Application Notes & Product Data Sheet

Lifexä Lithium Coin Cells & FB Encapsulated Lithium Coin Cells - Part 1

I. Introduction

Lithium has become a generic term representing a family of battery systems in which lithium metal is used as the active anode material or negative electrode. Variations in the cathode material, or positive electrode, and the cell electrolyte result in hundreds of possible combinations of lithium batteries. Rayovac Lifex™ lithium carbon-monofluoride (LiCFx) batteries are a solid-cathode type which optimizes reliability, safety, cost and performance.

II. Features

- Outstanding shelf life and excellent performance over a wide temperature range
- Stable discharge voltage
- High energy density and voltage (3V)
- Enhanced safety by the use of carbon-monofluoride electrode material and a non-corrosive, non-toxic electrolyte
- Excellent leak resistance
- Shelf life of ten years or more
- Pre-tinned nickel terminals are solderable
- Available with other wave-solderable terminal configurations

III. Quallty Systems Certification

CERTIFIED ISO 9001

Accredited by the Dutch Council for Certification for certification and registration activities.

IV. Applications

The following devices are examples of good uses for Lifex cells:

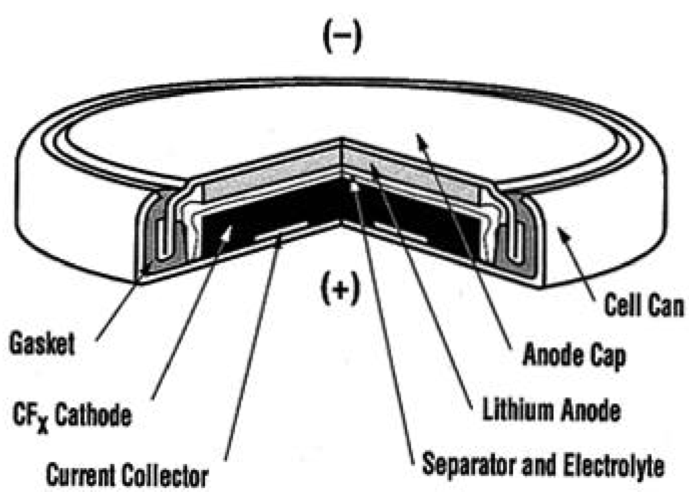
- Computer Memory and Real Time Clock Backup
- Electronic Counters, Process Controllers
- Portable Instruments
- Time/Data Protection
- Industrial Controls
- Electronic Gas, Water and Electric Meters
- Communication Equipment
- Watches
- Protection of Control Parameter Memory
- Portable Electronic Devices

Application Considerations

Rayovac Lifex coin cells and batteries should be considered for applications that are characterized by a need for:

Miniaturization
Leakage resistance
Light weight
Shock and vibration tolerance
Low to moderate current drains
Environments requiring extended operation or storage at a wide range of temperatures
The need for flat discharge voltage and consistent source impedance
Long shelf life
An extended service life due to low self-discharge rate
Enhanced safety and reduced product liability concerns
U.L. recognized components

V. Construction



VI. Battery Selection

Component Class Batteries and Cells

Today's circuit designers recognize the capabilities of Lifex coin cells and Lifex FB™ batteries to function as permanent components in theircircuits. Lifex FB batteries exhibit reliability rates similar to diodes and resistors.

The combination of very low power Complementary Metal-Oxide Semiconductor (CMOS) memory devices with high energy, long life batteries now allow for batteries to be used as life-of-product components.

The traditional approach to product design is to provide sufficient energy to meet a design target for a stated period, at which time the batteries would be replaced. The decision to provide component or expendable power is fundamental to the product concept of the device being powered.

Component batteries allow the designer to increase the reliability and functionality of the device by eliminating the need for consumer replacement of batteries. Component batteries eliminate the problems of reversed polarity, wrong chemical system, mismatched capacities, and higher operating costs. However, component batteries require careful selection. The batteries must assure adequate energy for the expected load to compensate for self-discharge and the thermal environment expected, and the batteries must also have a high reliability connection to the circuit.

