RS

Data Sheet

Thermistors

NTC thermistors

The **RS** range of NTC thermistors includes standard tolerance negative temperature coefficient thermistors, a range of small close tolerance R/T curve matched thermistors and a range of DO-35 package devices.

Standard tolerance thermistors

A range of 13 negative temperature coefficient bead thermistors and 4 disc thermistors constructed from a compound of nickel manganite. Of the 13 bead thermistors, ten types are sealed in glass and three are incorporated into stainless steel probe assemblies. This range was designed primarily for temperature measurement and control, flow measurement and liquid level detection. The four NTC disc thermistors are intended for use in temperature compensation, measurement and control applications. Disc diameter in all cases is 10mm with a lead pitch of 5mm (nominal).

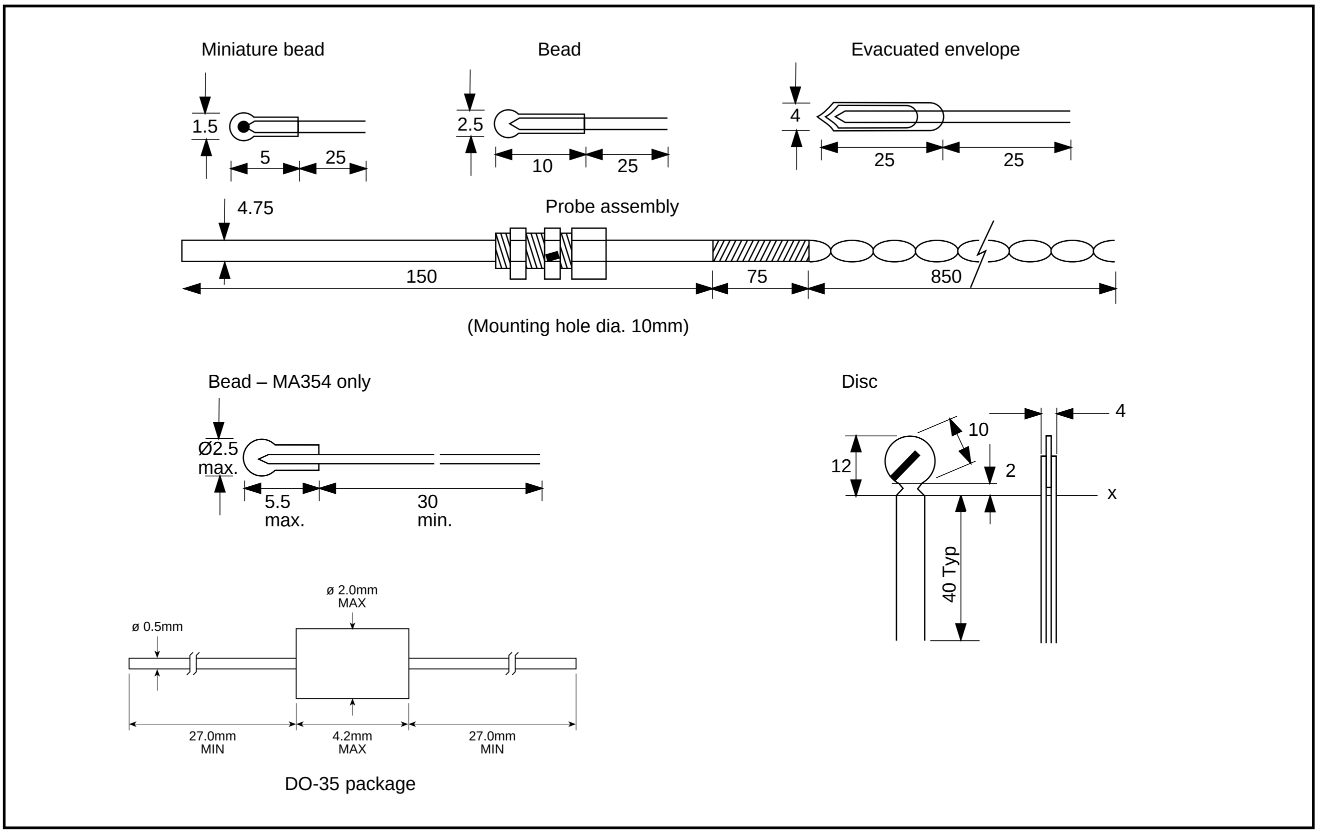
The range of DO-35 packaged NTC thermistors is designed for temperature measurement and control in applications which demand cost effective reliability. Typical applications include domestic appliances, automotive systems, data processing equipment and heating/ventilating/air conditioning control.

