Bridges and Their Application

Bridge circuit are extensively used for ***measuring component values***, such as *resistance, inductance, capacitance*, and other circuit parameters directly derived from component values such as *frequency, phase angle, and temperature*. Bridge accuracy measurements are very high because their circuit merely compares the value of an unknown component to that of an accurately known component (a standard).

1- ***D.c Bridges:***

The basic d.c bridges consist of four resistive arms with a source of emf (a battery) and a null detector usually galvanometer or other sensitive current meter. D.c bridges are generally used for the measurement of resistance values.

Wheatstone Bridge

This is the best and commonest method of measuring ***medium*** resistance values in the range of 1Ω to the low megohm. The current through the galvanometer depends on potential difference between point (c) and (d). The ***bridge*** is said to be ***balance*** when potential difference across the galvanometer is zero volts, so there is no current through the galvanometer (***Ig=0***). This condition occurs when Vca=Vda or Vcb=Vdb hence the bridge is balance when

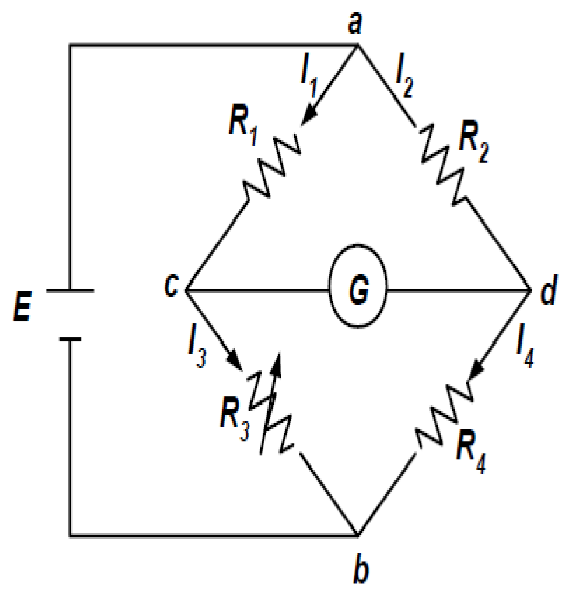
$V1 = V2$ ....(1) Since $I_g = 0$ so by voltage divider rule

$$V_1 = E\frac{R_1}{R_1 + R_3} \quad \text{..... (2) and}$$

$$V_2 = E\frac{R_2}{R_2 + R_4} \quad \text{..... (3)}$$

Substitute equations (2) & (3) in equ. (1)

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



Thus $\boxed{R_1 R_4 = R_2 R_3}$ is the balance equation for Wheatstone bridge

So, if three of resistance values are known, the fourth unknown ones can be determined.

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

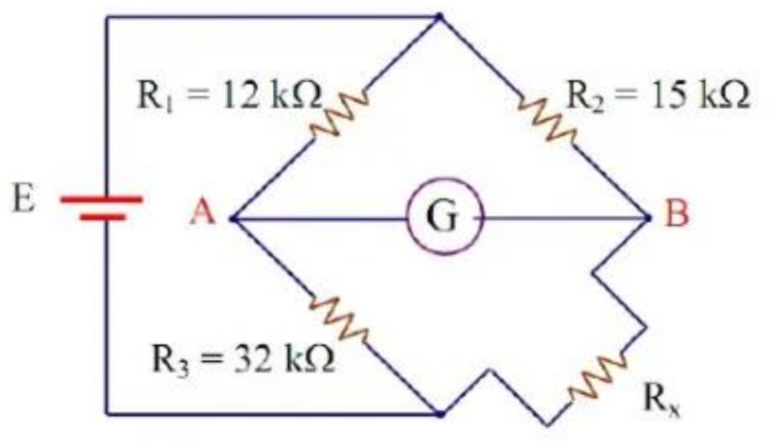
R_3 are called the standard arm of the bridge and resistors R_2 and R_1 are called the ratio arms.

Applications

1. Used in Light detecting devices.
2. For measuring the changes in the pressure.

4. Used for the Sensing of mechanical and electrical quantities.
5. Also, photoresistive devices use this circuit.
6. Thermometers also use Wheatstone bridges for the temperature measurements which need to be accurate.
7. Values like capacitance, inductance, impedance, etc. can be measured with some variations in the Wheatstone bridge circuit.
8. The Wheatstone Bridge is used for measuring the very low resistance values precisely.

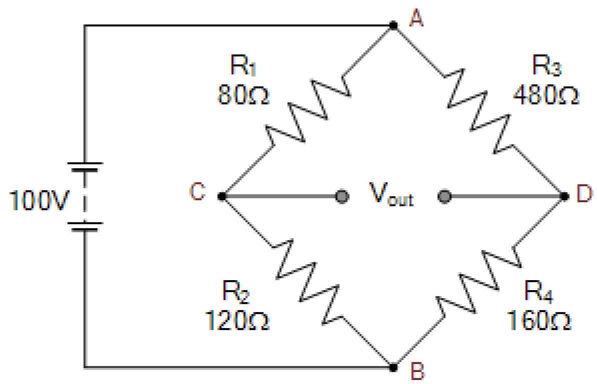
Example 1: Determine the value of the unknown resistor *RX*. Assuming the circuit is balanced at $R1 = 12k\Omega$, $R2 = 15k\Omega$, and $R3 = 32k\Omega$.



$$R_X = \frac{R_2 . R_3}{R_1} = \frac{15 \times 32}{12} = 40k\Omega$$

Example 2:

The following unbalanced Wheatstone Bridge is constructed. Calculate the output voltage across points C and D and the value of resistor R_4 required to balance the bridge circuit.



