as a wider temperature range (–80°C to 125°C). A key feature of bobbin-type $LiSOCl_2$ chemistry is its exceptionally low annual self-discharge rate (less than 1 percent per year for certain cells), permitting up to 40-year battery life.

Self-discharge shortens battery life

Battery self-discharge is common to all chemistries, as chemical reactions naturally consume energy even while a cell is inactive. Fortunately, you can modify the self-discharge rate of a bobbin-type $LiSOCl_2$ battery by controlling the passivation effect.

Passivation occurs only with $LiSOCl_2$ batteries, caused by a thin film of lithium chloride (LiCl) that forms on the surface of the lithium anode, separating the anode from the electrode to limit the chemical reactions that cause self-discharge. When a load is placed on the cell, the passivation layer causes initial high resistance along with a temporary drop in voltage until the discharge reaction slowly dissipates the LiCl layer: a process that repeats itself each time the load is removed.

Several other factors can influence cell passivation, including current discharge capacity, the length of storage and storage temperature, discharge temperature, and prior discharge, as partially discharging a cell and then removing the load can increase the amount of passivation relative to when the cell was new.

The good side of passivation is its ability to minimize battery self-discharge. The bad side is that too much of it can restrict energy flow.

Self-discharge is also affected by the cell's current discharge potential, the method of manufacturing, and the quality of the raw materials. The highest-quality bobbin-type $LiSOCl_2$ cell can feature a self-discharge rate as low as 0.7 percent per year, retaining 70 percent of its original capacity after 40 years. Conversely, a lower-quality bobbin-type $LiSOCl_2$ cell can experience a self-discharge rate of up to 3 percent per year, losing 30 percent of its initial capacity every 10 years, making 40-year battery life impossible.

Be aware that it can take years for battery self-discharge to become fully apparent and that theoretical test data tends to be unreliable. For these reasons, thorough due diligence is required, especially if the battery needs to run for the life of the device.

Figure 2. Bobbin-type $LiSOCl_2$ batteries can be combined with a patented hybrid layer capacitor (HLC) to offer up to 40-year operating life while also providing high pulses to power two-way wireless communications.

Two-way wireless connectivity demands high pulses

A growing number of remote wireless devices require periodic high pulses to power two-way wireless communications. To conserve energy, these devices typically incorporate a low-power communications protocol (e.g., WirelessHART, ZigBee, or LoRa), along with a low-power chipset and proprietary energy-conserving techniques.

Standard bobbin-type $LiSOCl_2$ cells cannot deliver the high pulses required for two-way communications: a challenge that can be easily overcome with the addition of a patented hybrid layer capacitor (HLC). The bobbin-type $LiSOCl_2$ cell delivers nominal background current during "standby" mode, while the HLC works like a rechargeable battery to generate high pulses up to 15A. As an added bonus, the HLC also features

The Runner Analogy: Winning a Marathon

The distance is equivalent to the battery/device operating life. The farther a runner can travel, the more years a device will be able to operate.

The incline is equivalent to the battery's self-discharge rate. The higher the self-discharge rate, the larger the incline, which draws more power and shortens the duration of the run. Similarly, higher battery self-discharge consumes more energy to shorten the cell's operating life.

Hurdles are equivalent to pulses. The higher the hurdle, or obstacle, the higher the pulse required to support two-way wireless communications and other advanced functionality.

