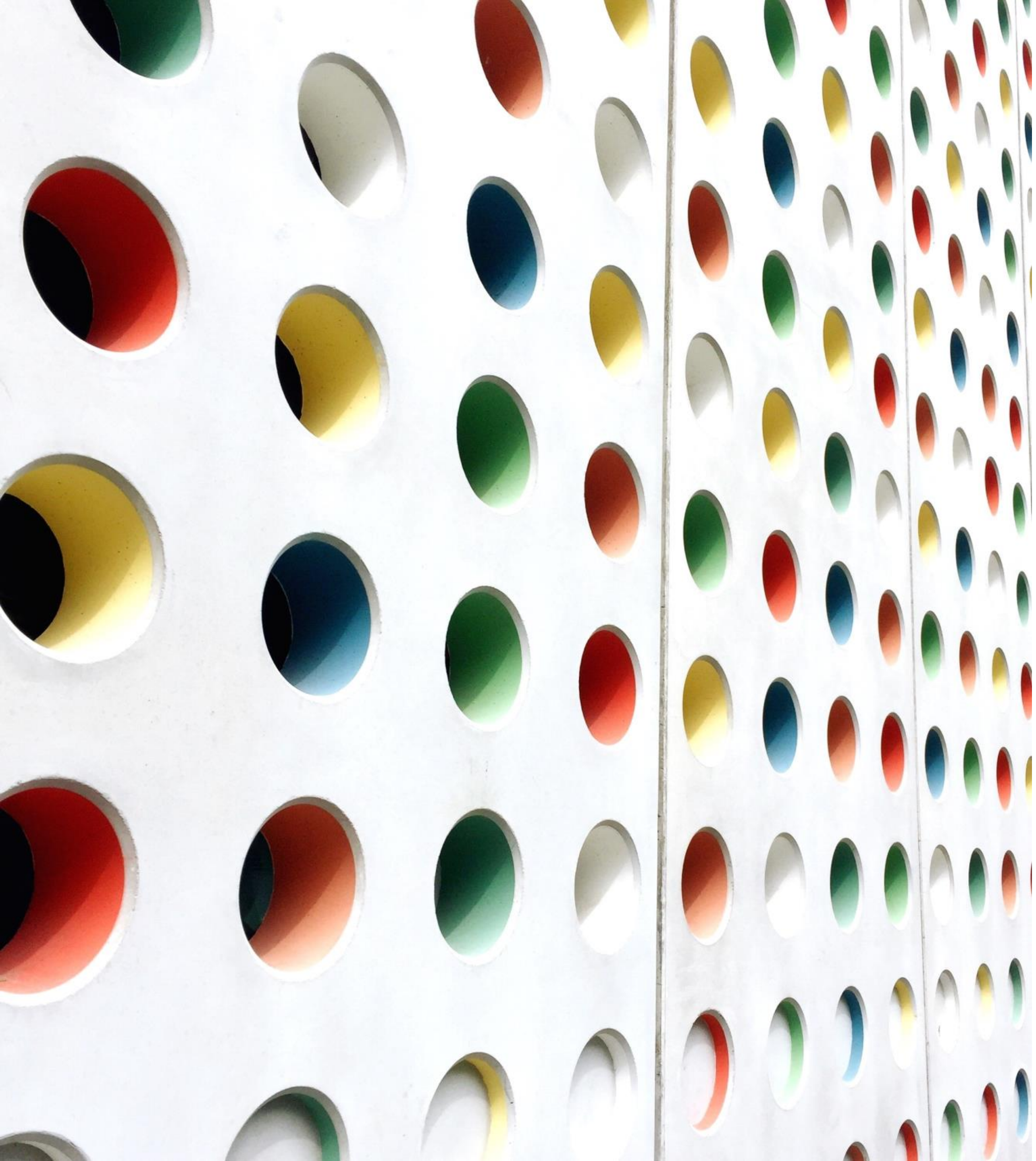


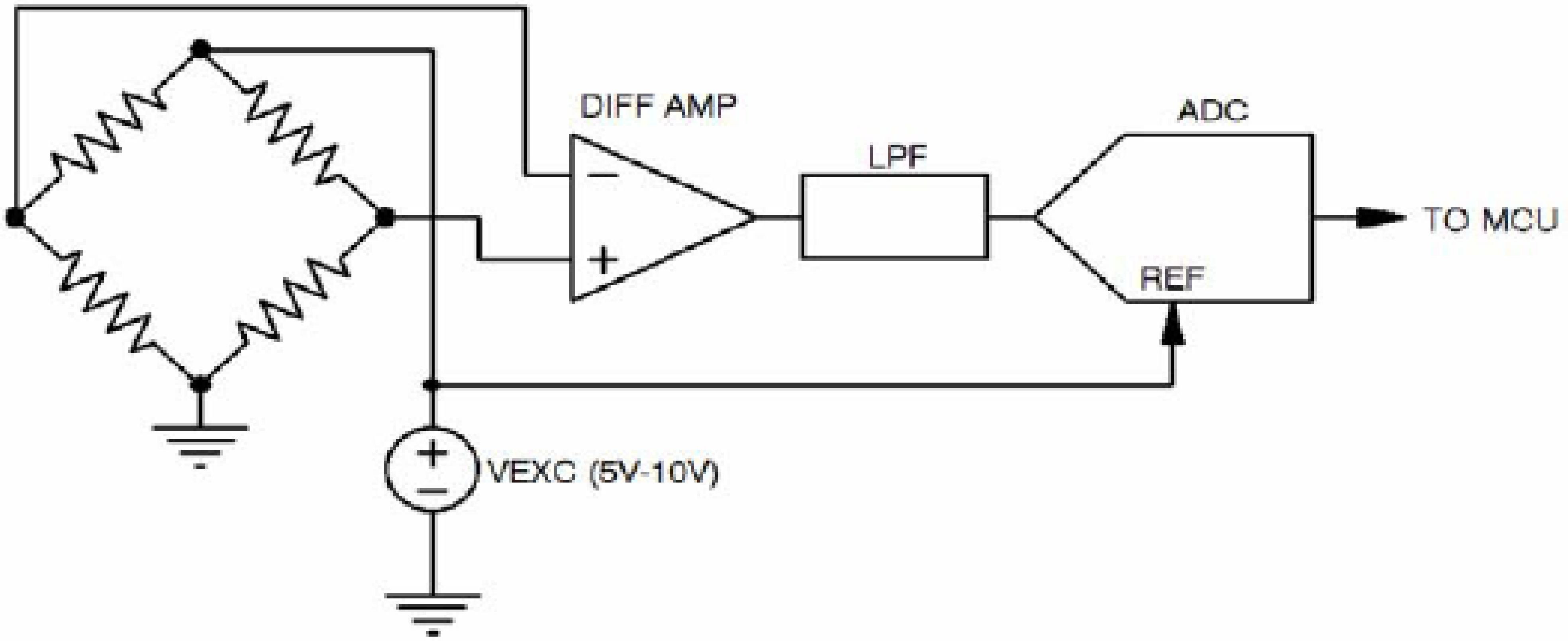
DC BRIDGES-I

WHEATSTONE'S BRIDGE AND ITS APPLICATIONS

DC Bridge

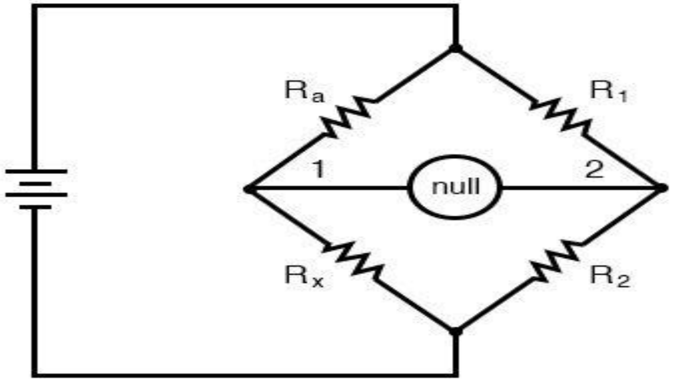
- A bridge circuit in its simplest form consists of a network of four resistance arms forming a closed circuit, with a DC of current applied to two opposite junctions and a current detector connected to the other two junctions.
- The bridge circuit works as a pair of two-component voltage dividers connected across the same source voltage, with a *null-detector* meter movement connected between them to indicate a condition of “balance” at zero volts
- To measure parameters *R, L, C, f, Q* (Quality factor of a coil) and ‘*D*’ (Dissipation factor of a capacitor) of electronic circuits, bridge circuits are employed.
- The advantage with bridge-measuring circuits is that some errors which occur in measurements due to parasitic values, temperature effects, errors due to improper grounding and shielding can be eliminated.

