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SERIES K: PROTECTION AGAINST INTERFERENCE

**Surge protective component application guide –
Self-restoring thermally activated overcurrent
protectors**

Recommendation ITU-T K.144



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Surge protective component application guide – Self-restoring thermally activated overcurrent protectors

Summary

Recommendation ITU-T K.144, which is a part of the surge protective component application guide series, covers self-restoring thermally activated overcurrent protectors (OCPs). Unlike fuses and heat coils, which break the circuit, these series connected self-restoring thermally activated overcurrent protectors (OCPs) automatically reset when the electrical event causing the overcurrent stops, without the need for manual intervention.

Self-restoring thermally activated overcurrent protector (OCP) components operate by the increasing in resistance value, which reduces the circuit current when the overcurrent exceeds a given value for a sufficient time. The resistance transition is caused by the component body reaching a critical temperature caused by the i^2R heating of the overcurrent flowing through the component. The generic name for components with this type of action is positive temperature coefficient (PTC) thermistors. Being thermally operated, these PTC thermistors generally do not operate for short duration electrical transients, such as coupled lightning currents, but will operate for longer term AC and DC overcurrents.

There are two types of material used to make PTC thermistors; ceramic and polymer. Many of the component parameters apply to the both types of material. Some parameters are specific to the material used and these differences are explained. This Recommendation describes positive temperature coefficient (PTC) thermistor construction, operation, production, ratings and characteristics and gives application examples.

History

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Keywords

Ceramic, current limiter, holding, operate time, polymer, positive temperature coefficient (PTC), thermally activated, trip.

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Table of Contents

		Page
1	Scope.....	1
2	References.....	1
3	Definitions	1
	3.1 Terms defined elsewhere.....	1
	3.2 Terms defined in this Recommendation.....	2
4	Abbreviations, acronyms and symbols	2
	4.1 Abbreviations and acronyms	2
	4.2 Symbol.....	3
5	Conventions	3
6	Overview PTC thermistor operation.....	3
	6.1 PTC thermistor resistance.....	3
	6.2 Polymeric and ceramic material resistance change	4
	6.3 PTC thermistor overcurrent operation.....	5
7	Polymeric PTC thermistor	6
	7.1 Production.....	6
	7.2 Operation	6
	7.3 Characteristics	7
	7.5 Ratings.....	8
8	Ceramic PTC thermistors	8
	8.1 Construction	8
	8.2 Operation	9
	8.3 Production.....	11
	8.4 Characteristics	11
9	Characteristic parameters.....	12
	9.1 General	12
	9.2 Hold current, I_h , and trip current, I_t	12
	9.3 Resistance, R	12
	9.4 Resistance 1 h after tripping, R_1 for polymer PTC thermistors.....	13
	9.5 Impulse resistance, R_{imp} for ceramic PTC thermistors	13
	9.6 Time-to-trip, t_{trip}	14
10	Ratings	16
	10.1 General	16
	10.2 Impulse voltage withstand.....	16
	10.3 AC power fault: maximum current, I_{max} , and voltage, V_{max}	16
	10.4 Impulse endurance test (life test).....	16
	10.5 AC endurance test (PTC thermistor) (life test).....	16
11	Applications.....	16

	Page
11.1 General	16
11.2 Telecom POTS protection	17
11.3 Power supply overcurrent protection.....	17
11.4 Battery packs	17
11.5 Loudspeaker	18
11.5 Motors.....	18
11.6 Heaters	18
Bibliography.....	19

Recommendation ITU-T K.144

Surge protective component application guide – Self-restoring thermally activated overcurrent protectors

1 Scope

This Recommendation in the surge protective component application guide series covers self-restoring thermally activated overcurrent protectors (OCPs). These OCPs are operated by self-heating and are automatically reset after the end of the overcurrent condition without the need for manual intervention. This Recommendation covers the two types of body material; polymer and ceramic. These components are referred to as follows:

- a) polymer positive temperature coefficient (PPTC) thermistors;
- b) ceramic positive temperature coefficient (CPTC) thermistors;

Guide topics include:

- Construction
- Operation
- Production
- Ratings
- Characteristics
- Application examples

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T K.82] Recommendation ITU-T K.82 (2010), *Characteristics and ratings of solid-state, self-restoring overcurrent protectors for the protection of telecommunications installations.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 endurance test (life test) AC [ITU-T K.82]: Application of a specified number of trip events under specified temperature and trip cycle (on and off time) conditions.

NOTE – After the test, the product shall meet specified mechanical and electrical parameters.

3.1.2 endurance test (life test) impulse [ITU-T K.82]: Application of a specified number of impulses under specified temperature and impulse repetition rate conditions.

NOTE – After the test, the product shall meet specified mechanical and electrical parameters.

3.1.3 fault current, I_{fault} [b-IEC 62319-1]: Current used when measuring time-to-trip.

3.1.4 hold current, I_h [b-IEC 62319-1]: Maximum current at specified ambient temperature, which will not cause the trip event.

NOTE – Sometimes known as rated or non-tripping current.

3.1.5 impulse generator charge voltage, V_c [ITU-T K.82]: Value of impulse generator charging voltage.

3.1.6 impulse resistance (ceramic PTC thermistor) R_{imp} [ITU-T K.82]: Quotient of the peak impulse voltage between the terminals by the peak impulse current through the PTC thermistor.

NOTE – Ceramic PTC thermistors are also voltage-dependent resistors and conduct higher currents (up to three times) under impulse conditions than predicted from the untripped resistance value.

3.1.7 impulse voltage, V_{imp} [ITU-T K.82]: Value of peak impulse voltage.

NOTE – V_{imp} is the impulse voltage across the OCP, not necessarily the impulse generator peak open-circuit voltage value.

3.1.8 maximum current AC, I_{max} [b-IEC 62319-1]: Value of current for the operating temperature range, which should not be exceeded.

3.1.9 maximum voltage AC, V_{max} [b-IEC 62319-1]: Maximum AC voltage that may be applied.

3.1.10 positive temperature coefficient thermistor [b-IEC 62319-1]: Thermistor that exhibits a very sharp increase in resistance over a narrow temperature range.

NOTE – In this Recommendation, the change of temperature that results in resistance increase is caused by the current flow through the PTC thermistor.

3.1.11 regional values [ITU-T K.82]: AC test parameters to suit local conditions in accordance with the variations permitted in the ITU-T K-series Recommendations for equipment.

3.1.12 resistance R [ITU-T K.82]: Untripped value of DC resistance measured at specified ambient temperature.

3.1.13 resistance 1 h after tripping (polymer PTC thermistor), R_1 [b-IEC 62319-1]: Resistance of a Polymer PTC thermistor 1 h after a trip event or 1 h after reflow for surface mounting devices.

NOTE – R_{1max} is the maximum allowed value of R_1 .

3.1.14 time-to-trip, (PTC thermistor) t_{trip} [b-IEC 62319-1]: Under specified ambient conditions, starting from the time the fault current (I_{fault}) is applied, the time-to-trip is the time required for a device to transition into a tripped state.

NOTE – An PTC thermistor shall have passed into the tripped condition as indicated by the measured voltage exceeding 90% of the supply open-circuit voltage.

3.1.15 trip current, I_t [b-IEC 62319-1]: Lowest current which will cause a trip event at a specified temperature and within a time specified in the product specification.

