Ministry of Higher Education and Scientific Research

Al-Mustaqbal University College

Department of Technical Computer Engineering

instrument and measurement

Lecturer: Ali Rashid

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Wheatstone bridge

Bridge Networks or Circuits are one of the most popular and popular electrical tools, often used in measurement circuits, transducer circuits, switching circuits and also in oscillators.

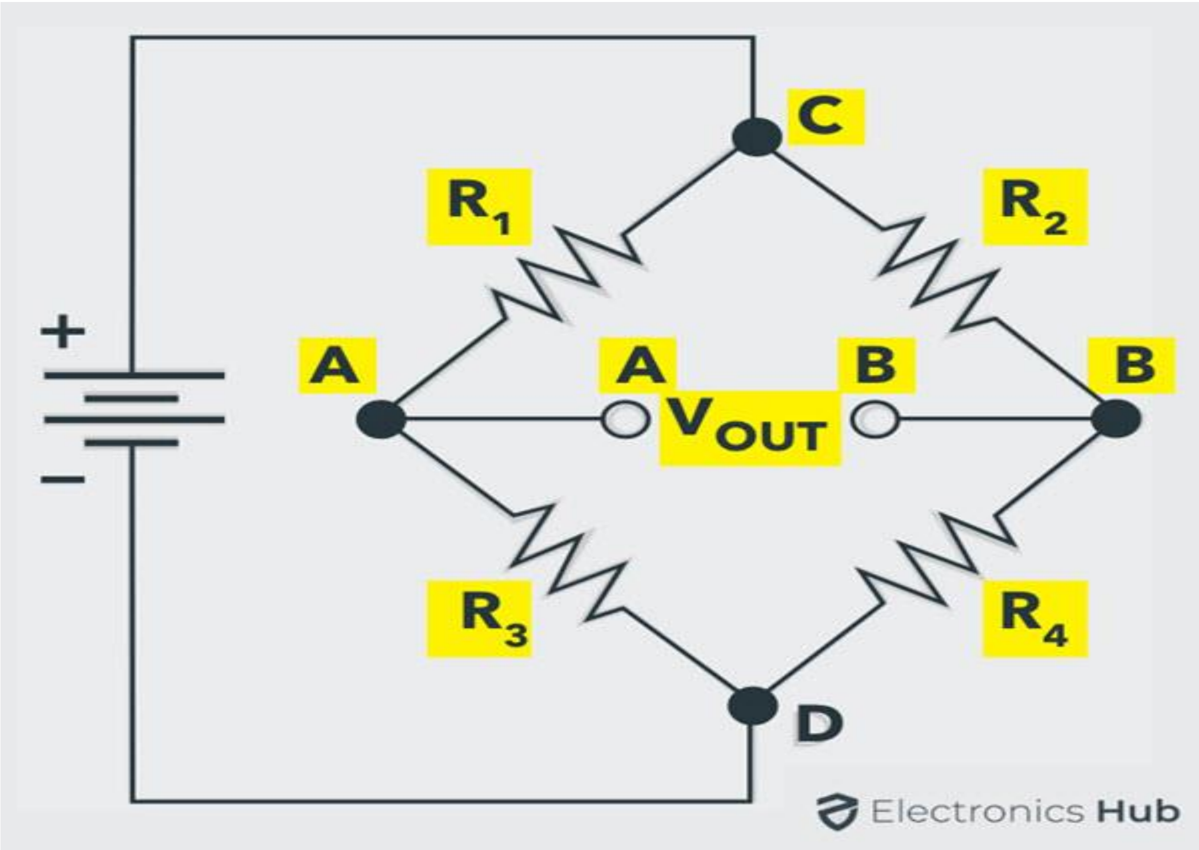
The Wheatstone Bridge is one of the most common and simplest bridge network / circuit, which can be used to measure resistance very precisely. But often the Wheatstone Bridge is used with Transducers to measure physical quantities like Temperature, Pressure, Strain etc.

Wheatstone Bridge is used in applications where small changes in resistance are to be measured in sensors. This is used to convert a change in resistance to a change in voltage of a transducer. The combination of this bridge with operational amplifier is used extensively in industries for various transducers and sensors.

For example, the resistance of a Thermistor changes when it is subjected to change in temperature. Likewise, a strain gauge, when subjected to pressure, force or displacement, its resistance changes. Depending on the type of application, the Wheatstone

Bridge can be operated either in a Balanced condition or an Unbalanced condition.

A Wheatstone bridge consists of four resistors (R1, R2, R3 and R4) that are connected in the shape of a diamond with the DC supply source connected across the top and bottom points (C and D in the circuit) of the diamond and the output is taken across the other two ends (A and B in the circuit).