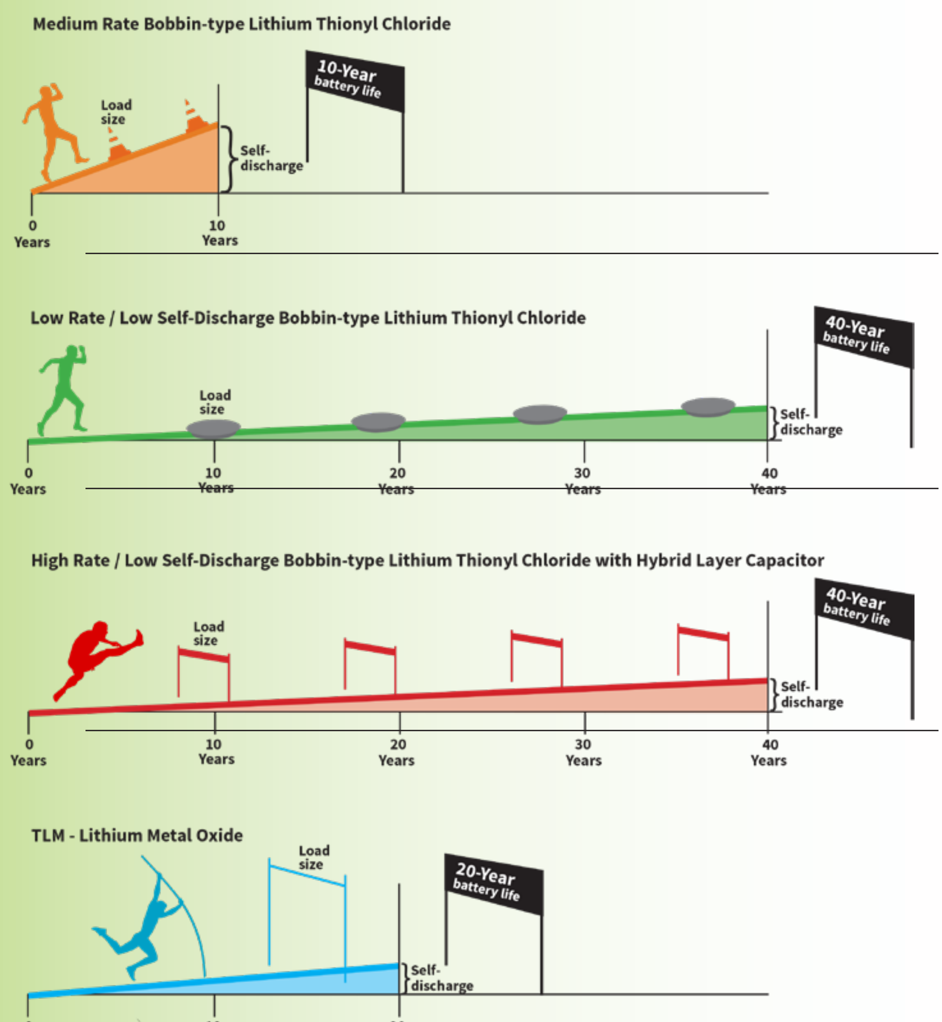


Figure 3. Runner analogy

an end-of-life voltage plateau that can be interpreted to communicate "low battery" status alerts (figure 2).

Supercapacitors provide the same function in consumer electronics but are generally not suited for industrial applications due to inherent limitations, including short-duration power, linear discharge qualities that do not permit full discharge of available energy, low capacity, low energy density, and a very high self-discharge rate of up to 60 percent per year. Supercapacitors linked in series require cell-balancing circuits that are bulky, expensive, and draw additional energy to further shorten their operating life.

Here are some typical real-life examples that rely upon bobbin-type $LiSOCl_2$ batteries:

Cryoegg: Researchers studying the relationship between climate change, rising sea levels, and deep-water channels beneath glaciers in Greenland and Antarctica use Cryoegg, a remote wireless sensor that continuously monitors temperature, pressure, and electrical connectivity (figure 4). Cryoegg eliminates the need for bulky and expensive cables that can be easily damaged by glacial movement. Bobbin-type $LiSOCl_2$ cells were specified due to their high capacity, high energy density, wide temperature range, and high pulse capabilities.

