

Bourns Battery Pack Protection Overview

WHITE PAPER



Bourns® Multifuse® PPTC
Resettable Fuse
MF-NSML/X Series



Bourns® Miniature
Resettable Thermal
Cutoff (TCO) Device
AC Series



Bourns® Current
Sense Resistor (CSR)

INTRODUCTION

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 operation, a battery pack is charged through a conventional wall outlet, a Universal Serial Bus (USB) port, or other adapters and then discharged through active use or standby operation. Throughout this repeated cycle, there are numerous threats to the integrity of the battery including potential 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.

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. 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. Looking at the future, Li-ion battery packs will extend beyond these applications, and are already being employed by vehicles, industrial machinery and stationary power storage.

Battery packs are becoming increasingly 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 challenges. 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.

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BATTERY REGULATION (CONTINUED)

Table 1 - Regulatory Tests for Battery Packs and Battery Cells

Test	Battery/Application
UL 1642	Secondary battery cells, including lithium
UL 2054	Secondary battery cells and primary batteries
IEC 62133	Secondary lithium and nickel cells and battery packs
IEC 1725-2006	Rechargeable batteries for cellular phones
IEC 60950-1	Battery-powered devices that suffer electric shock, energy, fire, mechanical, heat, radiation, chemical, and material hazards

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 Tests	Requirements
Crush	No explosion, no ignition
Impact	No explosion, no ignition
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 Enclosure Test	Requirements
Projectile	No explosion, no ignition

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CHARGE AND TEMPERATURE

During charging and discharging cycles, battery cells typically 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 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 circuit is sufficiently mild, little heat will be generated and the battery will simply discharge more rapidly. However, more severe short circuits may result in overheating and its associated threats. In a multi-cell pack, the cells adjacent to the shorted cell can overheat or fail.

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 external temperatures. Circuit protection solutions for battery packs comprise a combination of several devices, which are crucial design considerations during charging and discharging of the battery pack.

The two most popular overvoltage and overcurrent protection methods in cell designs utilize battery management Integrated Circuits (ICs) and FETs (Field-Effect Transistors). Most battery pack, battery cell and specifically single-cell Li-ion battery pack designs will need a second level of protection. Bourns® Multifuse® Polymer PTC (PPTC) devices or the Company's miniature resettable TCO devices, also known as mini-breakers, are optimal overtemperature protection solutions.

In addition, dual battery management ICs and FETs provide a two-fold level of overvoltage and overcurrent protection, where the protection design can include a Current Sense Resistor (CSR) to monitor the voltage/current.

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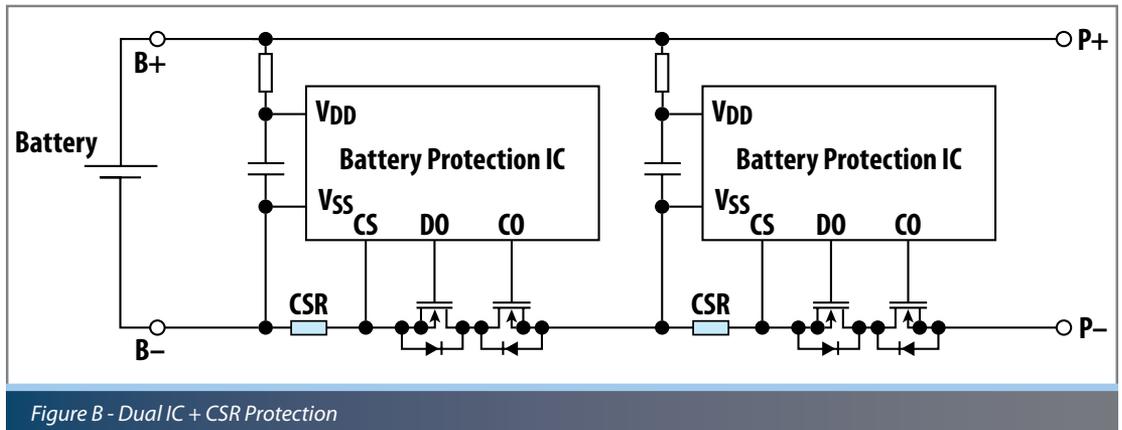
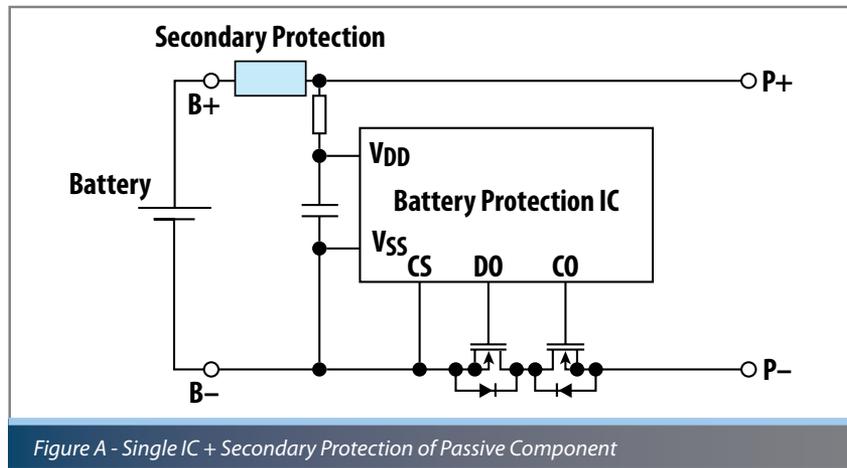
Bourns® Miniature Resettable Thermal Cutoff (TCO) Device AC Series