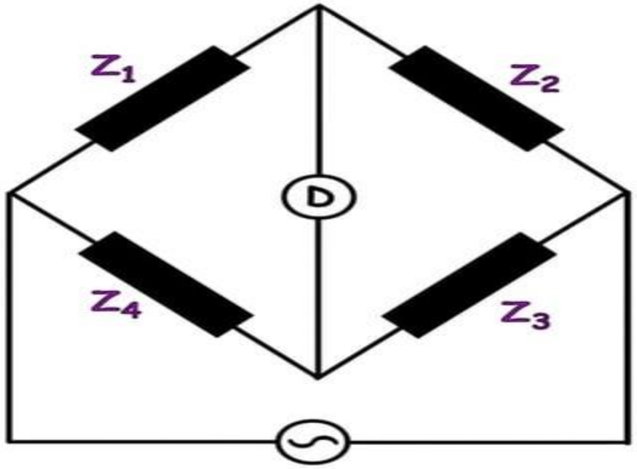
Bridges Measurement System



DC BRIDGE VS AC BRIDGE

- DC bridges are used to determine the unknown conducting value.
- Wheatstone bridge and Kelvin double bridge are the two types in this category.
- AC bridges can also be used for resistance measurements, but they are used to determine inductance, capacitance, impedance, admittance, or the frequency of the AC input.
- The D.C bridges use the D.C voltages as the excitation voltage while the A.C bridges use the alternating voltage as the excitation voltage.



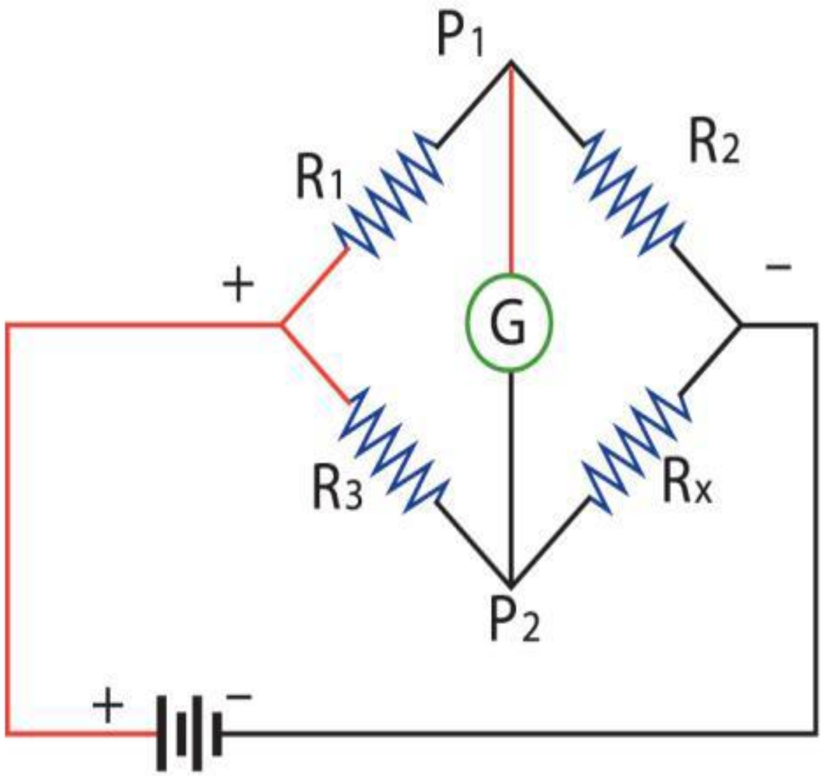


Basic DC Bridge

- Any one of the four resistors in the above bridge can be the resistor of unknown value, and its value can be determined by a ratio of the other three, which are "calibrated," or whose resistances are known to a precise degree.

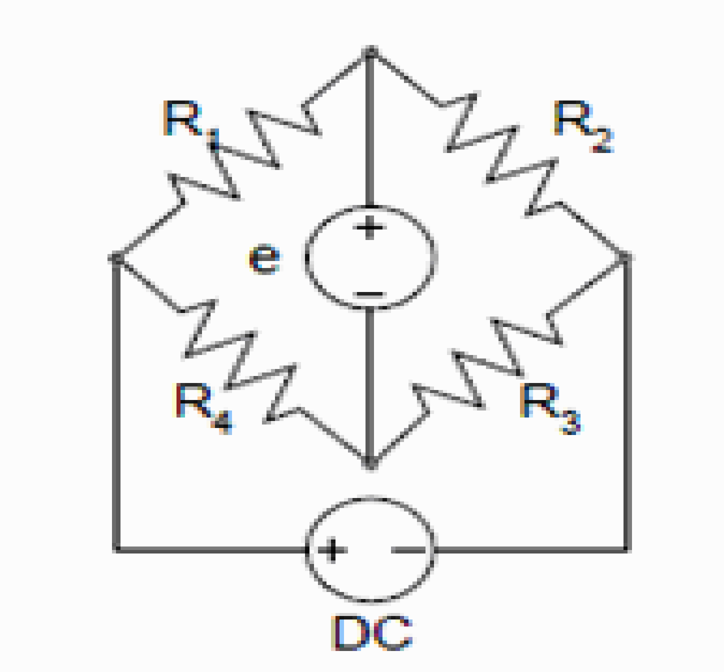
- When the bridge is in a balanced condition (zero voltage as indicated by the null detector), the ratio works out to be this:

$$R_1R_x=R_2R_3$$



WHEATSTONE'S BRIDGE

- The Wheatstone bridge is an *electrical bridge circuit* used to *measure resistance*.
- This bridge consists of a *galvanometer* and *TWO (2) parallel branches* containing *FOUR (4)* resistors.
- One parallel branch contains one *known* resistance and one *unknown*; the other parallel branch contains resistors of known resistances.