Today's demand for high performance, small footprint, reliable, and cost-effective electronic products can be realized by identifying the best match between the battery and its application. To do so requires a good understanding of the device's power requirements and the environment in which it is used as well as how the battery reacts to those loads and environments.

It is important that the battery be considered early in the design process. This will allow the optimization of battery life through the selection of power conserving circuit components. Moreover, early battery selection will also minimize circuit and mechanical layout changes later in the designprocess.

The following is a list of basic application characteristics and conditions that must be considered for an optimum selection of a lithiumcarbon-monofluoride power source.

Electrical Characteristics

- Voltage: maximum/minimum
- Current drain
- Pulse currents
- Pulse time/frequency of occurrence

Application Goals

- Duty cycle
- Service life goal
- Shelf life goal
- Reliability
- Safety
- Battery availability

Packaging

- Shape
- Terminals
- Weight
- Contact materials
- Case materials

Environmental

- Operating temperature range
- Storage temperature range
- Humidity
- Shock and vibration
- Atmospheric pressure

VII. Calculating Battery Life

The design of an electronic circuit powered by a component class battery requires the designer to consider two interacting paths that determine a battery's life: consumption of active electrochemical components and thermal wear-out.

To optimize battery life in powered devices, today's designers are first selecting power conserving circuit components, and then specifying high reliability component lithium 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.

Figure 1, below, gives an estimate of years of service at various discharge currents for Lifex™ lithium coin cells at room temperatures.

Consumption of Active Battery Components

Batteries produce electrical current by oxidation and reduction of their active electrochemical components. Once these components are consumed, the battery ceases to produce current. The sum of the energy consumed by the circuit over its expected life plus the electrochemistry's inherent loss of energy due to self-discharge, represents the first path in determining battery life.

Thermal Wear-Out

The second path in determining battery life is thermal wear-out, which is the loss of capacity caused by thermal mechanisms. Generally, thermal wear-out rates accelerate as temperatures in the operating environment rise.

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 thermal wear-out can only be addressed by selecting a more thermally capable battery.