The hermetically-sealed construction combines the advantages of high temperature operation and high reliability of glass bead types with the closer tolerances associated with chip devices. The glass encapsulation offers the additional benefit of high voltage insulation.

		Miniature beads **RS** stock no.						Beads **RS** stock no.		
Characteristic resistance	Units	151-136	256-045	151-142	151-158	256-051	151-164	256-118	151-029	151-013
R_{BEAD} +20°C	Ω	–	–	–	–	–	–	–	2k	1M
+25°C	Ω	1k	10k	4.7k	47k	220k	470k	†350k	–	–
R_{MIN} (HOT)	Ω	59	130	271	338	1.3k	440	1.5k	115	170
R_{BEAD} TOLERANCE	%	±20	±20	±20	±20	±20	±20	±20	±20	±20
T_A max. ambient temp. range maximum dissipation	°C	–80 to +125	–55 to +200	–80 to +125	–60 to +200	–55 to +200	–25 to +300	+100 to +450	–80 to +300	–25 to +300
Maximum dissipation	mW	75	130	75	130	130	205	–	130	340
Derate to zero at	°C	125	200	125	200	200	300	450	125	300
Dissipation constant	mW/°C	0.75	0.75	0.75	0.75	0.75	0.75	1.2	1.2	1.2
Thermal time constant	s	5	5	5	5	5	5	20	19	19
B constant (+25 to +85°C)	°K	2910	3555	3340	3940	4145	4725*	4700*	3200	4850
B tolerance	%	±3	±3	±3	±3	±3	±3	±5	±5	±5
Equivalent types		GM102 VA3400	GM103	GM472 VA3404	GM473 VA3410	GM224	GM474	MA354	GL23	GL16

*(100-200°C)
†100°C

			Probe assemblies **RS** stock no.			Evac type **RS** stock no.	Disc type **RS** stock no.					DO-35 package **RS** stock no.					
Characteristic resistance		Units	151-120	256-124	151-170	151-114		256-095	256-102	256-089	256-073		198-927	198-933	198-949	198-955	198-961
	R_{BEAD} +20°C	Ω	–	–	–	5K	R_{DISC}	–	–	–		$R_{DO\text{-}35}$					
	+25°C	Ω	4.7k	35k	1.0M	–	@25°C	470	lk	4.7k	10k	@25°C	10k	20k	30k	50k	100k
	R_{MIN} (HOT)	Ω	500	600	800	79		19	35	130	260		30	61	92	153	307
$R_{BEAD\ DISC}$	TOLERANCE	%	±2	±2	±2	±20		±10	±10	±10	±10		±10%	±10%	±10%	±10%	±10%
T_A, max. ambient temp. range maximum dissipation		°C	–30 to +100	–30 to +150	–30 to +250	0 to +155		–30 to +125	–18 to +125	–30 to +125	–30 to +125		–55 to +250	–55 to +250	–55 to +250	–55 to +250	–55 to +250
Maximum dissipation		mW	50	50	50	3.0		900	900	900	900		675	675	675	675	675
Derate to zero at		°C	100	150	250	225		125	125	125	125		250	250	250	250	250
Dissipation constant		mW°C	5.0	5.0	5.0	12.5×10^{-3}			3.6				3	3	3	3	3
Thermal time constant		s	180	180	180	11		30	30	30	30		7	7	7	7	7
B constant (+25 to +85°C)		°K	3275	4165	5000	3250		3850	4000	4300	4400		3960	3960	3960	3960	3960
B tolerance		%	±2	±2	±2	±5		±3	±3	±3	±3		±1%	±1%	±1%	±1%	±1%
Equivalent types			JA03	JA05	JA09	RA53		KED 471	KED 102	KED 472	KED 103		DKF 103B10	DKF 203B10	DKF 303B10	DKF 503B10	DKF 104B10



Basic formulae

The temperature coefficient ∝ at any temperature within the operating range may be obtained from the formula:

$$\propto = -\frac{B}{T^2} \text{ (per °C)}$$

To determine the resistance at any temperature within the operating range may be obtained from the formula:

$$R_2 = R_1 \,.\, e^{\left(\frac{B}{t_2} - \frac{B}{t_1}\right)}$$

where:

B = characteristic temperature constant (°K)
T = bead temperature in (°K)
R_1 = resistance of thermistor at temperature t_1 (Ω)
R_2 = resistance of thermistor at temperature t_2 (Ω)
e = 2.7183
(Temperature in °K = temperature in °C +273).

