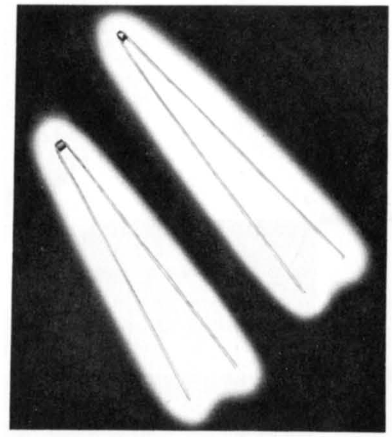
NL INDUSTRIES

Product Data

SECTION 3210
THERMISTORS
"BEAD SIZE" 0.05" DIA.



"Bead Size" D050 Thermistors are small, rugged Thermistors with close electrical tolerances. Their small mass gives short thermal time constants. The tinned copper leads are easily soldered into electrical circuits.

SPECIFICATIONS

Characteristics

†Catalog Number		4D051	4D053	1D051	1D053	2D052	2D054	3D052	3D054
Grade		4	4	1	1	2	2	3	3
Beta (25°C-75°C); β	Nominal °K	4500	4500	3965	3965	3530	3530	3000	3000
	Tolerance ±%	2.2	2.2	1.4	1.4	2.3	2.3	5	5
Resistance Ratio;	R_{25}/R_{75}	8.75	8.75	6.76	6.76	5.49	5.49	4.26	4.26
	R_{25}/R_{125}	48.78	48.78	29.85	29.85	19.80	19.80	12.95	12.95
Zero Power Resistance @ 25°C; Ω ±10%		200,000	100,000	20,000	10,000	2,000	1,000	200	100
Zero Power Nominal Resistance @150°C; Ω		2020	1010	360	180	60	30	9.64	4.82
*Dissipation Constant; $\frac{\text{milliwatts}}{°C}$; δ		2	2	2	2	2	2	2	2
**Thermal Time Constant; (sec.); τ		4.5	3.5	4.5	3.5	4	3	4	3
Thickness "B" (nominal); inches		.048	.024	.048	.024	.034	.017	.034	.017

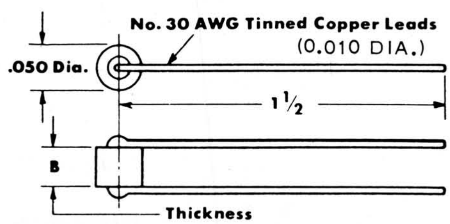
Maximum Ratings

Thermistor Temperature 150°C (302°F)

Other Special Thermistors available as indicated on reverse side.

Outline Drawing

(Dimensions in Inches)



†First digit indicates Grade of Thermistor Material.

* The ratio, at a specified ambient temperature, of a change in power dissipation in a thermistor to the resultant body temperature change.

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

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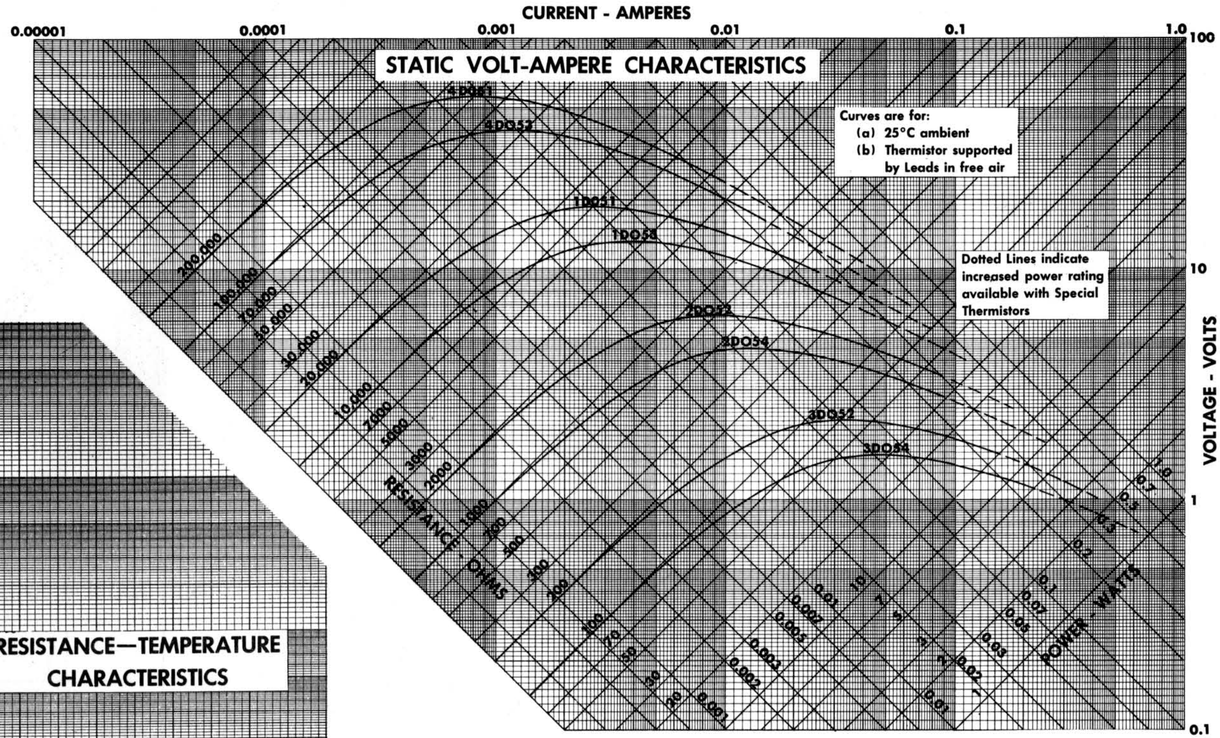
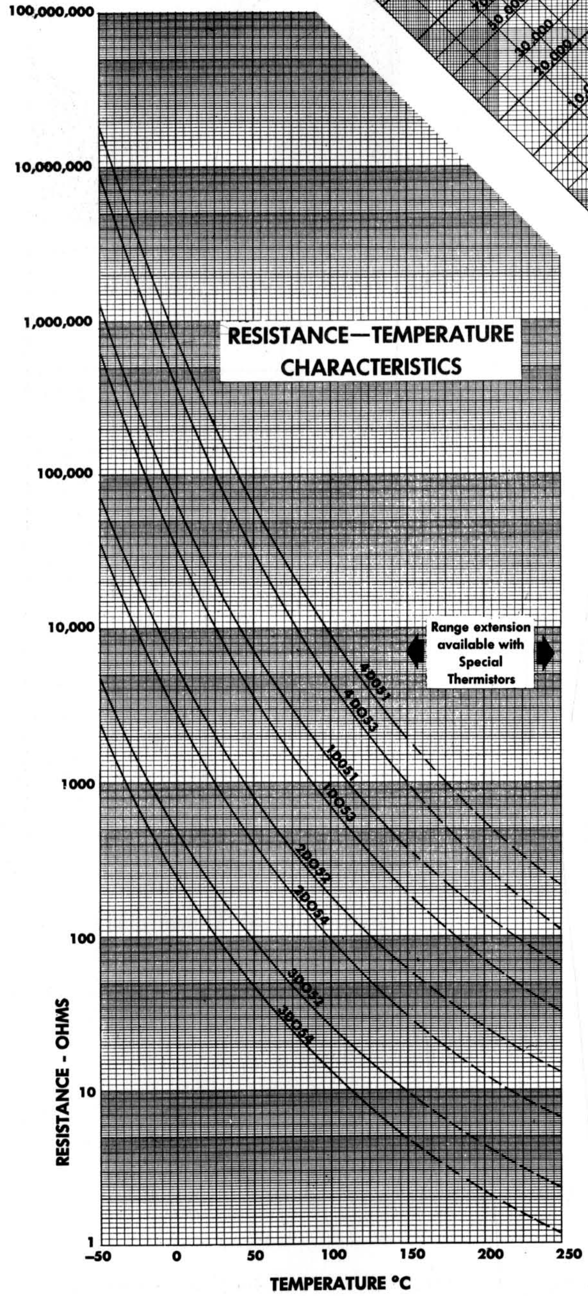
THERMISTOR D050 "BEAD SIZE" SERIES 0.05" DIAMETER CHARACTERISTICS





Special "Bead Size" Thermistors:

To meet special applications a "non-standard" Thermistor may be required. Quotations will be provided for:

Tolerances down to ±1% on resistance.
Resistance values other than stock standard.
Temperature range extension to 250°C.
Protective and/or Identification Coating.
Special Mounting or *Probe Assembly.*
Different Lead Arrangement.
Matched pairs.

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Product Data

SECTION 3211
THERMISTORS
D100 SERIES, 0.1″ DIA.

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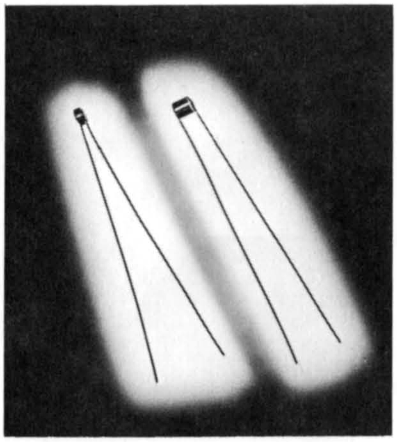


D100 Series Thermistors, 0.1″ diameter are small rugged Thermistors with close electrical tolerances. Their small mass gives short thermal time constants, yet they are not so small that it is difficult to handle them. The tinned copper leads are easily soldered into electrical circuits.

SPECIFICATIONS

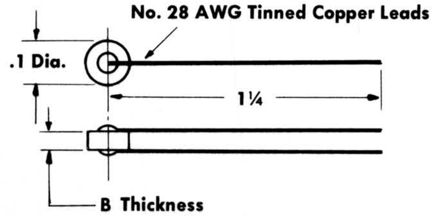
Characteristics

†New Order Number	1D101	1D103	2D102	2D104	3D102	3D104
Old Order Number	D101	D103	D102	D104	—	—
Grade	1	1	2	2	3	3
Beta (25°C-75°C) Nominal °K / Tolerance ±%	3965 1.4	3965 1.4	3530 2.3	3530 2.3	3000 5	3000 5
Resistance @ 25°C; Ω ±10%	10,000	5,000	1,000	500	100	50
Nominal Resistance @ 150°C; Ω	180	90	30	15	4.5	2.3
*Dissipation Constant; milliwatts/°C	4	4	4	4	4	4
**Thermal Time Constant (sec.)	12	8	10	6	10	6
Thickness "B" (nominal) inches	.095	.048	.070	.035	.070	.035

Maximum Ratings

Thermistor Temperature 150°C (302°F)

Outline Drawing



†First digit indicates Grade of Thermistor Material.

*Slope of the linear portion of the Dissipation Characteristic which is the Thermistor temperature rise above ambient versus the electrical power input.

**Time required for a Thermistor to change 63.2% of the temperature difference between its initial temperature and the temperature of its surroundings. No power is applied during the change and the Thermistor is supported by its leads in free air.

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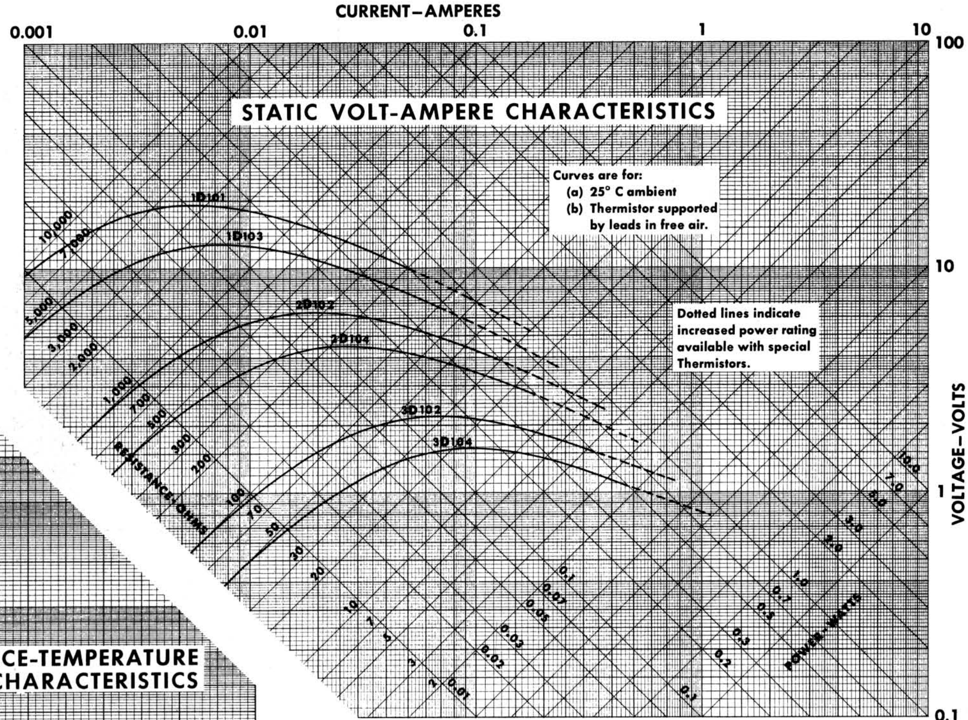
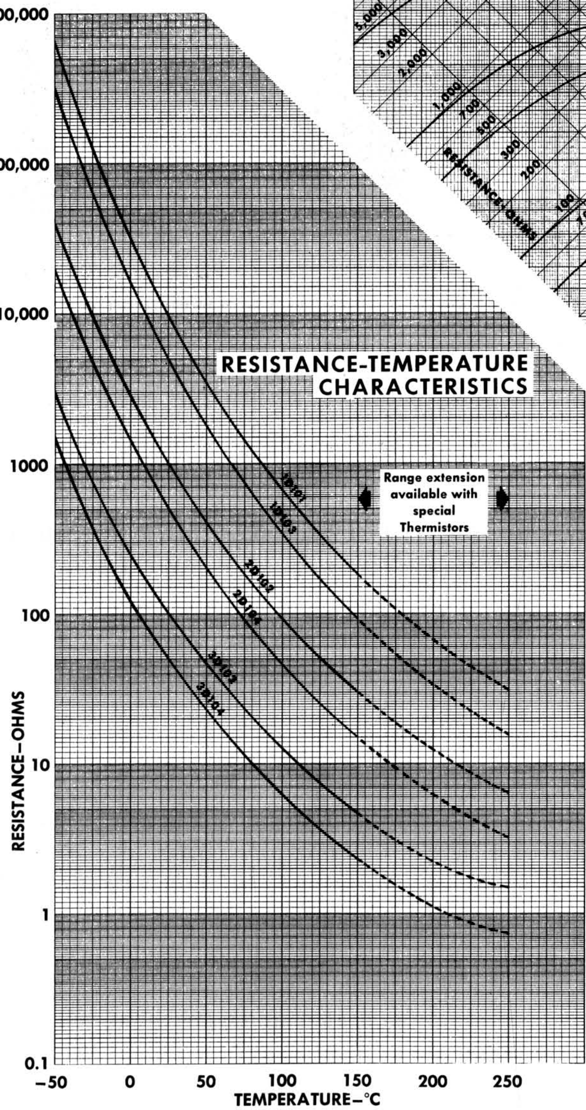
THERMISTORS, D100 SERIES, 0.1″ DIAMETER CHARACTERISTICS





Special Thermistors:

To meet special applications a "non-standard" Thermistor may be required. Quotations will be provided for:

Tolerances down to ± 1% on resistance.
Resistance values other than stock standard.
Temperature range extension to 250°C.
Protective and/or Identification Coating.
Special Mounting or *Probe Assembly.*
Different Lead Arrangement.
Matched Pairs

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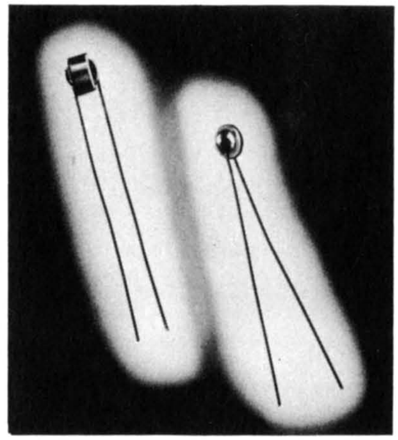


D200 Series Thermistors, 0.2″ diameter are small rugged Thermistors with close electrical tolerances. The tinned copper leads are easily soldered into electrical circuits.

SPECIFICATIONS

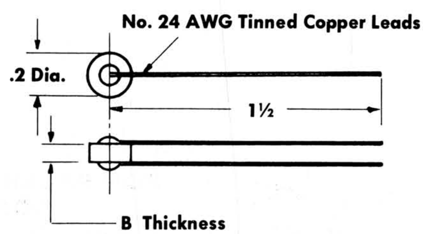
Characteristics

†New Order Number	1D201	1D203	2D202	2D204	3D202	3D204
Old Order Number	D201	D203	D202	D204	—	—
Grade	1	1	2	2	3	3
Beta (25°C-75°C) Nominal °K Tolerance ±%	3965 1.4	3965 1.4	3530 2.3	3530 2.3	3000 5	3000 5
Resistance @ 25°C; Ω ±10%	3000	1000	300	100	30	10
Nominal Resistance @ 150°C; Ω	54	18	9	3	1.4	.45
*Dissipation Constant; $\frac{\text{milliwatts}}{°C}$	8	7.5	8	7.5	8	7.5
**Thermal Time Constant (sec.)	34	19	28	16	28	16
Thickness "B" (nominal) inches	.114	.038	.084	.028	.084	.028

Maximum Ratings

Thermistor Temperature 150°C (302°F)

Outline Drawing



†First digit indicates Grade of Thermistor Material.

*Slope of the linear portion of the Dissipation Characteristic which is the Thermistor temperature rise above ambient versus the electrical power input.

**Time required for a Thermistor to change 63.2% of the temperature difference between its initial temperature and the temperature of its surroundings. No power is applied during the change and the Thermistor is supported by its leads in free air.