Analysis

Voltage at point D = $V \times R_X / (R_2 + R_X)$

Voltage at point C = $V \times R_3 / (R_1 + R_3)$

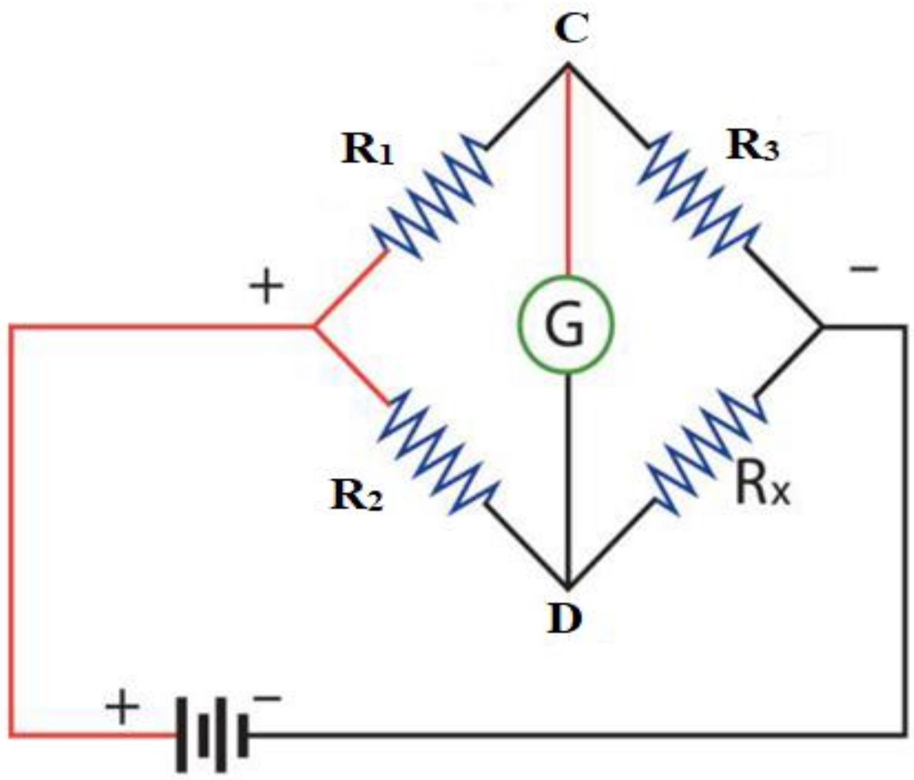
The voltage (V) across galvanometer

$V_{CD} = V \times R_X / (R_2 + R_X) - V R_3 / (R_1 + R_3)$

When the bridge is balanced $V_{CD} = 0$

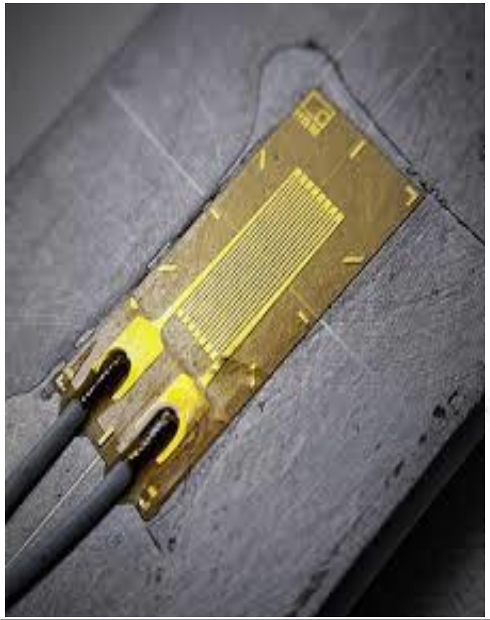
$V \times R_X / (R_2 + R_X) = V R_3 / (R_1 + R_3)$

