Linear Thermistor Components and Probes

DP80 Series; see Section M-73.

Linear Response Components

For applications requiring thermistors with linear response to temperature change, OMEGA offers linear components. These unique devices consist of a thermistor composite for temperature sensing and an external resistor composite for linearizing.

Thermistor composites 44018 and 44019 each contain two thermistors packaged in a single sensor (Figures 1A & 1B). Thermistor composite 44020 contains three thermistors packaged in a single sensor (Figure 1C).

Resistor composites for use with 44018 and 44019 thermistor composites consist of two metal film resistors of the size shown in Figure 2. Resistor composites for use with the 44020 thermistor composite consist of three of the same type metal film resistors.

Linear components are manufactured with different values for different temperatures ranges. When they are connected in networks shown in Figures 3 and 4, they produce a varying voltage or resistance which is linear with temperature.

One of the basic network manifestations is a voltage divider as in Figure 3A for components other than #44212, and as shown in Figure 3B for component #44212. The area within the dashed lines represents the thermistor composite. The network hookup for linear resistance versus temperature is shown in Figure 4A for linear components except #44212, and in Figure 4B for #44212.

Following is a description of why these networks produce linear information. The equation for a voltage divider network, consisting of R and R_0 in series, is:

$$E_{out} = E_{in}\frac{R}{R + R_0}$$

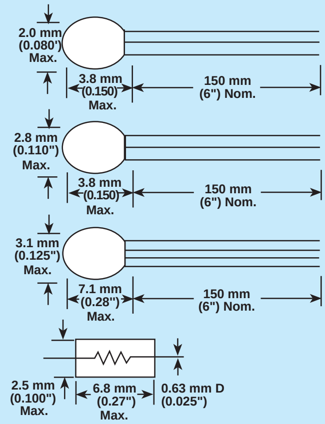
where E_{out} is the voltage drop across R. If R is a thermistor, and E_{out} is plotted versus temperature, the total curve will be essentially non-linear and of a general "S" shape, with linear or nearly linear portions near the ends and in the center.

Figure 1A Thermistor Composite 44018

Figure 1B Thermistor Composite 44019

Figure 1C Thermistor Composite 44020

Figure 2 Metal Film Resistor



If R is modified by the addition of other thermistors and resistors, linearity of the center section of the curve, where sensitivity is greatest, can be extended to cover a wide range of temperatures. This section follows the general equation for a straight line, y = mx + b or in terms of a linear component:

For Voltage Mode	For Resistance Mode
$E_{out} = \pm MT + b$	$R_t = MT + b$
where M is slope in volts/°T, T is temperature in °C or °F, and b is the value of E_{out} when T = 0°	where M is slope in ohms/°T, T is temperature in °C or °F, and b is the value of the total network resistance, R_t, in ohms when T = 0°

Linear Voltage vs. Temperature

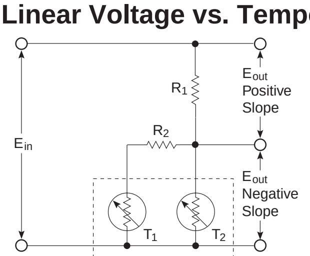


Figure 3A

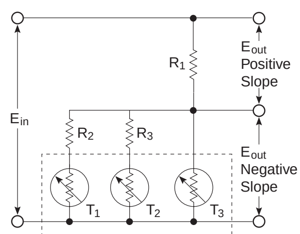


Figure 3B

Note: *Model 5830 precision benchtop thermometer includes linearized circuity, refer to section M.*

