PolyTron™ Positive Temeperature Coefficient (PTC) resettable device application gudelines

Overview

Positive Temperature Coefficient (PTC) devices are simple, inexpensive, but critical circuit components that protect against overload or short-circuit (fault) conditions. Although multiple differences exist between PTCs and traditional one-time fuses, the most notable is that PTCs can allow current to flow after the fault is cleared without replacing the device, often referred to as resettable.

This technical note introduces the basic concepts of the PolyTron™ PTC devices, their main features, benefits and typical applications. A detailed description of their operation, fault and protection modes, and typical circuit diagram is explored. Specific product details and ordering information is available on the data sheets at www.eaton.com/elx-datasheets.

Definition of terms

Note the terms below are related to DC operating parameters:

Hold current (I_{hold}): Maximum current a PTC device can sustain for four (4) hours without tripping at 23 °C.

Maximum current (I_{max}): Maximum fault current a PTC device can withstand without damage at rated voltage.

Maximum voltage, (V_{max}): Maximum voltage a PTC device can withstand without damage at Imax.

Trip current, (I_{trip}): Minimum current that will switch or trip a PTC device from low-to-high resistance state at 23 °C.

Initial resistance (R_i): - The PTC resistance in initial state, measured at 23 °C.

Post trip resistance (R_1): The maximum resistance measured one hour one hour post reflow (SMD) or one hour post trip (radial-leaded device), measured at 23 °C.

Power dissipation (P_d): Power dissipated from PTC device when in tripped state at 23 °C.

Maximum trip time - PTC response time from onset of fault current to trip.

Basic operation

PTC devices exhibit a positive temperature coefficient (resistance increases exponentially with increased temperature) allowing them to protect circuits exposed to increased currents or temperature. The PTC device protects itself and the circuit by increasing its internal resistance in the event of a short-circuit or overcurrent event as depicted in Figure 1.

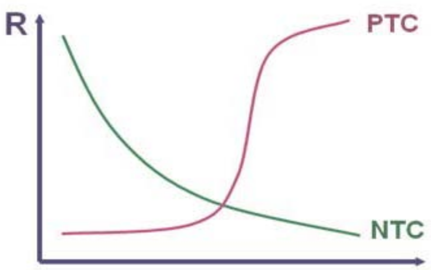

Figure 1. Positive and negative temperature coefficient curves

Figure 1 also shows the counterpart to the PTC, a negative temperature coefficient (NTC), which is a device where the internal resistance decreases as the temperature increases. This feature makes NTCs useful in applications such as push-pull amplifiers, battery protection and sensor applications.

- The simplified operation of PTC devices can be described by two distinct modes: ON and OFF.
  The "ON" or "tripped" mode corresponds to the state in which the device is operational, providing high resistance that provides circuit protection until the fault condition, short or overcurrent, is removed. "Tripping" refers to the quick transition from low to high resistance which happens when a certain current level is exceeded.
- The "OFF"or "normal" mode corresponds to the normal low resistance state in which the PTC device is "invisible" to the circuit, (i.e. there are no through losses due to them). This state is typically refered to as a standby mode.
- For reference purposes, the resistance ratio between ON vs.OFF state is in the 6 - 10x range.

PTCs are comprised of a mix of conductive and non-conductive materials. Under normal conditions the current flows easily through the conductive material, but as the current increases, the conductive particles heat up and the internal composition changes, limiting the current in the circuit. The device remains in this state until the current drops and the material cools down allowing the material to return to its initial composition (low resistance mode) as illustrated in Figure 2.

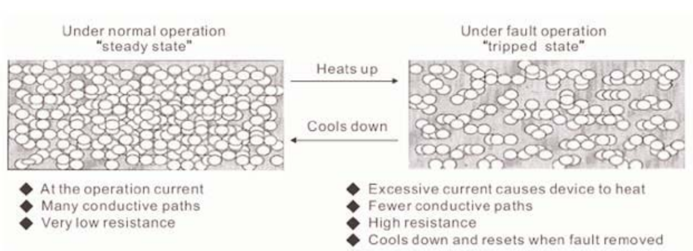

Figure 2. Conductive paths for normal and tripped states

PTCs are intended to protect both primary and secondary circuits and are connected in series with the load. PTCs are not sensitive to polarity. In some cases, such as sensitive or expensive loads where increased circuit protection is needed, both supply lines are protected as shown in Figure 3. All lines including the ground are typically protected in most telecommunication equipment (base stations, routers, gateways, etc.), where multiple supply lines are (potentially) exposed to external faults. Additional inductors and capacitors are also used on the power supply lines to help filter the noise and electromagnetic interference (EMI) often generated by motors to avoid affecting other surrounding electronic devices powered from the same lines.

