

# The power be with you

**While the end-users of RFID solutions are - and should be - primarily concerned with the operating performance of system hardware and software, the system manufacturer's choice of battery technology has a direct effect on how long and how reliably that performance is delivered**

**T**he use of active RF transponders has expanded into numerous fields of application. Each application has its special requirements for batteries, based on electrical, mechanical, and environmental considerations as well as cost and accessibility for replacement.

## Battery basics

The batteries employed in RFID tags are exclusively of the non-rechargeable type and are classified according to the chemical system by which they store and release electrical energy. The major classes are LeClanche (the traditional zinc/carbon/ammonium chloride "dry cell" type), alkaline (widely used in consumer applications), zinc-air (for hearing aids and similar applications) and lithium. Generally speaking, only the lithium cells are able to match the RFID tag application requirements.

## The power of Lithium

Batteries based on lithium chemistries have the highest specific energy and energy density of all types. The high

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energy density is a result of lithium's high negative potential and the fact that lithium reacts strongly with water. The latter characteristic precludes the use of any aqueous (water-containing) electrolyte, but this turns out to be a benefit: as the oxygen and hydrogen in water dissociate in the presence of a potential above 2 volts, cells using aqueous electrolytes (such as alkaline cells) are limited in voltage. Lithium cells, all of which use a non-aqueous electrolyte, have nominal open circuit voltages (OCVs) of between 2.7 and 3.6 volts.

Lithium batteries also have extended operating temperature ranges, enabled by the absence of water and the chemical and physical stability of the materials. Some lithium-based systems, including Tadiran's inorganic thionyl chloride system, can operate at temperatures as low as  $-55^{\circ}\text{C}$  and as high as  $+150^{\circ}\text{C}$ . Under the broad category of lithium battery, only lithium/manganese dioxide or  $\text{Li}/\text{MnO}_2$  and lithium/thionyl chloride or  $\text{Li}/\text{SOCl}_2$  types have characteristics that allow them to be used in RFID tag systems.

### Lithium/manganese dioxide

Lithium/manganese dioxide cells have an OCV of 3.1 V and moderately high energy density. They are best suited to applications having relatively high continuous or pulse current requirements. However, since most electronic components used in RFID tags require a minimum operating voltage of 3 V, at least two lithium/manganese dioxide cells must be connected in series to ensure a proper margin of safety for reliable system operation. This requirement adds weight and cost and potentially decreasing reliability.



**As RFID tag systems migrate to more feature-rich and current-hungry designs, it is logical to assume that cylindrical cells will find wider use**



### Lithium/thionyl chloride

Lithium/thionyl chloride cells have the highest energy density and the highest open-circuit voltage, 3.6 V. Thus, in most applications, only one cell is required to maintain sufficient operating voltage. Service life is an unmatched 15-20 years and holds for all case types - cylindrical and coin or wafer. Lithium/thionyl chloride cells are best suited for applications having very low continuous current and moderate pulse current requirements - a description that fits most RFID tag applications. Their extremely long service life and low self-discharge rate make them ideal for applications where physical access is limited, or where battery replacement is not desired or needed.

### Service life of RFID tags

For toll tags, expected service life is ten years, although systems-makers' specifications often call for a minimum of six years. The battery must be small and flat so that the tag can fit under a sun visor or on a license plate. The expected temperature range is  $-40^{\circ}\text{C}$  to  $+80^{\circ}\text{C}$  for exterior tags and  $-40^{\circ}\text{C}$  to  $113^{\circ}\text{C}$  as specified in SAE Paper J1211 for interior tags. It is also desirable to employ a UL-approved battery. Asset-tracking tags have similar environmental requirements for batteries, but some require higher pulse

currents because the transmitter needs to reach more distant readers than in the case of toll-tag applications. In wildlife-tracking, batteries must be able to survive a wide temperature range, but the primary considerations are compactness, weight and service life.

## Battery life

In early toll tag versions, a non-replaceable button cell was sufficient to supply current for the required minimum of six years. However, as toll tag designs have progressed, new features require more current. In fact, last generation tags are powered by cylindrical, AA-size ("penlight") cells. While the two lithium battery chemistries described above differ in important electrical and lifetime characteristics (see Table), the type of construction used in cylindrical cells separates the two types even more.

## Battery shapes

Lithium/manganese dioxide cylindrical cells are manufactured with a spiral-shaped cathode ("jelly roll" construction) and crimped, non hermetic elastomer seals.

Although generally safe, under extreme conditions the elastomer seals can fail before the case fails, thus allowing the cell constituents to escape. Moreover, the electrolyte can, over time, migrate through the elastomer seals, shortening battery life. Storage or operation at higher temperatures accelerates this process.

## Facing thermal stress

Lithium/thionyl chloride cells are manufactured in welded, hermetically-sealed cases using a "bobbin" construction, in which the electrodes are a central rod and a surrounding "can". The electrodes are well-separated and cannot come into contact with each other unless the cell is nearly completely crushed. Another significant difference between lithium/manganese dioxide and lithium/thionyl chloride is that the former has a limited operating and storage temperature range. A leading maker of wildlife-tracking systems has reported that lithium/manganese dioxide cells, when exposed to the temperatures often encountered during winters in the northern U.S., failed to deliver specified voltage. By switching to lithium/thionyl chloride, the problem was not encountered again. At the other end of the temperature scale, tags used to track pallets or work pieces through production processes may be subjected to temperatures in excess of 100°C. Only lithium/thionyl chloride cells can survive such elevated temperatures and continue to perform reliably.

### Lithium battery types for RFID tag applications

| <i>Characteristic</i>   | <i>Li/MnO<sub>2</sub></i> | <i>Li/SOCl<sub>2</sub></i>           |
|---|---------------------------|--------------------------------------|
| <i>Nominal OCV</i>  | <i>3.1 V</i>              | <i>3.6 V</i>                         |
| <i>Internal construction</i>                                      | <i>Spiral</i>             | <i>Bobbin</i>                        |
| <i>Hermeticity</i>  | <i>Nonhermetic</i>        | <i>Hermetic</i>                      |
| <i>Hermeticity after temp. cycling</i>                            | <i>Potential leakage</i>  | <i>Excellent</i>                     |
| <i>Flammability of electrolyte</i>                                | <i>Flammable</i>          | <i>Nonflammable</i>                  |
| <i>Energy density</i>   | <i>637 Wh/L</i>           | <i>1080 Wh/L</i>                     |
| <i>Specific energy</i>  | <i>319 Wh/Kg</i>          | <i>430 Wh/Kg</i>                     |
| <i>Operating temperature range</i>                                | <i>-20°C to + 60°C</i>    | <i>-55°C to + 85°C<sup>(1)</sup></i> |
| <i>Shelf life under manufacturer-specified storage conditions</i> | <i>10 years</i>           | <i>10 years</i>                      |
| <i>More than one source</i>                                       | <i>Yes</i>                | <i>Yes</i>                           |

<sup>(1)</sup> Standard - High temperature version to +125°C