Shrink Your Batteries... and Your Budget

By Sol Jacobs, Tadiran Batteries

Advanced lithium batteries enable remote wireless devices to be smaller and less expensive.

Battery-powered solutions for industrial grade wireless devices need to be intelligently designed to minimize size and weight without compromising overall performance. This objective is especially important if the wireless device needs to operate for extended periods in remote locations or extreme environments.

Choosing the incorrect battery can be problematic, as it can lead to an inefficient solution involving an unnecessarily large, heavy, expensive, and short-lived power supply. The resulting issues can include added logistical expenses to transport overly large batteries to hard-to-access locations, as well as more frequent battery replacements, thus raising the total cost of ownership.

Specifying the right-sized battery starts by understanding the fundamental differences between competing primary (non-rechargeable) battery chemistries (Table 1).

When comparing these chemistries, it pays to focus on the following performance characteristics:

Operating voltage. Basic math indicates that it takes more than two 1.5v cells to deliver the same voltage as a single 3.6v cell. Selecting a higher voltage battery effectively reduces the size and weight of a device, leading to potentially greater savings if fewer cells are required.

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	**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 consumer versus industrial Li-ion rechargeable batteries.

Temperature range. Exposure to extreme temperatures reduces battery voltage under pulsed load. Batteries with limited temperature ranges will perform less effectively in harsh environments, often resulting in the need to deploy oversized batteries in order to compensate for the expected drop in voltage under pulsed load.

The expected performance losses caused by extreme temperatures can be minimized with the use of bobbin-type lithium thionyl chloride ($LiSOCl_2$) batteries. These cells feature very high energy density along with the ability to handle high pulses across a wider temperature range, potentially eliminating the need for using cells carrying excess capacity and/or voltage just as a precaution (Figure 1).

Self-discharge rate. Every battery suffers from self-discharge, including certain cells that can exhaust up to 8% of their capacity each month. Such losses may require the use of a larger battery in order to offset the expected energy losses.

Most battery chemistries experience accelerated self-discharge when exposed to extreme temperatures. If extended battery life is essential, it is incumbent to select a battery with a very low annual self-discharge rate. Choosing an ultra-long-life battery could potentially enable the use of smaller cells and reduce or eliminate the need for future battery replacements.

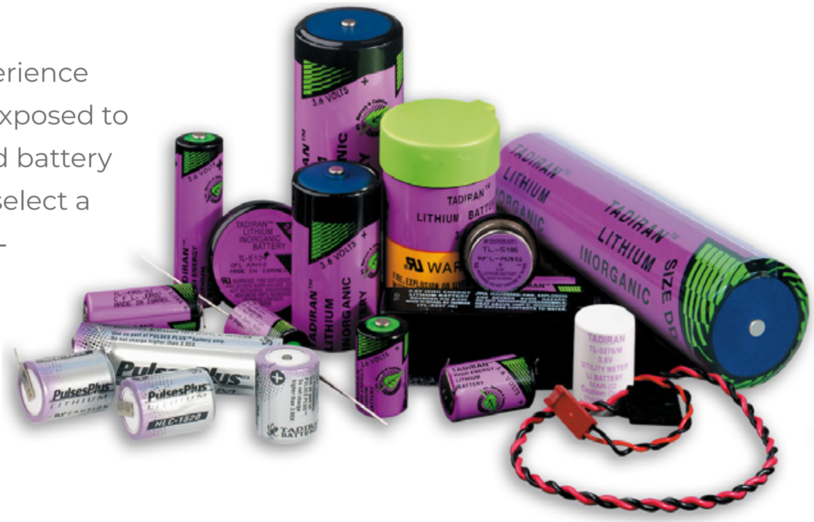


Figure 1. Bobbin-type $LiSOCl_2$ batteries feature high energy density, high capacity, and very low annual self-discharge, and a wide temperature range for remote applications.

For example, by carefully controlling the passivation effect, a superior quality bobbin-type $LiSOCl_2$ battery can offer a self-discharge rate of just 0.7% per year, able to retain over 70% of its original capacity after 40 years. By contrast, a lower quality battery using essentially the same chemistry can experience a much higher self-discharge rate of 3% per year, losing 30% of its capacity every 10 years, reducing its operating life down to just 10-15 years.

Don't Confuse Power with Energy

Battery power is a measure of short-term energy consumed. This term should not be confused with the cell's total amount of energy or nominal capacity.