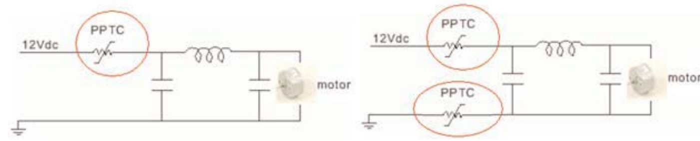

Figure 3. Typical PTC application: Single/multiple supply line protection

One-time fuse vs. PTC resettable device

The following is a short summary of the general differences between PTC devices and one-Time fuses.

Leakage current:

- One-time – After overload, no current flows in circuit
- PTC – After overload, limits current flow in circuit to a low leakage level

Fault current:

- One-time – Similar to interrupting rating, fuse will completely interrupt the current at this amp rating
- PTC – The maximum current the device can limit; the current is not interrupted

Operating voltage rating:

- One-time – Fuses can be rated up to 600 V
- PTC – Typically rated up to 60 V; though there are some rated for 125 V - 250 V for telecommunication applications

Hold current rating:

- One-time – Typically ratings up to 30 A and sometimes higher
- PTC – typically ratings up to 14 A

Temperature derating:

- One-time – Percent of rating typically varies approximately 80% to 110%
- PTC – Percent of rating varies from 40% to 150%

Resistance:

- One-time – Low resistance
- PTC – Typically has twice the resistance of similarly rated one-time fuse

Time current characteristics:

- One-time – Available in fast-acting and time-delay
- PTC – Time-current curves are most similar to a time-delay fuse

Key parameters and selcting a Polytron™ PTC device

Key parameters are important to help detrmine which PTC device is best suited for an application. The following is list of basic questions and guidlines that will aid in the selection process.

1. What is the normal operating current (I_{hold}) expected in the circuit?

- Select a PTC device that gives at least a 20% margin over the calculated current at 23 °C. For lower or higher temperature operation refer to the derating curves on the datasheets to detrmine the needed rating.

2. What is the maximum circuit voltage (V_{max})?

- Select a PTC device that has a voltage rating equal or higher than the maximum circuit voltage.

3. What is the maximum fault current (I_{max}) in the circuit?

- Select a device that can withstand the maximum current in the circuit. For capacitive loads account for in-rush currents.

4. How fast does the PTC response need to be?

- This greatly depends on the application. Refer to the time-to-tripcurves on the data sheet to detrmine the needed rating. Estimate at least a 10% - 20% margin to ensure proper operation, especially for capacitive loads.

5. What is the maximum power dissipation during the tripped state?

- For some specific battery powered applications with strict standby or operation current, the tripped current (and indirectly the power dissipation) is very important.

6. What is the resistance ratio (normal vs. tripped)?

- This is important to know in determining the voltage drop across the PTC device during normal or tripped state.

7. Verify the installation layout for proper selection product type.

- Eaton offers Radial or SMD solutions in a variety of sizes and ratings.. Verify the installation layout for proper selection product type.

The following information provides in-depth details of some of the key parameters and data sheet specifications.

The Eaton PTC data sheet provides a table of key specifications needed for selction of a device. Figure 4 provides a snap-shot specification table data sheet example. Selecting the PTR016V0090 as the example, it can be detrmined that the maximum voltage allowed is 16 Vdc and the maximum current allowed is 40 A. The hold current is 0.9 A and the trip current is 1.8 A. This device has a 0.6 W maximum power dissipation and takes 1.2 seconds to trip at 8 A maximum. The initial resistance is 0.07 Ω that increases to 0.18 Ω in tripped mode.