For the first series arm, ACB

$$V_C = \frac{R_2}{(R_1 + R_2)} \times V_S$$

$$V_C = \frac{120\Omega}{80\Omega + 120\Omega} \times 100 = 60 \text{volts}$$

For the second series arm, ADB

$$V_D = \frac{R_4}{(R_3 + R_4)} \times V_S$$

$$V_D = \frac{160\Omega}{480\Omega + 160\Omega} \times 100 = 25\text{volts}$$

The voltage across points C-D is given as:

$$V_{OUT} = V_C - V_D$$

$$\therefore V_{OUT} = 60 - 25 = 35\text{volts}$$

The value of resistor, R_4 required to balance the bridge is given as:

$$R_4 = \frac{R_2 R_3}{R_1} = \frac{120\Omega \times 480\Omega}{80\Omega} = 720\Omega$$

Note: We have seen above that the **Wheatstone Bridge** has two input terminals (A-B) and two output terminals (C-D). When the bridge is balanced, the voltage across the output terminals is 0 volts. When the bridge is unbalanced, however, the output voltage may be either positive or negative depending upon the direction of unbalance.

Example 3:

A Wheatstone bridge has a ratio arm of 1/100 (R2/R1). At first balance, R3 is adjusted to 1000.3 Ω. The value of Rx is then changed by the temperature change, the new value of R3 to achieve the balance condition again is 1002.1 Ω. Find the change of Rx due to the temperature change.

SOLUTION At first balance: $$R_x\text{old} = R_3\frac{R_2}{R_1} = 1000.3\times\frac{1}{100} = 10.003\ \Omega$$

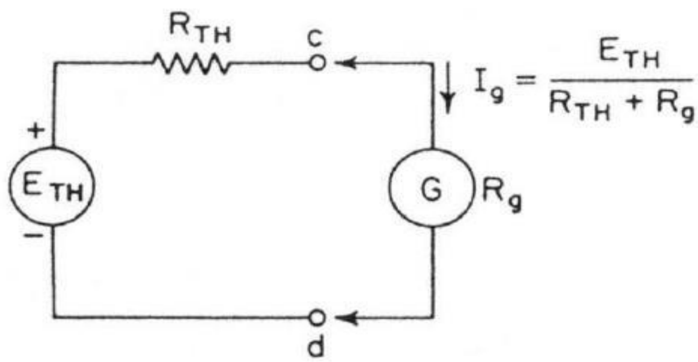
After the temperature change: $$R_x\text{new} = R_3\frac{R_2}{R_1} = 1002.1\times\frac{1}{100} = 10.021\ \Omega$$

Therefore, the change of R_x due to the temperature change is 0.018 Ω

THEVENIN EQUIVALENT CIRCUIT

It is necessary to calculate the galvanometer circuit -- to determine whether or not the galvanometer has the required **sensitivity** to **detect** an **unbalance** conditions. Different galvanometer not only may require different currents per unit deflection (**current sensitivity**), but also may have a difference **internal resistance**.

- **The deflection current** in the galvanometer is,



$$I_g = \frac{E_{th}}{R_{th} + R_g}$$

- Rg = the internal resistance in the galvanometer

Converting the Wheatstone bridge to its Thevenin equivalent circuit **in order to find the current follows** in the galvanometer:

There are two steps must be taken:

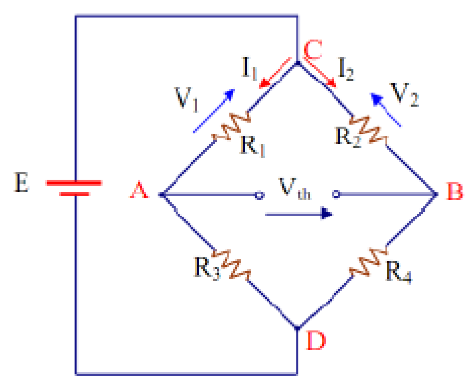
- Finding the **equivalent voltage** when the galvanometer is removed from the circuit (the open voltage between A and B of bridge).
- Finding the **equivalent resistance**, with the battery replaced by its internal resistance (removing the voltage source and makes its side short circuit and removing current source makes its side open circuit)

