Lithium Carbon Monofluoride Coin Cells in Real-Time Clock and Memory Backup Applications

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Introduction

Designers striving to comply with green motherboard and PC standards have sometimes had to make compromises in their product in order to meet a seemingly unending list of regulations.

For example, if a motherboard is going to have European distribution, the Blue Angel standard outlines elemental content and reclamation policies for everything from the computers case to the battery that backs up the real-time clock [RTC] and SRAM functions.

In the case of the memory back-up battery, the Blue Angel standard previously stated that the battery had to be user removable without the use of tools at the end of the motherboards life so that it could be disposed of separately. Within the last six months that legislation has been amended to allow the use of component-class lithium coin cells -- Cells that are designed to last the life of the device.

The memory backup battery on a PC motherboard typically powers the RTC/SRAM function in the I/O chip; devices such as a National 87C306 Super I/O or a discrete RTC/SRAM IC like a Dallas Semiconductor DS12885.

The PC motherboards designer can reduce the capacity requirements of the battery by choosing an energy-efficient chip. Likewise, by specifying a power supply for the system that has a standby function, the resulting decrease in the backup batteries duty cycle can dramatically reduce the capacity required to meet the life goal of the product.

There are three types of lithium cells that could be chosen to satisfy the component-class, memory backup requirements of a motherboard system: lithium manganese dioxide [CR], lithium thionyl chloride, and lithium carbon monofluoride [BR].

This paper identifies the important performance characteristics of the memory backup battery relative to the requirements of state-of-the-art motherboard designs. The performance characteristics of the various chemical systems discussed include: system self-discharge, thermal wear-out, internal operating resistance over depth-of-discharge, and product safety.

Along with outlining the advantages of lithium carbon monofluoride coin cells in this type of application, contact theory and circuit design options which can further enhance the reliability of the RTC/SRAM function are also presented.

Performance Characteristics of Batteries

Battery selection is based on an understanding of the thermal capabilities, effects of the operating environment, and the battery life requirements of the powered device.

The design of an electronic circuit powered by a battery requires that the designer consider two interacting paths: the consumption of the active electrochemical components and the effects of thermal wear out. It is very important to hold the paths of self-discharge and thermal wear out as separate issues. This is because self-discharge can sometimes be compensated for by increasing the specified battery capacity, while the effects of thermal wear out can only be addressed by selecting a more thermally capable battery.

Consumption of Active Battery Components
The first path a designer needs to consider is the consumption of the active battery components. Batteries generate an electrical current by producing oxidation and reduction reactions of their active components. Once these components have been consumed, the battery ceases to generate an electrical current. The sum of the energy consumed by the circuit over the expected life plus the inherent loss of energy due to self-discharge equals the battery capacity needed. Self-discharge of the chemical system is defined as the loss of capacity, typically referenced as a percentage rate over a given period of time, regardless if the battery is installed into a circuit. Temperature acts as a catalyst to the self-discharge rate.

Thermal Wear Out
The second path in determining battery life is thermal wear out. Thermal wear out is defined as the loss of capacity activated by thermal mechanisms. Generally, thermal wear out rates accelerate as temperatures in the operating environment rise.

Failures of Coin Cells At High Temperatures
Under conditions of high thermal stress the grommet of a coin cell can oxidize, become brittle, and crack. This reduces the compression of the crimp seal, which results in electrical degradation of the cell. Also, under extended storage conditions at high temperatures, a breakdown of the separator material takes place. This breakdown results in an increase in internal impedance within the cell and a loss of operating voltage.

High temperatures also cause an accelerated loss of electrolyte from within the cell, as shown in Figure 1.

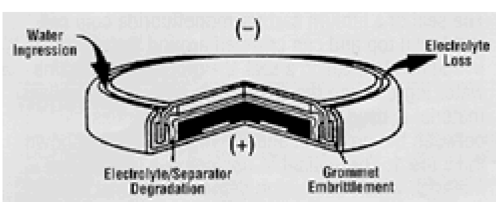

Figure 1. High Temperature Failure Modes of Lithium Coin Cells.

