Applications of PPTC in Circuit Protections

Among the circuit protection components, PPTC is often used to replace fuse-type fuses because of its over current protection. It can also be replaced and reused. In addition, PPTC has other functions in circuit protections, such as matching restrictions in surge protections, misconnection or power line load experiment in communication circuits, restrictions in wide pulses. The paper mainly introduces the structural principle of PPTC and its application schemes for several common scenarios.

1. Working Principles of PPTC

PPTC (Polymeric Positive Temperature Coefficient) is a kind of positive temperature coefficient thermistor made of polymer materials. The interior of PPTC mainly consists of a polymer matrix and carbon black conductive particles (as shown in Figure 1).

There is a small static impedance at normal temperature, which does not affect the normal operation of the circuit when PPTC is used in series. When an abnormal overcurrent flows through PPTC, PPTC will generate heat (I2R) to make the polymer matrix material expand. The conductive particles wrapped outside the polymer matrix material will gradually separate to increase the resistance of PPTC. After the resistance rises, PPTC will heat up more quickly and the polymer matrix material will distort greatly, further increasing the resistance. When the temperature reaches about 125℃, the resistance will increase sharply (as shown in Figure 2), which will make the current drop significantly. At this time, the current flowing is enough to keep PPTC in a high-resistance thermal equilibrium state. When the abnormal over current fault is eliminated (generally after power off), the body temperature of PPTC will gradually decrease and the polymer matrix material will shrink to the original shape. The conductive particles will reconnect and PPTC can return to the initial low resistance state. Because PPTC acts like a fuse in the process above and it does not need to be replaced after the fault is eliminated, it can protect the circuit repeatedly. So PPTC is often called as the resettable fuse.

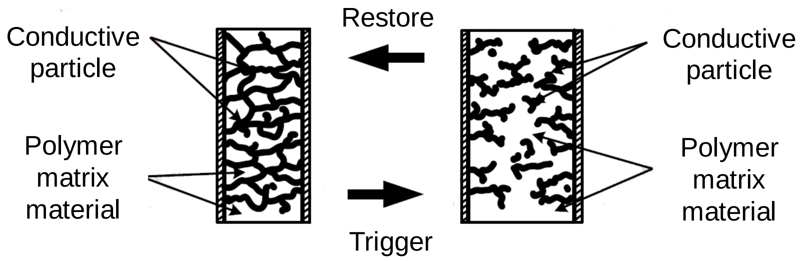

Figure 1. Operating Principle of PPTC

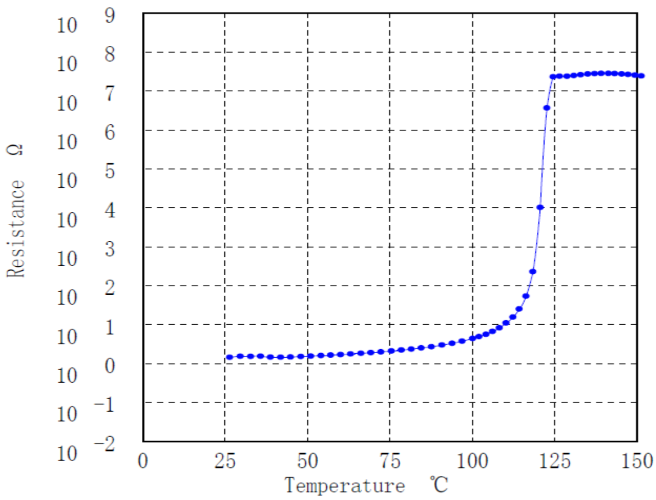

Figure 2. Typical Resistance-Temperature Curve of PPTC

2. Main Parameters of PPTC

Part Number	I_{hold} (A)	I_{trip} (A)	V_{max} (Vdc)	I_{max} (A)	$P_{d\ typ.}$ (W)	Maximum Time To Trip		Resistance	
						Time (Sec.)	Current (A)	R_{min} (Ω)	R_{1max} (Ω)
SMD1210B005TF	0.05	0.15	30	10	0.60	1.50	0.25	3.600	50.00

2.1 Ihold Holding Current

The maximum current that PPTC allows to flow through without actions in the still air environment at 23/25°C is called the holding current, also known as the maximum non-working current.