Calculate V_{th}

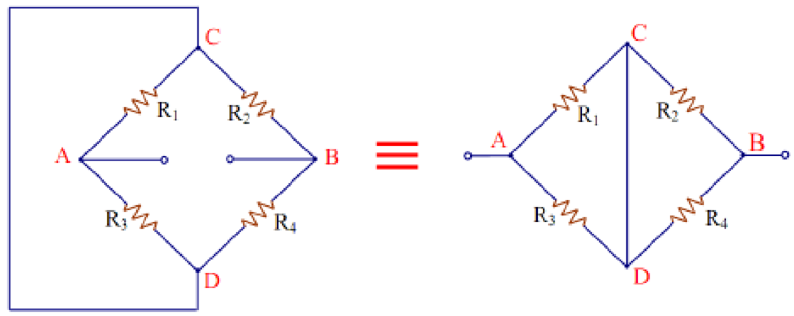
$$V_{th} = V_1 - V_2 = I_1 R_1 - I_2 R_2$$

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

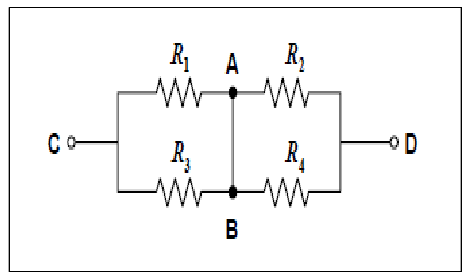
$$= E\left(\frac{R_1}{R_1 + R_3} - \frac{R_2}{R_2 + R_4}\right)$$



Calculate r_{th}



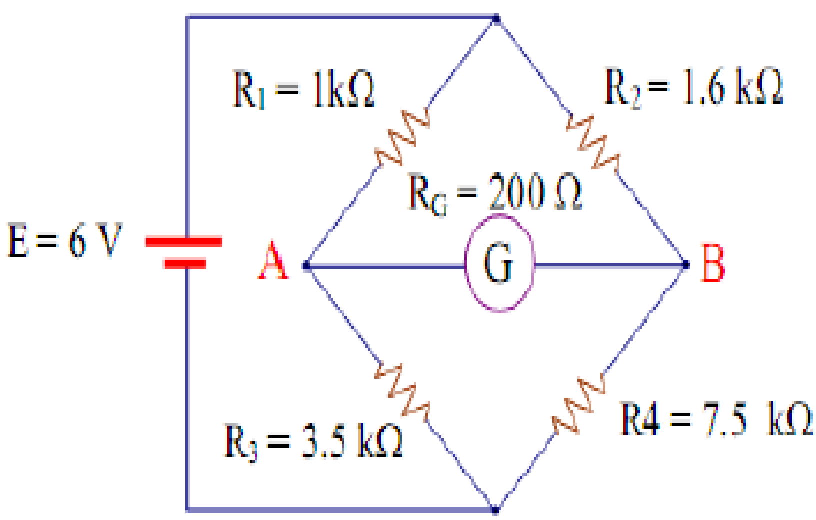
$$r_{th} = \frac{R_1 R_3}{R_1 + R_3} + \frac{R_2 R_4}{R_2 + R_4}$$

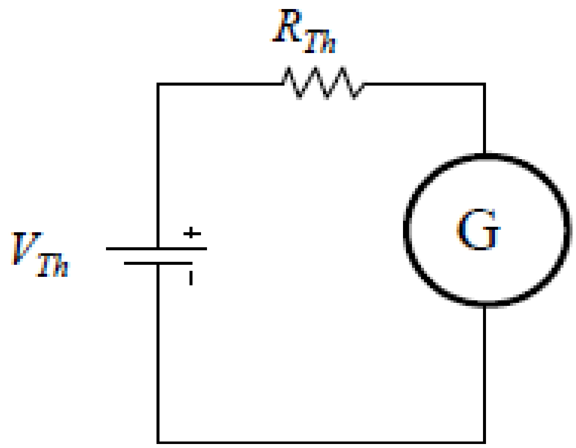


$$I_g = \frac{E_{th}}{R_{th} + R_g}$$

Example 4

Calculate the current passes in the galvanometer of the following circuit.





Solution:

1. Find V_{th}

$$V_{th} = E\left(\frac{R_1}{R_1 + R_3} - \frac{R_2}{R_2 + R_4}\right)$$

$$V_{th} = 6 \times \left(\frac{1\,k\Omega}{1\,k\Omega + 3.5\,k\Omega} - \frac{1.6\,k\Omega}{1.6\,k\Omega + 7.5\,k\Omega}\right) = 0.278\,V$$

2. Find r_{th}

$$r_{th} = \frac{R_1\,R_3}{R_1 + R_3} + \frac{R_2\,R_4}{R_2 + R_4}$$

$$r_{th} = \frac{1\,k\Omega \times 3.5\,k\Omega}{1\,k\Omega + 3.5\,k\Omega} + \frac{1.6\,k\Omega \times 7.5\,k\Omega}{1.6\,k\Omega + 7.5\,k\Omega} = 2.096\,k\Omega$$

3. Find I_G

$$I_G = \frac{V_{th}}{r_{th} + R_G} = \frac{0.278\,V}{2.096 \times 10^3\,\Omega + 200\,\Omega} = 121.4\,\mu A$$