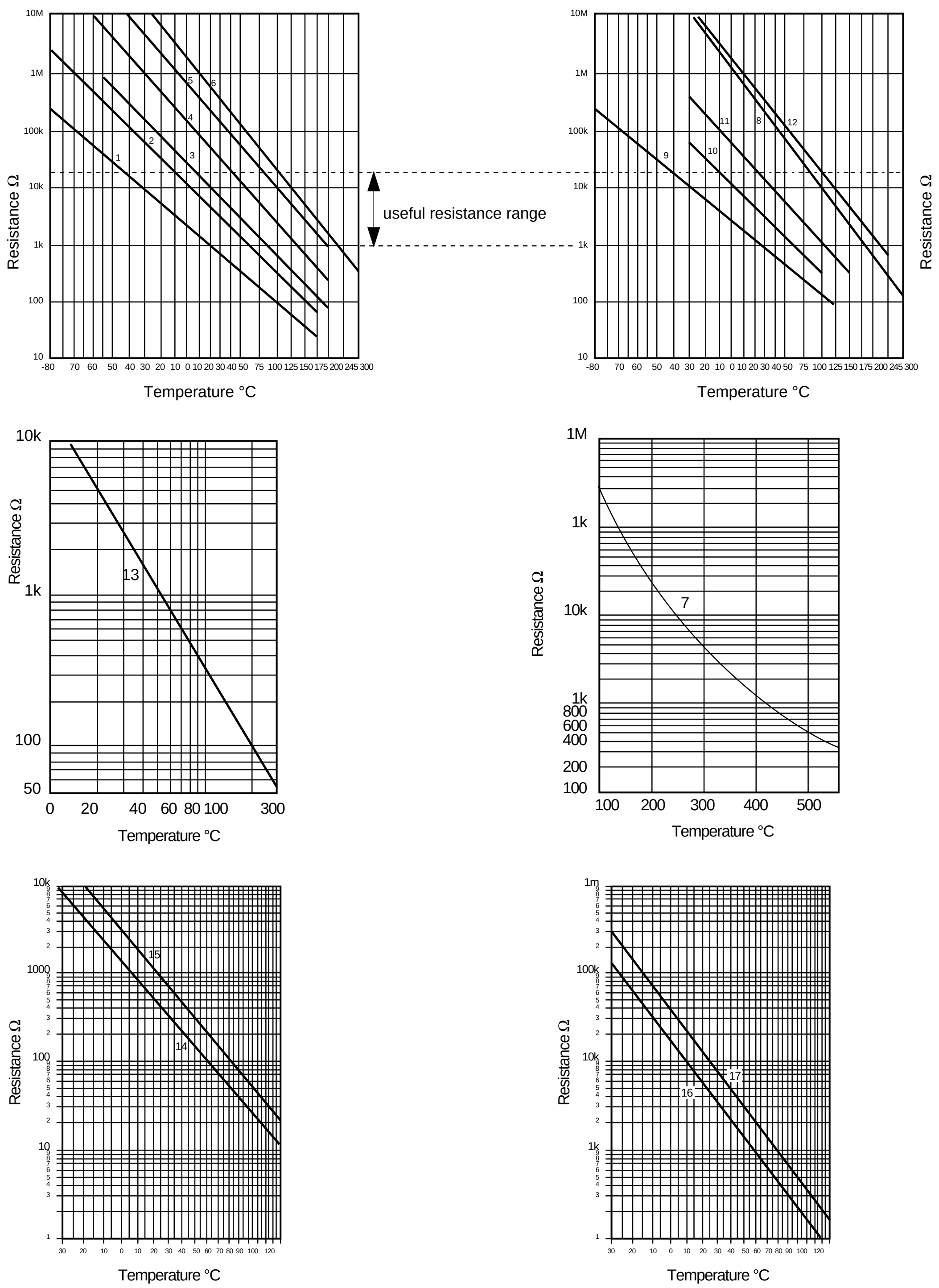
Application notes

Typical applications include temperature control of ovens, deep freezers, rooms and for process control, etc. Can also be used to drive high and low temperature alarms.

In the basic circuit below, calibration should be carried out by comparison with a known standard (eg. a thermometer or thermocouple). In the case of 0°C, a mixture of ice and water can be used and for +100°C, use boiling water.

Note: that non-linearity should be expected at extended temperatures.

Figure 1 Graphs of resistance vs temperature at zero power



Key

Miniature beads **RS** stock no.	Beads **RS** stock no.	Envelope **RS** stock no.	Disc **RS** stock no.
1) 151-136	7) 256-118	13) 151-114	14) 256-095
2) 151-142	8) 151-013		15) 256-102
3) 256-045	9) 151-029		16) 256-089
4) 151-158			17) 256-073
5) 256-051			
6) 151-164			
	Probes		
	10) 151-120		
	11) 256-124		
	12) 151-170		

Note: For DO-35 characteristics please refer to table 1.