Specifications												
Catalog Number	V_{max} (Vdc)	I_{max} (Amps)	I_{hold} @23°C (Amps)	I_{trip} @23°C (Amps)	P_d Typ. (W)	Time to Trip (Max.) (Amps)	Time to Trip (Max.) (Sec)	Resistance (Ω) Initial (R_i) Min.	Resistance (Ω) Initial (R_i) Max.	Resistance (Ω) Post Trip (R_1) Max.	Agency Information cURus	Agency Information TUV
PTR016V0090	16	40	0.90	1.80	0.60	8.00	1.20	0.070	0.120	0.180		X
PTR016V0110	16	40	1.10	2.20	0.70	8.00	2.30	0.050	0.095	0.140		X
PTR016V0135	16	40	1.35	2.70	0.80	8.00	4.50	0.040	0.074	0.120		X
PTR016V0160	16	40	1.60	3.20	0.90	8.00	9.00	0.030	0.061	0.110		X

Figure 4. Data sheet specification table

The time-to-trip curves are a usefull tool to help detrmine the proper needed trip current for an application. Each PTC value has a colored line representing the time it takes to trip for differnt current values. Using the example curve in Figure 5 and following the yellow line from the top of the graph to the bottom, the PTC device represents typical trips at:

- 1000 seconds @ 1.5 A
- 1 second @ 4.8 A
- 0.2 seconds @ 9 A
- 0.03 seconds @ 18 A
- 0.01 seconds @ 25 A

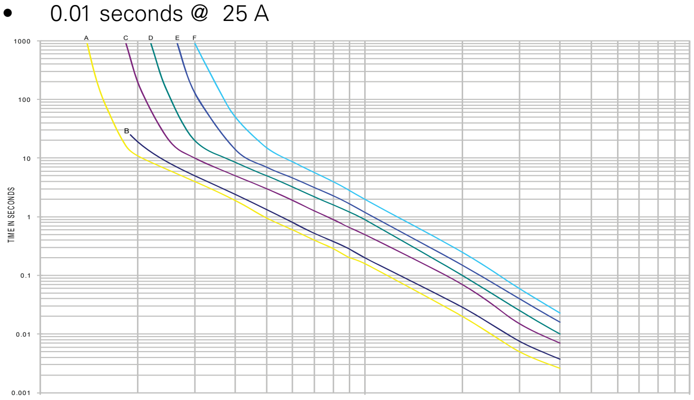

Figure 5. Typical time-to-trip curve

Temperature directly affects the performance of the PTC device. Derating of the specified or rated current is necessary to accommodate operating temepeatiures above or below the rated current specifications. The thermal derating curve is the tool to be used to help determine the proper derating.

Figure 6 is a typical derating curve example. One can select the temperature (horizontal axis) with the derating point (vertical axis). For example, the 100% derating point intersects the line at +20 °C.

To better understand this graph and the PTC behavior, the following are examples using the derating curve.

The example parameters are +20 °C and 100% derating corresponds to a current I_{hold} of 1 A.

If the PTC device is operating at -20 °C, the % derating is 130%.

The new current rating would be I(-20 °C) = I_{hold} * 1.3 = 1.3 A

If the PTC device operates at +80 °C, the derating % would be 50%. The new current would be I(+80 °C)= I_{hold} * 0.5 = 0.5 A

In summary, the PTC hold current (I_{hold}) is:

- 1.3 A at -20 °C
- 1 A at +20 °C
- 0.5 A at +80 °C

Increasing the operating temperature above +20 °C, the hold (or trip) current is reduced by a factor of 0.5 (50%). The opposite is true for low temperatures. By decreasing the operating temperature (below +20 °C) to -20 °C, the hold (or trip) current is increased by a factor of 1.3 (130%).

The designer must be aware of the variation of the circuit's operating temperature and apply the correct derating to ensure proper circuit protection operation.