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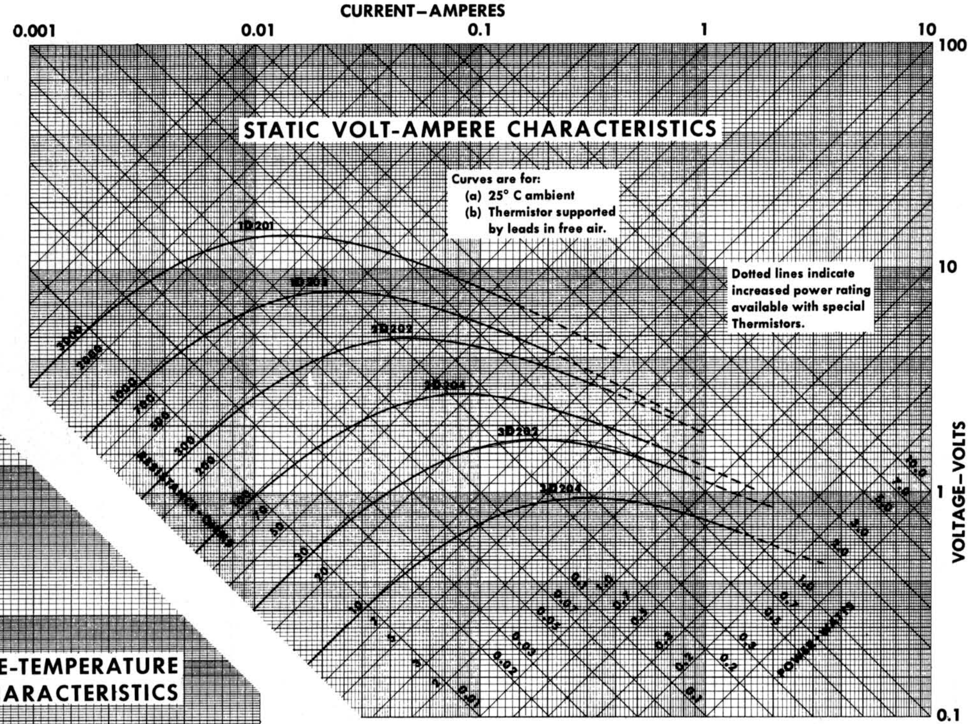
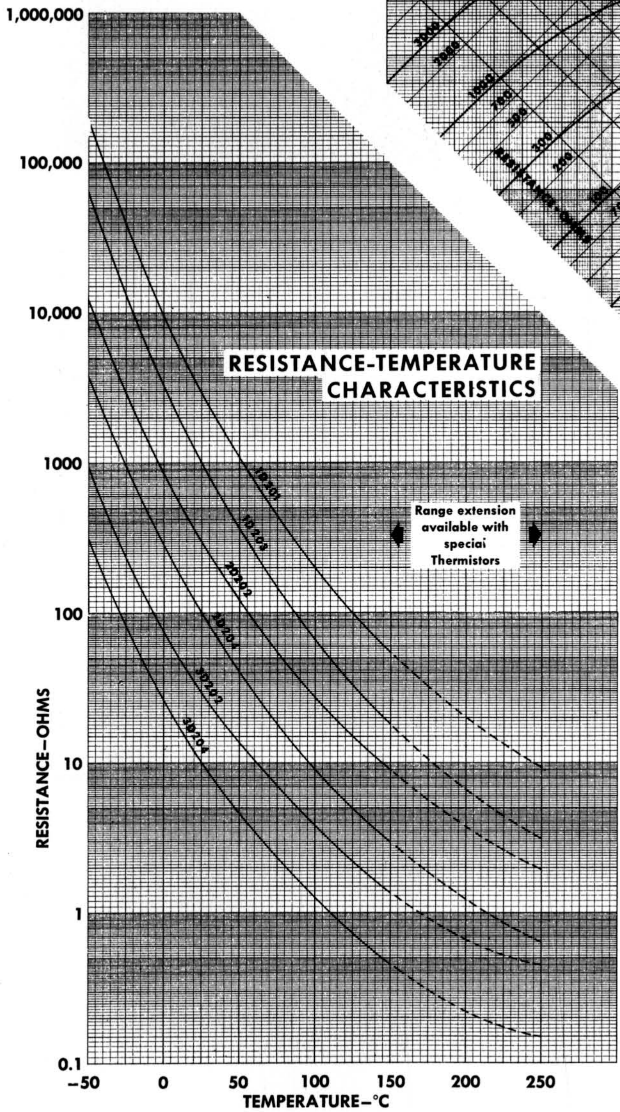
THERMISTORS, D-200 SERIES, 0.2″ DIAMETER CHARACTERISTICS





Special Thermistors:

To meet special applications a "non-standard" Thermistor may be required. Quotations will be provided for:

Tolerances down to ± 1% on resistance.
Resistance values other than stock standard.
Temperature range extension to 250°C.
Protective and/or Identification Coating.
Special Mounting or *Probe Assembly.*
Different Lead Arrangement.
Matched Pairs

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Product Data

SECTION 3213
THERMISTORS
D300 SERIES, 0.3″ DIA.

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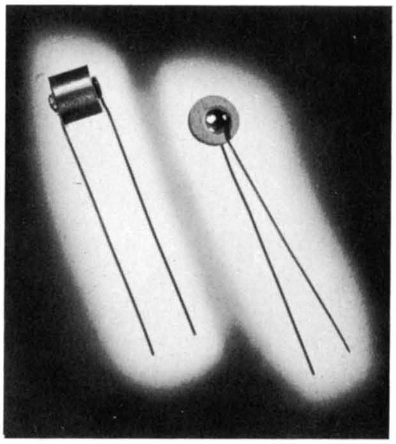


D300 Series Thermistors, 0.3″ diameter are small rugged Thermistors with close electrical tolerances. The tinned copper leads are easily soldered into electrical circuits.

SPECIFICATIONS

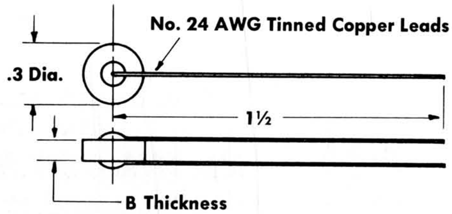
Characteristics

†New Order Number	1D301	1D303	2D302	2D304	3D302	3D304
Old Order Number	D301	D303	D302	D304	—	—
Grade	1	1	2	2	3	3
Beta (25°C-75°C) Nominal °K Tolerance ±%	3965 1.4	3965 1.4	3530 2.3	3530 2.3	3000 5	3000 5
Resistance @ 25°C; Ω ±10%	3000	1000	300	100	30	10
Nominal Resistance @ 150°C; Ω	54	18	9	3	1.36	0.45
*Dissipation Constant; $\frac{\text{milliwatts}}{°C}$	11.5	9.0	10.5	8.5	10.5	8.5
**Thermal Time Constant (sec.)	85	48	75	38	75	38
Thickness "B" (nominal) inches	.256	.086	.189	.063	.189	.063

Maximum Ratings

Thermistor Temperature 150°C (302°F)

Outline Drawing



†First digit indicates Grade of Thermistor Material.

*Slope of the linear portion of the Dissipation Characteristic which is the Thermistor temperature rise above ambient versus the electrical power input.

**Time required for a Thermistor to change 63.2% of the temperature difference between its initial temperature and the temperature of its surroundings. No power is applied during the change and the Thermistor is supported by its leads in free air.

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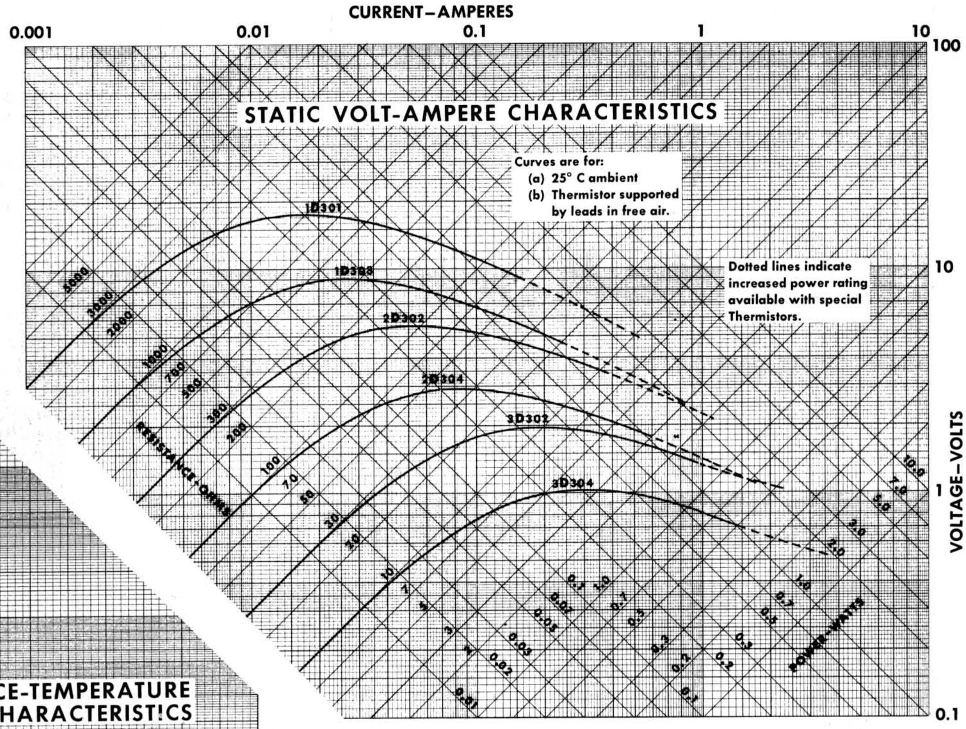
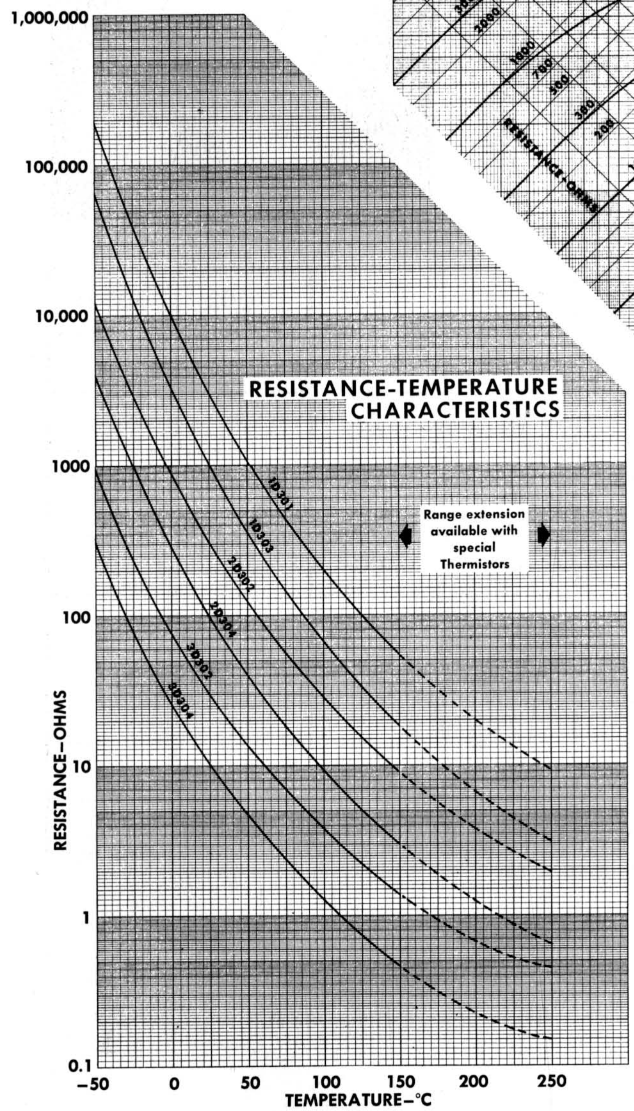
THERMISTOR, D300 SERIES, 0.3″ DIAMETER CHARACTERISTICS





Special Thermistors:

To meet special applications a "non-standard" Thermistor may be required. Quotations will be provided for:

Tolerances down to ± 1% on resistance.
Resistance values other than stock standard.
Temperature range extension to 250°C.
Protective and/or Identification Coating.
Special Mounting or *Probe Assembly.*
Different Lead Arrangement.
Matched Pairs

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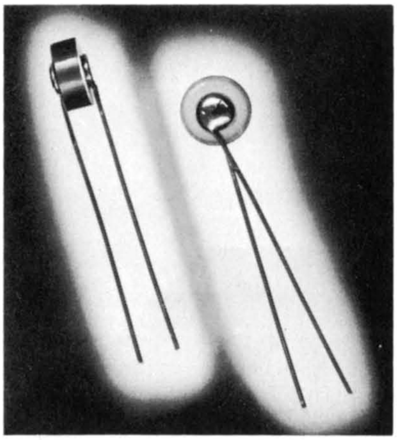


D400 Series Thermistors, 0.4″ diameter are medium-size rugged Thermistors with close electrical tolerances. Their mass is great enough to avoid much of the self-heating that affects smaller Thermistors.

SPECIFICATIONS

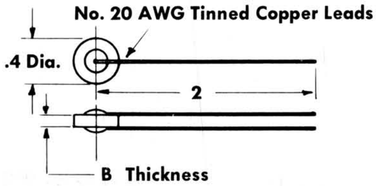
Characteristics

†New Order Number	1D401	1D403	2D402	2D404	3D402	3D404
Old Order Number	D401	D403	D402	D404	—	—
Grade	1	1	2	2	3	3
Beta (25°C-75°C) Nominal °K Tolerance ±%	3965 1.4	3965 1.4	3530 2.3	3530 2.3	3000 5	3000 5
Resistance @ 25°C; Ω ± 10%	1000	250	100	25	10	2.5
Nominal Resistance @ 150°C; Ω	18	4.5	3	0.75	0.45	0.11
*Dissipation Constant; milliwatts/°C	15.5	14	15.5	14	15.5	14
**Thermal Time Constant (sec.)	80	35	70	25	70	25
Thickness "B" (nominal) inches	.152	.038	.112	.028	.112	.028

Maximum Ratings

Thermistor Temperature 150°C (302°F)

Outline Drawing

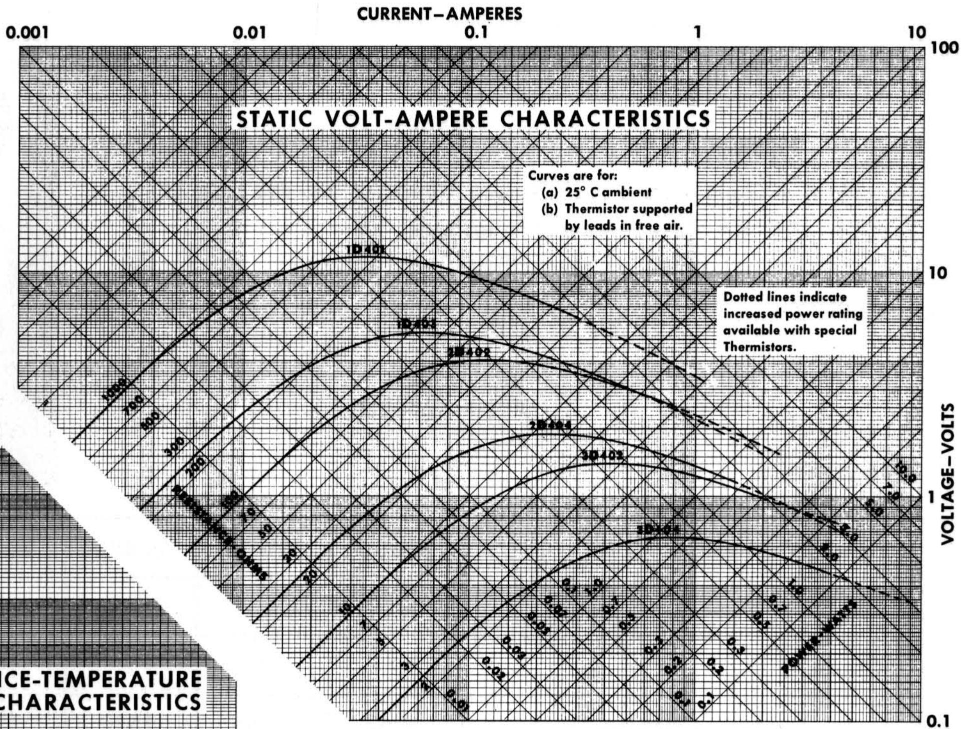


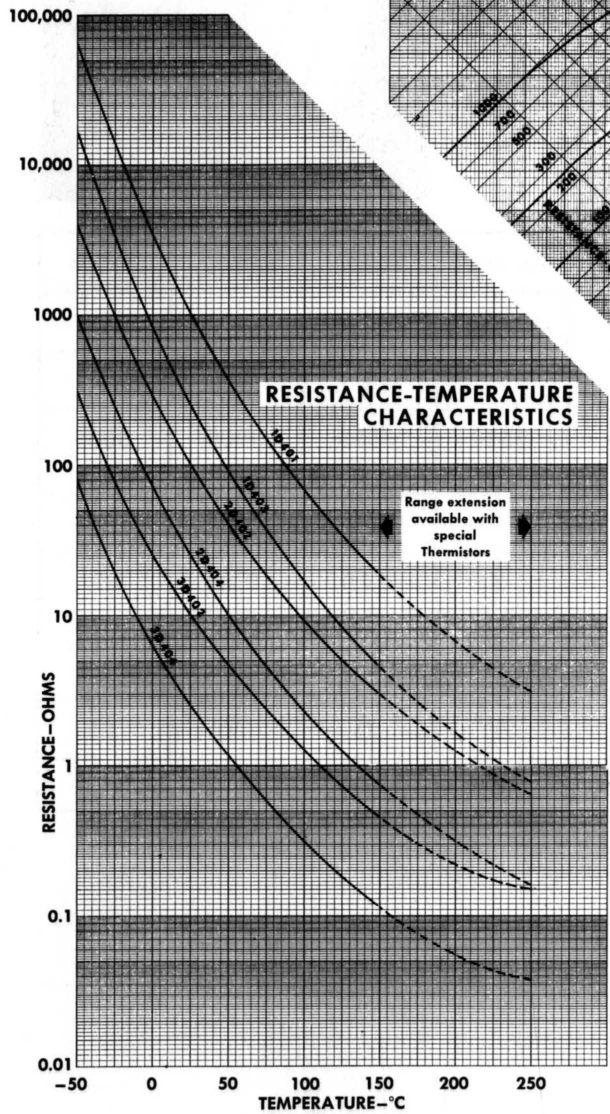
†First digit indicates Grade of Thermistor Material.

*Slope of the linear portion of the Dissipation Characteristic which is the Thermistor temperature rise above ambient versus the electrical power input.

**Time required for a Thermistor to change 63.2% of the temperature difference between its initial temperature and the temperature of its surroundings. No power is applied during the change and the Thermistor is supported by its leads in free air.

THERMISTOR, D400 SERIES, 0.4″ DIAMETER CHARACTERISTICS





Special Thermistors:

To meet special applications a "non-standard" Thermistor may be required. Quotations will be provided for:

Tolerances down to ± 1% on resistance.
Resistance values other than stock standard.
Temperature range extension to 250°C.
Protective and/or Identification Coating.
Special Mounting or *Probe Assembly.*
Different Lead Arrangement.
Matched Pairs

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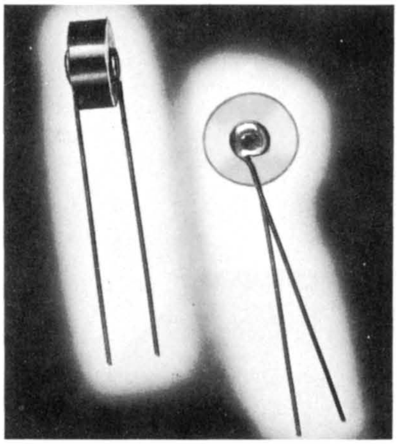


D500 Series Thermistors, 0.5″ diameter are medium-size rugged Thermistors with close electrical tolerances. Their mass is great enough to avoid much of the self-heating that affects smaller Thermistors.

SPECIFICATIONS

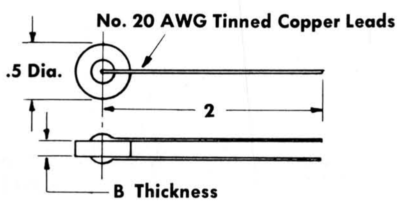
Characteristics

†New Order Number	1D501	1D503	2D502	2D504	3D502	3D504
Old Order Number	D501	D503	D502	D504	—	—
Grade	1	1	2	2	3	3
Beta (25°C-75°C) Nominal °K Tolerance ±%	3965 1.4	3965 1.4	3530 2.3	3530 2.3	3000 5	3000 5
Resistance @ 25°C; Ω ±10%	1000	500	100	50	10	5
Nominal Resistance @ 150°C; Ω	18	9	3	1.5	0.45	0.23
*Dissipation Constant; milliwatts/°C	19	16.5	17.5	15.5	17.5	15.5
**Thermal Time Constant (sec.)	140	90	120	70	120	70
Thickness "B" (nominal) inches	.238	.119	.175	.088	.175	.088

Maximum Ratings

Thermistor Temperature 150°C (302°F)

Outline Drawing



†First digit indicates Grade of Thermistor Material.

*Slope of the linear portion of the Dissipation Characteristic which is the Thermistor temperature rise above ambient versus the electrical power input.