Table 1 Nominal resistance/temperature characteristic for DK type (kΩ)

Temperature		RS stock no.				
°C	°F	198-927	198-933	198-949	198-955	198-961
–30.0	–22.0	176.0	352.0	528.0	880.0	1760
–20.0	–4.0	96.29	192.6	288.9	481.5	962.9
–10.0	14.0	54.85	109.7	164.6	274.3	548.5
0.0	32.0	32.41	64.82	97.23	162.1	324.1
10.0	50.0	19.80	39.60	59.40	99.0	198.0
20.0	68.0	12.47	24.94	37.41	62.35	124.7
25.0	77.0	10.00	20.00	30.00	50.00	100.00
30.0	86.0	8.066	16.13	24.20	40.33	80.66
40.0	104.0	5.342	10.68	16.03	26.71	53.42
50.0	122.0	3.618	7.236	10.85	18.09	36.18
60.0	140.0	2 502	5.004	7.506	12.51	25.02
70.0	158.0	1.763	3.526	5.289	8.815	17.63
80.0	176.0	1.265	2.530	3.795	6.325	12.65
90.0	194.0	0.9226	1.845	2.768	4.613	9.226
100.0	212.0	0.6834	1.367	2.050	3.417	6.834
110.0	230.0	0.5158	1.032	1.547	2.579	5.158
120.0	248.0	0.3942	0.7884	1.183	1.971	3.942
130.0	266.0	0.3048	0.6096	0.9144	1.524	3.048
140.0	284.0	0.2382	0.4764	0.7146	1.191	2.382
150.0	302.0	0.1881	0.3762	0.5643	0.9405	1.881
160.0	320.0	0.1495	0.2990	0.4485	0.7475	1.495
170.0	338.0	0.1204	0.2408	0.3612	0.6020	1.204
180.0	356.0	0.09818	0.1964	0.2945	0.4909	0.9818
190.0	374.0	0.08093	0.1619	0.2428	0.4046	0.8093
200.0	392.0	0.06739	0.1348	0.2022	0.3370	0.6739
210.0	410.0	0.05665	0.1133	0.1700	0.2833	0.5665
220.0	428 0	0.04805	0.09610	0.1441	0.2403	0.4805
230.0	446.0	0.04109	0.08218	0.1233	0.2054	0.4109
240.0	464.0	0.03540	0.07080	0.1062	0.1770	0.3540
250.0	482.0	0.03072	0.06144	0.09216	0.1536	0.3072
260.0	500.0					
270.0	518.0					
280.0	536.0					
290.0	554.0					
300.0	572.0					

Figure 2 Graph of voltage vs current for evacuated envelope type

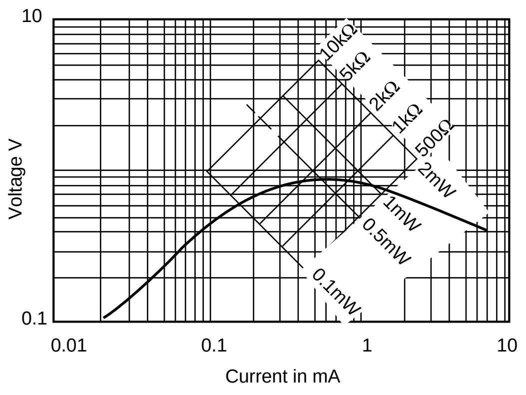


Figure 3 Basic temperature measuring circuit and add-on temperature controller

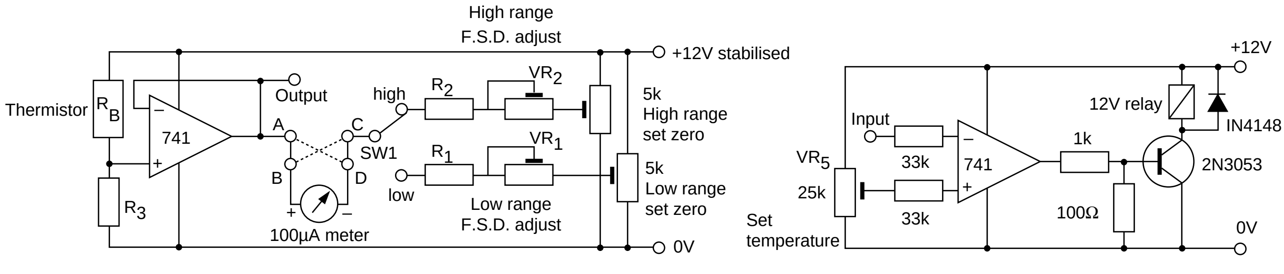


Table 2 Typical resistor values for temperature measuring circuit (above)

