Paramount Electronics Services

Series Parallel Resistive Circuits

Series Parallel Circuit Concepts

- Often found in electronic circuits are combinations of series and parallel circuits.
- It is important to be able to identify how the components in a circuit are arranged in terms of the series and parallel relationships.
- Recognize how each resistor in each circuit relates to the other resistors.
- Series resistors always share the same current through them.
- Parallel resistors always have their terminals connected to two common nodes.

Series Parallel Circuit Concepts

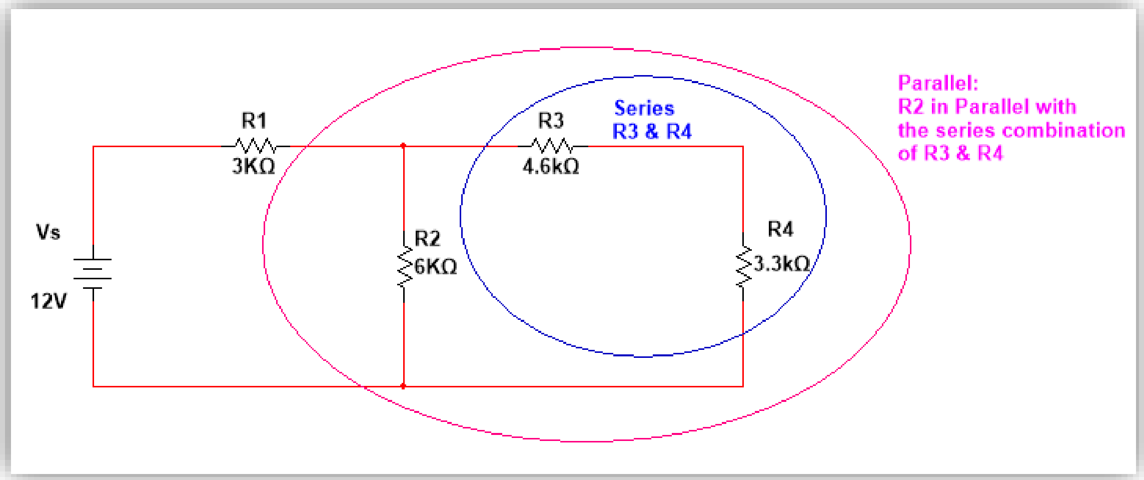
- An important circuit called the Wheatstone bridge is a very useful series-parallel circuit that is used extensively in a variety of residential and industrial applications.

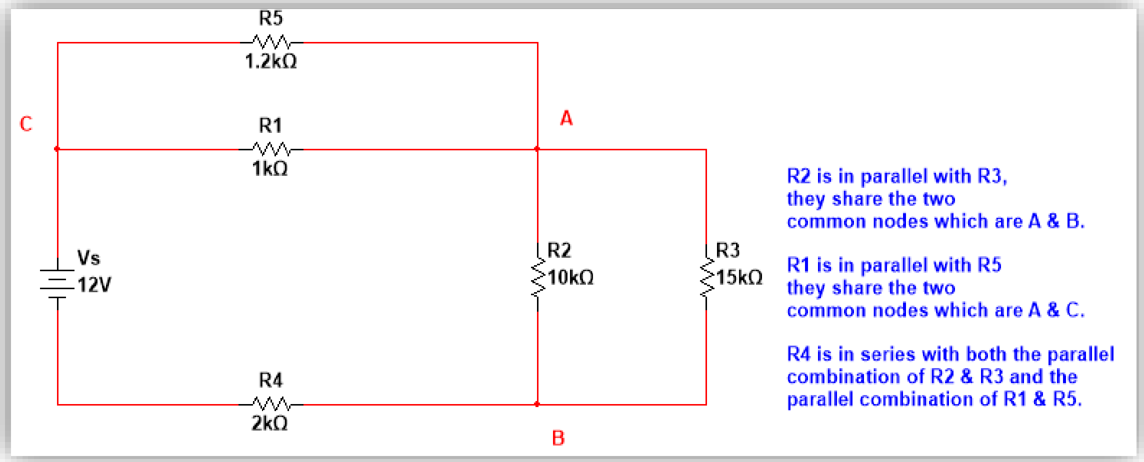
- A concept called the thevenin's equivalent can be used to simplify circuits that are seen by a certain load for the purpose of load matching and maximum power transfer, also for the purpose of protecting the load from going over the power rating of that load.

- Some circuits have one or more voltage sources, one or more current sources or any combination of both types of sources.
  - When a circuit contains such combinations, a principal called the superposition principal can be used to analyze the circuit.

Series Parallel Circuit Concepts

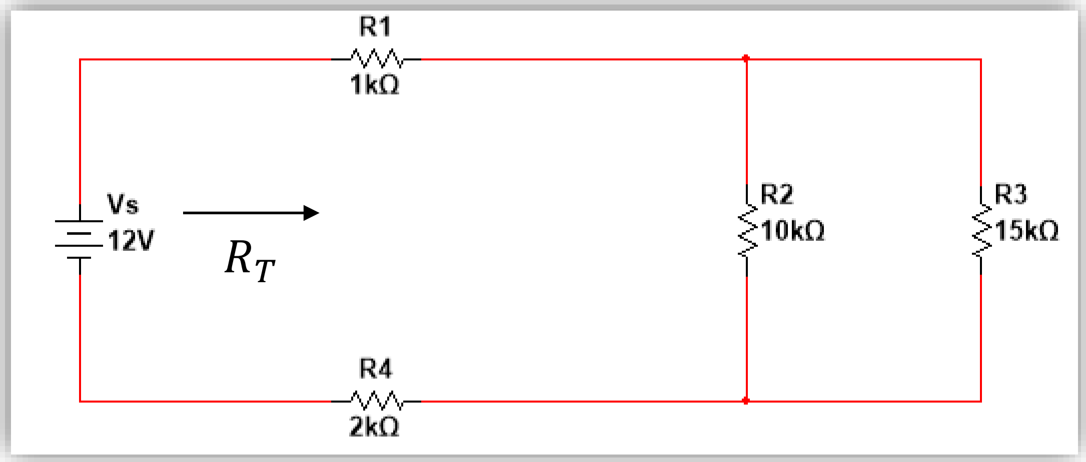
- The following circuits are examples of series parallel circuits.





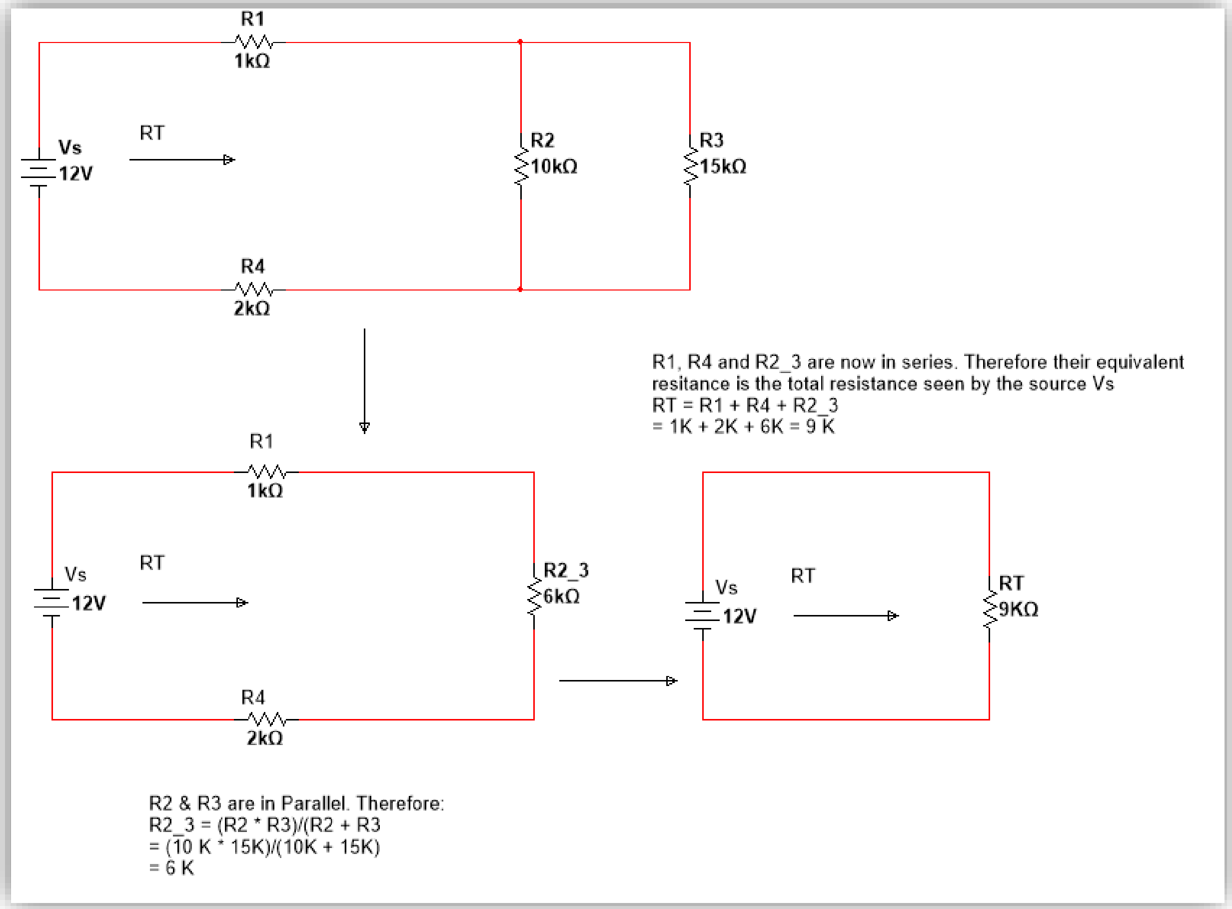
Series Parallel Circuits Example

- For the following circuit, find:
  - a- The total resistance seen by the voltage source.
  - b- The total current I_T sourced by the voltage source.
  - c- I_{R1}, I_{R2}, I_{R3} & I_{R4}.
  - d- V_{R1}, V_{R2}, V_{R3} & V_{R4}.
  - e- The power consumed by R_1 , P_{R1}



Series Parallel Circuits Example

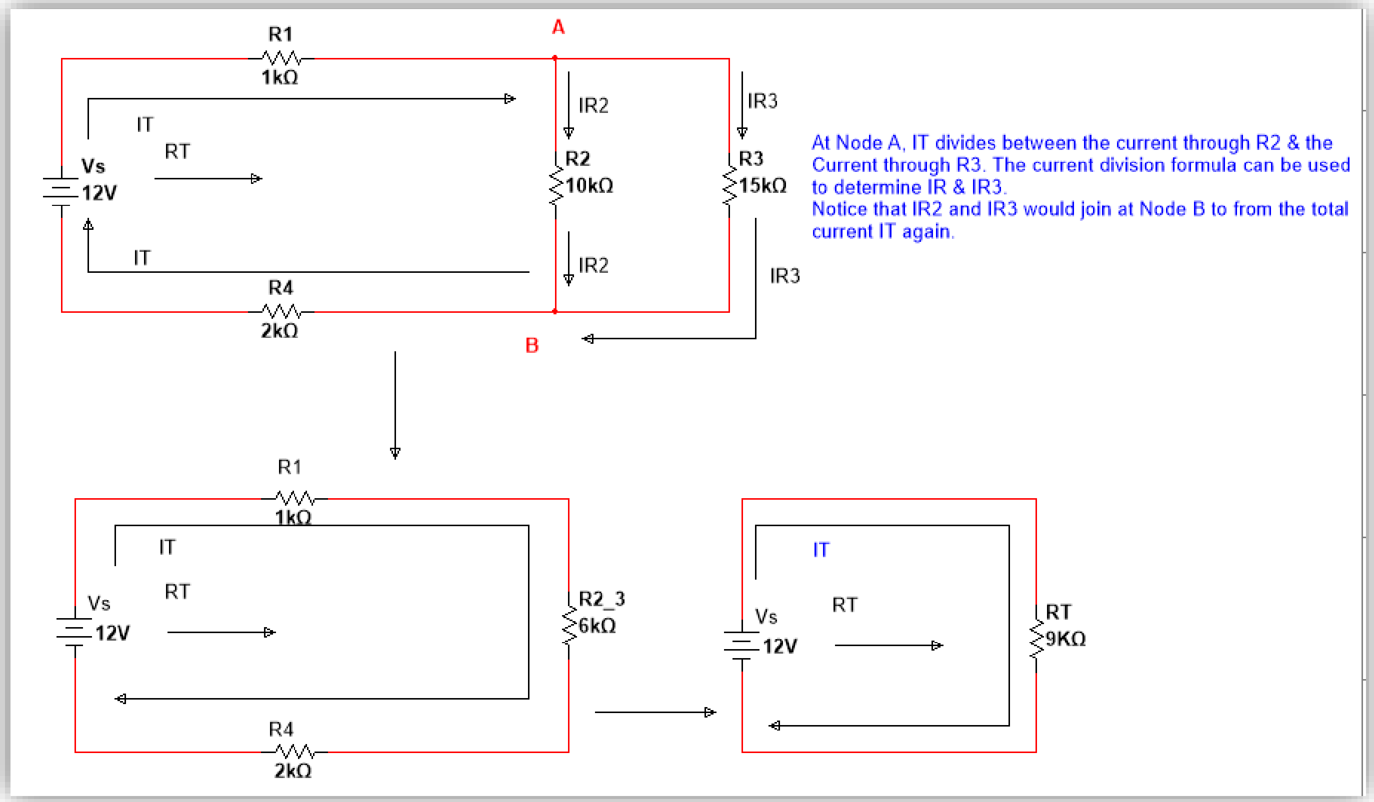
- For the following circuit, find:
    - a- The total resistance seen by the voltage source.



Series Parallel Circuits Example

- For the following circuit, find:
  - b- The total current I_T sourced by the voltage source.