3.1.16 trip event [b-IEC 62319-1]: Event of rapid increasing resistance in response to an overcurrent surge.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations, acronyms and symbols

4.1 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CPTC Ceramic Positive Temperature Coefficient (thermistor)

GDT Gas Discharge Tube

NTC	Negative Temperature Characteristic
OCP	Overcurrent Protector
POTS	Plain Old Telephone System
PPTC	Polymer Positive Temperature Coefficient (thermistor)
PTC	Positive Temperature Coefficient (thermistor)
R-T	Resistance-Temperature
SPD	Surge Protective Device
V-I	Voltage-Current
VDR	Voltage Dependent Resistor

4.2 Symbol

Figure 1 shows the [b-IEC 60617] graphical symbol used for a PTC thermistor

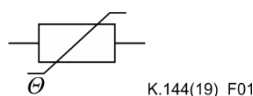


Figure 1 – Symbol for a PTC thermistor

5 Conventions

None.

6 Overview PTC thermistor operation

6.1 PTC thermistor resistance

PTC thermistors can be made from polymeric or ceramic materials. Generically both types have the same resistance-temperature (R-T) characteristic. Figure 2 shows a straight line approximation of a PTC thermistor R-T characteristic. At a critical temperature the resistance increases rapidly, ultimately rising by five orders of magnitude. When the resistance starts to rapidly increase, the PTC thermistor is termed to be tripped. On cooling the resistance resets close to the original low resistance value. The component temperature will be the sum of the ambient temperature, T_a , and component self-heating temperature rise caused by the current passing through it.

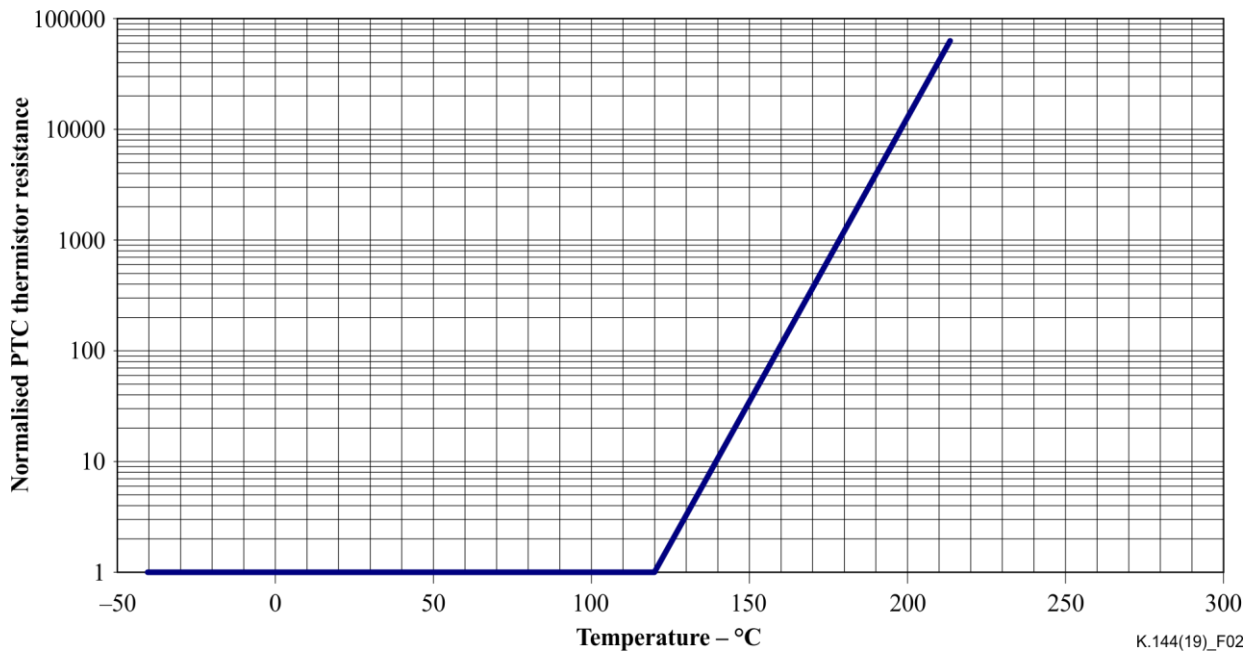


Figure 2 – Straight line approximation of PTC thermistor resistance versus temperature

6.2 Polymeric and ceramic material resistance change

These components are series connected in the circuit and pass the full overcurrent, which causes component self-heating. Both materials show a rapid increase in resistance once a specific temperature is exceeded and the resistance increase reduces the level of overcurrent. Polymer and ceramic resistance increases are due to different effects, see Figure 3.

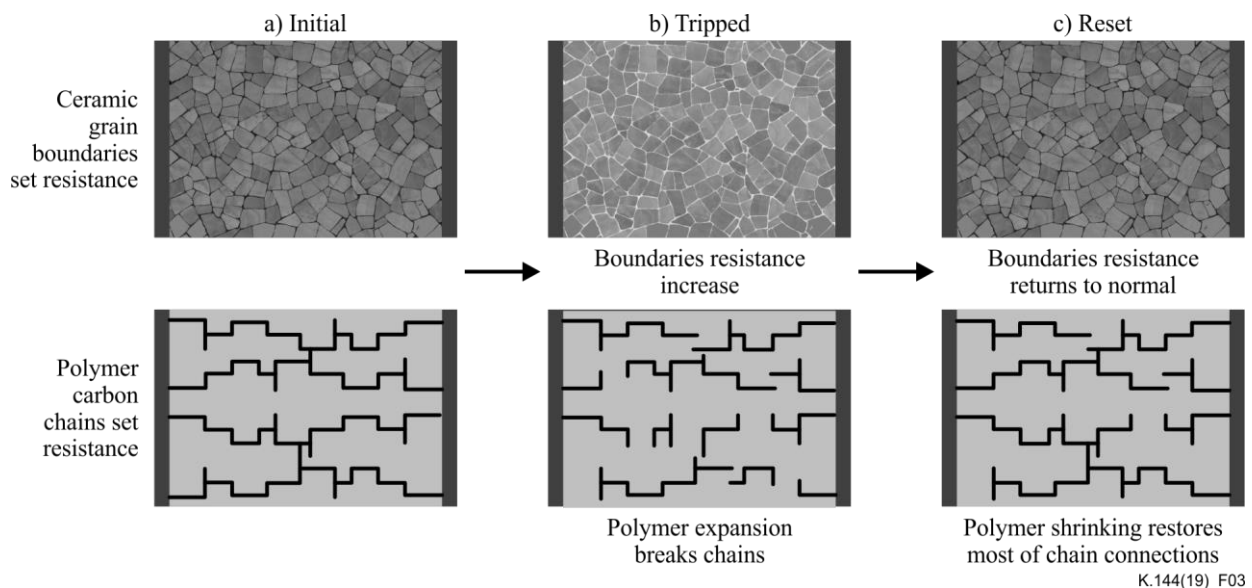


Figure 3 – Ceramic and polymer material resistance change with temperature

Ceramic grain boundaries (black lines) control the CPTC thermistor resistance variation. At the critical temperature (Tripped) the boundaries greatly increase in resistance (white lines) reducing the overcurrent level. When the overcurrent stops and the CPTC thermistor cools (Reset), the grain boundaries return to their original state (black lines).

The PPTC thermistor resistance is controlled by carbon chains through the polymer material (black lines). At the critical temperature (Tripped) the polymer expands sufficiently to break many of the chains causing a great increase in resistance (broken black lines) reducing the overcurrent level.

When the overcurrent stops and the PPTC thermistor cools and the polymer shrinks back (Reset), it makes most of the chains re-connect (continuous black lines).

6.3 PTC thermistor overcurrent operation

The PTC thermistor operation can be expressed as a voltage-current (V-I) characteristic. Figure 4 shows a straight line approximation of a generic PTC thermistor V-I characteristic. The solid black line represents the DC V-I characteristic, with the peak current representing the trip point when the line slope changes from positive to negative. Under dynamic overcurrent conditions the component thermal capacitance prevents an instantaneous change of resistance and the positive line slope line extends to the fault current level as shown by the dashed black line. When the self-heating causes the component temperature to reach the critical value the current then decreases. This time lag means that PTC thermistors can current limit for long duration AC and DC events, but cannot current limit short duration electrical events such as lightning.