	Thermistor	Temperature in (°C)		Resistor values (kΩ)				
	RS stock no.	Low	High	R_1	R_2	R_3	VR_1	VR_2
Miniature	151-136	0 to –60*	0 to +30	56	6.8	22	50	5
	151-142	0 to +30	0 to +100	18	33	22	10	20
	151-158	+50 to +100	+100 to +150	27	8.2	22	10	5
	151-164	+150 to +200	+200 to +250	12	3.9	22	5	2
Beads	151-029	0 to –30*	0 to +30	27	10	22	20	5
	151-013	+100 to +150	+150 to +200	39	8.2	22	20	5
Probe Assy.	151-120	0 to –30*	0 to +100	33	33	22	20	20

Note: *For negative ranges reverse meter by linking A to D and B to C

R-T curve matched thermistors

A range of high quality precision curve matched thermistors, available in four characteristic resistances. The range offers true interchangeability over a wide temperature range and eliminates the need for individual circuit adjustments or padding. These thermistors provide accurate and stable temperature sensing capability for applications such as temperature measurement and compensation.

Table 3 Resistance/Temperature characteristics

RS stock no. 151-215		**RS** stock no. 151-221		**RS** stock no. 151–237		**RS** stock no. 151–243	
Temp °C	Res Ω	Temp °C	Res Ω	Temp °C	Res Ω	Temp °C	Res Ω
–80	2,210,400	–80	3,684,000	–80	7,368,000		
–70	935,250	–70	1,558,800	–70	3,117,500		
–60	421,470	–60	702,450	–60	1,404,900		
–50	201,030	–50	335,050	–50	670,100		
–40	100,950	–40	168,250	–40	336,500	–40	4,015,500
–30	53,100	–30	88,500	–30	177,000	–30	2,064,000
–20	29,121	–20	48,535	–20	97,070	–20	1,103,400
–10	16,599	–10	27,665	– 10	55,330	–10	611,870
0	9,795.0	0	16,325	0	32,650	0	351,020
+10	5,970.0	+10	9,950.0	+10	19,900	+10	207,850
+20	3,747.0	+20	6,245.0	+20	12,490	+20	126,740
+25	3,000.0	+25	5,000.0	+25	10,000	+25	100,000
+30	2,417.1	+30	4,028.5	+30	8,057.0	+30	79,422
+40	1,598.1	+40	2,663.3	+40	5,327.0	+40	51,048
+50	1,080.9	+50	1,801.5	+50	3,603.0	+50	33,591
+60	746.40	+60	1,244.0	+60	2,488.0	+60	22,590
+70	525.60	+70	876.00	+70	1,752.0	+70	15,502
+80	376.50	+80	627.50	+80	1,255.0	+80	10,837
+90	274.59	+90	457.65	+90	915.30	+90	7,707.7
+100	203.49	+100	339.15	+100	678.30	+100	5,569.3
+110	153.09	+110	255.15	+110	510.30	+110	4,082.9
+120	116.79	+120	194.65	+120	389.30	+120	3,033.3
+130	90.279	+130	150.47	+130	300.93	+130	2,281.0
+140	70.581	+140	117.64	+140	235.27	+140	1,734.3
+150	55.791	+150	92.985	+150	185.97	+150	1,331.9

Dimensions in mm

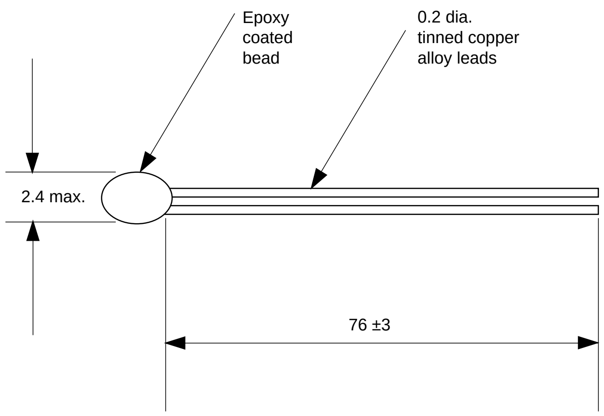


Table 4 Electrical characteristics

RS stock no.	151-215	151-221	151-237	151-243
Bead colour	Red	Orange	Yellow	Violet
Resistance at +25°C	3kΩ	5kΩ	10kΩ	100kΩ
Temperature range	–80°C to +150°C			
Tolerance (0 to +70°C)	±0.2°C			
Dissipation constant	1mW			
Time constant	10s			

Definitions

Dissipation constant. Represents the amount of power required to raise the temperature of the thermistor 1°C above its ambient temperature, expressed in milliwatts.