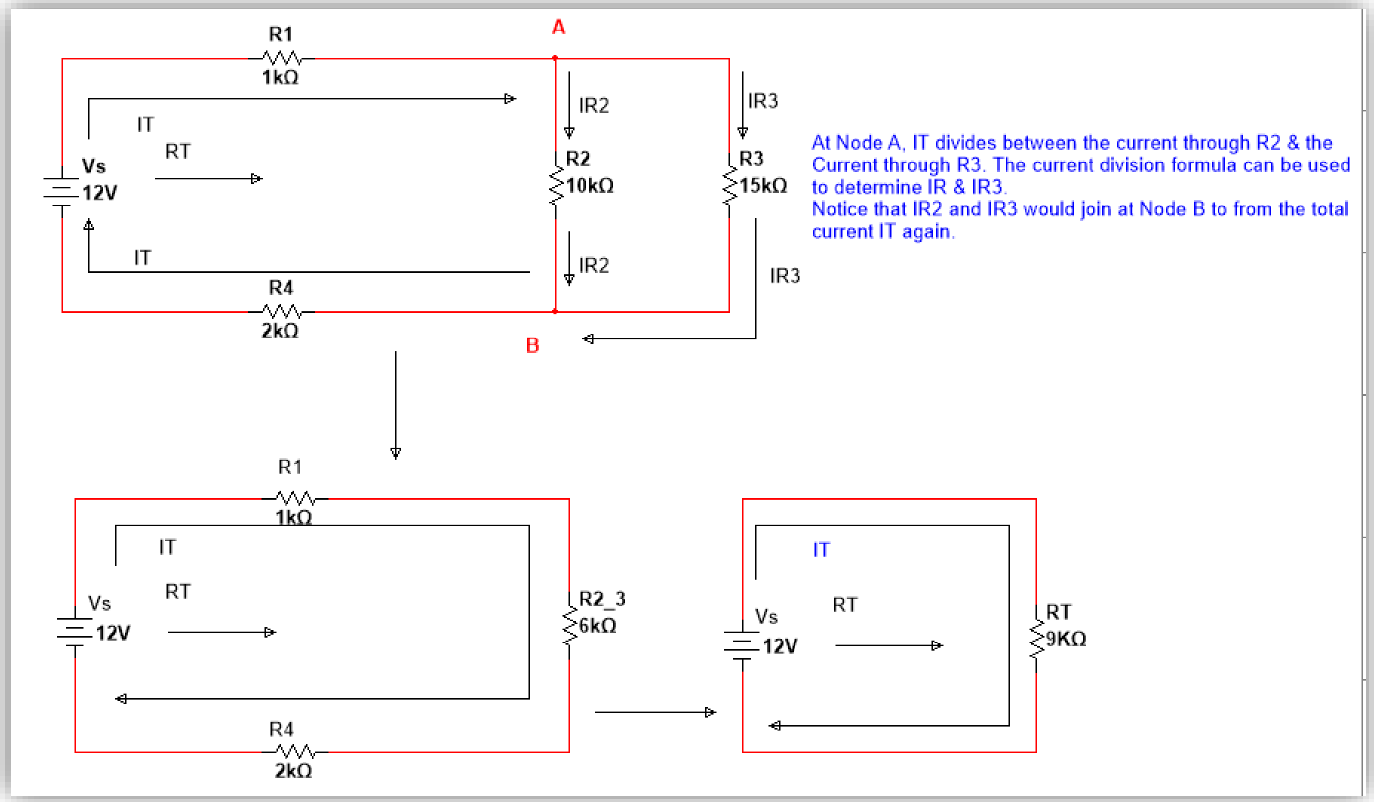
$$I_T = \frac{V_T}{R_T} = \frac{V_s}{R_T} = \frac{12V}{9K} = 1.3333\ \text{mA}$$



Series Parallel Circuits Example

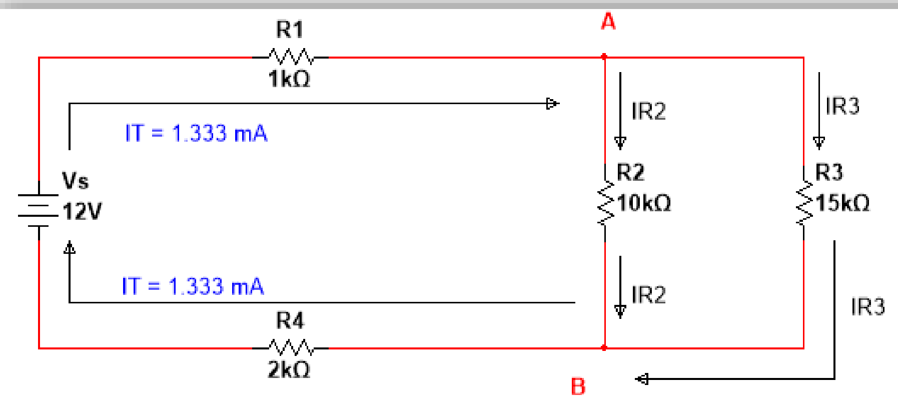
- For the following circuit, find:

  c- I_{R1}, I_{R2}, I_{R3} & I_{R4}.



Series Parallel Circuits Example

- For the following circuit, find:
  - c- I_{R1}, I_{R2}, I_{R3} & I_{R4}.



The total current IT passes through R1 as well as through R4. Therefore:
IT = IR1 = IR4 = 1.333 mA.

RT1 = (R2 * R3)/(R2 + R3) = (10K * 15K)/(10K + 15K)
RT1 = 6K

At Node A, IT divides between the current through R2 & the Current through R3. The current division formula can be used to determine IR2 & IR3.
Notice that IR2 and IR3 would join at Node B to from the total current IT again.

Using the current division formula, we can determine the currents through R2 & R3.
The current division formula is given by:
IRx = (IT * RT1) / Rx, where this RT1 is the equivalent resistance of the parallel Combination seen by the total current which in this case the R2_3 that was calculated earlier as 6K.

IR2 = (IT * RT1) / R2 = (1.333 mA * 6K) / 10K = 0.8 mA.
IR3 = (IT * RT1) / R3 = (1.333 mA * 6K) / 15K = 0.5333 mA.

Series Parallel Circuits Example

- For the following circuit, find:
  d- V_{R1}, V_{R2}, V_{R3} & V_{R4}.

- Using Ohm's Law, $V_{Rx} = I_{Rx} \times Rx$, Therefore:
  - $V_{R1} = I_{R1} \times R1$ = 1.333 mA × 1K = 1.333 V
  - $V_{R2} = I_{R2} \times R2$ = 0.8 mA × 10K = 8V = V_{A-B}
  - $V_{R3} = I_{R3} \times R3$ = 0.533 mA × 15K = 8V = V_{A-B}
  - $V_{R4} = I_{R4} \times R4$ = 1.333 mA × 2K = 2.667V

- Check that $V_s = V_{R1} + V_{R4} + V_{A-B}$ = 1.333V + 2.667V + 8V = 12V = Vs

Series Parallel Circuits Example

- For the following circuit, find:

  e- The power consumed by R_1 , P_{R1}

  The power consumed or absorbed by a resistance is given by any of the following equations:

$$P_R = V_R \times I_R$$

$$P_R = \frac{V_R^2}{R}$$

$$P_R = I_R^2 \times R$$

- Where:
  - P_R is the power consumed by R.
  - V_R is the voltage across R.
  - I_R is the current through R.

Series Parallel Circuits Example

- For the following circuit, find:

  e- The power consumed by R_1 , P_{R1}

Using any of the equations stated earlier, the power consumed by the resistance R_1 or absorbed by it is given by:

$$P_R = V_R \times I_R = 1.333 \text{ mA} \times 1.333\text{V} = 1.7777 \text{ mW}$$

This Concludes the Series Parallel Circuits

Paramount Electronics Services

The Thevenin’s & Norton’s Equivalent

Thevenin's Equivalent Concepts

- Often when an external circuit component is connected to two point on a circuit (ex: a system), it is imperative to realize what voltage and what resistance are seen between those two points by that external component.

- In fact, there is a voltage and a resistance seen between any two points in the circuit.

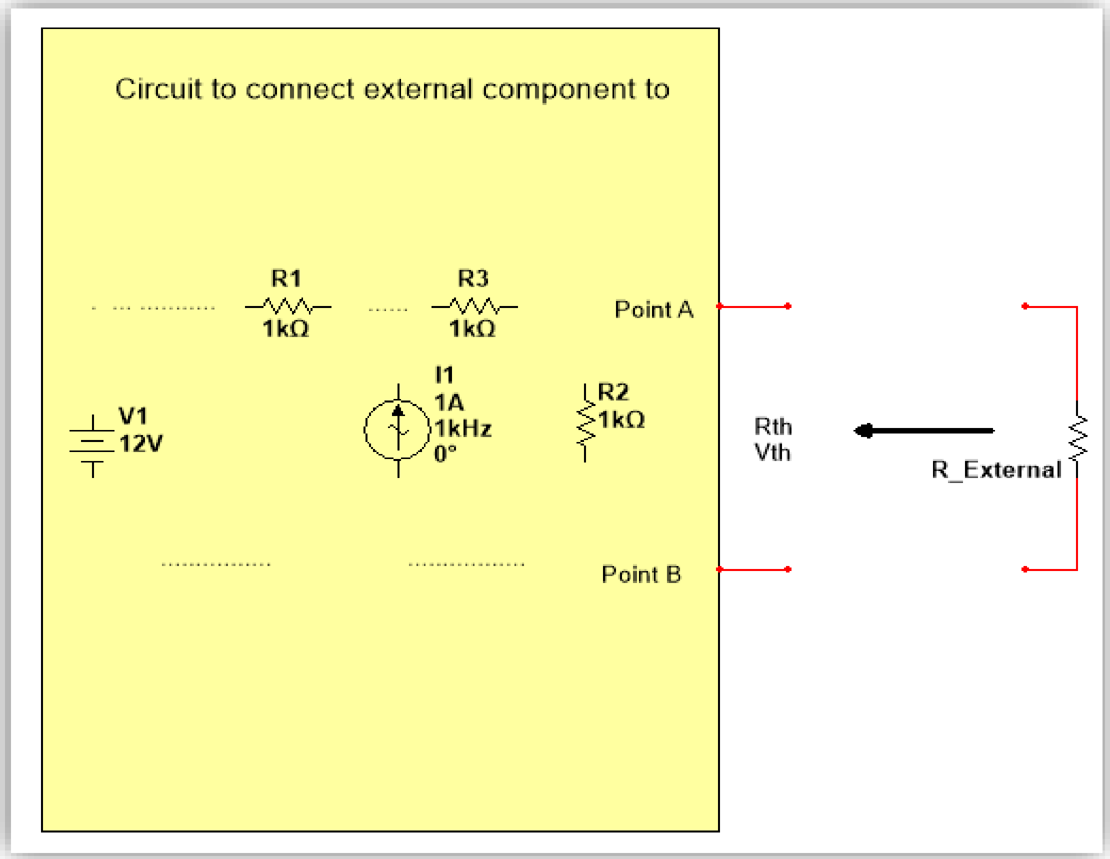
- The resistance and voltage seen between those two circuit points are called the Thevenin's equivalent between those two points, Vth & Rth.

- There is also the current equivalent of the thevenin's equivalent which is called the Norton Equivalent.

- The Norton equivalent is made of I-Norton (I_N)and R-Norton (R_N). Where I_N is represented by a current source that is in parallel with R_N and:
  - I_N = Vth / Rth &
  - R_N = Rth

Thevenin’s Equivalent Concepts

- Block diagram representation of a thevenin’s equivalent.

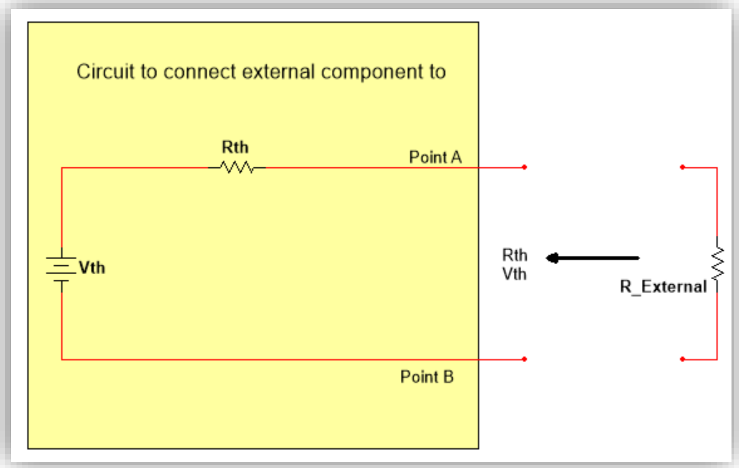


Circuit terms explained in later slide.

Thevenin’s & Norton’s Equivalent Concepts

Thevenin’s

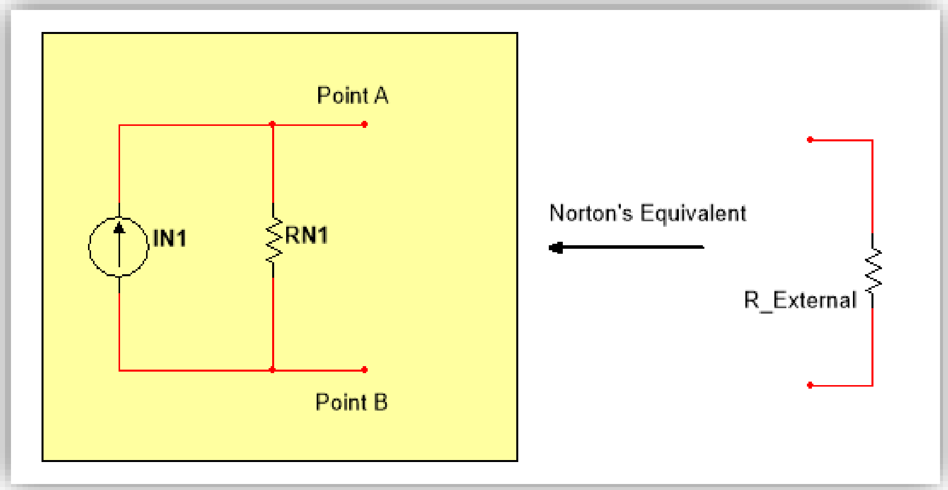
- The thevenin’s equivalent circuit.



Circuit terms explained in later slide.

Norton’s

- The Norton’s equivalent circuit:



I_N: Norton’s Current

R_N: Norton’s Resistance

$I_N = \frac{V_{TH}}{R_{TH}}$

$R_N = \text{Rth}$

Why Thevenin’s

- Some of the reasons why the thevenin’s equivalent is needed are:

  - The current that flows into the load connected to the circuit whose thevenin’s equivalent is determined would be known and based on that, the correct load with the correct power ratings can be determined.

  - Maximum power is transferred to the load if the value of the load is equal to the thevenin's resistance Rth. Examples of that are:
    - LAN segments are normally terminated by a 220 Ω resistance. This is because the thevenin’s resistance of the LAN segment has a value of 220 Ω. Therefore, maximum power transfer occurs.

    - TV antenna wires are connected to the TVs through two connectors on the back of the TV. One connector indicates 60 Ω and the other 75 Ω.
      - The 60 Ω is used for the VHF band (very high frequency). With those frequencies, the thevenin’s resistance of the antenna wires is equal to 60 Ω.
      - The 75 Ω is used for the UHF band (Ultra very high frequency). With those frequencies, the thevenin’s resistance of the antenna wires is equal to 75 Ω.

Thevenin's Equivalent Concepts

- R_External is the component that is to connect to two circuit point A & B.
- When finding the thevenin's equivalent, always disconnect the load which is in this case R_External.

- Between Points A & B, there are always:
  - Vth, which is the voltage seen between points A & B. Think of it as the voltage reading you get when you connect a voltmeter across points A & B.

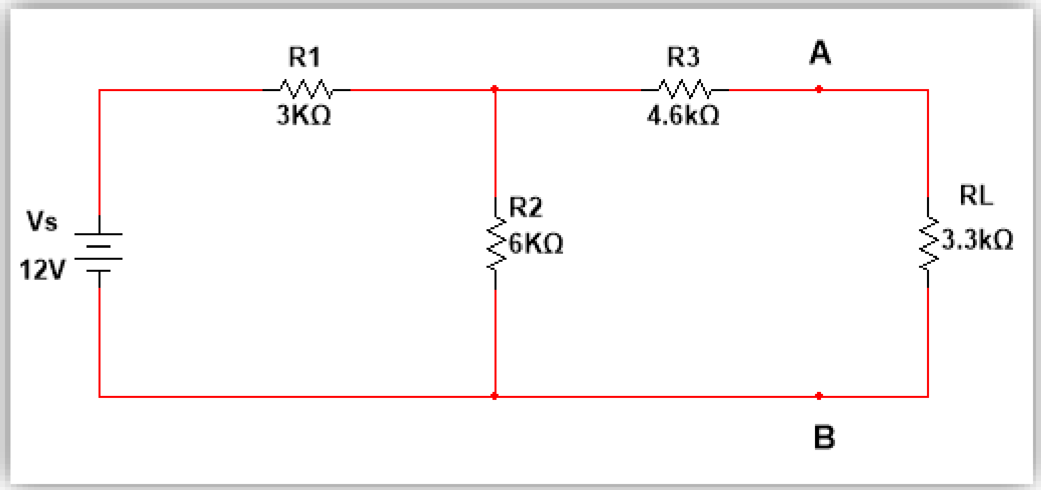
  - Rth, which is the resistance seen between points A & B. Think of it as the resistance reading you get when you connect an ohmmeter across points A & B with all the power sources replaced by their internal resistances. **When calculating Rth, all sources must be replaced by their internal resistances. There should no actual voltage sources or current sources in the circuit.**

  - **When calculating Rth:**
    - **The internal resistance of a voltage source is ideally 0, therefore the voltage source is replaced by a short circuit.**

    - **The internal resistance of a current source is ideally infinity; therefore, the current source is replaced by an open circuit.**

Thevenin's Equivalent With A Voltage Source Example

- For the following circuit:
  - a- Find the Thevenin's Resistance Rth seen by RL.
  - b- Find the Thevenin's Voltage Vth seen by RL.
  - c- Draw the thevenin's and the Norton's circuits including RL.
  - d- Use the thevenin's circuit to calculate the power delivered to the load resistance RL.
  - e- Is that the maximum power, if not, what is the maximum power that can be transferred?



