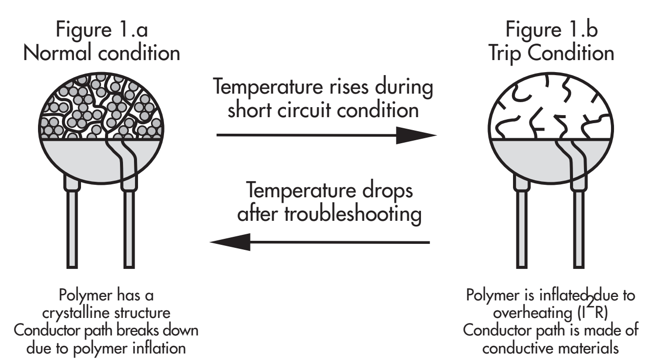
Overview

Raychem Circuit Protection's PolySwitch™ Polymeric Positive Temperature Coefficient (PPTC) devices are used to help protect against harmful overcurrent surges and overtemperature faults. Like traditional fuses, these devices limit the flow of dangerously high current during fault conditions. The PolySwitch device, however, resets after the fault is cleared and power to the circuit is removed, thereby reducing warranty, service and repair costs. This is achieved by using a polymeric PTC material, which is a matrix of a crystalline organic polymer containing dispersed conductive particles, usually carbon black. The sharp increase in resistance, as shown in Figure 1, is due to a phase change in the material. In its cool state the material is mostly crystalline, with the conductive particles being forced into the amorphous regions between the crystallites.

Figure 1: How a PolySwitch device works

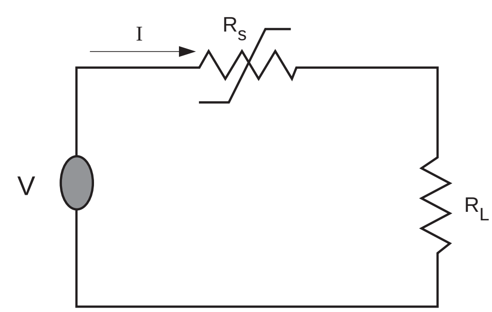


Overcurrent Protection using a Polymeric PTC Device

A polymeric positive temperature coefficient (PPTC) overcurrent protection device is a series element in a circuit. The PPTC device protects the circuit by going from a low-resistance to a high-resistance state in response to an overcurrent. This is called "tripping" the device. Figure 2 shows a typical application.

Generally the device has a resistance that is much less than the remainder of the circuit and has little or no influence on the normal performance of the circuit. But in response to an overcurrent condition, the device increases in resistance (trips), reducing the current in the circuit to a value that can be safely carried by any of the circuit elements. This change is the result of a rapid increase in the temperature of the device, caused by the generation of heat within the device by I^2R heating.

Figure 2: Typical PTC Application

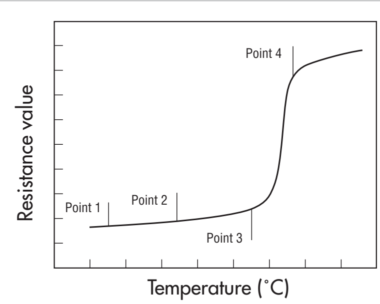


Principles of operation

The operation of polymeric PTC devices is based on an overall energy balance. Under normal operating conditions, the heat generated by the device and the heat lost by the device to the environment are in balance at a relatively low temperature, for example, Point 1 in Figure 3.

If the current through the device is increased while the ambient temperature is kept constant, the temperature of the device increases. Further increases in either current, ambient temperature, or both will cause the device to reach a temperature where the resistance rapidly increases, such as Point 3 in Figure 3.

Figure 3: Example of Operating Curve for Polymeric PTC Device



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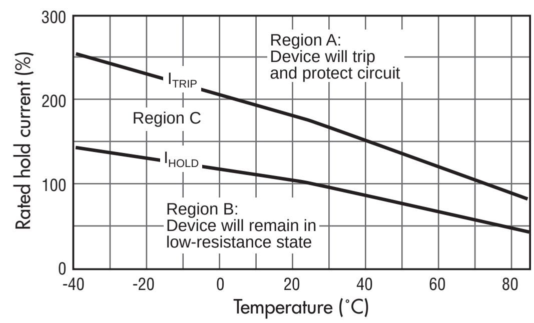
Any further increase in current or ambient temperature will cause the device to generate heat at a rate greater than the rate at which heat can be dissipated, thus causing the device to heat up rapidly. At this stage, a very large increase in resistance occurs for a very small change in temperature, between points 3 and 4 in Figure 3. This is the normal operating region for a device in the tripped state. This large change in resistance causes a corresponding decrease in the current flowing in the circuit. This relation holds until the device resistance reaches the upper knee of the curve (Point 4 in Figure 3). For a device that has tripped, as long as the applied voltage is high enough the device will remain in the tripped state (that is, the device will remain latched in its protective state). Once the voltage is decreased and the power is removed the device will reset.

