Lithium Batteries for Medical Applications

Lithium upgrades lead revolution

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Miniaturized, feature-rich devices are driving a growing need for reliable and cost-effective power management solutions using lithium battery technology.

Primary lithium batteries are commonly utilized in single-use devices as well as in applications that require exceptionally long battery life without worrying about battery status (i.e. automatic external defibrillators). Lithium chemistry is also preferred for devices that need to be small, lightweight, and ergonomically designed. Certain lithium chemistries are also well adapted to the high temperatures associated with autoclave sterilization cycles as well as the extremely low temperatures required by the medical cold chain.

Why lithium?

First utilized in pacemakers during the 1960s, primary lithium batteries now power all types of medical devices, including automatic external defibrillators, surgical saws, drills, robotic inspection systems, RFID asset tracking tags, infusion pumps, bone growth stimulators, glucose monitors, blood oxygen meters, cauterizers, and other medical devices.

Wireless blood oxygen meter powered by a lithium thionyl chloride (LTC) battery

Lithium batteries are the preferred choice for many of today's advanced medical devices because they offer the highest specific energy (energy per unit weight) and energy density (energy per unit volume) of any battery type. Lithium cells, all of which use a nonaqueous electrolyte, also have nominal open circuit voltages of between 1.7 and 3.9 V. However, the use of non-aqueous electrolytes results in relatively high internal impedance.

Lithium chemistries also offer an extended temperature range, made possible by the absence of water and the chemical and physical stability of the materials. Lithium thionyl chloride cells provide the widest temperature range of all (–55 °C to +125 °C) and can be specially modified to withstand temperatures as low as -80 °C to support the medical cold chain, delivering continuous power even at extremely cold temperatures to permit around-the-clock monitoring of pharmaceuticals, transplant organs and tissue samples that are frozen or packed in dry ice.

Not created equal

Within the category of lithium primary batteries, numerous competing chemistries are available, each offering certain advantages and disadvantages.

LITHIUM BATTERY CHARACTERISTICS

System	$Li/SOCl_2$ (LTC) Bobbin	$Li/SOCl_2$ (LTC) with HLC (*PulsesPlus*™)	Li metal oxide (TLM series)	Li/SO_2	Li/MnO_2
Energy density	1420 Wh/l	1420 Wh/l	680 Wh/l	410 Wh/l	650 Wh/l
Power	Low	High	High	High	Moderate
Voltage	3.6 V	3.6 V – 3.9 V	4.1 V	3.0 V	3.0 V
Pulse amplitude	Small	High	Very high	High	Moderate
Passivation	High	None	None	Fair	Moderate
Self discharge	Low	Low	Low	Moderate	Moderate
Temperature range	–50 °C ... +125 °C	–40 °C ... +85 °C	–40 °C ... +85 °C	–55 °C ... +60 °C	0 °C ... +60 °C
High temperature performance	Fair	Excellent	Excellent	Moderate	Fair
Low temperature performance	Fair	Excellent	Excellent	Excellent	Poor
Operating life up to	20+ years	20+ years	20 years	10 years	5 years
Typical medical applications	Bone healers, oxygen meters, glucose monitors, sterilizable devices, cold chain devices	Defibrillators (AED)	Defibrillators (AED), cauterizers, Disposable power tools, resuscitation	Defibrillators (AED)	Glucose monitors

Li/MnO_2 (lithium manganese dioxide) batteries, originally designed for consumer items such as toys and cameras, are now commonly utilized in glucose monitors. Li/MnO_2 cells feature relatively low cost and high current-pulse capabilities, but suffer from high self-discharge and low energy density, which makes for bulky devices. Likewise, Li/MnO_2 cells have a limited temperature range of –10 ºC to 60 ºC.

Li/SO_2 (lithium sulfur dioxide) batteries, found in certain types of external defibrillators, are capable of delivering high current pulses at low temperatures, but tend to be larger and heavier than other lithium chemistries. Li/SO_2 cells also suffer from higher self-discharge, which limits their potential service life.

$Li/SOCl_2$ (lithium thionyl chloride) cells are ideally suited for low-current applications where a steady low current (micro amps to low milli amps) is applied for an extended period of time. They feature high energy density, high capacity, and low self-discharge rate, and feature an operating life as long as 25+ years. Certain bobbin-type lithium thionyl chloride cells also can operate in extreme temperatures ranging from –80 °C to 125 °C.

A hybrid version of the lithium thionyl chloride cell, the PulsesPlus battery, combines the advantages of lithium thionyl chloride chemistry with a hybrid layer capacitor to deliver high current pulses. This hybrid cell is ideal for use in automatic external defibrillators (AEDs) and similar applications that generally operate with a low background current (sleep mode) but require periodic high current pulses (in the multi-amp range). PulsesPlus cells also offer the potential for an end-of-life indication when the battery has depleted 90 % to 95 % of its original capacity. This end-of-life feature can be useful for critical applications where the “readiness status” of the device needs to be continually monitored.

In addition, Tadiran developed the TLM Series lithium metal oxide batteries designed to deliver high cell voltage, high energy density, instant activation, and exceptionally long operational life even in extreme temperatures. TLM Series batteries deliver an open circuit voltage of 4.0 Volts with high current pulses of up to 15 A and 5 A continuous current at 3.2 V. Often used in disposable devices such as hand-held surgical drills, power tools and cauterizers, TLM Series batteries provide ergonomic solutions by allowing hand-held and strapped-on devices to be as small and as lightweight as possible.