Time constant. The time required for the thermistor dissipating zero power to change 63% of the difference between its initial temperature value and that of a new impressed temperature environment.

PTC thermistors

The RS range of PTC thermistors includes three types for over-temperature protection and four types for over-current protection.

Over-temperature protection

A range of three positive temperature coefficient (PTC) thermistors, manufactured from a compound of barium lead and strontium titanates. The range consists of two disc types and one stud mounted version. These devices are primarily designed for temperature sensing and protection of semiconductor devices, transformers and motors etc. As can be seen from the resistance/temperature characteristics of Figure 6, the resistance of the PTC thermistor is low and relatively constant at low temperatures. As the ambient temperature increases, the resistance rises. The rate of increase becomes very rapid at the reference temperature (Tr) of the device. Tr is also known as the threshold, critical or switching temperature. Above Tr the characteristic becomes very steep and attains a high resistance value.

Specification		Stud	Disc
RS stock nos.		158-250	158-266 158-272
Maximum operating and storage temperature		155°C	Tr + 100°C
Minimum operating and storage temperature		–20°C	–55°C
Typical thermal resistance (embedded)	(1)	–	0.05°C/mW
Typical dissipation constant (embedded)	(1)	–	20mW/°C
Maximum power dissipation at 25°C	(2)	–	690mW
Maximum applied voltage at 25°C	(2)	–	40V
Insulation between stud and lead		500Vdc	–
Typical resistance at or below Tr –20°C		100Ω	
Maximum resistance at or below Tr –20°C		250Ω	
Maximum resistance at Tr –5°C	(3)	550Ω	
Typical resistance at Tr	(3)	1000Ω	
Minimum resistance at Tr +5°C	(3)	1330Ω	
Minimum resistance at Tr +15°C	(3)	4000Ω	

Notes:
1. Dependent on method of insulation and mounting
2. Self heating in free air
3. Measured at 2.5Vdc
4. Measured at 7.5Vdc.

Figure 4

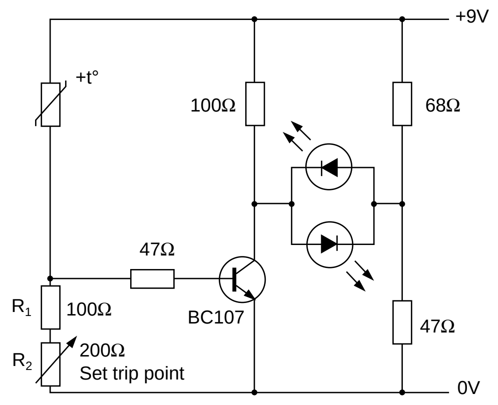


Figure 5

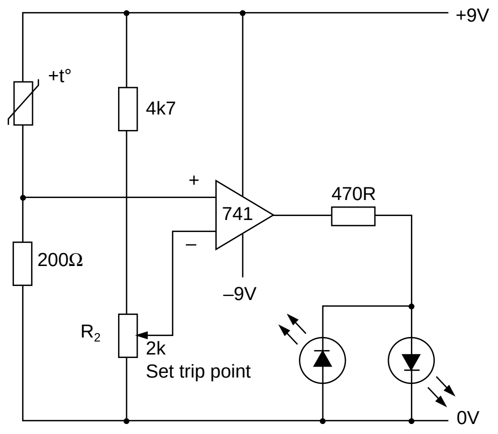
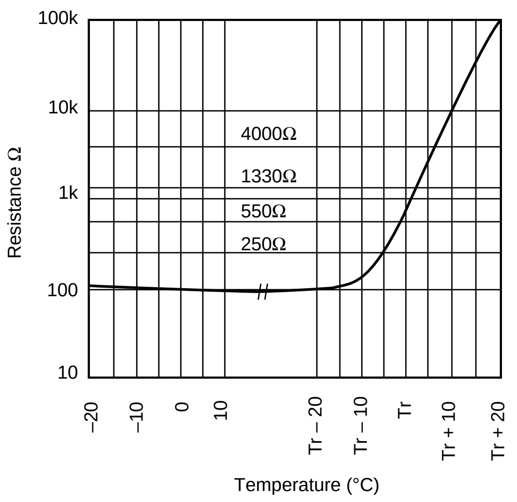


Figure 6 Resistance/Temperature graph



Calibration

Calibration should be carried out by heating the thermistor to the appropriate reference temperature and adjust R_2 such that the appropriate LED lights.

