BRIDGES AND THEIR APPLICATIONS

DC BRIDGES

INTRODUCTION

Bridges are used to measure the values of the electronic components. For example a Wheatstone Bridge is used to measure the unknown resistance of a resistor. However they are also used to measure the unknown inductance, capacitance, admittance, conductance or any of the impedance parameters.

Besides this bridge circuits are also used in the precision measurements in some circuits and for the interfacing of transducers. Actually nowadays fully automatic bridges which electronically null a bridge to make precision measurements are also used.

WHEATSTONE BRIDGE : BASIC OPERATION

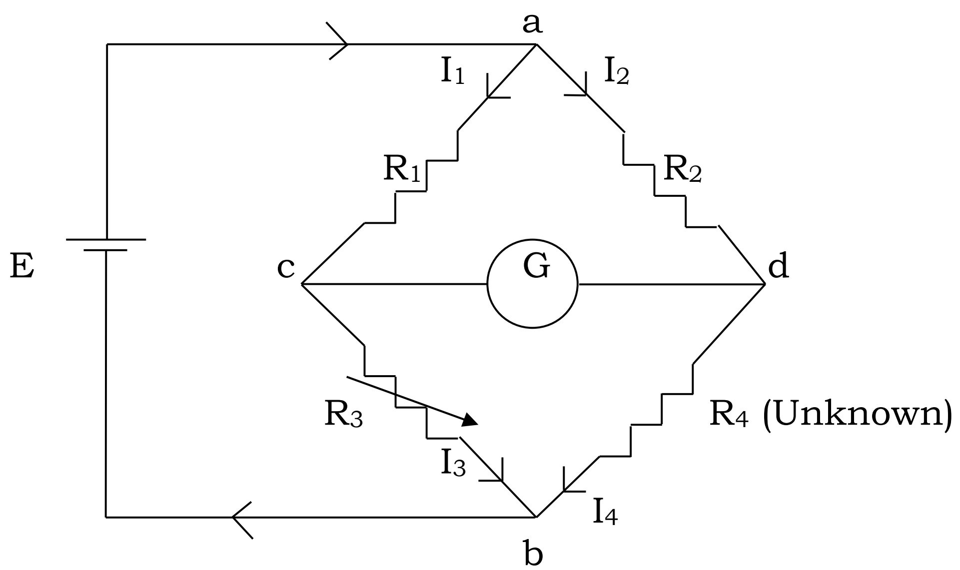

Fig. (1)

- The circuit diagram of Wheatstone Bridge is shown in Fig. (1). The four arms of the bridge ac, ad, cb and db contains the four resistors R_1, R_2, R_3 and R_4 respectively. G is a galvanometer or the null detector. E is the source of EMF.

- I_1, I_2, I_3 and I_4 are the currents through the resistors R_1, R_2, R_3 and R_4, respectively.

- When the current through galvanometer is zero, at that time terminals c and d are said to be at same potential with respect to point a i.e.,

$$E_{ac} = E_{ad} \tag{1}$$

- Hence the currents $I_1 = I_3$ and $I_2 = I_4$. This is called the balance of the bridge. And for this condition, we can write,

$$I_1R_1 = I_2R_2 \tag{2}$$

Where

$$I_1 = I_3 = \frac{E}{R_1+R_3} \tag{3}$$

and

$$I_2 = I_4 = \frac{E}{R_2+R_4} \tag{4}$$

- Substituting the values of I_1 and I_2 from equations (3) and (4) into (2), we get

$$\frac{E}{R_1+R_3}R_1 = \frac{E}{R_2+R_4}R_2$$

$$\frac{R_1}{R_1+R_3} = \frac{R_2}{R_2+R_4}$$

therefore, $R_1(R_2+R_4) = R_2(R_1+R_3)$

$$R_1R_4 = R_2R_3 \tag{5}$$

- Equation (5) is called the balance equation(condition) of the bridge. Here, if R_4 is an unknown resistor, then its resistance R_x can be measured using the equation

$$R_1R_x = R_2R_3$$

$$R_x = \frac{R_2 R_3}{R_1} \tag{6}$$

• Here resistor R_3 is called the standard arm, whereas R_2 and R_1 are called the ratio arms.

MEASUREMENT ERRORS (LIMITATIONS OF THE WHEATSTONE BRIDGE CIRCUIT *OR* SOURCES OF ERRORS IN WHEATSTONE BRIDGE MEASURREMENTS)

• The major sources of errors in the Wheatstone bridge measurements are as follows :

(1) Insufficient sensitivity of the null detector (galvanometer).

(2) Heating effects of currents through the arm resistors : The currents flowing thourgh the resistors produce heating effects in them and changes the resistance values. This affects the bridge balance. It leads to the I^2R losses in resistors. If an excess amount of current flows, the resistance values change permanently and this affects the subsequent measurements. This error becomes substantial particularly when low resistance values are to be measured. To avoid this, the current must be limited to a safe value.