Linear Resistance vs. Temperature

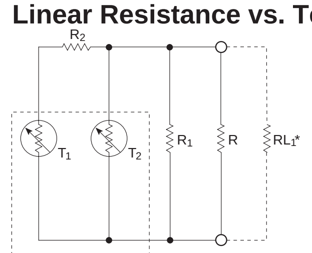


Figure 4A

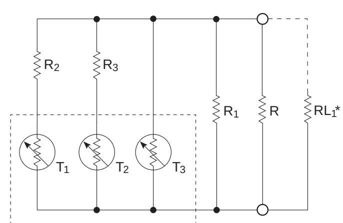
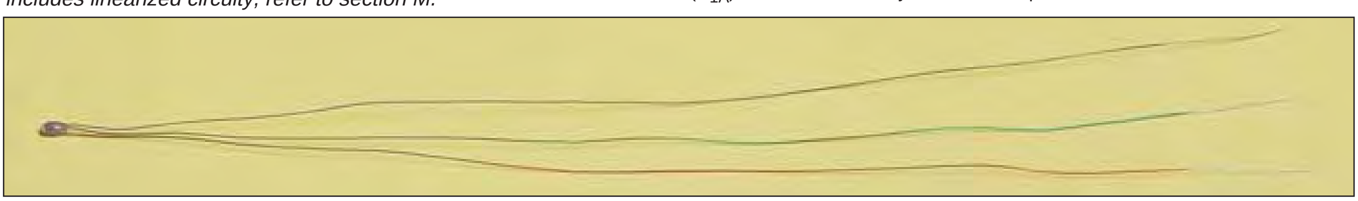


Figure 4B

*RL_1 may be any value as long as a new R_1 value (R_{1A}) is selected to satisfy the relationship:

$$R_{1A} = \frac{R_1 \times RL_1}{RL_1 - R_1}$$



Sensitivity is 400 times greater than an IC thermocouple. Thermistor values as high as 30 mV/°C are common. In addition, output voltage can be applied to a recorder or digital voltmeter to produce a precise, sensitive, direct reading thermometer.

Multiplexing

The 44018 thermistor composite is used in four of the linear components. The part that changes in each component is the resistor composite, which determines the temperature range. Therefore, the 44018 thermistor composite can be used over the entire -30 to 100°C temperature range by simply changing resistor composites. Its accuracy and interchangeability over the full range is ±0.15°C. It is not mandatory that OMEGA® resistor composites be used with the 44018 thermistor composite. Any 0.1% resistors of the proper values and with a temperature coefficient of 30 PPM or less may be substituted. In other situations, it is frequently desirable to have thermistor composite temperature sensors at more than one location. When this is required, it is not necessary to have a separate resistor composite for each thermistor composite. It is possible to multiplex any number of thermistor composites through a single resistor composite for greater design flexibility: Linear Thermistor Components are manufactured under U.S. and Canadian Patents.

MOST POPULAR MODELS HIGHLIGHTED!

To Order *(Specify Model Number)*

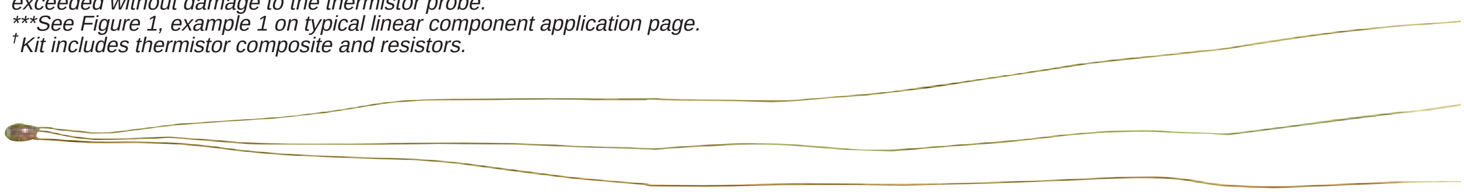
Linear Kit† Model No.	Price	Thermistor Composite Model No.	Price	Resistor Composite Model No.	Price
44201	$26	44018	$20	44301	$12
44202	26	44018	20	44302	12
44203	26	44018	20	44303	12
44204	26	44018	20	44304	12
44211A	37	44019	30	44311A	12
44212	58	44020	46	44312	16

† Kit includes thermistor composite and resistors.
See the next page for more information.

