ADVANCED THERMAL PRODUCTS, Inc.

PTC Thermistor APPLICATIONS

Introduction

PTC thermistors have been used in a wide variety of applications over the years. PTC thermistor applications make use of the characteristics inherent in their composition. Generally, applications are broken up into two distinct categories that utilize different characteristics of the PTC. The first category is those applications that utilize the voltage-current or current-time characteristics of the PTC thermistor. These are sometimes known as self heated applications. The other general category is zero power or sensing applications. Unlike the NTC thermistor, the resistance versus temperature characteristic of a PTC thermistor is not well defined and applications that utilize the resistance versus temperature characteristic tend to utilize only a small portion of the RvT curve and utilize broader tolerances than that of NTC thermistors.

A number of the applications will be discussed in depth on the following pages. For applications that are less prevalent, some background material will be provided and for others it will just be noted as a possible use.

Self Heated Applications

Some of the different types of applications that utilize the self heated characteristics of the PTC thermistor include:

- Self-Regulating Heaters
- Over-Current Protection
- Liquid level sensing
- Constant current
- Time delay
- Motor Starting
- Arc suppression

Self-Regulating Heaters

If a voltage is placed across a PTC, current will flow and begin to heat the part. Since most PTCs are in their NTC region when first energized (see Figure 12), heating causes the resistance of the part to drop. The decreasing resistance, in turn, causes more current to flow which heats the part still further. If the voltage is high enough, the unit will self-heat until it passes into the PTC region of resistance.

Once in the PTC region, this ceramic element exhibits a truly remarkable feature. It reaches the point where I^2R heat generated by the part is sufficient to make up for the loss of heat to the ambient. In this situation, the device is in equilibrium. If it starts to decrease in temperature, its resistance will decrease drawing more current and countering the cooling tendency. Conversely, any tendency to increase its temperature meets just the opposite effect. In this condition, the PTC is auto-stabilized at a fixed temperature.

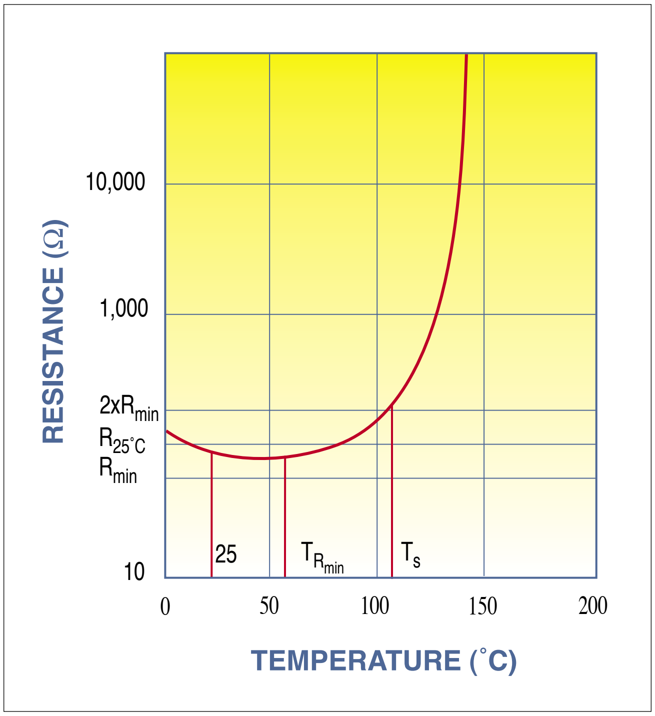

Figure 12: Resistance versus Temperature for a PTC

Even with regards to voltage changes, the constant temperature mechanism will be effective. If the operating voltage increases, the PTC initially consumes more power but, as a result, its temperature increases and thus the current becomes stabilized at a lower level. The performance of the PTC is not proportional to the square of the voltage as in the case of an ohmic resistance. In other words, the power consumed is nearly independent of voltage over a wide voltage range.