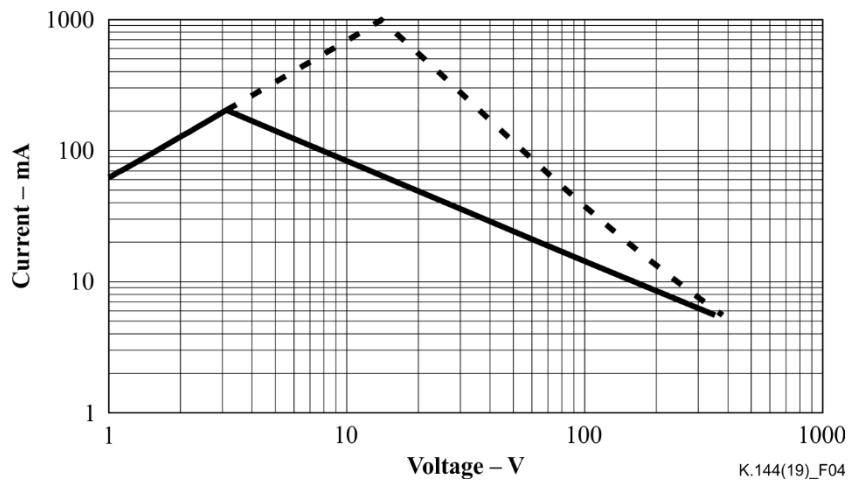


Figure 4 – Generic PTC thermistor V-I characteristic

Figure 5 shows an example of AC power fault operation. The waveform trace shows the AC overcurrent is unlimited until self-heating causes the component to trip and reduce the current. The example circuit shows the AC over voltage source, V_s , source resistance, R_s , the PTC thermistor and the following load.

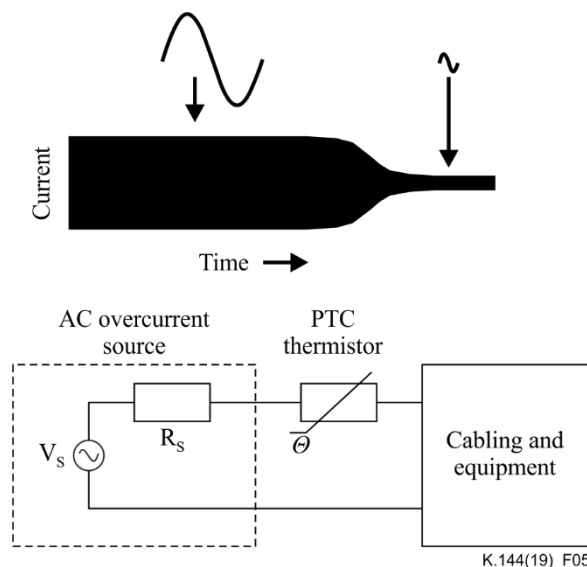


Figure 5 – Example of AC power fault current limiting

7 Polymeric PTC thermistor

7.1 Production

The active material in a PPTC thermistor is made by loading a conductive medium, typically carbon black, into a molten polymer. This polymer must have an adequate amount of crystallinity when cooled, to create carbon chains. The amount of conductive medium added depends on the nature of the medium, and on the cold resistance required.

The production process begins by extruding the mixture of conductive medium and polymer into relatively thin sheets. Foil electrodes are then attached to both sides of the sheet, forming what is often called plaque. Components are made by punching chips out of the plaque, and attaching leads to the chips. The resulting device may, or may not be encapsulated, depending on the application.

As the mixture is cooled, it starts to crystallize. As it does, the conductive medium is expelled from the crystalline region into the amorphous region. The result is an increasing concentration of conductive medium in the amorphous region. As the crystalline region of the polymer grows during the cooling process, the amorphous region shrinks, until the density of conductive medium is sufficient to allow the formation of conductive chains. Further shrinkage of the amorphous region causes the chains to grow. When the chains are long enough they form a bridge between the electrodes, making the component resistance drop - slowly at first, and then rapidly. Further cooling results in a further decrease in resistance, but at a lower rate.

7.2 Operation

A typical polymer R-T curve is shown in Figure 6. Note that the un-tripped resistance always decreases with decreasing temperature.

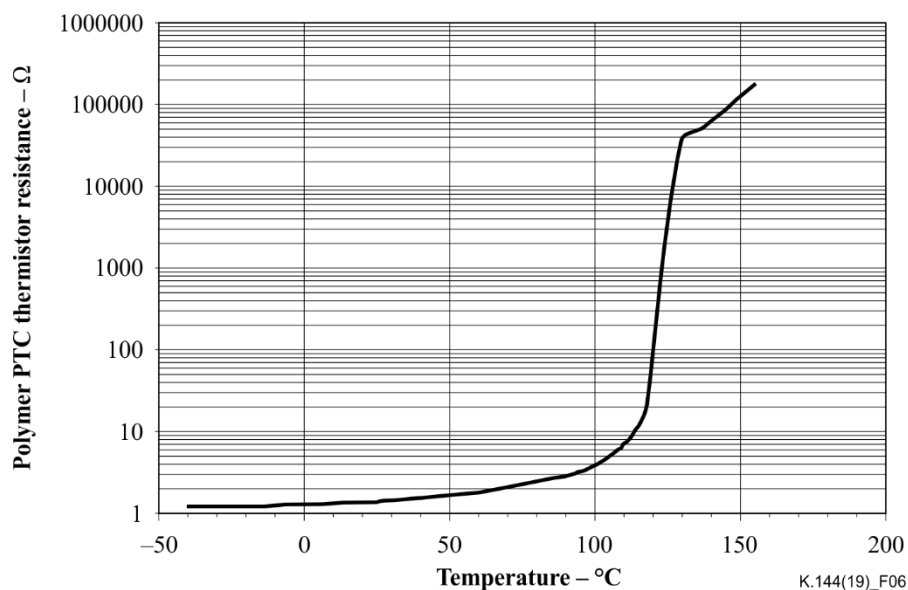


Figure 6 – Example of a polymeric PTC thermistor resistance-temperature (R-T) curve

Component operation occurs by traversing the R-T curve. The temperature of the device on the R-T curve is a combination of the ambient temperature and an incremental temperature due to component I^2R heating. Because of this combination, the current required to operate the component is a function of the ambient temperature, and is characterized by a derating curve such as that shown in Figure 7.

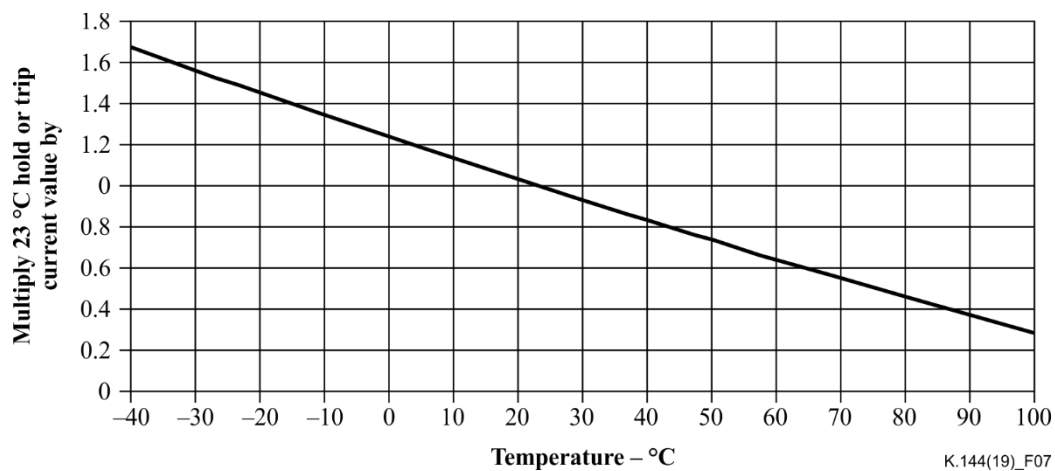


Figure 7 – Example of a typical derating curve for either hold or trip current

7.3 Characteristics

7.3.1 General

The characteristics listed on a data sheet typically include hold current, trip current, a time-to-trip value at a specified current, and a resistance range. Among these, the cold resistance range is the key parameter, because it determines the hold current, trip current and time-to-trip ratings.