Bourns® Current Sense Resistor (CSR)

ADDRESSING THREATS WITH PROTECTION (CONTINUED)

In order to provide reliable protection, the PPTC or miniature TCO device will need to be mounted in such a way that the device 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 A shows the schematic of a battery cell that uses a Bourns® Multifuse® PPTC resettable fuse or miniature resettable TCO device for protection. Figure B is a schematic of a new battery cell protection design that employs Bourns® current sense resistors.



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ADDRESSING THREATS WITH PROTECTION (CONTINUED)

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 situations. Under normal operating conditions, the Bourns® Multifuse® PPTC device has a small resistance (10 mΩ max.) 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. The Bourns® Multifuse® MF-USML/X series are new low-power-loss formulation PPTC devices featuring high hold currents (7 A max.) for additional stability and reliability, making them an optimal choice for high capacity battery packs.

Bourns has numerous miniature resettable TCO devices that support high current capacity with the Model AC Series featuring up to 20 A at 60 °C, which is the highest current-carrying TCO device Bourns offers. Bourns® latest TCO devices are designed to meet the next-generation protection needs of denser, higher capacity Li-ion battery cells. These new protection devices also deliver extremely low impedance and resistance (2 mΩ max.) while helping battery pack designers save valuable design space and weight. The lighter, smaller size and higher capacity current/voltage withstand advantages provided by these TCO devices also enable designers to extend Li-ion cell usage beyond the traditional laptop, tablet and smartphone applications to power tools, electric vehicles, e-bikes and grid storage applications.

Enhanced battery performance management that relies on tight and low Temperature Coefficient of Resistance (TCR) can be achieved with current sense resistors to accurately measure drift and resistance. Bourns has a comprehensive line of current sense resistors. The Bourns® Model CRK0612-FZ-R003E current sense resistor is offered in one of the industry's smallest packages, and features a low TCR of 50 PPM/°C, helping customers maximize performance and improve efficiencies in modern battery management systems.

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 PPTC devices for battery cells for nearly 20 years and the range today covers the traditional axial leaded battery strap design, bare disc devices for cylindrical cells (e.g., AA and AAA) and the latest low resistance, small sized SMD model series using proprietary ultra-high conductive fillers for enhanced resistance stability over the life of the product. The traditional axial leaded straps are available in the model MF-SVS, MF-VS, MF-LR, MF-LS, and MF-S families. These are used in a wide range of battery applications including mobile phones and tablets, powered toys, powered tools, and battery-powered handheld medical devices. They range in operating currents up to 9 A and operating voltages as high as 30 V.

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EFFECTIVE BATTERY PACK PROTECTION (CONTINUED)

The MF-D series resettable fuses are customized disc PPTC devices. 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 include the model MF-USML/X, MF-NSML/X, MF-PSML/X, MF-FSML/X, and MF-ASML/X Series. These families are unique because they do not use carbon as the conductive element. By using proprietary metallic conductive fillers, these devices can be made smaller while at the same time delivering higher hold current levels, and most importantly they offer resistance values in the single digit milliohm range. Table 3 compares the electrical characteristics of the standard carbon model MF-D, MF-SVS and the ultra-low resistance SMD model MF-USML/X series.

Table 3 - Standard and Low Ohmic PPTC Device Characteristics

Parameter	Bourns® MF-D Series	Bourns® MF-SVS Series	Bourns® MF-USML/X Series
V_{max} (V)	15	10	6 - 12
I_{hold} (A)	2.5 - 12.2	1.7 - 2.3	1.75 - 7
R_{min} (mOhm)	7 - 32	10 - 32	10 - 60
$R1_{max}$ (mOhm)	64	64	8 - 50
Package	Bare Disc or Chip	Axial Leaded Strap	Surface Mount (EIA 1210)

THE BOURNS ADVANTAGE

In order to meet the growing need for battery cell and battery pack designs, Bourns continues to innovate and expand its portfolio. Bourns has been a leader in the circuit protection industry for decades. The Company's broad portfolio allows designers to select the right circuit protection component to meet their increasingly complex, demanding, and compact battery pack requirements.

With a reputation for excellent customer service and the availability of knowledgeable and experienced field application engineers, Bourns works closely with designers to choose the appropriate components with modifications, as necessary. By leveraging Bourns' extensive circuit protection technology expertise, developers can concentrate on what they do best: their next battery pack design.

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