Series connection

In temperature sensing circuits two or more devices may be connected in series. The sensing circuit will then indicate if any of the thermistors exceeds the reference temperature. An increase in the value of R_1 may be necessary to compensate for the additional voltage drop across the thermistor.

Application notes

Basic temperature sensing circuits.

Figure 4 shows a basic circuit which indicates when the temperature of the PTC thermistor is below Tr (ie. safe operation) and will also indicate when Tr is exceeded. When both LEDs are off this indicates the Tr is being approached (approx. Tr –5°C).

Figure 5 shows a circuit which has a more defined 'trip point' than Figure 4 (set by R_2).

Over-current protection

Switching type Positive Temperature Coefficient (PTC) thermistors are prepared from barium titanate to give a ceramic disc. Electrical contacts are made by the metallising of the disc faces using nickel, silver, etc; the completed disc is then provided with soldered lead wires.

Definition of terms

R_{min}	–	Resistance of PTC at lowest point of R v T curve.
R_{25}	–	Resistance of PTC at +25°C.
I_{nt}	–	Not tripped temp. current.
I_t	–	Trip temp. current.
I_{rest}	–	Current value at V_{max}.
I_{peak}	–	Maximum allowable current through PTC.
V_{max}	–	Maximum voltage that may be applied to thermistor.

Specification

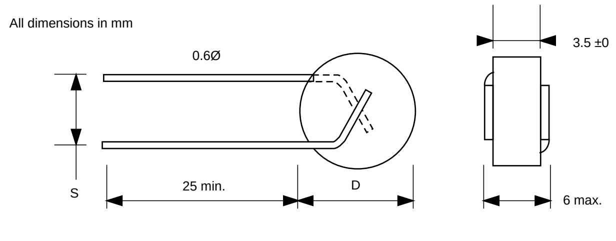
Ratings

Resistance tolerance at +25°C __________ +20%

Ambient temperature range

Operating __________ 0 to +55°C

Storage __________ –40 to +155°C



RS stock no.	Switch	Trip/Not trip currents (mA)				I_{REST}	I_{PEAK}	V_{max}	Dimensions (mm)	
		25°C		55°C	10°C					
		Int	It	Int	It	A	A	RMS	D	S
198-854		407	575	315	630	16	3.9	265	16.5	5
198-860		314	444	243	486	16	2.7	265	14	5
198-848	120°C	234	330	181	362	9	1.7	265	11.5	5
198-876		192	265	149	298	11	1.3	265	9.5	5
198-882		93	131	72	144	8	0.6	265	6.0	5
198-898		16	23	12	25	5	0.1	730	4.0	5

Figure 7

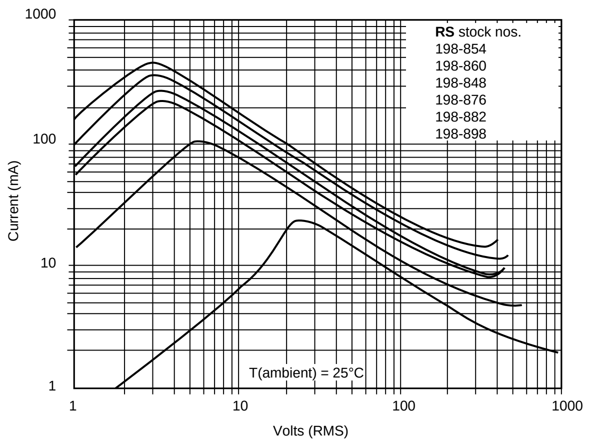


Figure 8

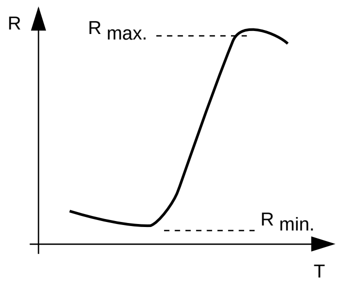


Figure 9

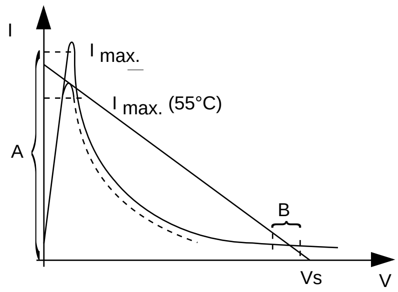
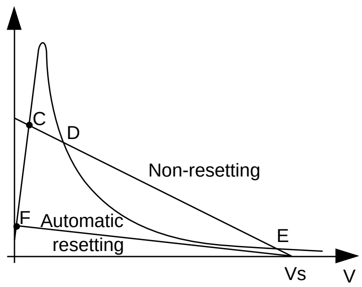


