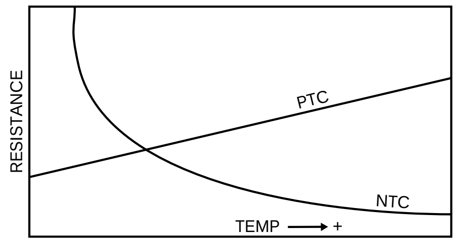
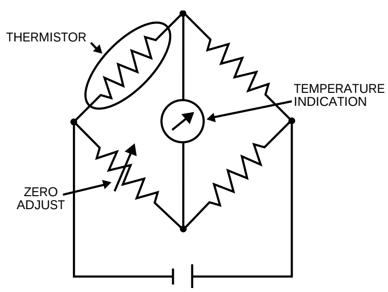
BASIC TEMPERATURE MEASUREMENT USING THERMISTORS

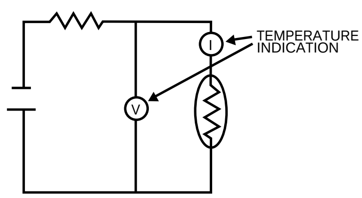
Thermistors (THERMally sensitive resISTORS) are solid state devices which can be used to directly measure temperature, as well as be incorporated into control and compensation circuits. An NTC thermistor's resistance changes inversely with a temperature rise, and a PTC thermistor's resistance changes proportionally to a temperature rise. Due to the larger delta R vs. T of an NTC device, NTC devices are usually more suitable for precision measurement although the resistance change is nonlinear vs. temperature. A PTC device exhibits a linear change in resistance for a linear change in temperature, however the delta R vs. T of these devices is not as large as an NTC device.



BASIC TEMPERATURE MEASUREMENT

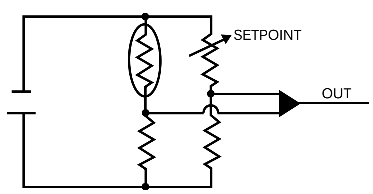
Temperature measurement can be accomplished with a simple Wheatstone bridge as illustrated, or in any configuration where the voltage across or current through the thermistor can be measured.





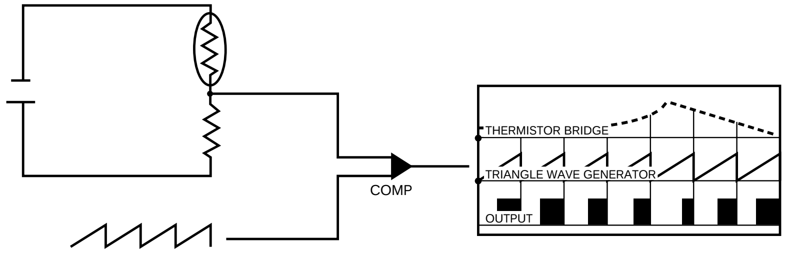
BASIC TEMPERATURE CONTROL

By using a thermistor in a voltage comparator circuit basic on-off temperature control as well as over-temperature protection can be incorporated.



PWM PRECISION TEMPERATURE CONTROL

The following circuit uses a thermistor as a sensor for precision temperature control.



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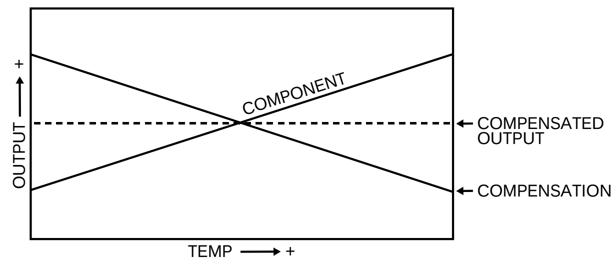
TEMPERATURE COMPENSATION USING THERMISTORS

Most electronic components and assemblies are temperature sensitive to some extent. Often circuit precision necessitates that there is some sort of temperature compensation. Oscillators, coils, and amplifiers are examples of circuits that are commonly in need of temperature compensation. Thermistors are easily utilized for general temperature compensation.