Component Specifications

	°C	°F	°C	°F
† Linear Components Kit Model No.	44201		44202	
Range	0 to 100°C	32 to 212°F	-5 to 45°C	23 to 113°F
Thermistor Composite Model No.	44018		44018	
Resistor Composite Model No.	44301		44302	
Resistor Composite Values	R_1 = 3200 Ω, R_2 = 6250 Ω		R_1 = 5700 Ω, R_2 = 12000 Ω	
Thermistor Accuracy & Interchangeability	±0.15°C -30 to 100°C	±0.27°F -22 to 212°F	±0.15°C -30 to 100°C	±0.27°F -22 to 212°F
E_0 Positive Slope	E_{out} = (+0.0053483 Ein) T +0.13493 Ein	E_{out} = (+0.00297127 Ein) T +0.03985 Ein	E_{out} = (+0.0056846 Ein) T +0.194142 Ein	E_{out} = (+0.00315851 Ein) T +0.093083 Ein
E_0 Negative Slope	Eout = (-0.0053483 E_{in}) T +0.86507 E_{in}	Eout = (-0.00297127 E_{in}) T +0.96015 E_{in}	Eout = (-0.0056846 E_{in}) T +0.805858 E_{in}	Eout = (-0.00315851 E_{in}) T +0.906917 E_{in}
Resistance Mode	R_t = (-17.115) T +2768.23	R_t = (-9.508) T +3072.48	R_t = (-32.402) T +4593.39	R_t = (-18,001) T +5169.42
*Ein MAX.	2.0 Volts		3.5 Volts	
*I_T MAX.	625 µA		615 µA	
***Load Resistance Minimum R.L.	3 MΩ		10 MΩ	
Linearity Deviation	±0.216°C	±0.388°F	±0.065°C	±0.12°F

*** Ein Max.** and ***I_T Max.** values have been assigned to control thermistor self-heating errors so they do not enlarge the component error band; i.e., the sum of the linearity deviation plus the probe tolerances. The values were assigned using a thermistor dissipation constant of 8MW/°C in stirred oil. If better heat-sink methods are used or if an enlargement of the error band is acceptable, Ein Max. and I_T Max values may be exceeded without damage to the thermistor probe.*
****See Figure 1, example 1 on typical linear component application page.*
† Kit includes thermistor composite and resistors.