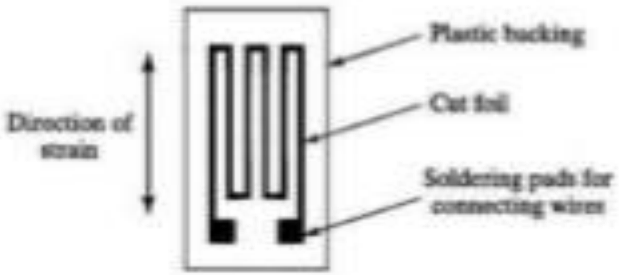
$R_X = R_3 \times (R_2 / R_1)$

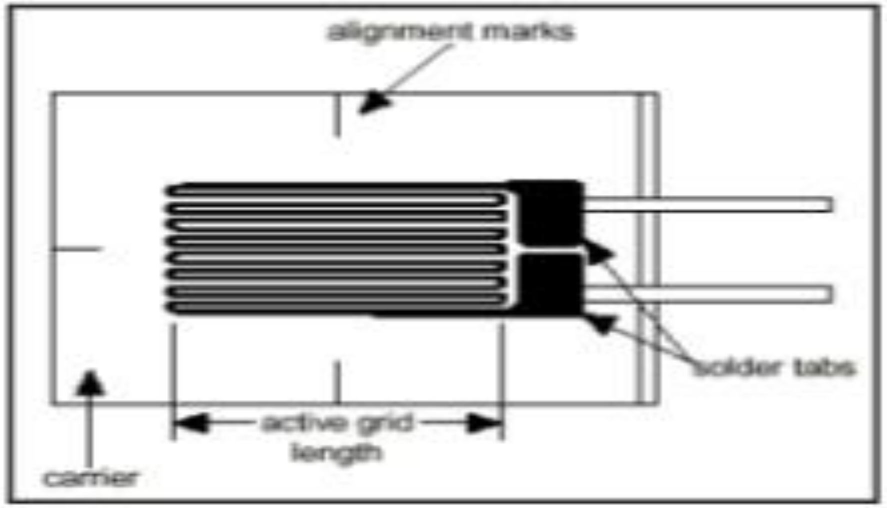


STRAIN GAUGE

- The strain gauge is a passive, resistive transducer which converts the mechanical elongation and compression into a resistance change.
- This change in resistance takes place due to variation in length and cross sectional area of the gauge wire, when an external force acts on it.

