Technical Note **11055**

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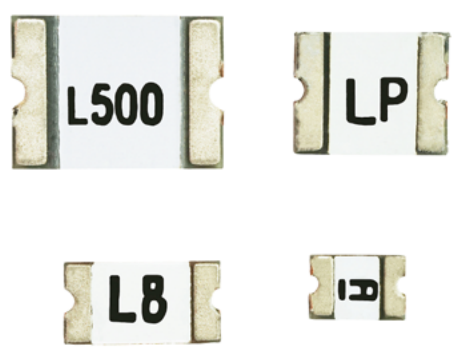
BUSSMANN SERIES

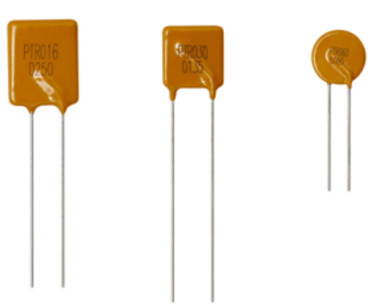
# PTC Resettable fuse application guidelines

### PTSLR family




### PTS family


### PTR family



## Overview

Eaton Bussmann® Series PolyTron positive temperature coefficient (PTC) resettable fuses are circuit protection devices providing overcurrent and overtemperature protection in a variety of applications. Eaton PTC resettable fuses can open electric circuits during fault events like one-time fuses, but are resettable, allowing them to achieve longer use over the product's lifetime. Each PTC fuse consists of a positive temperature coefficient material whose internal resistance increases exponentially with an increase in operating temperature.

Eaton PTC resettable fuses have two functional states — ON and OFF. In the ON, or "tripped" state, the device offers very high resistance in response to faults such as short-circuiting or overheating. This limits current flow through the device until the material cools, then reverts to low resistance mode. In the OFF, or "standby" state, the device maintains a low resistance as the current is within a safe range.

## Key terms

The following are essential terms associated with resettable PTC fuses:

**Hold current ($I_{HOLD}$)**: Hold current is the maximum current the PTC fuse can sustain for long periods of time (4 hours or longer) at +23 °C without tripping.

**Voltage rating ($V_{MAX}$)**: The maximum continuous operating voltage the device can withstand without damage at maximum current, $I_{max}$.

**Trip current ($I_{TRIP}$)**: Trip current is the minimum current required to interrupt current flow through the circuit at +23 °C. At this current level, the PTC resettable fuse is heated sufficiently to switch into a high-resistance state.

**Trip time ($t_{TRIP}$):** Trip time is the maximum amount of time taken for the fuse to switch to a non-conducting (high-resistance) state, at the stated trip current, limiting the flow of current through the circuit.

**Maximum current ($I_{MAX}$):**The maximum amount of fault current the PTC can withstand without damage at rated voltage.

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

**Post-trip resistance ($R_{TRIP}$):** The maximum resistance of the PTC resettable fuse measured one hour after reflow (for surface-mount fuses) or one hour after a trip (for radial leaded fuses), measured at +23 °C.

**Temperature derating:** The derating performed on the hold and trip current ratings at different operating temperatures.

**Power dissipation ($P_D$):** The amount of power dissipated (and heat transfer) by the device during its tripped state at +23 °C.

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## Device selection process

To select or specify the most suitable PTC resettable fuse for your application, Eaton recommends a 6-step process:

**1. Determine your circuit's parameters** - note your normal operating current, max operating voltage, max interrupt current, maximum ambient temperature.

**2. Select a PTC resettable fuse** - based on the maximum ambient temperature and steady-state current. Use thermal derating graphs/charts.

**3. Compare ratings** - use an electrical characteristics table, compare the selected device's maximum ratings with your circuit's maximum ratings.

**4. Determine time-to-trip** - use defined maximum time-to-trip and/or available time-to-trip curves if available.

**5. Verify your operating temperature range** - confirm desired performance in application operating temperatures.

**6. Verify fuse dimensions and mounting style** - for pad layout dimensions or lead dimensions and suitability in end product design.

