# PPTC Devices Protect Circuits and Maximize Battery Pack Run Time

## Low resistance PPTC devices provide both overcurrent and over-temperature protection

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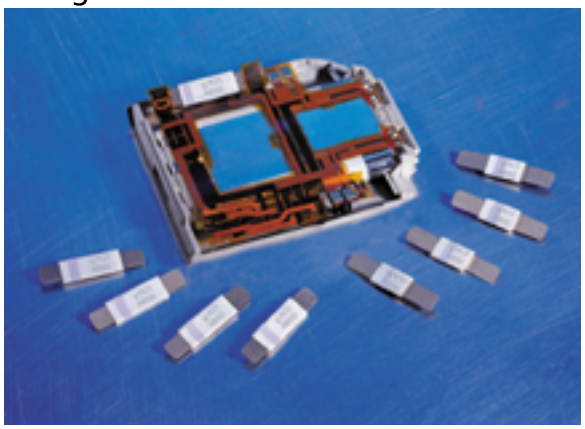
Wireless communication is transforming the way we live and work, and consumer demand for smaller portable equipment that provides longer run time is driving the development of smaller, lighter cells with higher energy density. Advances in digital wireless phones, cameras, and camcorders, which require a pulsed current supply, have made the cell's charge rate and internal impedance a critical issue. These new cell chemistries have also increased the complexity of battery circuit protection designs.



***PPTC devices used in a wide variety of portable electronics applications***

Battery cells and packs are sensitive to overcurrent/overtemperature conditions caused by accidental shorting and abusive or runaway charging. These conditions can raise the battery temperature, resulting in cell damage or equipment failure. Accidental short circuits can occur when a metal object, such as a spiral notebook binder or a key ring, bridges the exposed terminals of the battery pack. These short circuits can raise temperatures high enough to damage or burn other components and surrounding materials.

A battery pack overcharge condition may be caused by a runaway charge, in which the charger fails to stop supplying current to the pack once it is fully charged. Abusive charging, in which the pack is reverse-charged or charged under the wrong conditions by an incorrect or faulty charger, can also cause equipment damage.

***Figure 5. Raychem VLR.***

***New Low Resistance Strap Devices Enhance Thermal Protection for Li-Ion and NiMH Battery Packs.***

***Raychem Circuit Protection's new PolySwitch&reg VLR230 and VLR170 devices provide very low series resistance (VLR230 typical 15 mW) and thermal protection for Lithium-Ion (Li-Ion) and Nickel Metal Hydride (NiMH) rechargeable battery packs typically used in portable equipment. When an electrical short or overcharging condition occurs, VLR devices provide a high resistance trip condition that eliminates cycling and resets once the fault has been cleared and power has been removed.***

***The VLR device's narrow, low-profile form factor allows it to be welded directly onto battery cells, thus saving battery pack manufacturers space and added installation costs. VLR devices are well suited for single-cell Li-Ion applications. VLR devices' low trip temperature and fast time-to-trip &#151 typically 2.4 seconds or better at 10 A - provide protection for rechargeable battery applications, while allowing longer battery pack life and extended equipment operation time.***

**Circuit Protection Design Considerations**

In the past, designers of portable equipment had only one option for overcurrent protection &#151 single-use fuses. In addition to the fact that thermal fuses are difficult to set at the low temperatures required for charge protection, they may trip in high ambient temperatures, disabling an otherwise functional pack.

The evolution of resettable polymeric positive temperature coefficient (PPTC) devices has recently made them the device of choice. This trend is due to the fact that the majority of fault conditions a battery pack encounters are relatively infrequent or intermittent events, and resettable protection is a more effective and practical solution.

Ceramic PTCs and bimetallic circuit breakers can also be used to provide resettable protection, although these devices demonstrate significant disadvantages in portable equipment applications. Bimetallic circuit breakers are electromechanical and typically subject to cycling on and off, which causes contact arcing and wear. They are also relatively large. Ceramic PTC devices are higher in resistance and have slower trip times &#151 and low resistance is critical for maximum equipment run time.

