NTC Thermistor Applications
Introduction

Our NTC chip thermistors are excellent solutions in applications requiring temperature measurement and compensation from -50° to 150°C.

RTDs, thermocouples and silicon semiconductors cannot compete with the thermistor's sensitive response to temperature. This sensitivity is crucial for accurate temperature measurement.

Unlike RTDs and thermocouples, thermistors are virtually unaffected by lead resistance. This makes NTC thermistors the sensor of choice for remote sensing applications. With their excellent long term stability characteristics, design engineers utilize thermistors in critical applications for the medical, military, aerospace, industrial and scientific industries.

Systems utilizing thermistors are less expensive to produce than other solutions because fewer associated components are required for a high performance system. Chip thermistors can be ordered with tight tolerances to ±0.1°C, eliminating the costly calibration process required by temperature sensors such as silicon semiconductors, RTDs, thermocouples and glass beaded and disk thermistors with loose tolerances.

NTC thermistors provide the design engineer with desirable sensor performance advantages in a variety of applications. The following notes provide a few examples of how to utilize the NTC thermistor.

"Zero Power" Sensing - Dissipation Constant

When utilizing a thermistor for temperature measurement, control, and compensation applications, it is very important not to "self-heat" the thermistor. Power, in the form of heat, is produced when current is passed through the thermistor. Since a thermistor's resistance changes when temperature changes, this "self generated heat" will change the resistance of the thermistor, producing an erroneous reading.

The power dissipation constant is the amount of power required to raise a thermistor's body temperature 1°C. A standard chip thermistor has a power dissipation constant of approximately 2mW/°C in still air. In order to keep the "self-heat" error below 0.1°C power dissipation must be below 0.2mW. Very low current levels are required to obtain such a lower power dissipation factor. This mode of operation is called "zero power" sensing.

Thermistor Linearization - Voltage Mode
Wheatstone Bridge - Voltage Mode

To produce a voltage output that varies linearly with temperature, utilize the NTC thermistor as the active leg in a Wheatstone Bridge. As temperature increases, the voltage output increases. The circuit in **Figure 1** produces an output voltage that is linear with ±0.06°C from 25°C to 45°C. This circuit is designed to produce 1V at 25°C and 200mW at 45°C; this is achieved by the selection of R2 and R3. The value of R1 is selected to best provide linearization of the 10K ohm thermistor over the 25°C to 45°C temperature range. **Figure 2** illustrates the output voltage of the Wheatstone Bridge as a function of temperature.

The circuit in **Figure 3** provides improved output accuracy over a wide temperature range by substituting a 6K/30K ohm thermistor network in place of the single thermistor in the Wheatstone Bridge. This circuit is designed to provide 0V at 0°C and 537mV at 100°C. The maximum linear deviation of this circuit is ±0.234°C from 0°C to 100°C.

Figure 1: Wheatstone Bridge - Voltage Mode

T1 = 10K ohm "A" Curve
R1 = 4980 ohm
R2 = 4980 ohm
R3 = 10K ohm

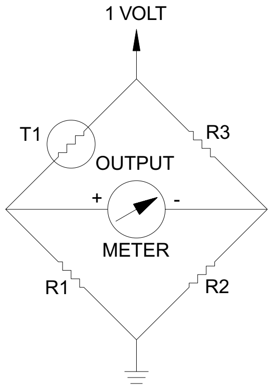


Figure 2: Wheatstone Bridge - Voltage Mode

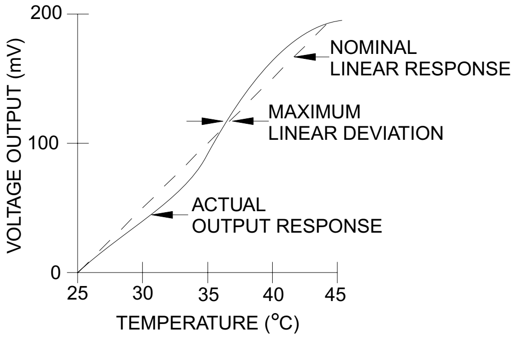
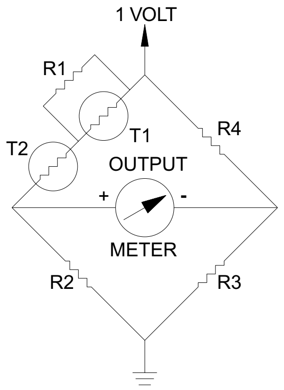


