Remote Wireless for Less

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Batteries are at the heart of most remote wireless devices, yet they are often considered an afterthought instead of a forethought.

When seeking to optimize a battery-powered device, the most cost-efficient solution is ideal: one that does not underperform and therefore damages brand reputation; or, conversely, does not wastefully overperform to add unnecessary bulk and expense. However, identifying the right-sized solution is easier said than done when considering all the variables and trade-offs involved.

Choosing the right battery can save money now and for decades.

Start by knowing your application. There is a common misconception that all batteries are essentially the same and disregarding the fact that each application has unique power requirements. Most low-power devices draw micro-Amps of average current with pulses in the multi-Amp range, typically requiring the use of a primary (non-rechargeable) battery. In addition, a small but growing number of low-power devices draw higher amounts of average current measurable in milli-Amps with pulses in the multi-Amp range, which can prematurely exhaust a primary battery. Such applications often require an energy-harvesting device in combination with a rechargeable Li-ion battery to store the harvested energy.

Numerous primary (non-rechargeable) batteries are available, thus requiring a fundamental understanding of the relative strengths and weaknesses of each competing chemistry. Key performance parameters to consider include:

Operating voltage – the battery's voltage can directly impact the size and weight of the device. Since it takes two 1.5v cells to deliver the same voltage as a single 3.6v cell, specifying a higher voltage battery could potentially reduce the size and weight of the power supply by 50%, and in some cases require the use of fewer cells. Where size and weight are not major considerations, choosing a lower voltage battery may be an acceptable trade-off to save money.

Low self-discharge – A battery's annual self-discharge rate is key to determining its potential operating life. Alkaline cells, for example, have self-discharge rates as high as 60% per year, requiring an oversized power supply to compensate for the expected energy loss. In situations where the device is easily accessible for battery replacement, and the operating environment is moderate, choosing a less inexpensive battery with a high self-discharge may be appropriate.

However, if the device is intended for long-term deployment at a remote site and must operate reliably for extended periods, even decades, then the application demands an ultra-long-life battery with a very low self-discharge rate.

Bobbin-type $LiSOCl_2$ cells deliver decades of reliable performance to help mitigate the risk of a highly disruptive and expensive large-scale battery.
Photo courtesy of Aclara.

While self-discharge is common to all batteries, bobbin-type $LiSOCl_2$ batteries stand apart for having the lowest self-discharge rate of all, mainly due to their unique ability to harness the passivation effect.

Passivation involves the formation of a thin film of lithium chloride (LiCl) that covers the surface of the anode of an inactive battery to act as a separation barrier from the electrode, thus limiting the chemical reactions that cause self-discharge. When a continuous current load is applied to the cell, the passivation layer causes initial high resistance and a temporary drop in voltage until the discharge reaction starts to de-passivate the battery. When the battery returns to an inactive state, the passivation layer begins to return, thus requiring another round of de-passivation.

The level of passivation is determined by numerous variables, including the cell's construction, its current discharge capacity, the length of time in storage, the storage and discharge temperature, and prior discharge conditions, as partially discharging a cell and then removing the load affects passivation over time. While ideal for extending battery life, passivation must be carefully controlled to avoid over-restricted energy flow.

Battery manufacturers differ in their ability to harness the passivation effect through the use of proprietary cell construction techniques and higher-quality raw materials. These differences can be substantial. For example, a superior quality bobbin-type $LiSOCl_2$ battery can feature a self-discharge rate of 0.7% per year, retaining over 70% of its original capacity after 40 years. By contrast, a lower grade bobbin-type $LiSOCl_2$ battery can have a much self-discharge rate of up to 3% per year, exhausting 30% of its original capacity every 10 years, making 40-year battery life unachievable.

Resensys structural stress monitors are mounted beneath bridge trusses and other hard-to-access locations. These monitors require ultra-long-life bobbin-type $LiSOCl_2$ batteries to minimize the need for costly and dangerous battery replacements.
Photo courtesy of Resensys.

Harsh environments. Battery performance can be severely reduced by prolonged exposure to extreme temperatures. Specifying a battery that is ill-suited for the operating environment may require the use of oversized batteries to compensate for an expected drop in voltage under pulsed load. Exposure to extreme temperatures often requires the use of bobbin-type lithium thionyl chloride ($LiSOCl_2$) cells that have a temperature range of -80ºC to +125ºC.

Specifying the ideal power supply takes on greater importance with long-term deployments at remote sites and harsh environments, where it is prohibitively expensive to access the battery (i.e. a structural stress sensor mounted beneath a bridge truss) or impossible to replace it once installed (i.e. a seismometer located on the ocean floor). Choosing the right battery is also critical for large scale deployments (i.e. municipal AMR/AMI metering network) where a systemwide battery failure could be costly and highly disruptive.

The IIoT has dramatically increased demand for low-power devices that require periodic high pulses to power two-way communications and other advanced functionality.

Don’t confuse power with energy

Battery power (the amount of current consumed over a short-term period) is often confused with the total amount of energy required (total battery capacity consumed). Certain wireless devices draw relatively high amounts of power (continuous high-rate current for brief periods), requiring the use of specialized batteries such as a TLM Series lithium metal oxide battery or TLI Series industrial grade rechargeable Li-ion battery that have been modified to deliver high-rate current. Common examples include surgical power tools that operate for a few minutes, devices that perform actuation functions (i.e. valve control), and specialized mil/aero applications (i.e. projectile guidance), to name a few. However, most remote wireless applications do not require a high power-per-energy ratio, so choosing a high-power battery would be wasteful by adding unnecessary bulk and capacity.

