X010994

UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE

Department of Electrical Engineering

Experiment No.______Use of the Wheatstone Bridge for R-Measurement

INTRODUCTION

The direct current resistance of a component can be measured by many different methods, depending on the accuracy desired. If accuracy is of extreme importance, the circuit used to measure this resistance should be in the form of a "bridge." Two of the more common types of bridges are the Wheatstone Bridge, which is used to measure resistances of 1 ohm to 100,000 ohms, and the Kelvin Double-Bridge, which is used to measure resistances in the range of .0001 ohms to 1 ohm.

The accuracy of a bridge depends on the quality of the bridge components and the sensitivity of the galvanometer used. Theoretically, the most precise measurement is found when the four arms of the bridge have the same resistance value. However, the most precise measurement is actually achieved when the four arms of the bridge have the same resistance value and the equivalent resistance of the bridge circuit appearing across the galvanometer terminals equals the galvanometer resistance.

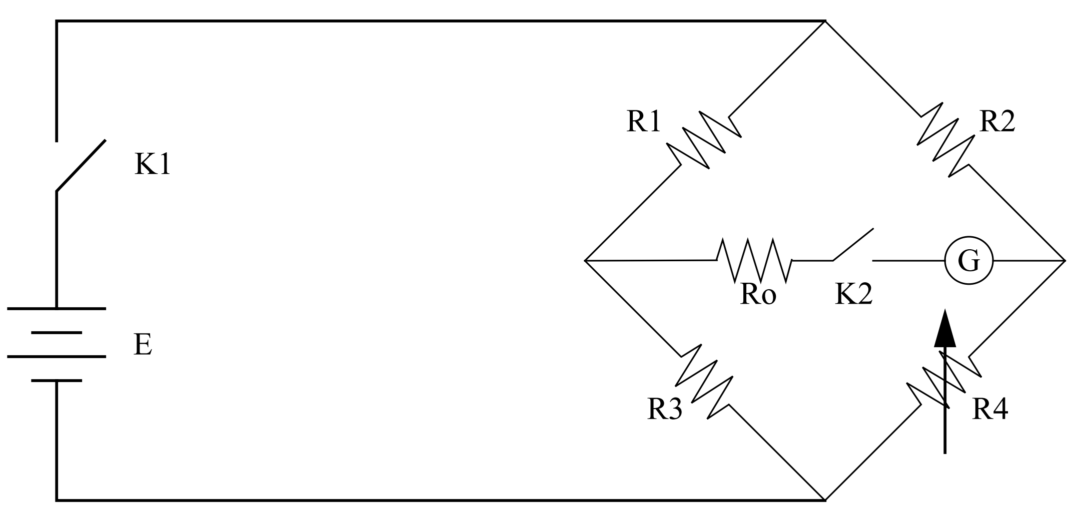

Figure 1.

In Figure l, R3 is assumed to be the unknown resistor, and R4 is assumed to be the standard that is variable in 1 ohm steps throughout the range of 1 ohm to 111,110 ohms. In general, R1 and R2 are chosen and R4 is varied until there is no deflection of the galvanometer needle when the switches K1 and K2 are closed momentarily. Under this condition, the bridge is said to be balanced. Assuming that the bridge is adjusted to the balanced condition, that there is no current flowing in the galvanometer, the Kirchhoff and Terminal Equations may be written as follows:

KVE

$$v1(t) - v2(t) = 0$$
$$v3(t) - v4(t) = 0$$

since io(t) = ig(t) = 0

KCE

$$i1(t) = i3(t)$$
$$i2(t) = i4(t)$$

since io(t) = ig(t) = 0

TE

$$v1(t) = R1\ i1(t)$$
$$v2(t) = R2\ i2(t)$$
$$v3(t) = R3\ i3(t)$$
$$v4(t) = R4\ i4(t)$$

Using the preceding equations, the following relationship may be found.

$$R3 = R4\ (R1/R2) \qquad (1)$$

In this experiment, the resistances R1 and R2 will be chosen such that the following ratios may be obtained:

1/1000, 1/100, 1/10, 1/1, 10/1, 100/1, 1000/1

The standard resistor R4 can then be adjusted to give a balanced condition for a wide range of unknown resistors. With the ratio of R1 and R2 set at the values ranging between the maximum and minimum values given above and with R4 variable in 1 ohm steps between 1 ohm and 111,110 ohms, R3 can be measured anywhere in the range .001

to 111,110,000 ohms, but with a definite loss of accuracy if R3 is outside of the range 1 ohm to 111,110 ohms.

In setting up a bridge circuit, R4 is first set to give the desired number of significant figures in the measured value of the unknown resistance R3. For example, if one significant figure is desired for R3, R4 would be allowed to vary between 1 ohm to 9 ohms. The range of R3 that could be measured then for the above ranges of R1 and R2 would be .001 ohms to 9ooo ohms (the small zeros mean that these figures are not significant). If the desired number of significant figures for R3 is three, then R4 would be allowed to vary between 100 ohms to 999 ohms. The range of R3 that could be measured in this case would be .100 ohms to 999ooo ohms.