7.3.2 Cold resistance

The cold resistance of the component is the resistance measured at a standard ambient temperature. As described in clause 7.1, the cold resistance of the component depends on its material composition. Because the density of carbon chains is not precisely uniform over the plaque, the resistance of any given chip punched from the plaque varies over a range of values. The minimum and maximum values of resistance (R_{\min} and R_{\max} , respectively) for components made from these chips are specified on the data sheet for the component.

7.3.3 Hold and trip currents

For a typical component, a plot of hold/trip current [they are the same for a given component] for a possible range of production lots is shown in Figure 8. The upper and lower lines shown in the plot are the 99.8% confidence lines for the distribution. If the confidence level is reduced, the confidence lines will move closer together; and the hold and trip currents will also move closer together. However reducing the confidence level will increase the probability that the customer will receive a part that is out of spec; unless a selection step is added to the production process to eliminate out-of-spec parts.

In Figure 8, the trip current is determined as the value of current corresponding to R_{\min} , and the hold current is determined as the value of current corresponding to R_{\max} (the resistance one hour after a trip event). Moving the resistance window will change the hold and trip currents, as will expanding or contracting the resistance window. Data is typically taken over a wider resistance range than will occur in production, to better establish the regression line, and to better show options for placement of the resistance window. Plots similar to Figure 4 can be made for the process variables of any component.

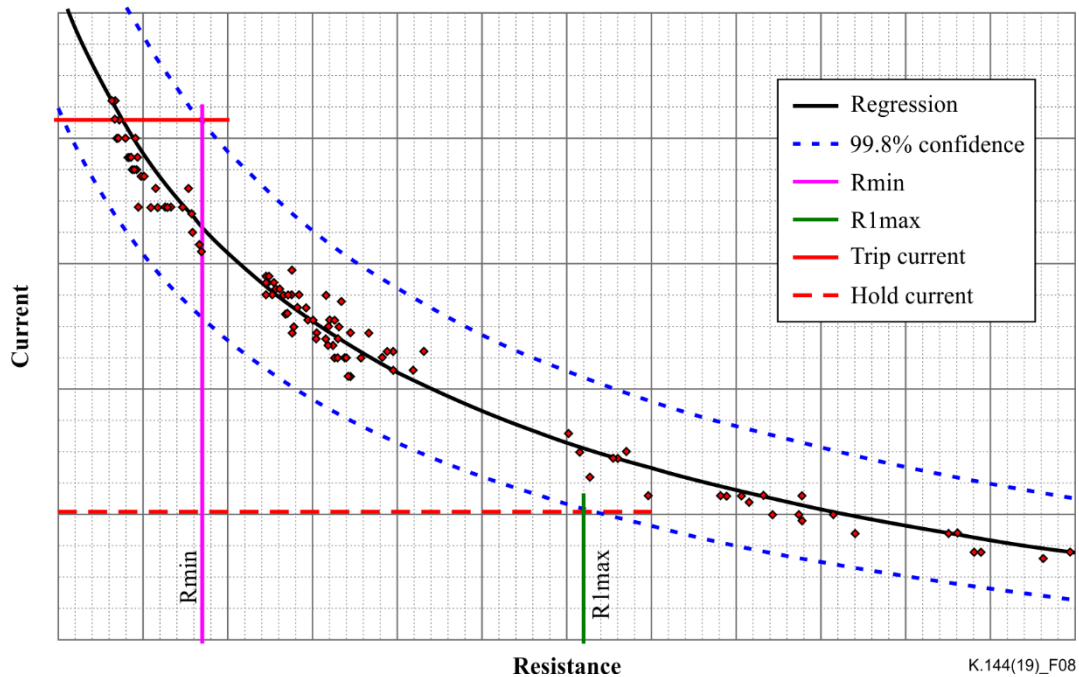


Figure 8 – An illustration of a dispersion plot of hold/trip current versus resistance

7.5 Ratings

7.5.1 General

The ratings listed on a data sheet typically include a maximum rated voltage, and a maximum rated current. Resistance recovery time (a characteristic) may also be measured, but is generally not specified.

8 Ceramic PTC thermistors

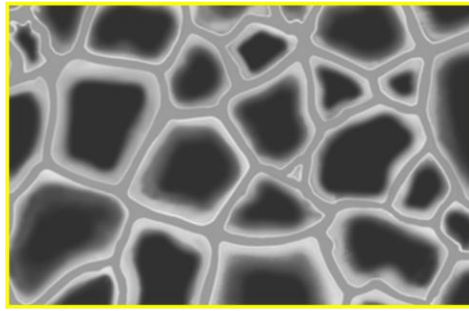
8.1 Construction

PTC thermistors are made of doped polycrystalline ceramic on the basis of barium titanate. Generally, ceramic is known as a good insulating material with a high resistance. Semiconduction and thus a low resistance is achieved by doping the ceramic with materials of a higher valency than that of the crystal lattice. Part of the barium and titanate ions in the crystal lattice is replaced with ions of higher valencies to obtain a specified number of free electrons which make the ceramic conductive.

The material structure is composed of many individual crystallites (see Figure 9). At the edge of these monocrystallites, the grain boundaries, potential barriers are formed. They prevent free electrons from diffusing into adjacent areas. The result is high resistance of the grain boundaries. However, this effect is neutralized at low temperatures. High dielectric constants and sudden polarization at the grain boundaries prevent the formation of potential barriers at low temperatures enabling a smooth flow of free electrons. The PTC thermistor resistance R is composed of individual crystal and grain boundary resistances. The grain boundary resistance is strongly temperature dependent.

$$R = R_{\text{grain}} + R_{\text{boundary}}$$

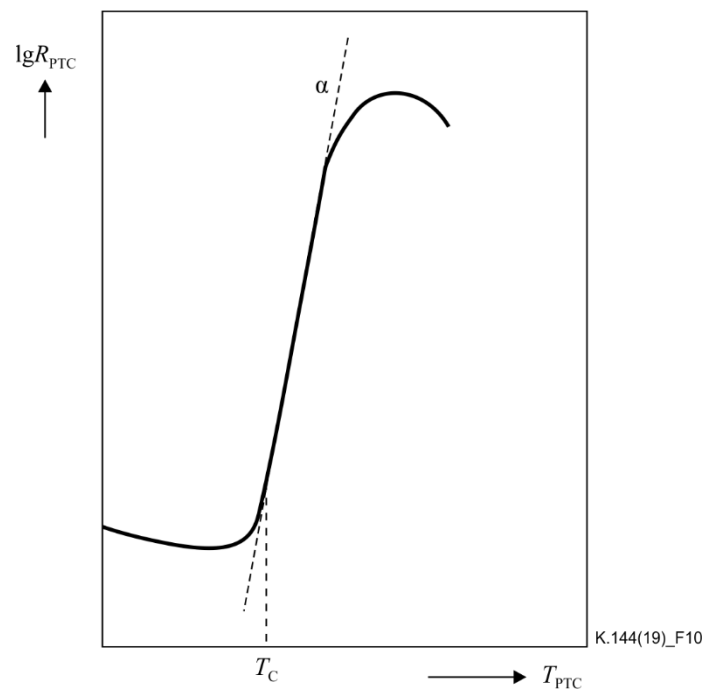
$$R_{\text{boundary}} = f(T)$$



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Figure 9 – Representation of the polycrystalline structure of a ceramic PTC thermistor

Above the ferroelectric Curie temperature, dielectric constant and polarization decline so far that there is strong growth of the potential barriers and thus of resistance. In a certain range of temperature above the Curie temperature T_C , the resistance of the PTC thermistor rises exponentially. Beyond the range of the positive temperature coefficient the number of free charge carriers is increased by thermal activation. The resistance then decreases and exhibits a negative temperature characteristic (NTC) typical of semiconductors (see Figure 10). In Figure 10, T_C is the ferroelectric Curie temperature and α = temperature coefficient. With rising temperature, the resistance of the PTC thermistor initially decreases and rises then steeply. Beyond the range of the positive temperature coefficient the resistance again decreases, which can lead to thermal run-away if the thermistor is operated in this region.