**Time required for a Thermistor to change 63.2% of the temperature difference between its initial temperature and the temperature of its surroundings. No power is applied during the change and the Thermistor is supported by its leads in free air.

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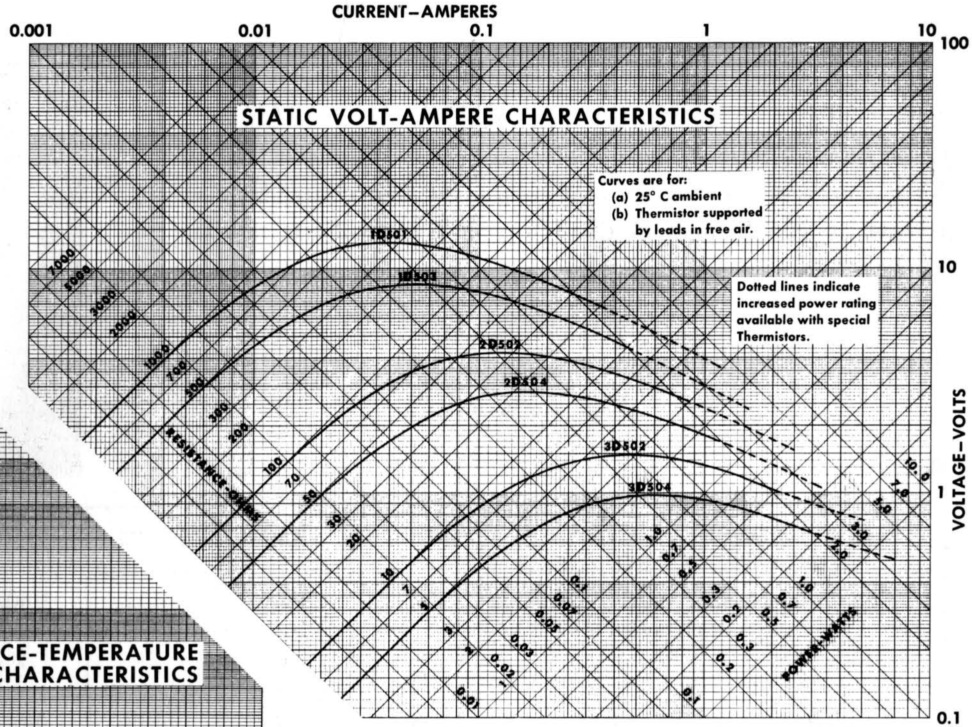
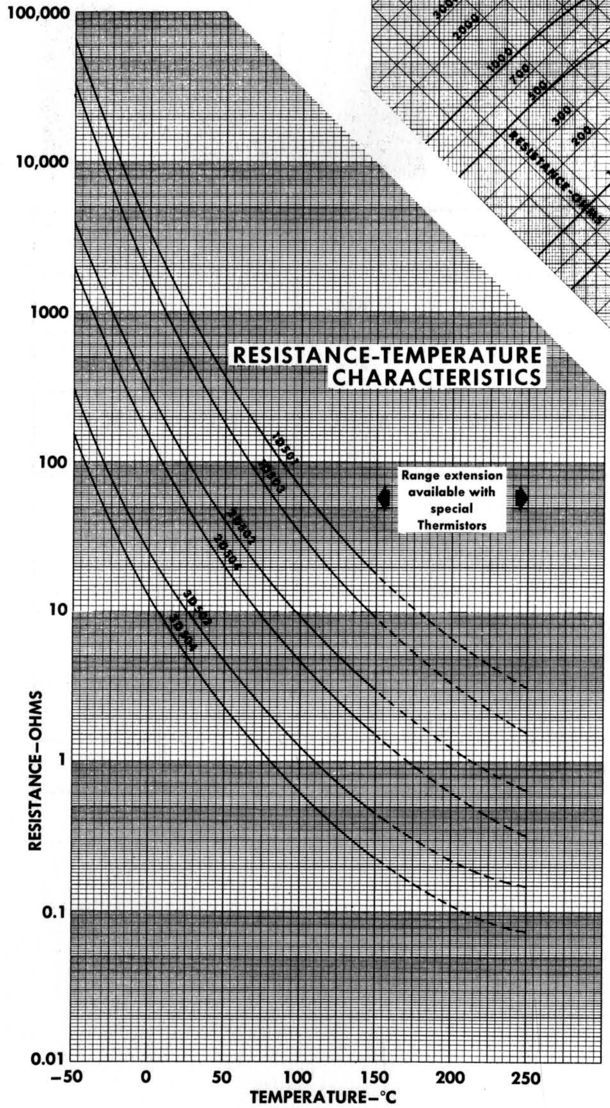
THERMISTOR D500 SERIES, 0.5″ DIAMETER CHARACTERISTICS





Special Thermistors:

To meet special applications a "non-standard" Thermistor may be required. Quotations will be provided for:

Tolerances down to ± 1% on resistance.
Resistance values other than stock standard.
Temperature range extension to 250°C.
Protective and/or Identification Coating.
Special Mounting or *Probe Assembly.*
Different Lead Arrangement.
Matched Pairs

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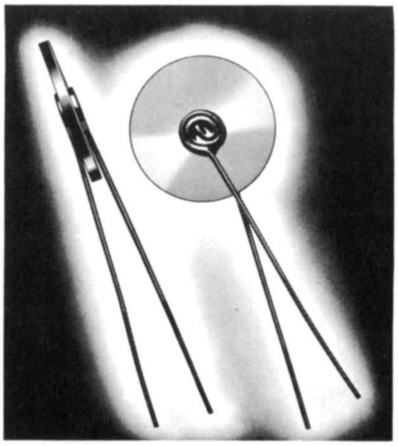
NL INDUSTRIES Product Data

SECTION 3217
THERMISTORS
D750 SERIES, 0.75″ DIA.



D750 Series Thermistors, 0.75″ diameter, are large-size, rugged Thermistors with close electrical tolerances. For temperature compensation circuits, their large mass permits relatively large currents without self-heating. In addition, these pieces are especially suited for current inrush suppression and time delay applications.

SPECIFICATIONS

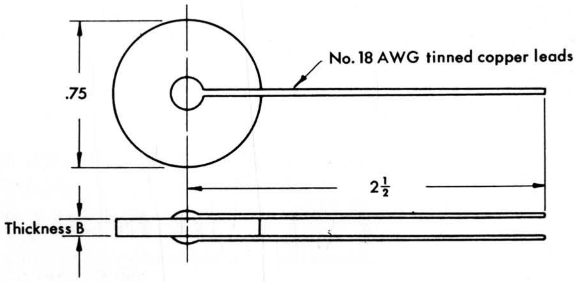
Characteristic

†New Order Number	1D751	1D753	2D752	2D754	3D752	3D754
Old Order Number	D751	D753	D752	D754	—	—
Grade	1	1	2	2	3	3
Beta (25°C-75°C) Nominal °K Tolerance ±%	3965 1.4	3965 1.4	3530 2.3	3530 2.3	3000 5	3000 5
Resistance @ 25°C; Ω ± 10%	250	100	25	10	2.5	1.0
Nominal Resistance @ 150°C; Ω	4.5	1.84	0.75	0.3	0.11	0.045
*Dissipation Constant; $\frac{\text{milliwatts}}{°C}$	26	22	24	20	24	20
**Thermal Time Constant (sec.)	150	80	120	50	120	50
Thickness "B" (nominal) inches	.134	.053	.098	.039	.098	.039

Maximum Ratings

Thermistor Temperature 150°C (302°F)

Outline Drawing



†First digit indicates Grade of Thermistor Material.

*Slope of the linear portion of the Dissipation Characteristic which is the Thermistor temperature rise above ambient versus the electrical power input.

**Time required for a Thermistor to change 63.2% of the temperature difference between its initial temperature and the temperature of its surroundings. No power is applied during the change and the Thermistor is supported by its leads in free air.

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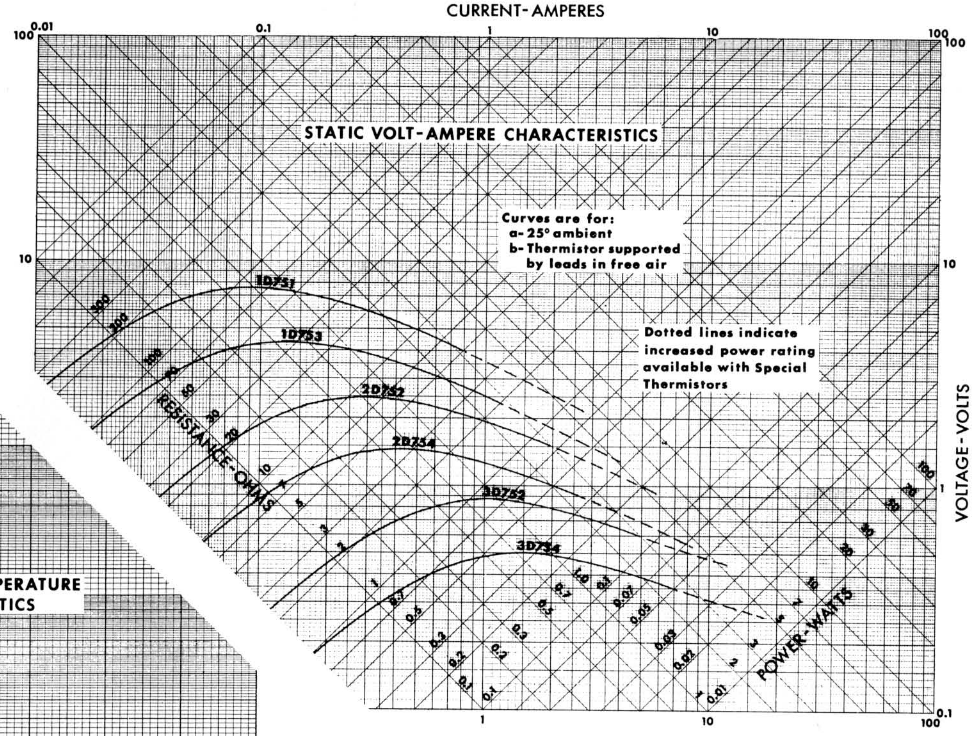
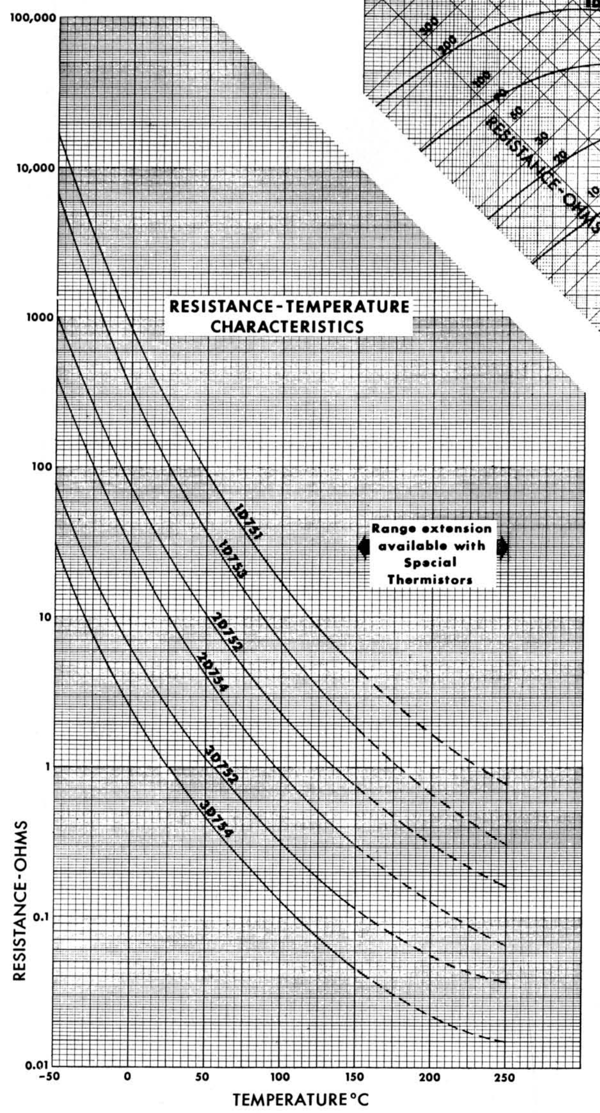
THERMISTOR, D750 SERIES, 0.75" DIAMETER CHARACTERISTICS





Special Thermistors:

To meet special applications a "non-standard" Thermistor may be required. Quotations will be provided for:

Tolerances down to ± 1% on resistance.
Resistance values other than stock standard.
Temperature range extension to 250 °C.
Protective and/or Identification Coating.
Special Mounting or *Probe Assembly.*
Different Lead Arrangement.
Matched Pairs

ELECTRONICS DEPARTMENT
NL INDUSTRIES

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HIGHTSTOWN, NEW JERSEY 08520

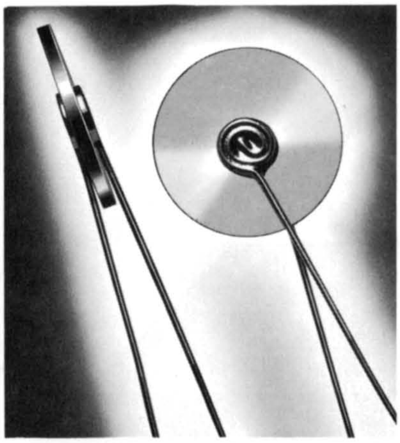
Product Data

NL INDUSTRIES

SECTION 3219
THERMISTORS
D900 SERIES, 1.0″ DIA.

NL INDUSTRIES, INC. • THERMISTORS • VARISTORS

D900 Series Thermistors, 1.0″ diameter, are large-size, rugged Thermistors with close electrical tolerances. For temperature compensation circuits, their large mass permits relatively large currents without self-heating. In addition, these pieces are especially suited for current inrush suppression and time delay applications.



SPECIFICATIONS

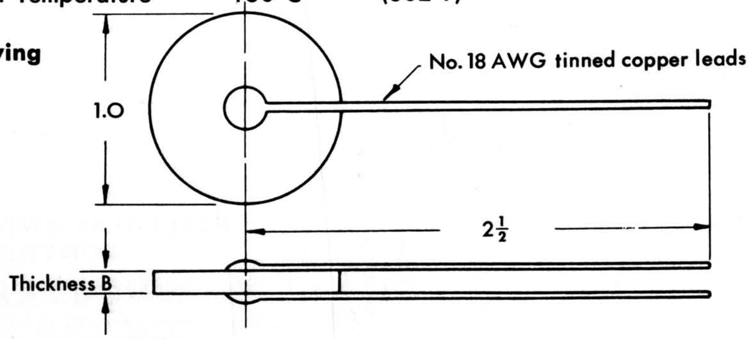
Characteristic

†New Order Number	1D901	1D903	2D902	2D904	3D902	3D904
Old Order Number	D1001	D1003	D1002	D1004	—	—
Grade	1	1	2	2	3	3
Beta (25°C-75°C) Nominal °K Tolerance ±%	3965 1.4	3965 1.4	3530 2.3	3530 2.3	3000 5	3000 5
Resistance @ 25°C; Ω ± 10%	250	100	25	10	2.5	1.0
Nominal Resistance @ 150°C; Ω	4.5	1.84	0.75	0.3	0.11	0.045
*Dissipation Constant; $\frac{\text{milliwatts}}{°C}$	37	32	34	30	34	30
**Thermal Time Constant (sec.)	260	155	230	120	230	120
Thickness "B" (nominal) inches	.238	.095	.175	.070	.175	.070

Maximum Ratings

Thermistor Temperature 150°C (302°F)

Outline Drawing



†First digit indicates Grade of Thermistor Material.

*Slope of the linear portion of the Dissipation Characteristic which is the Thermistor temperature rise above ambient versus the electrical power input.

**Time required for a Thermistor to change 63.2% of the temperature difference between its initial temperature and the temperature of its surroundings. No power is applied during the change and the Thermistor is supported by its leads in free air.

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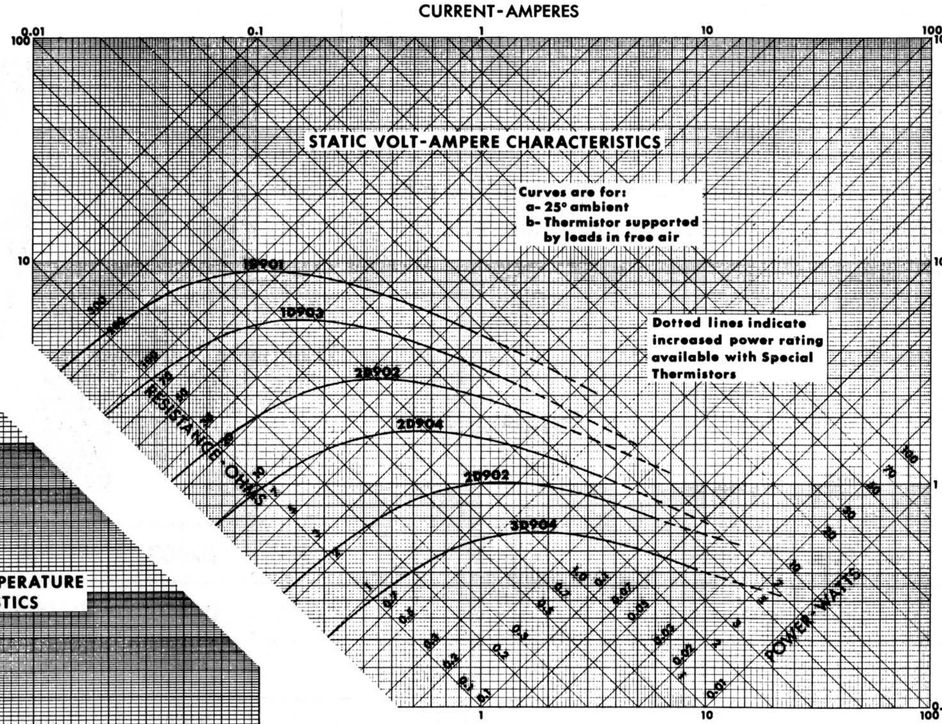
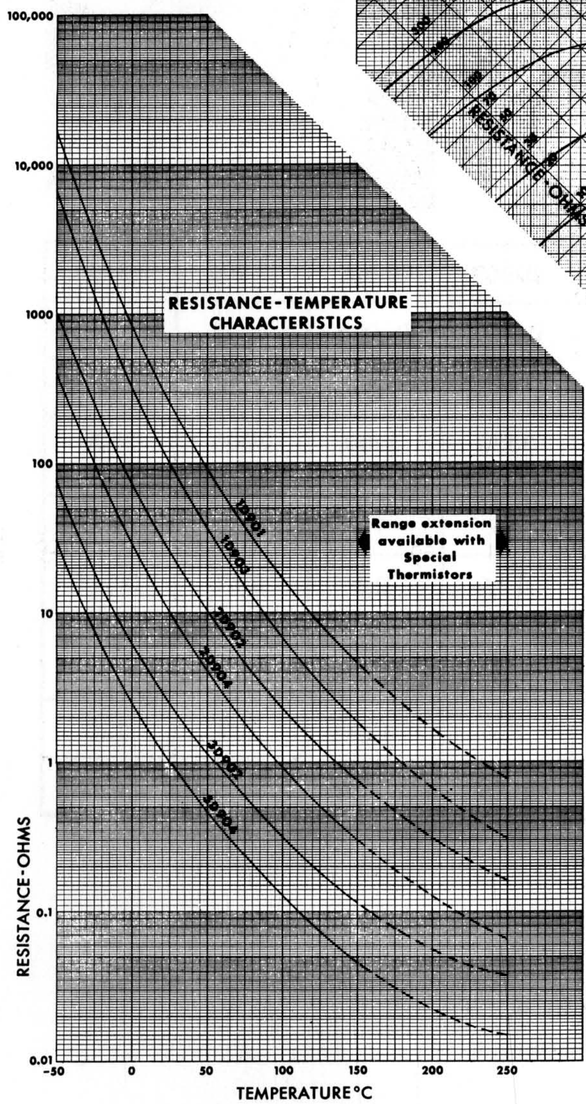
THERMISTOR, D900 SERIES, 1.0″ DIAMETER CHARACTERISTICS





Special Thermistors:

To meet special applications a "non-standard" Thermistor may be required. Quotations will be provided for:

Tolerances down to ± 1% on resistance.
Resistance values other than stock standard.
Temperature range extension to 250°C.
Protective and/or Identification Coating.
Special Mounting or *Probe Assembly.*
Different Lead Arrangement.
Matched Pairs

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Grade 4 broadens the range of Standard Thermistor Materials available to the Design Engineer. As compared to Grade 1, the temperature sensitivity is more than 10% greater and the resistivity is ten times higher.