## Key parameters and selecting a Polytron™ PTC fuse

The following information provides in-depth details of some key parameters and data sheet specifications. The Eaton PTC data sheet provides a table of key specifications needed to select a device. Figure 1 provides a snapshot specification table data sheet example. Selecting the PTR016V0090 as the example, it can be determined 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 trips at 8 A in a maximum of 1.2 seconds. The initial resistance is 0.07 Ω minimum, which increases to 0.18 Ω maximum after one hour of a trip event.

| Specifications | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Catalog Number | $V_{max}$ (Vdc) | $I_{max}$ (A) | $I_{hold}$ @ +23 °C (A) | $I_{trip}$ @ +23 °C (A) | $P_d$ Typ. (W) | Time to Trip (Max.) | | Resistance (Ω) | | | Agency Information | |
| | | | | | | | | Initial (R) | | Post Trip ($R_1$) | | |
| | | | | | | (A) | (sec) | Min. | Max. | Max. | cURus | 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 |
| PTR016V0185 | 16 | 40 | 1.85 | 3.70 | 1.00 | 8.00 | 10.00 | 0.030 | 0.051 | 0.090 | | X |

**Figure 1.** Data sheet specification table.

The time-to-trip curves are a useful tool to help determine the proper needed trip current for an application. If available, each PTC value has a colored line representing the time it takes to trip for different current values. Using the example curve in Figure 2 and following the yellow line from the top of the graph to the bottom, the PTC typically trips at the following:

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

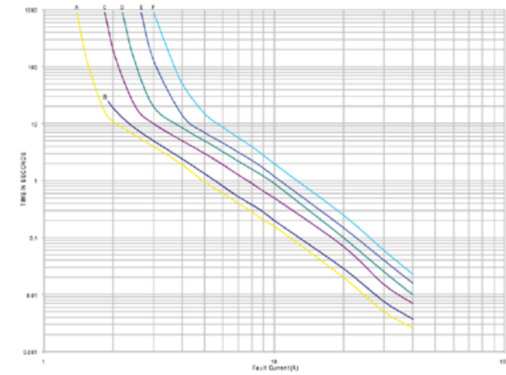

**Figure 2.** Typical time-to-trip curve.

Temperature directly affects the performance of the resettable PTC fuse. Derating of the specified or rated current is necessary to accommodate operating temperatures above or below the rated current specifications. The thermal derating curve is the tool to be used to help determine the proper derating. Figure 3 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.

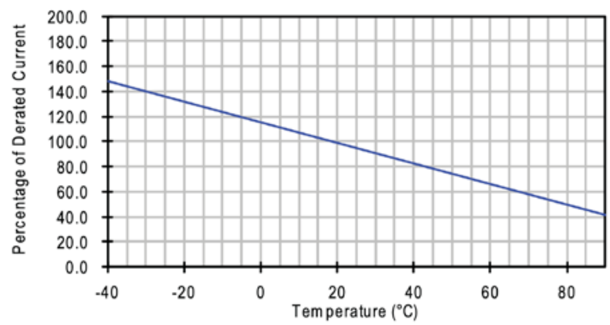


**Figure 3.** Typical thermal derating curve.

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 resettable fuse 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 fuse 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, up to +80° 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.

Trip time vs. current, measured at different operating temperatures (0 °C, +20 °C and +60 °C) illustrates the temperature influence on the trip time and current depicted in Figure 4 on the next page. For a 5 A trip current, the trip/response time is about 1 second at +60 °C, 10 seconds at +20 °C, and 10,000 seconds at 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.

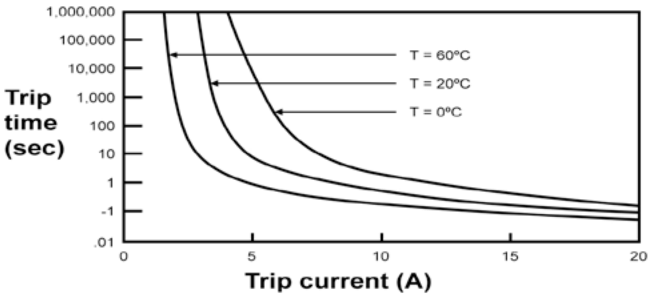


**Figure 4.** Trip-time vs. trip-current temperature dependancy chart.

## Resettable PTC fuses in parallel

There are applications that use resettable PTCs in parallel for a number of different reasons. In this case, only PTC resettable fuses of the same part number and rating should be used. Just as with two of the same resistors in parallel halves the effective resistance in the circuit per Ohm's law, an application with two parallel PTC fuses will experience the same resistance change (50% lower). However, the hold/trip current does not double. A general rule of thumb is that this hold and trip current increase is 1.6 to 1.8 * $I_{hold}$ of a single PTC resettable fuse. The maximum current, $I_{MAX}$ remains the same as a single PTC resettable fuse.

