Remote Possibilities

Using advanced battery technologies to unlock the dynamic growth potential of remote wireless sensors used in "smart infrastructure" and related applications.

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Contrary to all the recent economic news, the February 17, 2009 edition of The Wall Street Journal contained an upbeat article by Michael Totty entitled "Smart Roads. Smart Bridges. Smart Grids."

Totty describes how the new economic stimulus legislation will soon give federal, state and local governments the authority to spend tens of billions of dollars on infrastructure projects, which prompts him to raise a big question: "Will we simply spend the money the way we've been doing for decades on more concrete or steel? Or will we use it to make our roads, bridges and other assets more intelligent?"

These "smart infrastructure" programs could generate significant demand for remote wireless sensors interfacing with advanced communications, computers and the internet to efficiently monitor and manage everything from intelligent transportation systems to vehicle infrastructure integration (VII), vibration and stress sensors for bridges and tunnels, smart grids and smart metering, as well as smart water technologies. The long-term growth potential for remote wireless sensors is further magnified by the emergence of productivity-enhancing technologies such as wireless mesh networks, system control and data acquisition (SCADA), data loggers, measurement while drilling, oceanographic measurement, emergency/safety, as well as sensors for homeland security.

Often, remote wireless sensors utilized in these applications cannot be powered by

rechargeable batteries or AC power, as the locations may be difficult or impossible to access and hardwiring to the electrical grid is too cost prohibitive. Such instances typically require self-contained systems using primary batteries to provide the power needed for reliable long-term data collection, storage and communication.

Start By Reviewing Your Options

Specifying a battery can be a complicated decision-making process due to the breadth of choices between competing chemistries such as alkaline, carbon zinc, zinc-air, and lithium, as well as by the inherent difficulty in differentiating a superior quality battery from an inferior knock-off. So getting it right demands thorough product knowledge and careful due diligence to ensure that the optimal power source is being specified.

Application-specific requirements often dictate the solution. For example, consumer alkaline cells can suffice for certain applications that require only a few months of service life in a moderate temperature range, and where battery replacement is relatively simple due to easy accessibility. While inexpensive and readily available, alkaline batteries are ill suited for applications that require extended service life under extreme temperatures.

Choosing the right battery begins with a careful evaluation of power and performance requirements, from which competing chemistries can be compared based on a prioritized checklist of desired attributes such as voltage, capacity, size, weight and/or special packaging requirements, expected service life, temperature and/or environmental issues and cost. Special requirements such as the need for high current pulses or high discharge rate should also be considered.

In rare instances, energy harvesting can be considered for extracting power from heat, vibration or the sun. Energy harvesting is generally unproven, and its potential is limited due to inherent drawbacks such as increased size, cost, and reliability concerns that often demand back-up battery systems that negate the value proposition.

Long-term Applications Call for Lithium Batteries

Lithium chemistry remains the predominant choice for wireless remote sensor applications due its intrinsic negative potential, which exceeds that of all other metals. Lithium is the lightest non-gaseous metal, offering the highest specific energy (energy per unit weight) and energy density (energy per unit volume) of all available battery chemistries, with normal OCVs of between 2.7 and 3.6 V. All lithium cells use a non-aqueous electrolyte, and the absence of water enables certain lithium batteries to operate in extreme temperatures (-55°C to 125°C).

Despite the popular misconception that all lithium batteries are essentially equal, the lithium family of primary batteries is actually quite diverse. The choices include poly carbon monoflouride (Li/CFX), manganese dioxide (Li/MNO_2), sulfer dioxide ($LiSO_2$) and lithium thionyl chloride ($Li/SOCL_2$). Each chemistry offers unique advantages and disadvantages, so trade-offs are inevitable.

For applications requiring a maximum service life of about five years, under temperature ranges of -10°C to 60°C, suitable lithium chemistries may include poly carbon monoflouride (Li/CFX) and manganese dioxide (Li/MNO_2).

When very long battery life is required, the chemistry of choice is lithium thionyl chloride, which is available in two distinct designs: spiral wound cells; and bobbin-type cells.

Bobbin-type Versus Spirally Wound Construction

Both spirally wound and bobbin-type lithium thionyl chloride use of a non-aqueous electrolyte, resulting in relatively high impedance. Spirally wound cells reduce this impedance by increasing the surface area between the anode and the cathode,

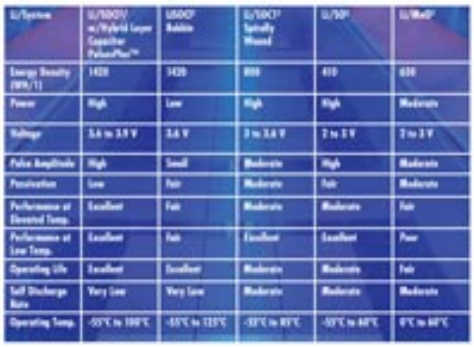
which reduces overall performance, including lower energy density (due to more inactive material within the cell) and shorter operating life (as extra surface area leads to higher self-discharge rate). As a result, spirally wound Li/$SOCL_2$ batteries deliver only 800 Wh/l energy density with a temperature range of -55ºC to 85ºC and a maximum service life of about 10 years.