Thevenin's Equivalent With A Voltage Source Example

a- Find the thevenin's resistance R_{TH} seen by R_L.

- When finding the thevenin's equivalent seen by an element across any two points, the element connected to those two points is to be disconnected.

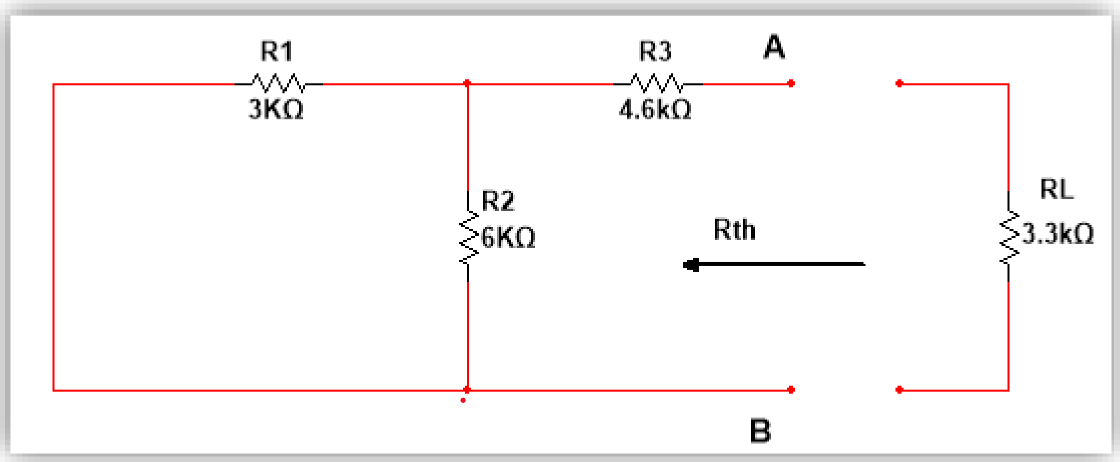
- In addition, when finding R_{TH}, all voltage sources are to be replaced by shorts & all current sources are to be replaced by opens.

Thevenin's Equivalent With A Voltage Source Example

a- Find the thevenin's resistance R_{TH} seen by R_L.

Finding R_{TH}:

- Disconnect the load resistance R_L and replace the voltage source by a short circuit. Then looking into the circuit calculate the total resistance seen between points A & B. That is R_{TH}.

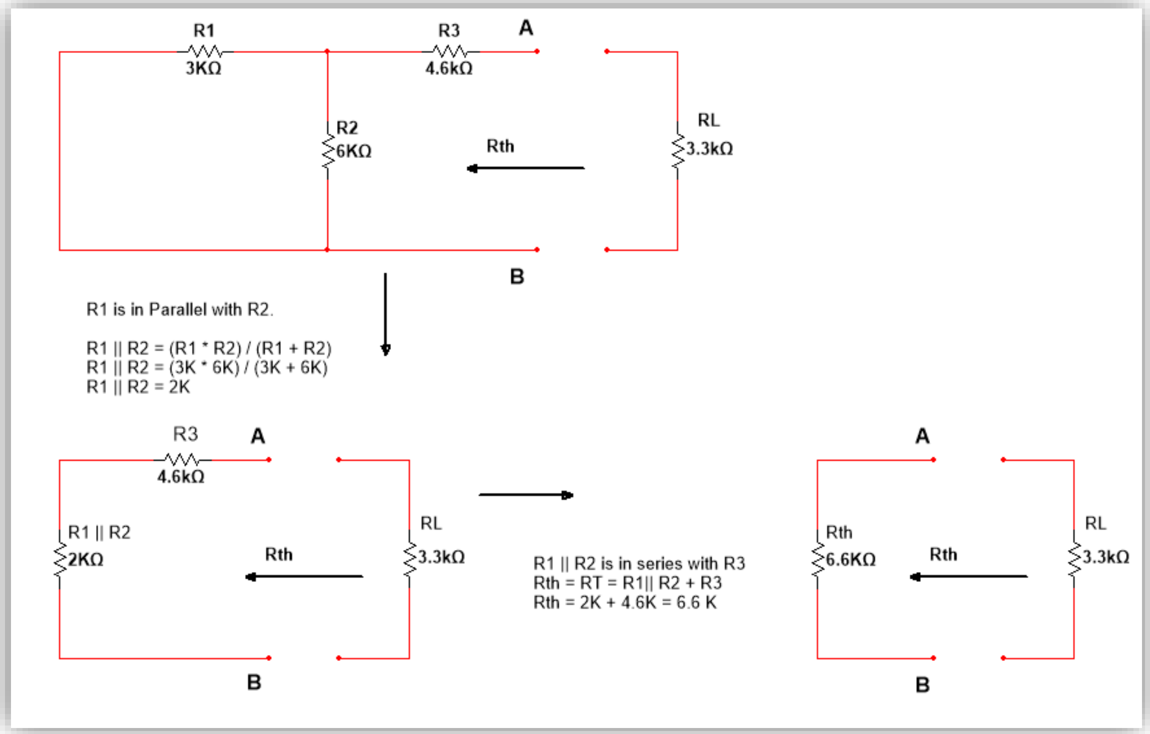


Thevenin's Equivalent With A Voltage Source Example

a- Find the thevenin's resistance R_{TH} seen by R_L.

Finding R_{TH}:

- Use the concepts of series and parallel resistances to end up with a total resistance called Rth as indicated below.



Thevenin’s Equivalent With A Voltage Source Example

b- Find the thevenin’s voltage V_{TH} seen by R_L.

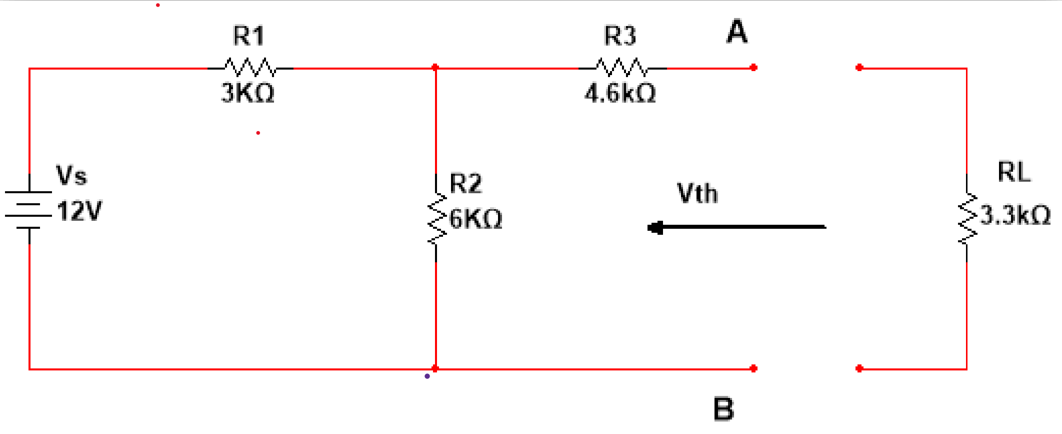
Finding V_{TH}:

- With the load resistance still disconnected, the voltage value between points A & B is V_{TH}. V_{TH} is calculated using any of the circuits analysis techniques discussed thus far.
- Also, the voltage source is replaced back into the circuit.

Thevenin's Equivalent With A Voltage Source Example

b- Find the thevenin's voltage V_{TH} seen by R_L.

Finding V_{TH}:



Vth is the sum of the voltages across R3 and the voltage across R2.
There is no current flowing through R3 since it is an open circuit. Therefore VR3 = 0.

The fact that R3 is an open circuit leaves the notion that the voltage source Vs sees R1 & R2 in series. Therefore, the voltage division formula can be applied to find the voltage across R2.

VR2 = (Vs * R2) / (R1 + R2)
VR2 = (12V * 6K) / (3K + 6K) = 8V

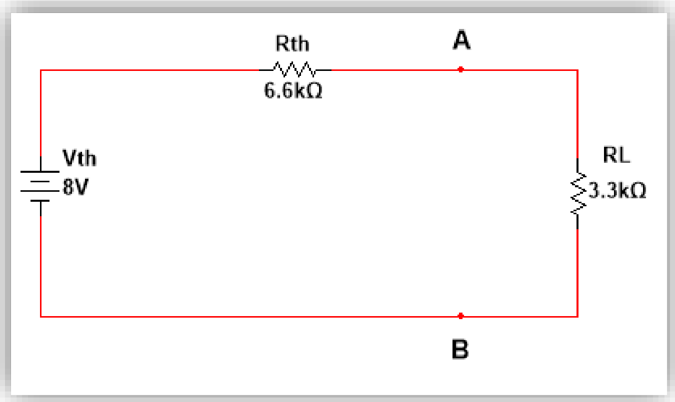
Therefore Vth = VR2 + VR3 = 8V + 0V = 8V

Thevenin's Equivalent With A Voltage Source Example

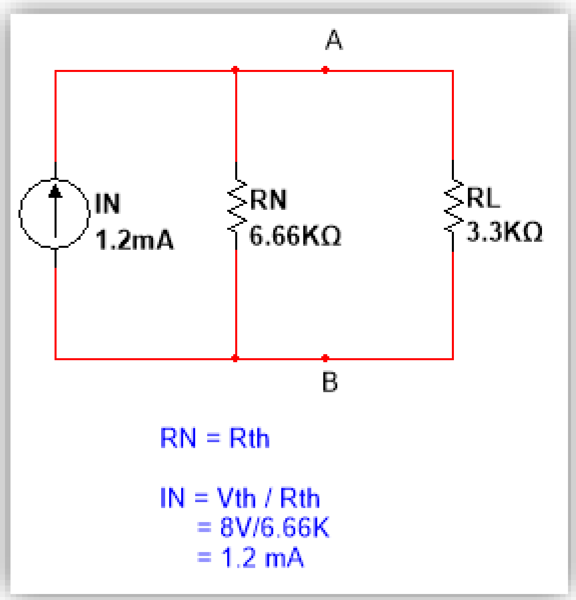
c- Draw the Thevenin's and the Norton's circuits including RL.

- The following circuit shows the thevenin's & the Norton's equivalent circuits respectively with R_L included.

Thevenin's

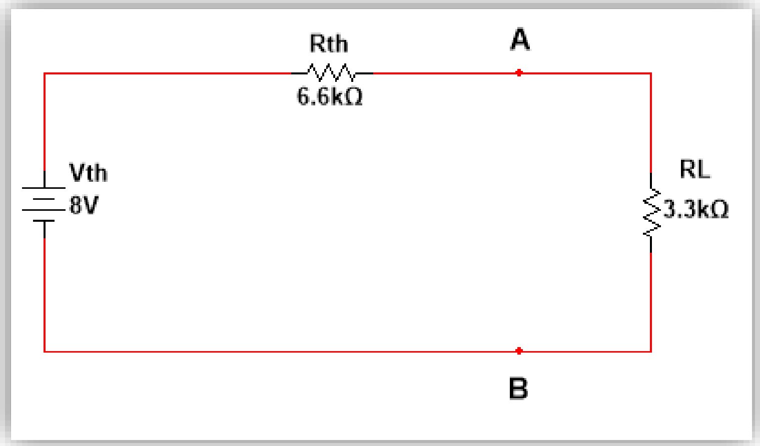


Norton's



Thevenin's Equivalent With A Voltage Source Example

- d- Using the thevenin's circuit calculate the power delivered to the load resistance R_L.
- The Power delivered and consumed by R_L is given by any of the following equations:
  - $P_{RL} = V_{RL} \times I_{RL} = \frac{V_{RL}^{\ 2}}{R_L} = I_{RL}^{\ 2} \times R_L$
  - The thevenin's circuit shows that R_{TH} and R_L are in series with each other. Therefore, using voltage division:
  - $V_{RL} = \frac{V_T \times R_L}{(R_{TH+} R_L)} = \frac{8V \times 3.3K}{(6.6K + 3.3K)} = 2.667\text{V}$
  - $P_{RL} = \frac{V_{RL}^{\ 2}}{R_L} = \frac{2.66V^2}{3.3K} = 2.155 \text{ mW}$



Thevenin's Equivalent With A Voltage Source Example

e- Is that the maximum power, if not, what is the maximum power that can be transferred?

- This is not the maximum power delivered. The maximum power delivered and consumed by RL only occurs when the value of RL is equal to Rth. The maximum power can then be determined by any of the following equations:

- $P_{RL} = V_{RL} \times I_{RL} = \frac{V_{RL}{}^2}{R_L} = I_{RL}{}^2 \times R_L$

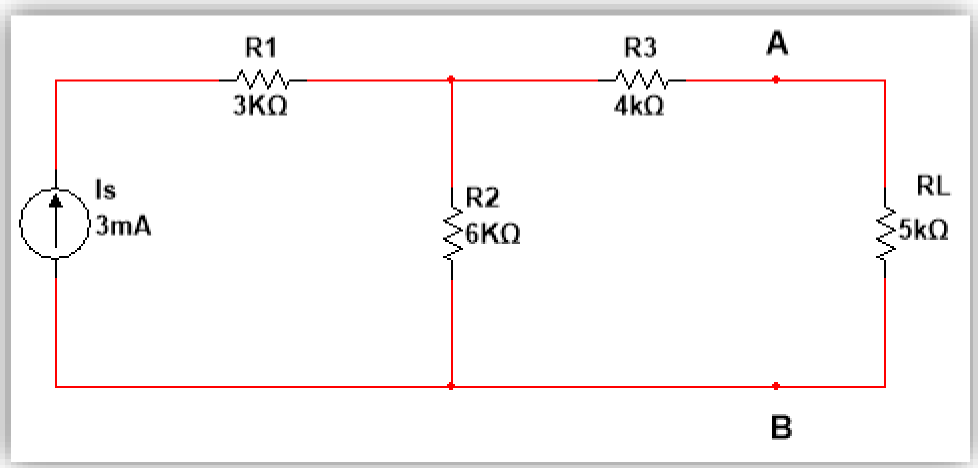
- The thevenin's circuit shows that Rth and RL are in series with each other. Assuming that RL is equal to Rth and using voltage division:

- $V_{RL} = \frac{V_T \times R_L}{(R_{TH+} R_L)} = \frac{8V \times 6.6K}{(6.6K+6.6K)} = 4\text{V}$

- $P_{RL} = \frac{V_{RL}{}^2}{R_L} = \frac{4V^2}{6.6K} = 2.42\text{ mW}$

Thevenin’s Equivalent With A Current Source Example

- For the following circuit:
  - a- Find the Thevenin’s Resistance R_{TH} seen by R_L.
  - b- Find the Thevenin’s Voltage V_{TH} seen by R_L.
  - c- Draw the thevenin's circuits including R_L.



Thevenin's Equivalent With A Current Source Example

a- Find the Thevenin's Resistance R_{TH} seen by R_L.

- When finding the thevenin's equivalent seen by an element across any two points, the element connected to those two points is to be disconnected.