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Figure 10 – An example of an RT curve for a ceramic PTC thermistor

8.2 Operation

A current flowing through a thermistor may cause sufficient heating to raise the thermistor's temperature substantially above the ambient temperature. As the effects of self-heating are not always negligible, a distinction has to be made between the characteristics of an electrically loaded thermistor and those of an unloaded thermistor. The properties of an unloaded thermistor are also termed "zero-power characteristics".

8.2.1 Resistance (untripped), R

The zero-power resistance value R is the resistance value measured at a given temperature with the electrical load kept so small that there is no noticeable change in the resistance value if the load is further reduced.

Figure 11 shows the typical dependence of the zero-power resistance on temperature. Because of the abrupt rise in resistance (the resistance value increases by several orders of magnitude), the resistance value is plotted on a logarithmic scale (ordinate) against a linear temperature scale (abscissa).

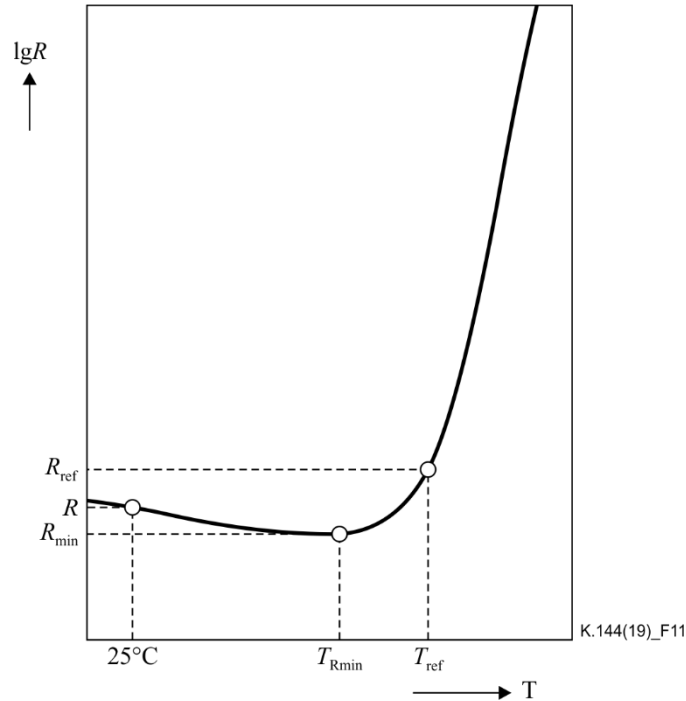


Figure 11 – Typical resistance/temperature characteristic

In Figure 11:

$$R = f(T)$$

R PTC thermistor resistance (resistance value at 25°C)

R_{\min} Minimum resistance

$T_{R\min}$ Temperature at R_{\min}

R_{ref} Reference resistance: $R_{\text{ref}} = 2 \cdot R_{\min}$

T_{ref} Reference temperature (resistance value reaches $R_{\text{ref}} = 2 \cdot R_{\min}$)

8.2.2 Electrically powered

When current flows through the thermistor, the component will heat up more or less by power dissipation. The properties of electrically powered PTC thermistors (in self-heated mode) are better described by the V-I characteristic than by the R-T curve (see Figure 12). It illustrates the relationship between voltage and current in a thermally steady state.

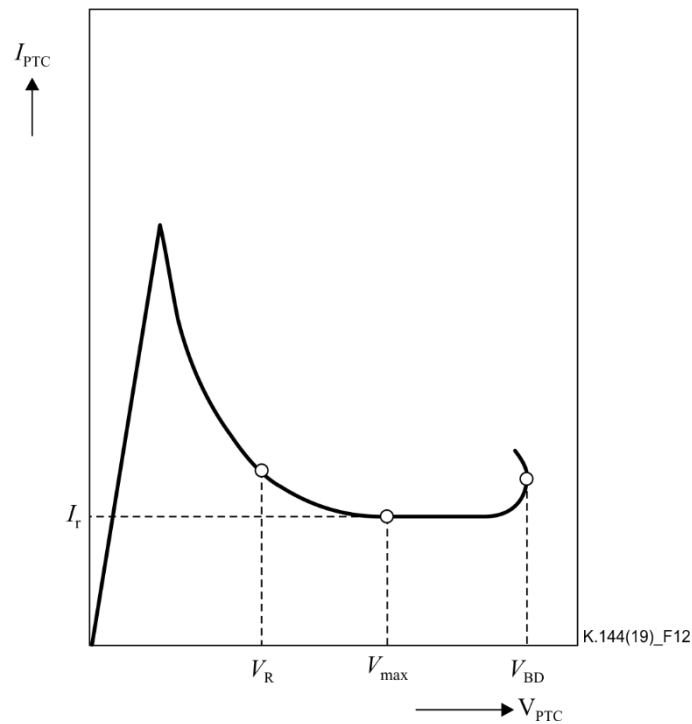


Figure 12 – I/V characteristic of a PTC thermistor

In Figure 12:

I_r Residual current at applied voltage V_{max} (current is balanced)

V_{max} Maximum operating voltage

V_R Rated voltage ($V_R < V_{max}$)

V_{BD} Breakdown voltage ($V_{BD} > V_{max}$)

8.3 Production

Mixtures of barium carbonate, titanium oxide and other materials whose composition produces the desired electrical and thermal characteristics are ground, mixed and compressed into disks, washers, rods, slabs or tubular shapes depending on the application. These blank parts are then sintered, preferably at temperatures below 1400°C. Afterwards, they are carefully contacted, provided with connection elements depending on the version and finally coated or encased.

8.4 Characteristics

8.4.1 General

The parameters listed on a data sheet typically include rated current, switching current, a time-to-trip value at a specified current, a rated resistance, a maximum operating voltage, and a maximum switching current. Among these, the cold resistance (rated resistance) is the key parameter, because it determines the hold current, trip current, and time-to-trip ratings in combination with the physical dimensions.

8.4.2 Resistance R

The resistance R is the resistance value at specified temperature. PTC thermistors are classified according to this resistance value. The measurement temperature is 25°C, unless otherwise specified.

As described in clause 8.1 the resistance is determined by the grain boundaries of the ceramic material. Because of impurities during the production process the potential barriers and therefore

the rated resistance varies over a range of values. The resistance tolerance is specified on the data sheet for the component.

As opposed to PPTC thermistors, ceramic PTC thermistors always return to their initial resistance value, even after frequent heating/cooling cycles.

9 Characteristic parameters

9.1 General

A component electrical characteristic value is measured during a test that applies specified conditions. There is a great variation in the terminology used to describe characteristic regions or points. This clause explains the terminology used in the Recommendation and what is the significance of a parameter.

The characteristics listed on a data sheet typically include hold current, trip current, a time-to-trip value at a specified fault current, and a resistance range all at a specified temperature. Among these, the cold resistance range is the key parameter, because it determines the hold current, trip current, and time-to-trip ratings.

