Five Keys to Powering Remote Wireless Devices

Consider environment, energy demands, self-discharge rate, and energy density when selecting batteries for remote wireless devices.

By Sol Jacobs, Tadiran Batteries

Battery-powered remote wireless devices are taking industrial automation to increasingly remote locations and extreme environments. The growing list of applications includes supervisory control and data acquisition (SCADA), process control, asset tracking and management, safety systems, field equipment status, flow monitoring, machine-to-machine (M2M), artificial intelligence (AI), and wireless mesh networks.

Identifying the ideal power source for a remote wireless device requires a fundamental understating of each application's unique power requirements, then selecting the ideal battery based on its performance capabilities. This decision-making process typically centers around five key considerations:

- Evaluating the device's specific energy demands
- Choosing the battery chemistry that best suits the needs
- Understanding the importance of battery self-discharge
- Adapting to high pulse requirements
- Doing your homework

Evaluating device energy requirements

If a wireless device is easily accessible and operates within a reasonably mild temperature range, it may allow for the use of an inexpensive consumer-grade alkaline or lithium battery. However, the performance requirements for a battery are far different for long-term deployments in hard-to-access and hostile environments. These devices must conserve energy by operating mainly in a standby state, drawing micro-amps of average current with periodic high pulses in the multi-amp range to power wireless communications. These low-power devices are predominantly powered by industrial grade lithium thionyl chloride ($LiSOCl_2$) batteries (figure 1) that feature very high capacity, high energy density, an extended temperature range, and an exceptionally low annual self-discharge rate.

A relatively small number of remote wireless devices draw milli-amps of average current with pulses in the multi-amp range, draining enough average energy to prematurely exhaust a primary (non-rechargeable) battery. These niche applications are often better suited for an energy harvesting device in combination with an industrial grade Lithium-ion (Li-ion) battery to generate high pulses.

Choosing the best battery type for the application

Numerous primary lithium battery chemistries are available (table 1), each offering unique advantages and disadvantages. At one end of the spectrum are inexpensive alkaline batteries that deliver high

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.

continuous energy but suffer from a very high self-discharge rate (which limits battery life) as well as low capacity and energy density (which adds size and bulk). In addition to being short-lived, consumer-grade alkaline cells cannot operate in extreme temperatures due to their water-based constituents. For this reason, many remote wireless devices are powered by industrial-grade lithium batteries.

Primary Cell	**$LiSOCL_2$** Bobbin-type with Hybrid Layer Capacitor	**$LiSOCL_2$** Bobbin-type	**Li Metal Oxide** Modified for high capacity	**Li Metal Oxide** Modified for high power	**$LiFeS_2$** Lithium Iron Disulfate (AA-size)	**$LiMnO_2$** Lithium Manganese Oxide
Energy Density (Wh/Kg)	700	730	370	185	335	330
Power	Very High	Low	Very High	Very High	High	Moderate
Voltage	3.6 to 3.9 V	3.6 V	4.1 V	4.1 V	1.5 V	3.0 V
Pulse Amplitude	Excellent	Small	High	Very High	Moderate	Moderate
Passivation	None	High	Very Low	None	Fair	Moderate
Performance at Elevated Temp.	Excellent	Fair	Excellent	Excellent	Moderate	Fair
Performance at Low Temp.	Excellent	Fair	Moderate	Excellent	Moderate	Poor
Operating life	Excellent	Excellent	Excellent	Excellent	Moderate	Fair
Self-Discharge Rate	Very Low	Very Low	Very Low	Very Low	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	-20°C to 60°C	0°C to 60°C

Table 1. Numerous primary lithium battery chemistries are available.

As the lightest non-gaseous metal, lithium features an intrinsic negative potential that exceeds all other metals, delivering the highest specific energy (energy per unit weight), highest energy density (energy per unit volume), and higher voltage (OCV) ranging from 2.7 to 3.6 V. Lithium battery chemistries are also non-aqueous and therefore less likely to freeze in very cold temperatures.