MATERIAL	SPECIFIC RESISTANCE AT 25° C OHM–CM	BETA 25° C TO 75° C DEGREES KELVIN
GRADE 4	**21000 ±10%**	**4500 ±100**

BASIC THERMISTOR CHARACTERISTICS:

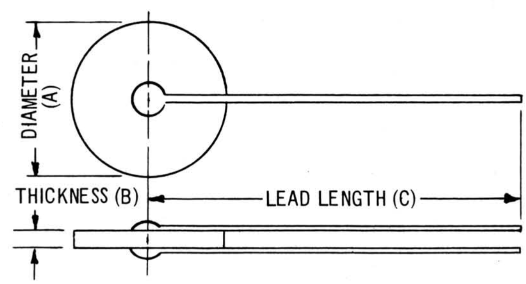
TYPE	ORDER† NO.	NOMINAL DIAMETER A (IN.)	NOMINAL LENGTH OR THICKNESS B (IN.)	RESISTANCE (OHMS AT 25° C) TOLERANCE ±10%	DISSIPATION* CONSTANT MILLIWATTS/°C	THERMAL** TIME CONSTANT SECONDS	LEADS LENGTH C (IN.)	LEADS WIRE SIZE AWG. #	LEADS WIRE SIZE DIAM.
DISK	4D051	.050	.048	200,000	2	4.5	1.5	30	.0100
	4D053	.050	.024	100,000	2	3.5			
	4D101	.100	.095	100,000	4	12	1.25	28	.0126
	4D103	.100	.048	50,000	4	8			
	4D201	.200	.114	30,000	8	34	1.5	24	.0201
	4D203	.200	.038	10,000	7.5	19			
	4D301	.300	.256	30,000	11.5	85			
	4D303	.300	.086	10,000	9	48			
	4D401	.400	.152	10,000	15.5	80	2.0	20	.0320
	4D403	.400	.038	2,500	14	35			
	4D501	.500	.238	10,000	19	140			
	4D503	.500	.119	5,000	16.5	90			

MAXIMUM RATINGS

Thermistor Temperature 150°C (302°F)

OUTLINE DRAWING

Disk Type

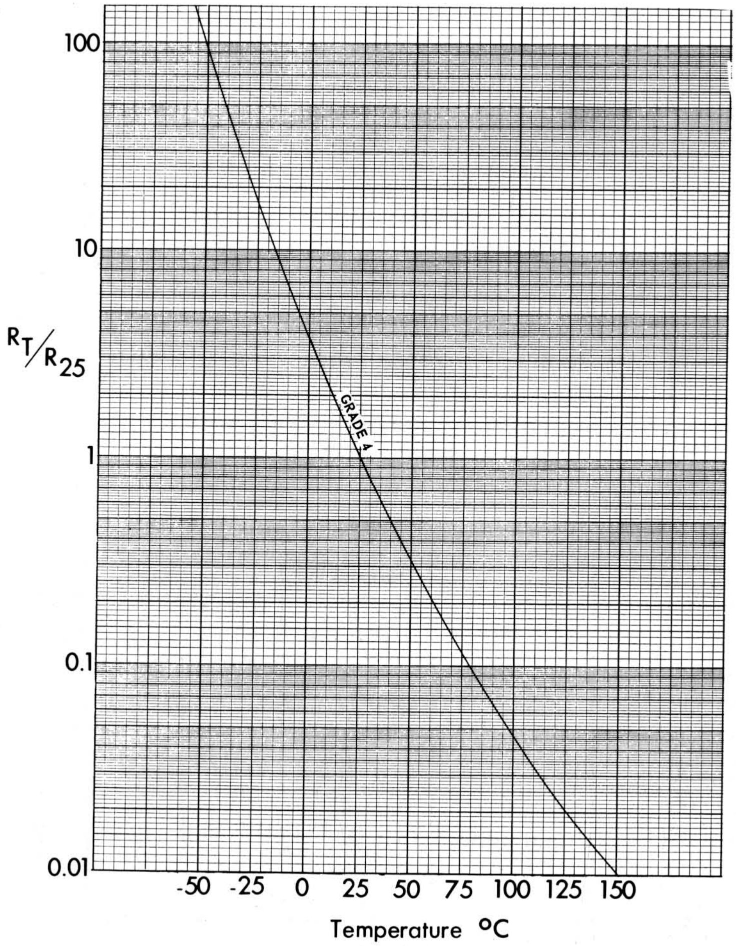


†First digit indicates Grade of Thermistor Material.

*Slope of the linear portion of the Dissipation Characteristic which is the Thermistor temperature rise above ambient versus the electrical power input.

**Time required for a Thermistor to change 63.2% of the temperature difference between its initial temperature and the temperature of its surroundings. No power is applied during the change and the Thermistor is supported by its leads in free air.

RESISTANCE RATIO TEMPERATURE CHARACTERISTIC



TEMP. °C	TEMP. °F	R_T/R_{25}
- 55	- 67	131
- 40	- 40	45.5
- 21.5	- 29.7	13.2
0	32	3.71
25	77	1.00
37.8	100	.543
50	122	.320
75	167	.1143
104.4	220	.0399
125	257	.0205
150	302	.0101

SPECIAL THERMISTORS:

To meet special applications a "non-standard" Thermistor may be required. Quotations will be provided for:

Tolerances down to ± 1% on resistance.
Resistance values other than stock standard.
Temperature range extension to 250°C.
Protective and/or Identification Coating.
Special Mounting or *Probe Assembly.*
Different Lead Arrangement.
Matched Pairs.

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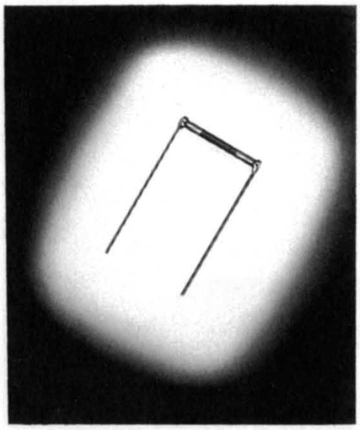


R050 Series Thermistors, 0.050" diameter, are small, high resistance rod Thermistors with close electrical tolerances. Their small mass gives short thermal time constants. The tinned copper leads are easily soldered into electrical circuits.

SPECIFICATIONS

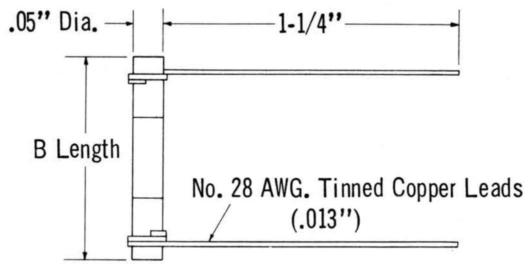
Characteristics

†New Order Number	1R051	2R052	3R052
Old Order Number	R051	R052	-
Grade	1	2	3
Beta (25°-75°C) Nominal °K Tolerance ± %	3965 1.4	3530 2.3	3000 5
Resistance @ 25°C; Ω ±10%	100,000	10,000	1,000
Nominal Resistance @ 150°C; Ω	1,840	300	45.4
*Dissipation Constant; milliwatts/°C	3	3	3
**Thermal Time Constant (sec.)	12	12	12
Length "B" (nominal) inches	0.5	0.5	0.5

Maximum Ratings

Thermistor Temperature 150°C (302°F)

Outline Drawing



†First digit indicates Grade of Thermistor Material.

*Slope of the linear portion of the Dissipation Characteristic which is the Thermistor temperature rise above ambient versus the electrical power input.

**Time required for a Thermistor to change 63.2% of the temperature difference between its initial temperature and the temperature of its surroundings. No power is applied during the change and the Thermistor is supported by its leads in free air.

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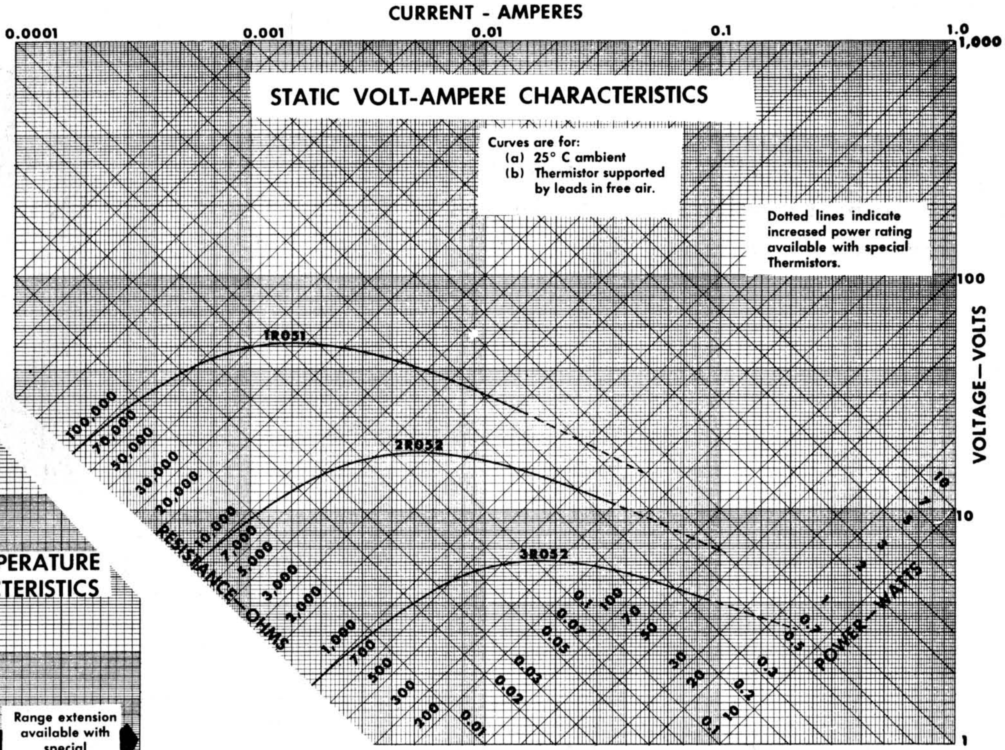
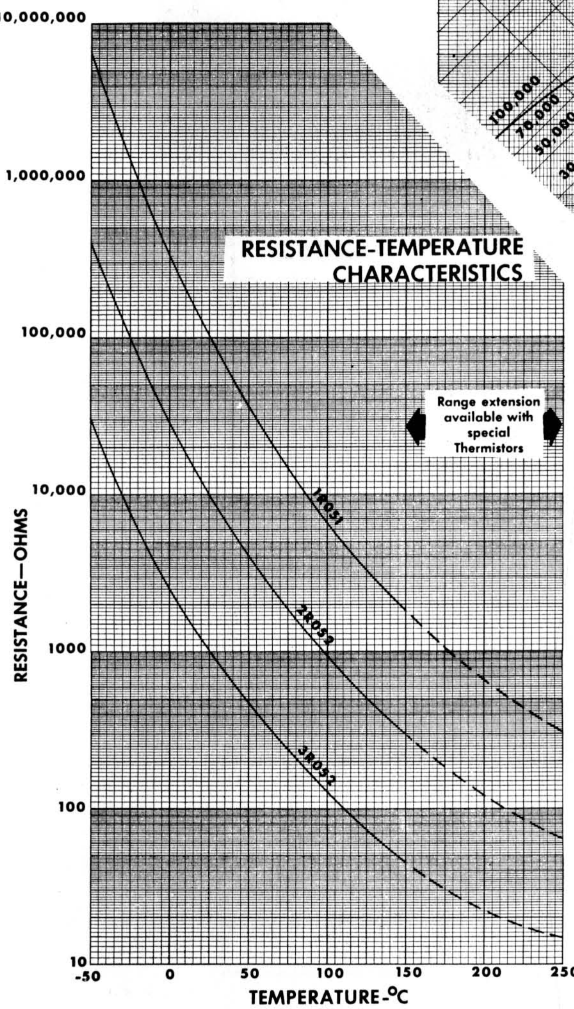
THERMISTOR, R050 SERIES, 0.050" DIAMETER CHARACTERISTICS





Special Thermistors:

To meet special applications a "non-standard" Thermistor may be required. Quotations will be provided for:

Tolerances down to ± 1% on resistance.
Resistance values other than stock standard.
Temperature range extension to 250°C.
Protective and/or Identification Coating.
Special Mounting or *Probe Assembly.*
Different Lead Arrangement.
Matched Pairs

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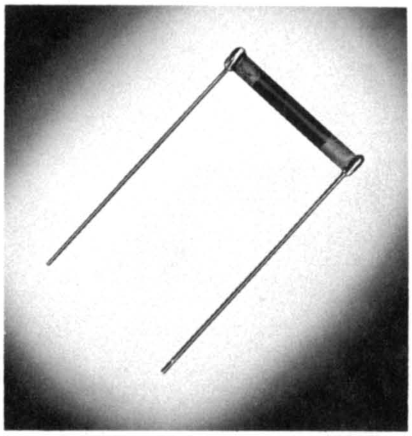


R112 Series Thermistors, 0.112" diameter, are rugged, medium-size Thermistors with close electrical tolerances. Their mass is great enough to avoid much of the self-heating that affects small Thermistors.

SPECIFICATIONS

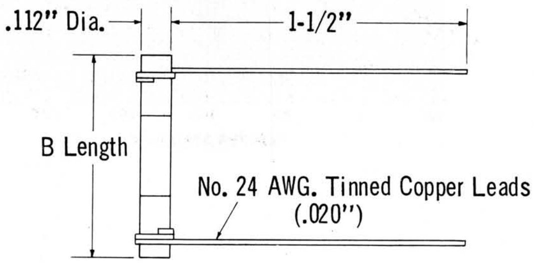
Characteristics

† New Order Number	1R111	1R113	2R112	2R114	2R116	3R112	3R114	3R116
Old Order Number	R111	R113	R112	R114	R116	-	-	-
Grade	1	1	2	2	2	3	3	3
Beta (25°C-75°C) Nominal °K / Tolerance ±%	3965 1.4	3965 1.4	3530 2.3	3530 2.3	3530 2.3	3000 5	3000 5	3000 5
Resistance @ 25°C; Ω ±10%	100,000	31,500	10,000	4,300	3,150	1,000	430	315
Nominal Resistance @ 150°C; Ω	1,840	580	300	129	94.5	45.4	19.5	14.3
*Dissipation Constant; milliwatts/°C	10	7	8	6	6	8	6	6
**Thermal Time Constant (sec.)	70	50	70	50	50	60	40	40
Length "B" (nominal) inches	1.6	0.9	1.6	0.9	0.9	1.6	0.9	0.9

Maximum Ratings

Thermistor Temperature 150°C (302°F)

Outline Drawing

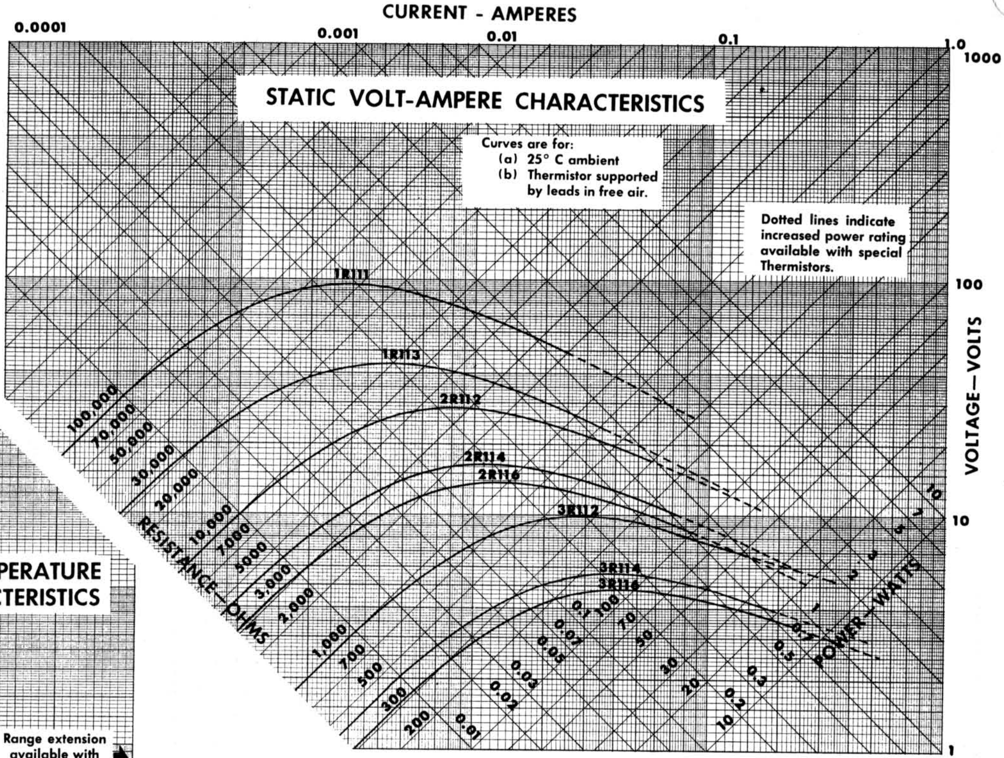


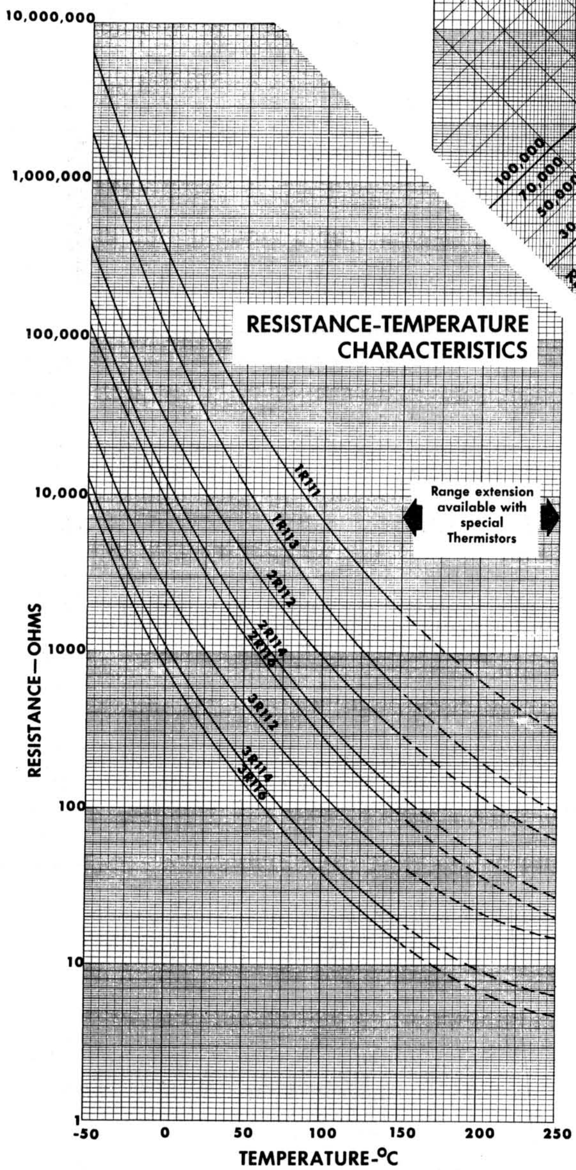
†First digit indicates Grade of Thermistor Material.

