Consumer versus industrial batteries for wireless applications

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Tadiran Batteries

Identifying the ideal power source for self-powered wireless devices

The world is truly wireless, and battery-powered devices are ubiquitous, powering everything from consumer electronics to all sorts of industrial applications connected to the Industrial Internet of Things (IIoT).

Consumer electronics are typically powered by alkaline batteries, consumer grade primary lithium (non-rechargeable) cells, or consumer grade rechargeable Lithium-ion (Li-ion) batteries. There is also a growing number of industrial applications that require long-life power to operate maintenance-free for decades while delivering 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.

Dramatic growth in remote wireless communications has been aided by new methods aimed at extending battery life, including low power chip sets, and low power wireless communications protocols such as ZigBee, WirelessHART, Bluetooth, DASH7, INSTEON, and Z-Wave.

Specify batteries based on your overall performance requirements

Each application is unique in terms of average daily power consumption based on key performance variables, which 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 a battery's capacity is exhausted, the voltage can drop too low for the device to operate, which can be magnified by prolonged exposure to extreme temperatures)
- Battery self-discharge rate (which can be higher than the amount of average daily energy consumed by actual use)

- Battery replaceability or rechargeability
- Total cost of ownership (factoring in the initial purchase price of the battery along with all expenses to replace batteries over the expected lifetime of the device, where applicable)

Specifying a power supply involves certain trade-offs, so you need to prioritize your list of desired attributes to ensure that the power supply best matches the requirements of the wireless device, especially in remote applications.

Don’t be misled by low initial expense

Consumer primary (non-rechargeable) batteries are mainly used to power flashlights, remote controls, and toys. In addition, consumer grade rechargeable Li-ion batteries typically power smart phones, tablets and notebook computers, and similar devices.

Be aware that the low initial cost of a relatively short-lived consumer battery can be highly 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 mindful of 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 major costs to erect scaffolding and where maintenance crews need to wear safety harnesses. Certain remote locations are completely inaccessible for battery replacement, such as seismic monitoring sensors deployed on the ocean floor.

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.

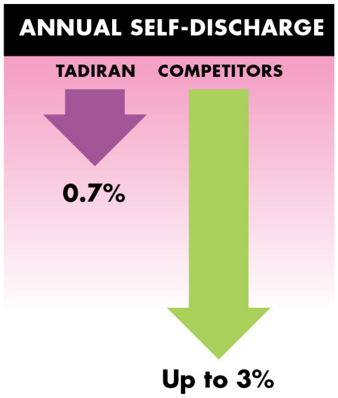
Consumer primary lithium cells are inexpensive, delivering 1.5 V or 3 V, along with high pulses to power a camera flash. These batteries have limitations that include a narrow temperature range (-20°C to 60°C), a high annual self-discharge rate, and crimped seals that may leak.

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

Lithium thionyl chloride ($LiSOCl_2$) cells are overwhelmingly preferred for remote wireless applications that require long-term power in extreme environments with daily energy usage measured in microamps. Bobbin-type $LiSOCl_2$ batteries feature 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 resists battery leakage.

How a bobbin-type $LiSOCl_2$ battery is manufactured, and the raw materials used, can greatly influence its operating life. For example, an inferior quality $LiSOCL_2$ battery may have an annual self-discharge rate of up to 3% per year, losing 30% of its available capacity every 10 years, thus making 40-year battery life impossible. Conversely, a superior quality bobbin-type $LiSOCl_2$ battery can feature an annual self-discharge rate as low as 0.7% per year, thus permitting certain



Don't be fooled by lower quality $LiSOCl_2$ batteries that can have a self-discharge rate of up to 3% per year.

wireless devices to operate for up to 40 years on a single battery. Specifying a superior grade $LiSOCl_2$ battery could substantially lower your total cost of ownership by eliminating the need for future battery replacements, as the labor savings alone will far exceed the cost of the batteries themselves.

To ensure long-term battery performance even in extreme environments, state-of-the-art manufacturing techniques are required to produce superior quality batteries. This starts 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, able to withstand extreme temperatures, humidity, shock, vibration, and puncture.

With the labor costs to replace battery replacement being many times more expensive than the batteries themselves, it is important to do your due diligence and inquire about the source of the raw materials, the manufacturing processes employed, and to verify the accuracy of all claims involving battery life expectancy based on expected daily energy usage along with energy lost to annual battery self-discharge.

Theoretical testing often fails to accurately predict real-life battery self-discharge rates, especially for cells that will be exposed to extreme temperatures for prolonged periods. To address this issue, Tadiran has created a vast database comprised of long-term lab test results and in-field data from batteries working under a variety of environmental condition. This reliable data enables highly accurate predictive models to simulate how bobbin-type $LiSOCl_2$ batteries will perform in virtually all 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 $LiSOCl_2$ 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 below -80°C.