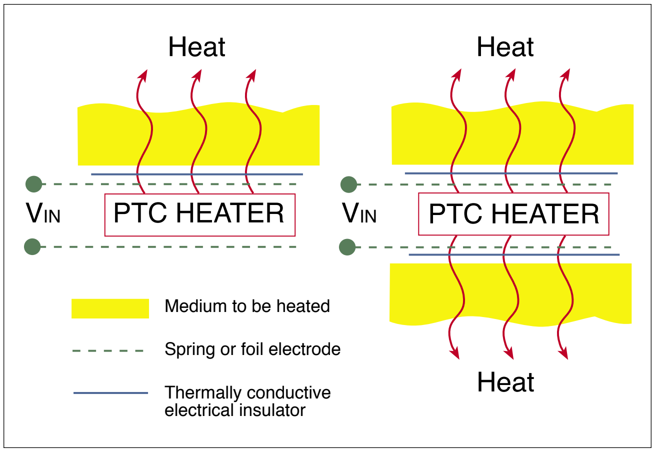

Figure 13: PTC Heater - Transfer

Design Considerations for Self-Regulating Heaters

When selecting a PTC, you should consider the following factors:

- Thermal connections
- Switch temperature (T_S)
- Resistance at 25˚C (R_{25})
- Surface area
- Maximum voltage (V_{max})

Ceramic PTC heaters are usually most efficient when they are flat and thin and have a smooth surface finish. For a PTC to operate as a heater, it must have a way to dissipate its heat to the medium, either by convection (air or liquid flow) or conduction. One common method is to use a spring contacts as both the electrical and mechanical connection (See Figure 13). One advantage of this “clamping” technique is that it allow stress free thermal expansion. Other techniques involve using electrically conductive epoxies or solder joints to connect the PTC to the heat spreader.

The switch temperature (T_S in Figure 12) is very important because in most heater applications, the maximum surface temperature of the PTC is just a few degrees above its switch temperature. Thus, the maximum temperature of the medium to be heated is directly related to the switch temperature T_S of the PTC.

The R_{25} of the PTC heater is typically not the most important design factor. It should not be so low that it causes inrush current problems, but not so high that there is not enough power available to heat the PTC to its switched condition. The PTC cold resistance will, however, influence the heat-up rate of the medium since a lower resistance allows for higher initial I^2R heating.

The surface area of the PTC heater influences the heat-up and cool-down rates of the medium as well as the power dissipated. Multiple PTCs are often used in heater design to obtain the desired results. As with any PTC thermistor application, the heater design should not exceed the maximum recommended voltage ratings. The maximum Voltage (V_{max}) specified on the ATP data sheets is for DC or 60Hz AC only.

PTC Over-Current Protectors

PTC thermistors are semiconducting ceramic devices that exhibit an ability to switch from a low resistance state to a high resistance state depending upon their body temperature. PTC ceramic thermistors have been proven reliable and effective over many years of use in a variety of over-current applications. Ceramic PTCs, unlike other PTC technologies, return to their same initial R_{25} after being subjected to a fault condition. Ceramic PTCs can be switched again and again and will return to their initial value and are not subject to hysteresis. Ceramic PTCs can be sorted into very tight resistance groups for matched pair applications, For over-current applications, the PTC element is normally placed in series with the component that requires over-current protection as shown in the figure below:

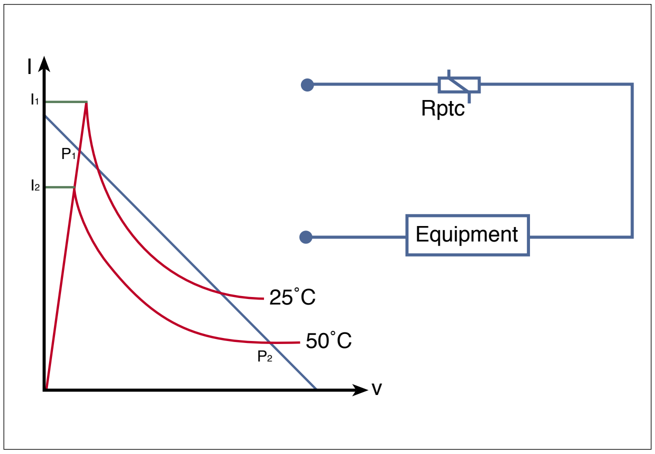

Figure 14: PTC Over-Current Protector Circuit

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The following is a description of how the PTC functions as an over-current protector:

1. Under normal conditions, the PTC element has a relatively low resistance value. The current flowing through the part does not provide enough energy to heat the PTC beyond the ambient temperature.

2. A short circuit or over-current condition causes $I^2 R$ heating within the PTC. When its body temperature reaches the Curie Point or Switch Temperature of the material, the PTC transforms into a high resistance element, thereby limiting current to the load.

3. Removing the fault condition decreases the current flow and allows the PTC to cool to its normal resistance mode.

When designing a PTC thermistor for use as an overcurrent protector, you should first determine the following information:

- Maximum steady state voltage across the PTC when it is the current limiting mode.
- Minimum and maximum ambient temperature.
- Maximum normal current and minimum fault current.