Drain vs. Duration

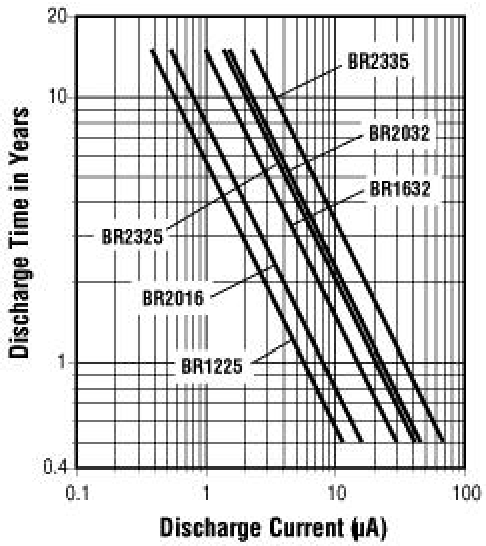


Figure 1

Battery Life and Capacity Estimates

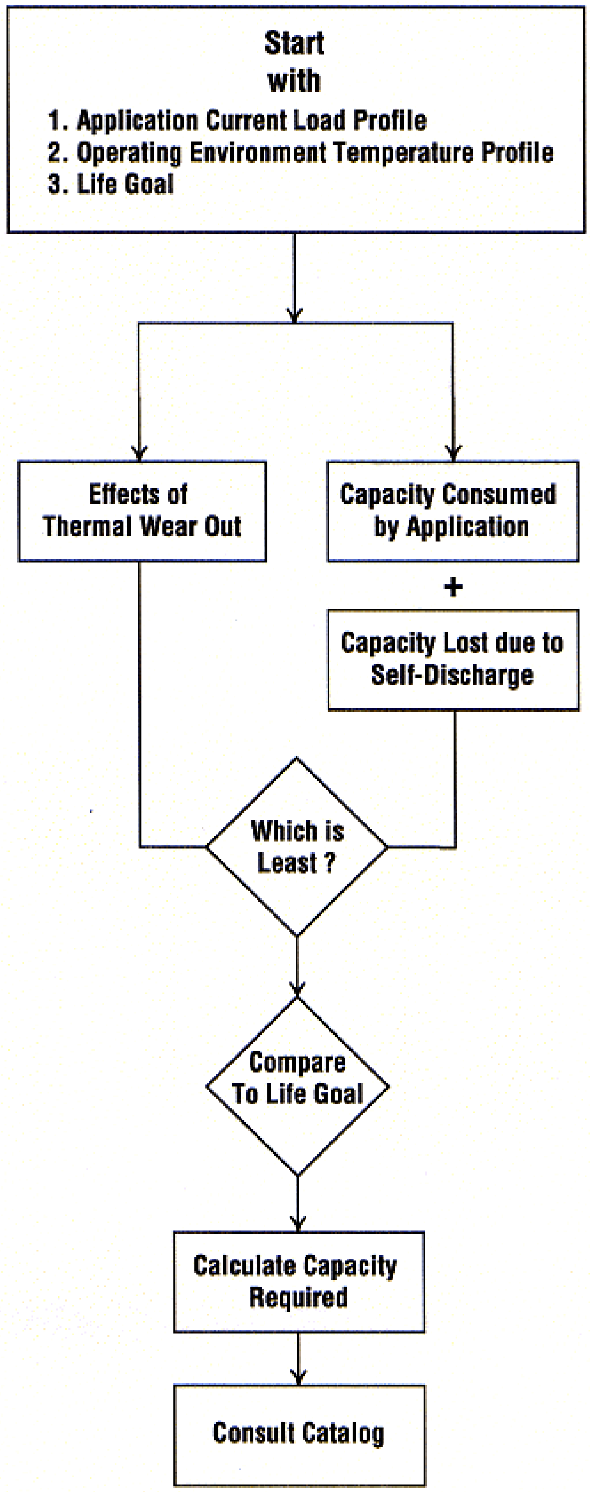
Rayovac has accumulated over 200 million device hours of accelerated reliability testing with a major semiconductor manufacturer. This data has allowed us to gain a better understanding of the time and temperaturedependent wear-out of Lifex coin cells and Lifex FB™ batteries during storage.

A set of Arrhenius equations developed from this database allows storage time and temperature effects to be included in a cell life estimate.

It became evident that the number of calculations required to adequately represent an actual application were too great to compute without some form of automation. As a result, Rayovac has developed a computer program to calculate both self-discharge and thermal wear-out as well as the capacity required for even complex load profiles.

To make use of the program, Lifex™ and Lifex FB™ Lithium Battery Design Template, please consult with Rayovac's Applications Engineering Department. They are equipped to assist at any time. Be ready to respond with the application's current load profile, operating environment temperature profile, and life goal. An Applications Engineering Work Sheet is provided for your convenience.

Using our database and calculations, we can compute annual capacity consumed, annual self-discharge, and the thermal wear-out life limit (TWOLL). By comparing the life goal to TWOLL, the needed battery capacity can be calculated. Then, you select the Rayovac battery solution that best fits your requirements.


Start
with
1. Application Current Load Profile
2. Operating Environment Temperature Profile
3. Life Goal
Effects of
Thermal Wear Out
Capacity Consumed
by Application
+
Capacity Lost due to
Self-Discharge
Which is
Least ?
Compare
To Life Goal
Calculate Capacity
Required
Consult Catalog

VIII. Performance Characteristics

A. System Self-Discharge Comparison

Lifex™ lithium carbon-monofluoride cells offer substantially lower self-discharge rates compared to other battery chemistries. Figure 2 compares the capacity loss due to self-discharge over a range of temperatures for various battery chemistries. Lifex lithium coin cells provide self-discharge rates of less than 0.3% per year and Lifex FB™ batteries less than 0.2% per year.

