Rechargeable Battery Pack Protection

Application Note

Battery packs for the power supply of portable electronics equipment such as cellular phones, PDAs and laptop computers have particular protection requirements. Pack protection is required to provide continuing pack performance and consumer safety following misuse. In the last few years many different battery cell technologies have evolved and each of them requires its own specific protection solution.

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Problem

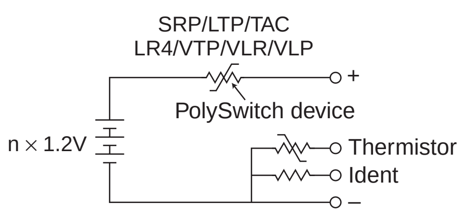
The principal electrical hazards faced by battery packs are the result of external terminal short-circuits during discharge and overcharge due to a faulty or incorrect charger. Internal pack faults are less common but if complex electronics for features such as fuel gauging or charge control are incorporated then there is an increased risk of internal faults. Any of the above conditions can result in a significant overtemperature event either inside or outside the pack.

Short-Circuits During Discharge

An unprotected battery pack typically can deliver up to 100A of short-circuit current when "hard" shorted by a low resistance element. Power dissipated in the battery cell's internal impedance leads to a rise in cell temperature, the severity of which will depend on the pack's thermal characteristics and the battery cell chemistry.

At a minimum the pack's performance will deteriorate, and with some packs thermal runaway may take place resulting in venting, smoke or flame. If an unprotected pack is "soft" shorted by an element with some resistance, for example a few hundred milliohms, then the hazard changes from being power dissipated in the cell to power dissipated in the shorting element. Tests have shown that the resistive shorting element can reach temperatures in excess of 600°C in this situation and may result in ignition of adjacent combustible materials.

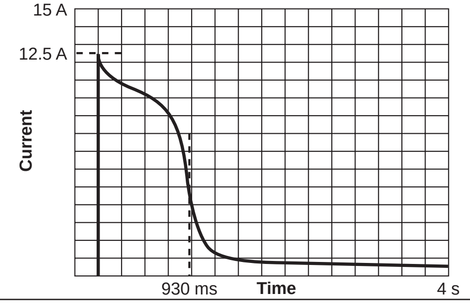
Figure 1. NiMH/NiCd Battery Pack Circuit Diagram



Battery Pack Overcharge

Each cell chemistry requires a specific charging profile to

Figure 2. NiMH Battery Pack Short-Circuit Interrupted by PolySwitch Strap Device



produce maximum performance and to minimize hazards. If this profile is not adhered to then overcharge can occur. A battery pack overcharge condition may be due to:

- A runaway charging condition, in which the charger fails to stop supplying current to the pack once it is fully charged. This is typically caused by a charger fault.
- Abusive charging occurs when the pack is charged under the wrong conditions by an incorrect or faulty charger. This is especially likely to happen when aftermarket chargers are used. To cope with the proliferation of battery chemistries, capacities and end-user products, a wide range of charger products has become available with limited standardization. Product reliability and/or safety issues may arise in some aftermarket products due to the proprietary nature of cell chemistry and charger designs.

Battery cell overcharge can result from an overcurrent or overvoltage condition or a combination of both. Nickel chemistries (NiCd, NiMH) tend to use a constant-current charge profile with charge termination determined by voltage, temperature, or time detection. Li-ion cells are charged with a constant current followed by charge completion with constant voltage. In both cases if current or voltage is allowed to exceed the prescribed values, then a significant rise in cell temperature may result, potentially resulting in venting, smoke or flame.

UL and IEC have set tests for battery pack resilience to both short-circuit and overcharge events (UL1950/IEC 6950). The characteristics of a series PolySwitch device to interrupt charging or discharging current during an unexpected short-circuit or overtemperature are very important.

NiMH & NiCd Pack

Design & Device Selection

Figure 1 shows a schematic of a typical NiMH or NiCd battery pack. The pack contains n x 1.2V cells, depending on the application, in series with a PolySwitch strap as the sole circuit protection component. A thermistor is often incorporated to allow adaptation of charging depending on pack temperature. Depending on the required pack resistance and degree of overtemperature protection required, SRP, LTP, LR4, VTP, and VLR series may all be used. If the cells were AAA form factor then a TAC part could also be considered. Figure 2 shows how a 100mΩ short-circuit of a three cell NiMH pack is interrupted within one second by a VTP210 device.