Figure 4. Mike Prior-Jones prepares Cryoegg for deployment.
Source: Mauro Werder

Cryoegg utilizes the same 169 MHz wireless M-Bus radio waves found in automated meter reading and advanced metering infrastructure water and gas utility meter transmitter units (MTUs). Bobbin-type $LiSOCL_2$ batteries lower the cost of ownership of a water or gas MTU by preventing widescale battery failures that can disrupt billing systems and disable remote startup/shutoff capabilities.

Oceantronics: To simplify the transport of scientific equipment across the Artic, Oceantronics redesigned the battery pack for its GPS/

ice buoy by replacing a huge battery pack consisting of 380 alkaline D cells with a more compact, lighter, and cost-efficient solution using 32 bobbin-type $LiSOCl_2$ cells and four HLCs. The company achieved a 90 percent reduction in size and weight (54 kg down to 3.2 kg), enabling the GPS/ice buoy to be more easily transported by helicopter. Converting from alkaline to $LiSOCl_2$ chemistry also multiplied the device's operating life manyfold.

Southwire: Reducing size and weight is highly beneficial to utility line crews installing line/connector sensors that monitor temperature, catenary, and line current on utility power lines to warn if a transmission line goes down. Use of bobbin-type $LiSOCl_2$ cells enables a more compact and lightweight (3.5 lb) solution that can handle extreme temperatures (–40°C to 50°C), providing months of backup power if no line current is detected.

Long-life energy harvesting applications growing

While primary batteries continue to dominate, we are also seeing a dramatic rise in applications that draw milliamps of current, enough to quickly exhaust a primary lithium battery. Returning to our runner analogy, these applications burn up more calories, thus requiring the use of an energy-harvesting device in tandem with an industrial-grade rechargeable lithium-ion battery.

For example, Cattlewatch combines small solar (PV) panels and Li-ion batteries to create a mesh network that tracks the location, health, and safety of animal herds. Similarly, solar/Li-ion hybrids power smart meters that collect parking fees and are equipped with AI-enabled sensors to communicate when open parking spots become available (figure 5).

Low-cost, consumer-grade rechargeable Li-ion cells cannot run such applications because of their relatively short operating life (five years and 500 recharge cycles), a limited temperature range (0–40°C), and their inability to deliver high pulses. By contrast, industrial-grade Li-ion batteries can operate

Figure 5. IPS solar-powered parking meters use industrial-grade rechargeable Li-ion batteries to ensure up to 20 years of 24/7/365 system reliability and connectivity for AI-enabled smart parking meters.
Courtesy of IPS Group

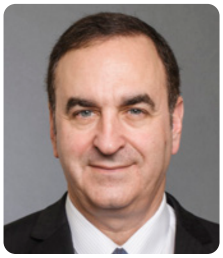
up to 20 years and 5,000 full recharge cycles, featuring an expanded temperature range (–40° to 85°C) and the ability to deliver periodic high pulses to power two-way wireless communications (table 2).

		TLI-1550 (AA) Industrial grade	**Li-ion** 18650
Diameter (max)	[cm]	1.51	1.86
Length (max)	[cm]	5.30	6.52
Volume	[cc]	9.49	17.71
Nominal voltage	[V]	3.7	3.7
Max discharge rate	[C]	15 C	1.6 C
Max continuous discharge current	[A]	5	5
Capacity	[mAh]	Up to 1000	3000
Energy density	[Wh/l]	129	627
Power [RT]	[W/liter]	1950	1045
Power [–20C]	[W/liter]	> 630	< 170
Operating temperature	deg. C	–40 to +90	–20 to +60
Charging temperature	deg. C	–40 to +85	0 to +45
Self-discharge rate	[%/year]	<5	<20
Cycle life	[100% DOD]	~5000	~300
Cycle life	[75% DOD]	~6250	~400
Cycle life	[50% DOD]	~10000	~650
Operating life	[Years]	>20	<5

Table 2.

In the long run, it often pays to specify an extended life battery to increase product reliability while also reducing the total cost of ownership.

ABOUT THE AUTHOR



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