This experiment is designed to introduce the student to the bridge method of measurement. In designing and operating a bridge for specific applications, there are many other factors to be taken into consideration. For more information, the following references are given:

1. <u>Electrical Measurements</u> by Dunn and Barker
2. <u>Basic Electric Measurements</u> by Stout

PRELIMINARY

P-1. Using the Kirchhoff and Terminal Equations given, derive equation (1) above.

P-2. For the ranges of R1, R2, and R4 given above, what is the largest number of significant figures that may be obtained for the unknown R3, and what is the range of R3 for which this would be true?

Number of significant figures___________________________.

The lowest value of R3__________________________________.

The largest value of R3_________________________________.

P-3. Given a standard resistor R4 which is variable in steps of 1 ohm from 1 ohm to 111,110, determine the value of the ratio R1/R2 for obtaining R3 to three significant figures for:

a. R3 between 3 ohms and 9 ohms.

R1/R2 = _______________/_________________.

b. R3 between 400 ohms and 900 ohms.

R1/R2 = _______________/_________________.

c. R3 between 300,000 ohms and 700,000 ohms.

R1/R2 = _______________/__________________.

(INSTRUCTOR'S SIGNATURE___________________________DATE__________)

PROCEDURE

L-1. Connect the bridge circuit as given in Figure 1. The resistors R1 and R2 have already been prepared for the experiment to give the ratios of 1/1000, 1/100, 1/10, 1/1, 10/1, 100/1, and 1000/1.

Also, the resistor R3 has been prepared for the experiment with eight unknown resistors (R1-R8). The first two unknown resistors (R1 and R2) are labeled as to their range in order to give the student some idea of what to expect.

The standard resistor R4 should be a General Radio resistance decade box (or its equivalent) that varies in 1 ohm steps from 1 ohm to 111,110 ohms.

The resistor Ro is used to protect the sensitive galvanometer and should be a variable resistor with a maximum value of at least 10,000 ohms.

The switches K1 and K2 should be a normally open, DUEL-KEY switch which should be closed only momentarily to check for balanced conditions. This is to prevent resistor values from changing due to heating. When the switches are closed, K1 should close first. If K2 were closed first, then any inductance or capacitance in the circuit might cause a transient current to deflect the galvanometer when K1 is closed even though a balanced condition may exist.

The power supply should be able to supply +50 VDC at 100 mA.

L-2. The unknown resistor between 1 ohm and 10 ohms (R3) is to be determined to three significant figures. To do this, follow the procedures outlined below.

a. CAUTION: Be sure that the resistor Ro is set at its maximum value before beginning the balancing procedure. As the bridge approaches a balanced condition, Ro should be reduced gradually to zero.

b. Set R1 to 1000 ohms and R2 to 1,000,000 ohms (1/1000).

c. Set R4 to 999 ohms.

d. Check and note the DIRECTION of deflection of the galvanometer needle by momentarily closing the switches K1 and K2.

e. Decrease R2 to 100,000 ohms and again check the DIRECTION of deflection of the galvanometer needle by closing the switches K1 and K2. Continue increasing the ratio of R1/R2 until a CHANGE in the DIRECTION of deflection of the galvanometer needle is noted. When this occurs, leave R1/R2 at that ratio and start decreasing R4 until a balance is obtained. The value of R3 can then be determined from equation (1) above.

f. If a CHANGE in DIRECTION of the deflection of the galvanometer needle does not occur for the maximum ratio of R1/R2, then set R1/R2 at its maximum ratio and start increasing R4 to see if a balance can be obtained (NOTE: This will result in more significant figures for R3).

g. If a CHANGE in DIRECTION of the deflection of the galvanometer needle does not occur for the maximum ratio of R1/R2 and the maximum value of R4, then perform the above procedures (a) through (c) again and try reducing R4 to see if a balance can be obtained (NOTE: This may result in less than three significant figures for R3).

h. If a balance cannot be obtained using procedures (a) through (g) above, and you know that your circuit is functioning properly, then the unknown R3 is out of range of the capability of the bridge.

L-3. The unknown resistor between 10,000 ohms and 20,000 ohms (R2) is to be determined to three significant figures. To do this, repeat the procedures outlined in L-2 above.

L-4. The unknown resistor between 10,000 ohms and 20,000 ohms (R2) is to be determined to four significant figures. To do this, repeat the procedures outline in L-2 above EXCEPT set R4 to 9999 ohms in procedure (c).

L-5. The remaining unknown resistors R3 through R8 are to be determined to three significant figures. To do this, repeat the procedures outline in L-2 above.

L-6. All of the unknown resistors (R1 through R8) are to be measured using a precision impedance bridge or an ohmmeter that will measure resistance to four significant figures.

REPORT

R-1. Calculate the percentage error between the measured values of the unknown resistors (R1 through R8) using the Wheatstone Bridge and the measured values using the precision impedance bridge or ohmmeter. Let the precision impedance bridge or ohmmeter be the standard.

R-2. Include a discussion on how R4 could be changed to increase the number of significant figures measured for an unknown resistor.

R-3. Also discuss how the ratio of R1/R2 could be changed to increase the range of unknown resistors measured.