Example of Hold and Trip Current as a Function of Temperature

Figure 4 illustrates the hold- and trip-current behavior of PolySwitch devices as a function of temperature. One such curve can be defined for each available device. Region A describes the combinations of current and temperature at which the PolySwitch device will trip (go into the high-resistance state) and protect the circuit. Region B describes the combinations of current and temperature at which the PolySwitch device will allow for normal operation of the circuit. In Region C, it is possible for the device to either trip or, remain in the low-resistance state (this will depend on the individual device resistance).

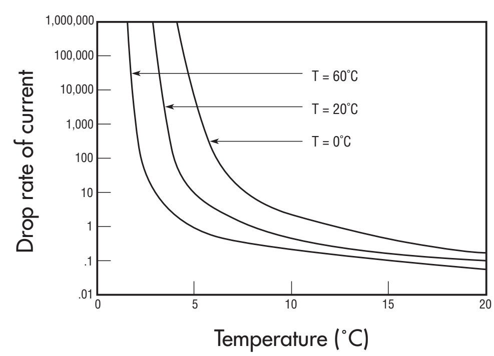
Figure 4: Example of Hold and Trip Current as a Function of Temperature



Operating Characteristics of Polymeric PTC

Figure 5 shows a typical pair of operating curves for a polymeric PTC device in still air at 0°C, 20°C and 60°C. The curves are different because the heat required to trip the device comes both from electrical I^2R heating and from the device environment. At 60°C the heat input from the environment is substantially greater than it is at 0°C, so the additional I^2R needed to trip the device is correspondingly less, resulting in a lower trip current at a given trip time (or a faster trip at given trip current).

Figure 5: Typical Resistance vs. Temperature Behavior



Typical Resistance Recovery after a Trip Event

Figure 6 shows typical behavior for a PolySwitch device that is tripped and then allowed to cool. In this figure, we can clearly see that even after a number of hours the device resistance is still greater than the initial resistance. Over an extended period of time, the resistance will continue to fall and will eventually approach the initial resistance.