2.2 Itrip Action Current

The minimum current that can make PPTC act in the still air environment at 23/25°C is called the action current, also known as the maximum working current. Normally, Itrip is 2-3 times Itrip.

2.3 Vmax Maximum Working Voltage

The maximum working voltage that PPTC can withstand without damage at the rated current (Imax).

2.4 Imax Maximum Fault Current

The maximum fault current that PPTC can withstand without damage at the rated voltage (Vmax).

2.5 Pdtyp Typical Power Dissipation

Typical power dissipation of PPTC in the still air environment at 23/25°C.

2.6 Maximum Time to Trip

In the still air environment at 23/25°C, PPTC is connected to an independent constant current source, when the current is preset to a specified value, the voltage of the current source should be less than 50% of V max or a specified voltage value. Maximum time to trip refers to the maximum time for the current drops from the beginning of the test to 50% of the specified value.

2.7 Rmin, Rmax, R1max

Rmin: the minimum static impedance of PPTC before welding.

Rmax: the maximum static impedance of PPTC before welding.

R1max: the maximum impedance of PPTC after the welding is completed and the device has been placed in an air environment at 23/25°C for one hour.

Note: After the first welding and cooling, PPTC's resistance will become larger than the value before welding. PPTCs with higher resistance values will heat up and act faster when the same fault current flow through them. As a result, to measure the Maximum Time To Trip, it is necessary to measure PPTC one hour after the welding and cooling.

3. Considerations for PPTC's Type Selection

3.1 Range of Ihold Holding Current and Working Ambient Temperature

In the type selection, Ihold should be guaranteed to be larger than the maximum normal working current of the circuit. If Ihold is too small, it may cause the false operation of PPTC in use. Because PPTC is a thermistor, it is sensitive to temperature, its Ihold will become smaller as the temperature rises (see Table 1 below). Therefore, it is necessary to ensure that Ihold at the maximum working temperature is greater than the maximum normal working current of the circuit.

Part Number	Ambient Operation Temperature								
	-40℃	-20℃	0℃	23℃	40℃	50℃	60℃	70℃	85℃
SMD1210B005TF	0.08	0.07	0.06	0.05	0.04	0.04	0.03	0.03	0.02

Table 1. SMD1210B005TF'S Ihold -Temperature Table

3.2 Vmax Maximum Working Voltage

During the selection, Vmax should be guaranteed to be larger than or equal to the maximum working voltage of the protected circuit. When PPTC is in the protection state, the impedance at both ends of PPTC is very large. The voltage drop of the circuit is basically added to both ends of PPTC. If PPTC's withstand voltage is insufficient at this time, its resistance may not be able to restore to the initial state after the fault is eliminated, thus affecting the service life of PPTC and making the circuit work abnormally.

When PPTC is used in the front-end of surge protection devices, the surge test will be impacted by the transient surge. If the maximum working voltage of PPTC is too low, PPTC will be damaged due to the surge. During the type selection, it is necessary to choose a model with a high withstand voltage or to connect PPTC in series after the primary surge protection device.

4. Typical Application Circuits of PPTC

4.1 Over Current Protection

PPTC is widely used in the over current protection of power lines, communication lines and various I/O ports of electronic products in the fields of communication, security, industry, automotive, consumption. It can effectively prevent products from damage caused by short circuits and serial high currents. Moreover, compared with ordinary fuses, the recoverability of PPTC eliminates the trouble of follow-up maintenance, repair and replacement. Figure 3 shows the common over current protection circuit for PPTC.