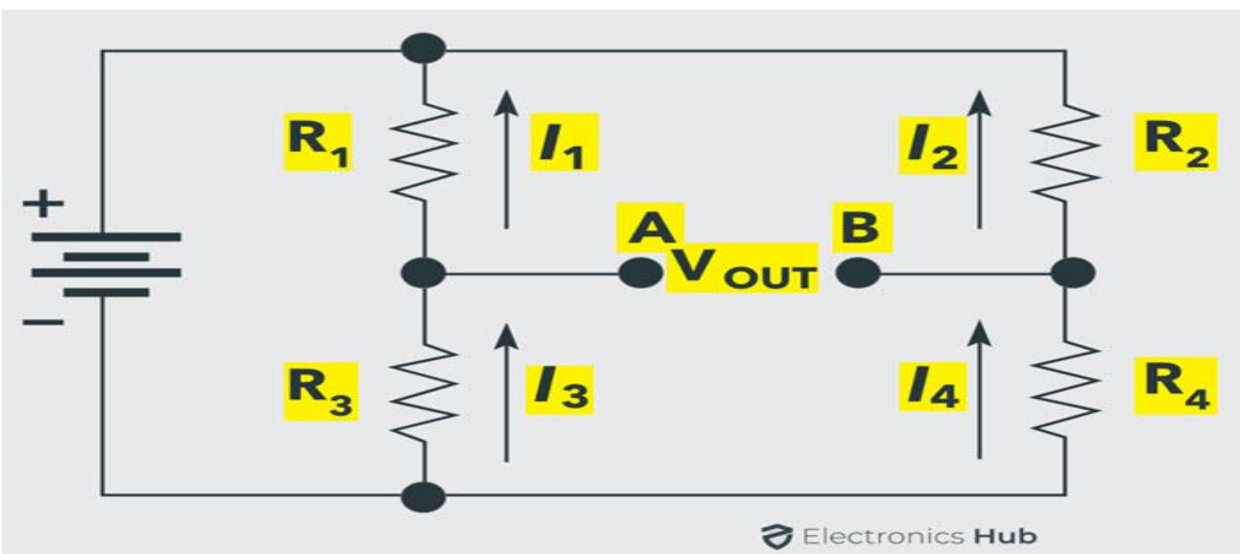
This bridge is used to find the unknown resistance very precisely by comparing it with a known value of resistances. In this bridge, a Null or Balanced condition is used to find the unknown resistance.

For this bridge to be in a Balanced Condition, the output voltage at points A and B must be equal to 0. From the above circuit:

The Bridge is in Balanced Condition if:

VOUT = 0 V

To simplify the analysis of the above circuit, let us redraw it as follows:



Now, for Balanced Condition, the voltage across the resistors R1 and R2 is equal. If V1 is the voltage across R1 and V2 is the voltage across R2, then:

$$V1 = V2$$

Similarly, the voltage across resistors R3 (let us call it V3) and R4 (let us call it V4) are also equal. So,

$$V3 = V4$$

The ratios of the voltage can be written as:

$$V1 / V3 = V2 / V4$$

From Ohm's law, we get:

$$I1\ R1 / I3\ R3 = I2\ R2 / I4\ R4$$

Since I1 = I3 and I2 = I4, we get:

$$R1 / R3 = R2 / R4$$

From the above equation, if we know the values of three resistors, we can easily calculate the resistance of the fourth resistor.

Alternative Way to Calculate Resistors

From the redrawn circuit, if VIN is the input voltage, then the voltage at point A is:

$$VIN \,(R3 / (R1 + R3))$$

Similarly, the voltage at point B is:

$$VIN \,(R4 / (R2 + R4))$$

For the Bridge to be Balanced, VOUT = 0. But we know that VOUT = VA – VB .

So, in Balanced Bridge Condition,

$V_A = V_B$

Using above equations, we get:

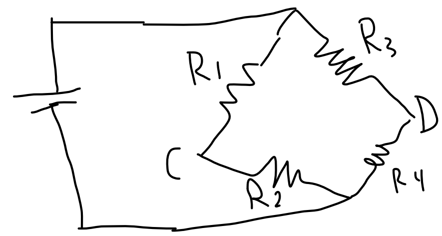
$V_{IN} (R_3 / (R_1 + R_3)) = V_{IN} (R_4 / (R_2 + R_4))$

After simple manipulation of the above equation, we get:

$R_1 / R_3 = R_2 / R_4$

From the above equation, if R1 is an unknown resistor, its value can be calculated from the known values of R2, R3 and R4. Generally, the unknown value is called as RX and of the three known resistances, one resistor (mostly R3 in the above circuit) is usually a variable Resistor called as RV.