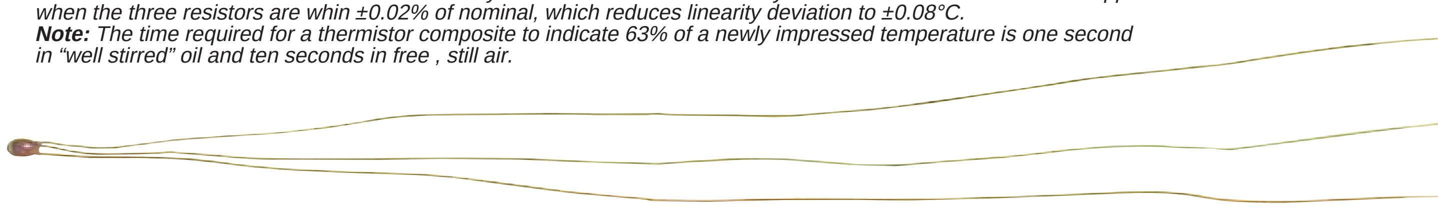
PATENTED

Covered by U.S and International patents and pending applications

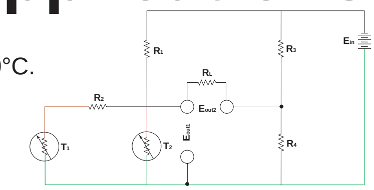
	°C	°F	°C	°F
† Linear Components Kit Model No.	**44203**		**44204**	
Range	-30 to 50°C	-22 to 122°F	-2 to 38°C	+30 to 100°F
Thermistor Composite Model No.	**44018**		**44018**	
Resistor Composite Model No.	**44303**		**44304**	
Resistor Composite Values	R_1 = 18,700 Ω R_2 = 35,250 Ω		R_1 = 5700 Ω R_2 = 12,400 Ω	
Thermistor Accuracy & Interchangeability	±0.15°C -30 to 100°C	±0.27°F -22 to +212°F	±0.15°C -2 to +38°C	±0.27°F -22 to +212°F
E_0 Positive Slope	E_{out} = (+0.0067966 E_{in}) T +0.34893 E_{in}	$E_{o_{out}}$ = (+0.00377588 E_{in}) T +0.228102 E_{in}	E_{out} = (+0.00563179 E_{in}) T +0.192439 E_{in}	E_{out} = (+0.0031289 E_{in}) T +0.09232 E_{in}
E_0 Negative Slope	E_{out} = (-0.0067966 E_{in}) T +0.65107 E_{in}	E_{out} = (-0.00377588 E_{in}) T +0.771898 E_{in}	E_{out} = (-0.00563179 E_{in}) T +0.807563 E_{in}	E_{out} = (-0.0031289 E_{in}) T +0.90768 E_{in}
Resistance Mode	R_t = (-127.096) T +12175	R_t = (-70.608) T +14435	R_t = (-32.1012) T +4603.1	R_t = (-17,834) T +5173.8
***Ein MAX.**	3.0 Volts		4 Volts	
*****I_T MAX.**	475 µA		685 µA	
*****Load Resistance Minimum R.L.**	10 MΩ		10 MΩ	
Linearity Deviation	±0.16°C	±0.29°F	±0.03°C	±0.055°F
† Linear Components Kit Model No.	**44211A**		**44212**	
Range	-55 to 85°C	-67 to 185°F	-50 to 50°C	-58 to 122°F
Thermistor Composite Model No.	**44019**		**44020**	
Resistor Composite Model No.	**44311A**		**44312**	
Resistor Composite Values	R_1 = 3550 Ω, R_2 = 6025 Ω		R_1 = 23,100 Ω R_2 = 88,200 Ω R_3 = 38,000 Ω	
Thermistor Accuracy & Interchangeability	±0.4°C, 0 to 85°C ±0.8°C, -55 to 0°C	±0.72, 32 to 185°F ±1.44, -67 to 32°F	±0.1°C -50 to 50°C	±0.18°F - 58 to 122°F
E_0 Positive Slope	E_{out} = (+0.005068 E_{in}) T +0.3411 E_{in}	E_{out} = (+0.002816 E_{in}) T +0.2510 E_{in}	E_{out} = (+0.00559149 E_{in}) T +0.40700 E_{in}	E_{out} = (+0.00310638 E_{in}) T +0.30760 E_{in}
E_0 Negative Slope	E_{out} = (-0.005068 E_{in}) T +0.6589 E_{in}	E_{out} = (-0.002816 E_{in}) T +0.7490 E_{in}	E_{out} = (-0.00559149 E_{in}) T +0.59300 E_{in}	E_{out} = (-0.00310638 E_{in}) T +0.69240 E_{in}
Resistance Mode	R_t = (-17.99) T +2339	R_t = (-9.994) T +2658.8	R_t = (-129.163) T +13698.23	R_t = (-71.757) T +15994.5
***Ein MAX.**	2.0 Volts		3.5 Volts	
*****I_T MAX.**	833 µA		700 µA	
*****Load Resistance Minimum R.L.**	10 MΩ		10 MΩ	
Linearity Deviation	±1.1°C	±2°F	±0.15°C (condition A)****** ±0.08°C (condition B)******	±0.27°F (A) ±0.15°F (B)

*** The maximum error at any point is the algebraic sum of the thermistor manufacturing tolerances, plus linearity deviation, a fixed network behavior. Condition "A" is the worst case linearity deviation of ±0.15°C and may occur with the ±0.1% resistors supplied. Condition "B" exists when the three resistors are whin ±0.02% of nominal, which reduces linearity deviation to ±0.08°C.*

Note: *The time required for a thermistor composite to indicate 63% of a newly impressed temperature is one second in "well stirred" oil and ten seconds in free , still air.*



Typical Linear Component Applications



Example 1:
To measure and record on a 100 mV recorder temperature in the range 30 to 40°C.
1. Select Part number 44202 (temperature range -5°to +45°C)
   basic equation $E_{out1} = (-0.0056846\ E_{in})\ T + 0.805858\ E_{in}$
2. Calculate E_{in} for 10°C equal to 100 mV

$$(E_{out},\ @30°C - E_{out1}\ @\ 40°C) = 100\ mV$$
$$[(-0.0056846\ E_{in})\ 30°C + 0.805858\ E_{in}] - [(-0.0056846\ E_{in})\ 40°C + 0.805858\ E_{in}] = 100\ mV$$
$$0.056846\ E_{in} = 100\ mV$$
$$E_{in} = 1.7591\ Volts$$

3. Using the Linear network as two legs of a Wheatstone bridge add the two additional legs, R_3 and R_4 so that $E_{out2} = 0$ when T = 30°C. (See Figure 1.) R_3 and R_4 are calculated from five known conditions.
   (1) The voltage drop across R_4 (E_{R4}) should equal $Eout_1$ at 30°C for E_{out2} to equal zero.
   (2) $E_{in} = 1.7591$ Volts
   (3) 1000 ohms $\leq R_3 + R_4 \leq$ 5000 ohms. (If $R_3 + R_4$ is less than 1 K, excessive battery drain may occur. If $R_3 + R_4$ is more than 5 K, some degradation of linearity will occur.)
   (4) $E_{R4} = \dfrac{E_{in}\ R_4}{R_3 + R_4}$
   (5) $E_{out1} = -0.0056846\ (1.7591\ Volts)\ (+30°C) + 0.805858\ (1.7591\ Volts) = 1.1180\ Volts$

   $E_{R4} = E_{out1} = E_{R4} = \dfrac{E_{in}\ R_4}{R_3 + R_3}$ or $1.1180 = \dfrac{R_4\ 1.7591}{R_3 + R_4}$ and let us choose $R_3 + R_4 = 1000$ ohms.

