Program- B.TECH

Semester- III

Session- 2020-21

Course- BEE/ECA

Course code- BTEE-211

Topic- Network Theorems. (Unit-1)

Superposition Theorem

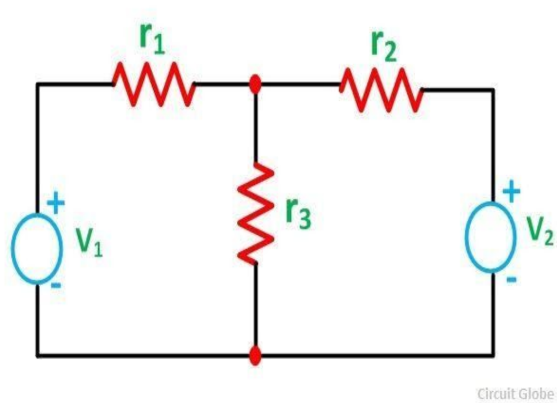
Superposition theorem states that in any linear, active, bilateral network having more than one source, the response across any element is the sum of the responses obtained from each source considered separately and all other sources are replaced by their internal resistance. The superposition theorem is used to solve the network where two or more sources are present and connected.

In other words, it can be stated as if a number of voltage or current sources are acting in a linear network, the resulting current in any branch is the algebraic sum of all the currents that would be produced in it when each source acts alone while all the other independent sources are replaced by their internal resistances.

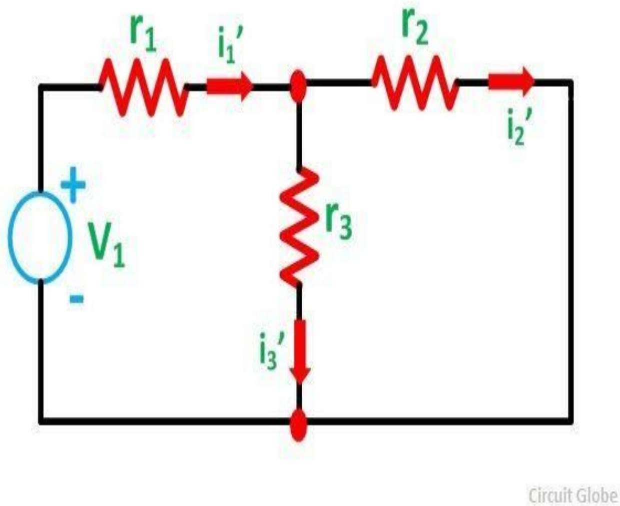
It is only applicable to the circuit which is valid for the ohm's law (i.e., for the linear circuit).

Explanation of Superposition Theorem

Let us understand the superposition theorem with the help of an example. The circuit diagram is shown below consists of two voltage sources V_1 and V_2.



First, take the source V_1 alone and short circuit the V_2 source as shown in the circuit diagram below:



Here, the value of current flowing in each branch, i.e. i_1', i_2' and i_3' is calculated by the following equations.

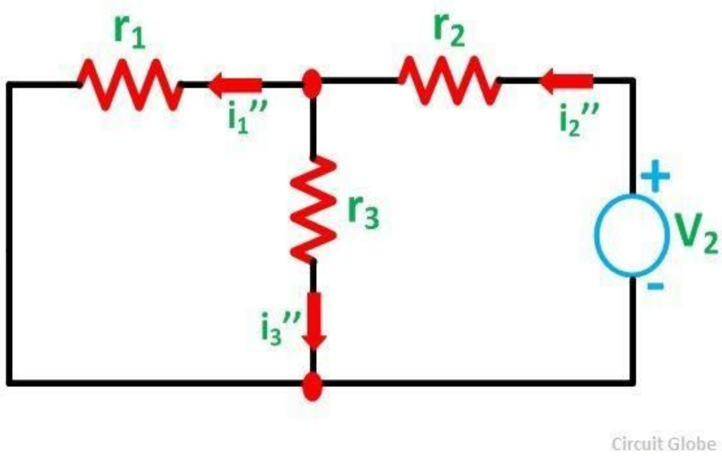
$$i_1' = \frac{V_1}{\frac{r_2 r_3}{r_2 + r_3} + r_1} \quad \dots\dots\dots\dots (1)$$