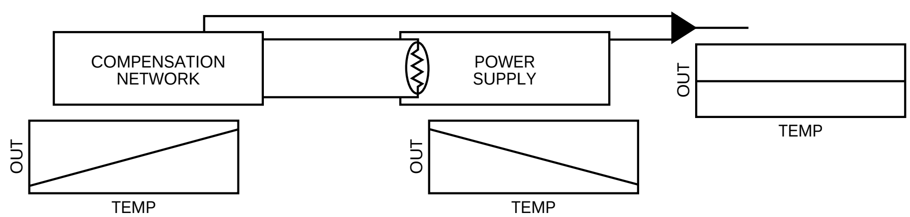
Circuits and components can use either active or passive compensation. Active compensation utilizes the thermistor as a sensing element which drives an active compensation circuit, whereas passive compensation uses a thermistor in a configuration to offset an element's characteristic R-T response. Active compensation is more suitable to applications where the temperature of an entire assembly is in question, where passive compensation focuses on a critical component.

The first step in electronic temperature compensation is to determine the R-T characteristic of the circuit or component which is to be compensated. The appropriate thermistor compensation network is then determined to inversely match this response as closely as possible.



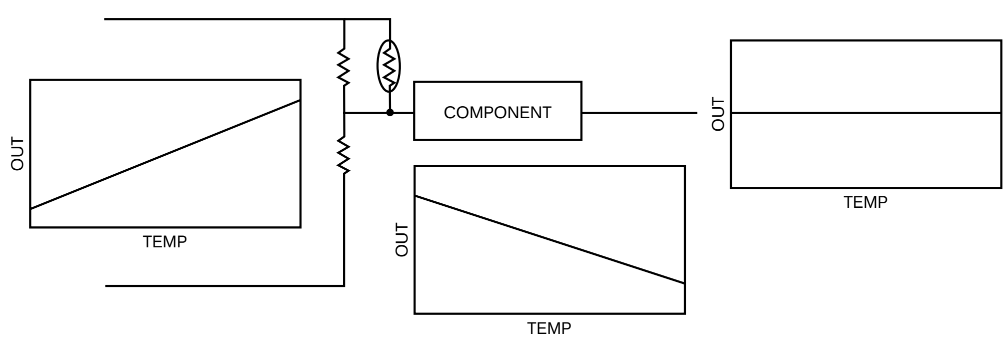
ACTIVE COMPENSATION

The following circuit is an example of a thermistor used to compensate a power supply. Assume that as temperature of the power supply board increases, the output voltage of the supply drifts in a negative direction. The thermistor is placed on the power supply in a location where the thermistor resistance accurately reflects the temperature of the supply circuit. As the supply heats up, the compensation amplifier voltage increases. The output of the power supply and the compensation amplifier are then fed through a summing amplifier, stabilizing the final output.



PASSIVE COMPENSATION

Assume the following component has the given R-T transfer characteristics. By incorporating the thermistor into the component biasing circuit, the effects of component temperature rise can be negated.



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COMPUTER INTERFACING TO AN NTC THERMISTOR

INTRODUCTION:

Using a precision NTC thermistor as a sensor for a uC or computer based instrument can be accomplished in a fairly straightforward manner. A thermistor/resistor voltage divider bridge can supply a strong signal to an A-D converter, which can then be interfaced to the desired instrument (Fig. 1). Using the entire range of the thermistor (-55°C to 125°C), a 12 bit A-D can give a resolution of .04°C, a 10 bit .175°C and an 8 bit .70°C. Since an NTC thermistor exhibits a nonlinear change in resistance with a linear change in temperature, the voltage output of the bridge must be interpreted for the actual temperature. This can be accomplished with an R-T look up table, or through the use of an equation which characterizes the thermistor response.

APPLICATION USING AN R-T LOOK UP TABLE:

Using this method, the A-D count is simply used as an offset to correlate to the temperature recorded in the table. The table is created by calculating or measuring the A-D count when the thermistor is at a given temperature or resistance value, and recording this in the table. This method has the advantage of the ability to manipulate the table to fit a particular thermistor's R-T characteristic very closely. The following example uses a 10K ohm thermistor/10K ohm fixed resistor bridge network, and an 8 bit A-D converter.

