SENSOR SOLUTIONS

Lithium Battery Power Sources for Remote or Portable Sensor Applications

Lou Adams, Tadiran Electronic Industries Inc.

THE PROBLEM

Technologies are fast being developed to provide power to remote or portable sensors under the most demanding conditions. These applications require small, long-lived, and environmentally rugged (operating in a temperature range of 55°C to 150°C) power sources that provide high voltage per cell, come in various sizes and shapes, and deliver good cost/performance ratio.

Primary batteries can provide the power needed in these applications, but this only narrows the scope of the problem. You must determine which of the battery technologies on the market has the characteristics required by the application. There are a number of technologies to choose from, and they include the following: traditional zinc/carbon/ammonium chloride (the LeClanche cell), zinc/ carbon/zinc chloride, alkaline/MnO₂ (the leading type for consumer use), and a variety of lithium-based chemistries.

THE SOLUTION

In the past, there have been safety concerns surrounding the use of lithium batteries because of the highly reactive constituents involved in the technology. The controversy has subsided since battery manufacturers have begun using safer chemistries and cell constructions (e.g., Tadiran's hermetically sealed, welded case bobbin cell).

Lithium is a good material for battery anodes because of its high intrinsic negative potential. Lithium is also the lightest nongaseous metal. Batteries

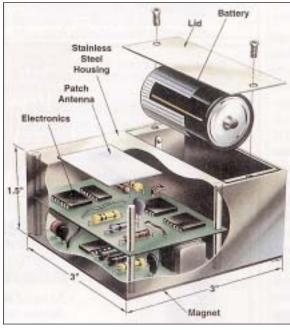


Figure 1. Sandia National Laboratories uses D cell Lithium/thionyl chloride batteries to power an array of motion and environmental sensors and associated electronics used to monitor nuclear materials extracted during the dismantling of weapons system.

based on lithium chemistries, therefore, have the highest specific energy (energy per unit weight) and energy density (energy per unit volume) of all chemistry types.

Other primary cell technologies can't have cell voltage above 2 V because they use aqueous (i.e., watercontaining) electrolyzes and water dissociates into oxygen and hydrogen at potential above 2 V. Because lithium reacts strongly with water, only non-aqueous electrolyzes can be used, and some lithium cells have a nominal open-circuit voltage of 3.6 V. The nonaqueous electrolyte used in the battery does, however, result in most lithium cell types having higher internal impedances then cells using aqueous electrolyzes.

Certain types of lithium batteries also have extended operating temperature ranges, enabled by the absence of water and the nature of the materials used. Specifically, lithium/thionyl chloride can operate at a temperatures as low as -55°C and as high as 85°C. Tadiran has a series of high-temperature cells that can operate at temperature as high as 150°C.

Under the broad category of primary lithium battery types, there are several chemical systems in mainstream use, each with its own set of performance and safety characteristics. These are lithium/poly (carbon monofluoride), or Li(CF)_x; lithium/manganese dioxide, or Li/MnO₂; lithium/thionyl chloride, or Li/SOC1₂; lithium/sulfur dioxide, or Li/SO₂; and lithium/iodine, or Li/I2. As can be seen from Table 1, lithium battery chemistries differ in several important characteristics. Carefully matching these charac-

teristics to the conditions of a particular application is key to safe and reliable operation of the system.

SELECTING A BATTERY TECHNOLOGY

The critical factors in selecting a battery technology for an application are minimum and maximum voltage; initial, average, and maximum discharge current; continuous or intermittent operation (if intermittent, the size and duration of current pulses); shelf and service life; operating temperature range; and optimum physical size and shape.

