PTC Thermistors

EXPLANATION OF TERMS

Switch temperature (T_s)

The switch temperature is the highest temperature at which the resistance R_s is equal to twice the minimum resistance R_{min} (see Fig.1), so at $T_s > T_{Rmin}$ and $R_s = 2\ R_{min}$.

Temperature coefficient (α)

The temperature coefficient: $\alpha = \frac{1}{R} \times \frac{dR}{dT}$ gives an indication of the relative resistance change per degree Celsius or kelvin.

For R/T curves plotted on a logarithmic R/T scale:

$$\alpha = \frac{d\ ln\ R}{dt} = \frac{1}{0.4343} \times \frac{d\ log\ R}{dT}$$

The maximum temperature coefficient (α) is measured at the point of inflection of the log R/lin T characteristic, i.e. the point where $d^2\ log\ R/dT^2 = 0$ (see Fig.2).

When one resistance decade is taken ($R_2 = 10\ R_1$), the formula becomes:

$$\alpha = \frac{100}{0.4343} \times \frac{1}{T_2 - T_1}\ \%/K$$

Trip time

The trip, or response time is defined as the time taken for the PTC thermistor to reach its switching temperature at a constant voltage. This time period is also equal to the time taken for the current to be reduced by a factor of 2.

The approximate trip time (t_s) can be calculated using the formula:

$$t_s = \frac{h \times v \times (T_s - T_{amb})}{I_t^2 \times R - D(T_s - T_{amb})}$$

where:

v = the volume of the ceramic in mm^3

$R = (R_{25} + R_{min})/2$

I_t = the trip current

h = the specific heat of the ceramic; $h = (2.5 \times 10^{-3}\ J/K/mm^3)$

D = dissipation factor

T_s = switching temperature

T_{amb} = PTC temperature at the beginning of the overload current (in general the ambient temperature).

The above formula is only valid for relatively short trip times (< 1 minute). For longer trip times, R should be adapted to:

$$R = \frac{3}{2} \times R_{min}$$

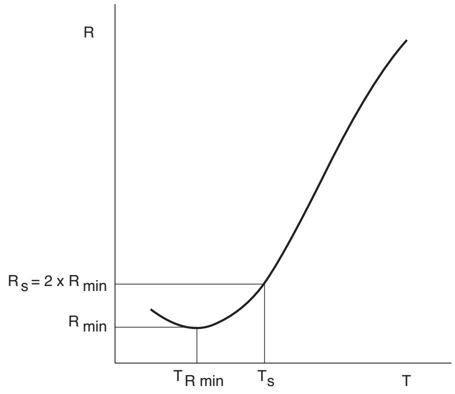

Fig.1 Switch temperature.

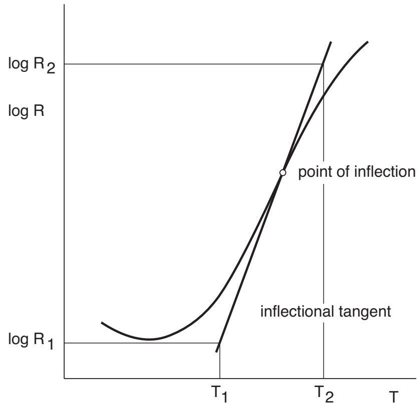

Fig.2 Temperature coefficient.

Dissipation factor (D)

The dissipation factor (measured in mW/K) is the ratio at a specified ambient temperature of a change in power dissipation in a thermistor, to the resultant body temperature change. By convention, the dissipation factor can only be calculated at the peak of the I/V curve, also making use of the corresponding point on the R/T characteristic.

By definition:

The electrical power injected in the PTC thermistor is:

$$P = I^2R$$

where R is the resistance (before switching) at T_{amb}.

The power dissipated by the ceramic is given by:

$$D(T_s - T_{amb})$$

where T_s is the switch temperature and T_{amb} is the ambient temperature, then:

$$I^2R = D(T_s - T_{amb})$$

Remark: This equation is only valid for temperatures lower than T_s.

Trip current (I_t)

The trip current (I_t) is defined as the minimum guaranteed current which will cause the thermistor to switch, and can be calculated using the formula:

$$I_t^2 R = D[T_s - (T_{amb} + \omega)]$$

Therefore: $I_t = \sqrt{\dfrac{D[T_s - (T_{amb} + \omega)]}{R}}$

where R is the PTC thermistor resistance at T_s.

Normally, a security margin of + ω °C is maintained in order to assure thermistor switching due to inaccuracies in the values of T_s and T_{amb}.