R-T multiplier @ -55°C = 96.4
Thermistor R @ -55°C = 964K ohm
Bridge voltage @ -55°C = 4.948V

R-T multiplier @ 125°C = .03461
Thermistor R @ 125°C = 346.1 ohm
Bridge voltage @ 125°C = .00048V

R-T multiplier @ 25°C = 1
Thermistor R @ 25°C = 10K ohm
Bridge voltage @ 25°C = 2.5V

Using these values, the A-D high ref would be set at 4.984V, and the low ref at .00048V, yielding (4.984V-.00048V)/
256 count or ~.0194V per A-D count, giving the following:

A-D count at 125°C = 00000000, table element 0 = 125
A-D count at -55°C = 11111111, table element 255 = -55
A-D count at 25°C = 2.5V/.0194V = 128.8dec = 10000001bin, table element 129 = 25

The in-between values are calculated in the same manner. The number of values in the table can be any power of 2 up to the resolution of the A-D converter. By dividing the A-D count by the appropriate number and using linear interpolation between the table entry numbers, required table memory space can be reduced with a minimum decrease in accuracy.

```
DIM TABLE (255) AS SINGLE                'this is the lookup table
     TABLE (0) = 125
          .
          .
     TABLE (129) = 25                     .
          .
     TABLE (255) = -55

OPEN "A-D" FOR INPUT AS #1               'open A-D
INPUT #1, ADCOUNT                        'and get count
TEMP = TABLE(ADCOUNT)                    'get temperature at pointer
PRINT TEMP                               'and the final output in deg C
```


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The following is an example in BASIC how to implement this using a 64 element look up table and 8 bit A-D converter.

```
DIM TABLE (64) AS SINGLE                    'this is the lookup table
     TABLE (0) = 125
          .
          .
     TABLE (32) = 25                        'this is ~129/4
          .
          .
     TABLE (63) = -55

OPEN "A-D" FOR INPUT AS #1                  'open A-D
INPUT #1, ADCOUNT                           'and get count
TABLEOFFSET = INT(ADCOUNT/4)                'divide by 4 for lookup table of 64
                                            'elements.  Round result to next
                                            'lowest integer value
TEMP = TABLE (TABLEOFFSET)                  'get temperature at pointer
NEXTTEMP = TABLE (TABLEOFFSET+1)            'get temperature above pointer (next
                                            'pointer location) Actual temperature
                                            'is between these two.

DIFFTEMP = ABS (ADCOUNT-(TEMP*4))           'this is the distance from TEMP
                                            'between TEMP and NEXTTEMP

                                            'This is the interpolated temperature.
                                            'Remember that values in table
                                            'decrease as the A-D count increases.
                                            'Note that this assumes that a table
                                            'point lies on 0.  If there is no 0 entry
                                            'separating positive and negative
                                            'table entries, some additional
                                            'conditions must be added to
                                            'correctly interpolate.

INTERPTEMP = TEMP + (((TEMP-NEXTTEMP)/4)*DIFFTEMP)

PRINT INTERPTEMP                            'and the final output in deg C
```

APPLICATION USING THERMISTOR CHARACTERIZATION EQUATION:

The equation for thermistor characterization is known as the Steinhart-Hart equation. This equation requires the computation of the coefficients a, b, c and d. These can also be obtained from the thermistor manufacturer. The resulting temperature is given in degrees K. The following BASIC program demonstrates this method, using the same circuit as above, with A-D high ref = bridge voltage (5V) and A-D low ref at 0V.

```
a = ?                                       'these constants need to be
b = ?                                       'entered
c = ?
d = ?
resolution = 256                            'for 8 bit A-D
vref = 5                                    'bridge voltage
rfix = 10000                                'fixed bridge resistor

OPEN "A-D" FOR INPUT AS #1                  'open A-D
INPUT #1, ADCOUNT                           'and get count
VBRIDGE = ADCOUNT*(vref/resolution)         'convert to voltage across thermistor
RTHERM = VBRIDGE/((vref-VBRIDGE)/rfix)      'find thermistor resistance

                                            'convert to temperature using given
                                            'coefficients and equation.  This is
                                            'the standard Stienhart-Hart equation,
                                            'with the 273.15 added to yield
                                            'deg C.

TEMP = (1/(a + b*(lnRTHERM) + c*(lnRTHERM)^2 + d*(lnRTHERM)^3)) + 273.15

PRINT TEMP                                  'and the final output in deg C
```

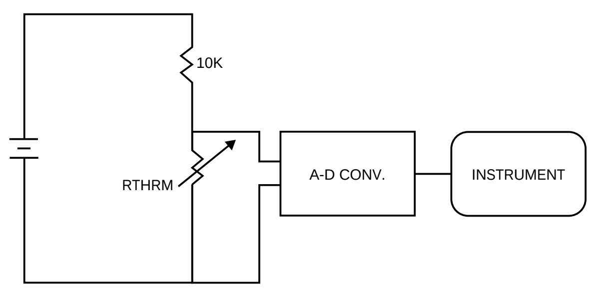

FIG. 1

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