Figure 3: Wheatstone Bridge - Voltage Mode

T1 = 30K ohm "B" Curve
T2 = 6K ohm "A" Curve
R1 = 5420 ohm
R2 = 3970 ohm
R3 = 3970 ohm
R4 = 24720 ohm



Thermistor Linearization
Operational Amplifier - Resistance Mode

A linear voltage output that varies with temperature can also be produced by utilizing an operational amplifier and a linearized thermistor network as illustrated in **Figure 4**. The voltage output decreases linearly as temperature increases. This circuit may be calibrated by adjusting R3 for an output voltage of 200mW at 25°C and 0V at 45°C.

Temperature Measurement and Control
Digital Thermometer

The most common application for the NTC thermistor is temperature measurement. Accurate temperature measurement can easily be accomplished by interfacing a Wheatstone Bridge, 6K/30K ohm thermistor network and a digital voltmeter integrated circuit as illustrated in **Figure 5**. The IC consist of an analog to digital converter with built-in 3-1/2 digit LCD driver providing resolution of 0.1°C. Using the 6K/30K ohm thermistor network makes it possible to achieve an overall system accuracy of ±0.4°C from 0°C to 100°C. This digital thermometer can easily be interfaced with additional circuitry to provide a temperature control circuit with a digital display.

Micro Controller System

The advent of low cost micro controllers used with precision interchangeable NTC thermistors, provides the design engineer with unlimited design possibilities for temperature measurement and control systems. These systems are relatively inexpensive to produce yet offer very high temperature accuracy and various software controlled outputs.

For example, a micro controller system utilizing remote thermistor sensors can monitor and control the temperature in several locations in an office building. For this case, the micro controller is comprised of a built-in microprocessor, analog to digital converter, RAM and several digital inputs/outputs. The complete system **Figure 6** utilizes the micro controller, multiplexer, EPROM, digital display, keypad and display driver.

The micro controller is programmed in assembler language. The temperature measurement is calculated within the micro controller using the resistance versus temperature algorithm and the a, b and c, constants for the specific thermistor resistance and curve material. Refer to the Steinhart Equation on page 5. An alternative method to convert the thermistor resistance to temperature is to program a "look-up" table in EPROM. After programming, the micro controller tells the multiplexer to send back temperature data from a particular zone (room in the office building) and converts the resistance of the thermistor into a temperature reading.

The micro controller can then turn on or off the heating or air conditioning systems in a specific zone.

The thermistor/micro controller system can be used for security, temperature control, monitoring activities and many other applications. The possibilities are endless.

Figure 4: Linearization - Resistance Mode

T1 = 10K ohm "A" Curve
R1 = 4980 ohm
R2 = 5K ohm
R3 = 10K ohm potentiometer

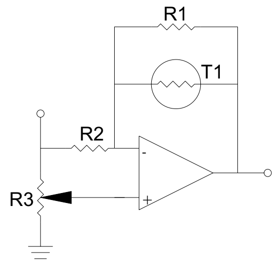


Figure 5: Digital Thermometer

R7 = 1.50K ohm
R8 = 100K ohm
R9 = 470K ohm
R10 = 15K ohm
C1 = 100 pF
C2 = 0.22
C4 = 0.1