Certain types of devices require high amounts of power (high pulses) for short bursts without exhausting a large amount of total energy. These applications include surgical power tools that operate for minutes, cells that actuate an electro-mechanical device, and military applications that draw large amounts of energy for limited periods (i.e., guided munitions).

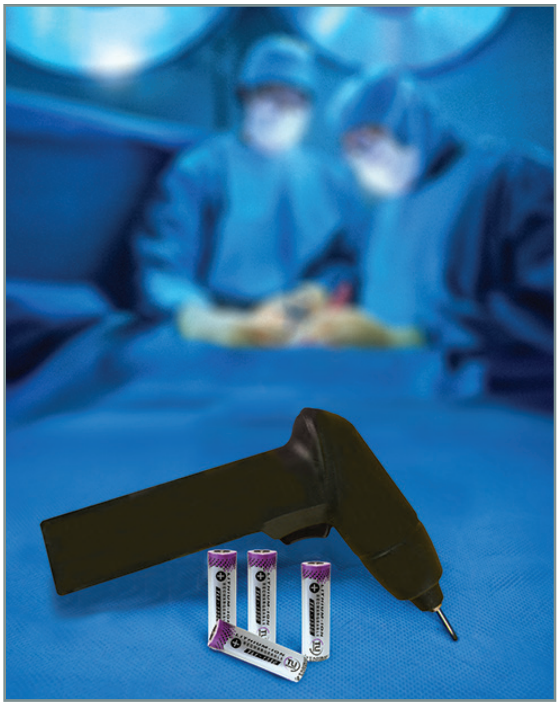


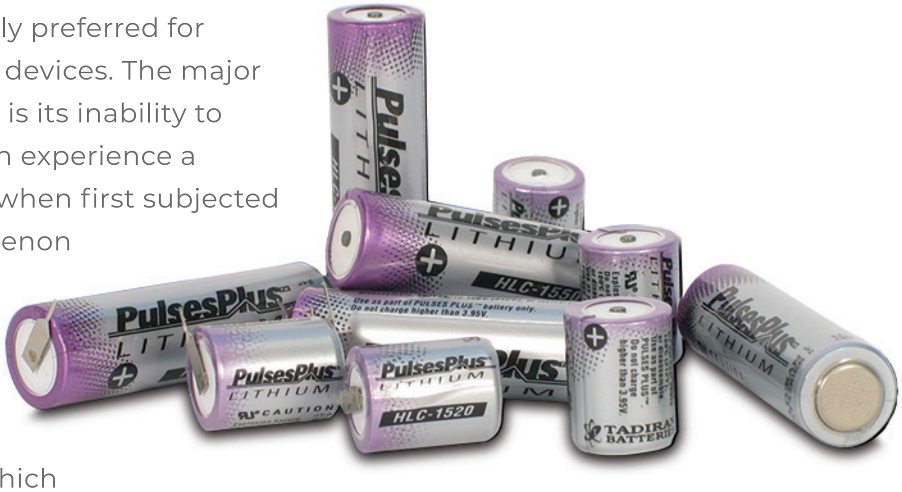
Figure 2. TLM Series lithium metal oxide batteries deliver the high-rate energy required to make surgical power tools smaller, lighter and ergonomic yet more powerful.

These specialized applications are not well served by ordinary battery technologies that cannot deliver a high power-per-energy ratio. Such specialized requirements could demand the use of more and larger cells to compensate for their low pulse design. This often leads to a compromise solution involving the use of larger or more cells with unused energy capacity. One possible alternative is to utilize TLM Series lithium metal oxide batteries that feature a very high power-per-energy ratio (Figure 2).

Do You Have High Pulse Requirements?

The IIoT is increasingly reliant on remote wireless devices that require high pulses to power two-way wireless communications. Alkaline batteries are ideal for delivering high pulses due to their high-rate design. However, they have major limitations for use in industrial applications, including low voltage (1.5 V): a limited temperature range (0°C to 60°C); a very high self-discharge rate that shortens their life expectancy; and crimped seals that may leak. Alkaline batteries often need be replaced every few months, making them totally unsuited for long-term deployment in remote locations.

Standard bobbin-type $LiSOCl_2$ battery chemistry is overwhelmingly preferred for low-power remote wireless devices. The major drawback of this chemistry is its inability to deliver high pulses, as it can experience a temporary drop in voltage when first subjected to a pulsed load. a phenomenon known as transient minimum voltage (TMV).



