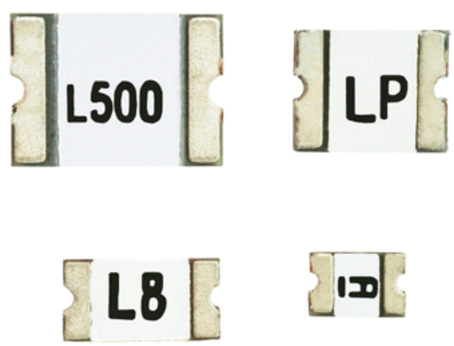
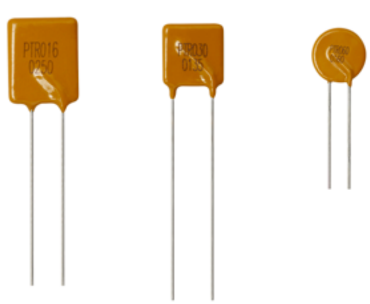
PTC Fuses provide compact, resettable protection for electronic devices

PTSLR family



PTS family

PTR family



Executive summary

Positive Temperature Coefficient (PTC) resettable fuses are simple, cost-effective overcurrent protection devices. These thermistor-based components protect circuits and downstream components against too much current due to an overload or short circuit fault condition. PTCs are compact, self-resetting fuses that provide reliable circuit protection when replacing a one-time fuse is either too costly, impractical, or impossible to perform. PTCs are passive devices in that they do not require an external power source to limit current, protecting the circuit downstream.

Resettable PTC fuses are found in most of today's rechargeable battery systems, protecting both the charging system and its load. Since PTC fuses are small, cost-effective overcurrent protection devices, they are often found in the battery systems for laptops, tablets, mobile phones, and wearables. PTCs are almost universally used to protect data lines such as I/O or USB ports, as well.

Other applications include automotive and consumer electronics, large appliances, industrial power and transmission equipment, and medical, test, measurement, telecommunications, and networking equipment. Resettable PTC fuses can help prevent the additional servicing and down-time that one-time fuses might require. PTCs are also used where replacing fuses is not feasible, such as in sealed laptops, ebook readers, motor drive circuits, and in unreachable places in avionics and aerospace.

In the aforementioned data line protection applications, resettable PTCs are often accompanied by Electrostatic Discharge (ESD) suppressors, which protect against overvoltage.

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The basic, inner workings of a PTC resettable fuse

The material inside PTC resettable fuses demonstrates a positive temperature coefficient, where the PTC's resistance increases exponentially with a temperature increase. Under normal operation, PTC resettable fuses insert a trivial amount of resistance with little or no influence on the circuit's performance. However, an over-current condition heats up the PTC, which causes it to advance to a state of high resistance, often defined as "trips."

After the source of the overcurrent condition has been removed and the surrounding circuit cools down, the PTC fuse resets itself by reverting to a low state of in-circuit resistance, and normal operation resumes. PTCs can be mounted where they can swiftly sense a temperature increase so a quick response time is certain.

Comparing PTC fuses to one-time fuses

Every fuse has an amperage rating and protects downstream circuit components from damaging overcurrents. Both one-time and PTC resettable fuses connect in series with the load and are not polarity sensitive. PTC fuses reset themselves, whereas one-time fuses open the circuit as a one-time positive disconnect and must be replaced before resuming operation. Both technologies require the removal of the overcurrent condition to resume normal operation. Due to this key characteristic, selection parameters differ — some of which are compared in Table 1.

Other key selection parameters for PTC selection

Key parameters are important in determining which PTC resettable fuse is best suited for your application. In addition to Table 1's parameters, PTC selection key parameters include:

- **Initial resistance (R_i)**: the PTC resettable fuse's resistance in initial state, measured at +23 °C.
- **Post-trip resistance (R_{TRIP})**: the maximum resistance measured one hour post-reflow (for surface-mount PTC fuses) or one-hour post-trip (for radial-leaded PTC devices), measured at +23 °C.
- **Power dissipation (P_D)**: power dissipated from the PTC fuse when in tripped state at +23 °C.
- **Maximum trip time (t_{TRIP})**: PTC resettable fuse defined response time from onset of fault current.