The primary result of NiMH battery overcharging is the electrolytic generation of gas inside the battery. As this gas is generated, both internal cell pressure and temperature increase. In some cases, the internal heating can raise the temperature high enough to damage the battery's internal structure permanently or even result in venting. Figure 3 shows the combined overtemperature and overcurrent protection of a VTP210 device during an over-

Figure 3. NiMH Battery Pack Overtemperature due to Overcharge Interrupted by VTP Strap Device

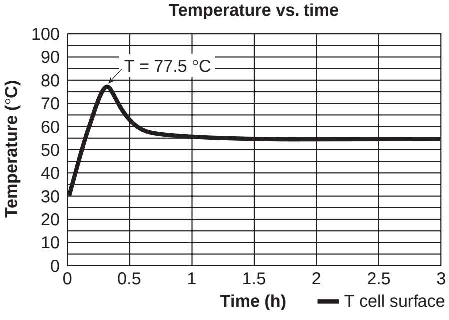
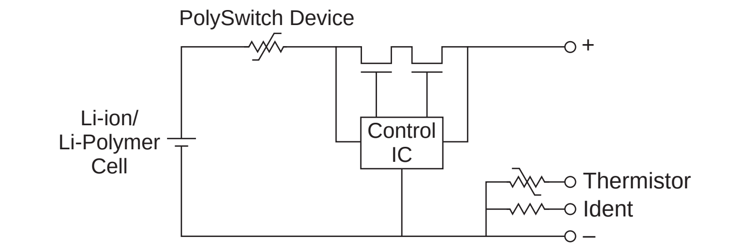


Figure 4. Single Cell Li-ion/Li-Polymer Battery Pack Circuit Diagram



charge event. In this case a 1.5C (825mA) overcharging current was interrupted once the cell surface temperature exceeded 77°C.

Li-ion & Li-Polymer Pack Design and Device Selection

Figure 4 shows a schematic of a typical single-cell Li-ion battery pack for cellular phone or PDA applications. Similar principles apply for multicell applications, such as those for notebook PCs. In addition to a thermistor, packs including Li-ion cells with cobalt-based cathodes typically include two redundant series protection schemes as shown in Figure 4. Two series MOSFETs and a control IC provide overvoltage, undervoltage, and overcurrent protection while a PolySwitch device provides cell overtemperature protection on charge, discharge, and redundant overcurrent protection. Some Li-Polymer cell manufacturers and Li-ion cell manufacturers with manganese-based cathodes may recommend using only a PolySwitch device (perhaps in conjunction with a thermal fuse) without over/undervoltage protection from MOSFETs and a control IC. The precise protection requirement is cell chemistry-dependent and advice should be sought from the cell manufacturer on the exact protection required.

For Li-ion & Li-Polymer based packs, a low temperature/low resistance PolySwitch strap is required, such as devices from the VTP or VLR series. The device's low resistance overcomes the additional series resistance introduced by the MOSFETs and low temperature can provide optimum protection of the cell against thermal runaway in the case of an abusive overcharge. Figure 5 shows how a VTP170 will interrupt a 2.5C overcharge current when the cell temperature reaches 75°C. Welding to the cell body improves heat transfer from an overheating cell into the PolySwitch device.

Regardless of the pack chemistry device hold current is selected on the basis of the maximum average charge or discharge current taking into account maximum operating temperature. Form factor depends on the available space within the pack. A full range of PolySwitch strap devices is available to meet individual pack requirements.

Standards

There are various international standards for battery packs most based on original UL and IEC specifications. Both standards bodies specify short-circuit protection and overcharge tests. For example, UL specifies short-circuits of 8A or greater must be interrupted in 1 minute or less and packs must be capable of withstanding a 2.5C high rate charge. Further details and exact test conditions can be found in UL and IEC specifications.

Technology Comparison

PolySwitch PPTC devices are often used to replace bi-metal or thermal fuse protectors. Bi-metals are often bulky, high cost protectors which frequently do not latch in the protected position in a fault condition. This can result in a cycling battery pack fault and battery cell damage.
Conventional thermal fuses are not resettable and are therefore limited in their ability to match the low temperature protection of PolySwitch devices. The selection of minimum fusing temperature of conventional thermal fuses is limited by the need to avoid nuisance tripping in temporary high ambient temperature environments (such as car dashboards on a hot day or high storage temperatures). Even thermal fuses with 94°C or higher fusing temperatures often nuisance trip during normal operation or pack assembly.

Table 1. Device Selection Summary

Temperature Protection	Resistance	Strap Series*
Low	Low	VLR, VTP
Med	Med	LTP
High	Low	LR4, TAC
High	High	SRP, TAC

*For a full description of suitable part numbers, see the Protection Application Selection Table for Strap Battery Devices in Section 4.