*Slope of the linear portion of the Dissipation Characteristic which is the Thermistor temperature rise above ambient versus the electrical power input.

**Time required for a Thermistor to change 63.2% of the temperature difference between its initial temperature and the temperature of its surroundings. No power is applied during the change and the Thermistor is supported by its leads in free air.

THERMISTOR, R112 SERIES, 0.112" DIAMETER CHARACTERISTICS





Special Thermistors:

To meet special applications a "non-standard" Thermistor may be required. Quotations will be provided for:

Tolerances down to ± 1% on resistance.
Resistance values other than stock standard.
Temperature range extension to 250°C.
Protective and/or Identification Coating.
Special Mounting or *Probe Assembly.*
Different Lead Arrangement.
Matched Pairs

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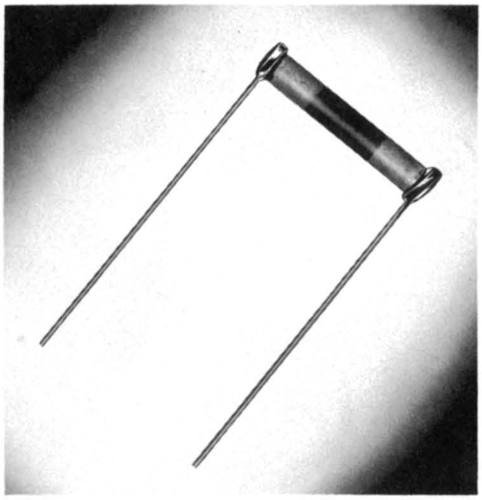


R173 Series Thermistors, 0.173" diameter, are rugged, medium-size rod Thermistors with close electrical tolerances. Their mass is great enough to avoid much of the self-heating that affects small Thermistors.

SPECIFICATIONS

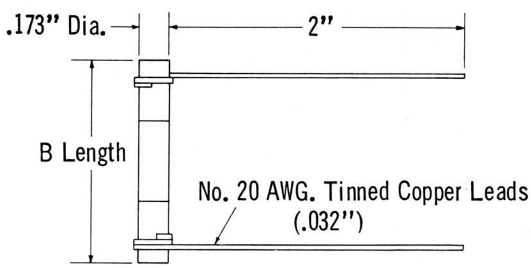
Characteristics

†New Order Number	1R171	1R173	2R172	2R174	3R172	3R174
Old Order Number	R171	R173	R172	R174	-	-
Grade	1	1	2	2	3	3
Beta (25°C-75°C) Nominal °K Tolerance ±%	3965 1.4	3965 1.4	3530 2.3	3530 2.3	3000 5	3000 5
Resistance @ 25°C; Ω ±10%	50,000	20,000	5,000	2,000	500	200
Nominal Resistance @ 150°C; Ω	920	368	150	60	22.7	9.1
*Dissipation Constant; milliwatts/°C	18	13	15	11	15	11
**Thermal Time Constant (sec.)	120	80	120	80	110	80
Length "B" (nominal) inches	1.8	1.1	1.8	1.1	1.8	1.1

Maximum Ratings

Thermistor Temperature 150°C (302°F)

Outline Drawing



†First digit indicates Grade of Thermistor Material.

*Slope of the linear portion of the Dissipation Characteristic which is the Thermistor temperature rise above ambient versus the electrical power input.

**Time required for a Thermistor to change 63.2% of the temperature difference between its initial temperature and the temperature of its surroundings. No power is applied during the change and the Thermistor is supported by its leads in free air.

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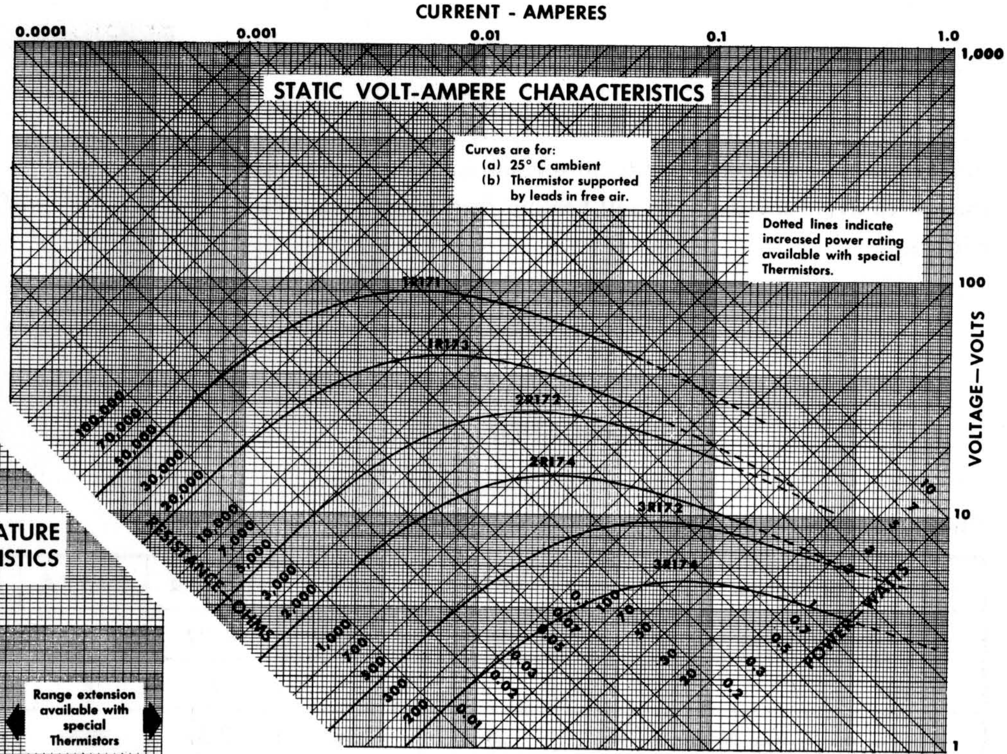
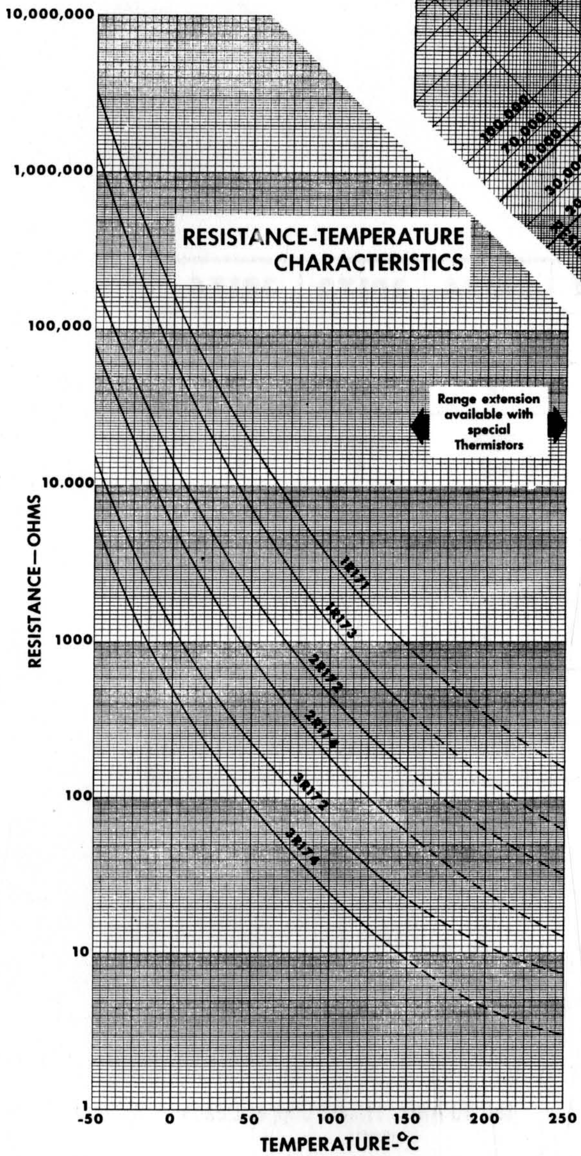
THERMISTOR, R173 SERIES, 0.173" DIAMETER CHARACTERISTICS





Special Thermistors:

To meet special applications a "non-standard" Thermistor may be required. Quotations will be provided for:

Tolerances down to ± 1% on resistance.
Resistance values other than stock standard.
Temperature range extension to 250°C.
Protective and/or Identification Coating.
Special Mounting or *Probe Assembly.*
Different Lead Arrangement.
Matched Pairs

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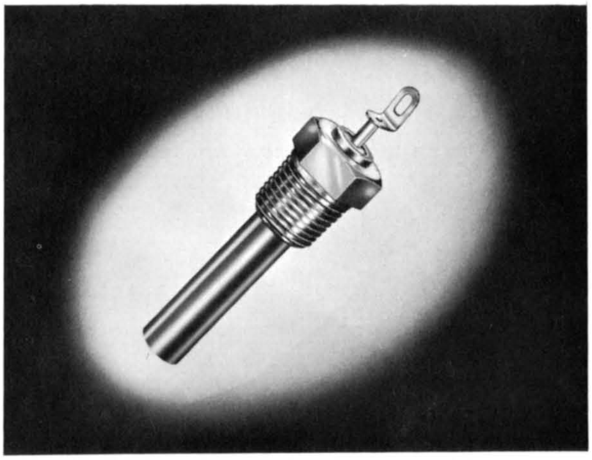
Thermistor probes, utilizing Grade 1 through Grade 4 materials, are now available from NL Industries, Inc. in a resistance range of 50 to 100,000 ohms.

Standard probe diameter is 1/4" with 1/8" pipe thread mounting. Other configurations and dimensions may be adjusted to specific customer requirements.



SPECIFICATIONS

CHARACTERISTICS

ORDER NUMBER		9RT2G1	9RT2G2	9RT2G3	9RT2G4	9RT2G5	9RT2G6	9RT2G7	9RT2G8
GRADE		3	3	2	2	1	1	4	4
BETA (25°C-75°C)	NOMINAL °K	3000	3000	3530	3530	3965	3965	4500	4500
	TOLERANCE ±%	5	5	2.3	2.3	1.4	1.4	2.2	2.2
RESISTANCE @ 25°C	OHMS ±10%	50	100	500	1,000	5,000	10,000	50,000	100,000
NOMINAL RESISTANCE @ 150°C	OHMS	2.3	4.5	15	30	90	180	505	1,010
*DISSIPATION CONSTANT	MILLIWATTS / °C	30 – Fully Immersed In Oil							
**THERMAL TIME CONSTANT	SECONDS	14 – Fully Immersed In Oil							

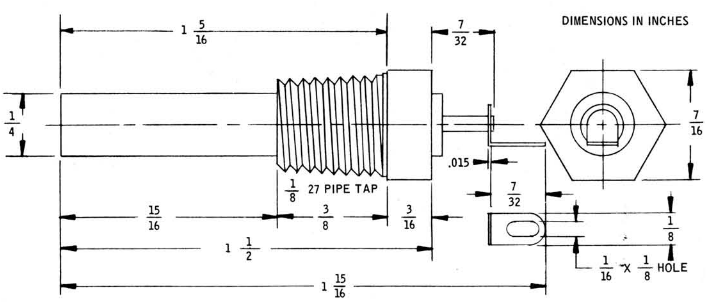
MAXIMUM RATINGS

Thermistor Temperature 150°C (302°F)

ELECTRICAL CONNECTION

Center terminal with probe body return path.

OUTLINE DRAWING



*The ratio, at a specified ambient temperature, of a change in power dissipation in a probe to the resultant body temperature change.

**The time required for a probe to change 63.2% of the difference between its initial and final body temperature when subjected to a step function change in temperature under zero-power conditions.

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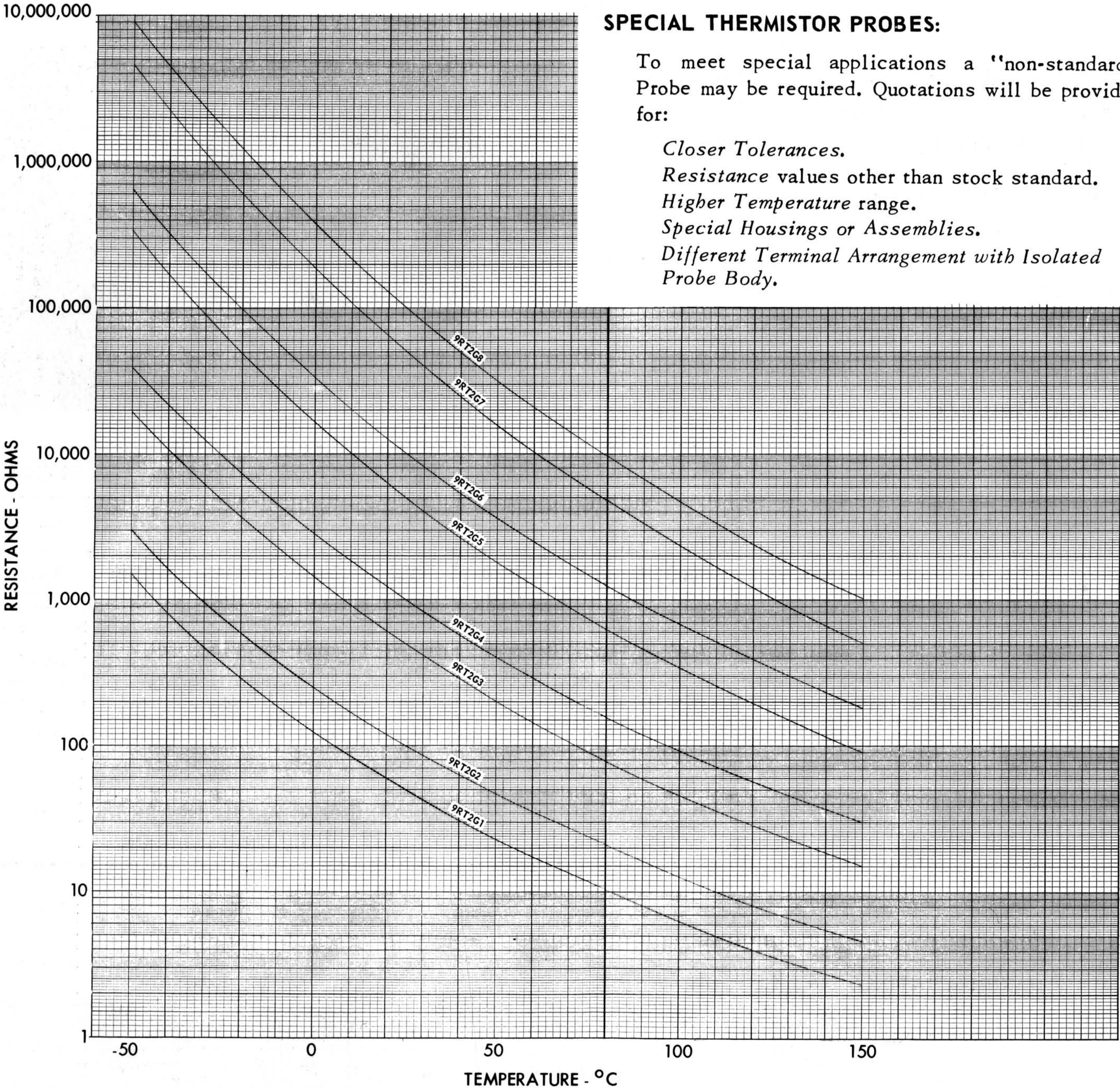
THERMISTOR PROBE CHARACTERISTICS, 9RT2G SERIES, 1/4" DIAMETER

RESISTANCE-TEMPERATURE CHARACTERISTICS (FULLY IMMERSED)



SPECIAL THERMISTOR PROBES:

To meet special applications a "non-standard" Probe may be required. Quotations will be provided for:

Closer Tolerances.
Resistance values other than stock standard.
Higher Temperature range.
Special Housings or Assemblies.
Different Terminal Arrangement with Isolated Probe Body.

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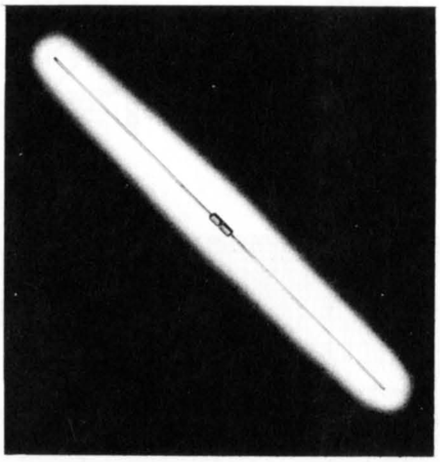
H-Series Hermetically Sealed Thermistors are small, rugged, and good for use up to 400°C. Uniform dimensions make them desirable for automatic insertion in printed circuit boards. Gold plated Dumet leads are weldable and/or solderable.



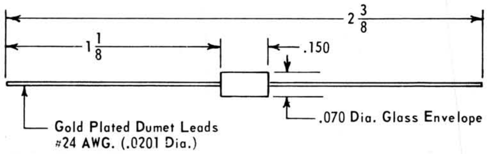
SPECIFICATIONS

Typical Characteristics

Catalog Number	1H-104	1H-503	1H-203	2H-103	2H-502	2H-202
Zero Power Resistance @ 25°C; OHMS ± 10%	100,000	50,000	20,000	10,000	5,000	2,000
Resistance Ratio; $\frac{R_{25°C}}{R_{125°C}}$	29.85	29.85	29.85	19.80	19.80	19.80
*Dissipation Constant (δ); $\frac{\text{milliwatts}}{°C}$	2	2	2	2	2	2
**Thermal Time Constant (τ); (sec.)	8	8	8	8	8	8
Maximum Operating Temperature; (°C)	400	400	400	400	400	400

OUTLINE DRAWING

(Dimensions in Inches)



Temperature		Resistance Ratio Characteristics	
°C	°F	R_T/R_{25} MULTIPLIER 1H-	2H-
-55	-67	95	54
-40	-40	34	21.7
-21.5	- 6.7	10.5	8.0
0	32	3.3	2.82
25	77	1.00	1.00
37.8	100	.58	.62
50	122	.36	.41
75	167	.148	.182
104.4	220	.0595	.082
125	257	.0335	.0505
150	302	.0180	.0300
200	392	.00670	.0116
250	482	.00280	.00555
300	572	.00140	.00291
350	662	.000800	.00178
400	752	.000450	.00104

To find the resistance of a particular H-Series Thermistor at any temperature in this table, multiply its 25°C resistance by the multiplier for that temperature.

*The ratio, in a 25°C still air ambient, of the power input to raise the Thermistor temperature to 125°C and its temperature rise (125°C–25°C) above ambient.

$$\left[\frac{(E_{Th} I_{Th} \text{ @ } 125°C \text{ operating temperature})}{125°C - 25°C}\right]$$

**Time required for a Thermistor to change 63.2% of the temperature difference between its initial and final body temperature, when subjected to a step function change in temperature under zero-power conditions.