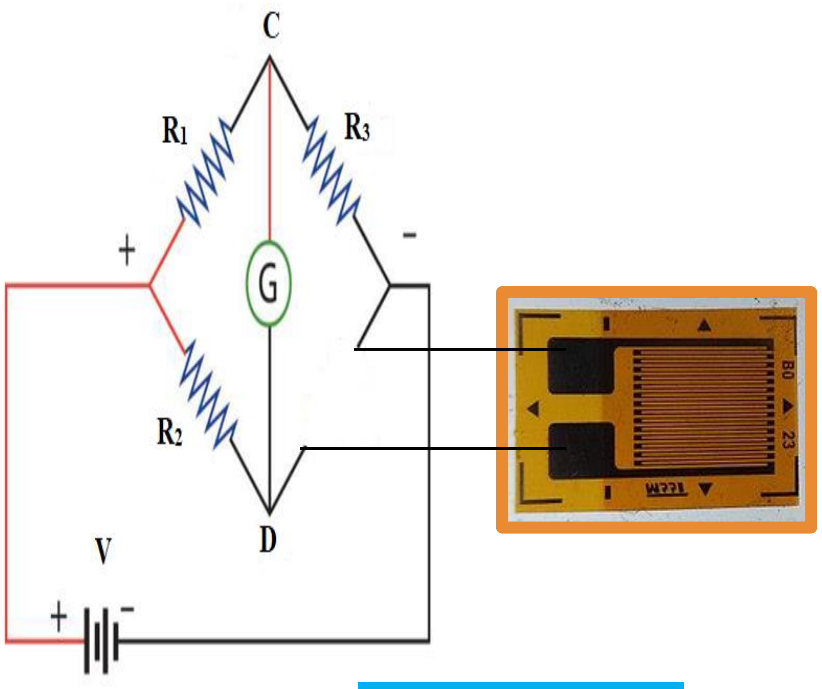






Use of Wheatstone bridge for resistive Transducers

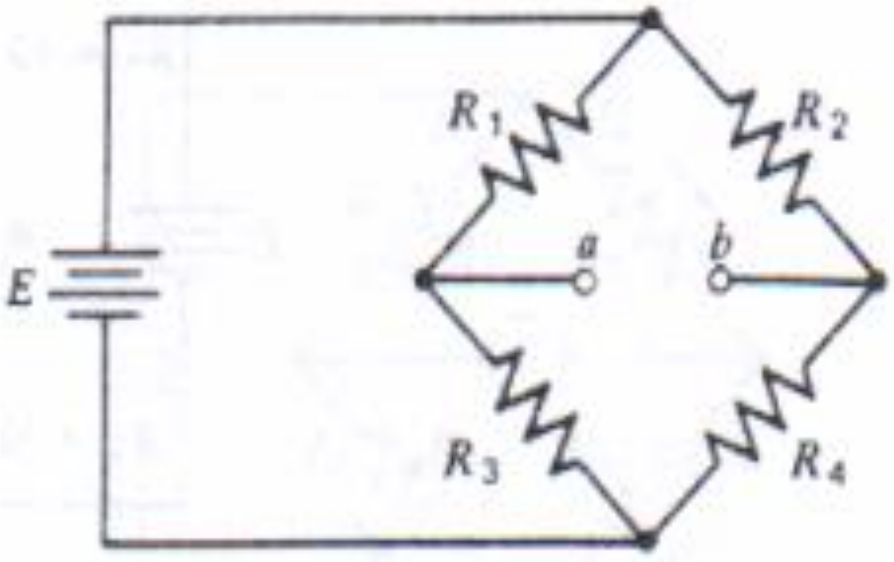
- If the strain gauge is either tensed or compressed, then the resistance can increase or decrease.
- Therefore, this causes unbalancing of the bridge.
- This produces a voltage indication on voltmeter corresponds to the strain change.
- If the strain applied on a strain gauge is more, then the voltage difference across the meter terminals is more.
- If the strain is zero, then the bridge balances and meter shows zero reading.



$R_1R_x=R_2R_3$

Thevenin's Theorem

- Thevenin's theorem is an approach used to determine the current flowing through the galvanometer.
- *Thevenin's equivalent voltage* is found by removing the galvanometer from the bridge circuit and computing the **open-circuit voltage** between terminals *a* and *b*.
- Applying the **voltage divider equation**, we express the voltage at point *a* and *b*, respectively, as



$$V_a = E\frac{R_1}{R_1 + R_3}$$

$$V_b = E\frac{R_2}{R_2 + R_4}$$

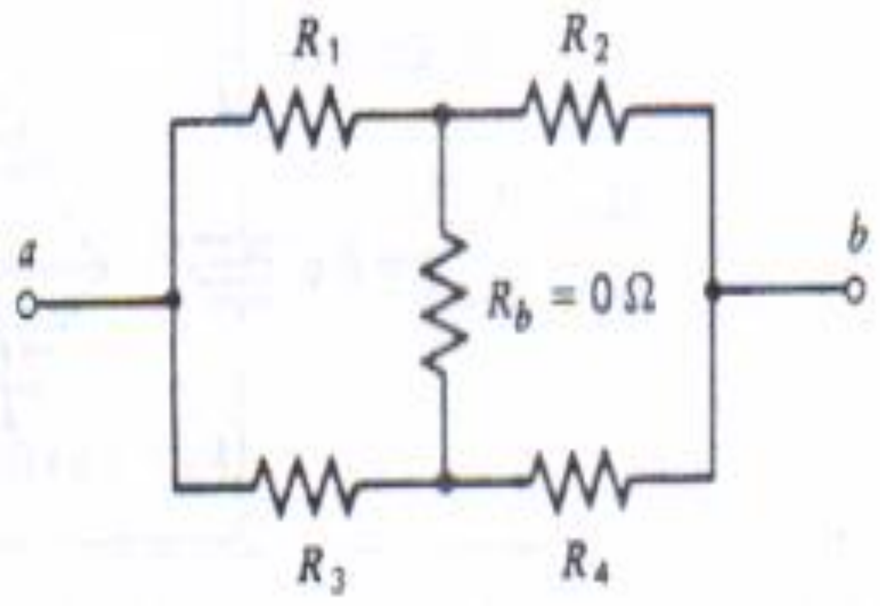
Contd..

The difference in V_a and V_b represents Thevenin's equivalent voltage.

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

Thevenin's equivalent resistance is found by replacing the voltage source with its internal resistance, R_b as
Since R_b is assumed to be very low ($R_b \approx 0\ \Omega$)