PPTC devices are now considered the most effective method for battery circuit protection, due to their resettable functionality, low resistance, and thermal protection characteristics.

**PPTC Principle of Operation**

PPTC circuit protection devices are made from a conductive polymer blend of specially formulated plastics and conductive particles. At normal temperature, the conductive particles form low-resistance chains in the polymer (Figure 1). However, if the temperature rises above the device's switching temperature, the crystallites in the polymer melt and become amorphous. The increase in volume during melting of the crystalline phase causes separation of the conductive particles and results in a non-linear increase in the resistance of the device. The heating can take place due to an increase in ambient or cell temperature, or it can be generated by resistive heating as in the case of an overcurrent condition. It can also be a combination of the two as in the case of a faulty charge.

The PPTC's increased resistance protects the equipment in the circuit by reducing to a minimal level the amount of current that can flow under the fault condition. Once the fault is cleared and power to the circuit is removed the device automatically resets, restoring the equipment to normal operating conditions.

PPTC devices are employed as series elements in a circuit, and protect the circuit by going from a low-resistance to a high-resistance state in response to an overcurrent or overtemperature event (Figure 2). This is referred to as &quottripping&quot the device. PPTC devices are available for a variety of operating currents, and each device is specified by a &quothold&quot current, which is the maximum current that the device will pass without tripping at a designated temperature (typically 20 &#176 C).

**Internal and External Protection with PPTCs**

The common industry practice for protecting individual Li-Primary and cylindrical Li-Ion cells from overcurrent conditions is the PPTC device, in the form of annular discs inside the lid assembly of each cell. These work in conjunction with other safety devices, such as separators and pressure vents. Because the design of lid assemblies varies from manufacturer to manufacturer these are usually custom devices.

The system designed to protect the battery pack from overcurrent and overcharge damage typically includes bimetallic circuit breakers or PPTC devices. In the case of NiMH packs this may be the only protection. However Li-Ion packs include an active safety circuit (IC and MOSFETs). During fault conditions voltages can be significantly higher than in normal operation and currents for both applications can be several ten's of amps depending on the shorting resistance. During the runaway charge condition, packs need to be protected against temperatures, exceeding approximately 100°C for packs containing NiCd cells, and 80 &#151 90 &#176 C for those containing NiMH or Li-Ion cells.

In response to the increased sensitivity of higher energy density chemistries, such as NiMH and Li-ion, to overtemperature during charge new low-temperature PPTCs have been developed to cut charging current to cells in the case of excessive temperature rise. Whether this rise is due to external short circuits or abusive charging, the PPTC strap device, installed in series with the cells inside the pack, provides both overcurrent and overtemperature protection, and eliminates the need for a thermal fuse or bimetallic breaker (Figure 3).

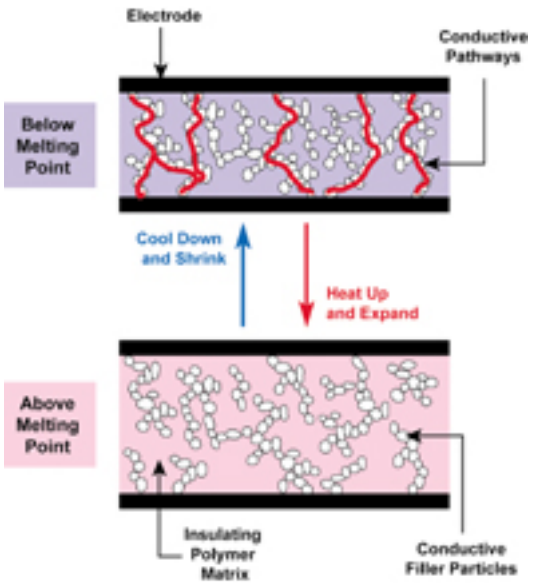



***Figure 1. PPTC devices protect the circuit by going from a low-resistance state to a high-resistance state in response to an overcurrent or over-temperature condition.***