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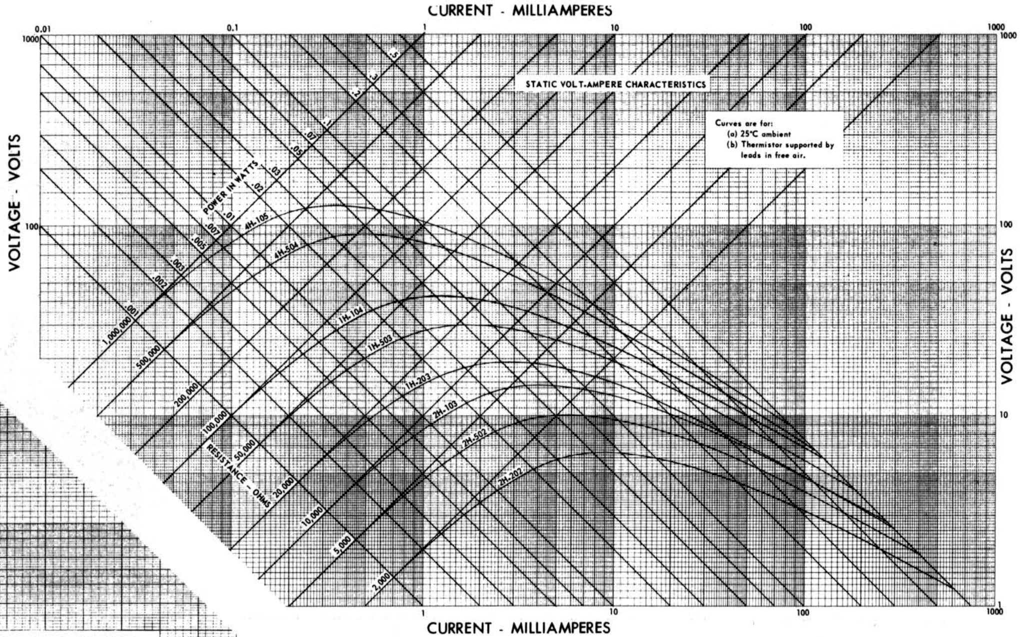
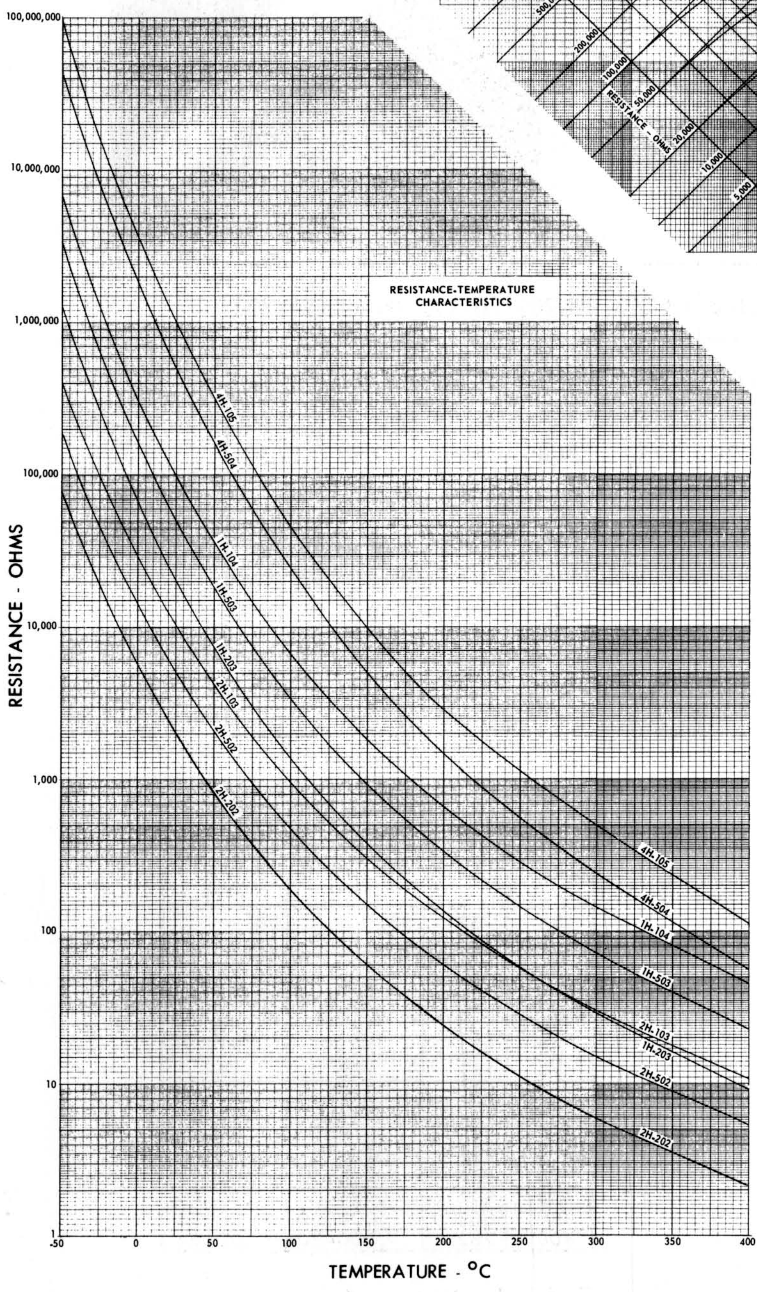
H-SERIES THERMISTOR CHARACTERISTICS





Special H-Series Thermistors:

To meet special applications a "non-standard" Thermistor may be required. Quotations will be provided for:

Tolerances down to ±2% on resistance.
Resistance values other than stock standard.
Identification Marking.
Special Mounting or *Probe Assembly.*
Matched Pairs.

Grade 4 H-Series not available as standard.

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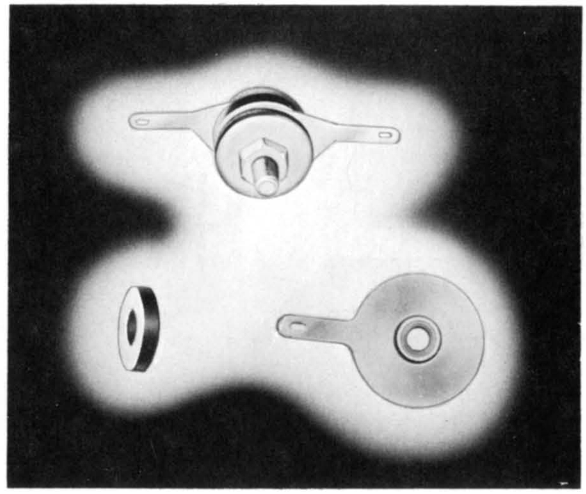
HIGHTSTOWN, NEW JERSEY 08520



W750 Series Washers and 9RT1 Series Washer Assemblies are large-size rugged thermistors especially suited for applications where space is at a premium yet a large mass is required. They are ideal where flat or surface mounting is desired and can be easily mounted on a chassis or heat sink.

SPECIFICATIONS

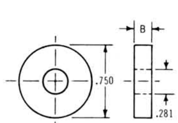
CHARACTERISTICS:

CATALOG NUMBER			ZERO POWER RESISTANCE @ 25°C OHMS ±10%	GRADE	BETA β (25°C-75°C) °K	RESISTANCE RATIO		ZERO POWER NOMINAL RESISTANCE @ 150°C OHMS	THERMISTOR THICKNESS "B" NOMINAL IN.
WASHER †	BOLTED ASSEMBLY	SOLDERED ASSEMBLY				R_{25}/R_{75}	R_{25}/R_{125}		
4W751	9RT1A10	9RT1C10	4150	4	4500 ±100	8.75	48.78	41.9	0.191
4W753	9RT1A11	9RT1C11	3150	4	4500 ±100	8.75	48.78	31.8	0.145
4W755	9RT1A12	9RT1C12	1000	4	4500 ±100	8.75	48.78	10.1	0.046
1W751	9RT1A1	9RT1C1	415	1	3965 ±55	6.76	29.85	7.47	0.191
1W753	9RT1A3	9RT1C3	315	1	3965 ±55	6.76	29.85	5.67	0.145
1W755	9RT1A5	9RT1C5	100	1	3965 ±55	6.76	29.85	1.80	0.046
2W752	9RT1A2	9RT1C2	41.5	2	3530 ±80	5.49	19.80	1.25	0.140
2W754	9RT1A4	9RT1C4	31.5	2	3530 ±80	5.49	19.80	.945	0.106
2W756	9RT1A6	9RT1C6	10	2	3530 ±80	5.49	19.80	0.3	0.034
3W752	9RT1A7	9RT1C7	4.15	3	3000 ±150	4.26	12.95	0.200	0.140
3W754	9RT1A8	9RT1C8	3.15	3	3000 ±150	4.26	12.95	0.152	0.106
3W756	9RT1A9	9RT1C9	1	3	3000 ±150	4.26	12.95	0.0482	0.034

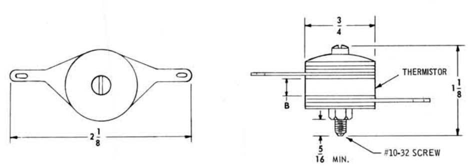
RATINGS: Thermistor Temperature 150°C Max. (302°F)

*Dissipation Constant (δ); 55 MW/°C nominal
**Thermal Time Constant (τ);
400 Seconds typical for the 9RT1C Series
150 Seconds typical for the 9RT1A Series

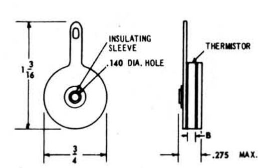
OUTLINE DRAWINGS:
(Dimensions in Inches)



WASHER



BOLTED ASSEMBLY



SOLDERED ASSEMBLY

†First digit indicates grade of thermistor material for washers only.

*The ratio, at a specified ambient temperature, of a change in power dissipation in a thermistor to the resultant body temperature change. (See note.)

**The time required for a thermistor to change 63.2% of the difference between its initial and final body temperature when subjected to a step function change in temperature under zero power conditions. (See note.)

NOTE: The values given for Dissipation Constant and Thermal Time Constant are for reference purposes only since these constants are dependent upon the method of mounting. These values result from mounting the thermistor on a 3/16 inch thick aluminum plate in a 25°C still air ambient with the plate held vertically. The plate dimensions were:
1-5/8 x 1-5/8 for the 9RT1C Series
3 x 3 for the 9RT1A Series.

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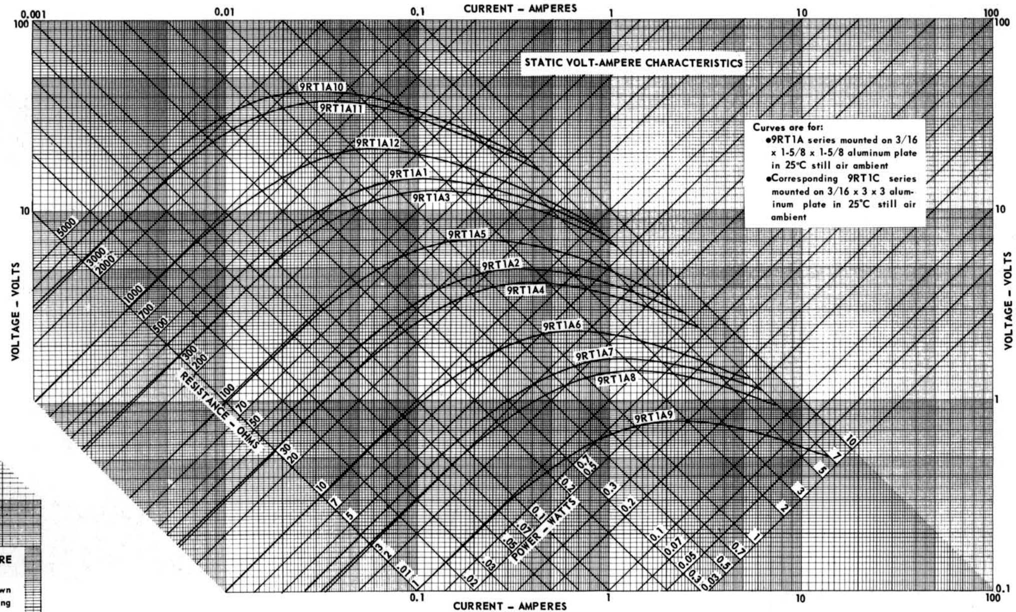
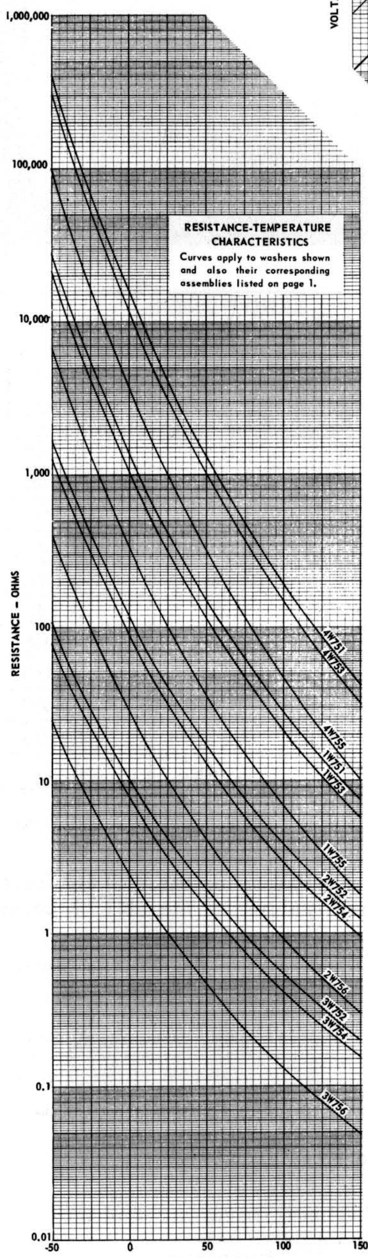
THERMISTOR W750 AND 9RT1 SERIES, 0.75" DIAMETER CHARACTERISTICS





Special Thermistors:

To meet special applications a "non-standard" Thermistor may be required. Quotations will be provided for:

Grades of material not listed.
Resistance *Tolerance to* ±1%.
Special *Resistance* values.
Higher maximum *temperature.*
Coatings – for protection and identification.
Special Mounting or Assembly.
Matched Pairs.
Multiple Thermistor Assembly.

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Glass coated bead Thermistors feature SMALL SIZE, FAST RESPONSE, and improved HIGH-TEMPERATURE STABILITY. Leads are fired-in platinum-iridium. Bead probes, incorporating the bead in the tip of a glass probe, offer the additional advantages of more rugged construction in an easy to mount package which can be used in liquid media. Tinned Dumet leads are supplied on probes. The maximum operating temperature for beads and bead probes is 400°C.

TYPE	Zero Power Resistance at 25°C ohms ±20%	Catalog Number	Resistance Ratio R_{25}°C/R_{125}°C ±5%	*Dissipation Constant (δ) Milliwatts/°C	**Thermal Time Constant (τ) Seconds	Figure Number
Bead	2,000	81B-202	19.8	0.7	2	1
	10,000	81B-103	29.85			
	15,000	81B-153	29.85			
	50,000	81B-503	35.0			
	150,000	81B-154	39.7			
	500,000	81B-504	46.5			
	1,000,000	81B-105	51.5			
Bead Probe	2,000	81G-20250	19.8	1	25	2
	10,000	81G-10350	29.85			
	15,000	81G-15350	29.85			
	50,000	81G-50350	35.0			
	150,000	81G-15450	39.7			
	500,000	81G-50450	46.5			
	1,000,000	81G-10550	51.5			

Outline Drawings (Dim. in inches)

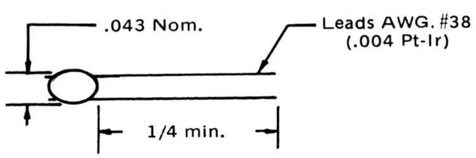

FIGURE 1

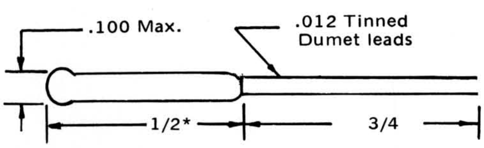

FIGURE 2

*Bead probes also available in 2" lengths.

***Resistance Ratio Temperature Characteristics

Temp.		R_t/R_{25} Multiplier					
°C	°F	81G-20250 81B-202	81G-10350 81G-15350 81B-103 81B-153	81G-50350 81B-503	81G-15450 81B-154	81G-50450 81B-504	81G-10550 81B-105
−55	−67	54	95	121	132	149	170
−15	−5	5.75	7.3	8.05	8.47	9.31	9.47
0	32	2.82	3.3	3.46	3.58	3.74	3.86
25	77	1.00	1.00	1.00	1.00	1.00	1.00
50	122	.410	.36	.342	.333	.318	.308
75	167	.182	.148	.135	.126	.116	.109
100	212	.092	.079	.0591	.0539	.0477	.0434
125	257	.0505	.0335	.0286	.0252	.0215	.0194
200	392	.0116	.00607	.00496	.00385	.00316	.00268
275	527	.00386	.00194	.00134	.000990	.000748	.000606
300	572	.00291	.00140	.000935	.000671	.000505	.000394
350	662	.00170	.000800	.000482	.000346	.000245	.000192
400	752	.00104	.000450	.000281	.000194	.000131	.000102

*The ratio, at a specified ambient temperature, of a change in power dissipation in a Thermistor to the resultant body temperature change.

**Time required for a Thermistor to change 63.2% of the temperature difference between its initial and final body temperature, when subjected to a step function change in temperature under zero-power conditions.

***To find the resistance of a particular Bead Thermistor at any temperature in this table, multiply its 25°C resistance by the multiplier for that temperature.

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TEMPERATURE COMPENSATION

INTRODUCTION

Most materials used for electrical conductors, circuit components, and active circuit elements are temperature sensitive to some degree. Depending on the function being performed and the accuracy desired, it may be necessary to compensate for this temperature sensitivity. This can readily be accomplished using thermistors.

Thermistors are being used successfully for temperature compensation of copper elements in electromechanical devices; compensation of the combined effects of copper windings and temperature sensitive electromagnetic core materials in television deflection yokes; temperature compensation of transistor power amplifiers in radio, TV, and communications equipment; and a host of other temperature compensation applications including such circuits as voltage regulators, automobile ignition circuits, and oscillator circuits. For proper compensation, the first step is to determine the required resistance-temperature characteristic of the compensator. Since copper is a common circuit element and reacts linearly with temperature, multiplier tables have been developed for use in compensating copper. To obtain the required characteristic for materials or components other than copper it has been found that the use of the resistance substitution method provides an efficient solution. By adjusting a decade box to obtain proper circuit function at various temperatures over the anticipated temperature range of operation, a resistance vs. temperature table is derived. From this table the required resistance temperature characteristic curve can be quickly constructed, keeping in mind the maximum allowable tolerances for the circuit. The next step is to determine the proper circuit configuration for the compensator network.

TYPES OF COMPENSATOR CIRCUITS

Most compensation problems require a characteristic in which the resistance change is less than the resistance change of the thermistor alone. Copper compensation is one example. Figure #1 illustrates that the thermistor has a large non-linear negative temperature coefficient of resistance while copper has a relatively small linear positive value. It is apparent that the thermistor would over compensate and would not give the desired results. By shunting the thermistor with a linear resistor a more linear characteristic results (compensator), and the required compensation can be obtained (compensated copper).

Although the shunted thermistor is one of the more common circuit configurations for a compensator, certain requirements may demand more complex circuits.