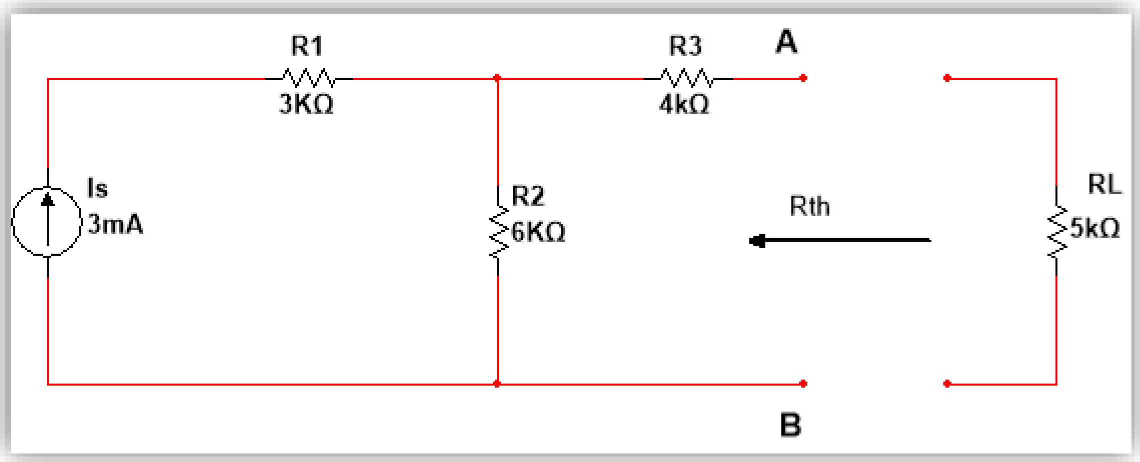
- In addition, when finding Rth, all voltage sources are to be replaced by shorts & all current sources are to be replaced by opens.

Thevenin's Equivalent With A Current Source Example

a- Find the Thevenin's Resistance R_{TH} seen by R_L.

Finding R_{TH}:

- Disconnecting R_L to obtain:

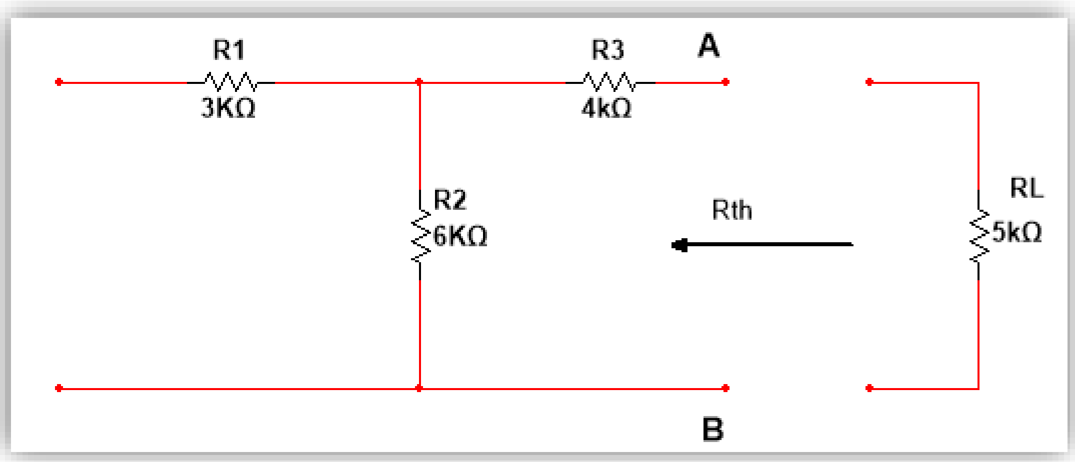


Thevenin's Equivalent With A Current Source Example

a- Find the Thevenin's Resistance R_{TH} seen by R_L.

Finding R_{TH}:

- Replacing the current source with an open circuit to obtain:

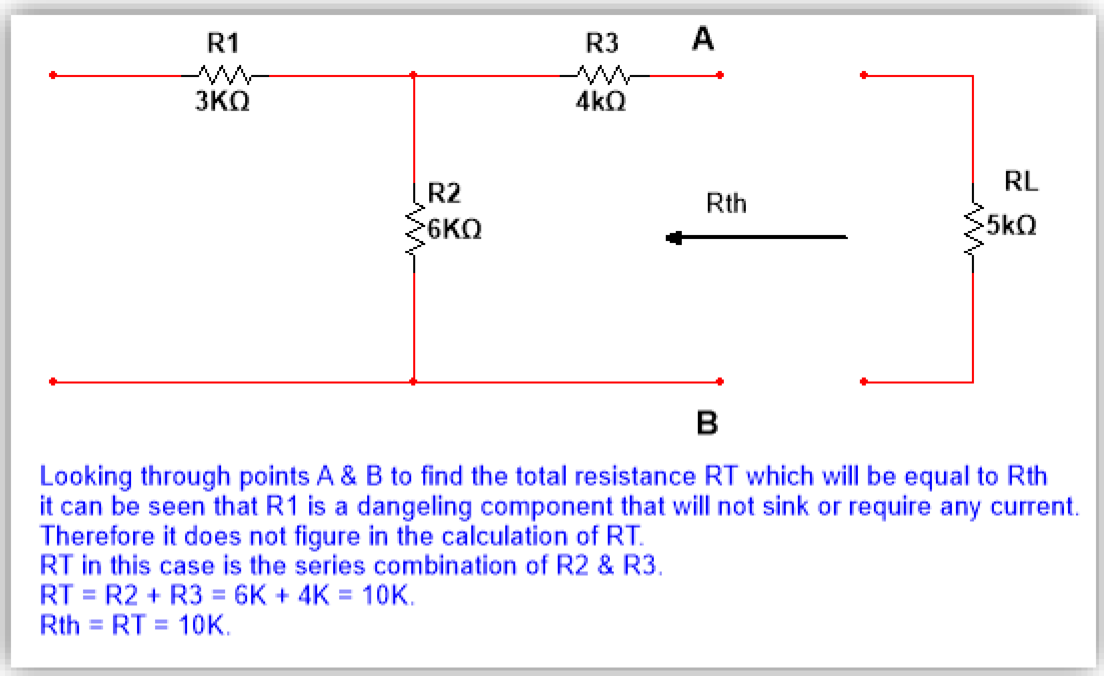


Thevenin's Equivalent With A Current Source Example

a- Find the Thevenin's Resistance R_{TH} seen by R_L.

Finding R_{TH}:

- Use the concepts of series and parallel resistances to end up with a total resistance called Rth as indicated below.

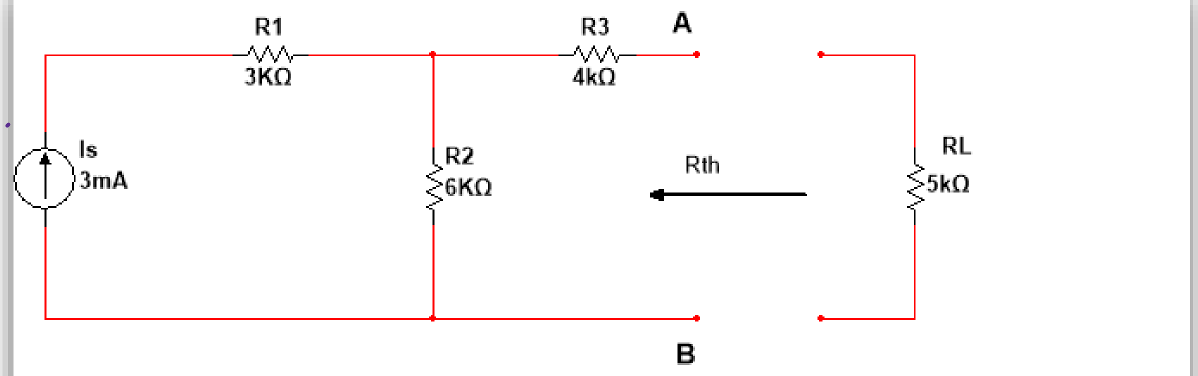


Thevenin's Equivalent With A Current Source Example

b- Find the Thevenin's Voltage V_{TH} seen by R_L.

Finding V_{TH}:

- With the load resistance still disconnected, the voltage value between point A & B is V_{TH}. It is calculated using any of the circuits analysis techniques discussed thus far.



Looking through points A & B, Vth is tyhe sum of the voltages seen between points A & B. Therefore:
Vth = VR3 + VR2.
Since R3 is a dangeling element as far as Is is concerned, it does not have any current passing through ot and the voltage across it is equal to 0.

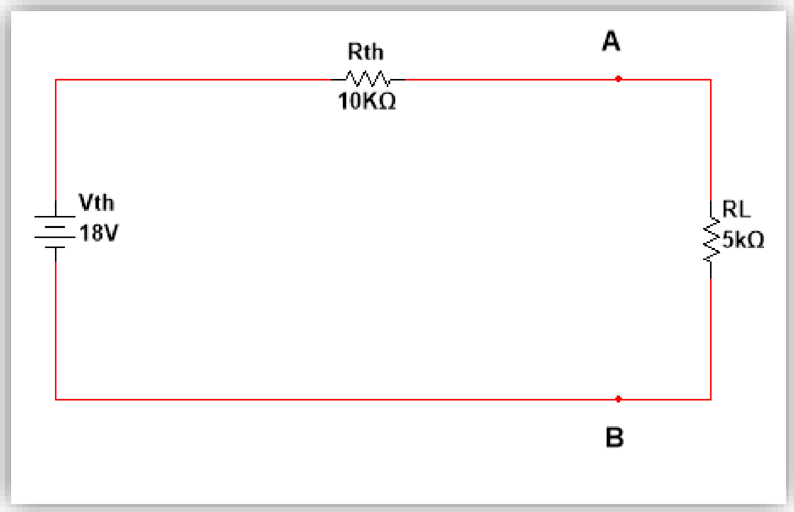
The current Is will then only pass through R1 & R2. This implies that the voltage across R2 is given by:
VR2 = Is * R2 = 3mA * 6K = 18V.

Therefore:
Vth = VR2 + VR3 = 18V + 0V = 18V.

Thevenin's Equivalent With A Current Source Example

c- Draw the thevenin's circuits including R_L.

- The following circuit shows the thevenin's equivalent circuit with RL reconnected.



This Concludes the Thevenin’s & Norton’s Equivalent

Paramount Electronics Services

The Wheatstone Bridge

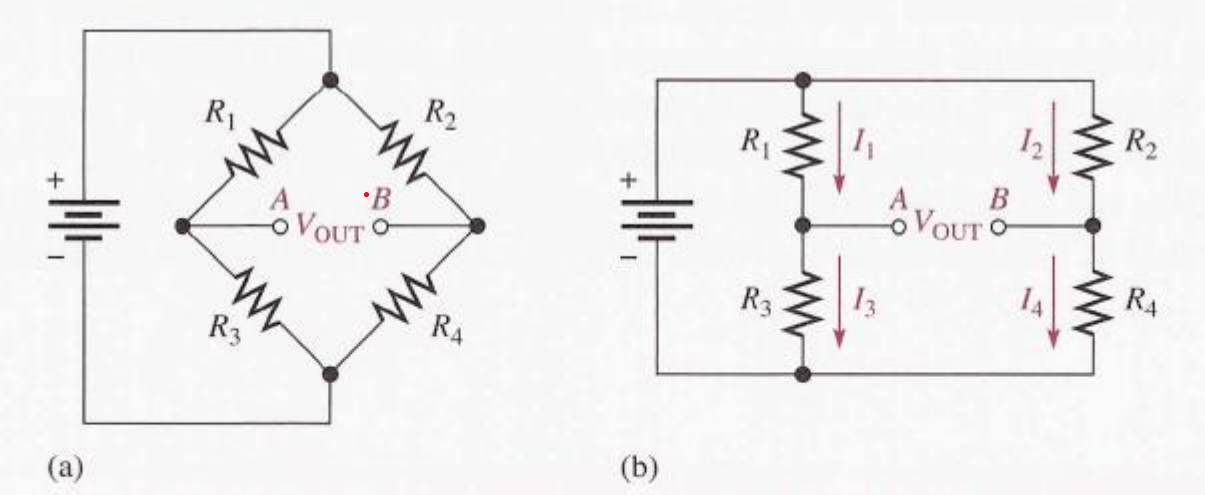
The Wheatstone bridge

- The Wheatstone bridge **circuit** is widely used to precisely measure resistance. Also, the bridge is used in conjunction with transducers to measure physical quantities such as strain, temperature, and pressure.
- Transducers are devices that sense a change in a physical parameter and convert that change into an electrical quantity such as a change in resistance or voltage.
- For example, a strain gauge exhibits a change in resistance when it is exposed to mechanical factors such as force, pressure, or displacement.
- A thermistor exhibits a change in its resistance when it is exposed to a change in temperature.
- The Wheatstone bridge is basically designed based on the concept of it being **balanced** or **nulled**.

The Wheatstone bridge

- A Wheatstone Bridge circuit is shown in its most common "diamond" configuration as shown in figure (a). It consists of four resistors, a voltage source connected across the top and bottom points of the "diamond". The output voltage is taken across the left and right points of the "diamond" between A and B.

- In figure (b), the circuit is drawn in a slightly different manner to clearly show its series-parallel configuration.



The Balanced or Nulled Wheatstone bridge

- The Wheatstone bridge is in the **balanced bridge** condition when the output voltage (V_{OUT}) between terminals A and B is equal to zero, $V_{OUT} = 0$ V.

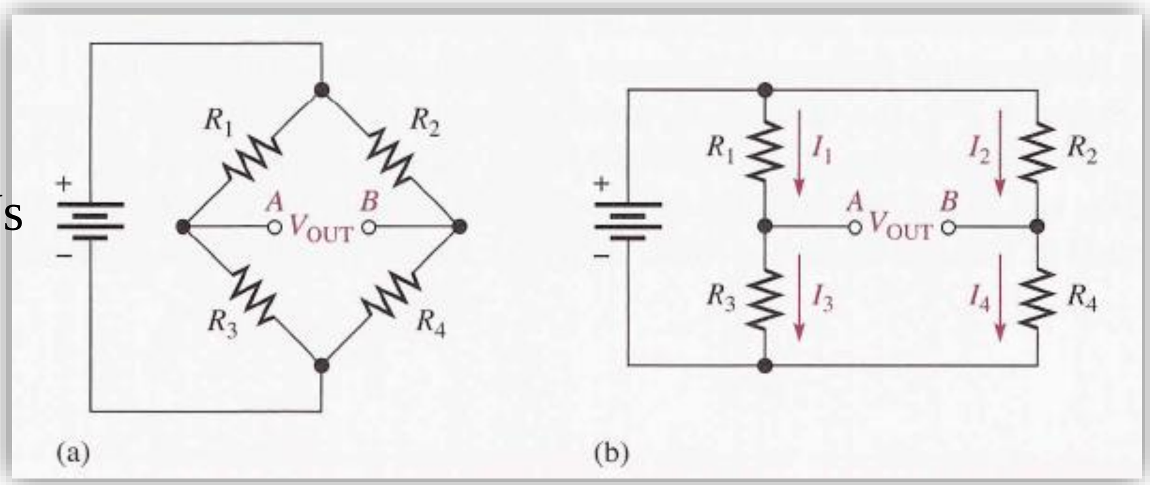
- When the bridge is balanced, the voltages across R_1 and R_2 are equal ($V_{R1} = V_{R2}$) and the voltages across R_3 and R_4 are equal ($V_{R3} = V_{R4}$) Therefore, the voltage ratios can be written as:
- $\frac{V_{R1}}{V_{R3}} = \frac{V_{R2}}{V_{R4}}$
- $\frac{I_{R1} \times R_1}{I_{R3} \times R_3} = \frac{I_{R2} \times R_2}{I_{R4} \times R_4}$
- Since $I_{R1} = I_{R3}$ & $I_{R2} = I_{R4}$, then the above formula reduces to: $\frac{R_1}{R_3} = \frac{R_2}{R_4}$
- Therefore, the bridge is said to be balanced or nulled when the ratio of $\frac{R_1}{R_3}$ is equal to the ratio of $\frac{R_2}{R_4}$.

