

purchased separately may result in improper charge cycles. The end user may have selected the wrong charger or the charger selected may not have been designed to properly coordinate charge protection. The proliferation of charge adapters for the automobile and airplane have increased the risk for improper charge conditions.

The use of an overcurrent device as a secondary protection circuit will provide protection from excessive current early in the charge cycle, in a short circuit condition that exceeds the power handling capability of the primary protection circuitry and in the event of circuit failure.

Selection of Secondary Overcurrent Protection

The two primary methods for providing secondary overcurrent protection in Lithium-Ion and Lithium Polymer battery packs are one time fuses and resettable polymer PTC devices. Both devices provide protection from current surges but operate in different methods.

The polymer PTC devices are made from a mix of conductive particles and polymer, which are designed to separate upon heating and result in a non-linear shift in resistance. The heating occurs when the device is subjected to an overcurrent event beyond its specified operating range. The shift to a high resistance state limits the current until the source of the fault is removed. A one-time fuse uses a conductive metal that is designed to melt at a specified current level and interrupt the circuit.

The most obvious difference between the two technologies is resettable but there are other factors to consider when selecting an overcurrent device for battery pack protection. A critical factor is the resistance of the protection device. The resistance of polymer PTCs for battery protection can range from 0.015 to 0.250 ohms depending on the rating and terminal configuration. The polymer PTC resistance also will normally shift upwards upon initial operation. The resistance of fuses for battery pack applications is between 0.005 and 0.035 ohms and will be maintained over the life of the device. The lower resistance can have a significant impact on battery life in many applications.

In addition the size and configuration of each technology may dictate which solution is used. The PTC products are available in either a strap configuration or surface mount. Due to limitations in the PTC technology the smallest strap devices are over 12.7 mm (.500") in length. The strap devices must be welded to the battery pack terminals for proper assembly. Surface mount versions of the polymer PTCs are available but the ratings required to prevent nuisance tripping are still 4.57 x 3.04 mm (.180 x

.120") in size. High amperage fuses, up to 7 amperes, are available in surface mount packages measuring as small as 3.18 x 1.52 mm (.125 x .060"). Both surface mount fuses and polymer PTCs require a substrate to mount to. While previous battery pack technologies such as Ni-Cd or Ni-Mh were not suited for surface mount solutions the Lithium technologies require a primary protection circuit which is surface mounted. This provides the option of using a surface mount device for secondary protection, which can be placed using automated equipment to lower the overall pack cost.

While the resettable is a desirable function in many applications where there is significant user contact, such as computer ports, the use in a safety critical application requires some additional considerations. Because the overcurrent device is providing secondary protection in the case of primary protection failure the resettable feature may be a disadvantage. The primary protection circuit uses a control IC/MOSFET that is resettable. It monitors the circuit conditions as resets when the voltage and current return to normal operating levels. In the event the secondary overcurrent device operates this would signal a condition where the primary was not able to trigger properly. A polymer PTC solution would resume conducting current once the fault is removed. In this situation it is likely that a damaged protection circuit is put into operation. The advantage of a one time fuse is that the circuit is permanently disabled and the pack will be inoperable until replaced. It eliminates the possibility of a damaged safety circuit being put into operation.

Model and Rating Selection

Based on form factor, resistance and safety level analysis the device selection can be conducted. The key circuit parameters which must be determined is the normal operating current of the circuit under both charge and discharge, the maximum fault current, any current pulses and the primary protection circuit response time to an overcurrent event.

The overcurrent device selected must have a normal operating current above the charge and discharge current levels. The rating selection must take into account any ambient temperature conditions and appropriate device derating should be conducted using the manufacturers' recommendations.

Once the appropriate normal operating rating is determined the form factor desired will present a number of models which may meet the parameters of the circuit. The model selected must have an interrupting rating greater than the maximum fault current of the application. This will allow the secondary protection device to safely interrupt the overcurrent event.

After the model and normal operating rating have been determined the device must be checked to verify that it will withstand surge currents which may occur. The surge currents are normally caused by start up pulses, or in some applications transmit pulses such as a mobile phone. In addition to the normal pulses, the use of the device as a secondary protection circuit requires that it be coordinated with the primary protection circuit. Circuit designers will normally specify a secondary protection device that is sized to open only under primary protection failure or very large current surges. Because the IC control/MOSFET solution is resettable it will be sized to operate under all normal fault conditions. Under a short circuit the IC/MOSFET circuitry has a built in delay time before it operates. This delay time in a short circuit condition creates an additional pulse that must be compensated for when selecting a fuse to prevent nuisance opening. The delay pulse is usually the largest pulse that the circuit will see and the fuse should be selected to withstand repetitions of this pulse. Consult the I_{2t} rating of the fuse selected and the pulse cycle withstand calculations to ensure proper coordination with the primary protection circuitry.

For single cell battery pack applications the Littelfuse 429 series 4 to 7 ampere ratings provide coordinated protection for many primary protection circuits. For single cell applications where the IC delay time is minimized lower ratings and smaller sizes may be appropriate. The 435 series is available up to 2 amperes in a surface mount package as small as 1.04 x .51 mm (.041 x .020") and the 434 series is available up to 5 amperes in an 1.60 x .813 mm (.060 x .032") package.

For applications where higher energy surge currents are likely to occur, Slo-Blo® Fuses are available, including the 430 and 452 series.

For multiple cell packs the 451 series is available in ratings up to 15 amperes to meet the higher discharge currents.

Conclusion

The use of an overcurrent device as a secondary protection circuit will provide protection from excessive current early in the charge cycle, in a short circuit condition that exceeds the power handling capability of the primary protection circuitry and in the event of circuit failure. With the increased use of Lithium-Ion and Lithium Polymer battery packs in applications where user safety is critical the implementation of secondary protection circuits will ensure an unsurpassed level of safety with minimal cost impact.