Figure 10



Theory of operation

The shape of the PTC thermistor resistance vs temperature characteristics (Figure 8) can be considered in three distinct parts. The region from below 0°C to $R_{min.}$ has a negative temperature coefficient of the order of 1%/°C; the region from $R_{min.}$ to $R_{max.}$ has a positive temperature coefficient in which values as high as 100%/°C can be realised. Beyond $R_{max.}$ the TC is again negative. As a PTC thermistor is sensitive to voltage variation. R vs T curves are usually measured at a constant voltage. Figure 9 shows the characteristics of the load to be protected, together with the I/V of the thermistor on a linear scale. Region 'A' indicates the permissible load current range for normal operation.

An increase in load current beyond the $I_{max.}$ value will cause the thermistor to self-heat to a high resistance state thereby shifting its operating point to the region B. This reduces the current through and voltage across the load, effectively protecting the equipment, etc.

Similarly, if the ambient temperature surrounding the thermistor should, due to a fault condition, increase, the I/V curve will depress towards the dotted position. The load attempts to consume more than $I_{max.}$ (+55°C) and the thermistor will again self-heat and shift its operating point into the low current region.

Selection

In order to ensure that the load is protected at the desired level and in the required reset mode, the following parameters must be taken into account:

1. Normal operating current range – Region ‘A’.
2. ‘Overload’ current – $I_{max.}$
3. Operating temperature range – I/V curve shift.
4. Operating voltage range (Vs).
5. Time response – position in Region ‘A’.
6. Thermistor tolerances.
7. Permissible voltage drop across device.
8. Mounting arrangement.

The reset mode required, ie. return to the ‘A’ region, is decided by the position of the load line in relation to the I/V curve. Figure 10 shows load line positions for the two modes, the auto-reset line intersects the I/V curve at only one point (F), thereby restricting stable operating to this point for normal load conditions. The manual or non-resetting line crosses the I/V curve at three positions, giving the possibility of operation at either point. However, point D is in an unstable region so that in practice operation only occurs at points C or E.

If response time is a particularly important factor, the position of the operating point within region ‘A’, for a given device (Figure 9) and the switch temperature of the PTC must be carefully considered. In circumstances where the circuit being protected is subject to short term overloads (which may be tolerated), the operating point should be the lower portion of region ‘A’. Alternatively, where response time must be rapid, the operating point must be as close to the $I_{max.}$ value as practicable, not forgetting the shift in characteristic with temperature.

Tolerances are usually quoted on the room temperature resistance (zero power), the higher values of R_{25} giving the lower $I_{max.}$

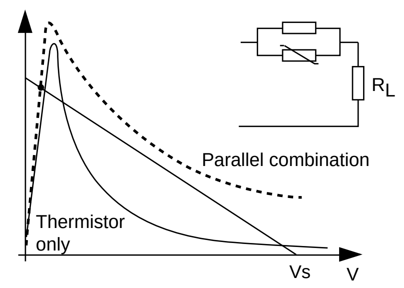
As a thermistor is a resistive device there will inevitably be a voltage drop across it when in circuit. The maximum permissible voltage drop for the circuit concerned will dictate the room temperature or R_{25} resistance value. It is usual to make the R_{25} value in the order of 10% of the circuit resistance (or impedance).

The thermistor should be positioned in the equipment such that the surrounding air is reasonably still and unconfined. Moving air will effectively increase the $I_{max.}$ value (at a given temperature) whilst confining the device will create a high ambient temperature, and therefore a lower $I_{max.}$

Modification of I/V characteristics

In certain applications it is necessary to modify the I/V curve in order to produce the necessary characteristics. To obtain an auto-resetting device with a relatively high current rating, a resistor may be connected in parallel with the thermistor to ‘lift’ the characteristic to the dotted position (Figure 11). This permits the load line to occupy a position in the upper ‘A’ region, but still crossing the combination curve at one stable point.

Figure 11



Parallel operation

In instances where a sufficiently high $I_{max.}$ value cannot be realised with existing devices, it is permissible to parallel connect two or more devices to achieve the required values; this may also be used to obtain lower R_{25} resistances.

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