Training Agenda

– PTC Definition and Circuit Protection
– PTC Basic Characteristics and Related Physics
– Typical PTC Application Examples
– PTC Selection Concepts
– Littelfuse PTC Brands and Future Development
– Frontiers of PTC Technology
Section 1  PTC Definition and Circuit Protection

PTC Definition
– In the electrical circuits Polymer PTC (PPTC) Resistors are over-current protection devices that change from low resistance to high resistance to limit current flow, and reset when current subsides.

PTC Circuit Protection Concepts
– Potential safety threats that require circuit protection
  • Protect abnormal operation of a circuit caused by component failure

– Regulatory requirements related to circuit protection
  • IEC/UL requirements where faults are expected to occur frequently and changing fuses or resetting breakers is undesirable
PTC Definition

- Polymer PTC (PPTC) Resistors are overcurrent protection devices. Like a fuse, they have two terminals and are placed in line with the circuit being protected.

- Under normal conditions, they act as a low value resistor – dissipating little power and barely warm.

- Under fault conditions, they heat up due to $I^2R$ (Ohmic heating; $>100^\circ\text{C}$) and their resistance increases 1000X or more, limiting the current to a small value.

- When the current is removed, the PPTC will return to normal temperature and resistance, restoring the circuit.
Circuit Protection Needs in Consumer PTC Segment

- Motors that might jam or overheat from abuse
  - copiers, computer hard disk drives, paper shredders

- Terminals that might get grounded or shorted
  - USB sockets, cell phone batteries, DC power ports.

- Places where automatically resetting is a key/desired feature

- Systems that need to stay “on line”
  - fire alarm, security, and phone systems

- Process controllers and monitors

- Self-resetting function for remote applications & powered user interface PCBs

- Protect load and power management ICs
PTC Advantages/Disadvantages as Over Current Protection Device

Advantages:
– Limits current to a safe level
– User-transparent, no component replacement required
– Reduces warranty and service cost
– Ideal for remote applications where service difficult/unavailable

Disadvantages:
– Places where the current must be completely and permanently interrupted
  • Primary power inputs
– High Ambient Temperature Applications
  • Or placement near heat sources
  • May cause nuisance tripping
– Memory Effect
  • Repeated cycling can cross-link polymer material and alter “normal” resistance
Section 2  PTC Characteristics and Device Physics

Basic PTC Characteristics
– Current rating
– Voltage rating
– Temperature rating
– Time-current characteristic
– Interrupt rating

PTC Construction and Effects on Related PTC Characteristics
– PTC element vs. electrical characteristics
– PTC element vs. maximum ratings
– PTC package vs. maximum ratings
– PTC de-rating
PTC Electrical Characteristics

- PTC stands for Positive Temperature Coefficient, meaning the resistance of the PTC increases as temperature goes up.

- PPTC devices are made of Polymers which is the plastic material used to produce the resettable characteristic of the PTC.

- PTC device will reset when cooled as compared to the action of a typical “one time” fuse.
PTC Characteristics and Device Physics

**PTC Electrical Characteristics**

Typically, PTCs react slower to overloads than fuses because the device must heat to the trip temperature.

PTCs trip time specifications are specific to each class of product (SMD, Battery, Telecom, etc.) and do not have the same capabilities as fuses.

**SMD PTC Example:**

PTC device will trip at 200% but no maximum time specification
PTC Characteristics and Device Physics

PTC Electrical Characteristics

PTC Trip Times are influenced by:

- Resistance of the device
- Ambient temperature & air currents
- PCB trace size and copper weight
- Proximity of other components

Other items that influence the effective heat transfer rate from the device to its surroundings can also impact performance.
Conductive material (Carbon Black) is blended with a non-conductive polymer (High Density Poly-Ethylene).

Normal Operation: Carbon Black is concentrated between the polymer crystal boundaries and provides a low resistance path.

Overload: At Critical Temperature (achieved through $I^2R$ heating), polymer volume expands as crystals melt, breaking the Carbon Black chains. The result is a very high resistance path.

Resetting: The current must be removed, then the device will begin to cool. As it cools, the Carbon Black is pushed back into the crystal boundaries and resistance will decrease back to a value close to its initial value.
Resistance vs. Temperature curve is the most common way to demonstrate the characteristics of a PTC.

Package style, current rating, and polymer composition all influence the shape of the curve.