The electrolyte diffuses from the cell through and around the grommet and seal area. This loss of solvent results again in an increase in cell impedance and electrical degradation.

Battery Safety and Environmental Concerns
When designing a battery into an application, the chemical stability and toxicity of the battery system are primary concerns. One of the desirable traits of a lithium batteries chemical makeup is a solid cathode material rather than a liquid. Compared to a liquid cathode system, a solid cathode is less volatile and much less rate capable in the event that the battery is subjected to an abuse condition when.

In the event the battery is driven to the point of electrolyte leakage, the desired properties of the salts present in the electrolyte are nontoxic and non corrosive versus the alternative of corrosive and volatile.

Battery products are being subjected to a growing number of agency and legislative guidelines for environmental and safety, during both the active life cycle in a product and at the time of disposal.

Among the safety agencies, Underwriters Laboratory, UL, is one of the most sought after approvals for signifying a products safety and fitness for use. Under UL's guidelines, a battery which meets the component-class recognition guideline, meaning the battery is designed to be a life-of-the-device part in a product, is preferable to a product that would require a trained technician to replace the battery.

At some point in time, every battery needs to be disposed of. There are two major European regulations that impose elemental content restrictions and disposal regulations of many types of products, including batteries. The European Community Directive published in 1992, [also know as the ECç92 Directive] imposes restrictions on the amount of Cadmium, Mercury, and Lead in batteries and other products.

More recently, Blue Angel, a regulatory group in Germany, published their guidelines for electronic equipment. The 1996 Blue Angel regulations address an electronic devices energy consumption, elemental content of its components, and product disposal.

Under the guidelines of the Blue Angel legislation, component-class batteries are acceptable provided they do not contain Cadmium, Mercury, or Lead. The battery must also have a documented ten year shelf life.

Competitive Lithium Technologies
There are three types of lithium cells that could be chosen to satisfy the component-class, memory backup requirements of a motherboard system: lithium manganese dioxide [CR], lithium thionyl chloride, and lithium carbon monofluoride [BR].

Lithium Thionyl Chloride
This 3.6 volt Lithium chemistry, originally designed to be a military cell, is a high energy, high current drain rate cell. Unlike most battery systems, thionyl chloride cells are hermetically sealed. Because of its high rate capability, the cell must be constructed with an internally fused design. If the battery is inadvertently charged or shorted, and the fuse mechanism fails, the cell could rupture and explode. Because of the relatively high volatility of this lithium chemistry, Underwriters Laboratory requires that only a trained technician replace the batteries in the applications where this chemistry has been designed. Environmentally, because of the highly toxic and corrosive thionyl chloride in the cell, this chemistry of lithium cell is not recognized as normal waste and requires special handling and disposal.

Lithium Manganese Dioxide [CR]
This 3.0 volt lithium chemistry is popular because of its lower cost and wide range of availability. Because of the MnO_2 content in the cell, it has a tapered discharge profile. As a CR cell discharges, its operating voltage drops over time because of the rise internal impedance.

The maximum temperature rating of the CR cell is limited to 60®C, due once again to its MnO2 content. The limitations of the cell include a rapid increase in self-discharge at its maximum temperature to a rate of over 8% per year, with one percent of a population of cells failing in less than one year.

The CR chemistry is preferred in higher rate, intermittent pulse mode applications such as remote keyless entry systems and in applications where replacement of the battery is routine.

Lithium Carbon Monofluoride [BR]
The flat, stable discharge profile of this 3.0 volt lithium chemistry, Figure 2, makes it ideal for real-time clock and memory backup applications.