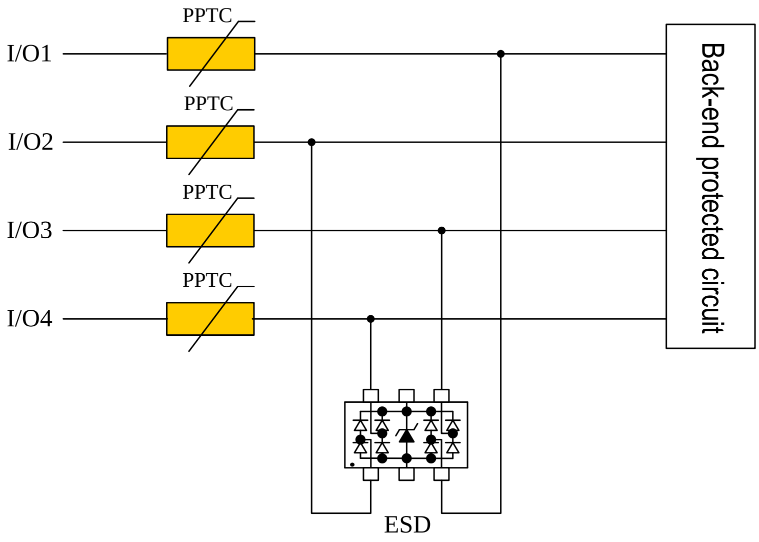

Figure 3. PPTC's Typical Over Current Protection Circuit

4.2 Matching Function in Two-Level Surge Protection

In surge protections, because the power of TVS and ESD devices with strong clamping capabilities is limited, MOV, GDT and other devices are often used in their front-end. However, MOV and GDT have higher residual voltages, while TVS and ESD devices have faster response speeds. Therefore, devices need to be connected in series between the front-end and back-end circuits to ensure that the front-end circuit can absorb more surge energy and the back-end circuit can perform precise clamping. Generally, the commonly used matching series devices are inductors and resistors. However, because of the large volume, easy magnetic saturation and limited common resistance power of the inductor, PPTC has become an ideal series matching device for the two-level surge protection because of its static impedance and over current protection capability. As shown in Figure 4, when the surge voltage rises and a certain inrush current flows through TVS, the static impedance can make PPTC have a higher voltage division, which ensures that GDT can reach the breakdown voltage so as to open the protection and absorb the surge energy.