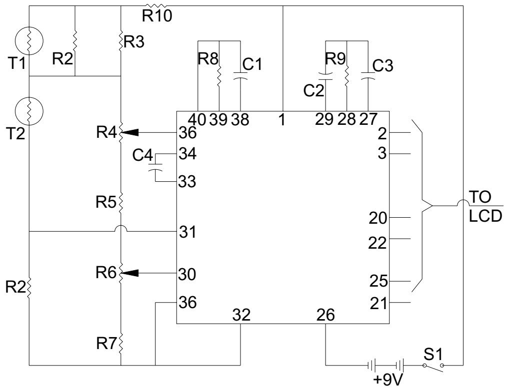
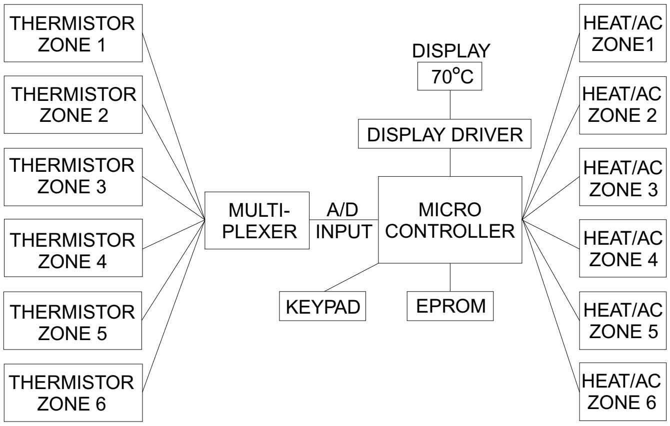


Figure 6: Micro Controller System



Temperature Compensation

NTC thermistors can be used to compensate for the temperature coefficient response of various components such as crystal oscillators, mechanical meters and infrared LEDs. A thermistor/resistor network **Figure 7** is placed in series with a PTC component requiring compensation. The resistor values are selected to provide the proper NTC slope to offset the PTC component. The net effect is a constant circuit response that is independent of temperature.

"Self-Heat" Sensing Applications

To "self-heat" a thermistor, it must be subjected to power levels that raise the thermistor's body temperature above the environmental surroundings. Self-heat applications include the sensing of liquid, air level, and flow rates. This application is dependent on the fact that the environment surrounding a thermistor directly affects the amount of power the thermistor can dissipate. For example, submerged in liquid, a thermistor can typically dissipate 500% to 600% more power than it can air.

Therefore, a thermistor being "self-heated" in air is able to dissipate much more power when transferred to a fluid environment. This increase in power dissipation generates a significant increase in resistance. It is this change in resistance, which makes it possible to sense the fluid level.

A simple liquid level control system can be designed by putting a thermistor in series with a coil **Figure 8**, which operates a valve that releases the liquid in the tank. The thermistor is placed in the tank and operated in a "self-heat" mode.

In air, the thermistor's resistance is low and allows enough current flow to energize the relay coil and keep the relay contact closed. When the fluid level in the tank surrounds the thermistor, its resistance increases and de-energizes the relay, which opens a valve and releases the fluid. As the fluid is released from the tank, the thermistor's resistance decreases and the relay coil energizes and closes the valve.

Fuel injection in automobiles utilize the thermistor in the "self-heat" mode in order to properly control the air/fuel mixture. Forced air heaters may use the NTC thermistor in the "self-heat" mode in order to maintain proper air flow characteristics. This technology is utilized to monitor the flow rate and level of air and fluids in a variety of applications.

Figure 7: Temperature Compensation

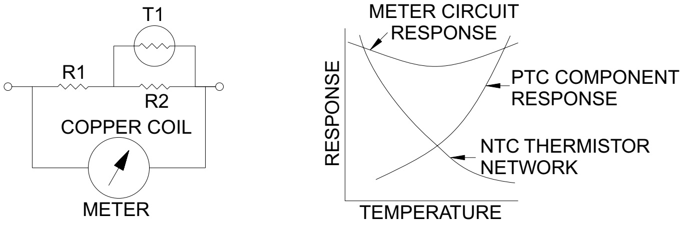


Figure 8: Self-Heat Applications