System Self-Discharge Rate vs. Temperature

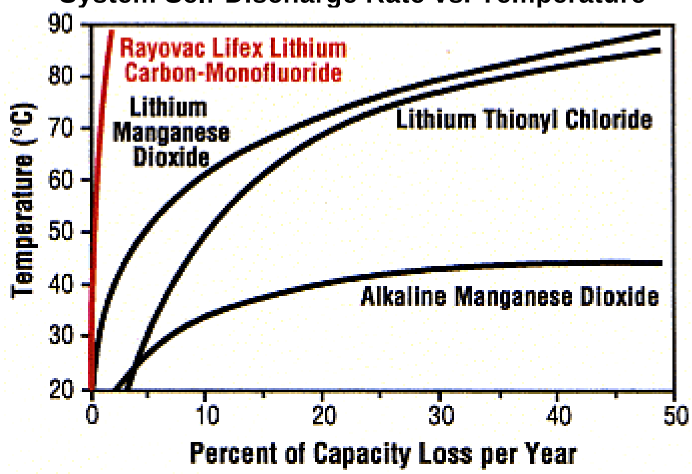


Figure 2

B. Thermal Wear-Out

At high temperatures, Rayovac's Lifex coin cells and Lifex FB batteries offer significantly lower failure rates over competing coin cells. Figure 3 shows the relationship between temperature and the years to 1% failure of 12.5mm diameter cells of similar capacity. A failure is defined as a closed circuit voltage less than 2.0 volts on a 250K ohm load of 0.5 second duration.

Lithium Coin Cells Temperature/Life Relationship

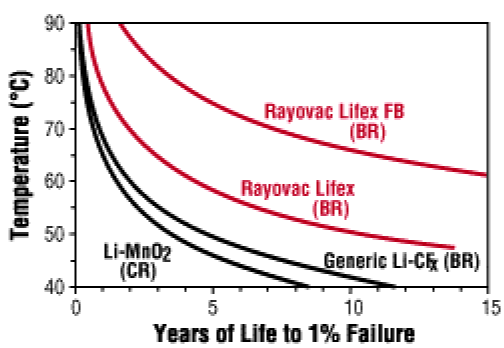


Figure 3

C. High Temperature Storage Performance

The advantage of Rayovac Lifex coin cell performance after high temperature storage is further illustrated in the figure below. Figure 4 shows how the Lifex BR2325 coin cell compares with other lithium carbon-monofluoride (BR) and lithium manganese dioxide (CR) cells when stored at high temperature. The data presents the results of weekly closed circuit voltage measurements on a 1K ohm load at 0.5 second duration after high temperature storage. The test was started at a storage temperature of 70°C and then later increased to 85°C to allow for the temperature limitations of the CR cell.

High Temperature Performance Comparison

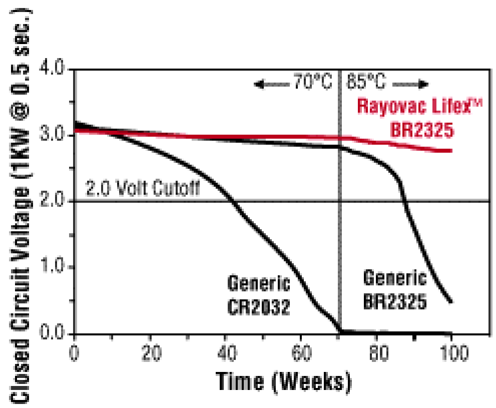


Figure 4

D. Internal Operating Resistance During Discharge

Figure 5 below shows how the internal resistance and voltage changes on a BR1225 cell as a percent of discharge. Similar profiles with slightly different values are observed with other cell sizes. The typical initial 1KHz AC internal resistance for each cell size is shown in Figure 6.