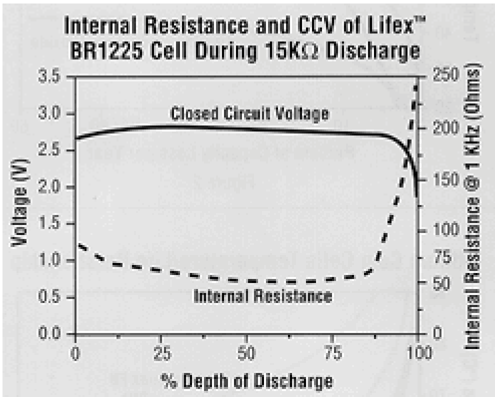

Figure 2. Closed Circuit Voltage and Internal Resistance Over Discharge.

The stable voltage over the entire life of the cell is due to the internal formation of carbon as a by-product of the discharge reaction.

Electrochemically, the system self-discharge of the BR chemistry at elevated temperatures is superior to the other lithium coin cell chemistries. At 60®C, self-discharge is less than 0.5% per year. Even at its maximum temperature rating of 85®C, the rate is still less than one percent per year.

A critical element to a cells resistance to the effects of thermal wear out is the construction of the coin cell. Typical lithium carbon-monofluoride coin cells use polypropylene as the grommet and separator material. This material is effective is sustaining a cells mechanical and electrical characteristics over an operational and storage temperature range of -40® to +85®C.

The seal of a lithium carbon monofluoride coin cell is a metal top and can crimped around the grommet, as shown below in Figure 3.

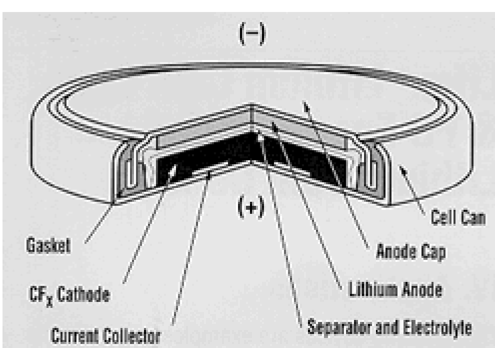

Figure 3. Construction of a Lithium Carbon Monofluoride Coin Cell.

In addition to creating a seal, the grommet constrains water ingress into the cell in high humidity environments. A sealant material is used to fill voids and irregularities between the grommet and metal parts. The sealant is a bituminous material which has a high degree of thermal stability. The separator component of the cell acts as both a physical insulator between the anode and cathode, and as an electrolyte absorbent which maintains the desired ionic conductivity in the cell, The electrolyte itself is the ionic conductor within the cell. A lithium tetrafluoroborate [$LiBF_4$] salt in a solution of propylene carbonate and dimethoxyethane [PC & DME] is used as the electrolyte.

When combined with a secure crimp seal design, the effects of thermal wear out are minimal with this chemistry even to 60®C, shown below in Figure 4.

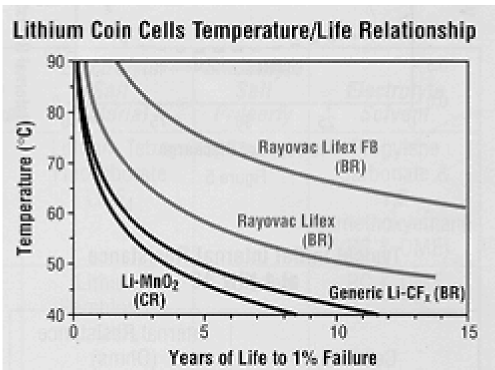

Figure 4. Effects of Thermal Wear Out on Lithium Coin Cells.

At this elevated temperature, the one percent failure point of a population of cells is extended out to over four and a half years.

The outstanding electrochemical reliability of this chemistry is further augmented by its safety and environmental properties, as shown in Figure 5.

