

Comparing Consumer And Industrial Batteries For Wireless Applications

by [Sol Jacobs](#) | Jul 14, 2017 12:00am



SENSORS INSIGHTS

By Sol Jacobs, Guest Contributor



The world is now truly wireless, and self-powered devices are becoming integral to everything from mass consumer electronics to remote industrial applications, each with very unique power requirements.

Consumer electronic devices are generally powered by either alkaline batteries, consumer grade lithium primary (non-rechargeable) batteries, or consumer grade Lithium-ion (Li-ion) rechargeable batteries. There is also a growing list of industrial applications that require long-life power sources capable of supporting two-way wireless communications. These applications include utility meter reading (AMR/AMI), wireless mesh networks, M2M and system control and data acquisition (SCADA), data loggers, measurement while drilling, oceanographic measurements, and emergency/safety equipment, to name a few.

The growth in remote wireless communications is being propelled by technologies designed to extend battery life, including low power components, ICs and circuitry, along with low power communications protocols such as ZigBee, WirelessHART, Bluetooth, DASH7, INSTEON, and Z-Wave.

Start by understanding your overall performance requirements

Each application is unique in terms of its power requirements. The most common performance variables include:

- Energy consumed in 'stand-by' mode (the background current)
- Energy consumed during 'active' mode (including the size, duration, and frequency of pulses)
- Storage time (a battery will self-discharge during storage, diminishing its capacity)
- Thermal environments (including storage and in-field operation)
- Equipment cut-off voltage (as the battery's capacity is exhausted, the voltage can drop too low for the device to operate; an effect that is magnified in extreme temperatures)
- Battery self-discharge rate (which can be higher than the average daily current consumed)
- Battery replaceability or rechargeability
- Total cost of ownership (factoring in the battery's initial purchase price along with all future maintenance and battery replacement costs, where applicable)

Specifying a power supply invariably involves certain trade-offs, so you need to prioritize your list of desired attributes to ensure that the wireless device performs as required.

Don't be fooled by low initial expense

Consumer primary (non-rechargeable) batteries are mainly used to power flashlights, remote controls, and toys, while consumer grade rechargeable Li-ion batteries typically power smart phones, tablets and notebook computers, and similar devices. However, the low initial cost of a relatively short-lived consumer battery can be very misleading when applied to long-term industrial applications, including the risk of reduced productivity and/or the loss of sensitive data due to battery failure.

With long-term deployments, you need to determine the total cost of ownership, factoring in all costs associated with future battery maintenance or replacement, which can skyrocket if the wireless device is being deployed in a remote, difficult-to-access location. For example, accessing a wireless device that measures structural stress on a bridge abutment can involve the erection of scaffolding and safety harnesses. Other remote locations are simply inaccessible, such as seismic monitoring sensors deployed on the ocean floor.

Comparing Primary (non-rechargeable) 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	Alkaline	LiFeS ₂ Lithium Iron Disulfate	LiMnO ₂ 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 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

Alkaline cells are readily available and extremely inexpensive, but have major drawbacks, including low voltage (1.5 V), a limited temperature range (-0°C to +60°C), a high annual self-discharge rate that reduces life expectancy to 2-3 years, and crimped seals that may leak.

Consumer primary lithium cells are also inexpensive, delivering 1.5 V or 3 V, along with high pulses to power a camera flash. These batteries have several limitations, including a narrow temperature range (-20°C to +60°C), a high annual self-discharge rate, and crimped seals that may leak.

Lithium thionyl chloride (LiSOCL₂) cells are the preferred choice for wireless applications that require long-term power, especially in extreme environments. Bobbin-type LiSOCL₂ batteries offer the highest capacity and highest energy density of any lithium chemistry, along with an extremely low annual self-discharge rate (less than 1% per year). This chemistry also features the widest temperature range (-80°C to +125°C), and a glass-to-metal hermetic seal that is less prone to leakage.



An assortment of lithium thionyl chloride (LiSOCI₂) cells.

How a bobbin-type LiSOCI₂ battery is manufactured, and the raw materials used, can greatly influence its operating life. An inferior quality LiSOCI₂ battery may have an annual self-discharge rate of up to 3% per year, losing 30% of its available capacity every 10 years. Conversely, a superior grade bobbin-type LiSOCI₂ battery can feature an annual self-discharge rate as low as 0.7% per year, thus permitting certain wireless devices to operate for up to 40 years on a single battery. Selecting a superior grade battery could lower your total cost of ownership substantially by eliminating future expenses associated with battery replacement, which far exceeds the cost of the battery itself.

To ensure long-term battery performance in extreme environments, state-of-the-art manufacturing techniques must be used to produce top quality batteries. This process begins by choosing the highest grade of raw materials, then employing total quality management tools such as six sigma methodologies and statistical process controls (SPC) during all phases of manufacturing to ensure greater lot-to-consistency. Not all batteries are manufactured to such high standards, so due diligence is required to verify that the batteries are UL-approved and offer a higher safety margin by being able to withstand extreme temperature, humidity, shock, vibration, and puncture.