(3) Thermal EMF in the bridge circuit or the galvanometer circuit can also cause problems when low-value resistors are being measured. This limitation can be overcome using high sensitivity galvanometer having copper coil and copper suspension system in it.

(4) Leads and Contacts : the resistance drops in the leads (wires) and contacts which are used in the external

bridge circuit affects the balance of bridge. This error can be minimized using a Kelvin bridge circuit.

THEVENIN EQUIVALENT CIRCUIT (OF WHEATSTONE BRIDGE)

• With what accuracy a Wheatston bridge can be balanced depends upon the sensitivity of galvanometer.

• The amount of current per unit deflection is called the sensitivity of galvanometer.

• The balance of bridge is also affected by the internal resistance of galvanometer.

• The suitability of galvanometer for a particular bridge circuit can be known by using Thevenin equivalent circuit of that bridge.

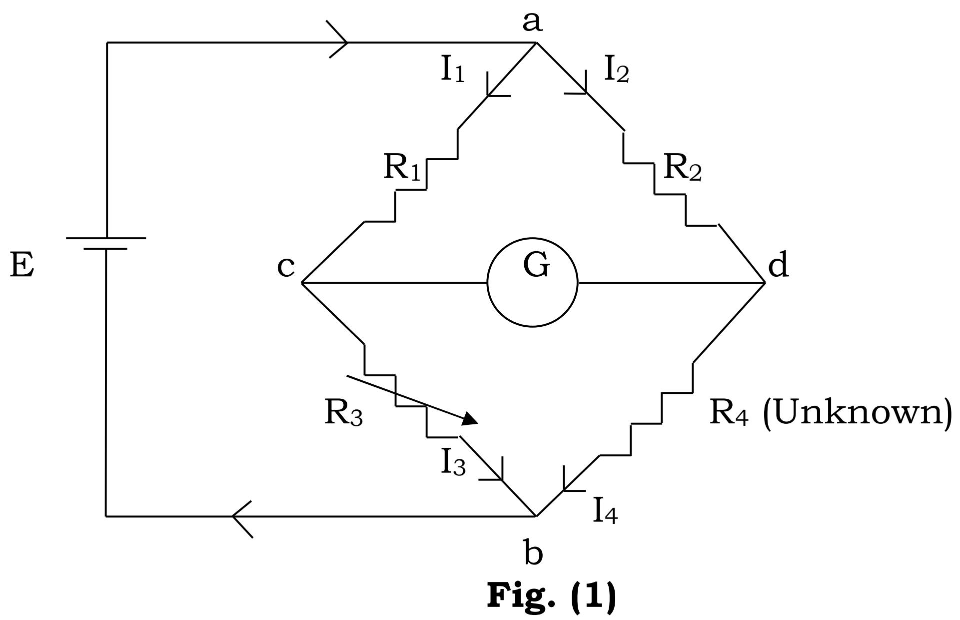

Fig. (1)

• Let us consider a Wheatston bridge circuit as shown in Fig. (1).
• When the bridge is balanced, points c and d are at the same potential with respect to point. Therefore, we can write

$$E_{cd} = E_{ac} - E_{ad} = I_1R_1 - I_2R_2 \qquad (1)$$

• Also we can write currents I_1 and I_2 as

$$I_1 = I_3 = \frac{E}{R_1+R_3} \qquad (2)$$

and $$I_2 = I_4 = \frac{E}{R_2+R_4} \qquad (3)$$

• Then, substituting values of I_1 and I_2 from equations (2) and (3) into equation (1), we get

$$E_{cd} = E\left(\frac{R_1}{(R_1+R_3)} - \frac{R_2}{(R_2+R_4)}\right) \qquad (4)$$

• In the circuit of Fig. (1) we can find the current through galvanometer by obtaining the Thevenin equivalent circuit of the bridge looking into the terminals c and d. This circuit is shown in Fig. (2).

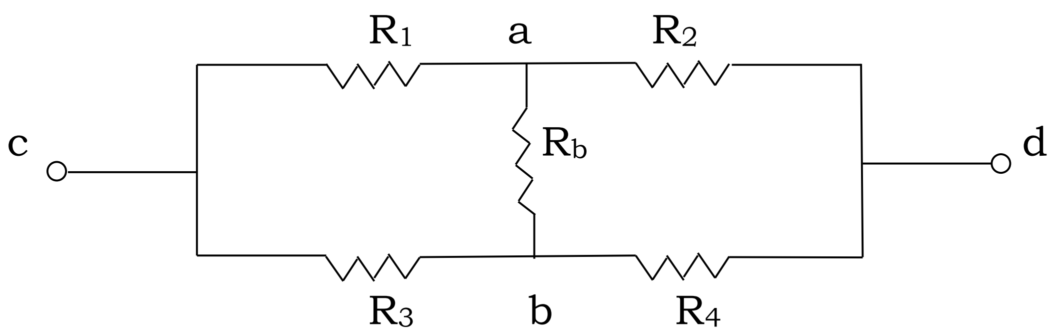

Fig. (2)

• The Thevenin Resistance , looking into the terminals c and d in Fig. (2) then becomes

$$R_{TH} = \left(\frac{R_1R_3}{(R_1+R_3)} + \frac{R_2R_4}{(R_2+R_4)}\right) \qquad (5)$$

• The Thevenin equivalent voltage source E_{TH} is given by

$$E_{TH} = E_{cd}$$

• Now the Thevenin equivalent circuit can be shown as shown in Fig. (3) below.