Are high pulses required?

The IIoT has dramatically increased demand for low-power devices that require periodic high pulses to power two-way communications and other advanced functionality.

Inexpensive consumer-grade alkaline batteries can deliver the required high pulses due to their high-rate design but have serious drawbacks that make them unfit for long-term deployments, including low voltage (1.5 V), a limited temperature range (0°C to 60°C), and crimped seals that may leak. Most notably, alkaline cells have a high self-discharge rate of up to 60% per year, which is highly problematic for long-term deployments.

Bobbin-type $LiSOCl_2$ batteries are overwhelmingly preferred for remote wireless applications due to their extremely low-self-discharge rate of less than 1% per year, along with their high energy density, high capacity, and a wide temperature range of -80ºC to +125ºC.

One downside to bobbin-type $LiSOCl_2$ batteries is an inability to deliver high-rate current due to their low-rate design, resulting in transient minimum voltage (TMV) when first subjected to a pulsed load. To overcome the TMV challenge, PulsesPlus™ batteries were developed that combine a standard bobbin-type $LiSOCl_2$ cell with a patented Hybrid Layer Capacitor (HLC). This hybrid solution uses the bobbin-type $LiSOCl_2$ cell to deliver low-level background current in the 3.6 - 3.9 V nominal range while the HLC generates high pulses to support two-way wireless communications. The patented HLC also features a unique end-of-life voltage curve

Ayyeka AI-enabled edge devices utilize ultra-long-life bobbin-type $LiSOC_{l2}$ batteries to monitor the long-term performance of hard infrastructure, delivering the energy required to enable enhanced data intelligence that recognizes patterns, detects anomalous events, and supports real-time reporting and predictive modeling.
Photo courtesy of Ayyeka.

plateau that can be interpreted to provide 'low battery' status alerts that enhance predictive maintenance programs.

While supercapacitors perform a similar function for consumer electronics, they are generally unsuited for industrial applications due to numerous drawbacks, including added weight and bulkiness; a high annual self-discharge rate; a narrow temperature range; and the need for expensive balancing circuits when multiple supercapacitors are linked in series, which adds bulk and draws additional current to accelerate self-discharge.

Primary batteries and rechargeable Li-ion batteries can be utilized in tandem.

Long-life rechargeable Li-ion cells

Low-power devices that draw average current measurable in milli-Amps with pulses in the multi-Amp range may require the use of an energy harvesting device in combination with a rechargeable Lithium-ion (Li-ion) battery to store the harvested energy.

Consumer-grade Li-ion batteries have severe limitations, including a maximum battery life of roughly 3 years and 300 full recharge cycles. These cells also have a narrower temperature range that does not permit them to be discharged or recharged at extremely cold temperatures. Additionally, if more than 300 full recharge cycles are required, additional cells may be necessary to reduce the average depth of discharge per cell. Consumer-grade Li-ion cells are also unable to generate high pulses.

By contrast, TLI Series industrial-grade rechargeable Li-ion batteries can operate for up to 20 years and 5,000 recharge cycles while delivering up to 15 A pulses and 5 A continuous current. TLI Series cells also feature an extended temperature range (-40°C to 85°C) that allows the battery to be charged and discharged at extremely cold temperatures.

Primary batteries and rechargeable Li-ion batteries can be utilized in tandem. For example, applications using small solar PV panels may require extra rechargeable Li-ion batteries to accommodate a worst-case scenario such as five straight days of cloudiness. Bobbin-type $LiSOCl_2$ cells can serve as a backup power supply that recharges the Li-ion batteries on sunless days, potentially permitting the use of smaller PV panels and/or smaller batteries during polar winters or in situations where extended battery storage is required.

You need to consult an expert

With long-term battery deployments, there are no one-size-fits-all solutions. You should consult with an experienced applications engineer who can assist you in matching the power management solution to your specific requirements for voltage (maximum, nominal and shut-off), constant current, pulses current (size, duration, and frequency), expected operating life, storage life, and expected temperatures both during stage and operation, and more.

When evaluating competing battery chemistries, make sure that you receive fully documented and verifiable long-term lab test results along with real-life data from batteries performing in the field under similar loads and environmental conditions, both during storage and deployment. Customer references should also be requested and contacted.

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 to power wireless communications.
Photo courtesy of Tadiran.

Over many decades, Tadiran has developed a large and continually growing database that accurately predicts long-term battery performance under virtually all scenarios. Tadiran also monitors customer-supplied batteries from the field that have been operating under virtually all performance requirements and environmental conditions. Similar testing is also performed on competing brands.

Since bobbin-type $LiSOCl_2$ batteries are slightly more expensive, you must calculate whether the added investment is warranted by the long-term savings, taking into consideration such factors as the need for future battery replacements, since the cost of a battery change-out will far exceed its cost.

For long-term deployments at remote sites and extreme environments, it invariably pays to invest a little more for a battery that can operate maintenance-free for the entire lifetime of the device. A knowledgeable applications engineer can help identify the right-sized power management solution.

ABOUT THE AUTHOR

Vitaly Milner, Ph.D. is product and marketing manager at Tadiran Batteries. He has more than 20 years of experience in industrial roles, including 14 years in the battery sector. Milner specializes in innovative battery applications for IIoT, transportation, oil & gas, telecom, utilities, and more. He has a Doctor of Philosophy degree in physics and mathematics from Lomonosov Moscow State University.