Given the aforementioned PTC tripping behavior at different operating temperatures, PTCs installed in parallel shall be operated in similar environments to ensure they operate similarly and do not cause nuisance trips.

## PTC resettable fuse selection example

PTC resettable fuses come in a wide range of footprints, ratings, packaging, and mounting styles suitable for several applications.

**Example: Circuit Protection of a 12 V Programmable Logic Controller**

Based on the 6-step device selection process outlined on page 2, you need the following information about the circuit to accurately select a PTC resettable fuse:

Step 1:

- Normal steady-state operating current (including surge current)
- Max operating voltage (including possible voltage spikes)
- Max interrupt current (short circuit current)
- Max ambient temperature

Given the following parameters, as an example:

- Normal operating current = 350 mA
- Max operating voltage = 12 V
- Available short circuit current = 20 A
- Max ambient temp = +50 °C

Choose maximum temperature and normal operating current:

- Normal operating current / max temp: 350 mA / +50 °C
- Use a thermal derating curve to find the percentage of derated current at max temp: 75%
- Find required $I_{Hold}$ rating (at room temp): 350 mA / 75% = 467 mA

Step 2: Find the Eaton product with the closest $I_{hold}$>= derated current. Eaton's **PTS12066V050** or **PTS120615V050** are well suited for this application given the initial information gathered in step 1.

**Product specifications**

| Part number[7] | Vmax[1] ($V_{dc}$) | Imax[2] (A) | Ihold[3] (A) | Itrip[4] (A) | Pd[5] typical (W) |
|---|---|---|---|---|---|
| PTS120660V005 | 60 | 100 | 0.05 | 0.15 | 0.4 |
| PTS120660V010 | 60 | 100 | 0.10 | 0.25 | 0.4 |
| PTS120630V012 | 30 | 100 | 0.12 | 0.29 | 0.5 |
| PTS120630V016 | 30 | 100 | 0.16 | 0.37 | 0.5 |
| PTS120624V020 | 24 | 100 | 0.20 | 0.42 | 0.6 |
| PTS120616V025 | 16 | 100 | 0.25 | 0.50 | 0.6 |
| PTS120616V035 | 16 | 100 | 0.35 | 0.75 | 0.6 |
| PTS12066V050 | 6 | 100 | 0.50 | 1.0 | 0.6 |
| PTS120615V050 | 15 | 100 | 0.50 | 1.0 | 0.9 |
| PTS12066V075 | 6 | 100 | 0.75 | 1.5 | 0.6 |

**Figure 5.** Product specifications from PTS1206 data sheet.

Step 3: Now that there are two options available for this application, review the maximum circuit parameters and compare the different options.

- Operating voltage of 12 V
- Available fault current of 20 A

Since the PTS120615V050 has a $V_{MAX}$ of 15 V, it is the only device between the two options that should be applied in this circuit.

Step 4: Evaluate the time-to-trip characteristics of the device selected to confirm that it can provide the desired protection. This can be done by reviewing the $I_{trip}$, the time-to-trip (maximum) information, and time current curves (if available). The PTS120615V050 has an $I_{trip}$ with a maximum time-to-trip of 0.1 seconds at a current of 8 A. At +50 °C operating temperature, the $I_{trip}$ is derated to 750 mA (75% derating factor * 1.0 A).

In this example, required trip times for 2 A and 10 A overcurrent conditions are evaluated. Curve J is the curve for PTS120615V050. This results in approximately 1 second and 30 millisecond trip times at +23 °C, respectively.

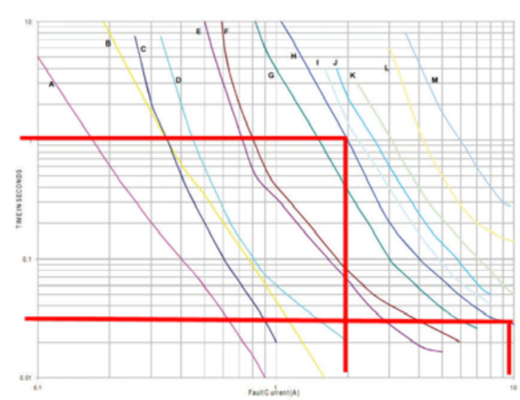

**Figure 6.** Time current curves from PT1206 datasheet.

Step 5: The PTS120615V050 has an operating temperature range of -40 °C up to +85 °C, which more than covers the +50 °C maximum operating temperature of the application.