Battery System	Lithium Carbon Monofluoride	Lithium Manganese Dioxide	Lithium Thionyl Chloride
IEC Nomenclature	$Li/(CF)_x$ BR	Li/MnO_2 CR	$LiSOCl_2$
Class	Solid Cathode	Solid Cathode	Soluble Cathode
Cathode Material	Poly Carbon Monofluoride	Manganese Dioxide	Thionyl Chloride
Cathode Properties	Solid Stable	Solid Stable	Liquid Toxic Corrosive
Electrolyte Salt Material	Lithium Tetra Fluoroborate $LiBF_4$	Lithium Perchlorate $LiClO_4$	Lithium Tetra Chloro-aluminate $LiAlCl_4$
Electrolyte Salt Property	Stable	Explosive	Corrosive
Electrolyte Solvent	Propylene Carbonate & 1,2 Dimethoxyethane (PC & DME)	PC & DME	Thionyl Chloride ($SOCl_2$)
Safety Rank	A	B	C

Figure 5. Properties and Relative Safety of Lithium Coin Cell Chemistries.

The safety of the BR chemistry is enhanced by the use of a carbon monofluoride electrode material and noncorrosive and nontoxic electrolyte.

Circuit Connection Options: Coin Cell Holders

Figure 6. Typical Coin Cell Holder

Although it may be one of the least expensive ways to connect a battery into a circuit, coin cell holders, Figure 6, are also one of the least reliable methods. The reliability of the coin cell can be compromised due to a loss of contact between the cell and the holder.

Another failure mode of coin cell holders is oxidation of the contact material. The oxidation of the contact material can be caused by environmental or mechanical influences. Environmentally, humidity can cause oxidation of both the contact and even the cells surface if it is prolonged and severe enough. It is the mechanical influences, that most often lead to failure.

Contact Reliability

Contact theory states that when two flat surfaces are brought together, they appear to form a large continuous surface. In reality, these smooth surfaces are made up of peaks and valleys and it is only these asperities or "A-spots" which make contact. The A-spots constitute as little as one percent of the apparent surface area. Any micro-movement of these surfaces can cause surface oxidation at the A-spots ultimately results in a loss of intimate metal-to-metal contact between the cell and the cell holders contact material.

Component-Class Tabbed Coin Cells

Lithium carbon monofluoride cells are suitable for direct soldering onto printed circuit boards [PCB].

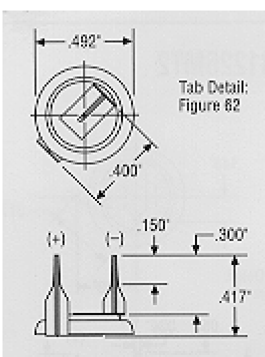

Figure 7. Tabbed BR1225 Lithium Coin Cell.

A welded tab, Figure 7, or pin soldered to a PCB ensures the highest contact reliability possible and eliminates any of the concerns associated with coin cell holders.

The carbon monofluoride cells are also suitable for wave soldering. During the period that the battery tabs are in the solder bath, the battery is short circuited, as shown below in Figure 8.

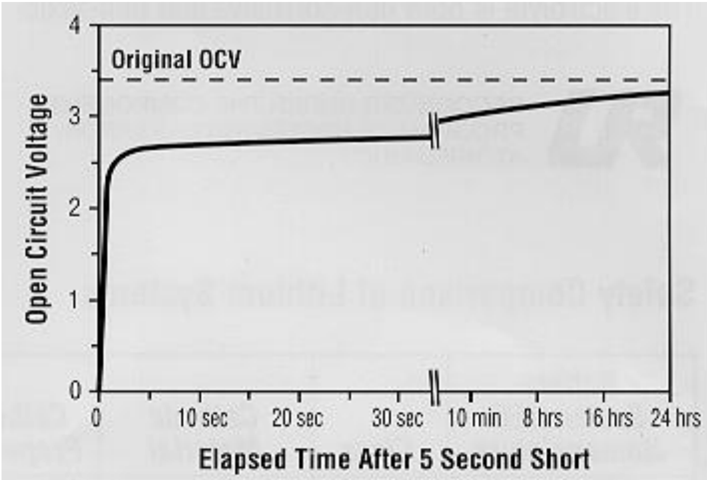

Figure 8. Short Circuit Recovery of a Lithium Carbon Monofluoride Coin Cell.