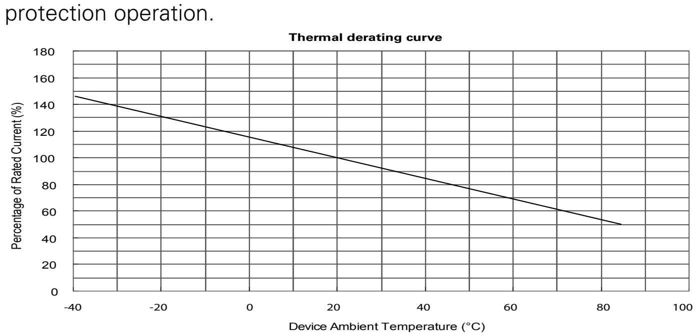

Figure 6. Typical thermal derating curve

Trip time vs. current, measured at different operating temperatures (0 °C, +20 °C and +60 °C) illustrates the the temperature influence on the trip time and current depcted in Figure 7.

For a 5 A trip current the trip/response time is about 1 second @ +60 °C, 10 seconds @ +20 °C and 10,000 seconds @ 0 °C.

The higher the temperature, the shorter the trip time. The designer should understand the variation in trip time with temperature and consider how the trip time affects the specific application.

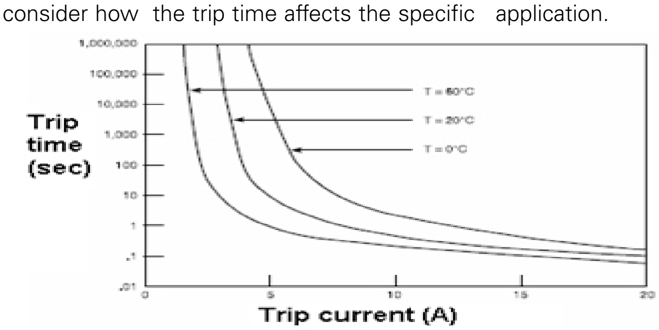

Figure 7. Trip time vs trip current temperature dependency

Product offering and application examples

PTCs are available in a variety of sizes, shapes and packages both surface mount and through-hole making them suitable for a wide range of circuit protection applications. Figure 8 displays a snapshot of the Eaton PTC product offering.

Eaton offers a complete range of overcurrent and overvoltage protection solutions, including the PTC, one time fuses, and ESD suppressors. These solutions are suited to fit even the most complex application requirements in terms of currents, voltages, response

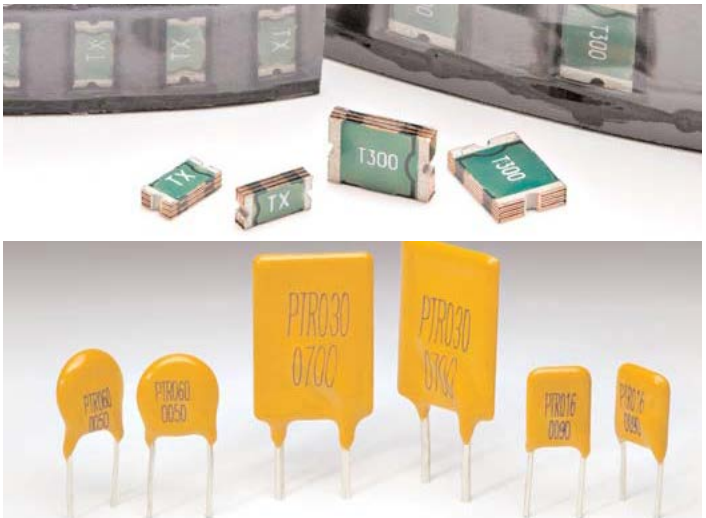

Figure 8. Eaton SMD and through-hole PTC product offering

For more complete circuit protection against ESD faults and short-circuit, PTCs are typically complemented by ESD suppressors, providing full circuit protection (current and voltage).

The USB example in figure 9 shows the PTC device protecting the circuit against short-circuit or overload on the USB supply line. The ESD suppressors protect the data lines against any voltage spikes that can damage the microcontroller or the load.

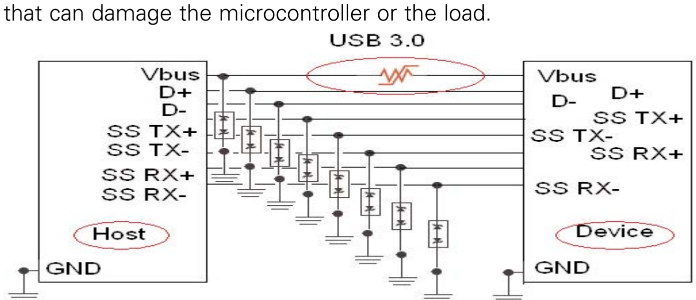

Figure 9. Typical PTC and ESD USB 3.0 application.