Non-trip current (I_{nt}) or hold current (I_H)

The non-trip current (I_{nt}) is defined as the guaranteed maximum continuous current at which the thermistor will not switch, and is given by:

$$I_{nt}^2 R = D[T_s - (T_{amb} + \omega)]$$

Therefore: $I_{nt} = \sqrt{\dfrac{D[T_s - (T_{amb} + \omega)]}{R}}$

A security margin of −ω °C is maintained to ensure that the thermistor will not switch.

Since heat dissipated by the device is proportional to the ambient temperature, the currents have to be derated for ambients higher than 25 °C according to Fig. 3.

CURRENT DEVIATION AS A FUNCTION OF THE AMBIENT TEMPERATURE

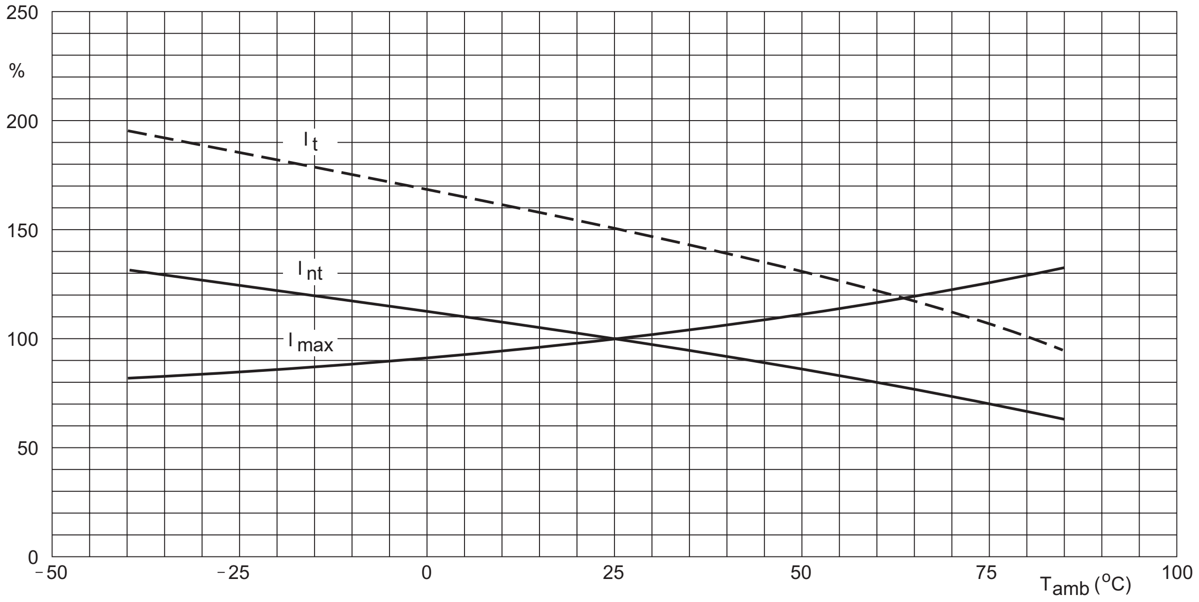

Fig.3 Ambient Temperature

Maximum current (I_{max})

The maximum current as stated in our datasheets, is the maximum overload current that may flow through the PTC when passing from the low ohmic to high ohmic state at rated voltage.

When other voltages are present after tripping, the I_{max} value can be derived from Fig.4 I_{max} as a function of voltage graph. Voltages below V_{rated} will allow higher overload currents to pass through the PTC.

