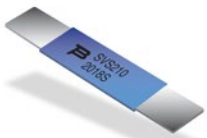
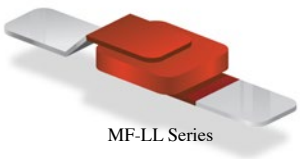
Addressing Li-ion Battery Pack & Battery Cell Reliability Threats

with Bourns® Multifuse® Polymer Positive Temperature Coefficient (PPTC) Resettable Fuse Protection

BATTERY PACK OVERVIEW WHITE PAPER


MF-D Series


MF-SVS Series


MF-LL Series

BACKGROUND

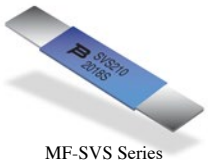
With the exponential growth, increasing complexity and computing power of virtually all electronics applications (particularly portable devices) comes the need for battery cells and battery packs that provide long life and high durability in a compact form factor. To simplify its operation, a battery pack is charged through a conventional wall outlet, a Universal Serial Bus (USB) port, or other adapter and then discharged through active use or standby operation. Throughout this repeated cycle, there are numerous threats to the integrity of the battery including overvoltage, overcurrent and overtemperature conditions.

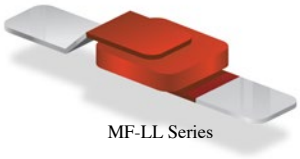
To maintain the reliability of devices that use battery packs, Bourns offers a comprehensive line of circuit protection solutions. One of the leading battery technologies is Lithium-ion (Li-ion). This paper will explore methods for protecting Li-ion battery packs during charging and discharging.

Addressing Li-ion Battery Pack & Battery Cell Reliability Threats

with Bourns® Multifuse® Polymer Positive Temperature Coefficient (PPTC) Resettable Fuse Protection


MF-D Series


MF-SVS Series


MF-LL Series

BATTERY REGULATION

The multi-billion dollar battery industry continues to grow, spurred by the demand for mobile technology and other types of smart consumer electronics products. New mobile devices such as smartphones, tablets, and single-lens digital cameras are released on a regular basis and almost always employ Li-ion battery packs. For future trends, it is expected that Li-ion battery packs will extend beyond these applications into vehicular use, industrial machinery, and stationary power storage. Battery packs are becoming more safety-sensitive because of their widespread use. Regulatory testing requirements are necessary to ensure that battery packs are protected from possible safety threats.

Battery cells have inherent electrical, environmental, and mechanical hazards. When overcharged or overheated, it is possible for a battery cell to rupture, combust, or explode. Even if overcharging or overheating does not result in a fire, the battery can still be compromised and thus, may be more susceptible to further damage from physical factors including vibration, impact, and exposure to heat. Regulatory requirements including those listed in table 1 are based on the battery and its application. Table 2 provides details of the UL 2054 requirement set which tests for safety from threats relating to venting, explosion, fire, and temperature.

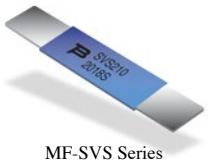
Table 1. | *Regulatory Tests for Battery Packs and Battery Cells*

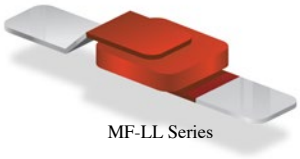
Test	Battery/Application
UL 1642	Secondary battery cells and primary batteries
UL 2054	Secondary battery packs, including lithium
IEC 62133	Secondary lithium and nickel cells and battery packs
IEC 1725-2006	Rechargeable batteries for cellular phones

Addressing Li-ion Battery Pack & Battery Cell Reliability Threats

with Bourns® Multifuse® Polymer Positive Temperature Coefficient (PPTC) Resettable Fuse Protection


MF-D Series


MF-SVS Series


MF-LL Series

CHARGE AND TEMPERATURE

During charging and discharging cycles, battery cells face overcurrent, overvoltage, and overtemperature conditions. The charging process for Li-ion batteries consists of two phases: constant current and constant voltage. In the constant current charging phase, the charge current is applied to the battery until the voltage limit per cell is reached. Li-ion batteries cannot accept a higher voltage charge than specified, typically 4.2 V, without being damaged. The constant voltage phase then begins as the applied current declines to a few percent of the constant charge current. During this time, the maximal cell voltage is applied to the battery. For multi-cell battery packs, a balancing phase occurs between the constant current and constant voltage phases to ensure a consistent charge among cells. In such packs, the voltage applied in the constant voltage stage is the product of the number of cells and the maximal voltage per cell.

Li-ion battery cells must never be discharged below their specified minimal voltage. Once voltage drops to this level, battery management circuitry may stop the flow of current. This precaution ensures that the battery can be recharged safely with a conventional charger and protects the battery from a short circuit, which is a real threat to its integrity. If a short is sufficiently mild, little heat will be generated and the battery will simply discharge more rapidly. However, more severe shorts may result in overheating and its associated threats. In a multi-cell pack, the cells adjacent to the shorted cell can overheat or fail.