Originally developed for military applications, where the lithium/sulfur dioxide and lithium/thionyl chloride types have been used frequently, lithium batteries are becoming popular for industrial applications as well. The military prefers lithium batteries

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Table 1: Lithium Battery Chemistries							
Chemistry	Cathode Material	Specific Energy	Voltage	Operating Temperature Range	Maximum Service Life	Construction	Application Class
Li/SOCI ₂	Thionyl chloride	700 Wh/kg	3.6	-55°C to 150°C	15-20 years	Bobbin hermetic weld	Industrial/commercial
Li/SO ₂	Sulfur dioxide	260 Wh/kg	2.8	-55°C to 70°C	5 years	Spiral, hermetic welded, vented	Military/ aerospace
Li/MnO ₂	Manganese dioxide	330 Wh/kg	3.1	-20° to 60°C	5 years	Spiral, crimped elastomer seal	Consumer
Li/(CF) _X	Poly (carbon monofluoride)	310 Wh/kg	2.8	-20° to 60°C	5 years	Spiral, crimped elastomer seal	Consumer
Li/l ₂	lodine	230 Wh/kg	2.7	0° to 70°C	10 years	Welded	Implanted medical devices

because of their long shelf life (i.e., low self-discharge rate) — up to 15 years, depending on storage conditions.

At Sandia National laboratories, Albuquerque, New Mexico, a system of remote motion and environmental sensors was developed to safeguard the nuclear materials that have accumulated during the U.S.'s nuclear weapons dismantling activities. The battery for this application (see Figure 1) was required to supply a current in the range of several µA when the system was "asleep" and 100 mA at low-duty cycle during periodic system reporting. A cell with a working voltage of > 3 V was required to bias the sensors and power the associated microprocessor. The application required a service life of 10 years under controlled temperature conditions, but long shelf life, with potential high-temperature excursion, was also an issue.

Other concerns had to do with the behavior of the battery if it short-circuited. A battery type that exploded when shorted could not be tolerated. The choice was narrowed to a D cell



inorganic Lithium/thionyl chloride battery. lithium/thionyl chloride cells heat up when shorted, but because of their high internal impedance—a by product of their bobbin construction and electrolyte chemistry—will not deliver sufficient current fast enough to create the heat required to cause a safety hazard.

Dallas Instrument, Inc., of Dallas, Texas, uses a lithium/thionyl chloride wafer cell in its ShockRanger R-1 single-axis shock monitor. The device consists of a piezoelectric "bimorph bender" that senses the maximum shock experienced by delicate equipment or other goods during shipping. The information is stored until it is retrieved for display by one of a bank of LEDs. A typical version of the device (see Photo 1) records maximum shock in four ranges — 10 g, 20 g, 30 g, 40 g — in the sample unit. The user interrogates the unit by pressing a recessed button, and the LED indicates the maximum shock recorded.

Because the ShockRanger is intended to serve several purposes, the choice of battery technology was important to the designers. Quiescent current drain is up to $100~\mu A$ and increases to 2~mA when a LED is lighted. The required service life is 1 year, over an industrial temperature range of $0^{\circ}C$ to $85^{\circ}C$. A small high capacity power source was required to make this device practical.

Lithium/thionyl chloride, in wafer cell form factor, was chosen because it complied with electrical, environmental,



Photo 1. Dallas Instruments' R-1 ShockRanger, containing a piezoelectric sensor and powered by a lithium/thionyl chloride wafer cell, records maximum shock experienced by shipment of delicate goods.

and cost requirements. In addition, these cells have excellent survival characteristics for typical electronic assembly operation. They can withstand wave soldering at a temperatures up to 280° C for as long as 10 s, even while the leads are shorted by molten solder. Loss of capacity under these conditions is > 0.3%.

CONCLUSION

Lithium battery technology has progressed to the extent that it is effective in a broad range of applications, particularly in long-term remote sensing. In addition to the applications cited here, lithium/thionyl chloride batteries, which come in wide variety of shapes and sizes, are used extensively in seismic sensors, downhole oil-rig instrumentation, automotive applications, ocean buoys, balloon-borne radiosondes, and human and wildlife biotelemetry. Lithium/thionyl chloride offers the highest specific energy, energy density, and shelf life of any primary battery system, with excellent safety, manufacturing-process compatibility, and reliability.