9.2 Hold current, I_h , and trip current, I_t

Holding current, I_h , and trip current, I_t , are minimum and maximum values of the nominal component current characteristic. Figure 13 shows how these two values vary with temperature. For design I_h is the most important. The component I_h must not be lower than the nominal system current at the highest expected ambient at the component location to avoid system disruption. Normally, the maximum trip current, I_t , is twice the I_h value over the temperature range. The following circuitry must be able to cope with the I_t value at the lowest expected ambient at the component location to avoid system damage.

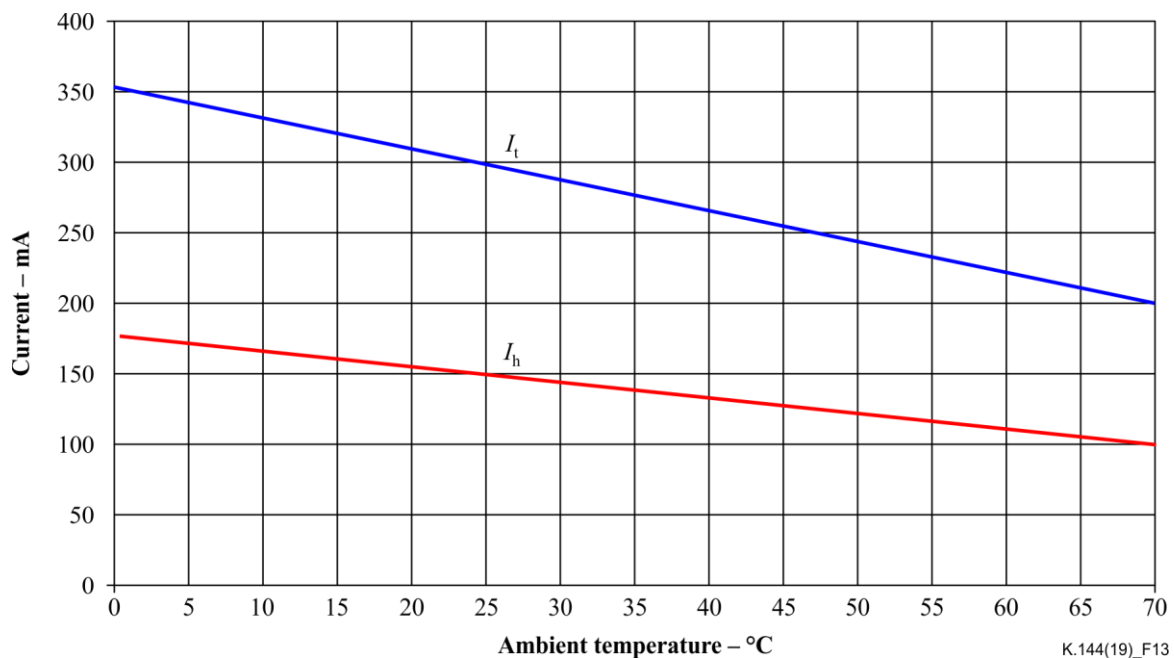


Figure 13 – PTC thermistor hold and trip currents variation with temperature

9.3 Resistance, R

The un-tripped resistance R is the resistance value at specified temperature. PTC thermistors are classified according to this resistance value. The measurement temperature is 25°C, unless otherwise specified.

PPTC thermistors resistance decreases with decreasing temperature. However CPTC thermistors have an inverted bell shaped resistance curve with temperature, see Figure 11.

9.4 Resistance 1 h after tripping, R_1 for polymer PTC thermistors

A PPTC thermistor which is tripped by a fault current greater than the rated trip current for the component will stay in the tripped state until the fault power is removed. Once the power is removed the component will cool, and the resistance will drop toward the cold resistance. The rate at which it returns has a significant dependence on a number of things, including the amount of the fault current, the rate of heat transferred out of the component, and the size of the component. An example of one of many possible resistance recovery curves is shown in Figure 14 Typically, an hour is allowed for the resistance to stabilize near its cold value; and on the data sheet this value of resistance can be listed as R_{1max} . Often a value of resistance near R_{1max} is achieved in a much shorter time than one hour. The cooling time scale of the figure depends on the factors mentioned earlier.

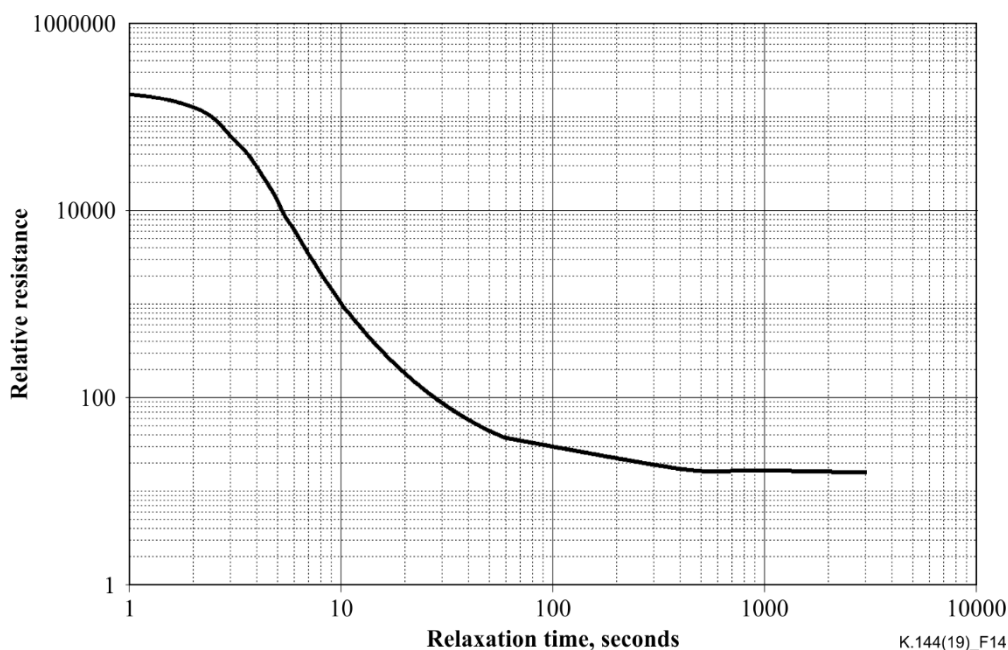


Figure 14 – General shape of a PPTC thermistor resistance recovery curve

9.5 Impulse resistance, R_{imp} for ceramic PTC thermistors

CPTC thermistors also act as voltage dependent resistors (VDRs). Although the CPTC thermistor does not trip during a transient voltage event, its un-tripped resistance does decrease with increasing voltage, Figure 15 shows how the resistance, R , decreases from 50Ω to 16Ω with increasing 1.2/50-8/20 generator voltage. As the generator effective output impedance is 2Ω , most of the generator voltage will be across the CPTC thermistor. This three to one resistance change means the current delivered to the following circuitry is three times higher than might be expected.