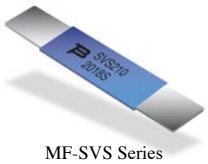
Table 2. | *UL 2054 Tests and Requirements for Battery Packs*

Electrical Tests	Requirements
Short circuit test	No explosion, no fire, temperature < 150 °C
Abnormal charging test	No explosion, no fire
Abusive overcharge test	No explosion, no fire
Forced discharge test	No explosion, no fire
Limited power source test	No explosion, no fire
Battery pack component temperature test	Temperature within specification
Battery pack surface temperature test	Temperature within specification
Environmental Tests	**Requirements**
Heating test	No explosion, no fire
Temperature cycling test	No explosion, no fire, no venting, no leaking
Mechanical Test	**Requirements**
Crush	No explosion, no ignite
Impact	No explosion, no ignite
Shock	No explosion, no fire, no venting, no leaking
Vibration	No explosion, no fire, no venting, no leaking
Battery Enclosure Tests	**Requirements**
250 lb. crush	No explosion, no fire
Mold stress relief	No explosion, no fire
Drop impact	No explosion, no fire
Fire Exposure Test	**Requirements**
Projectile	No explosion, no ignite

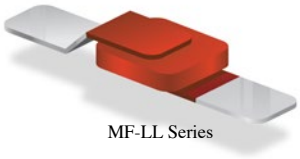
Addressing Li-ion Battery Pack & Battery Cell Reliability Threats

with Bourns® Multifuse® Polymer Positive Temperature Coefficient (PPTC) Resettable Fuse Protection

MF-D Series



MF-SVS Series



MF-LL Series

ADDRESSING THREATS WITH PROTECTION

In order to ensure that Li-ion batteries can power electronics safely and meet regulatory requirements, several precautions need to be taken. Layers of protection include the construction method, density of the cell and safety mechanisms integrated within the cell. Electronics are then used outside the cell in order to protect from overcharge, undercharge, and extraneous temperatures. Circuit protection solutions for battery packs are typically a combination of several devices, which are crucial design considerations during charging and discharging of the battery pack.

Battery management Integrated Circuits (ICs) and FETs (Field-Effect Transistors) provide overvoltage and overcurrent protection. Integrating Bourns® Multifuse® PPTC devices is an optimal overtemperature protection solution for battery packs, battery cells and specifically for single-cell Li-ion battery packs. In order to provide reliable protection, the PPTC device is mounted in such a way that it is linked thermally with the cell. Typically, the PPTC device will be in contact with the battery cell, so it can react to the increased temperature in the cell. Figure 1 shows the schematic of a battery cell using Bourns® Multifuse® PPTC resettable fuse protection.

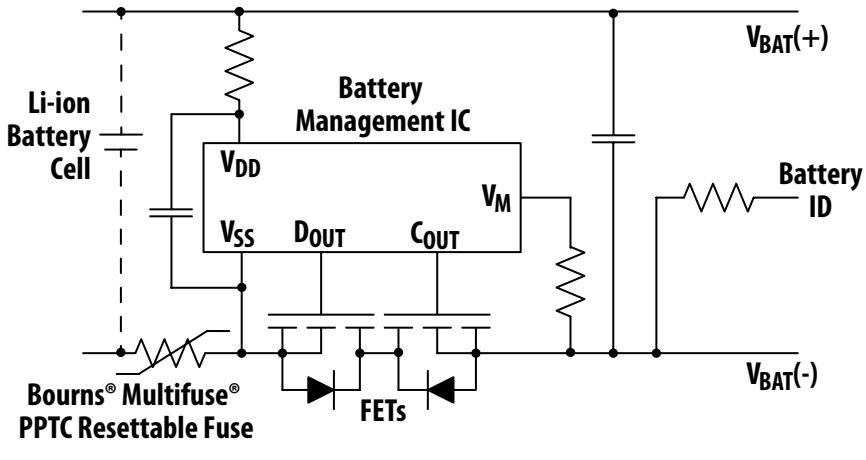
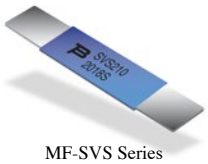


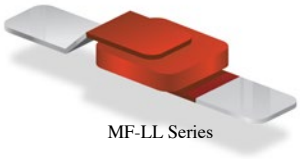
Figure 1. | *Li-ion Battery Cell Protection Circuit*

Addressing Li-ion Battery Pack & Battery Cell Reliability Threats

with Bourns® Multifuse® Polymer Positive Temperature Coefficient (PPTC) Resettable Fuse Protection


MF-D Series


MF-SVS Series


MF-LL Series

ADDRESSING THREATS WITH PROTECTION *(Continued)*

The operation of a battery management IC is illustrated in figure 1. This IC uses the difference in voltage between V_{DD} and V_{SS} to monitor the battery voltage, and the difference in voltage between V_M and V_{SS} to detect charge overcurrent voltage and discharge overcurrent voltage. As long as the battery voltage is between the specified minimal discharge voltage and maximal charge voltage levels and the overcurrent voltage is within the charge and discharge levels, the IC turns on the charging FET at C_{OUT} and the discharging FET at D_{OUT}. This is the normal operating state and either charging or discharging can take place. An overcharge condition occurs when the battery voltage exceeds the maximal charge voltage. If it persists for longer than a given delay, the charging FET is turned off so that charging is disabled. Similarly, an overdischarge condition occurs when the battery voltage falls below the minimal charge voltage over a given delay, and the discharging FET is turned off to ensure the battery does not discharge further. From either condition, the battery can return to the normal operating state when the battery voltage and charge and discharge overcurrent voltage levels return to the normal ranges.

