HOW PTC THERMISTORS PROTECT AGAINST OVERLOADS

When connected in series with the input of an electrical or electronic circuit (see Fig. 1), such as a small motor or power supply, the PTC thermistor acts as a non-destructive fuse, protecting the circuit against current, voltage and temperature overloads.

Normally the thermistor resistance is low (see Fig. 2), and the current is below its non-trip \((I_{\text{nt}})\) value. However, an overload will quickly heat up the PTC thermistor until, at around the switch temperature \((T_s)\), its resistance becomes high, limiting the current to below its trip value \((I_t)\), and so protecting the circuit.

Removing the overload or switching off the supply allows the PTC thermistor to cool down and return to its low-resistance state, ready to resume its protective function.

There are in fact, three overload possibilities:

1. Overcurrent (see Fig. 3), where the load current increases due to a decrease in load resistance, for example when a motor winding short-circuits.

2. Overvoltage (see Fig. 4), caused for example, when the 220 V mains is accidentally applied to a 115 V mains appliance.

3. Overtemperature (see Fig. 5), where the PTC thermistor is in intimate thermal contact with an overheating load \((T_{\text{amb}})\). Here, due to external heating the PTC thermistor needs less external energy to reach its switch point B, so B2 moves below the load-line CD.

Figure 3 shows the PTC thermistor I/V characteristic \((ABD)\) superimposed on the load-line \((CD)\). The circuit will be designed such that, under normal conditions, the load-line \((CD)\) lies below point B, the top of the thermistor I/V characteristic. Under this condition the PTC thermistor resistance is low, so most of the voltage \((V)\) will appear across the load \(R_{L1}\). Under an overload condition \(R_{L2}\), the load-line \((CD)\) will move above point B. The PTC thermistor will switch to its high-resistance state \((BE)\) and the overload current will heat up the PTC thermistor to its overload working point \((E)\). The PTC thermistor will therefore absorb the overload current and protect the load.
PTC Applications
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PTC thermistors in series with a load

It can be shown from the I/V characteristics that, because of the non-linearity of the PTC thermistors curve, three working points are possible when a load $R_L$ is connected in series with a PTC thermistor (see Fig. 6). The characteristic of the load is a straight line intersecting the voltage co-ordinates at the supply voltage, $V_a$. $P_1$ and $P_2$ are stable working points; $P_3$ is unstable.

When the voltage $V_a$ is applied to the series connection, equilibrium is reached at $P_1$, a point with a relatively high current. $P_2$ can only be reached when the peak of the I/V curve lies below the load characteristic. This may happen in a number of cases:

1. $V_a$ increases (see Fig. 7)
2. The ambient temperature increases (see Fig. 8)
3. The load resistance decreases (see Fig. 9)

It can therefore be seen that the PTC thermistor provides excellent protection properties, limiting the load to a safe value if the supply voltage, temperature or current exceeds a critical value.

Resetting resistance

When the PTC thermistor is switched i.e. its temperature rises above the switching temperature $T_s$, it can only return from $P_2$ to $P_1$ if the load line lies below the I/V characteristic curve. This means that:

1. Either the supply voltage $V_a$ decreases (at constant load resistance); see Fig. 10
   or
2. The load resistance increases (at constant voltage); see Fig. 11.

Remark: When the temperature of the PTC thermistor is greater than $T_s$ (i.e. the thermistor is in its tripped state), the thermistor will heat up causing the ambient temperature to increase (see Fig. 8). This must be taken into account when calculating the value of the load resistance (i.e. the resistance of the PTC thermistor).
Fig. 6  PTC thermistor in series with a load showing the possible working points

Fig. 7  PTC thermistor in series with a load showing the influence of the supply voltage $V_a$

Fig. 8  PTC thermistor in series with a load showing the influence of the ambient temperature

Fig. 9  PTC thermistor in series with a load showing the influence of the load resistance

Fig. 10  PTC thermistor in series with a load showing the influence of a decrease in supply voltage $V_a$

Fig. 11  PTC thermistor in series with a load showing the influence of an increase in load resistance
APPLICATION EXAMPLES

As soon as the current increases, the PTC limits it to a safe value.

The increased current heats the PTC to its switch temperature. As a result, the total dissipated power is reduced to a safe value. The example shown could also be used as protection against overheating in transformers, lamps, printed-circuit boards, rechargeable batteries, power supplies, etc.

Fig. 12 Current limiting

Fig. 13 Protection of a stalled electric motor against overheating

The PTC may be thermally coupled to the transformer to increase thermal electricity.

By using a resistor fitted in parallel to the PTC, a current stabilization circuit is obtained that compensates slowly varying supply voltages.

Fig. 14 Protection of transformers, power-supplies and charging equipment

Fig. 15 Current stabilization