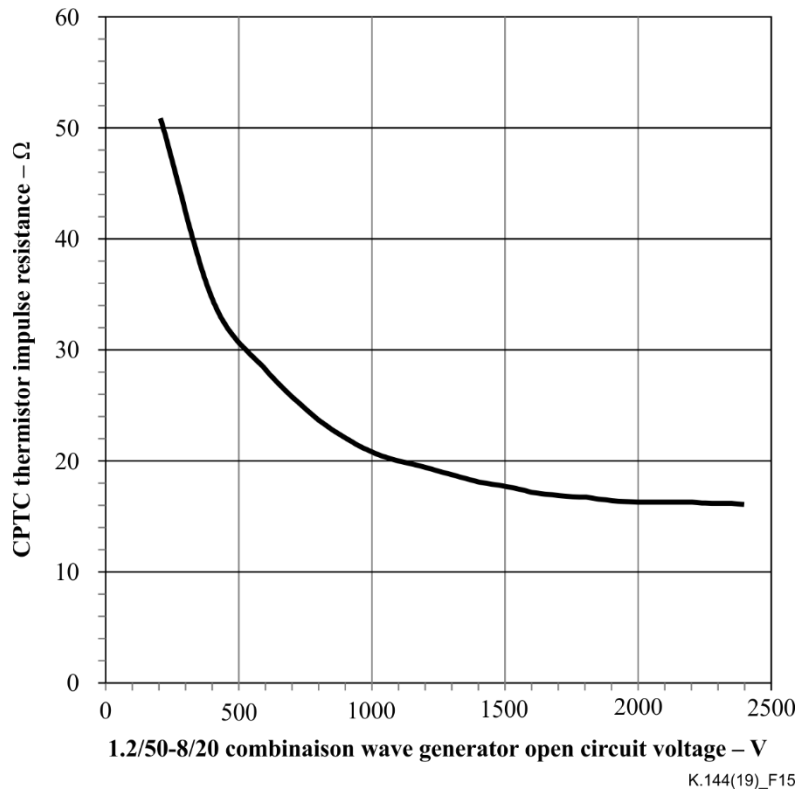


Figure 15 – Example CPTC thermistor impulse resistance versus 1.2/50-8/20 generator voltage

9.6 Time-to-trip, t_{trip}

9.6.1 General

The time-to-trip test in [ITU-T K.82] states that the PTC thermistor has passed into the tripped condition when measured voltage exceeds 90% of the supply open-circuit voltage.

9.6.2 PPTC thermistor

As was the case for hold and trip currents, the time for a PPTC thermistor to trip at a specified fault current is also a function of resistance. Being a lower resistance than CPTC thermistors, PPTC thermistors will typically have higher fault current values. Figure 16 shows a typical current versus time-to-trip plot. Components of lower resistance will have a time-to-trip curve that lies above the curve shown in Figure 16. Components of higher resistance will have a time-to-trip curve that lies below the curve shown in Figure 16. At higher temperatures the line moves down (faster trip times for a given current). At lower temperatures the line moves up (longer trip times for a given current). The curve moves up or down with temperature, according to the derating curve for the component (see Figure 7). As PPTC thermistors tend to have lower resistance values than CPRC thermistors fault currents are higher. Overall PPTC thermistors tend to trip faster than CPRC thermistors.

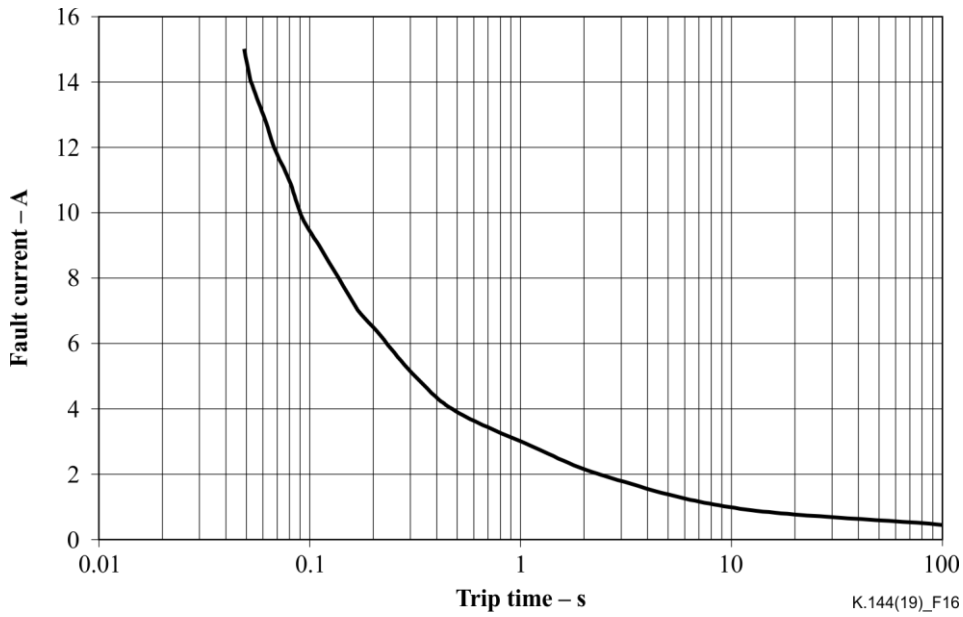


Figure 16 – Example PPTC thermistor time-to-trip versus fault current

9.6.3 CPTC thermistor

The dynamic heating behaviour of the PTC thermistor is determined by the specific heat capacity of the titanate material, which is approx. 2.7 Ws/Kcm^3 . At short time-to-trips (less than 5 s with commonly used overcurrent protection components) heat dissipation through the surface and lead wires is virtually negligible. Almost the entire electrical dissipation is consumed to heat up the ceramic material, to increase the temperature above the reference temperature and thus to produce a stable operating point on the R-T characteristic. When dissipation increases with rising difference between component temperature and ambient, only a small amount of excess energy remains for heating the component and the result is the trip time curves as a function of fault current shown in Figure 17.

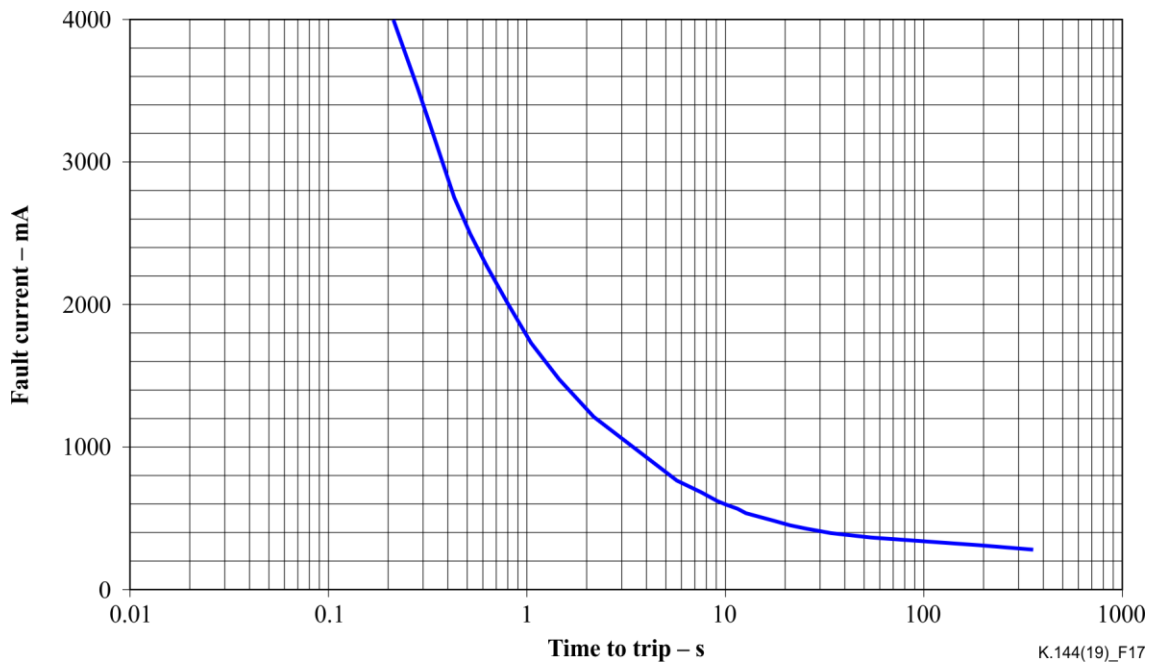


Figure 17 – Example CPTC thermistor time-to-trip versus fault current

10 Ratings

10.1 General

A component electrical rating is verified by applying the rated value followed by a test to check for degradation. Degradation is evaluated by measuring specified electrical characteristic parameters, which should remain within specified limits.