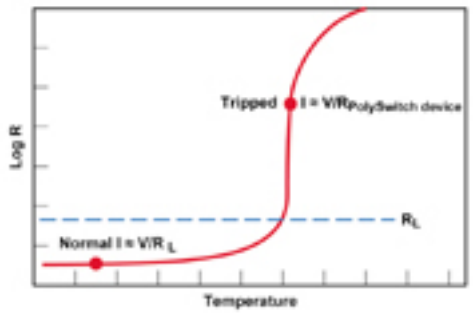



***Figure 2. Typical operating curve for a PPTC device.***

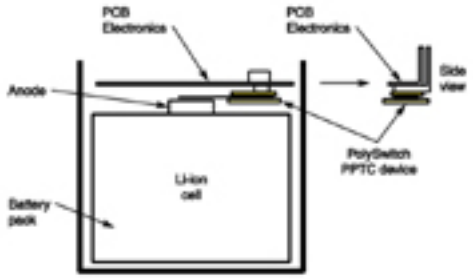



***Figure 3. PPTC strap device protects cellular handset battery pack from overtemperature and overcurrent damage.***

**Charging Li-Ion Cells**

Li-Ion chemistries require particular control to ensure that they are charged and discharged within specified limits. Electrically, the first level of pack protection is provided by an electronic integrated circuit and series FETs. Although this silicon circuitry is considered reliable, there are conditions under which failures may occur, such as excessive electrostatic discharge, high temperature, or oscillation during a short circuit condition.

The permitted charge and discharge profiles for Li-Ion cells differ from manufacturer

to manufacturer, and often include tight tolerances, particularly in the case of charging.

The normal charging method for Li-Ion chemistry is constant current/constant voltage. When charging Li-Ion cells the charger interrogates the pack to determine the exact cell chemistry, capacity and configuration. The charge profile is then adapted to the pack's characteristics. In the case of a non-sanctioned or faulty charger that applies excess voltage, the primary protection circuit will activate and cut the charging current, unless it has also been damaged. If the electronics are inoperative, the high voltage will reach the cell, and if the charger is capable of supplying sufficient energy and no secondary current interrupt device is included, a significant rise in cell temperature may occur. These effects will be compounded if the charger does not accurately measure the pack's temperature during charge.

In this application, the PPTC is often included for secondary protection. In the event of an electronic failure or the occurrence of events outside the electronics' detection capability, the PPTC device limits the cell charge or discharge current to a safe level.

Low temperature PPTC devices are uniquely suited to limiting the charge current close to the functional pack's operating temperature. The device's resettable function means that nuisance tripping, which can be caused by exposure to direct sunlight or other heat sources, does not permanently disable the pack.

**Conclusion**

Polymeric PTCs are widely used to protect battery packs for wireless equipment. The principal advantage of new low-temperature PPTCs is that they provide both overcurrent and overtemperature protection in a single device. The PPTC is resettable, and once the device has tripped a low-level trickle current keeps the device in its high-resistance state, preventing the cycling that occurs with typical bimetals. Although new latching bimetals have been developed, they do not always latch at the low-voltage levels found in portable electronics applications.

The nickel leads and low profile of PPTC devices allow them to be welded directly to battery cells without encumbering pack design. They meet UL1950/ IEC 950 safety requirements and are available in a wide range of sizes and ratings, allowing the designer to select the best device for a specific battery pack protection application.

**Frank Owen is the Marketing Director of the Raychem Circuit Protection Division of Tyco Electronics. He is specifically responsible for battery and portable electronics marketing. In addition to ensuring the successful market introduction of new PPTC circuit protection products he is responsible for identifying and championing Raychem's new material and device opportunities in the rapidly growing portable electronics market.**

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