The Wheatstone bridge General Equations

- The Wheatstone bridge output voltage is the voltage between points A & B. This is the voltage that is used as the basis of finding variations in quantities such as temperature, pressure, flow rate, etc.
- The voltage at point A, V_A is determined by using the voltage division formula, where V_S is divided between R_1 & R_3 where V_A is the voltage across R_3 . Therefore:

$$V_A = V_{R3} = \frac{V_S \times R_3}{R1+R3}$$

Vs



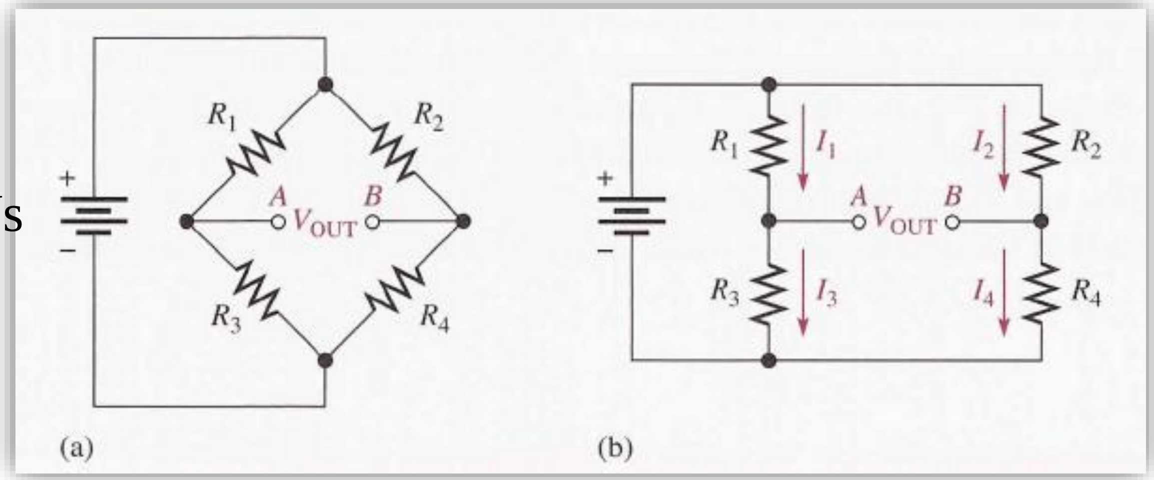
Ref Point Ref Point

The Wheatstone bridge General Equations

- The Wheatstone bridge output voltage is the voltage between points A & B. This is the voltage that is used as the basis of finding variations in quantities such as temperature, pressure, flow rate, etc.
- The voltage at point A, V_A is determined by using the voltage division formula, where V_S is divided between R_1 & R_3 where V_A is the voltage across R_3 . Therefore:

$$V_B = V_{R4} = \frac{V_S \times R_4}{R2+R4}$$

Vs



Ref Point Ref Point

The Wheatstone bridge General Equations

- The Wheatstone bridge output voltage is the voltage between points A & B. This is the voltage that is used as the basis of finding variations in quantities such as temperature, pressure, flow rate, etc.

$$V_{A-B} = V_A - V_B$$

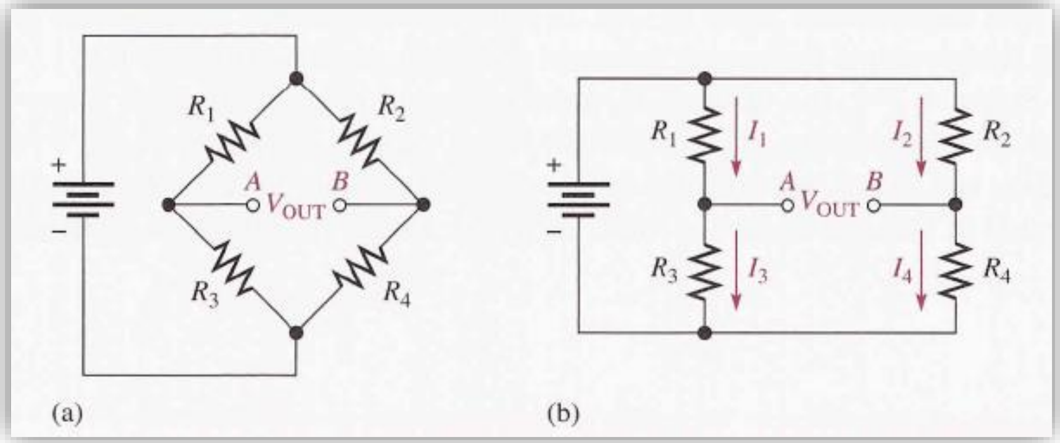
- When the bridge is balanced, the value of $V_{out} = V_{A-B} = 0$.
- When the bridge is unbalanced, the value of $V_{out} = V_{A-B}$ could be either positive or negative.

The Wheatstone bridge General Equations

- The value of V_{out} can also be given by the following equation:

$$V_{A-B} = V_{out} = V_S \frac{R_3 R_2 - R_1 R_4}{(R_1 + R_3)(R_2 + R_4)}$$

Vs



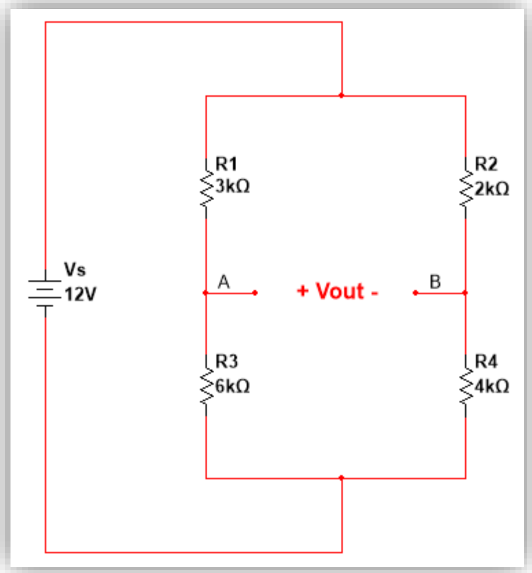
Balanced Wheatstone bridge Example1

- For the following Wheatstone bridge:

a- Is the bridge balanced?

b- What are the values of the voltages at point A, V_A & at point B, V_B?

c- What is the value of the voltage between points A & B, V_{A-B} ?



Wheatstone bridge Example1

- For the following Wheatstone bridge:

a- Is the bridge balanced?

- For the bridge to be balanced or nulled the ratio of $\frac{R_1}{R_3}$ must be equal to the ratio of $\frac{R_2}{R_4}$.

$$\frac{R_1}{R_3} = \frac{3K}{6K} = \frac{1}{2}$$

$$\frac{R_2}{R4} = \frac{2K}{4K} = \frac{1}{2}$$

- The two ratios are equal which indicates that the bridge is balanced or nulled.

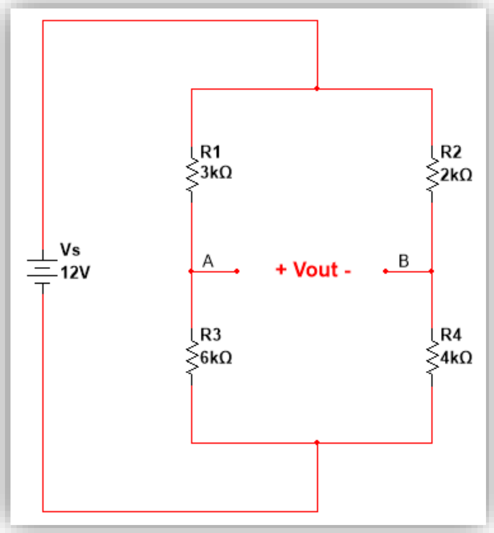
Wheatstone bridge Example1

- For the following Wheatstone bridge:

b- What are the values of the voltages at point A, V_A & at point B, V_B?

$$V_A = V_{R3} = \frac{V_S \times R_3}{R1+R3} = \frac{12V \times 6K}{3K+6K} = 8\text{V}$$

$$V_B = V_{R4} = \frac{V_S \times R_4}{R2+R4} = \frac{12V \times 4K}{2K+4K} = 8\text{V}$$



Wheatstone bridge Example1

- For the following Wheatstone bridge:

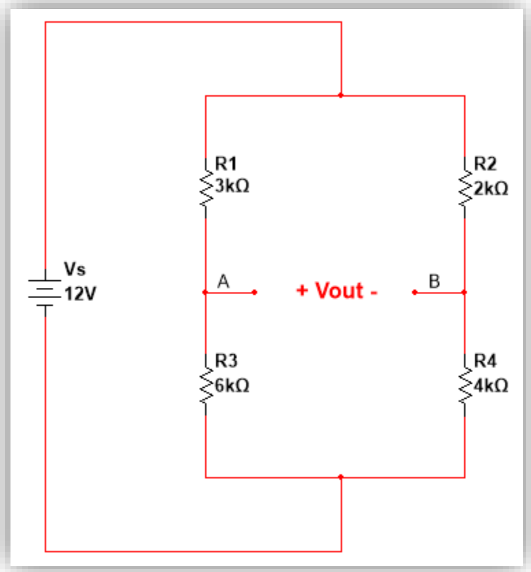
c- What is the value of the voltage between points A & B, V_{A-B} ?

- The value of V_{A-B} or V_{out} can be given by:

$$V_{A-B} = V_A - V_B = 8\text{V} - 8\text{V} = 0\text{V}$$

- Also, it can be given by:

$$V_{out} = V_s \frac{R_3 R_2 - R_1 R_4}{(R_1 + R_3)(R_2 + R_4)} = 12\text{V} \times \frac{6K\,.\,2K - 3K.\,4K}{(3K+6K)(2K+4K)} = 0\text{V}$$



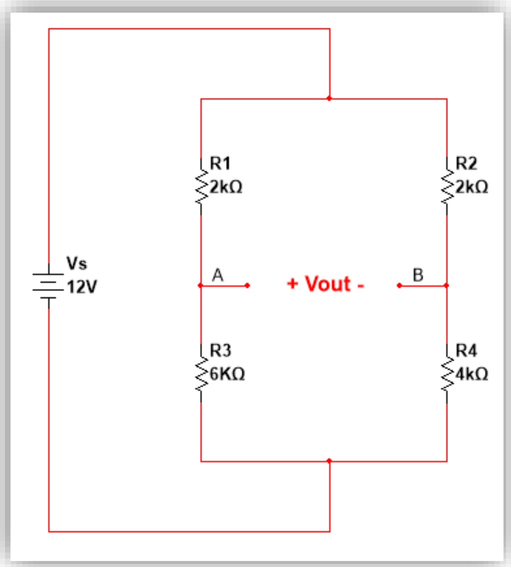
Unbalanced Wheatstone bridge Example2

- For the following Wheatstone bridge:

a- Is the bridge balanced?

b- What are the values of the voltages at point A, V_A & at point B, V_B?

c- What is the value of the voltage between points A & B, V_{A-B} ?



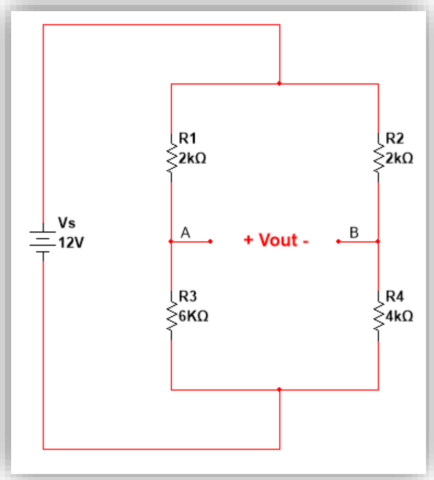
Unbalanced Wheatstone bridge Example2

- For the following Wheatstone bridge:
- Is the bridge balanced?
- For the bridge to be balanced or nulled the ratio of $\frac{R_1}{R_3}$ is equal to the ratio of $\frac{R_2}{R_4}$.

$$\frac{R_1}{R_3} = \frac{2K}{6K} = \frac{1}{3}$$

$$\frac{R_2}{R4} = \frac{2K}{4K} = \frac{1}{2}$$

- The two ratios are not equal which indicates that the bridge is not balanced or not nulled.



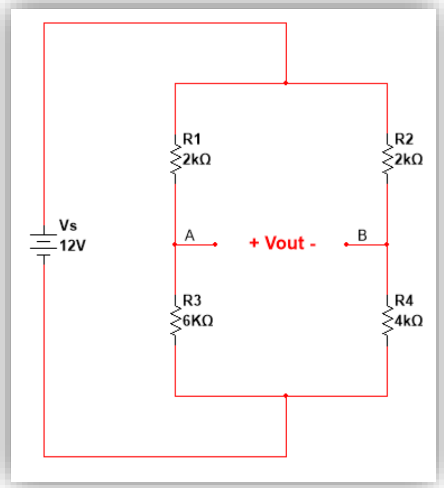
Unbalanced Wheatstone bridge Example2

- For the following Wheatstone bridge:

b- What are the values of the voltages at point A, V_A & at point B, V_B?

$$V_A = V_{R3} = \frac{V_S \times R_3}{R1+R3} = \frac{12V \times 6K}{2K + 6K} = 9\text{V}$$

$$V_B = V_{R4} = \frac{V_S \times R_4}{R2+R4} = \frac{12V \times 4K}{2K+4K} = 8\text{V}$$



Unbalanced Wheatstone bridge Example2

- For the following Wheatstone bridge:

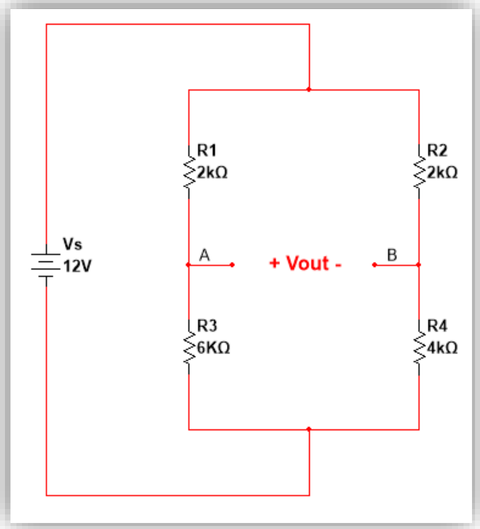
c- What is the value of the voltage between points A & B, V_{A-B} ?