If this period is kept to under five seconds, the battery capacity loss will be minimized. Following a short circuit the battery voltage will recover to above 2.5 volts almost immediately while full recovery to its final working voltage may take a number of hours.

Backup Batteries For Pentium-Based Systems

There are three trends in desktop and notebook systems that have now made it possible to shift the backup battery design from a coin cell in a holder to a component-class, life of the device solution: operating environments, standby power supplies, and reduced current drain requirements for the memory backup function.

Operating Environments

In Pentium-based desktop platforms, the trend is towards lower profile units. This has resulted in reduced airflow through the box. This changed the operating environment for the battery by increasing the ambient temperature. A more thermally capable battery is now required to meet the products life goal.

Standby Power Supplies

One of the more recent developments for personal computers has been the standby power supply. This type of power supply has a standby or trickle mode. It incorporates a 5.0 VDC rail which supplies the RTC/SRAM functions of the Super or Ultra I/O chip whenever the system is connected to AC power.

Given this scenario, the RTC/SRAM battery backup is only required when the unit is unplugged. This limited duty cycle includes the following: shipping, extended user storage time, residential or commercial power outages, or if the end-user has a system power strip connected to the PC, monitor, and printer.

Reduced Current Drains

The third innovation which has made component-class batteries possible is the dramatic reduction in the current requirements of the real-time clock functions of the major I/O chip manufacturers. Both National Semiconductor and Standard Microsystems [SMC] have I/O chips which have current drain rates below one microAmpere. For example Nationals very popular 87C306, 307 and 308 boast a maximum rated current drain of 2.0 µA. Nationals production parts typically are below 0.8µA. Using the standby power supply scheme, a Rayovac BR1225 cell with 50 milliAmp-hours [mAh] can provide over seven years of battery backed [70% duty cycle] of unplugged time over a period.

SMC's Ultra I/O, the FDC37C93X, has a rated maximum drain of 1.0 µA but their production parts are typically less than 0.6 µA. In this application, using the standby power supply, a Rayovac BR1225 cell can provide over nine years of battery backed [90% duty cycle] of unplugged time over a ten year period.

Replacement Of The Backup Battery
After a decade of service, replacement of the Rayovac BR1225 coin cell would be facilitated by an industry standard four-pin header. The header, EXT_BATT, has a jumper, J_BATT, which, when removed allows electrical introduction of the external battery and electrical disconnection [open circuit] of the coin cell, as shown in the circuit diagram below, Figure 9.

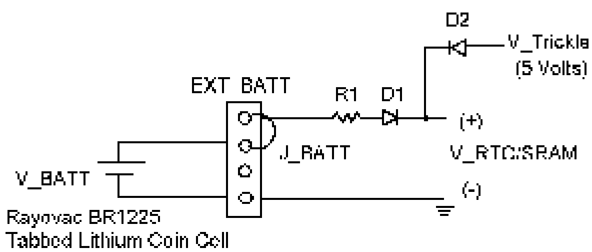

Figure 9. RTC/SRAM Circuit Using a Rayovac BR1225 and a Trickle/Standby Power Supply.

Using this circuit design, there is no possibility of a reverse charge current being applied to the coin cell by an external source. Lastly, because there is no remaining lithium or capacity in the cell, physical removal of the coin cell from the circuit board is not necessary.

Conclusion
With the recent innovations in personal computer components such as the ultra-low current drain requirements of the RTC/SRAM functions in the state-of-the-art I/O chips, the standby power supply, and the increasing internal operating temperatures of both desktop and notebook platforms, a component-class lithium carbon monofluoride coin cell such as a Rayovac BR1225 can provide between seven and nine years of backup time over a ten year period.