Figure 6: Typical Resistance Recovery after a Trip Event

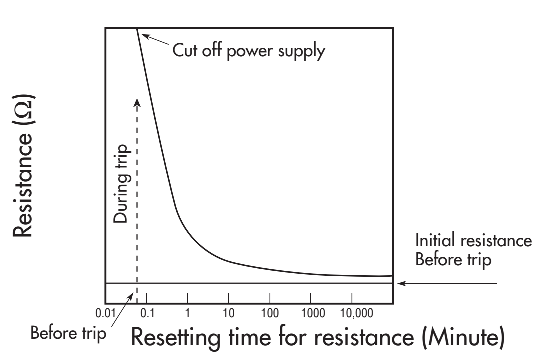


Table 1 - PolySwitch Characteristic

PolySwitch Family	Max. Rated V	Max. Interrupt V	Operating Current Range	Temp. Range	Form Factor	Agency Spec.	Application
LVR	240V	265V	0.05 to 0.55A	-40 to 85°C	Radial-leaded	UL, CSA, TÜV	Line Voltage
LVRL	120V	135V	0.75 to 2A	-20 to 85°C	Radial-leaded	UL, CSA, TÜV	Line Voltage
RGEF	$16V_{DC}$	-	2.5 to 14.0A	-40 to 85°C	Radial-leaded	UL, CSA, TÜV	General Electronics
RHEF	$16V_{DC}$ to $30V_{DC}$	-	0.5 to 15A	-40 to 125°C	Radial-leaded	UL, CSA, TÜV	General Electronics
RTEF	33V	-	1.2 to 1.9A	-40 to 85°C	Radial-leaded	UL, CSA, TÜV	General Electronics
RUEF	30V	-	0.9 to 9.0A	-40 to 85°C	Radial-leaded	UL, CSA, TÜV	General Electronics
RXEF	60 to 72V	-	0.05A to 3.75A	-40 to 85°C	Radial-leaded	UL, CSA, TÜV	General Electronics
RUSBF	6 to $16V_{DC}$	-	0.75 to 2.5A	-40 to 85°C	Radial-leaded	UL, CSA, TÜV	Computer/General Electronics
microSMD	6 to 30V	-	0.5 to 1.75A	-40 to 85°C	Surface-mount	UL, CSA, TÜV	Computer/General Electronics
midSMD	6 to 60V	-	0.3 to 2.0A	-40 to 85°C	Surface-mount	UL, CSA, TÜV	Computer/General Electronics
miniSMDC	6 to 60V	-	0.14 to 2.6A	-40 to 85°C	Surface-mount	UL, CSA, TÜV	Computer/General Electronics
miniSMDE	16V	-	1.9A	-40 to 85°C	Surface-mount	UL, CSA, TÜV	Computer/General Electronics
nanoSMDC	6V	-	1.5A	-40 to 85°C	Surface-mount	UL, CSA, TÜV	Computer/General Electronics
SMD	6 to 60V	-	0.3 to 3.0A	-40 to 85°C	Surface-mount	UL, CSA, TÜV	Computer/General Electronics
SMD2	15 to 33V	-	1.5 to 2.5A	-40 to 85°C	Surface-mount	UL, CSA, TÜV	Computer/General Electronics
AGRF	$16V_{DC}$	-	4.0 to 14.0A	-40 to 85°C	Radial-leaded	-	Automotive
AHRF	$16V_{DC}$	-	4.5 to 13A	-40 to 125°C	Radial-leaded	-	Automotive
AHS	16V	-	0.80 to 1.	-40 to 125°C	Surface-mount	-	Automotive
ASMD	16V	-	0.23 to 1.97A	-40 to 85°C	Surface-mount	-	Automotive
BBRF	90V	-	0.55 to 0.75A	-40 to 85°C	Radial-leaded	UL, CSA	Telecom & Networking
TCF	60V	250V	0.12 to 0.18A	-40 to 85°C	Chip	-	Telecom & Networking
TRF250	60V	250V	0.08 to 0.18A	-40 to 85°C	Radial-leaded	UL, CSA, TÜV	Telecom & Networking
TRF600	60V	600V	0.15 to 0.16A	-40 to 85°C	Radial-leaded	UL, CSA, TÜV	Telecom & Networking
TS250	60V	250V	0.13A	-40 to 85°C	Surface-mount	UL, CSA, TÜV	Telecom & Networking
TSL250	80V	250V	0.08A	-40 to 85°C	Surface-mount	UL, CSA, TÜV	Telecom & Networking
TSV250	60V	250V	0.13A	-40 to 85°C	Surface-mount	UL, CSA, TÜV	Telecom & Networking
LR4	15 to 20V	-	1.7 to 14.1A	-40 to 85°C	Axial-leaded	UL, CSA, TÜV	Battery
LTP	15 to 24V	-	0.7 to 3.4A	-40 to 85°C	Axial-leaded	UL, CSA, TÜV	Battery
SRP	15 to 30V	-	1.2 to 4.2A	-40 to 85°C	Axial-leaded	UL, CSA, TÜV	Battery
VLR	12V	-	1.7 to 2.3A	-40 to 85°C	Axial-leaded	UL, CSA, TÜV	Battery
VTP	16V	-	1.1 to 2.4A	-40 to 85°C	Axial-leaded	UL, CSA, TÜV	Battery

Table 2 - Thermal Derating

PolySwitch	-40°C	-20°C	0°C	20°C	25°C	30°C	40°C	50°C	60°C	70°C	85°C	125°C
LVR	-	1.48	1.24	1.00	0.99	0.93	0.82	0.72	0.60	0.51	0.35	-
RGEF	1.54	1.37	1.21	1.04	1.00	0.96	0.88	0.79	0.71	0.63	0.50	-
RHEF	1.50	1.35	1.19	1.04	1.00	0.96	0.88	0.81	0.73	0.65	0.54	0.23
RTEF	1.48	1.32	1.16	1.00	0.96	0.92	0.84	0.76	0.68	0.60	0.48	-
RUEF	1.48	1.32	1.16	1.00	0.96	0.92	0.84	0.76	0.68	0.60	0.48	-
RXEF	1.56	1.37	1.19	1.00	0.95	0.91	0.82	0.72	0.63	0.54	0.40	-
RUSBF	1.41	1.27	1.14	1.00	0.97	0.93	0.87	0.80	0.73	0.66	0.56	-
microSMD	1.45	1.30	1.15	1.00	0.96	0.93	0.85	0.78	0.70	0.63	0.51	-
midSMD	1.41	1.27	1.14	1.00	0.97	0.93	0.87	0.80	0.73	0.66	0.56	-
miniSMD	1.45	1.30	1.15	1.00	0.96	0.93	0.85	0.78	0.70	0.63	0.51	-
nanoSMD	1.56	1.39	1.15	1.04	1.00	0.96	0.87	0.79	0.70	0.61	0.49	-
SMD	1.45	1.30	1.15	1.00	0.96	0.93	0.85	0.78	0.70	0.63	0.51	-
AGRF	1.54	1.37	1.21	1.04	1.00	0.96	0.88	0.79	0.71	0.63	0.50	-
AHRF	1.50	1.35	1.19	1.04	1.00	0.96	0.88	0.81	0.73	0.65	0.54	0.23
AHS	1.41	1.28	1.16	1.03	1.00	0.97	0.91	0.84	0.78	0.72	0.62	0.37
ASMD	1.59	1.41	1.23	1.05	1.00	0.95	0.86	0.77	0.68	0.59	0.45	-
BBRF	1.56	1.37	1.19	1.00	0.95	0.91	0.82	0.72	0.63	0.54	0.40	-
TCF	1.54	1.36	1.18	1.00	0.96	0.91	0.82	0.73	0.64	0.55	0.42	-
TRF(except TRF250-180U)	1.54	1.36	1.18	1.00	0.96	0.91	0.82	0.73	0.64	0.55	0.42	-
TRF250-180U	1.48	1.32	1.16	1.00	0.96	0.92	0.84	0.76	0.68	0.60	0.48	-
TS	1.54	1.36	1.18	1.00	0.96	0.91	0.82	0.73	0.64	0.55	0.42	-
LR4	1.41	1.27	1.14	1.00	0.97	0.93	0.87	0.80	0.73	0.66	0.56	-
LTP	1.72	1.48	1.24	1.00	0.94	0.88	0.76	0.64	0.52	0.40	0.22	-
SRP	1.47	1.31	1.16	1.00	0.96	0.92	0.85	0.77	0.69	0.61	0.50	-
VLR	2.05	1.70	1.41	1.08	1.00	0.92	0.74	0.59	0.41	0.18	-	-
VTP	1.88	1.67	1.43	1.05	1.00	0.95	0.76	0.62	0.48	0.33	0.04	-