An ideal way to circumvent TMV is to use a PulsesPlus battery, which combines a standard bobbin-type $LiSOCl_2$ cell with a patented hybrid layer capacitor (HLC). The battery and the HLC work in parallel—the battery supplies low-current background power in the 3.6 to 3.9 V nominal range, while the single-unit HLC delivers periodic high pulses to power two-way wireless communications. The HLC also delivers an added bonus: a unique end-of-life voltage curve plateau that can be interpreted to generate low battery status alerts (Figure 3).

Figure 3. PulsesPlus cells combine a standard bobbin-type $LiSOCl_2$ battery with a hybrid layer capacitor (HLC) to deliver high pulses to power two-way wireless communications.

Supercapacitors are commonly used to minimize TMV in consumer electronics but are ill-suited for most industrial applications due to major drawbacks, including bulkiness, a high annual self-discharge rate, and an extremely limited temperature range. Moreover, when multiple supercapacitors are combined, it requires the use of expensive balancing circuits that draw additional current, adds expense, and draws greater current to further shorten battery life.

Industrial Grade Li-ion Rechargeable Cells

If your low-power application draws enough energy to prematurely exhaust a primary (non-rechargeable) lithium battery, then it may require the use of an energy harvesting device in combination with a rechargeable Li-ion battery.

Consumer grade rechargeable Lithium-ion (Li-ion) cells have limitations for industrial applications, including a maximum battery life of roughly 5 years and 500 full recharge cycles; a narrow temperature range with no ability to discharge or recharge at extremely cold temperatures; and the inability to generate the high pulses needed to power two-way wireless communications (Table 2). If more than 500 full recharge cycles are required, then additional consumer Li-ion cells may be needed to reduce the average depth of discharge per cell.

By contrast, industrial grade rechargeable Li-ion batteries can operate up to 20 years and 5,000 full recharge cycles while also

		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]	15C	1.6C
Max Continuos 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 Temp	deg. C	-40 to +90	-20 to +60
Charging Temp	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. Comparison of consumer versus industrial Li-ion rechargeable batteries

delivering the high pulses (15 A pulses and 5 A continuous current) needed to power two-way wireless communications. These industrial grade Li-ion batteries also feature an extended temperature range (-40°C to 85°C) that allows them to be charged and discharged at extremely cold temperatures (Figure 4).

Figure 4. IPS solar-powered parking meters use TLI Series industrial grade Li-ion batteries to communicate billing information and to identify open parking spaces.

Specialized solutions may be required in instances where the energy harvesting source is somewhat unreliable. One common example involves solar PV panels that need to be designed oversized to accommodate worst-case scenarios such as up to 5 continuous days without sun. Bobbin-type $LiSOCl_2$ cells can be utilized as a back-up power source to keep Li-ion batteries charged during sunless periods, thus enabling the use of smaller and less expensive PV panels and/or smaller Li-ion batteries. Use of a primary $LiSOCl_2$ battery as back-up enhances product reliability especially during periods of extended darkness (i.e., polar winters) or if the device remains in extended storage.

Don't be penny wise and pound foolish

Certain applications permit design engineers to think short-term and choose a low-cost battery that reduces the initial purchase price. Conversely, if your remote application requires a long-term power source to reduce the total cost of ownership, then a far different calculus needs to be applied.

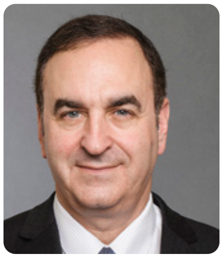
If your wireless device is intended for long-term deployment in a highly remote and inaccessible location, then you will need to minimize or eliminate future battery replacements since the cost of labor, loss of data integrity, and downtime will invariably exceed any initial savings realized with a low-cost consumer grade battery.

In addition, there are hidden costs associated with excessive battery size and weight, including higher transportation costs, as the shipping of lithium batteries has become far more expensive due to increasingly restrictive UN and IATA shipping regulations.

As a general rule, if your remote wireless device is easily accessible and operates at moderate temperatures, a consumer grade battery could suffice. However, if your application involves a highly remote location or extreme temperatures, then pay a little more for an industrial grade lithium battery that can operate for the entire life of your wireless device, reducing your total cost of ownership.

For more information, visit Tadiran Batteries.

ABOUT THE AUTHOR



Sol Jacobs, Vice President & General Manager, Tadiran Batteries
Sol Jacobs has more than 30 years of experience in powering remote devices. His educational background includes a BS in engineering and an MBA.