MAXIMUM CURRENT DEVIATION AS A FUNCTION OF THE VOLTAGE

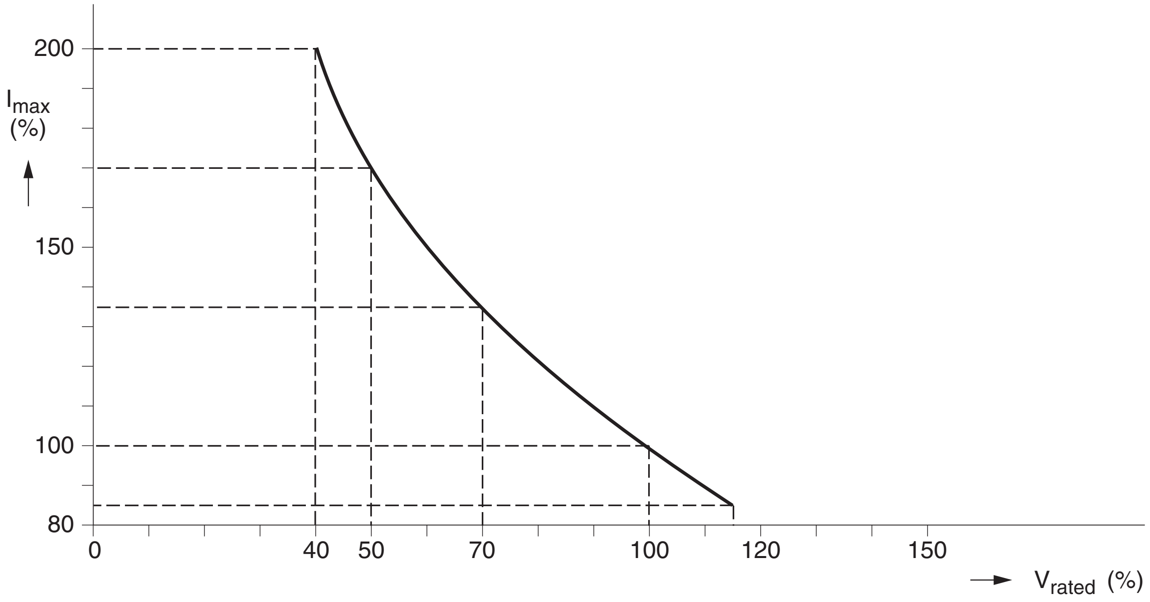

Fig.4 Maximum Current

Thermal time constant (τ)

The thermal time constant is the time required for a thermistor to convert 63.2 % of the total difference between its initial and final body temperature when subjected to a step function change in temperature under zero power conditions.

Voltage dependence (VDR effect)

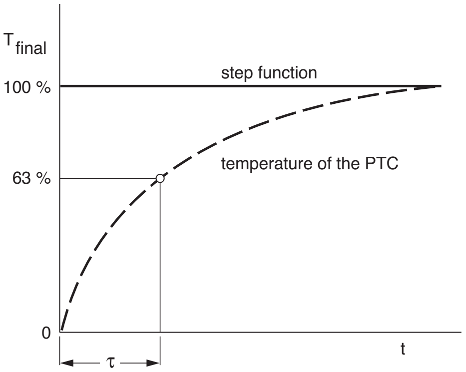

Fig.5 Thermal time constant

PTC thermistors exhibit voltage dependence. The higher the voltage applied, the more the R/T curve deviates from the R/T characteristic at ‘zero voltage’ (measured at a negligibly small voltage). This voltage dependency can be demonstrated by applying a pulse voltage to the thermistor and then measuring the R/T characteristic.

This effect can be explained with the aid of a parallel connection of an ‘ideal’ PTC thermistor, having no voltage dependence, and an ‘ideal’ VDR.

Plotted on a log I/log V scale at an arbitrary constant temperature, the ‘ideal’ PTC and the ‘ideal’ VDR characteristics are straight lines (see Fig.7).

These lines coincide with the PTC thermistors curve (measured under pulse conditions to avoid internal heating) at low voltages where the ohmic behaviour is the deciding factor, and at high voltages where the VDR effect becomes more significant.

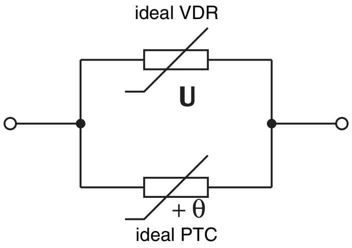

Fig.6 VDR effect

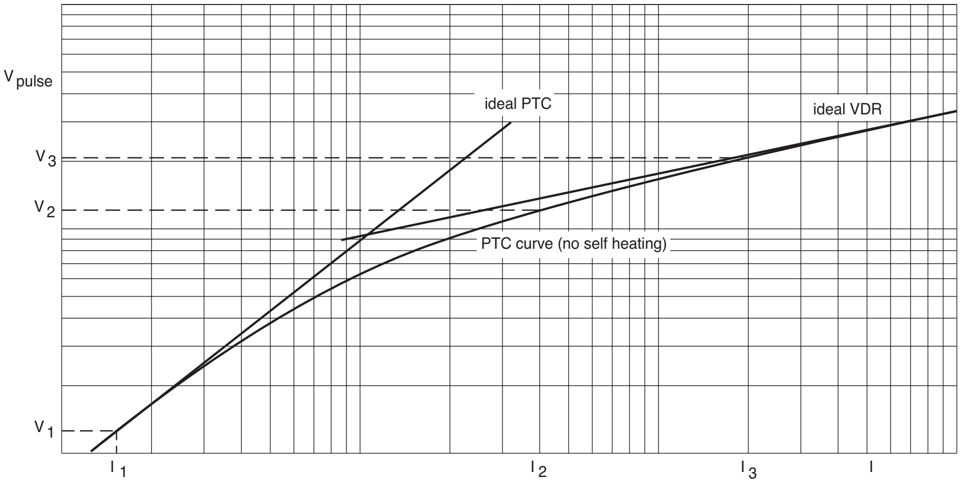

Fig.7 Relationship between an ‘ideal’ PTC and an ‘ideal’ VDR