$$R_{Th} = R_1 // R_3 + R_2 // R_4$$



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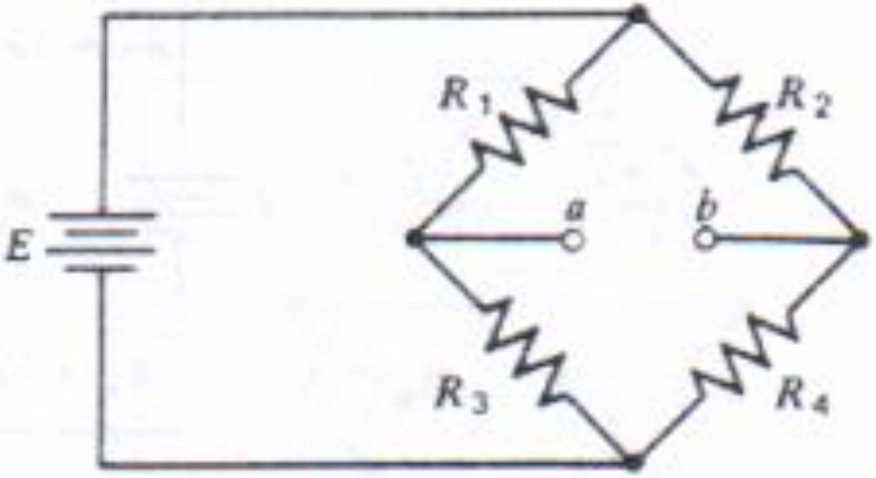
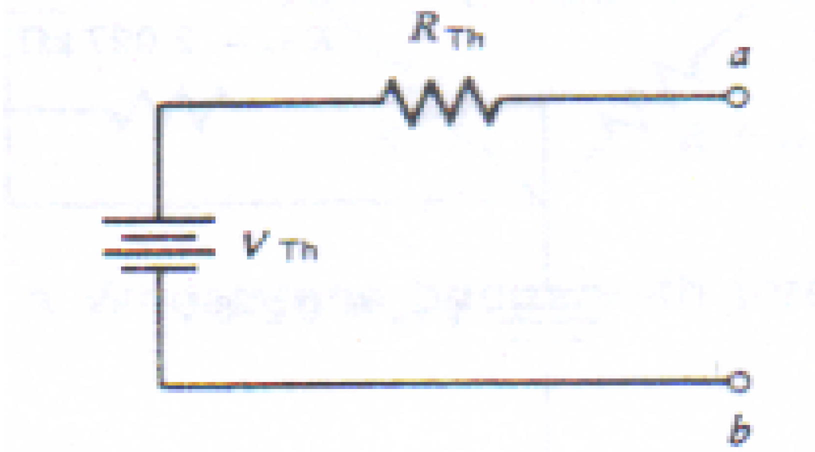
- If the values of Thevenin's equivalent voltage and resistance have been known, the **Wheatstone bridge circuit** in Figure can be changed with **Thevenin's equivalent circuit**

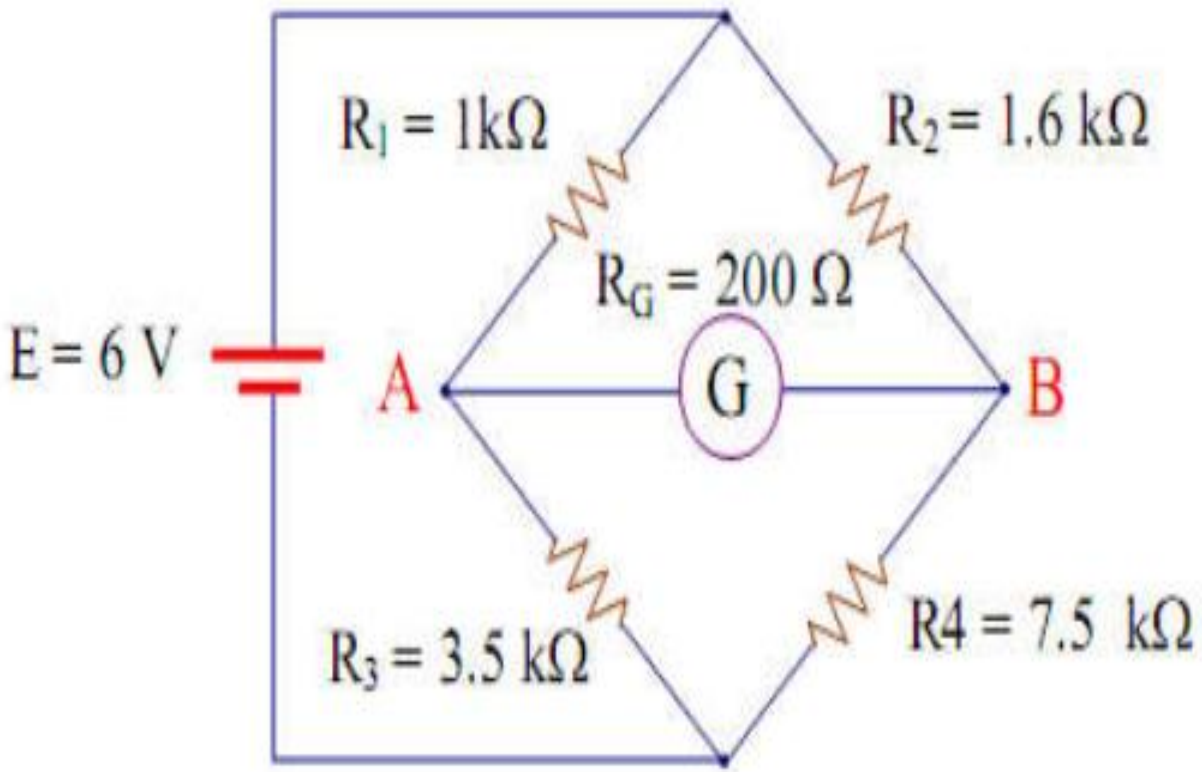
- If a galvanometer is connected to terminal a and b, the deflection current in the galvanometer is