Awarepoint medical asset tracking RFID tags contain bobbin-type $LiSOCl_2$ batteries that can withstand high temp. autoclave sterilization without having to remove the battery, saving labor and providing a continuous data stream.

Bobbin-type $LiSOCl_2$ batteries can also be modified to handle extremely high temperatures up to 125°C. For example, these cells are used in active RFID tags that monitor the location and status of medical equipment, allowing these portable devices to undergo autoclave sterilization without having to remove the battery.

Wireless devices also increasingly require periodic high pulses to power two-way wireless communications, remote shut-off capabilities, and other advanced functionality. To offset the added power consumption, these devices must be designed to conserve energy by operating mainly in a “stand-by” state that draws nominal amounts of current, only becoming “active” for brief intervals to sample and transmit data.

Standard bobbin-type $LiSOCl_2$ 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 2.5 V capacitors in series also requires a balancing circuit, which draws added current.

PulsesPlus™ batteries can last up to 40 years while delivering the periodic high pulses required for two-way wireless communications.

For long-life industrial applications, the predominant solution is to combine a standard bobbin-type $LiSOCl_2$ cell with a patented Hybrid Layer Capacitor (HLC). The battery and HLC work in parallel, with the standard battery supplying background current while the single-unit HLC acts like a rechargeable battery to store and deliver periodic high pulses. As an added bonus, this hybrid bobbin-type LiSOCl2 battery features a unique end-of-life voltage plateau that can be interpreted to provide low battery status alerts.

Certain wireless applications are ideal for energy harvesting

A growing number of wireless applications consume milliamps of daily energy (enough to prematurely exhaust a primary lithium battery), making them better suited for an energy harvesting device in combination with a rechargeable Lithium-ion (Li-ion) battery that stores and delivers periodic high pulses.

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 only designed to last approximately 5 years and 500 full recharge cycles.

Industrial grade TLI Series rechargeable Li-ion batteries operate up to 20 years and 5,000 recharges, delivering high pulses and an extended temperature range.

Consumer grade rechargeable Li-ion batteries are ill suited for long-term deployments in extreme environments due to a gradual degradation of the cathode, making them less receptive to future recharging, which reduces their potential lifespan. Consumer grade Li-ion batteries also have other drawbacks, including a high self-discharge rate and a relatively narrow operating temperature range.

To overcome these limitations, industrial grade rechargeable Li-ion batteries are now available that can operate maintenance-free for up to 20 years and 5,000 full recharge cycles.

Industrial grade Li-ion 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 and help prevent battery leakage.

A Comparison of Rechargeable Li-ion Cells		**TLI-1550 (AA)** Industrial Grade	**18650 Li-ion** Consumer Grade
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]	[Wh/liter]	1950	1045
Power [-20°C]	[Wh/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 @ 4.1V	~300
Cycle Life	[75% DOD]	~35,000 @ 3.9V	~400
Cycle Life	[50% DOD]	~50,000 @ 3.67V	~650
Operating Life	[Years]	>20	<5

TADIRAN BATTERIES

IPS solar-powered parking meters use industrial grade LI-ion batteries to store harvested energy and to deliver high pulses for two-way wireless communications. These industrial batteries can reduce the cost of ownership by eliminating the need for battery replacement every 5 years.

For example, IPS solar-powered parking meters use industrial grade rechargeable Li-ion batteries to deliver true wireless connectivity to the IIoT, thus reducing installation costs tremendously by eliminating the need to hard-wire metropolitan sidewalks. These batteries further reduce the cost of ownership by eliminating the need to replace consumer grade batteries every 5 years, eliminating the need for three (3) system-wide battery change-outs over an expected product lifespan of 20 years.

These wireless networked solar powered parking meters offer state-of-the-art functionality, including multiple payment system options; access to real-time data; integration to vehicle detection sensors; user guidance and enforcement modules. All IPS parking meters can also be wireless-networked to a comprehensive web-based management system.

Small photovoltaic (PV) panels gather solar energy, with industrial grade rechargeable Li-ion batteries storing the harvested energy to deliver periodic high pulses that power two-way wireless communications, ensuring 24/7/365 system reliability for up to 20 years.

Conclusion

Rapid expansion of the IIoT has created dynamic growth opportunities for bobbin-type $LiSOCl_2$ batteries and for industrial grade Li-ion rechargeable batteries. Application-specific requirements dictate the ideal power supply.

Generally speaking, consumer grade batteries are best suited for moderate temperatures and where the batteries are easily replaceable. Conversely, industrial grade batteries are better suited for long-term deployment in remote hard-to-reach locations and challenging operating environments.

When specifying an industrial grade battery, remember that thorough due diligence is required to differentiate between superior and inferior grade batteries, as choosing the cell with the lowest self-discharge rate can often reduce your total cost of ownership.

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