Internal Resistance and CCV of
Lifex™ BR1225 Cell During 15K ohm Discharge

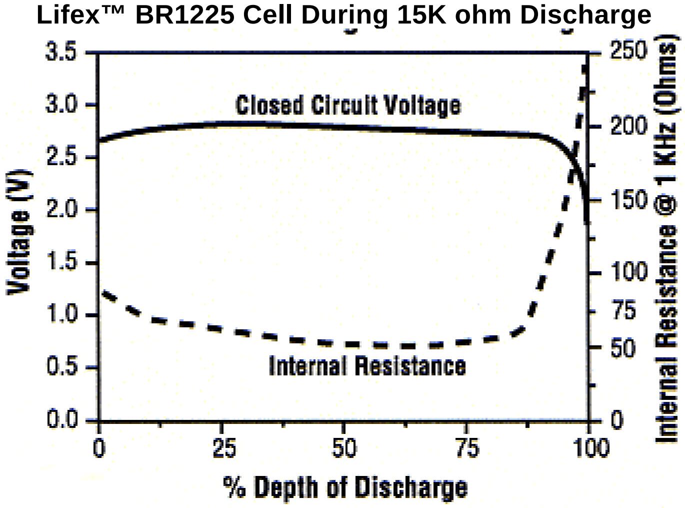


Figure 5

Typical Initial Internal Resistance at 1 KHz AC

Cell Size	Internal Resistance (Ohms)
BR1225	85
BR1632	34
BR2016	19
BR2032	25
BR2325	16
BR2335	21

Figure 6

E. System Internal Resistance Comparison

Rayovac Lifex coin cells provide more stable internal resistance throughout discharge compared to lithium manganese dioxide coin cells as shown in Figure 7. This is due to the formation of conductive carbon as a discharge by-product in the cell cathode during discharge. This carbon prevents a change in internal resistance until the active compnents of the cell are consumed.

Internal Resistance During 30K ohms Discharge
Lifex Br2016 Cell vs. Cr2016 Cell

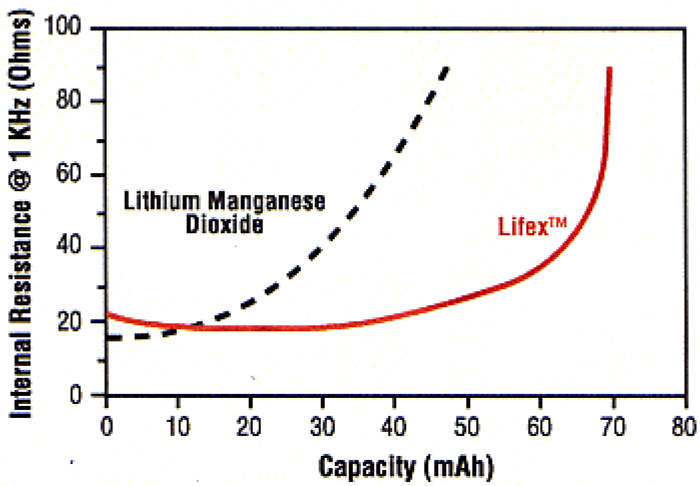


Figure 7

F. Operating & Storage Temperature Range

Rayovac Lifex lithium coin cells and Lifex FB™ batteries provide excellent performance over a wide range of temperatures. The operating and storagetemperature ranges are as follows:

Lifex Coin Cells	-40°C to +85°C (-40°F to +185°F)
Lifex FB Batteries	40°C to +100°C (-40°F to +212°F)

G. Safety

Figure 8 below compares the safety of the three most common lithium systems. The figure demonstrates that the Rayovac Lifex™ battery components are extremely safe.

Rayovac Lifex batteries have been granted U.L. Component Recognition (file no. MH12542). The battery's components are both chemically and thermally stable before, during, and after discharge. The electrolyte is bothnon-corrosive and non-toxic.

RECOGNIZED UNDER THE COMPONENT PROGRAM OF UNDERWRITERS LABORATORIES® INC.

Safety Comparison of Lithium Systems

Battery System/IEC Nomenclature	Class	Cathode Material	Cathode Properties	Electrolyte Salt Material	Electrolyte Salt Property	Electorlyte Solvent
Lithium Carbon-Monofluoride Li/(CF)x BR	Solid Cathode	Poly Carbon-Monofluoride	Solid Stable	Lithium Tetra Fluoroborate LiBF4	Stable	Propylene Carbonate & 1,2 Dimethoxyethane (PC & DME)
Lithium Manganese Dioxide Li/MnO2 CR	Solid Cathode	Manganese Dioxide	Solid Stable	Lithium Perchlorate LiClO4	Explosive	PC & DME
Lithium Thionyl Chloride LiSOCl2	Soluble Cathode	Thionyl Chloride	Liquid Toxic Corrosive	Lithium Tetra Chloroaluminate LiAlCl4	Corrosive	Thionyl Chloride (SOCl2)