   Solve for R_3 and R_4 $\qquad 1.1180 = \dfrac{R_4\ 1.7591}{R_4 + 100 - R_4}$ $\qquad R_4 = 635.55$ ohms, $R_3 = 364.45$ ohms
4. Apply E_{out2} to the recorder input terminals and the result is a direct reading 10°C full scale thermometer.

Example 2:
To make a 4 digit 100 mV sensitivity digital voltmeter into a direct reading differential thermometer whose ambient range is -30 to 40°C;
1. Select Part number 44203 (temperature range -30 to 50°C)
   basic equation Eout = (-0.0067966 Ein) T +0.65107 Ein
2. Calculate Ein so that 10 mV equals one degree C. (This is done so that the Digital Volt Meter will read directly in temperature with 0.01°C readability)

$$(E_{out},\ @ -30°C - E_{out},\ @ +40°C) = 0.700\ Volts$$
$$[(-0.0067966\ E_{in})(-30) + 0.65107\ E_{in}] - [(-0.0067966\ E_{in})\ (40) + 0.65107\ E_{in}] = 0.700$$
$$0.47576\ E_{in} = 0.700$$
$$E_{in} = 1.4713\ Volts$$

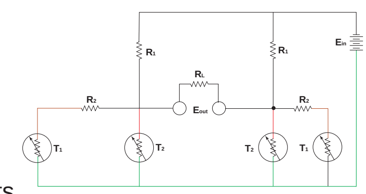


Figure 2

3. Connect two linear networks (#44203) as shown in Fig. 2.
4. Apply E_{out} to the Digital Volt Meter input terminals for a direct reading differential thermometer.

Example 3:
To make a 2-wire system from a 3-wire system using any Linear component:
1. For voltage mode, connect R_2 to the thermistor composite. (See Figure 3.) This unit can function as the temperature sensor and be located remote from the signal conditioning circuit by up to distance "D".
2. The resistance mode differs from the voltage mode only by removal of the power source. (See Figure 4.)
3. Acceptable distance "D" varies according to the temperature range. Using #22 wire "D" may be as follows without loss of accuracy in both 2-wire and 3-wire systems. Where distance "D" is greater than indicated, heavier gauge wire may be used.

Temperature Range	Distance "D"
0 to 100°C	100 ft.
-5 to 45°C	300 ft.
-30 to 50°C	300 ft.
+30 to 100°C	300 ft.

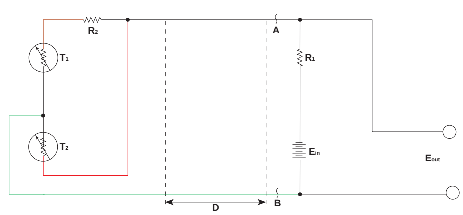


Figure 3 Voltage Mode

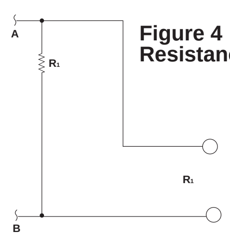


Figure 4
Resistance Mode

Example 4:
Multiplexing to connect any number of thermistor composites to a single signal conditioning circuit. (See Figure 5.) Multiplexing can be accomplished much more easily with a two-wire system, such as shown in Figure 5.

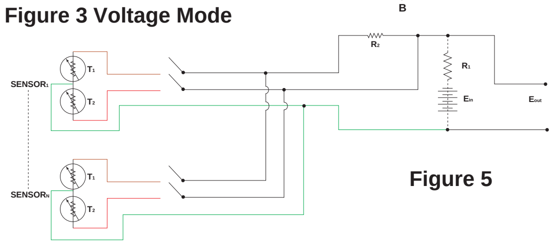


Figure 5

Lead Colors:
Green: Common to T1 & T2
Brown: T1 **Red:** T2