- The value of V_{A-B} or V_{out} can be given by:

$$V_{A-B} = V_A - V_B = 9V - 8V = 1V$$

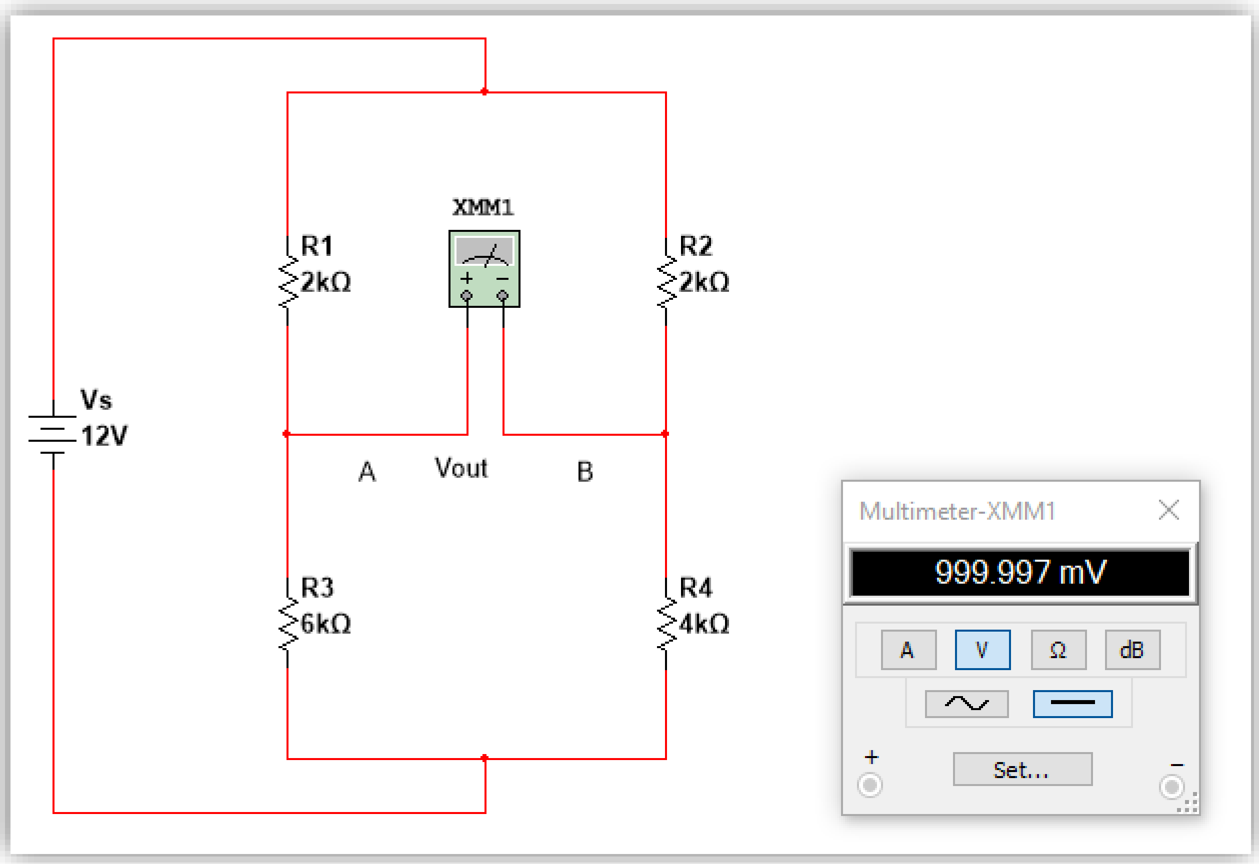
- Also, it can be given by:

$$V_{out} = V_s \frac{R_3 R_2 - R_1 R_4}{(R_1 + R_3)(R_2 + R_4)} = 12V \frac{6K \,.\, 2K - 2K \,.\, 4K}{(2K+6K)(2K+4K)} = 1V$$



Unbalanced Wheatstone bridge Example2 Simulation Results

- The following shows the Multisim simulation results for the unbalanced Wheatstone bridge.



The Unbalanced Wheatstone bridge

- The unbalanced bridge, is used to measure several types of physical quantities such as mechanical strain, temperature, or pressure.

- This can be done by connecting a transducer (Temperature sensor, pressure sensor or strain gauge sensor) in one leg of the bridge.

- The changes of the resistance/voltage of the transducer is proportional to the physical changes in the parameter that it being measured (such as mechanical strain, temperature, or pressure).

- The bridge is balanced at a known point (such as room temperature). The amount of deviation from the balanced condition, as indicated by the output voltage, indicates the amount of change in the parameter being measured (which is the temperature).

- Therefore, the value of the parameter being measured can be determined by the voltage amount that indicates the bridge is unbalanced.

A Bridge Circuit For Measuring Temperature

- If the temperature to be measured, the transducer can be a thermistor, which is a temperature-sensitive resistor.

- The thermistor resistance changes in a predictable way as the temperature changes.

- A change in temperature causes a change in thermistor resistance, which causes a corresponding change in the output voltage of the bridge as it becomes unbalanced.

- The output voltage is proportional to the temperature; therefore, either a voltmeter that is connected across the output, can be calibrated to show the temperature of the element being measured, or:

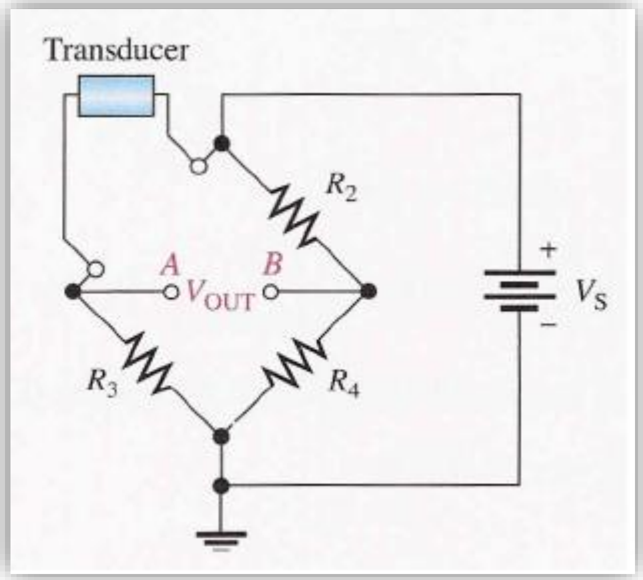
- The output voltage can be amplified and converted to digital form that is fed into a microcontroller to drive a temperature readout display.

A Bridge Circuit For Measuring Temperature

- Bridge circuit showing how a temperature sensor (transducer) is connected.

- The temperature sensor exhibits a certain resistance value that is dependent on its temperature

- The concept behind using the temperature sensor as one leg of the Wheatstone bridge is to balance the bridge at a certain temperature T_{null}. This is done by using a variable resistance in place of R_3.
- R_3 is then varied while monitoring the output voltage V_{out} until the value of vout is equal to zero.

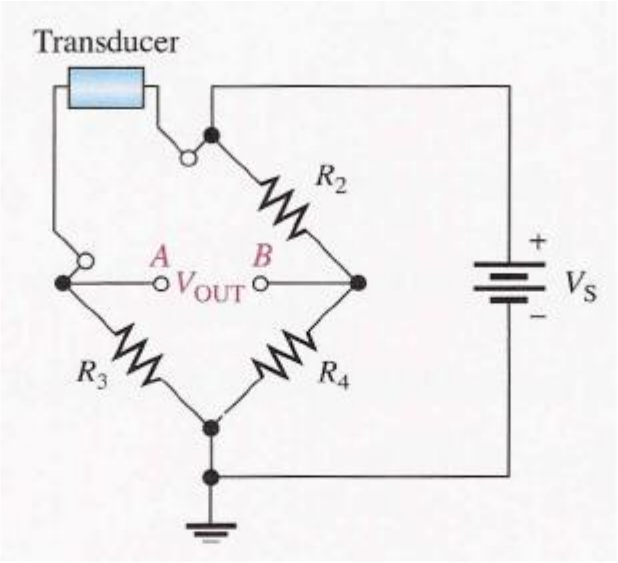


The transducer can also be a
fluid flow sensor, pressure sensor,
Strain gauge sensor, light sensor, etc.

A Bridge Circuit For Measuring Temperature

- Once the bridge is balanced, a change in temperature causes V_{out} to change. That voltage is conditioned and then fed into a microcontroller where a high-level language program is written to read the changes in the output voltage of the bridge circuit.

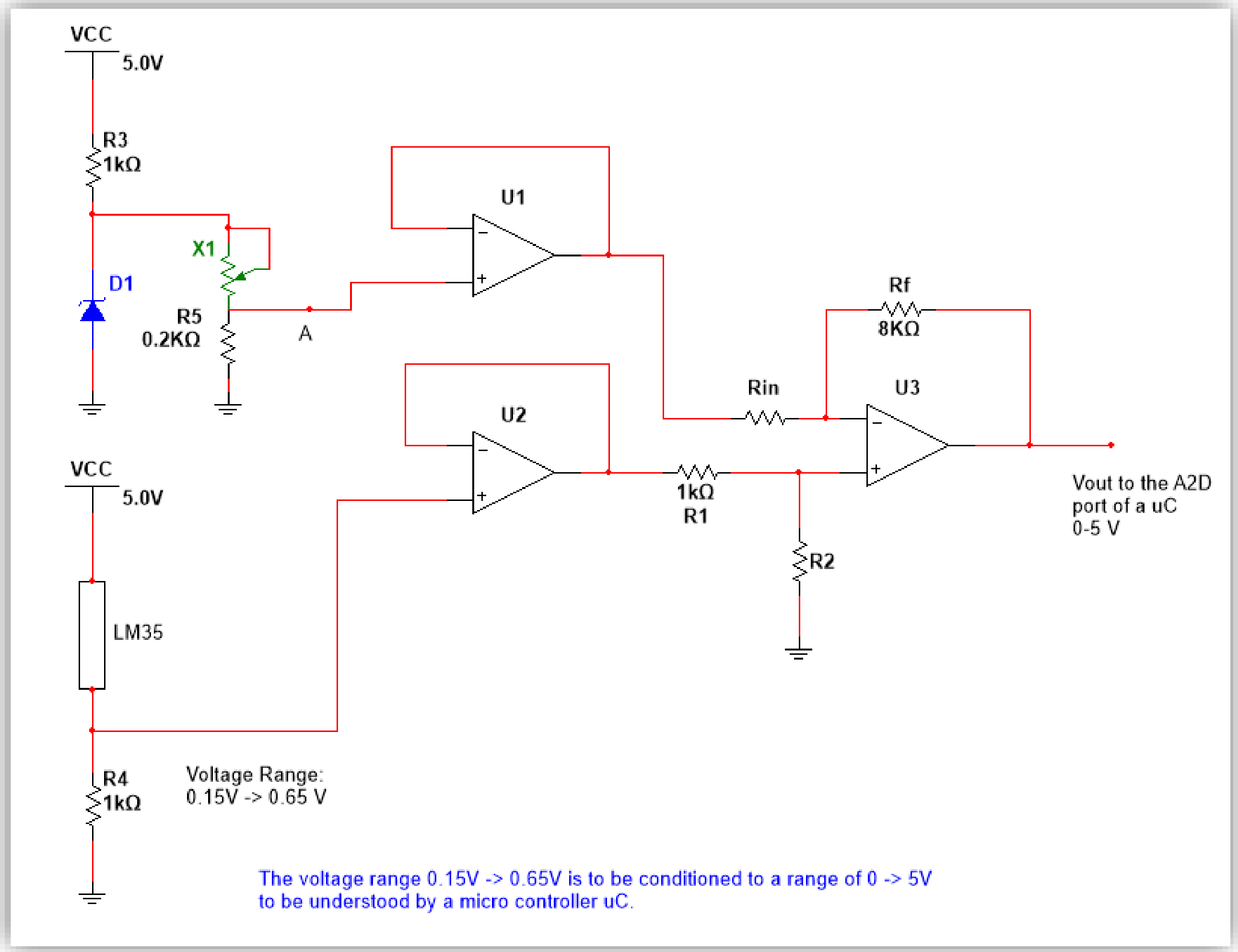
- The change will then be translated into an index position of an array that holds temperature values to be displayed as well as used to either activate a furnace or an air condition unit based on the setting of the thermistor temperature controller.



The transducer can also be a
fluid flow sensor, pressure sensor,
Strain gauge sensor, light sensor, etc.

A Conditioning Circuit

- You are not responsible for this. It is just here to show you how a conditioning circuit looks like.



This Concludes the Wheatstone Bridge Circuit

Paramount Electronics Services

The Superposition Principal

Superposition Concepts

- Often there is more than one power source in the circuit which could be in any combination of voltage and current sources.
- All elements in a circuit including the power sources have voltages across them in addition to currents passing through it.
- Given that the circuit is linear, then the value of that voltage or current is the sum of multiple responses where each response is due to one of the power sources in the circuit.
- For example, if there are two power sources in the circuit, then the volage across a certain resistance is the sum of two voltage responses, one due to each source.

Superposition Concepts

- For example, in a certain circuit that contains a voltage source and a current source, the voltage across a resistance R_x in the circuit is the sum of:

- V_{Rx1} and V_{Rx2} , where:
  - V_{Rx1} is the voltage across R_x due to the voltage source.
  - V_{Rx2} is the voltage across R_x due to the current source.

- When calculating the value of V_{Rx1} which is due to the voltage source, only the voltage source should be considered in the circuit while getting rid (discarding) of the current source.

- When calculating the value of V_{Rx2} which is due to the current source, only the current source should be considered in the circuit while getting rid (discarding) of the voltage source.

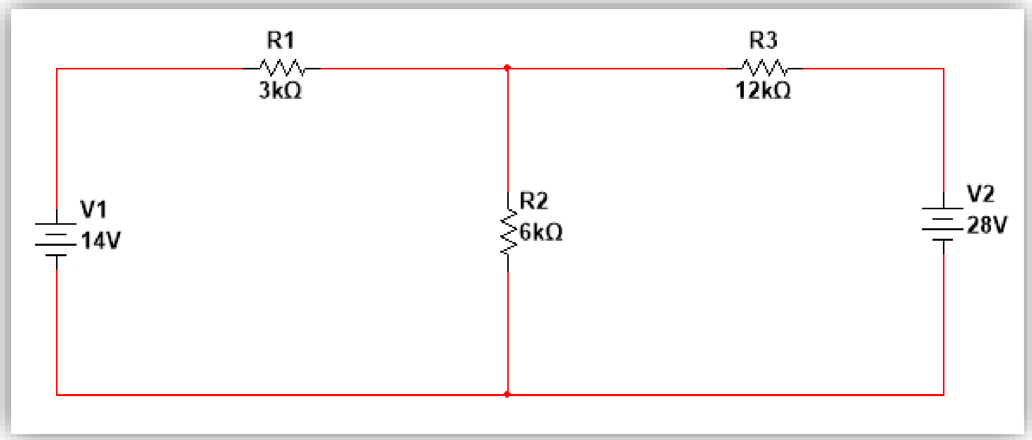
- To get rid of a voltage source, it is replaced by its internal resistance which is 0, **therefore a voltage source is replaced by a short circuit.**

- To get rid of a current source, it is replaced by its internal resistance which is theoretically infinity, **therefore a current source is replaced by an open circuit**.

Two Voltage Sources Superposition Example1

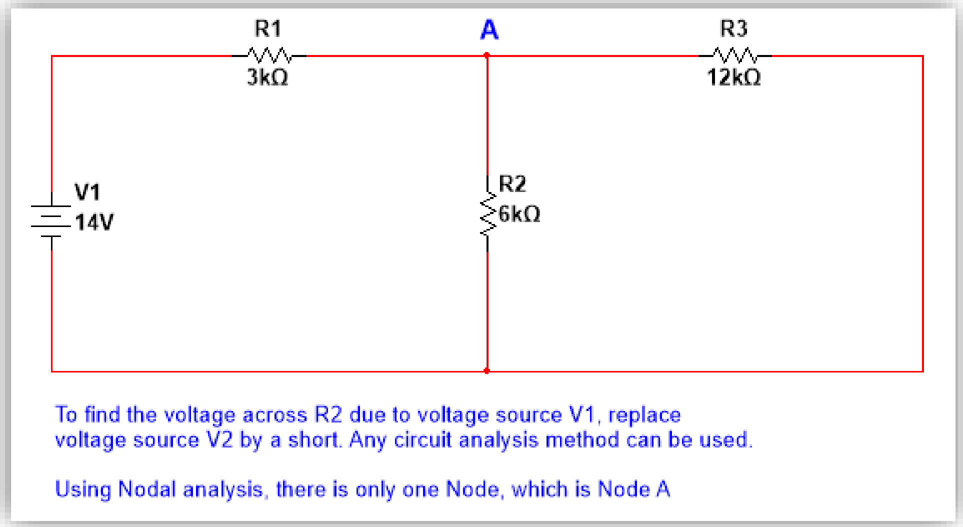
- For the following circuit, find the voltage across R_2 using the Superposition principal.

- the voltage across R_2 is the sum of:
  - V_{Rx1} and V_{Rx2} , where:
    - V_{Rx1} is the voltage across R_2 due to the voltage source V_1 .
    - V_{Rx2} is the voltage across R_2 due to the voltage source V_2 .