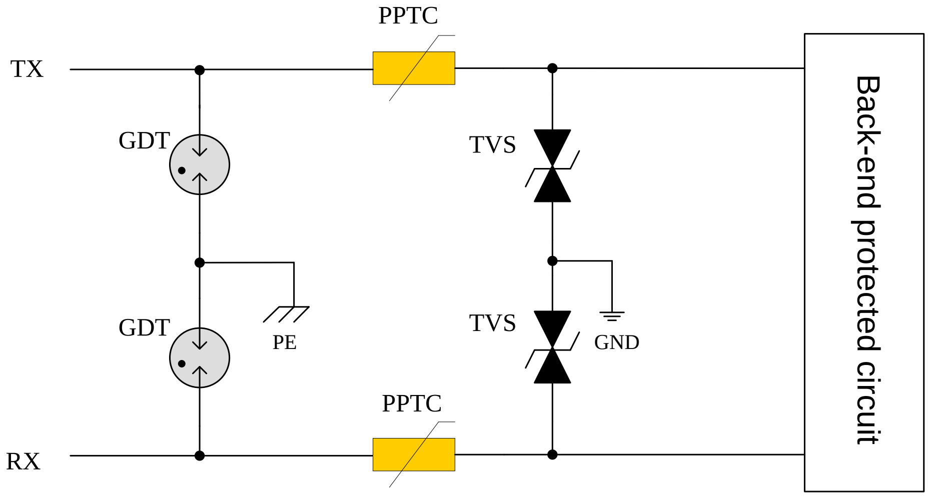

Figure 4. PPTC's Matching Application Circuit in Surge Protections

4.3 Anti-high Voltage Misconnection

There are often test requirements for anti-high voltage misconnection in circuit protections. Generally, PPTC can be used together with over voltage protection devices to protect against the high voltage misconnection. When the high voltage is mistakenly connected to the circuit, the back-end over voltage protection device will react quickly and generate a large current to limit the back-end voltage within a certain range. The large current generated by the back-end over voltage protection device can make PPTC act quickly and limit the total current of the system, thus ensuring that the back-end over voltage protection device will not be damaged due to over current for a long period of time. The key to this cooperation is that PPTC can quickly act and limit the cyclic current before the back-end over voltage protection device reaches the limit value after withstanding surges for a long period of time. Therefore, PPTC with a small current can cooperate with the back-end over voltage protection device more effectively so as to prevent misconnection. In addition to the anti-misconnection application, it is also necessary to ensure that the maximum working voltage of PPTC is greater than the high voltage of misconnection so that PPTC won't fail due to the insufficient maximum operating voltage after PPTC protection. Figure 5 shows the XDSL line protection scheme against surges and power line contact (ITU K.21 standard for communication industry, which requires to satisfy the AC220V 50Hz 15min test). Generally, the front-end device uses a 470V ceramic gas discharge tube and the back-end device uses a 190V semiconductor discharge tube. The selected PPTC is a 250V voltage-resistant BK250 low current type. When it is connected with AC220V, the front-end ceramic gas discharge tube does not act while the back-end semiconductor discharge tube acts rapidly and generates an over current. Then PPTC acts and limits the current to make sure that the back-end will not be damaged due to the access to AC220V.

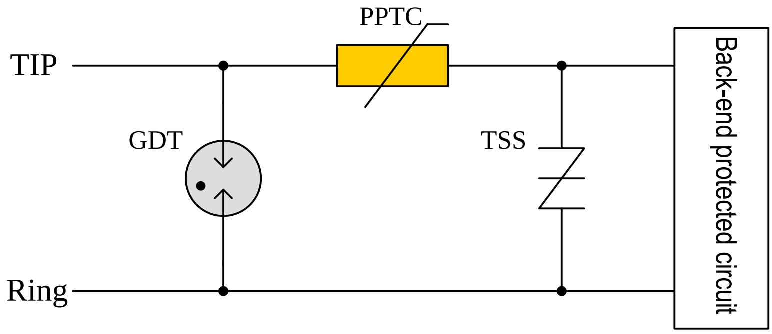

Figure 5. PPTC's Anti-high Voltage Misconnection Application Circuit

4.4 Anti-reverse Connection Protection

Generally speaking, DC power supply circuits have protection requirements for anti-reverse connection, which are protected by series anti-reverse diodes in many cases. However, in some cases, anti-reverse diodes are not suitable due to the series voltage drop. At this moment, the anti-reverse connection protection can be realized through the cooperation between PPTC and the one-way TVS based on the surge protection. As shown in Figure 6, when the DC power supply is reversely connected, the one-way TVS is positively connected and generates an over current to make PPTC quickly act and limit the current. The scheme also needs to consider the withstand voltage of PPTC and the power of TVS when applied.

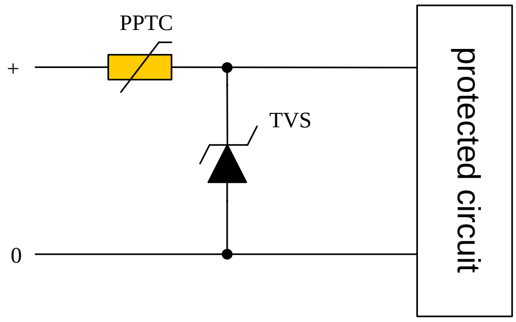

Figure 6. PPTC's Anti-reverse Connection Application Circuit