For a PTC thermistor, values for the minimum current that the part will switch (I_{ms}) and for the maximum current that the part will not switch (I_{ns}) can be calculated. These values are dependent upon the ambient temperature, the resistance value of the PTC, the dissipation factor (δ) as well as the switch temperature (T_s). The values listed in the ATP catalog for I_{ms}, and I_{ns} are based on a minimum ambient temperature of 0°C and a maximum ambient temperature of 50°C. If these ambient conditions are not desired then the following equations can be used to calculate the values.

Minimum Must Switch Current

$$I_{ms} = \sqrt{\frac{\delta\,(107 - 0.85 * Ta_{min})}{0.8 * R_{25}}}$$

Maximum No-Switch Current

$$I_{ns} = \sqrt{\frac{\delta\,(93 - 0.85 * Ta_{max})}{1.2 * R_{25}}}$$

Where: δ = dissipation factor
Ta_{min} = minimum ambient temperature (°C)
Ta_{max} = maximum ambient temperature (°C)
R_{25} = nominal resistance at 25°C (Ω)

For example, for a small transformer that you would like to protect, you have determined the following:

V_{app} = 24 volts
Normal current = 80mA
Fault current = 300mA
Ta_{min} = 20°C
Ta_{max} = 60°C

For this application, we will need a part that is rated for at least 24 volts and can carry 80mA of current at 60°C and will switch with less than 300mA through it at 20°C. Looking through the parts rated for 50V we find ATP Part Number P3006C120X201F, which is a 20Ω part. Going through the requirements we find that :

$V_{max} > V_{app}$	50 volts > 24 volts
I_{ms} < Fault Current	$I_{ms} = \sqrt{\frac{.008\,(107 - 0.85 * 20)}{0.8 * 20}} = .21 < 0.30$ amps
I_{ns} > Normal Current	$I_{ns} = \sqrt{\frac{.008\,(93 - 0.85 * 60)}{0.8 * 20}} = .12 > 0.08$ amps

Therefore, ATP type P3006C120X20lF will provide adequate protection for the 24 volt transformer.

The PTC's listed in the standard over-current protector data sheet are often modified to fit each individual application. By varying the resistance at 25°C, the switch temperature Ts, the type of lead wire or the part size, ATP can customize a PTC to meet your requirements.

As noted previously, PTC's cannot be connected in series to obtain higher voltage ratings. One device would heat more rapidly than the others and prevent the other PTC's from switching. However, PTC's can be connected in parallel to increase their current rating.

Motor Starting

PTC thermistors can be used to protect the auxiliary starter winding of induction motors or single-phase motors as shown if figure 15.

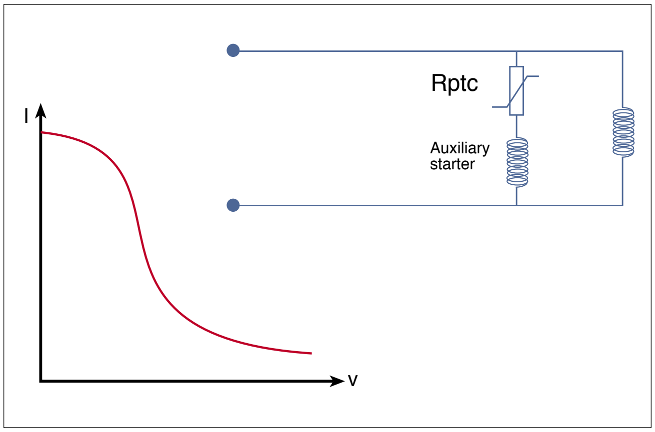

Figure 15: Starter Motor Circuit and I versus T for Application

When the circuit is turned on, the PTC has a low resistance and most of the line voltage is applied to the starter winding. After motor starting, the PTC heats up and switches to a high resistance state. The time for this to occur is determined by the size and resistance of the PTC as well as the amount of current flowing through the starter winding. When the PTC has reached a high resistance state, the current flowing through it as well as the starter winding falls substantially.