Figure 8

H. High Altitude Exposure

It is possible for components to be exposed to reduced pressures during shipment by air. Rayovac Lifex batteries that were tested at reduced pressures of 3 mm mercury for 10 days and then discharged at normal rates exhibited the following results:

1. No change in cell appearance.
2. No observed leakage.
3. No change in resulting capacity.

I. Charging Characteristics

Although any charging of Lifex™ cells is to be avoided, some charging may occur even in a well designed electrical circuit due to leakage current of the protecting diodes. The diode used in a circuit design with a Lifex cell should minimize leakage to within 3% of the rated capacity of the cell over the lifetime of the cell's use. Figure 9 below provides the maximum total charge allowance for all cell sizes. Figure 10, which illustrates these limits as they apply to the BR1225 and BR2325 cell sizes at various drain rates, follows.

Maximum Total Charge Allowance

Cell Size	Rated Capacity	3% of Capacity
BR1225	50 mAh	1.50 mAh
BR1632	130 mAh	3.90 mAh
BR2016	70 mAh	2.10 mAh
BR2032	195 mAh	5.85 mAh
BR2325	180 mAh	5.40 mAh
BR2335	300 mAh	9.00 mAh

Figure 9

Formula to calculate charge current:

Imax(nA) = 114.15 x c/t

Where:

I_{max} =Maximum allowable charge current in nanoAmperes (nA)

c = Maximum total charge capacity in mAh from table above

t = Time on charge in years

Maximum Total Charge Allowance

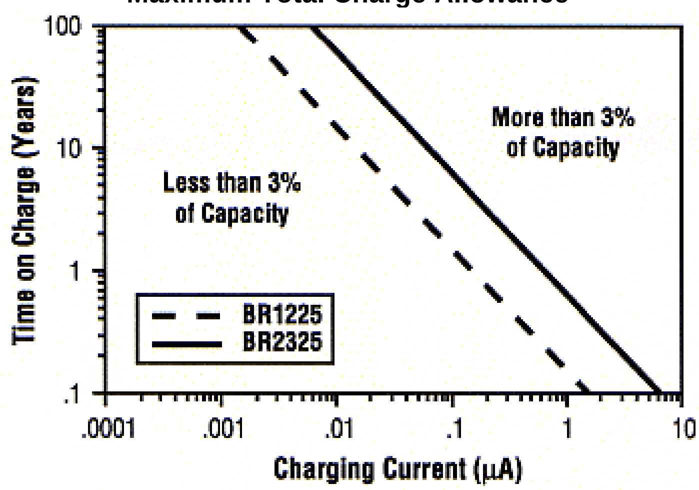


Figure 10

J. Short Circuit Recovery

In the process of wave soldering tabbed versions of the Lifex batteries to circuit boards, a temporary short will occur. Figure 11 below shows the voltage recovery of a Rayovac BR2325 coin cell after a 5 second short circuit which would typically occur in the wave soldering process.

BR2325 Voltage Recovery after 5 Second Short

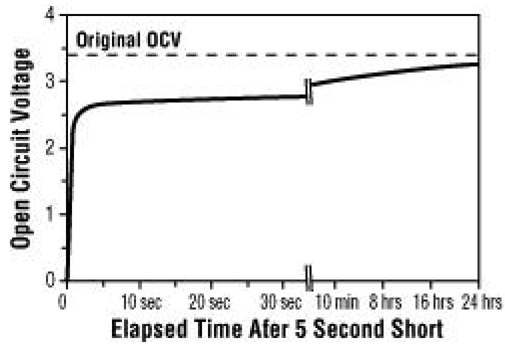


Figure 11

K. Leakage Resistance

The electrolyte in Lifex batteries is based on an organic solvent instead of a corrosive alkaline or acidic solution found in most conventional batteries. This greatly improves the cell's leakage resistance and guards against the negative effects caused by leakage.

L. Orientation

Since Rayovac batteries use solid active components, the performance characteristics described are obtained regardless of the installation position.

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