With battery replacement costs estimated at many times the initial cost of the original battery, it is important to know the source of the raw materials, the manufacturing processes employed, and to verify the accuracy of all claims involving battery life expectancy based on typical annual self-discharge rate.

Long-term lab test results and data from the field have been assembled by Tadiran to create a huge database that accurately predicts battery performance for all types of remote wireless applications.

Industrial applications require more robust batteries

Consumer batteries do not perform well in extreme environments. A prime example is the cold chain, where wireless devices continually monitor the transport of frozen foods, pharmaceuticals, tissue samples, and transplant organs at controlled temperatures as low as -80°C. Bobbin-type LiSOCI₂ batteries are uniquely suited for the cold chain due to their high specific energy (energy per unit weight), high energy density (energy per unit volume), and their non-aqueous electrolyte, as the absence of water allows specially modified cells to operate in extreme temperatures ranging from -80°C to +125°C.

Wireless devices increasingly require high pulses of energy to support two-way wireless communications and other functionality. To offset the added power drain, these devices must be designed to conserve energy by operating mainly in a "stand-by" state and drawing nominal amounts of current, periodically querying the data, and only becoming "active" for brief intervals to manage data retrieval and wireless communications.

Standard bobbin-type LiSOCI₂ batteries are ideal for delivering low rate current. But when a high pulse is required, these batteries can experience a temporary drop in voltage, or transient minimum voltage (TMV). Consumer electronic devices use supercapacitors to minimize TMV. However, supercapacitors are ill suited for industrial applications due to their inherent drawbacks, including a high self-discharge rate - up to 60% per year - and a limited temperature range that prohibits their use in harsh environments. A supercapacitor made up of two 2.5V capacitors in series also requires a balancing circuit, which draws additional current.

For long-life industrial applications, the predominant solution is to combine a standard bobbin-type LiSOCI₂ cell in combination with a patented Hybrid Layer Capacitor (HLC). The battery and HLC work in parallel, with the standard cell supplying the background current while the single-unit

HLC acts like a rechargeable battery to store and deliver high pulses. These hybrid batteries feature a unique end-of-life performance curve with a measurable voltage plateau that can be interpreted to issue low battery status alerts.

Certain wireless applications are ideal for energy harvesting

A growing number of wireless applications are proving to be well suited for energy harvesting devices that use rechargeable Li-ion batteries to store the harvested energy. Consumer grade Li-ion batteries have become extremely popular due to their high efficiency and high-power output.

The most popular type of Li-ion cell, the 18650, was developed by laptop computer manufacturers as an inexpensive solution that could last approximately five years and 500 full recharge cycles. However, consumer grade rechargeable Li-ion batteries are not well suited for long-term deployment in extreme environments, as these cells experience a gradual degradation of the cathode, making them less receptive to future recharging, which reduces their potential lifespan. Consumer grade Li-ion batteries have other drawbacks, including a high self-discharge rate and a narrow operating temperature range.

To overcome these limitations, industrial grade rechargeable Li-ion batteries were developed that can operate maintenance-free for up to 20 years and 5,000 full recharge cycles. These ruggedized batteries feature a very low annual self-discharge rate and can be recharged in extreme temperatures (-40°C to +85°C). Unlike consumer batteries, these cells can deliver the high pulses needed for two-way wireless communications (up to 15A pulses from an AA-sized cell), and also feature a glass-to-metal seal to withstand harsh environments.

Table 2 comparison of consumer versus industrial Li-ion rechargeable batteries.xlsx				
		TLI-1550 (AA)	Li-Ion	
		Industrial Grade	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 Continuous Discharge Current	[A]	5	5	
Capacity	[mAh]	330	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	

For example, IPS solar-powered parking meters use industrial grade rechargeable Li-ion batteries to deliver true wireless connectivity to the IIoT. They save millions of dollars in initial installation costs by eliminating the need to hard-wire metropolitan sidewalks.



IPS solar-powered parking meters eliminate hard-wiring issues.

These wireless networked solar powered parking meters are state-of-the-art and include multiple payment system options, access to real-time data, integration to vehicle detection sensors, user guidance, and enforcement modules. All parking meters are wirelessly networked to a comprehensive web-based management system. Small photovoltaic panels gather solar energy, with industrial grade rechargeable Li-ion batteries used to store energy and to deliver the high pulses required for advanced, two-way wireless communications, thus ensuring 24/7/365 system reliability for up to 20 years.

Technological advancements are creating dynamic opportunities for bobbin-type LiSOC12 batteries and industrial grade Li-ion rechargeable batteries to deliver intelligent, long-term power sources for all sorts of remote wireless devices. Demand for industrial grade batteries will accelerate as billions of wireless devices become integrated into the burgeoning IIoT.

About the Author

Sol Jacobs is the Vice President and General Manager of [Tadiran Batteries Ltd.](#)