$$I_g = \frac{V_{Th}}{R_{Th} + R_g}$$





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



Solution:

Step1 Find V_{th}

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

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

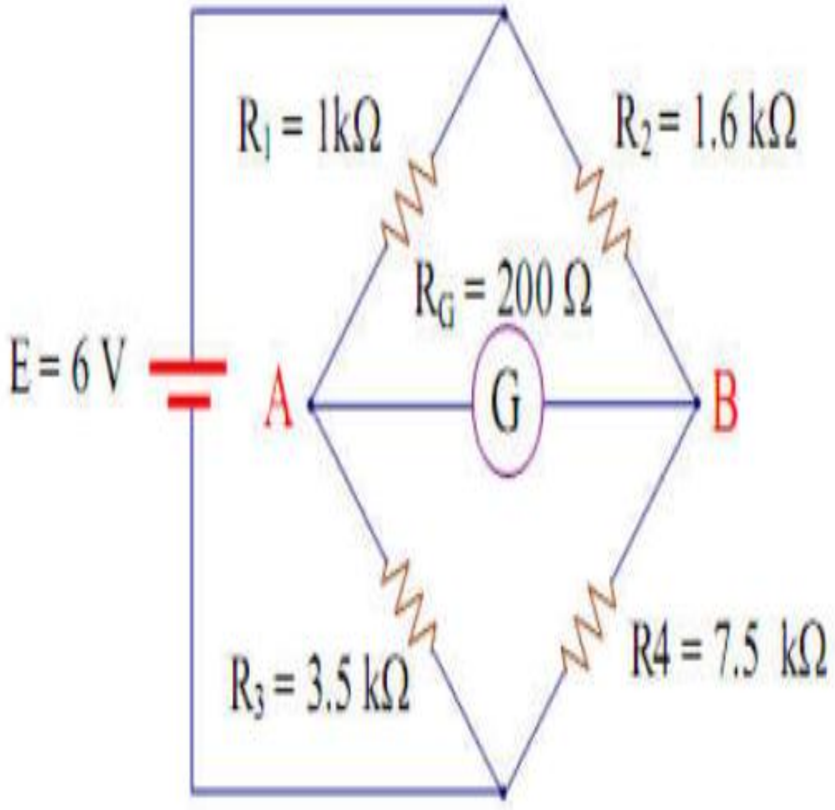
Step 2 Find R_{th}

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

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

Step 3 Calculate I_G

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



Sensitivity of the Wheatstone bridge

- When the pointer of a galvanometer deflects towards right or left hand side, this means that current is flowing through the galvanometer and the bridge is called in an unbalanced condition.

- The amount of deflection is a function of the sensitivity of the galvanometer. For the same current, greater deflection of pointer indicates more sensitive a galvanometer.

Sensitivity S can be expressed in linear or angular units as follows:

$$I_g = \frac{V_{Th}}{R_{Th} + R_g}$$

$$S = \frac{Deflection}{Current} = \frac{D}{I}$$

$$S = \frac{millimeters}{\mu A} \quad or;$$

$$S = \frac{degrees}{\mu A} \quad or;$$

$$S = \frac{radians}{\mu A}$$

Measurement Errors

- The main source of error: limiting errors of the three known resistors. Insufficient sensitivity of the null detector. calculate the galvanometer current to determine Measurement Errors whether or not the galvanometer has the required sensitivity to detect an unbalance condition.

- Changes in resistance of the bridge arms due to the heating effect of the current through the resistors. The power dissipation in the bridge arms must be computed in advance and the current must be limited to a safe value.

- Thermal emf's in the bridge circuit of the galvanometer circuit can also cause problems when low-value resistors are being measured. The more sensitive galvanometers sometimes have copper coils and copper suspension systems to avoid having dissimilar metals in contact with one another and generating thermal emfs.

- Errors due to the resistance of leads and contacts exterior to the actual bridge circuit.

References

Kalsi H S, Electronic instrumentation, Tata McGraw-Hill Education, 2004

E.O. Doebelin, **Measurement System, T**ata McGraw-Hill Education, 2013.