Constant Current

It is possible to obtain a nearly constant current by connecting a PTC thermistor in parallel with a resistor. The nearly constant temperature of a self heated PTC results in a circuit that can adjust the current over a wide range of voltages. When the voltage of the circuit is increased, the temperature of the PTC increases slightly which will cause an increase in the resistance of the PTC thermistor and a small decrease in the current through the thermistor compensating for the increase in current through the parallel resistor. The overall current through the load will remain relatively constant over a wide range of voltages. An equation that approximates the current through the load is:

$$I_S \cong \frac{V_O - V_S}{R_P} + \frac{\delta(T_S - T_A)}{V_O - V_S}$$

Where:

T_S = PTC switch temperature (˚C)
T_A = ambient temperature (˚C)

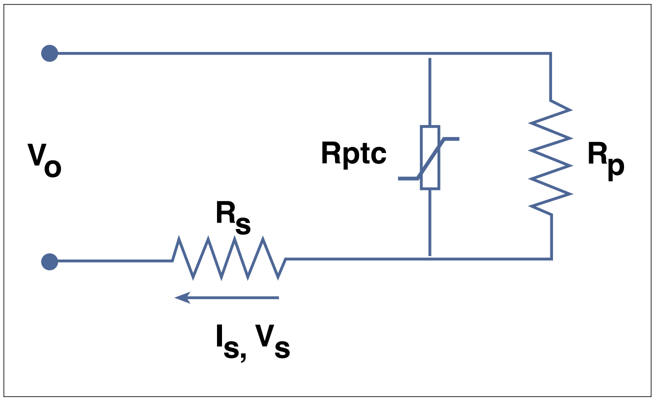

Figure 16: Constant Current Circuit

Arc Suppression

The circuit shown in Figure 17 shows how a PTC is used for arc suppression. When the switch is open, the PTC changes from low resistance to high resistance. The initial low value of the PTC provides for effective arc

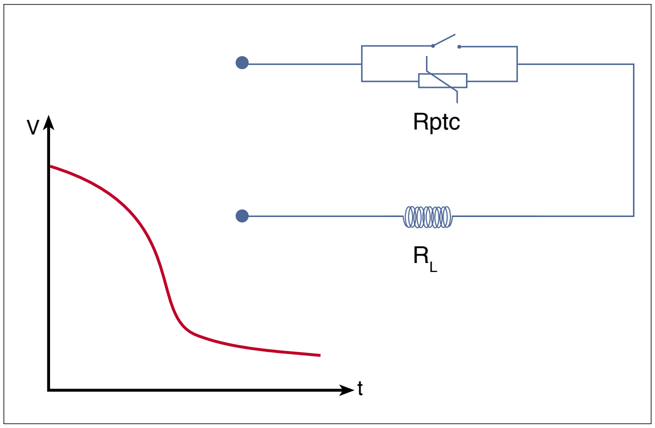

Figure 17: ARC Suppression Circuit

suppression as most of the voltage is dropped across the PTC. As the PTC switches to its high resistance state more and more of the supply voltage is transferred to the inductive load.

Time Delay

The time needed for a PTC thermistor to switch from it's low resistance state to a self-heated high resistance state may be used to provide for a time delay in a circuit. For example, if a PTC is connected in parallel with a relay, the relay will only be energized after the time necessary for the PTC to switch from low to high resistance. When a PTC is connected in series with a relay, the relay would energize immediately and would stay energized until the PTC heats up and increases in resistance. At that point, most of the voltage would be dropped across the PTC and the relay would no longer be energized. The time for the PTC to switch in either case would be dependent upon the resistance and size of the PTC as well as the ambient temperature and other circuit parameters such as supply voltage and other components in the circuit.

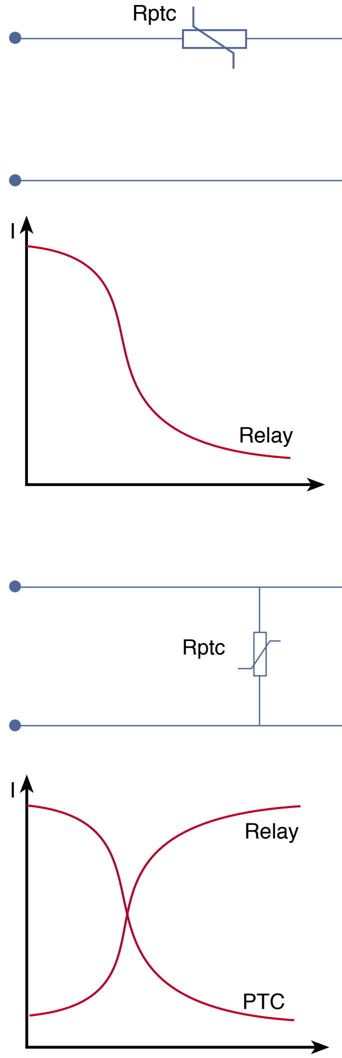

Figure 18: Time Delay Circuits

Liquid Level/Air Flow

These applications are based on the principle that the dissipation factor of a thermistor, δ, changes with respect to changes in the environment surrounding it. This change in δ allows the thermistor to either be able to shed more or less heat to its surroundings. See the figure below for a typical circuit configuration for a PTC used as a liquid level or air flow sensor.