Selection steps from the Catalog

Step 1. Determine your circuit's parameters

You will need to determine the following parameters of your circuit:

Maximum ambient operating temperature
Normal operating current
Maximum operating voltage
Maximum interrupt current

Step 2. Select a PolySwitch device that will accommodate the circuit's maximum ambient temperature and normal operating current.

Use the Thermal Derating [hold Current (A) at Ambient Temperature (°C)] table and choose the temperature that most closely matches the circuit's maximum ambient temperature. Look down that column to find the value equal to or greater than the circuit's normal operating current. Now look to the far left of that row to find the part family or part for the PolySwitch device that will best accommodate the circuit.

Step 3. Compare the selected device's maximum electrical ratings with the circuit's maximum operating voltage and interrupt current.

Use the Electrical Characteristics table to verify the part you selected in Step 2 will handle your circuit's maximum operating voltage and interrupt current. Find the device's maximum operating voltage (VMAX) and maximum interrupt current (IMAX). Ensure that VMAX and IMAX are greater than or equal to the circuit's maximum operating voltage and maximum interrupt current.

Step 4. Determine time-to-trip.

Time-to-trip is the amount of time it takes for a device to switch to a high-resistance state once a fault current has been applied across the device. Identifying the PolySwitch device's time-to-trip is important in order to provide the desired protection capabilities. If the device you choose trips too fast, undesired or nuisance tripping will occur. If the device trips too slowly, the components being protected may be damaged before the device switches to a high-resistance state.

Use the Typical Time-to-trip Curves at 20°C to determine if the PolySwitch device's time-to-trip is too fast or too slow for the circuit. If it is go back to Step 2 and choose an alternate device.

Step 5. Verify ambient operating temperature.

Ensure that your application's minimum and maximum ambient temperatures are within the operating temperature of the PolySwitch device. Most PolySwitch devices have an operating temperature range from -40°C to 85°C with some exception to 125°C.

Step 6. Verify the PolySwitch device dimensions.

Use the Dimensions table to compare the dimensions of the PolySwitch device you selected with the application's space considerations.

Definitions of terms:

- I_H the maximum steady state current at 20°C that can be passed through a PolySwitch device without causing the device to trip
- I_T the minimum current that will cause the PolySwitch device to trip at 20°C
- V_{max} the maximum voltage that can safely be dropped across a PolySwitch device in its tripped state also called: Maximum Device Voltage, Maximum Voltage, Vmax, Max Interrupt Voltage
- I_{max} the maximum fault current that can safely be used to trip a PolySwitch™ device
- P_D the power (in watts) dissipated by a PolySwitch™ device in its tripped state
- R_{max} the maximum resistance prior to the trip of PolySwitch device
- R_{min} the minimum resistance prior to the trip of PolySwitch device
- R_{1max} the maximum resistance of a PolySwitch™ device at 20°C 1 hour after being tripped or after reflow soldering. Also called: Maximum Resistance
- $R_{Tripped\ TYP}$ the typical resistance of PolySwitch 1 hour after the initial trip and reset