A typical rechargeable battery pack for mobile phones, MP3, and cameras is shown in Figure 10, but the analogy of its functionality can be easily extended for any other rechargeable systems. IThe PTC device is used to protect the charging system and the load. The PTC is typically mounted very close to the battery and charging module, so that any temperature increase is easily and quickly detected, ensuring a proper response time.

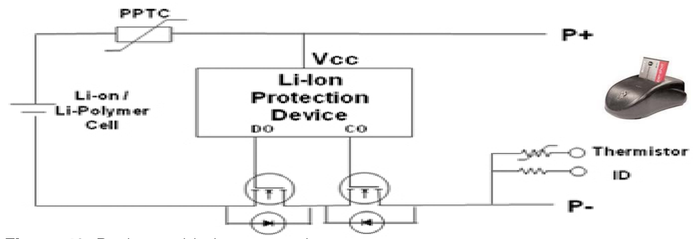

Figure 10. Rechargeable battery pack

The notebook, netbook, laptop or e-book application, the input and output ports are protected by PTC devices shown in Figure 11 (an ESD suppressor is also recommended). The potential for a short-circuit/overload event is very real and PTC devices are ideally suited for this application. Without a resettable overcurrent protection device, the application would require expensive service and long down time.

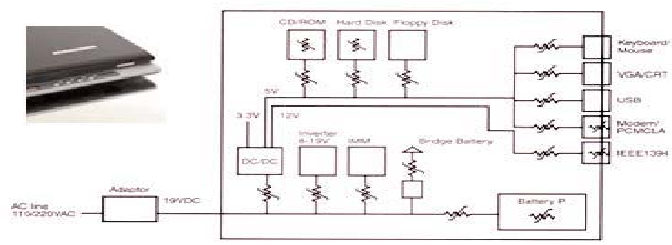

Figure 11. Notebook/laptop protection for I/O Ports, USB and A/V.

Figure 12 is a simplified DC motor drive circuit, the PTC device is designed to protect the power supply and motor from any short circuit or overload condition. The PTC should be selected to carry the inrush current and expected overload current spikes in addition to the normal operating current of the motor.

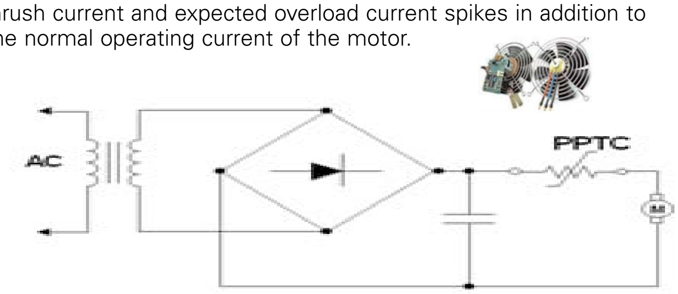

Figure 12. Motor drive protection

Some additional PTC applications include, but are not limited to:

Medical Equipment, Industrial power and transmission, White goods,

Test and measurement, Telecommunications and networking, Computer & Peripherals, Automotive electronics, Consumer electronics, Battery & Rechargeable Devices

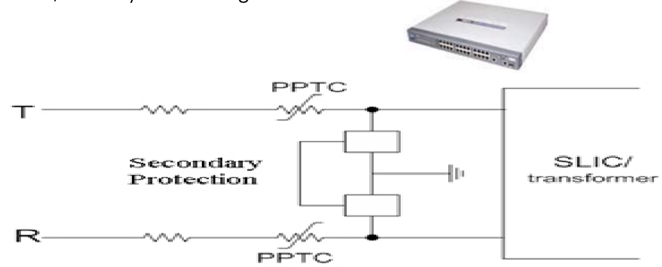

Figure 13. Telecommunication equipment

Eaton
1000 Eaton Boulevard
Cleveland, OH 44122
United States
www.eaton.com/electronics

Printed in USA
Publication No. 4072
December 2016

Powering Business Worldwide