10.2 Impulse voltage withstand

The impulse voltage test in [ITU-T K.82] uses a 10/700 generator. At the rated withstand voltage the PTC thermistor should not trip. For PPTC thermistors the current passed will be the withstand voltage divided by R_{\min} . Because of voltage dependent resistor, VDR, action, CPTC thermistors will pass an approximate current of the withstand voltage divided by $R_{\min}/3$. For lower values of impulse voltage, the current passed should be reduced appropriately. The following circuitry must be able to withstand the PTC thermistor current

10.3 AC power fault: maximum current, I_{\max} , and voltage, V_{\max}

[ITU-T K.82] applies a specified power fault condition five times. If the power fault is represented by a voltage source, V_S , source resistance, R_S feeding just the PTC thermistor of resistance R_{\min} , see Figure 5. Then:

$$I_{\max} > V_S / (R_S + R_{\min})$$

If the power fault time is sufficient to cause tripping then:

$$V_{\max} > V_S$$

If there is a primary protector that precedes the PTC thermistor, then the PTC thermistor I_{\max} , and V_{\max} may be set by the primary protector limiting voltage, if the primary protector limiting voltage is $< \sqrt{2} \times V_S$.

10.4 Impulse endurance test (life test)

This optional impulse voltage withstand test from [ITU-T K.82] applies 100 impulses from a 10/700 generator. As this test does not involve tripping, 100 impulses are more than sufficient to verify the rating. For shorter duration and higher voltage impulse generators the component manufacturer should be consulted.

10.5 AC endurance test (PTC thermistor) (life test)

This optional AC endurance test from [ITU-T K.82] applies 100 AC power fault trip events to the component. PPTC thermistors suffer the greatest parameter change here with a progressive increase in R_1 .

11 Applications

11.1 General

PTC thermistors are used to reduce overcurrent in an AC or DC situation. The overcurrent event can occur when a high-current capability source is short-circuited, the source voltage becomes excessive creating an overcurrent condition or there is an external electrical event, such as power fault, causing an overcurrent in a circuit. In balanced signal systems, a pair of matched PTC thermistors are often used (one in each conductor) to maintain line balance. After reset it is important that the PTC thermistors are still reasonably balanced. In plain old telephone systems (POTSs) having a line impedance of 300 Ω , 10 Ω matched CPTC thermistors, sometimes supplied as a single component, were often used.

11.2 Telecom POTS protection

Figure 18 shows two stages of overvoltage protection with a gas discharge tube (GDT) providing primary protection and two thyristors Th1 and Th2 providing secondary protection. The current into the secondary protection and equipment is limited by a matched pair of PTC thermistors. The PTC thermistors must be selected to withstand the maximum GDT sparkover voltage under impulse conditions. For AC power fault conditions, the PTC thermistors must be selected to withstand 0.707 times the maximum GDT DC sparkover voltage. The maximum PTC thermistor AC current rating will be set by the applied AC fault conditions.

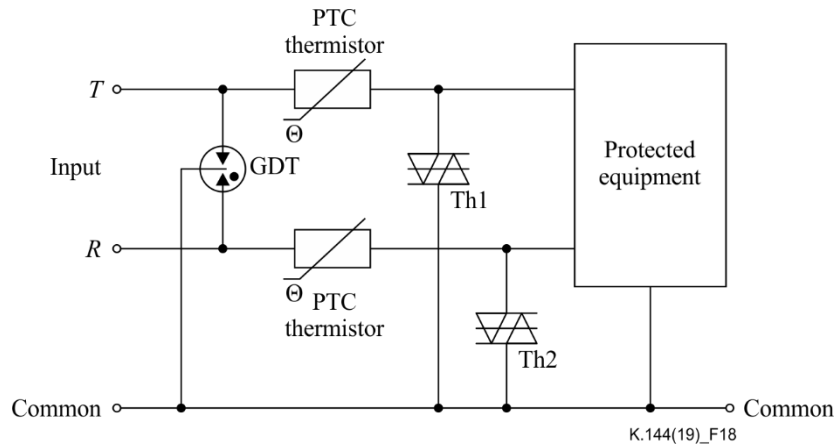


Figure 18 – Basic POTS protection scheme using a PTC thermistor for equipment overcurrent protection and primary-secondary surge coordination

11.3 Power supply overcurrent protection

Simple power supplies can use a series connected PPTC thermistor to limit the short circuit current. A PPTC thermistor is chosen as it is available in low resistance values that will not cause a substantial voltage loss in normal operation.

11.4 Battery packs

Shorted batteries can supply high levels of current. Low profile strap, see Figure 19, and circular PPTC thermistors are available for series connection in rechargeable battery packs. Key electrical selection parameters are maximum voltage; normal operating current; resistance and maximum short-circuit at the maximum ambient operating temperature.

Typically the battery protection PPTC thermistors will have a resistance in the 0.01 Ω to 0.1 Ω range and voltages in the range of 10 V to 30 V. To match the battery chemistry it is possible to have manufacture PPTC thermistor trip temperatures in the range of 80°C to 120°C. Holding currents are typically available in the 1 A to 10 A range with fault currents of 10 A to 50 A.

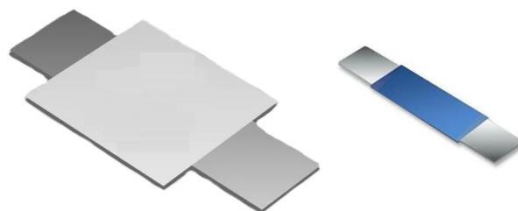


Figure 19 – Two examples of PPTC thermistor battery straps

11.5 Loudspeaker

Moving coil loudspeakers are usually low impedance ranging from 2 Ω to 16 Ω . Loudspeakers have a power limitation to avoid voice coil burnout. A series connected PTC thermistor can be used to limit the current, hence, the power to the loudspeaker, see Figure 20. Any extra series impedance must be much lower than the loudspeaker impedance making the low-resistance PPTC thermistor an obvious choice for this application.

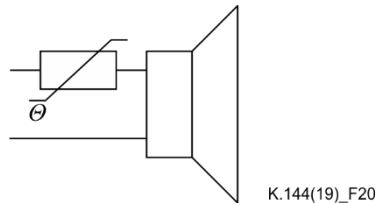


Figure 20 – Loudspeaker over current protection using a PPTC thermistor

Where multiple speakers are used to cover various parts of the audio range by using a crossover network it is often the high frequency speaker (tweeter) that has the smallest power rating. In this case it may be the most effective to place a PPTC thermistor directly in series with the high frequency speaker and after the crossover network.

11.5 Motors

In a stalled or jammed condition, a DC motor will not develop a back emf and high currents can flow. A series PTC thermistor, possibly embedded in the motor winding, can mitigate this condition.

11.6 Heaters

In the tripped condition a PTC thermistor is a self-regulating heater. Any increase in temperature causes a resistance increase, which will reduce the heating power and cause the temperature to reduce. Similarly, any decrease in temperature causes a resistance decrease, which will increase the heating power and cause the temperature to increase. Form factors are typically blocks, fin shaped, sheets and honey comb depending on purpose.

Transportation heating use examples include seats, camera and sensor de-icing, steering wheels, rear-view and wing mirrors, fuel and air heating. Medical heating use examples include surgical tables, beds, trolleys, chairs, mobility vehicles, blankets, and therapy heat pads. Miscellaneous heating uses include outdoor clothing, sleeping bags, domestic air heaters, towel drying racks, tropical fish-tanks, hand-held items, food and transport containers.

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