

EXPERIMENT 5

USING A WHEATSTONE BRIDGE TO MEASURE THERMISTOR RESISTANCE AND DETERMINE AMBIENT TEMPERATURE

INTRODUCTION

A bridge circuit is commonly used for precise measurement of resistance, capacitance, or inductance. The Wheatstone bridge, developed by C. Wheatstone in 1843, is particularly suited to measuring resistances above $1\ \Omega$ with high accuracy—commercial versions can achieve $\sim 0.1\%$ precision—making it significantly more reliable than many standard multimeters. For resistances below $1\ \Omega$, a Kelvin Bridge can be used [1].

A Wheatstone bridge consists of a voltage source and two parallel voltage dividers, as shown in Figure 1. The bridge is said to be *balanced* when $v_{12} = 0$. For the balanced condition, the voltage v_3 is divided in the path containing resistors R_a and R_b in the same ratio as in the path containing resistors R_c and R_x , which allows the unknown resistance R_x to be determined in terms of R_a , R_b and R_c .

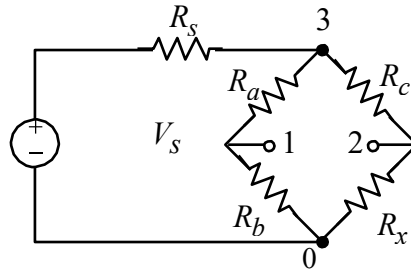


Figure 1: Wheatstone Bridge Circuit.

We can find R_x in terms of R_a , R_b and R_c as follows. Using the voltage divider relation,

$$v_1 = \frac{R_b}{R_b + R_a} v_3, \quad v_2 = \frac{R_x}{R_x + R_c} v_3$$

For the balanced condition, $v_{12} = 0$, or $v_1 = v_2$. Equating the above expressions for v_1 and v_2 gives

$$\frac{R_b}{R_b + R_a} = \frac{R_x}{R_x + R_c}$$

Multiplying both sides by $(R_x + R_c)$ and $(R_b + R_a)$ gives $R_b(R_x + R_c) = R_x(R_b + R_a)$. Subtracting $R_b R_x$ from both sides and solving for R_x gives

$$R_x = \frac{R_b R_c}{R_a}.$$

In this experiment, R_x represents the thermistor's resistance.

The thermistor used has a nominal resistance of $4.7\ \text{k}\Omega$ at $25\ ^\circ\text{C}$, with a negative temperature coefficient. To convert resistance into temperature, the Steinhart–Hart equation is applied:

$$\frac{1}{T} = A + B \ln(R) + C [\ln(R)]^3$$

where

T is the temperature in Kelvins

R is the resistance in ohms

A , B , C are constants derived from the information in the thermistor data sheet which specifies the Beta (β) value as 3892. The particular thermistor is a Digi-Key part number 900-2152723407-Nd.

To find the A , B , and C constants, one uses the “Beta” formula

$$R = R_0 e^{\beta(1/T + 1/T_0)}$$

to calculate the resistance at three temperatures. R_0 is the nominal resistance (4700 Ω) and T_0 is the nominal temperature (298.15 °K, or 25 °C). Typically, $T = 5, 25$, and 45 °C are used. An online calculator for determining the A , B , and C constants is at:

<https://www.thinksrs.com/downloads/programs/Therm%20Calc/NTCCalibrator/NTCcalculator.htm>

For the particular thermistor,

$$A = 1.181 \times 10^{-3}$$

$$B = 2.570 \times 10^{-4}$$

$$C = -1.049 \times 10^{-10}$$

Lab Work

1. Construct the Wheatstone bridge shown in Figure 1. Use resistor values $R_a = 4.7$ k Ω and $R_c = 4.7$ k Ω . Use a decade resistance box for R_b and a DC power supply adjusted to 5 volts.
2. Apply 5 V DC across the bridge terminals.
3. Adjust R_b (starting coarse, then fine tuning) until the measured differential voltage, v_{12} , is approximately zero.
4. Record the value of R_b at balance
5. Compute the thermistor resistance using

$$R_x = \frac{R_b R_c}{R_a}$$

6. Convert the resistance R_x to temperature T using the Steinhart–Hart equation.
7. Repeat measurements for multiple trials and under different ambient conditions (optional exercise).

DISCUSSION

1. Accuracy: Evaluate how closely calculated temperatures match actual ambient conditions.
2. Sensitivity: Discuss the bridge’s responsiveness to small changes in temperature via R_x

observations.

3. Sources of Error: Consider DMM resolution, resistor tolerances, thermal gradients, or self-heating of the thermistor.
4. Improvements: Suggest enhancements such as using an op-amp to buffer, using precision resistors, or implementing automated data acquisition.

CONCLUSION

The Wheatstone bridge setup allowed precise measurement of thermistor resistance and accurate calculation of ambient temperature. With proper balancing and parameter conversion, measured values can be consistent with actual room temperature. The method highlights both the sensitivity and practical limitations of using a bridge circuit and thermistor combination for temperature sensing.

[1] Wolf, Stanley, *Guide to Electronic Measurements and Laboratory Practice*. Prentice-Hall, Englewood Cliffs, New Jersey, 1973.