Technical Paper

PPTC Circuit Protection for Power Management in Portable Communications/PDA Equipment
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Abstract
Circuit protection is an important component in determining the safety and reliability of battery powered portable electronics equipment. Increasingly complex systems and the profusion of accessories have increased the importance of ensuring that accidental misconnection or short circuit do not permanently damage valuable equipment. This paper presents the use of PPTC (Polymer Positive Temperature Coefficient) devices, sold by Raychem Circuit Protection under the name PolySwitch devices, for overcurrent and overtemperature protection in elements of the power management chain. Line adapters, CLAs (Cigarette Lighter Adapters), cellular phone equipment and battery pack protection are all discussed with the objective of improving overall system reliability during real world use.

Introduction
Power management in cellular phone, PDA or other portable electronics equipment can be broken down into a chain of elements:
• Power conversion (line adapters, CLAs),
• Charge control circuits (cradles or in the equipment)
• Discharge control circuits (portable electronics equipment)
• Accessories (data modems, hands-free kits)
• Battery packs (NiMH, Li-ion, Li-Polymer)

Continued satisfactory operation between all elements is necessary to ensure trouble free operation and satisfied customers. However elements are often physically separated from each other by cables and/or contact assemblies potentially allowing a user to misconnect items or create accidental short circuits. Additionally there is no assurance that original equipment will continue to be used as intended when after-market accessories are introduced by the user. As a result circuit protection must be considered between the elements to address equipment reliability and safety concerns.

Figure 1 considers the type of faults that might occur between the interconnected components of a cellular phone. The majority of faults are temporary in nature and resettleable protection is therefore a distinct advantage in allowing continued operation once the fault condition has been resolved. The use of PPTC devices in resettleable protecting equipment from overcurrent and overtemperature faults in a variety of electrical equipment is well established and indeed PPTC devices are also a good choice for protecting elements of a portable electronics power system.

How PPTC devices protect against overcurrent and overtemperature faults
Polymer PTC 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 2). 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 the melting of crystalline phase causes separation of the

Figure 1: Examples of Faults in Cellular Phone Power Systems (those faults benefiting from resettleable protection shown in italics)
Conductive particles and results in a non-linear increase in the resistance of the device. The heating can take place due to increases in ambient or cell temperature or be generated by resistive heating in the case of an overcurrent. This increased resistance reduces to a minimal level the amount of current that can flow under the fault condition and protects the cell and equipment in the circuit.

The PolySwitch device protects the circuit by going from a low-resistance to a high-resistance state in response to either an overcurrent or an overtemperature event (Figure 4). This is called “tripping” the device. In the overcurrent case, this change is the result of a rapid increase in temperature caused by the generation of heat within the device by resistive heating. PolySwitch devices are available for a variety of operating currents. Each device is specified by “hold” current, which is the minimum current that the device will pass without tripping at 20°C.

PolySwitch device functional description

PolySwitch devices are employed as series elements in a circuit (Figure 3).

Resettable overtemperature protection of linear line voltage adapters

As part of UL1950/1310 and IEC specifications there are limits on the maximum transformer winding temperature for a given class of insulation. For Class A insulation (generally the lowest cost) the maximum permitted winding temperature is 65°C above ambient during normal operation under full load. With the output short circuited the maximum winding temperature permitted is 150°C. The temperature measurement is preferably achieved by measuring the change of winding resistance although it may be ascertained by thermocouple with correction.

Small linear transformers do not necessarily allow significant overcurrent even when directly short-circuited due to circuit impedance and transformer magnetics design. However even a slightly elevated current can lead to a continuous increase in winding temperature which, if left unchecked, may exceed the UL limits. Figure 5 shows how a PolySwitch device can be installed to protect against excessive winding overtemperatures in a resettable manner.
Figure 5: Example of an Unregulated Linear Adapter protected by a PolySwitch Device

Figure 6 shows the arrest of an increasing secondary winding temperature to below the UL limits as the PolySwitch device trips.