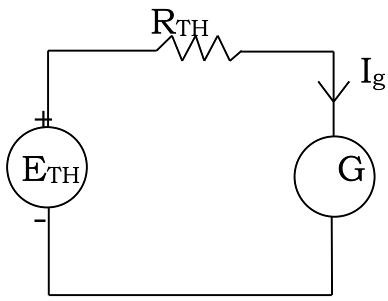

Fig. (3)

• Then the current through galvanometer is given by

$$I_g = \frac{E_{TH}}{R_{TH}+R_g} \qquad (6)$$

Where R_g is the resistance of galvanometer.

LIMITATIONS OF WHEATSTONE BRIDGE

• The Wheatstone bridge is limited to the measurement of resistances ranging from a few ohms to several megohms.

• The upper limit is set by the reduction in sensitivity of the bridge to unbalance condition, which is produced due to high resistance values of Thevenin equivalent resistance. This reduces the galvanometer current.

• The lower limit is set by the resistance of the connecting leads(wires/cables) and the contact resistances at the binding points. These resistances makes the measurements of low resistances difficult.

KELVIN BRIDGE : EFFECTS OF CONNECTING LEADS

• The Kelvin bridge is the modification of Wheatstone bridge. It measures the low resistance values with more accuracy.
• Fig. (1) below shows the circuit diagram for the Kelvin bridge circuit.

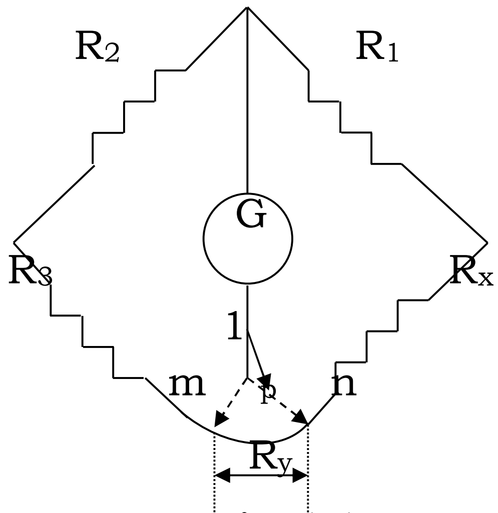

Fig. (1)

•As shown in the Fig. (1) above R_y is the rresistance of the connecting lead from R_3 to R_x. Points m and n shows the two possible connections for galvanometer.
• When connection is made along 1n, R_y is added to R_3 and when connection is made along 1m, R_y is added to R_x. However, when connection is made along 1p, resistance R_{np} is added to R_x and R_{mp} is added to R_3.
• The balancing condition demands that if the connection is along 1p, the ratio of resistance between n and p and between m and p, namely, R_{np} and R_{mp} respectively, will be given by

$$\frac{R_{np}}{R_{mp}} = \frac{R_1}{R_2} \qquad (1)$$

$$\frac{R_{np} + R_{mp}}{R_{mp}} = \frac{R_1 + R_2}{R_2}$$

Therefore, $R_{mp} = \frac{R_2 R_y}{R_1 + R_2}$ (2)

Similarly, $R_{np} = \frac{R_1 R_y}{R_1 + R_2}$ (3)

- Now, the balance condition for the bridge becomes,

$$(R_x + R_{np})R_2 = R_1(R_3 + R_{mp})$$

$$R_x + R_{np} = \frac{R_1}{R_2}(R_3 + R_{mp})$$

- Then substituting the values of R_{np} and R_{mp} from equations (2) and (3) into the above equation, we get

$$R_x + \frac{R_1 R_y}{R_1 + R_2} = \frac{R_1}{R_2}\left(R_3 + \frac{R_2 R_y}{R_1 + R_2}\right)$$

$$R_x + \frac{R_1 R_y}{R_1 + R_2} = \frac{R_1 R_3}{R_2} + \frac{R_1 R_y}{R_1 + R_2}$$

$$R_x = \frac{R_1 R_3}{R_2} \quad (4)$$

- Equation (4) above is called the balance equation and it shows that the effect of resistance of the connecting lead from m to n has been removed by connecting the galvanometer to the intermediate position p.