Two Voltage Sources Superposition Example1

- Finding the voltage V_{Rx1} :
- The voltage V_{Rx1} is the voltage across R_2 due to voltage source V_1 , therefore voltage source V_1 will be the only one considered in the circuit and voltage source V_2 should be replaced by a short circuit. The resulting circuit is:

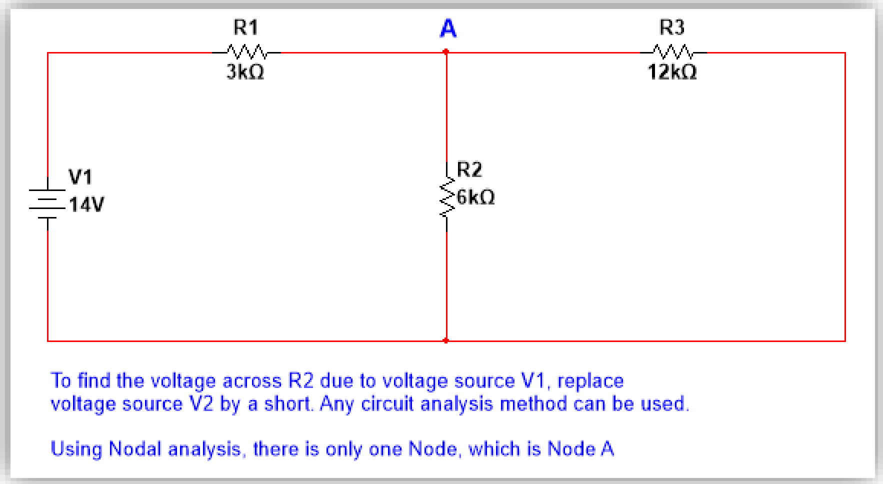


Two Voltage Sources Superposition Example1

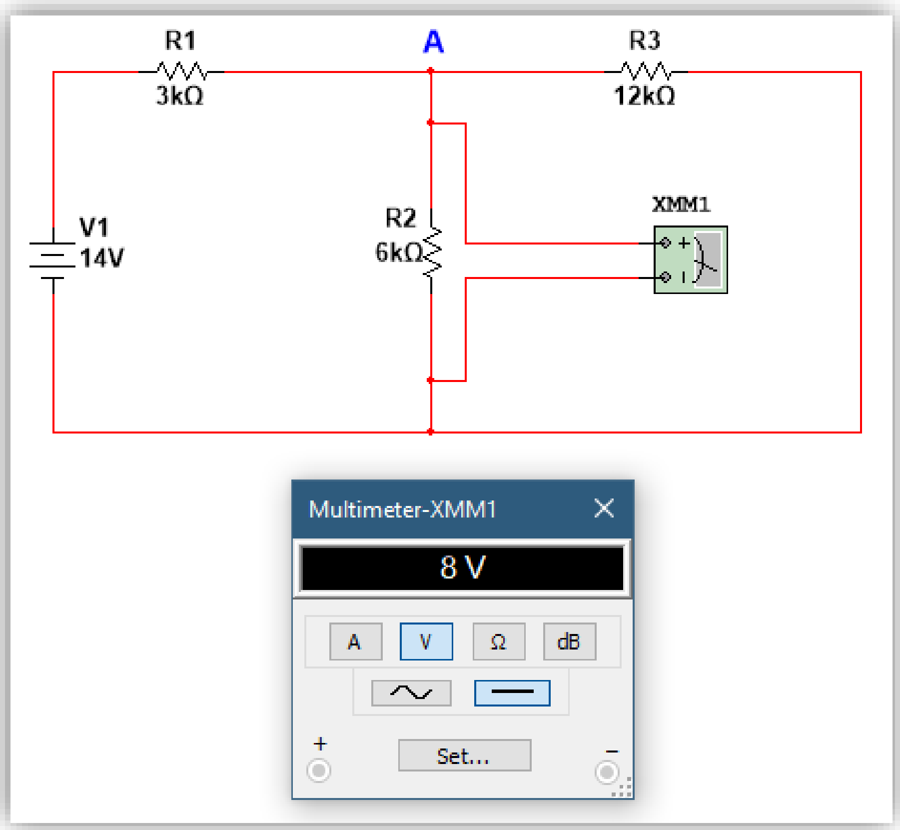
- Finding the voltage V_{Rx1} :
- Nodal Analysis can be used to find the voltage across R_2 due to voltage source V_1

- Using nodal analysis at node A using nodal analysis:
- $\frac{V_A - V_1}{R_1} + \frac{V_A}{R_2} + \frac{V_A}{R_3} = 0$
- $\frac{V_A - 14}{3K} + \frac{V_A}{6K} + \frac{V_A}{12K} = 0$

- Multiply by 12:
  - $4(V_A – 14) + 2\ V_A + V_A = 0$
  - $7\ V_A = 56$
  - $V_A = V_{Rx1} = 8V.$

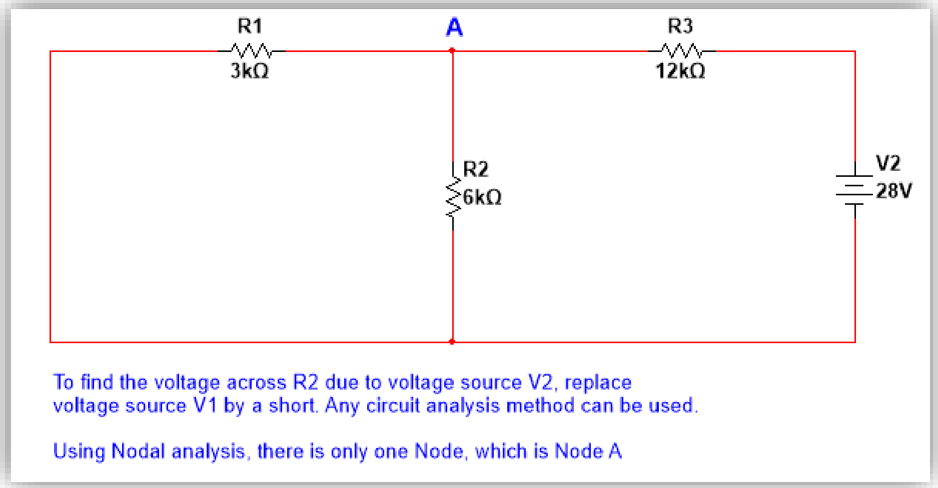


Simulation Results For the voltage across R2 Due to V1 Source With V2 Discarded



Two Voltage Sources Superposition Example1

- Finding the voltage V_{Rx2} :
- The voltage V_{Rx2} is the voltage across R_2 due to voltage source V_2 , therefore voltage source V_2 will be the only one considered in the circuit and voltage source V_1 should be replaced by a short circuit. The resulting circuit is:

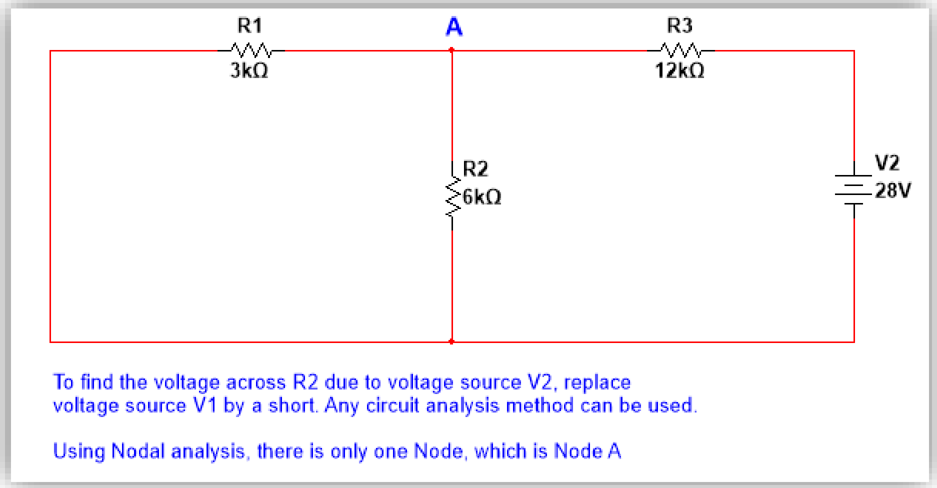


Two Voltage Sources Superposition Example1

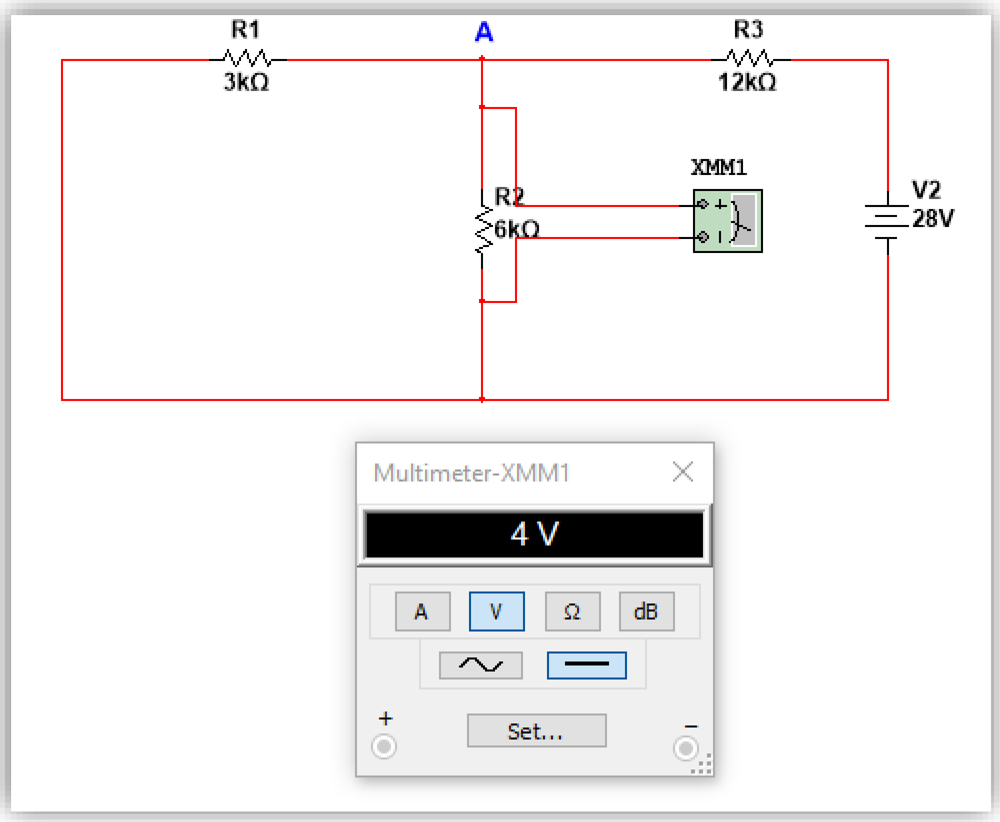
- Finding the voltage V_{Rx2} :
- Nodal Analysis can be used to find the voltage across R_2 due to voltage source V_2

- Using nodal analysis at node A using nodal analysis:
- $\frac{V_A - V_2}{R_3} + \frac{V_A}{R_2} + \frac{V_A}{R_1} = 0$
- $\frac{V_A - 28}{12K} + \frac{V_A}{6K} + \frac{V_A}{3K} = 0$

- Multiply by 12:
  - $(V_A - 28) + 2\,V_A + 4V_A = 0$
  - $7\,V_A = 28$
  - $V_A = V_{Rx2} = 4\text{V}.$



Simulation Results For the voltage across R2 Due to V2 Source With V1 Discarded

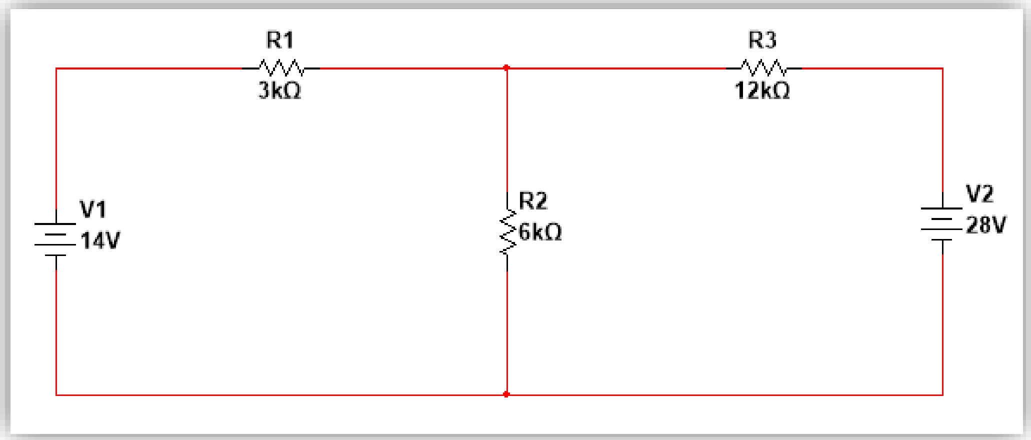


Two Voltage Sources Superposition Example1

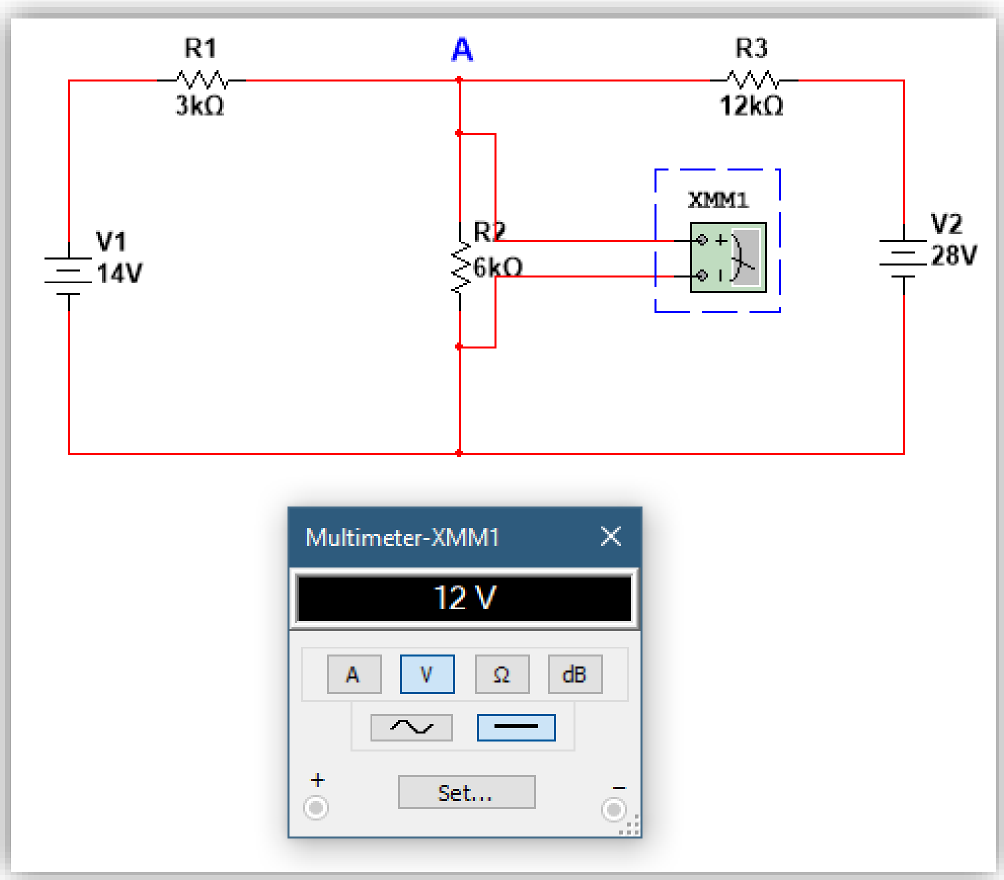
- Finding the voltage V_{R2} :
- The voltage V_{R2} is the sum of V_{Rx1} & V_{Rx2}. Therefore:

$$V_{R2} = V_{Rx1} + V_{Rx2}$$

$$V_{R2} = 8\text{V} + 4\text{V} = 12\text{V}$$

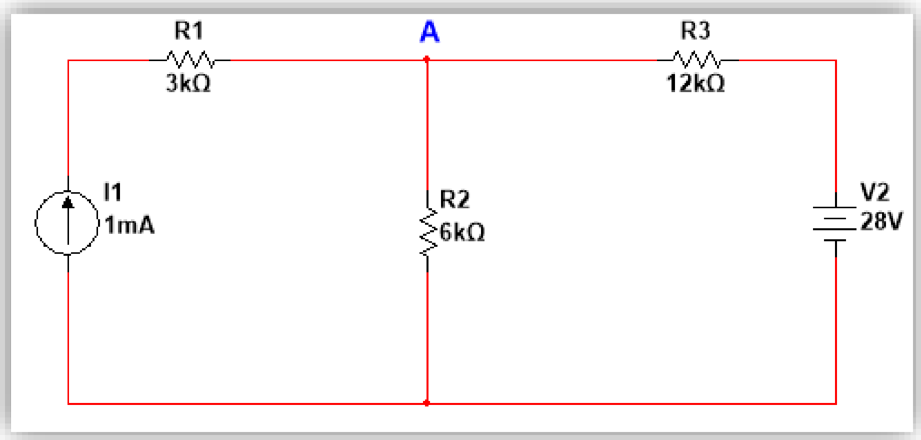


Simulation Results For the voltage across R2 Due to Both V1 & V2 Sources



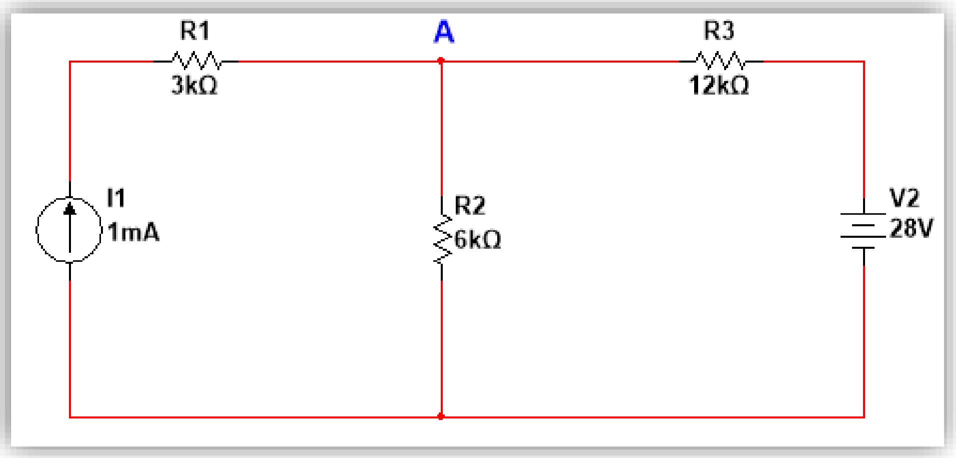
Voltage & Current Sources Superposition Example2

- For the following circuit, using the superposition principal, find V_{R2} .



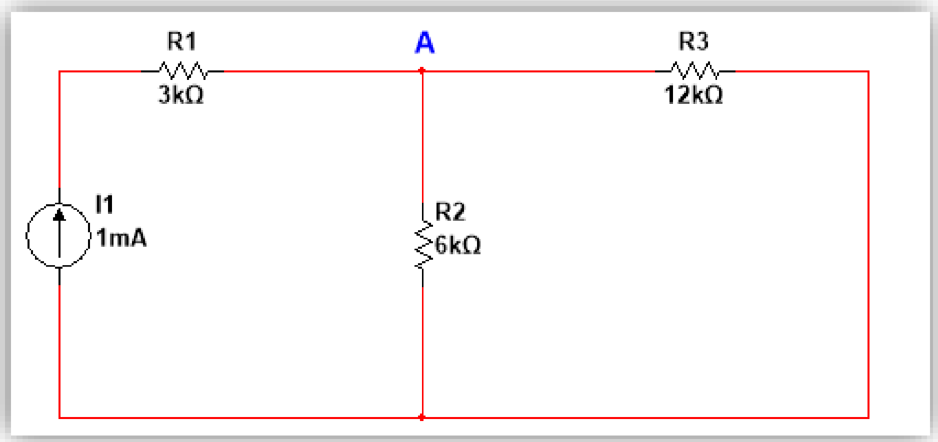
Voltage & Current Sources Superposition Example2

- the voltage across R_2 is the sum of:
  - V_{Rx1} and V_{Rx2} , where:
    - V_{Rx1} is the voltage across R_2 due to the current source I_1 .
    - V_{Rx2} is the voltage across R_2 due to the voltage source V_2



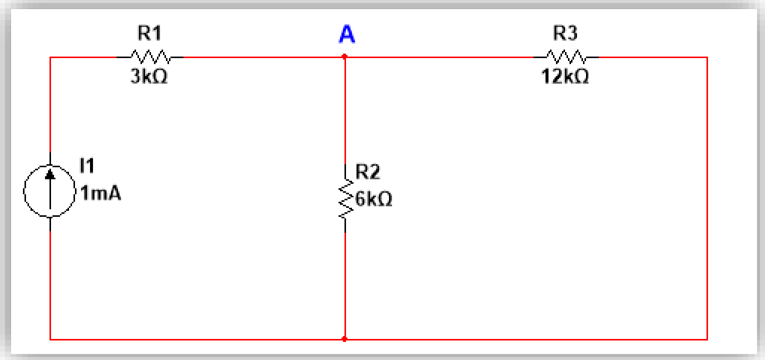
Voltage & Current Sources Superposition Example2

- Finding the voltage V_{Rx1}:
- The voltage V_{Rx1} is the voltage across R_2 due to current source I_1 , therefore current source I_1 will be the only one considered in the circuit and voltage source V_2 should be replaced by a short circuit. The resulting circuit is:



Voltage & Current Sources Superposition Example2

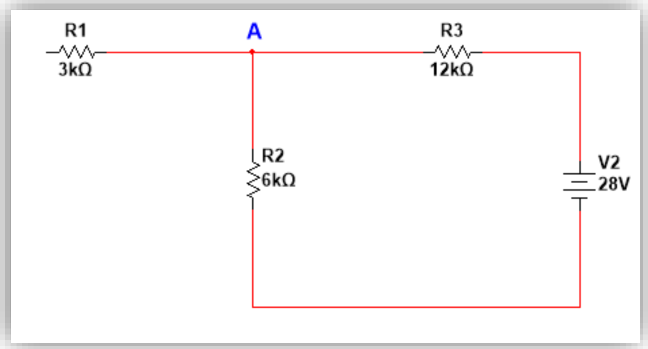
- Finding the voltage V_{Rx1} :
- At node A using nodal analysis:
- -1 mA + $\frac{V_A}{R_2} + \frac{V_A}{R_3} = 0$
- -1 mA + $\frac{V_A}{R_2} + \frac{V_A}{R_3} = 0$
- $\frac{V_A}{6K} + \frac{V_A}{12K} = 1$ mA, Multiply by 12 to get:
- $2V_A + V_A = 12$
- $3V_A = 12$
- $V_A = 4V$



Voltage & Current Sources Superposition Example2

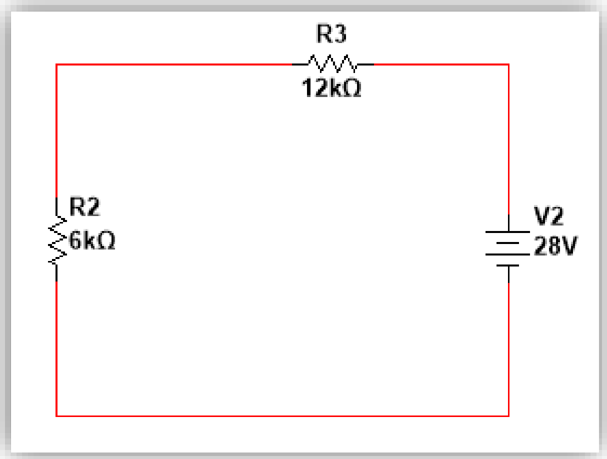
- Finding the voltage V_{Rx2} :
- The voltage V_{Rx2} is the voltage across R_2 due to voltage source V_2 , therefore voltage source V_2 will be the only one considered in the circuit and current source I_1 should be replaced by an open circuit.

- The resulting circuit is shown below. Notice that R_1 is a dangling element now and it is not seen by the voltage source V2. Therefore R_1 can be discarded and the voltage source V_2 will only see R_2 & R_3 in series.



Voltage & Current Sources Superposition Example2

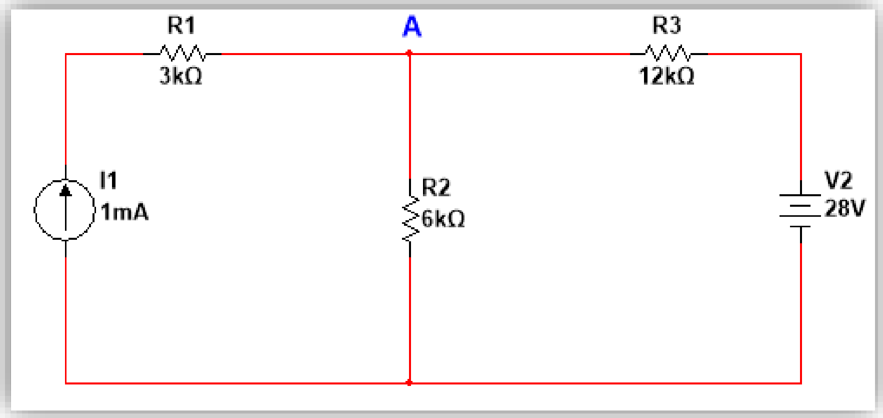
- Finding the voltage V_{Rx2} :
- So, effectively the circuit that is to be used to calculate V_{Rx2} will look like the following. The voltage division formula can be used to calculate the voltage across R_2 which is also V_{Rx2}.
- $V_{Rx2} = V_{R2} = \dfrac{V_2 \times R_2}{R_2 + R_3}$
- $V_{Rx2} = V_{R2} = \dfrac{28V \times 6K}{12K + 6K}$ = 9.334V



Voltage & Current Sources Superposition Example2

- Finding the voltage V_{R2}:

- The voltage V_{R2} is the sum of V_{Rx1} & V_{Rx2}. Therefore:
- $V_{R2} = V_{Rx1} + V_{Rx2}$
- V_{R2} = 4V + 9.334V = 13.334V



This Concludes the Superposition Principal

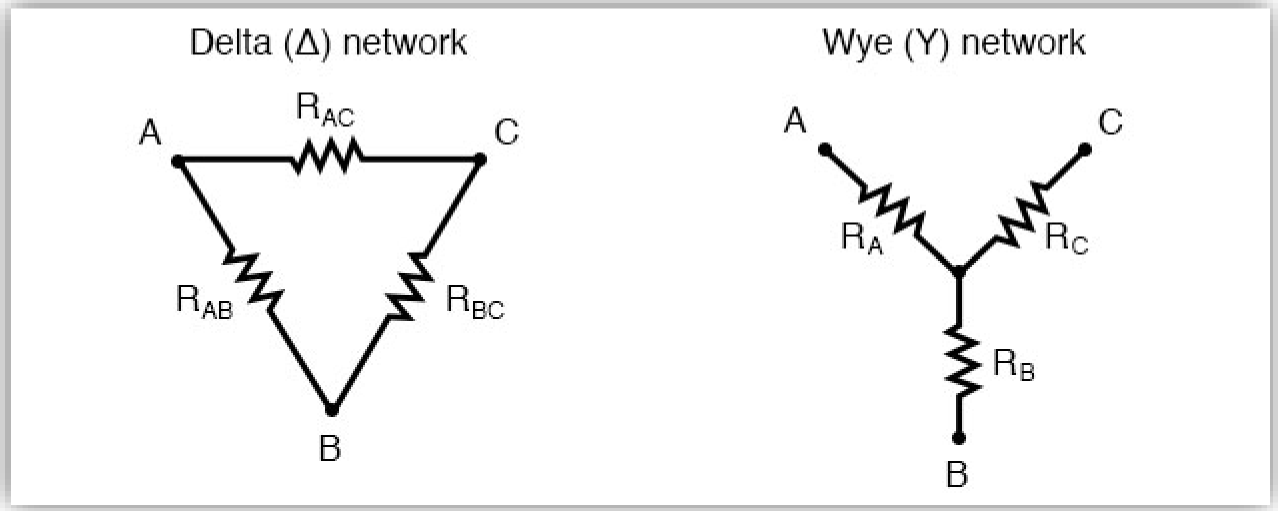
Paramount Electronics Services

Y to Δ & Δ to Y Transformation

Y to Δ & Δ to Y Transformation

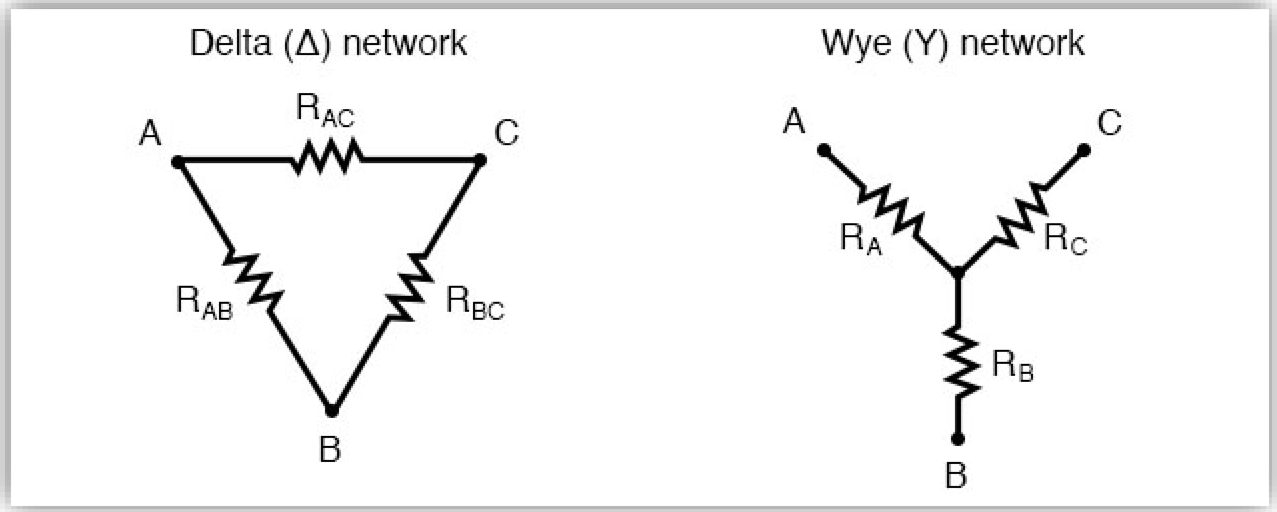
- Conversion between Y and Δ is very helpful in analyzing circuit which are not analyzable using traditional circuit analysis. They help in areas such as bridge analysis and three-phase systems.

- When transforming between the Y and the Δ, the transformed network will be bound by the same three nodes that bound the original network.



Δ to Y Transformation

- Referring to the figure shown, the transformation from a Δ to Y and Y to Δ equations are:



$$R_A = \frac{R_{AB}R_{AC}}{R_{AB} + R_{AC} + R_{BC}} \qquad R_{AB} = \frac{R_AR_B + R_AR_C + R_BR_C}{R_C}$$

$$R_B = \frac{R_{AB}R_{BC}}{R_{AB} + R_{AC} + R_{BC}} \qquad R_{BC} = \frac{R_AR_B + R_AR_C + R_BR_C}{R_A}$$

$$R_C = \frac{R_{AC}R_{BC}}{R_{AB} + R_{AC} + R_{BC}} \qquad R_{AC} = \frac{R_AR_B + R_AR_C + R_BR_C}{R_B}$$

This Concludes The Y to Δ & Δ to Y Transformation