Figure 6: PolySwitch devices can limit transformer-winding temperatures to well below UL/IEC specifications

**Cigarette Lighter Adapter Protection Against Overcurrent and Reverse Polarity Faults**

A block diagram of a typical CLA circuit is shown in Figure 7. The PolySwitch device and a transient voltage suppression (TVS) diode provide input protection. An IC-controlled buck converter performs regulation and dc/dc voltage conversion. The PolySwitch device replaces the previous single-use fuse, creating a “plug and forget” product for the user. Four types of faults may be resettably protected by the PolySwitch alone or in combination with a TVS.

- **Load Overcurrent** - Excessive current demand by the mobile phone in a fault condition will trip the PolySwitch device to a high impedance until the faulty load is removed.
- **Reverse polarity** - On incorrect automobile battery installation, the TVS diode will forward conduct through the RUE185-33, which will trip to a high impedance, thus protecting the TVS diode and limiting the reverse voltage across the converter to the TVS forward voltage drop.
- **Automobile circuit protection on converter failure** - If the converter or control IC fails, the resulting short circuit will cause the PolySwitch device to trip to a high impedance, thus protecting the automobile wiring harness and fuses.
- **Transients on engine start** - On engine start, the alternator may generate transient voltage spikes, which would normally be suppressed by the TVS diode. However, if the transients are of sufficient magnitude, they can exceed the TVS diode’s rating. The inclusion of the PolySwitch device prevents damage to the TVS diode by tripping to high impedance before excessive current can cause damage.

Figure 7: Typical CLA Circuit with PolySwitch and TVS Diode Protection

**Cellular Phone and PDA Equipment Protection from Faulty/Incorrect Chargers**

Figure 8 illustrates a simplified charging circuit that might be included within a charging cradle or directly in the portable communications equipment. Two positions for protection can be envisaged, either before or after the active switching regulator.

Figure 8: Charge Control Circuit Protection in Portable Equipment and Charging Cradles
The benefits of including protection before the regulating device include resettable protection against temporary surges, reverse voltage conditions or the connection of a faulty or incorrect line adapter. It also potentially allows the downsizing of the regulator device as it is not required to withstand maximum overvoltage conditions.

The benefits of including protection after the regulating device include resettable protection against reverse battery pack polarity (when primary and/or single rechargeable cells are used) and protecting the pack against overcurrent due to regulating device or other equipment failure.

**Short Circuit and Overcharge Protection of Battery Packs**

PolySwitch devices in a strap format are often used to limit discharge current during accidental pack short circuits or to limit charge current if cells overheat during the charging process. In the case of NiMH packs the PolySwitch device alone is often sufficient for both overcurrent and overtemperature protection. In the case of Li-ion where voltage control is also required then PolySwitch protection would be combined with an electronic circuit capable of detecting and interrupting current on overvoltage, undervoltage and overcurrent faults. In Li-ion packs, depending on the precise electronic circuit implementation and device mounting, a PolySwitch device would have some of the following functions:

- Limiting charge current if excessive current is permitted by the charging circuit during the early part of the charging cycle
- Limiting charge current if cell temperature exceeds a certain level
- Limiting discharge current in the case of a short circuit and electronic circuit failure

Figure 9 shows an example of where complex Li-ion protection circuitry may be simplified with the use of a PolySwitch device providing protection at a lower temperature than would typically be achieved by a thermal fuse. Being resettable, nuisance tripping in storage or on sunny car dashboards is also avoided.

**Conclusion**

The importance of circuit protection between individual power system elements has been discussed and the importance of resettable protection demonstrated.

It has been shown how PolySwitch devices can play a key role in protecting the interfaces between the various elements of a battery powered portable electronics system. The use of lower temperature PPTC materials permits the simultaneous interruption of both overcurrent and overtemperature faults.
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