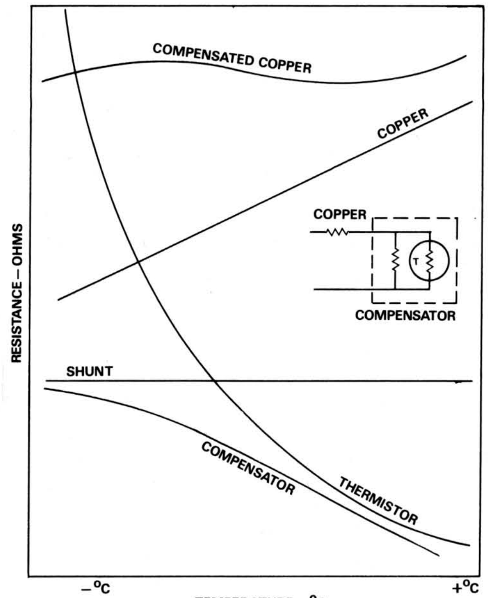


FIGURE 1

Figure #2 illustrates three common networks along with their respective characteristics. The thermistors are identified with their resistance at 25°C. It should be noted that each network produces a different resistance change for the same temperature

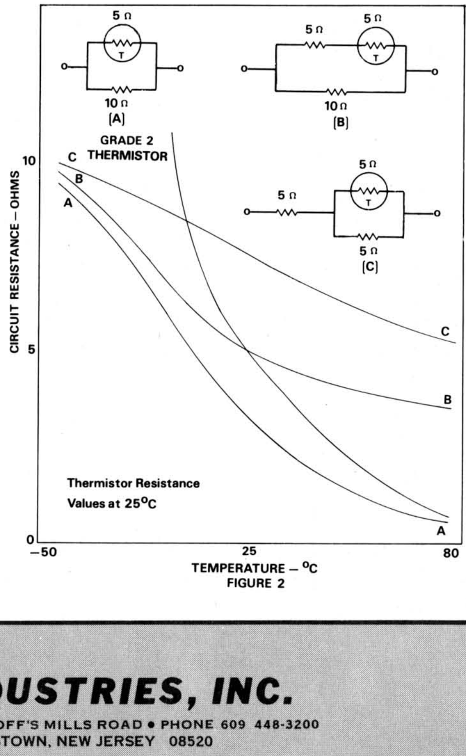


FIGURE 2

range and that network "A" produces a greater change while networks "B" and "C" progressively reduce the slope of the curve. By using other thermistors and more complex circuit configurations, an infinite number of curves could be produced, making the selection of the best circuit for a given compensation problem very time consuming. Much of the time and effort can be eliminated by using "Unit" Curves described below.

SOLUTION METHOD

UNIT CURVE CONSTRUCTION

Since most compensator networks require the use of a shunted thermistor, a family of curves can be constructed showing the affects of this circuit on a unit basis. For example, if both thermistor and shunt resistor were reduced to one ohm each and the equivalent resistance calculated over a temperature range, the shape of the curve would not change regardless of the resistance level, as long as the thermistor material grade and its resistance ratio to the shunt resistor remained the same. Therefore, by increasing or decreasing this ratio, a family of curves can be generated which will show the various possible shapes for a given temperature range. Figures 5, 6, 7 and 8 represent the Unit Curves for NL Industries, Inc. thermistor grades #1, 2, 3, and 4 respectively. The curves represent a plot of equivalent resistance vs. temperature. On each curve is a number representing a ratio of the thermistor resistance at 25°C to the value of the shunt. With the equivalent resistances plotted on a unit basis such as this, they can then be used as multipliers of the shunt resistor to obtain the actual equivalent resistance of the parallel network at any given temperature.

UNIT CURVE USE

There remain only two unknowns to determine in order to satisfy the required compensation; (1) Select a Unit Curve with the proper shape; (2) Calculate the value of the shunt resistor. For example, first construct a graph (fig. 3a) of the resistance-temperature characteristic required of the compensator network. Compare this graph to the Unit Curves until one is found which most nearly matches the shape of the required characteristic. Assuming that it matched the .4 Unit Curve of the Grade #3 family (Fig. 7) and the temperature range required was 0°C to 90°C, the value of the shunt resistor can then be calculated. Refering to the Unit Curve, 0°C corresponds to an equivalent resistance of .507 ohms and 90°C represents .049 ohms. Letting "a" represent the compensator network resistance required at 0°C and "b" the comparable resistance required at 90°C, the following simultaneous equations can be set up:

1. @ 0°C, $.507X + Y = a$
2. @ 90°C, $.049\,X + Y = b$

where "X" represents the value of the shunt resistance and "Y" the series resistance in the circuit shown in Figure 3b:

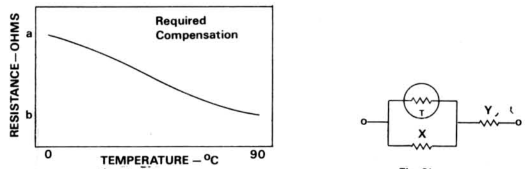


Fig. 3a

Fig. 3b

FIGURE 3

To obtain the value of the shunt resistor (X), subtract equation #2 from equation #1 and solve for "X".

To obtain the series resistance "Y" (if required) substitute "X" back into either one of the equations.

To obtain the value of the thermistor at 25°C, multiply (X) by the thermistor ratio (.4) and specify the grade of material which corresponds to the family of curves that were used. The resistance of the compensator circuit can be found at any temperature by multiplying the shunt resistor by the equivalent per-unit resistance which corresponds to the required temperature then add the series resistance.

Although this method may not match the required characteristic at all temperatures, in most cases it will yield a curve which comes close to the requirement. Slight adjustments in the thermistor resistance or shunt resistance may be necessary for a more accurate match of the requirement.

Copper (such as in a copper coil) has a positive temperature coefficient of resistance, its actual change in resistance with respect to temperature may be computed as follows:

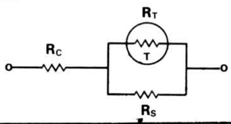
$$R_t = R_{25}\left[1 + 0.00385\,(T-25)\right]$$

where R_t = resistance in ohms at temperature T, R_{25} = resistance in ohms at 25°C and T = temperature of copper in °C.

Analyzing the Unit Curves with respect to copper compensation, it is only necessary to consider the straight portion of the curves since copper has a linear characteristic. Experience has shown that Grade #2 material in most cases provided the best resistance level with the least deviation for a given temperature range. Optimum selections were made for various temperature ranges and the network component multipliers in Figure #4 were tabulated for convenient use when copper is the element being compensated.

Symbols used in the table and diagrams include: Network Terms: R_c, copper resistance at 25°C; R_t, shunt resistance; R_{ave}, average network resistance; % Dev, percent of deviation from average network resistance. Component values can be calculated as follows: Grade #2 thermistor resistance at 25°C (R_T) = (R_c) (r_t), shunt resistance (R_s) = (R_c) (r_s), average resistance of circuit including copper = (R_c) (r_{ave}), and % deviation can be read directly.

Network Component Multipliers For Temperature Compensation



Temp (°C)		+150	+120	+100	+85	+70	+50	+35
-60	r_t	1.64	0.70	0.38	0.34	0.21	0.20	0.09
	r_s	0.82	0.70	0.63	0.57	0.52	0.50	0.43
	r_{ave}	1.52	1.37	1.28	1.25	1.18	1.17	1.07
	% Dev	5.45	5.12	4.42	3.55	3.05	2.13	1.81
-40	r_t	3.26	1.33	0.91	0.53	0.30	0.28	0.17
	r_s	0.82	0.66	0.61	0.53	0.50	0.46	0.41
	r_{ave}	1.60	1.43	1.36	1.28	1.21	1.19	1.12
	% Dev	3.82	2.80	2.44	1.83	1.65	1.17	0.73
-20	r_t	2.80	1.82	1.11	0.79	0.49	0.46	0.24
	r_s	0.70	0.61	0.56	0.53	0.49	0.46	0.40
	r_{ave}	1.53	1.43	1.36	1.32	1.25	1.23	1.15
	% Dev	3.22	1.69	1.44	1.20	0.97	0.55	0.35
0	r_t	4.13	2.43	1.65	1.01	0.72	0.43	0.25
	r_s	0.69	0.61	0.55	0.51	0.48	0.43	0.41
	r_{ave}	1.57	1.47	1.40	1.33	1.29	1.22	1.16
	% Dev	1.76	1.24	0.86	0.76	0.63	0.36	0.31
+20	r_t	4.11	3.55	2.15	1.56	0.95	0.64	0.26
	r_s	0.69	0.59	0.54	0.52	0.48	0.43	0.43
	r_{ave}	1.56	1.51	1.43	1.38	1.31	1.26	1.17
	% Dev	1.75	0.78	0.57	0.49	0.37	0.17	0.11

FIGURE 4

EXAMPLE SOLUTIONS

COPPER (using the multiplier table of Fig. 4)

If a 900-ohm copper coil is to be compensated for a range of -60°C to +85°C, the user first locates the square at the intersection of the -60°C and +85°C columns in the table. Multiplying 900 by 0.34 will give the R_t (thermistor resistance at 25°C) value: multiplying 900 by 0.57 provides the r_s (shunt resistance – low-temperature-coefficient material such as manganin, cupron, etc.). Finally, multiplying 900 by 1.25 gives r_{ave}, the average network resistance. Deviation percentage from this average, 3.55%, can be read directly from the table. Respective values for thermistor, shunt, and average resistance are: 306 ohms, 513 ohms, and 1125 ohms.

OTHER MATERIALS

Compensation for materials other than copper can best be demonstrated with an example. Assume that the following resistance-temperature characteristic was required in a circuit for optimum performance:

Temp °C	-30	-10	10	25	50	90
Res - Ohms	78	65	49	41	31	24

Plotting this curve on graph paper and comparing its shape to the Unit Curves, we find that it compares very nearly to the .4 curve of the Grade 3 thermistor material. Using the end points of the temperature range, solve for the shunt resistor:

1. At -30°C $.804X + Y = 78$
2. At 90°C, $.060X + Y = 24$

Subtracting equation 1 from equation 2,

$$X = \frac{54}{.744} = 72.6 \text{ ohms.}$$

Substituting this value back into equation 1, we find that an additional series resistance is required to raise the level of the curve:

$$(.804)(72.6) + Y = 78, \quad Y = 19.7 \text{ ohms}$$

(refer to Figure #3b for Circuit Configuration)

Since the .4 curve was used, the resistance of the thermistor at 25°C is (.4) (72.6) = 29 ohms (the ratio times the shunt resistance). In checking the catalog data, we find that the closest stock standard Grade 3 resistance is 30 ohms in either the 3D202 or 3D302 units. Since the stock thermistors have a resistance tolerance of plus or minus 10%, either one of these units could be used without too much deviation in the characteristic. To obtain a true picture of the compensator across the temperature range, the unit equivalent resistances can be used as multipliers, and circuit resistances at any temperature can be calculated as follows:

Temp °C	Equivalent Parallel Resistance	Series Res.	Compensator
-30	(.804)(72.6) = 58.4 ohms +	19.7 ohms =	78.1 ohms
25	(.286)(72.6) = 20.8 ohms +	19.7 ohms =	40.5 ohms
90	(.060)(72.6) = 4.35 ohms +	19.7 ohms =	24.05 ohms

ADDITIONAL CONSIDERATIONS

EFFECTS OF SELF HEATING

After determining the basic component values of the compensator, the circuit should be analyzed to insure that the dissipation constant of the thermistor is not exceeded and self heating introduced. The self heating effects can be determined as follows:

1. Obtain the maximum power dissipated by the thermistor.
2. Divide this power by the dissipation constant of the thermistor to obtain the approximate increase in temperature of the thermistor.
3. Add this increase to the ambient temperature to obtain the actual temperature of the thermistor. The new resistance can then be taken from a Resistance vs. Temperature curve for the particular grade of material.

It may be found that the tolerance requirements of the compensator dictate that a physically larger thermistor with a greater dissipation constant be selected. It should be noted however that the dissipation constant listed on the catalog data sheets was obtained in a 25°C ambient while the thermistor was suspended by its leads in still air. Therefore, the dissipation constant will vary depending on the mounting techniques and environmental conditions and will normally be larger in practice than the values shown.

UNIQUE APPLICATIONS

It should be recognized that this method by itself will not provide the optimum solution to all temperature compensation problems. It will, however, provide a reasonably accurate solution to the more common types of compensation problems. For unusual applications or where close tolerances are required, merely submit the resistance-temperature characteristic you require along with the tolerance limitations to NL Industries, Inc., Electronics Department, Hightstown, New Jersey 08520 for application engineering assistance.

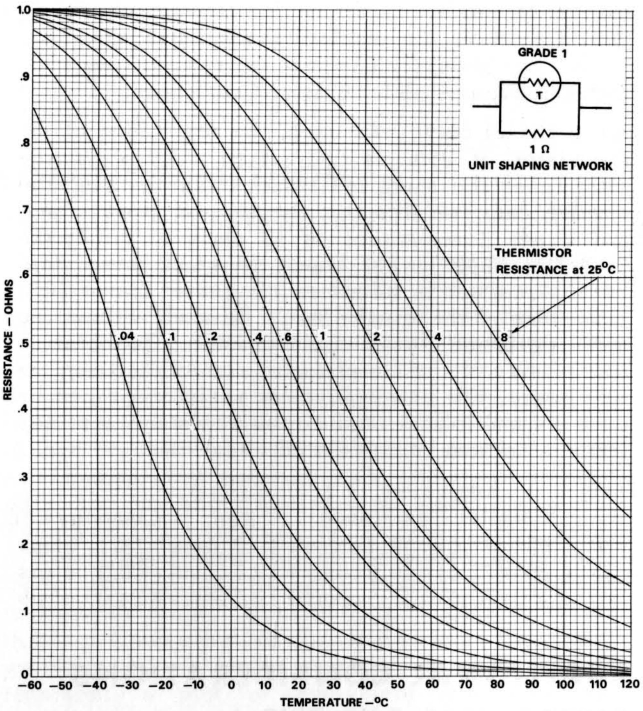


FIGURE 5

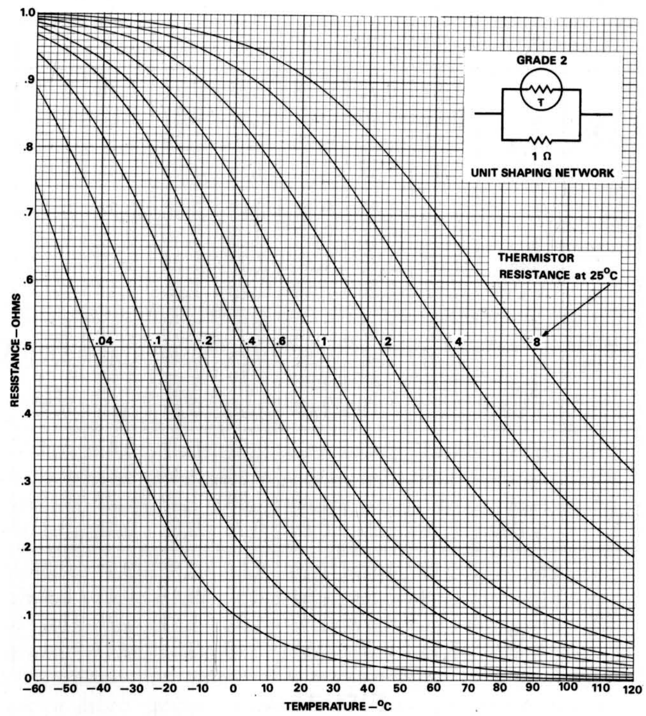


FIGURE 6

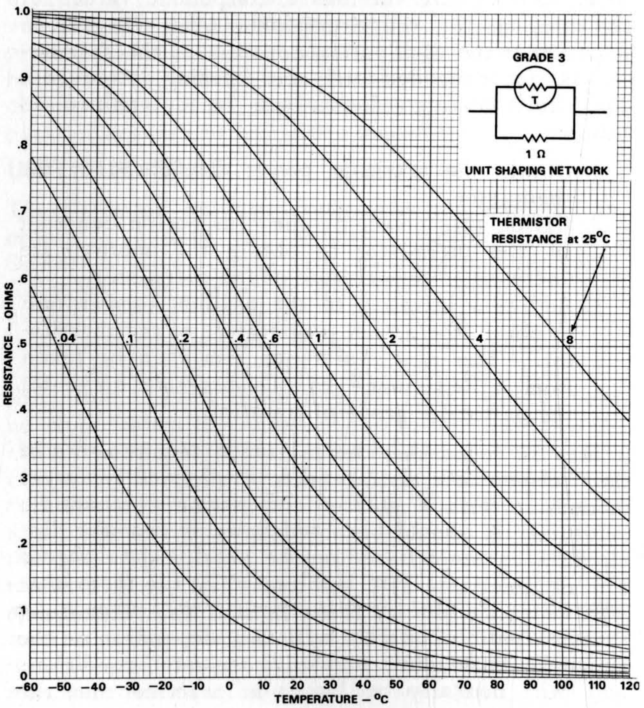


FIGURE 7

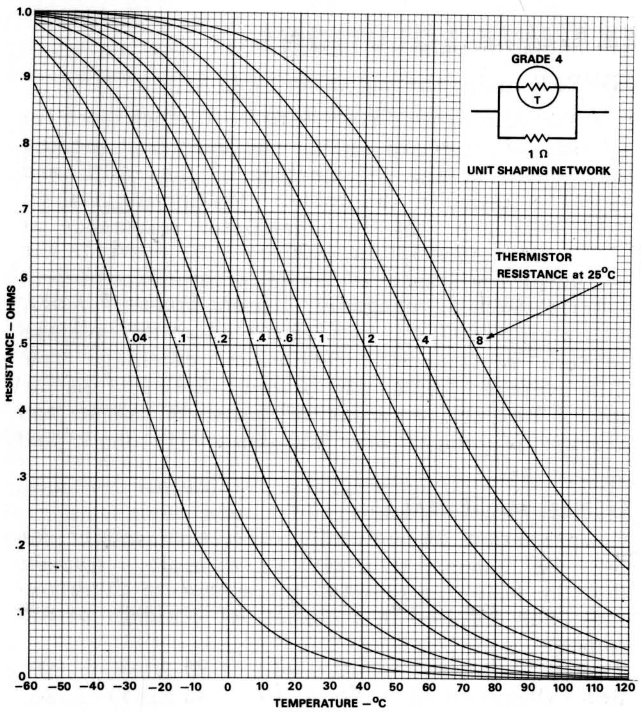


FIGURE 8

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GENERAL CHARACTERISTICS OF THERMISTORS

DESCRIPTION:

Thermistors (Thûr·mĭs′tẽrs) are thermally sensitive resistors whose primary function is to exhibit a change in electrical resistance with a change in body temperature. They are passive electronic semi-conductors whose electrical resistance varies with temperature and lies between that of conductors and insulators. An important characteristic of thermistors is their extreme sensitivity to relatively minute temperature changes.

While most metals have small positive temperature coefficients of resistance, thermistors exhibit a wide range of negative or positive temperature coefficients. The large temperature coefficients and the non-linear resistance-temperature characteristics of thermistors enable them to perform many unique regulatory functions.

Figure 1 shows the resistivity of both negative and positive temperature coefficient materials, over a range of temperature, as compared to a representative metal. It is possible in some types of thermistors to double the resistance with a temperature change of as little as 1 degree Centigrade (°C). Figure 1 also graphically illustrates the wide range of resistivities available in negative temperature coefficient materials.

NL Industries, Inc. thermistors are made in various material grades from manganese, nickel, and cobalt oxides; and many other materials. After these raw materials are milled and mixed in accurate proportions, suitable binders are added and the units are pressed or extruded to the desired shape. Thermistor elements are then sintered under carefully controlled atmospheric and temperature conditions to produce hard ceramic-like material. Various electrode materials can be applied and lead wires attached when desired.

PERFORMANCE:

Certain characteristics explained in detail below govern the behavior of thermistors in electrical or electronic circuits. The values and graphs shown will be for negative temperature coefficient (NTC) material. The same general principles apply equally well to positive temperature coefficient (PTC) material.

ZERO-POWER RESISTANCE-TEMPERATURE CHARACTERISTIC

This is the relationship, shown graphically in Figure 2, between the zero-power resistance of a thermistor and its body temperature. The resistance measurement should be made by a method that dissipates negligible power in the thermistor so that little or no self heating is involved.