By contrast, bobbin-type Li/$SOCL_2$ cells are capable of delivering far higher energy density (1420 Wh/l), higher capacity, the ability to withstand extreme temperatures (-55°C to 125°C.), and offer extremely long service life of up to 20+ years due to low annual self-discharge (less than 1% per year).

While the theoretical service life of a bobbin-type lithium thionyl chloride battery is over 20 years, actual service life varies based on the self-discharge rate, which is governed by the chemical composition of the electrolyte, the manufacturing processes used, as well as mechanical and environmental considerations.

Lithium thionyl chloride batteries have a proven track record for remote wireless application. For years, these batteries have been used to power E-ZPass electronic toll tags, one of the first widespread wireless RFID applications. Also, in 1984, Hexagram (now Aclara), introduced their first automatic meter reading (AMR) devices for the gas and electric utility market, which was powered by AA-size lithium thionyl chloride batteries. Over 3 million of these devices have been deployed worldwide, and virtually all continue to operate on their original batteries after 25 years. Long-term reliability is especially critical to the utility industry, as extended battery life translates into higher productivity and profitability by eliminating the need for system-wide battery change outs.

Modifying Lithium Battery Design for High Current Pulses



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A growing number of remote wireless sensors require high current pulses to transmit data via satellite, cell phone, or by low power radio frequency (RF) communication protocols such as ZigBee. To offset this increased energy demand, design engineers can incorporate special energy-saving design features. For example, AMR meter transmitter units (MTUs) can be designed to operate in multiple modes, including: sleep or standby, where power consumption is nil or a low background current; a measurement or interrogation mode, where the unit requires a few hundred milliamps of energy; and a transmission mode, which may

require high current pulses, before returning to an energy-saving sleep or standby status.

While standard bobbin-type lithium thionyl chloride chemistry is ideal for long-term, low current requirements, it does not have the ability to deliver high current pulses. To address this, PulsePlus technology was developed that combines a bobbin-type $Li/SOCL_2$ cell with a high rate low impedance hybrid layer capacitor (HLC) to deliver extremely high current pulses with an excellent safety margin. This hybrid design has also been utilized to deliver short duration high rate power for military/aerospace and medical applications.

PulsesPlus employs a standard $Li/SOCL_2$cell to supply long-term low-current power; while the HLC stores current pulses up to 15 A, eliminating the voltage drop that normally occurs when a pulsed load is initially drawn. One alternative solution would be to combine a primary cell with a discreet capacitor, which would be unnecessarily bulky and result in a higher rate of charge leakage, as the discreet capacitor would continuously discharge the battery, albeit at a low rate.

A second alternative involves the use of super capacitors to store electrical charges in bulk electrolytes rather than on plates. Super capacitors are small and lightweight, but they cause higher impedance, which limits the amount of instantaneous current available to deliver high current pulses. In addition, super capacitors made up of multiple 2.3 V units working in series tend to suffer from balancing problems as well as greater current leakage, which limits their service life.

By comparison, the HLC works as a single unit in the 3.6 to 3.9 V nominal range to avoid the balancing and current leakage problems associated with super capacitors. The HLC is also field-proven, and is currently used in millions of wireless sensors worldwide.

Manufacturing Processes Can Extend Battery Service Life

With the market being flooded with imitation batteries, one can no longer assume that two batteries that utilize the exact same chemistry will deliver equivalent performance, as experienced battery manufacturers continually modify their cell designs and use proprietary techniques and materials to enhance battery power and performance.

Lithium battery chemistries exhibit varying self-discharge rates, which are government by the chemical composition of the electrolyte, the manufacturing process used, as well as mechanical and environmental considerations. In addition, self-discharge can be negatively impacted if the electrolyte contains high levels of impurities. Exposure to high temperatures can severely impact both self-discharge and voltage.

High internal impedance can also have a negative impact on battery life and performance, resulting from interaction between the electrolyte, anode and cathode. Experienced battery manufacturers can effectively reduce impedance

through higher quality controls and production processes.

Conducting Thorough Due Diligence

Once the ideal power management solution has been identified, the next step is to thoroughly evaluate potential battery suppliers, as it is not easy to differentiate batteries of superior quality and reliability. Therefore, you should insist that all potential battery suppliers provide numerous customer references as well as fully documented and verified test results for battery pulse, low-temperature pulses, discharge, repeatability, and product safety. Conducting thorough due diligence will help ensure that your power management solution delivers decades of trouble-free performance.

Those equipped with a thorough understanding of lithium battery technology, and the keen eye to distinguish quality batteries from poor imitations, will be better positioned to benefit from the coming boom in smart infrastructure and related technologies. WDD

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