Principles of operation for PTC resettable fuses

A polymeric PTC's response to heat can be plotted as a non-linear curve (see Figure 1 below). Under normal operation, resistance and temperature are in balance at point A, since the amount of heat that's generated is being successfully dissipated. At point B, an increase in current causes a slight increase in resistance, since most of the excess heat is dissipated. At point C, overcurrent causes heat buildup. The PTC fuse enters a state of high resistance at Point D, after Point C, and limits current flow. (Current flow produces heat at a rate proportional to I^2R.) Since PTC resettable fuses are thermally activated, the ambient temperature of the surrounding environment has an impact on its operation.

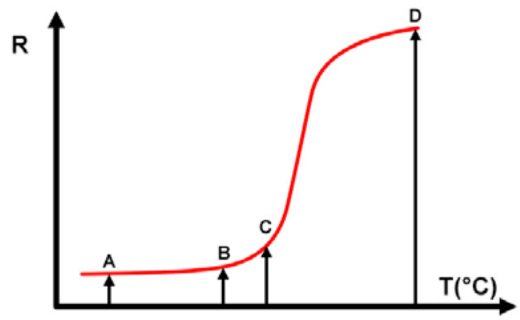

Figure 1: R/T curve.

In a PTC resettable fuse, the relationship between resistance (R) and temperature (T) can be plotted as a non-linear curve. As temperature increases (due to overcurrent), the PTC rapidly increases resistance. The high resistance effectively blocks current flow through the PTC fuse and protects the downstream circuit.

A PTC resettable fuse will trip at or above the trip current (I_{TRIP}) that's listed in the datasheet, up to the I_{max} current, and protect the circuit. The hold current (I_{HOLD}) is the maximum current a PTC can sustain for a minimum of four hours without tripping (at +23 °C). A PTC trips at or above $I_{TRIP,}$ or the minimum current that will switch or trip a PTC resettable fuse from a low- to high-resistance state (at +23 °C).

Table 1: Differences between PTC fuses and one-time fuses

Parameter/ specification	Leakage current, I_L (current after device senses an overcurrent event)	Interrupting rating vs. Maximum current (I_{MAX})†	Operating voltage rating	Hold current rating, I_{HOLD}† (maximum current at which the device is guaranteed not to trip)	Maximum voltage, (V_{MAX}) †	Temperature derating*	Resistance	Time-current characteristics
PTC fuses	PTCs limit current flow in circuit to a low level of leakage current	The maximum fault current a PTC resettable fuse can withstand without damage at the rated voltage. Current will not be fully interrupted (see leakage current)	Typically rated up to 60 V and DC voltages, though some are rated for line voltage applications	Ratings typically up to 15 A	Max voltage the PTC can withstand without damage at I_{MAX}	Percent of rating varies from 40% to 150%	Traditional PTCs typically have higher resistances, but newer products have resistance values down to 1mohm	Time-current graph curves of PTCs are somewhat like those of a time-delay fuse (e.g., curves found in datasheets)
One-time fuses	No circuit current flows; they are a one-time positive disconnect	Interrupting rating (sometimes referred to as breaking capacity) is the amount of fault current the fuse will safely and completely interrupt	Can be rated to more than 600 Vac/dc	Referred to as nominal current rating; typical ratings are up to 30 A, but can be even higher	Max voltage the fuse can withstand without damage at Interrupting Rating	Percent of rating typically varies approximately 80% to 110%	Generally have lower resistance values	Available in many different opening characteristics from very fast acting to time-delay

*More about temperature derating below.
†DC operating parameters.

However, both I_{HOLD} and I_{TRIP} decrease as ambient temperature increases. In Figure 2 below, the rated hold and trip currents decrease as the ambient air temperature increases. In general, the higher the temperature, the shorter the time it will take to trip. As a rule of thumb, I_{TRIP} is often roughly double I_{HOLD}.

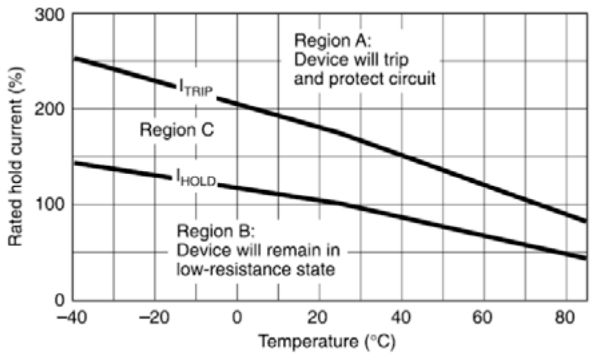

Figure 2: Rated hold and trip currents.