**PTC Polymer Current Conduction Mechanism**

**Under Normal Operation**
- At operating current
- Many conductive paths
- Very low resistance

**Under A Fault Condition**
- Excessive current causes device to heat
- Fewer conductive paths, high resistance, cools down and resets
- When current is removed, memory effect occurs due to cross linked polymer

**Normal Operation**

**Fault Condition**
Section 3       PTC Consumer Electronics Applications Examples

Typical PTC Consumer Electronics Application Examples

- Computers and Peripherals
  - Keyboard and Mouse Port Protection
  - Plug and Play Applications
  - Motherboards
  - Disk Drives
- PC Cards
- Printers
- Video Cards
- Network Cards
- Battery Protection of computer technologies using USB 2.0 and IEEE 1394B (FireWire, I-Link).
- Portable devices (cell phones, laptop, & palm computers).
- General Electronics applications such as transformers, security systems, and process / industrial control systems.
For products that include an external AC adapter, a DC voltage (typically in the range of 5VDC to 18VDC) will be supplied. As shown at the left, a fuse or PTC can be used for short circuit and overload current conditions.
DC line protection of USB port

The USB 1.1 and 2.0 standards provide a power line for the device connected. These power lines could be used to power hard disc drives, memory cards, cameras, and other computer peripherals. A PTC can be used for the DC power line for short circuit and overload protection.
For the Vbus line of video and audio game ports, a PTC should be added for overcurrent and short circuit protection.
For portable devices, the power bus of the battery pack should be protected against an overcurrent runaway condition of Li-ion cells. A strap (or SMD) resettable PTC should be used for short circuit and over current protection.
Global Lab Capabilities

• Qualification of all LF products
• UL-Approved Customer Testing in ISO 17025 Lab (Des Plaines)
  – High power (AC/DC up to 1KV/50KA) UL approvals available in DP
  – Telcordia approvals in DP planned (2008)
• Verification of Telcordia, ITU, IEC, FCC, and other industry, regulatory, and safety standards
  – Verification to various OC and OV standards
    • Insure application meets standards before submitting for approval
• Customer Application testing
  – Assistance with design-in and performance verification
    • Help with selection of appropriate technology and rating
  – Application troubleshooting
    • Assistance insuring proper OV/OC and primary/secondary protection coordination
  – Competitive evaluations
    • Competitive or technology performance comparisons
  – Reliability & Tin Whisker data/testing
Section 4  PTC Consumer Electronics Application Product Selection

Key Considerations
- Application temperature
- Hold Current requirement

Other Critical Considerations for Component Selection
- Maximum circuit voltage
- Maximum available short circuit current
- Desired trip current and trip time
- In-rush or transients that may be present
- Package size, mounting method
# Typical LF SMD Polyfuse PTC selection Guide

<table>
<thead>
<tr>
<th>Series Name</th>
<th>0805L</th>
<th>1206L</th>
<th>1210L</th>
<th>1812L</th>
<th>2016L</th>
<th>2920L</th>
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<td><strong>Chip Size</strong></td>
<td>0805 (2012)</td>
<td>1206 (3216)</td>
<td>1210 (3225)</td>
<td>1812 (4532)</td>
<td>2016 (5041)</td>
<td>2920 (7351)</td>
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<tr>
<td><strong>Hold Current (I_{\text{Hold}})</strong>*</td>
<td>0.10-1.00A</td>
<td>0.125-2.00A</td>
<td>0.05-1.75A</td>
<td>0.10-2.60A</td>
<td>0.3-2.00A</td>
<td>0.30-3.00A</td>
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<tr>
<td><strong>Max voltage (V_{\text{Max}})</strong>*</td>
<td>15V</td>
<td>30V</td>
<td>30V</td>
<td>60V</td>
<td>60V</td>
<td>60V</td>
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<tr>
<td><strong>Max fault current (I_{\text{Max}})</strong>*</td>
<td>40A</td>
<td>100A</td>
<td>100A</td>
<td>100A</td>
<td>40A</td>
<td>40A</td>
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<td><strong>Operating Temperature Range</strong></td>
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<td><strong>Lead-Free</strong></td>
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PTC Rating Selection and PTC TC Curve

- Time Current (TC) Curves present the average values of the trip time at a given current for every part number
- PTC trip times will be distributed above and below the curve
- Lower percentage overloads produce a greater variation in trip time
- Customer Verification Test need to be done for actual applications to insure proper component selection
Resistance of the PTC device changes directly with temperature.

The rating of the PTC is influenced by ambient temperature as shown at the temperature de-rating chart.

The heat required to trip the device may come from several sources. Some common sources are:

- resistive heating from the electrical current
- ambient environment
- adjacent components
Some PTC Board Application Guide Lines

- PTC Devices have two distinct resistance ranges:
  - $R_{\text{MIN}}$: the minimum resistance of un-soldered devices
  - $R_{\text{AT}}$: the maximum resistance after soldering
  - $R_{1\text{MAX}}$: the maximum resistance of a device at 20°C, measured one our after tripping or reflow soldering at 260°C for 20 seconds

- Measuring Resistance:
  - Always perform at room temperature
  - Perform at least 1 hr after any heating process to ensure that the device has cooled thoroughly (soldering, testing, etc.)

- Catalog specifications (trip time, hold current, etc.) assume the parts have been mounted to a PCB and the resistance shift has already occurred.
Section 5  Littelfuse PTC  Product Road Map

Polyfuse Brand PTC

– SMD road map
– Radial leaded road map
– Telecom road map
– Axial Leaded road map
Section 6  Consumer Electronics PTC Technology Challenges

- PTC TC curve and tolerance control
- Higher Vmax in a smaller package
- Multiple elements in a single package
- PTC technology combined with other technologies in the same package
- Improved de-rating characteristics
- Higher operating temperatures
- Hi-rel PTC