Real-life examples

The following case studies illustrate how lithium chemistry can be ideal for certain types of applications:

• **Bone growth stimulator requiring low continuous current.** 5 % to 10 % of the nearly 6 million bone fractures that occur annually in the United States show delayed or impaired healing. Bone growth stimulators use high frequency sonic pressure waves to stimulate bone growth and healing. These devices are usually strapped on over the fracture site or fitted into a cast and emit low-intensity, pulsed ultrasound.

This application typically utilizes a battery pack made up of AA-size $Li/SOCl_2$ cells to deliver long-term continuous power. The battery's high energy density reduces size and weight, which is a critical requirement since the device is worn by the patient.

• **Automatic external defibrillators (AEDs) requiring low background current, periodic low current- pulses, and very high current pulses when in use.** AEDs are portable devices used to restore normal heart rhythm to patients in cardiac arrest, a sudden and potentially fatal condition. The AED automatically analyzes the patient's heart rhythm and advises the rescuer as to whether or not a shock is needed to restore a normal heart beat.

AEDs are often located in public places, such as schools, restaurants, airports, and office buildings (public access AEDs) where hardwired AC power may not be available to ensure continual battery recharging. These remote locations also may be exposed to extreme temperature that could compromise battery performance. As a result, these devices often rely on primary lithium batteries for long-term reliability, enabling them to deliver high current-pulses even after extended periods of inactivity.

For example, a leading manufacturer of automatic external defibrillators utilizes PulsesPlus hybrid $Li/SOCl_2$ batteries to deliver the high-current pulses required to stimulate the human heart. The PulsesPlus battery was also chosen for its extremely long shelf life (self-discharge of less than 1 % per year) and its ability to withstand extreme temperatures, which translates into greater system reliability, since battery failure can result in a patient fatality.

• **Hand-held surgical drill requiring no background current with very high current-pulses.** The manufacturer of a single-use hand-held bone saw previously designed the device using a strapped-on battery pack consisting of 8 Li/MnO_2 cells, which was then wire harnessed to the bone saw and discarded after one use.

To deliver a more ergonomic solution, the device was redesigned utilizing 3 TLM high-energy lithium batteries located within the saw's handle, thus eliminating the need for the wire harness and the external battery pack, permitting greater mobility for the surgeon. TLM high-energy batteries were chosen for this high rate application because they can deliver high current-pulses of up to 15 Amps.


Bone drill powered by TLM batteries

Similarly, BioAccess, a Baltimore based manufacturer of a single-use, handheld bone drill, created an alternative version of its device using TLM-1550HP batteries instead of alkaline cells. The lithium metal oxide cells delivered an open circuit voltage of 4.1 V along with the ability to handle high current-pulses of 15 A with a 5 A continuous load. An equivalent alkaline battery pack would require 3 times the weight and 2 times the volume (requiring 15 AA-size alkaline batteries versus 6 AA-size TLM-1550HP batteries). Use of the lithium metal oxide cell also enabled faster drilling speeds, extended drilling time, and increased torque for more efficient drilling cycles.

• **Sterilizable RFIDs.** Lithium batteries have dynamic potential for use in portable and hand-held medical devices, as well as in more exotic applications such as spider-like robotic capsules that are swallowed and crawl through the gastrointestinal tract to perform diagnostic and surgical procedures. In addition, a new generation of medical devices is emerging that combine telematics, GPS, and RFID tracking capabilities. These devices can be coupled with heart rate, temperature, and other advanced sensors that enable healthcare providers to monitor a patient's vital signs and precise whereabouts in hospitals, nursing homes, assisted living quarters, or remote locations via satellite.

Sterilisable RFID powered by a lithium thionyl chloride battery

For example, Awarepoint, San Diego, recently introduced an RFID asset tracking tag for medical applications that uses lithium thionyl chloride batteries capable of withstanding the high temperatures associated with autoclave and chemical sterilization cycles. Previously, medical asset tracking devices had to be removed from medical equipment prior to sterilization in order to protect the battery from heat-related damage. Medical devices and equipment equipped with Awarepoint asset tags can now remain online during sterilization cycles, thus enabling continuous realtime tracking and reporting.

Looking to the future

Examples such as this demonstrate how recent advancements in lithium battery technology are playing a critical role in an industry undergoing revolutionary change. As medical technology continues to evolve, exciting possibilities and challenges will emerge involving long-term power management solutions that enhance the performance and reliability of next generation medical devices.

About Tadiran:

Tadiran is a world leader in design, development, manufacture and marketing of Lithium batteries for industrial applications.

Product series LTC batteries

Tadiran lithium thionyl chloride (LTC-)Batteries (series SL-) are suitable where a 3.6 Volt high energy primary battery is required for up to 25 years stand-alone operation.

Product series PulsesPlus™ batteries

The PulsesPlus battery technology (series TLP-) is best where power is required such as long range GPRS and GSM applications. It offers a combination of a high energy lithium primary battery and a hybrid layer capacitor. This HLC adds the power capability for pulse currents.

Product series TLM batteries

The Tadiran Lithium Metal Oxide (TLM-)Batteries High Power Battery Technology (series TLM-) offers a compact power source with high current capability, ideally suited for emergency back-up of automotive applications.

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