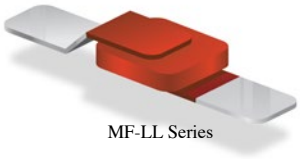
The Bourns® Multifuse® PPTC resettable fuse provides overcurrent protection beyond the battery management IC, protecting the battery from surge current while also protecting against overtemperature conditions. Under normal operating conditions, the Bourns® Multifuse® PPTC device has a small resistance that does not affect the operation of the circuit. If the current or temperature exceeds the set operating limits, then the Bourns® Multifuse® PPTC device will switch to a high impedance mode. In this tripped state, it acts like an open circuit and only a very small amount of current can flow through it. Once the condition is cleared and power has been cycled, the Bourns® Multifuse® PPTC device can resume normal operation.

Addressing Li-ion Battery Pack & Battery Cell Reliability Threats

with Bourns® Multifuse® Polymer Positive Temperature Coefficient (PPTC) Resettable Fuse Protection


MF-D Series


MF-SVS Series


MF-LL Series

EFFECTIVE BATTERY PACK PROTECTION

A wide range of Bourns® Multifuse® PPTC resettable fuse devices are available to meet the needs of Li-ion battery protection. Bourns has been designing its PPTCs for battery cells for well over 10 years and the range today covers the traditional axial leaded strap, the bare disk type devices for cylindrical cells (e.g. AA & AAA) and the latest low resistance, small sized MF-LL series using ultra-high conductive fillers.

The traditional axial leaded straps are available in the MF-SVS, MF-VS, MF-LR, MF-LS, and MF-S families. These are used in a wide range of battery applications such as mobile phones, powered toys, powered tools and electric vehicles. They range in operating currents up to 9 A and operating voltages as high as 24 V.

The MF-D series resettable fuses are customized disk PPTCs. They are made from a PTC plaque material and can be customized in shape, dimension, resistance and operating current for specific battery cell applications.

Bourns' newest addition to battery pack applications is the MF-LL Series. This family is unique as it is the first in the Bourns® PTC range not to use carbon as the conductive element. By using metallic conductive fillers, the device can be made smaller, holds higher current levels and most importantly, offers resistance values in the single digit milliohm range. Table 3 compares the electrical characteristics of the standard carbon MF-D, MF-SVS and the MF-LL Series.

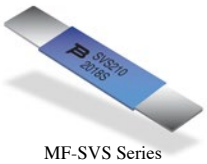
Table 3. | *Standard and Low Loss PPTC Characteristics*

Parameter	Bourns® MF-D Series	Bourns® MF-SVS Series	Bourns® MF-LL Series
V_{max} (V)	10	10	6 – 10
I_{hold} (A)	1.7 – 2.3	1.7 – 5.2	1.8 – 3.7
R_{init} (mOhm)	10 – 32	10 – 32	5 – 10
$R1_{max}$ (mOhm)	64	64	24
Package	Disk	Strap	Strap

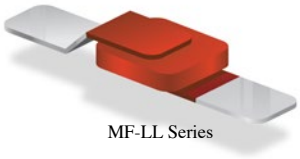
Addressing Li-ion Battery Pack & Battery Cell Reliability Threats

with Bourns® Multifuse® Polymer Positive Temperature Coefficient (PPTC) Resettable Fuse Protection

MF-D Series



MF-SVS Series



MF-LL Series

BOURNS TECHNOLOGY ADVANTAGES

In order to meet the growing needs for battery cell and battery pack design, Bourns continues to innovate and expand its portfolio. Bourns has been a leader in the circuit protection industry for decades. Bourns offers a broad portfolio and provides designers with circuit protection components to meet the needs of increasingly complex, demanding, and compact battery packs. Advances in Bourns' technology include the use of low-loss nickel powder in the Bourns® MF-LL Series. With excellent customer service and the availability of field application engineers, Bourns works closely with designers to choose the appropriate components, with modifications as necessary. Leaving the details of circuit protection technology to Bourns allows designers to concentrate on their expertise.

ADDITIONAL RESOURCES

For more information on Bourns® circuit protection components, visit Bourns online at:

www.bourns.com

COPYRIGHT© 2012 • BOURNS, INC. • 4/12 • e/MF1202
"Bourns", and "Multifuse" are registered trademarks of Bourns, Inc. in the U.S. and other countries.

BOURNS®

4/12 • e/MF1202

Americas: *Tel* +1-951 781-5500
Fax +1-951 781-5700

EMEA: *Tel* +41-(0)41 768 55 55
Fax +41-(0)41 768 55 10

Asia-Pacific: *Tel* +886-2 256 241 17
Fax +886-2 256 241 16