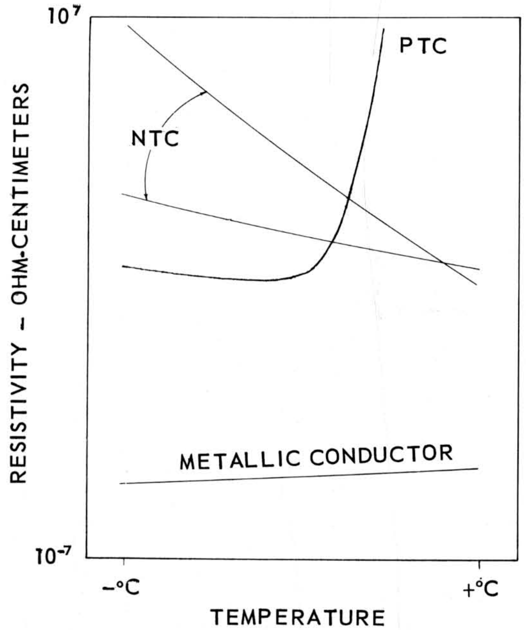

FIGURE 1

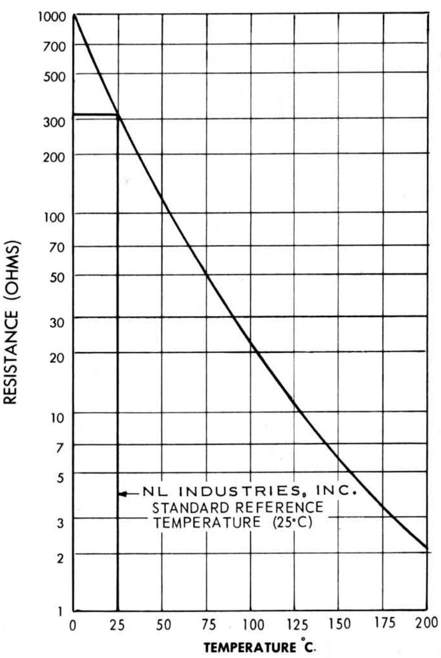

FIGURE 2

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HIGHTSTOWN, NEW JERSEY 08520

The Thermistor Standard Reference Temperature is the thermistor body temperature at which nominal zero-power resistance is specified. This is shown on Figure 2 as 25° C for NL Industries, Inc. thermistors.

The time required for a thermistor to change 63.2% of the difference between its initial and final body temperature when subjected to a step function change in temperature under zero-power conditions is known as the Thermal Time Constant. It is to be noted that this is measured under zero or negligible power and should not be confused with Dissipation Constant or Current-Time Characteristic defined later.

STATIC VOLT-AMPERE CHARACTERISTIC

The thermistor whose Resistance-Temperature Characteristic is shown in Figure 2 has a Static Volt-Ampere Characteristic as shown in Figure 3. This curve was obtained with the thermistor in a circuit with provisions for limiting the current. Current is applied in increasing steps to the thermistor; at each step, sufficient time must be allowed for the circuit to reach equilibrium before recording voltage and current readings.

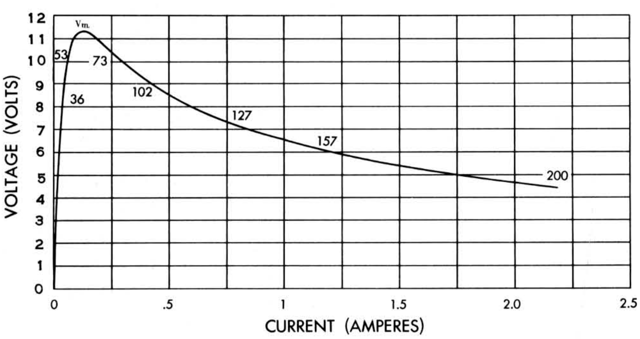

FIGURE 3

For very small currents the power dissipated is too small to appreciably heat the thermistor and Ohm's law is followed. As the current is increased, the power dissipated increases, and the thermistor temperature rises with a corresponding decrease in resistance. At some value of current the voltage reaches a peak value, V_m, which is known as the self-heat voltage; beyond this value the curve has a negative slope. The numbers on the curve give the thermistor temperature in °C. These were obtained by using Figure 2 to convert resistance to temperature.

Figure 4 shows the data from Figure 3 replotted on log-log coordinates. Since lines of +45° and −45° represent constant resistance and power respectively, thermistor voltage, resistance, and power can be depicted on one curve for convenience and practical use. With the aid of the Resistance-Temperature Characteristic, thermistor temperature can also be shown.

The test data can also be used to plot (Figure 5) the relationship between power dissipated and temperature rise above ambient. The ratio, at a specified ambient temperature, of a change in

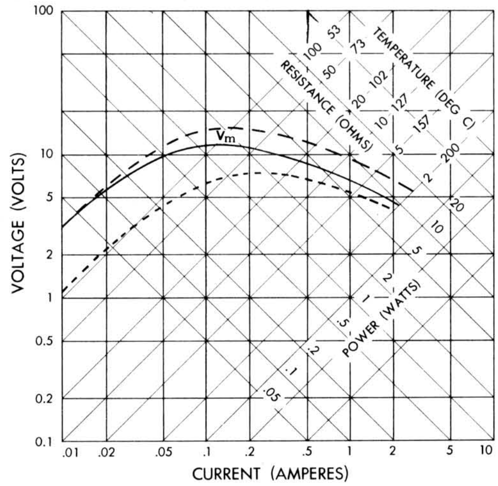

FIGURE 4

power dissipation in a thermistor to the resultant body temperature change is called the Dissipation Constant.

The data so far discussed are for a typical thermistor supported by small terminals in still air at an ambient of 25°C. If it were mounted in moving air, or in a liquid, or on a metal block the temperature rise to dissipate a given amount of heat would be much less; in other words, the dissipation constant would be increased. Repeating the previous tests with the same thermistor mounted on a metal block in still air at an ambient of 25°C yields the dashed curves of Figures 4 and 5. It is noted that the Static Volt-Ampere Characteristic for this condition has the same shape as the solid curve but is displaced from the original along a line with a slope of 45°. Power dissipation at the high temperature has been increased by the mounting. The effect of

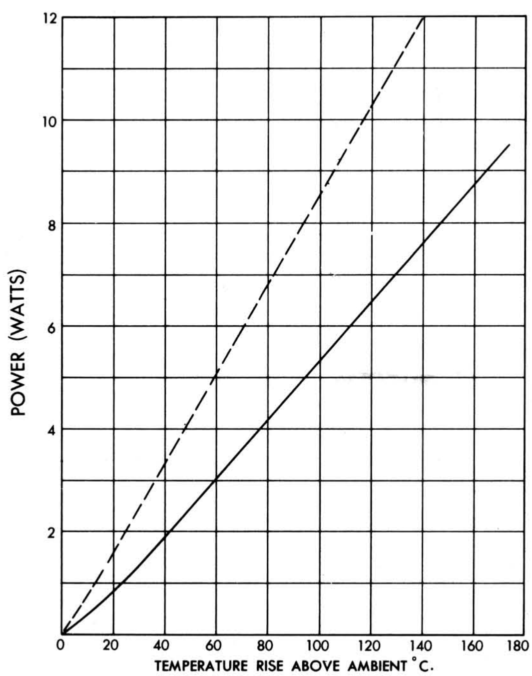

FIGURE 5

mounting on dissipation constant is difficult to predict accurately and is usually best determined by experiment.

Static Volt-Ampere Characteristics for standard thermistors suspended by their leads in still air at an ambient of 25°C are shown in individual Product Data Sheets. If the characteristic is desired for the same mounting in still air at some other ambient temperature, this can readily be calculated. The power dissipation curve can be reconstructed from the published Static Volt-Ampere Characteristic, and since it is in terms of temperature rise (rather than temperature) it can be applied to some other ambient, such as shown in the lower dotted curve in Figure 4.

CURRENT TIME CHARACTERISTIC

Discussion has thus far been limited to steady state conditions in which the power supplied to a thermistor is equal to the power dissipated by it. In many applications it is important to consider transient conditions when the temperature and other quantities vary with time. This relationship at a specified ambient temperature between the current through a thermistor and time upon application of a step function of voltage to it is called the Current-Time Characteristic.

Application of a fixed voltage to a thermistor in series with a fixed resistor produces a Current-Time Curve as in Figure 6. The thermistor's zero power resistance and the fixed resistor determine the initial current at time equal to zero seconds. The initial current heats the thermistor and lowers its resistance allowing more current to flow and the process continues until the current is limited by the circuit resistance.

Under fixed external circuit conditions the thermal mass of an element determines the Current-Time Characteristic; obviously, a very small element will change temperature more rapidly than a relatively larger unit. In Figure 6 the Current-Time Characteristics are shown for three thermistors of the same material and resistance, the only difference being physical size.

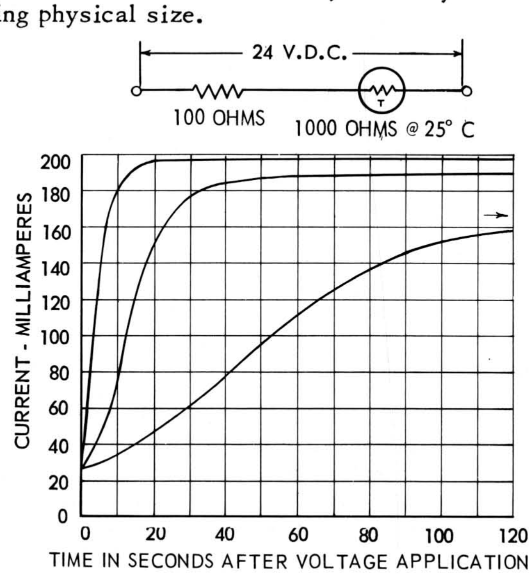

FIGURE 6

APPLICATIONS:

MEASUREMENT AND CONTROL OF TEMPERATURE

Because the resistance of a thermistor is a function of ambient temperature, thermistors can be effectively used in devices to measure or control temperature. In this application the current through the thermistor is limited to a value so that appreciable self-heating does not occur. The device may be calibrated to read directly as a thermometer or used in a control circuit.

The high resistance of a thermistor as compared to the resistance of long leads makes possible accurate temperature measurement and control from remote locations.

Thermistors may be used in simple ohmmeter circuits or in bridge circuits. The bridge, shown in Figure 7, may be used as a deflection device where the output can be calibrated directly in temperature or as a null type of bridge where the variable resistance is adjusted to null the bridge output and calibrated in terms of temperature.

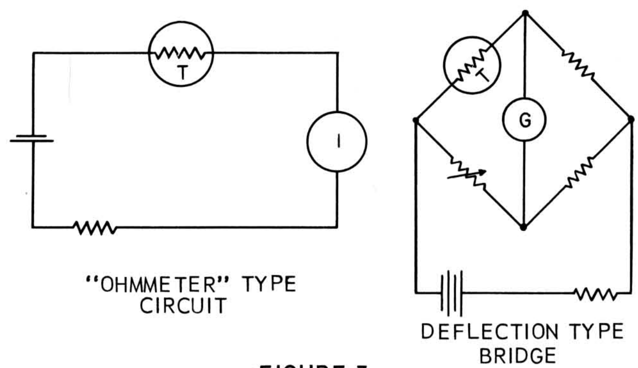

FIGURE 7

Where differential measurements of temperature are desired, a matched pair of thermistors are used in two adjacent bridge arms, or for increased sensitivity four thermistors may be used. The indicating or recording instrument may have a zero-centered scale, so that either an increase or a decrease in the temperature of one thermistor with respect to another can be detected.

The temperature sensitivity and accuracy of these temperature measurement circuits is dependent upon the sensitivity of the bridge detection circuit. Any change in temperature, however small, will cause a resistance change in a thermistor. The sensitivity of the detection device thus determines the smallest temperature change that can be measured. For example, a bridge circuit with a high gain amplifier on the output could measure differentials of 0.0005 °C (0.001 °F).

MEASUREMENT AND CONTROL OF OTHER PHENOMENA

Changes in the surrounding medium in which a thermistor is suspended can change the Dissipation Constant. Using this feature and self heating the thermistor with power, it is possible to measure vacuum or flow.

Using a circuit such as Figure 8, where thermistor T_1 is exposed to the medium being measured, such as air or liquid; and the temperature compensation thermistor T_2 is exposed only to the ambient temperature of the medium to be measured; the changes in the dissipation constant of T_1 will produce a reading on the galvanometer which can be directly calibrated.

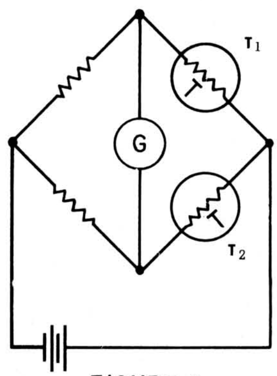

FIGURE 8

TEMPERATURE COMPENSATION

A thermistor's change in resistance with temperature is useful for temperature compensation. Figure 9 shows the Resistance-Temperature Characteristic of a thermistor alone and with a resistor in series or shunt. Many variations in the network Resistance-Temperature Characteristic are possible with the use of different network arrangements.

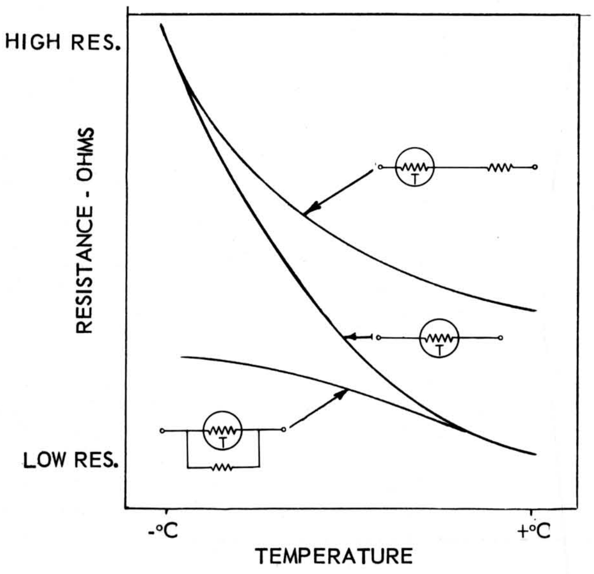

FIGURE 9

Note that the shunted Thermistor curve is approximately linear. Most metals, including copper, have a relatively linear positive temperature coefficient. The shunted thermistor is an excellent compensation network when placed in series with metals.

Thermistors can be used to accomplish temperature compensation of transistor circuits. Use of an NTC thermistor in shunt with R_2 or a PTC in place of R_4 in Figure 10 are examples of this type of application.

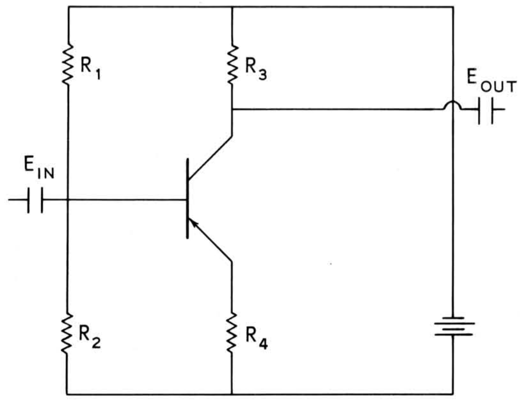

FIGURE 10

APPLICATIONS USING CURRENT-TIME CHARACTERISTIC

Time Delay:

Thermistors function in time delay devices because of their Current-Time Characteristic. Time delay cycles may be varied from a fraction of a second to several minutes by using an appropriate thermistor and a suitable circuit design. Changes in ambient temperature change the time delay. The delay period is shortened if the thermistor resistance does not return to its original value before the next operation.

Multiple time delays can be achieved by selecting parallel circuits consisting of thermistors and loads in a circuit powered by the same source of voltage. This arrangement may be used as a sequence switching device where a controlled order of operations is desired.

Current Inrush Surge Suppression:

The cold resistance of a filament is 1/6 to 1/8 of its hot resistance. Application of voltage to cold filaments such as tubes and lamps can cause undesirably high inrush currents. Insertion of a thermistor in series with the filaments will suppress these surges. After voltage application, the thermistor resistance, initially high, decreases and the current increases allowing filament warm up; then, when equilibrium is reached, the thermistor resistance is negligible.

Safety and Warning Circuits:

Multiple time delay action can be used to good advantage in safety and warning devices for the protection of personnel working with and around hazardous machinery and electrical equipment. These devices may delay the start of electrical equipment after power is applied and operate visual or audible warning signals; or both functions may be combined in one circuit.

For specifications of particular thermistors refer to the Short Form Catalog 1082 or the specific Product Data Section.

THERMISTORS

Questionnaire to be used for obtaining application assistance

Name of Company________________________ Division ______________

Address____________________ City___________ Zone_____ State__________

Individual________________ Dept.______________ Area Code Phone__________

By far the largest number of applications for Thermistors are for the automatic detection, measurement and control of physical energy. In most cases only a few questions need to be answered, see below.

Other applications may demand more information, see back of this sheet.

CONVENTIONAL APPLICATIONS: Temperature compensation ☐
Measurement and Control: of temperature ☐ of other phenomena ☐

1. Ambient temperature range – Operating_______°(C, F) to_______°(C, F)
Exposure_______° (C, F) to_______°(C, F)

Surrounding Medium ☐ Liquid ☐ Gas ☐ Air ☐ Solid ☐ Still or ☐ Moving

If moving liquid or gas: Flow rate__________ ft/sec; Density__________________

If air, maximum relative humidity__________%; Media Name __________________

2. Special environmental conditions: (MIL-STD), Etc.________________________

3. Source voltage:________volts ☐ DC ☐ AC (______volts______cycles per second)

4. Space and/or weight limitation, if any_____________________________

5. Configuration required ☐ Disk; ☐ Rod; ☐ Washer; ☐ Any of these; ☐ Probe; ☐ Other________
Terminals required; ☐ None; (☐ Leads; Number______, length______; Wire size______ Insulation______)
Connector required____________; No of Pins ________; Mating Connector______________
Other____
☐ Coating required ☐ Identification ☐ Protection
Dielectric/Insulation Resistance ____________________________

6. If the desired resistance-temperature characteristics are known, fill in columns below:

Temperature (C)	Temperature (°F)

Zero Power Resistance (ohms)	Tolerance (±%)

7. Approximate Quantities required per year ____________________________

OTHER APPLICATIONS FOR THERMISTORS

1. Type and function of apparatus in which Thermistor is to be used ____________________

2. (a) Brief statement of what is to be accomplished by use of Thermistor. Give numerical values where possible.
____

   (b) Please attach a circuit diagram showing circuit constants and proposed connections including expected voltages, currents, resistance vs temperature curve required, etc.

SPECIFIC INFORMATION ON THESE APPLICATIONS

1. Temperature Measurement and Control – Details of indicating or control system to be used with Thermistor
____

   Precision of measurement or control desired ____________________

   Calibration Accuracy__________ % of Range ____________________

2. Temperature Compensation:
   Temperature resistance characteristic to be compensated (in detail)__________
   Range of current in circuit __________
   Temperature range over which compensation is desired__________
   Degree of compensation desired __________
   Voltage drop across circuit being compensated at a specified temperature and current condition __________
   Circuit tolerances __________
   Voltage drop allowable across compensating network __________
   Will Thermistor be thermally coupled to circuit or device being compensated – describe__________
   Resistance of component to be compensated (measured at 25°C) and material of component __________

3. Time Delay
   Normal and maximum ambient temperature range __________
   Time delay required and tolerance __________
   Circuit values, resistances, tolerances, voltages: __________
   Relay pull-in and drop-out ratings and tolerances and or manufacturers types and catalog number of relay __________
   Is rapid recycling required? Describe duty cycle __________
   Can you supply a sample relay? __________

After completing questionnaire
please send to:

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