We can derive the mathematical expression for Wheatstone bridge



At balance

Rc=RD

$$\frac{R2}{R1+R2}=\frac{R4}{R3+R4}$$

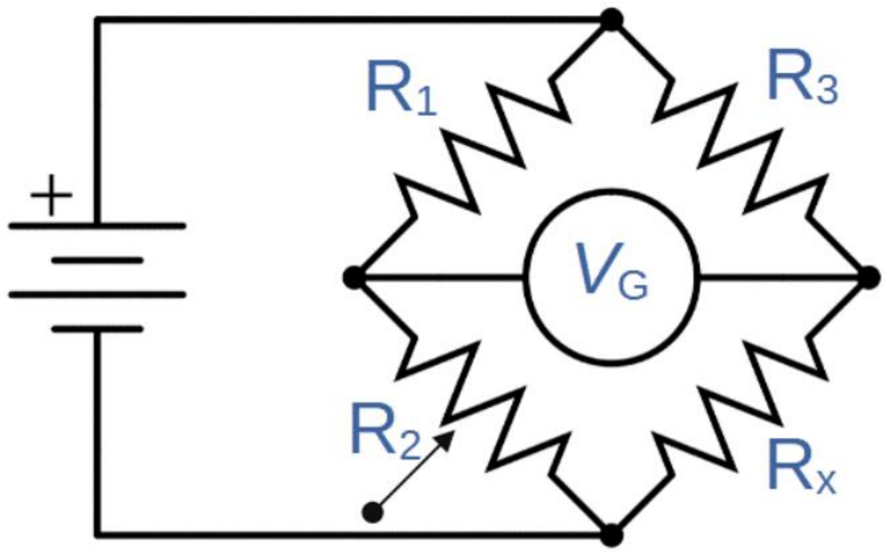
R2(R3+R4)=R4(R1+R2)

R2R3+~~R2R4~~=R4R1+~~R4R2~~

R2R3=R4R1

$\boxed{R4=\frac{R2R3}{R1}=Rx}$

Example / The Wheatstone bridge calculate Rx when, R1= 2Ω,R2 =4Ω,R3=4Ω,



solution

$$R4 = \frac{R2R3}{R1}$$

R4= $\frac{4*4}{2} = \frac{16}{2}$ = 8 Ω

Example/ when the bridge circuit below have

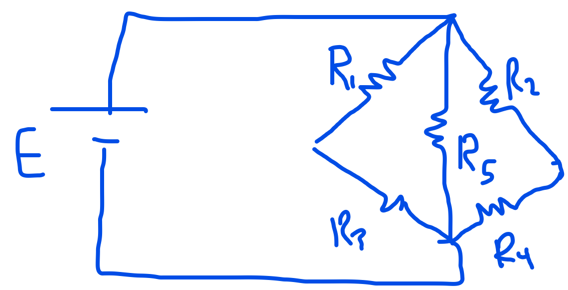
R1=2Ω

R2=4 Ω

R3=4 Ω

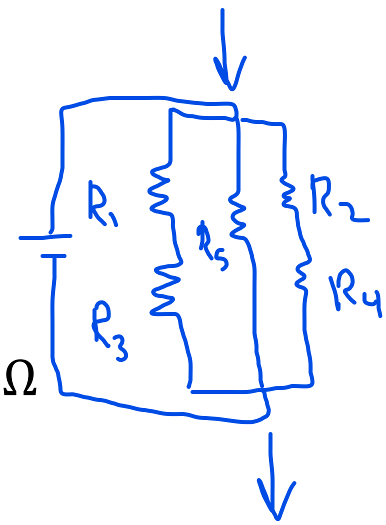
R4=8 Ω

R5=6 Ω



Calculate the equivalent resistance

<u>solution</u>



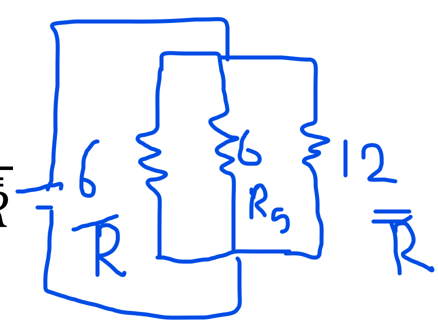
$$\bar{R} = R1 + R3$$

$$\bar{R} = 2 + 4 = 6\ \Omega$$

$$\bar{\bar{R}} = R2 + R4$$

4+8 = 12 Ω

$$\frac{1}{Req} = \frac{1}{\bar{R}} + \frac{1}{R5} + \frac{1}{\bar{\bar{R}}}$$



$$\frac{1}{6} + \frac{1}{6} + \frac{1}{12}$$

2 2 1

$$\frac{1}{Req} = \frac{2+2+1}{12} = \frac{5}{12}$$

$$Req = \frac{12}{5} = 2.4\Omega$$