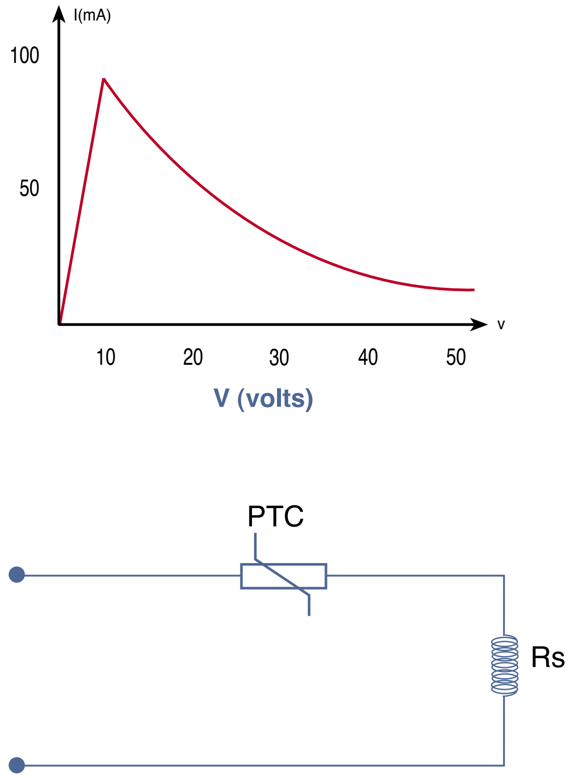

Figure 19: Liquid Level/Air Flow

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In general, a self-heated thermistor in a liquid can dissipate approximately four to six times as much power as it can in air. Likewise, a self-heated thermistor can shed more heat in flowing air than it can in still air. A good liquid level/air flow design should ensure that the design operates under worst case conditions. For example, for a liquid level application, the design should function such that the thermistor can dissipate more power when submerged in the hottest liquid than it can when subjected to the coolest air.

Temperature Sensing and Control

Unlike the NTC thermistor with its ability to sense temperature accurately over a wide temperature range, the PTC thermistor is only useful as a temperature measuring device over a relatively short range of temperatures near the switch temperature. Because the resistance versus temperature characteristic of the PTC thermistor does not lend itself to an equation, most specifications are for the PTC thermistor to be a resistance value at some specific temperature plus or minus some tolerance. When the PTC is being used as a temperature sensor, the amount of current through the PTC must be small so as not to self-heat the thermistor and cause errors. Normally, it is not possible to use a PTC thermistor as a temperature sensor when it is in a self-heated mode of operation.

Underwriters Laboratories (UL®) Certification for PTC Heaters

For PTC thermistors that are to be used as self-regulating heaters it is now possible to obtain UL recognition for a variety of parts. UL recognition of ceramic PTC devices is listed under heading XPGU2 Component – Thermistor Type Devices. Advanced Thermal Products is listed under file number E157106. Within this classification, a wide variety of PTC thermistors can be recognized. Both disc and rectangular styles can be listed, In addition, a wide variety of switch temperatures (T_s), R_{25} values and voltage ratings can be recognized. Because the testing has been completed for a “family” of parts, as long as the new thermistor falls within the parameters of the parts that were tested, ATP can immediately assign UL model numbers based on the part parameters.

UL Recognition for PTC Heaters	
Disc Style Size	**0.100” to 0.750” (2.5mm to 19.1mm)**
Rectangular Size Style	**Length: 0.100” to 2.00” (2.5mm to 50.8mm)** **Width: 0.100” to 2.00” (2.5mm to 50.8mm)**
Part Thickness	**0.030” to 0.250” (0.76mm to 6.35mm)**
Switch Temperature (T_s)	**40˚C to 180˚C**
Voltage Rating (V_{max})	**12 volts to 240 volts**
Resistance at 25˚C (R_{25})	**<100k**

Note: Parts outside the ranges listed in the table can be recognized. However, individual testing will need to be performed for qualification