Among all commercially available primary lithium chemistries, bobbin-type lithium thionyl chloride ($LiSOCl_2$) stands apart as being overwhelmingly preferred for ultra-long-term deployments. Bobbin-type $LiSOCl_2$ chemistry delivers the highest capacity and highest energy density of all, endures extreme temperatures (-80°C to 125°C), and features an annual self-discharge rate as low as 0.7 percent per year that enables up to 40-year battery life. Bobbin-type $LiSOCl_2$ batteries are specifically designed for use with low-power communications protocols such as WirelessHART, ZigBee, and LoRa, to name a few. The main performance benefits of bobbin-type $LiSOCl_2$ batteries include:

- Higher reliability: Ideal for remote locations where battery replacement is difficult or impossible and highly reliable connectivity is required.
- Long operating life: Since the battery's self-discharge rate often exceeds actual energy usage, high initial capacity and a low self-discharge rate are often critical.
- The widest temperature range: Bobbin-type $LiSOCl_2$ cells can be modified to work reliably in extreme temperatures (-80°C to 125°C).
- Smaller size: Higher energy density could permit the use of smaller batteries.
- Higher voltage: Could allow for the use of fewer cells.
- Lower lifetime costs: A critical consideration since the manpower and logistical expenses to replace a battery far exceed its cost.

Importance of battery self-discharge

A remote wireless device is only as reliable as its battery, so design engineers must specify the ideal power source based on a number of factors, including: the amount of energy consumed in active mode (including the size, duration, and frequency of pulses); energy consumed in standby mode (the base current); storage time (as normal self-discharge during storage diminishes capacity); thermal environments (including 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 sensor to operate). Often, the most critical consideration can be the battery's annual self-discharge rate, as the amount of current consumed by self-discharge can exceed the amount of energy required to operate the device.

All batteries experience some amount of self-discharge as chemical reactions draw current even while the cell is unused or disconnected. Self-discharge can be minimized by controlling the passivation effect, whereby a thin film of lithium chloride (LiCl) forms on the surface of the lithium anode, separating it from the electrode to reduce the chemical reactions that cause self-discharge. Whenever a current load is placed on the cell, the passivation layer causes initial high resistance and a temporary drop in voltage until the discharge reaction begins to dissipate the passivation layer—a process that continually repeats each time a load is applied.

Passivation can be affected by the cell's current discharge capacity, the length of storage, storage temperature, discharge temperature, and prior discharge conditions, as partially discharging a cell and then removing the load increases the level of passivation over time. Controlling passivation is ideal for minimizing self-discharge but too much of it can overly restrict energy flow.

Competing bobbin-type $LiSOCl_2$ cells vary considerably in terms of their self-discharge rate. For example, the highest quality $LiSOCl_2$ batteries can feature a self-discharge rate as low as 0.7 percent per year, able to retain nearly 70 percent of their original capacity after 40 years.

Conversely, lower quality $LiSOCl_2$ cells can have a self-discharge rate as high as 3 percent per year, exhausting nearly 30 percent of their available capacity every 10 years, limiting maximum battery life to 10 – 15 years.

Adapt for high pulse requirements

To support two-way wireless communications and other advanced functionality, remote wireless devices must generate periodic high pulses up to 15 A. Standard bobbin-type $LiSOCl_2$ cells normally cannot deliver high pulses due to their low-rate design. However, they can be easily modified with the addition of a patented hybrid layer capacitor (HLC) (figure 2). This hybrid solution uses the standard bobbin-type $LiSOCl_2$ cell to deliver low-level background current during standby mode while the HLC delivers the high pulses required to support data queries and transmission. As an added benefit, the HLC features a unique end-of-life voltage plateau that can be interpreted to deliver low battery status alerts.

Supercapacitors perform a similar function with consumer products but are generally ill-suited for industrial applications due to serious limitations including short-duration power, linear discharge qualities that do not allow for the use of all available energy, low capacity, low energy density, and very high self-discharge rates up to

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.

60 percent per year. Supercapacitors linked in series require the use of expensive cell-balancing circuits that add bulk and drain additional current to further shorten their operating life.

Do your homework

When designing for a long-term deployment in a highly remote location or extreme environment, it pays to spend a little more for a superior grade battery that can last for the entire lifetime of the device, thus eliminating the need for costly battery change-outs. Accomplishing this cost-saving goal requires careful due diligence as lithium batteries are not created equal.

For example, the annual self-discharge rate of a bobbin-type $LiSOCl_2$ battery can vary significantly based on how it is manufactured and the quality of the raw materials. Unfortunately, a lower quality cell with a high self-discharge rate may be hard to distinguish as capacity losses are not easily measurable for years and theoretical battery life expectancy models tend to underestimate the passivation effect as well as long-term exposure to extreme temperatures.

To properly compare competing battery brands, users must demand fully documented and verifiable test results along with in-field performance data under similar loads and environmental conditions. Learning about the subtle differences between seemingly identical cells can pay huge dividends by reducing your long-term cost of ownership.

ABOUT THE AUTHOR

Sol Jacobs is vice president and general manager at Tadiran Batteries.