Step 6: The final step is to review the selected resettable PTC footprint and mounting. In consulting the data sheet, the PTS120615V050 is a 1206 (3216 metric) surface mount footprint that has the provided minimum and maximum dimensions along with the recommended pad layout.

## PTC resettable fuse example applications

Eaton's PTC resettable fuses can provide overload protection in USB 2.0, 3.0, 3.1, 3.2 ports, e.g., on the panels of industrial controllers or consumer electronics. In combination with Eaton's ESD suppressors, they provide robust protection against shorts and ESD faults.

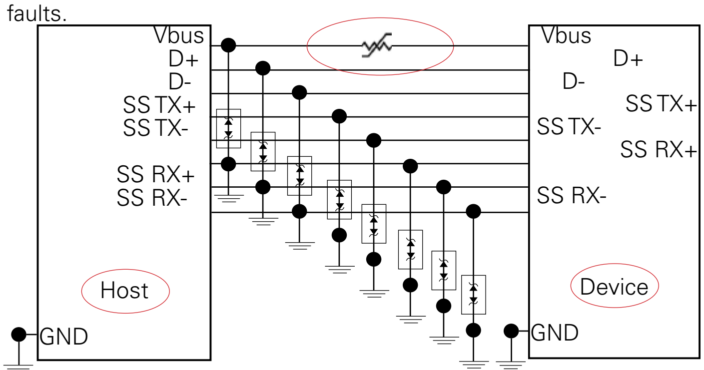


**Figure 7.** Typical PTC and ESD USB 3.0/3.1 application.

Figure 7 shows a PTC resettable fuse protecting a circuit against overload or short circuits on the USB supply line. The ESD suppressors are protecting the data lines against voltage spikes that can damage the microcontroller or the load.

## Overload protection in rechargeable battery

Eaton's PTC fuses can replace one-time fuses to prevent overcharging or overheating in battery packs of low-voltage devices such as mobile devices, smartphones, digital cameras, and gaming consoles.

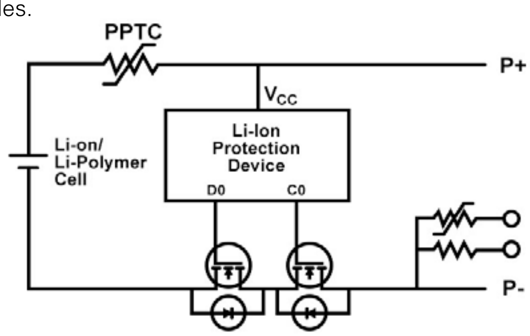


**Figure 8.** PTC fuse protection of passive components in a battery pack.

The figure above shows a typical rechargeable battery pack for a smartphone or digital camera. Here, the PTC resettable fuse is protecting the circuit against shorts or overload on the supply line.

## Overload protection in DC motors

Overload conditions or short circuits can damage the coils of DC motors. Eaton's PTC resettable fuses help to extend the lifespan of DC motors by preventing damage due to thermal overstress in the motor windings.

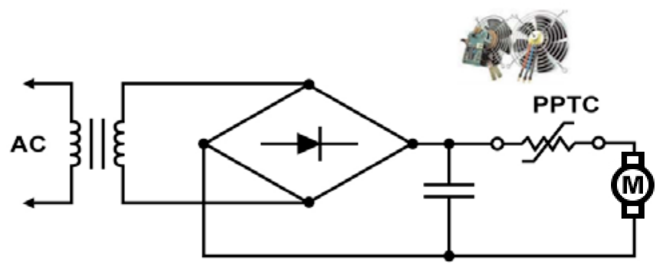


**Figure 9.** Motor drive protection.

Figure 9 shows a PTC resettable fuse connected to a simplified DC motor drive circuit. Here, the fuse is protecting the power supply and motor from overloading or short circuits. The PTC selected should be able to carry the inrush current along with expected overload current spikes and normal operating current of the motor.

## Final notes

A PTC resettable fuse is a protection device only intended to operate during overcurrent and/or overtemperature events that are not normal operation and are generally undesired conditions. They are not intended to be a switch that operates numerous times in normal operation. Treating PTC fuses as switches can cause them to fatigue if cycled too many times or held in a tripped position for extended periods of time.

Also, a resettable PTC fuse is not a one-time fuse (or positive one-time disconnect). There still is a small amount of residual current that flows through the PTC when in a tripped position where a one-time fuse is a one-time disconnect that is designed to permanently open during an overcurrent event.

**For more information about Eaton's PTC resettable fuses, please contact Eaton Electronics or your local Eaton sales representative.**

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