Selecting a PTC resettable fuse requires knowledge about the ambient temperatures in which your application normally operates. A PTC resettable fuse does not trip below or at I_{HOLD}. A PTC fuse isn't guaranteed to trip until it reaches I_{TRIP} or higher.

PTC resettable fuses are in a state of initial resistance (Ri) when there is little or no power applied. In this cold resistance state (+23 °C), atoms are arranged in a crystalline pattern permitting electrons to easily move around. The more "free" electrons there are to move about, the easier it is for electricity to flow through the PTC, at a state of low resistance.

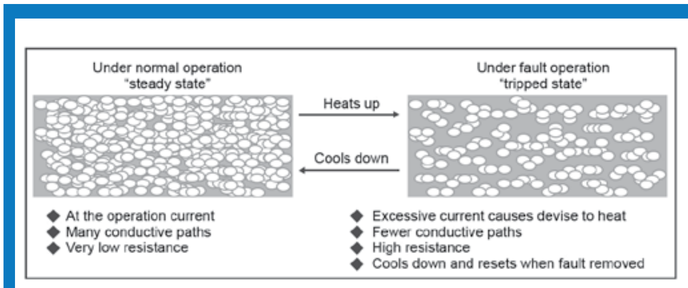

Figure 3: The material science of PTC resettable fuses

The materials science on how positive temperature coefficient devices work depends on the particles in the material. 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 device's let-through current. The device remains in this state until the current drops and the material cools down, allowing the material to return to its initial composition.

However, if trip current (I_{TRIP}) is reached, enough heat is generated to rapidly increase the PTC resistance.

At a molecular level, the PTC fuse "trips" as heat causes its atoms to rearrange themselves, locking free electrons down, and causing current to dramatically decrease. With very little current flow, the PTC is effectively in a state of high resistance at or above I_{TRIP}. As the device cools down, electrons are released to flow freely again. At a circuit-level, this resets the fuse and again makes a low-impedance connection so normal level of current flows again through the protected circuit. In short, the PTC fuse will reset once it cools down, returning to a post-trip resistance value (R1), which is the maximum resistance measured one hour post trip.

Temperature derating and expected ambient operating temperatures

Derating a component refers to choosing one that's going to be operated at less than its maximum rated parameters. Ambient temperature affects how long it takes to trip a PTC resettable fuse. The higher the temperature, the quicker the trip time. Thus, circuit designers should consider variations in rated current versus temperature and how temperature might affect their application. Is the application's circuit in a server room at a well-maintained temperature? Or is it located in a panel on the roof of a building? As an example, note the thermal derating curve from a resettable PTC fuse data sheet as shown in Figure 4 below.

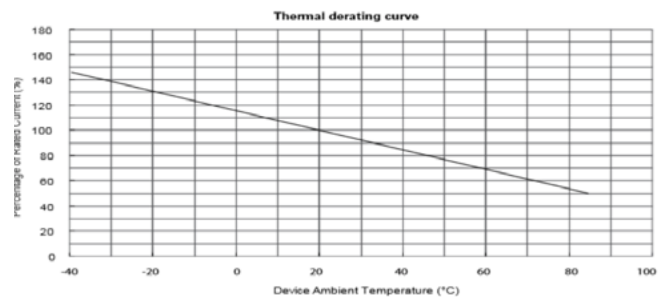

Figure 4: Thermal derating curve.

Consider the expected ambient operating temperatures for your application and reduce — or derate — the PTC's rated current at higher temperatures.

It's important to know of any possible operating temperature variations the PTC resettable fuse will experience under operation and derate values to ensure proper circuit protection. Ambient temperature conditions can significantly impact the R/T curve seen in Figure 1 earlier in this white paper.

Asking the right questions to get the most out of your PTCs

Circuit protection devices are widely used. Becoming familiar with all aspects of the environment in which the protected circuit operates is crucial. Please consult the following resources below for more information:

- PTC resettable fuse application note
- Request technical support
- Parametric search
- Cross reference

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