

## EXPERIMENT NUMBER 4 WHEATSTONE BRIDGE

A bridge is a special class of circuits that can be used for measuring resistance, capacitance, or inductance. A resistance bridge is especially useful when a very accurate measurement of a resistance is required. The Wheatstone bridge or four arm bridge, invented by C. Wheatstone in 1843, is the most widely used resistance bridge for measuring resistance values above  $1 \Omega$ . Commercial Wheatstone bridges are accurate to about 0.1 percent, making the values of resistance obtained far more accurate than values obtained from many types of meters. 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  $R_c$ .

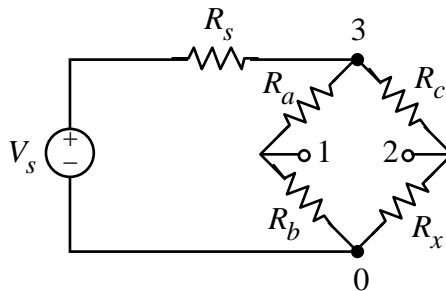


Figure 1

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

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

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 order to achieve balance for a specific unknown resistance  $R_x$ , let  $R_a$  and  $R_c$  have fixed, known values, and let  $R_b$  be a calibrated (adjustable) resistor. The procedure is to adjust  $R_b$  until  $v_{12} = 0$ , and then use the expression derived above to determine  $R_x$ .

### Lab Work

1. Construct the Wheatstone bridge shown in figure 1. Use resistor values  $R_a = 1 \text{ k}\Omega$ ,  $R_c = 10 \text{ k}\Omega$ , and  $R_s = 10 \text{ k}\Omega$ . Use a decade resistance box for  $R_b$  and a DC power supply adjusted to 5 volts.
2. Measure the value of an "unknown" resistance supplied by your lab GTA  $1 \text{ k}\Omega \leq R_x \leq 10 \text{ k}\Omega$ . In adjusting  $R_b$  using the decade resistance box, start with the coarsest scale and work toward the finest scale, while monitoring  $v_{12}$  with the DMM.
3. Calculate the unknown resistance.

Next, perform one (or both, if time permits) of the following exercises (your choice):

4. Measure the resistance of a photo-resistor under various lighting conditions.
5. Measure the resistance of ten different  $1 \text{ k}\Omega$  resistors and plot their values in terms of percent deviation from the nominal value. A bar graph is a convenient form for this plot.

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