$$i_2' = i_1' \frac{r_3}{r_2 + r_3} \quad \dots\dots\dots\dots (2)$$

The difference between the above two equations gives the value of the current i3'

$$i_3' = i_1' - i_2'$$

Now, activating the voltage source V_2 and deactivating the voltage source V_1 by short-circuiting it, find the various currents, i.e. i_1'', i_2'', i_3'' flowing in the circuit diagram shown below:



$$i_2'' = \frac{V_2}{\frac{r_1 r_3}{r_1 + r_3} + r_2} \quad \text{and} \quad i_1'' = i_2'' \frac{r_3}{r_1 + r_3}$$

And the value of the current i_3'' will be calculated by the equation shown below:

$$i_3'' = i_2'' - i_1''$$

As per the superposition theorem, the value of current i_1, i_2, i_3 is now calculated as:

$$i_3 = i_3' + i_3''$$

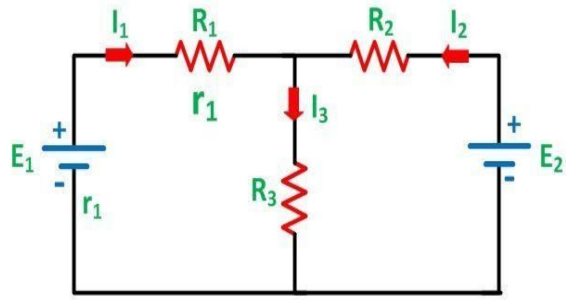
$$i_2 = i_2' - i_2''$$

$$i_1 = i_1' - i_1''$$

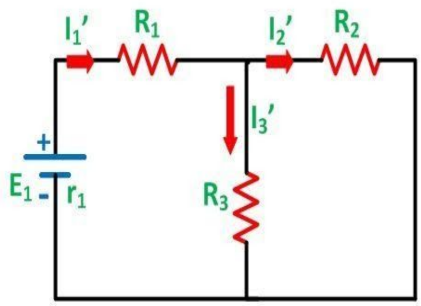
The direction of the current should be taken care of while finding the current in the various branches.

Steps for Solving network by Superposition Theorem

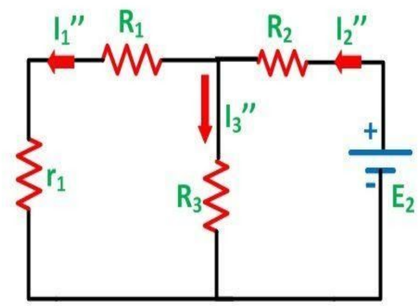
Considering the circuit diagram A, let us see the various steps to solve the superposition theorem:



Circuit Diagram A



Circuit Diagram B



Circuit Diagram C

Circuit Globe

Step 1 – Take only one independent source of voltage or current and deactivate the other sources.

Step 2 – In the circuit diagram B shown above, consider the source E_1 and replace the other source E_2 by its internal resistance. If its internal resistance is not given, then it is taken as zero and the source is short-circuited.

Step 3 – If there is a voltage source than short circuit it and if there is a current source then just open circuit it.

Step 4 – Thus, by activating one source and deactivating the other source find the current in each branch of the network. Taking the above example find the current I_1', I_2'and I_3'.

Step 5 – Now consider the other source E_2 and replace the source E_1 by its internal resistance r_1 as shown in the circuit diagram C.

Step 6 – Determine the current in various sections, I_1'', I_2'' and I_3''.

Step 7 – Now to determine the net branch current utilizing the superposition theorem, add the currents obtained from each individual source for each branch.

Step 8 – If the current obtained by each branch is in the same direction then add them and if it is in the opposite direction, subtract them to obtain the net current in each branch.

The actual flow of current in the circuit C will be given by the equations shown below:

$$I_1 = I_1' - I_1''$$

$$I_2 = I_2' - I_2''$$

$$I_3 = I_3' - I_3''$$

Thus, in this way, we can solve superposition theorem.

Thevenin’s Theorem

Thevenin’s Theorem states that any complicated network across its load terminals can be substituted by a voltage source with one resistance in series. This theorem helps in the study of the variation of current in a particular branch when the resistance of the branch is varied while the remaining network remains the same.

For example in designing electrical and electronics circuits.

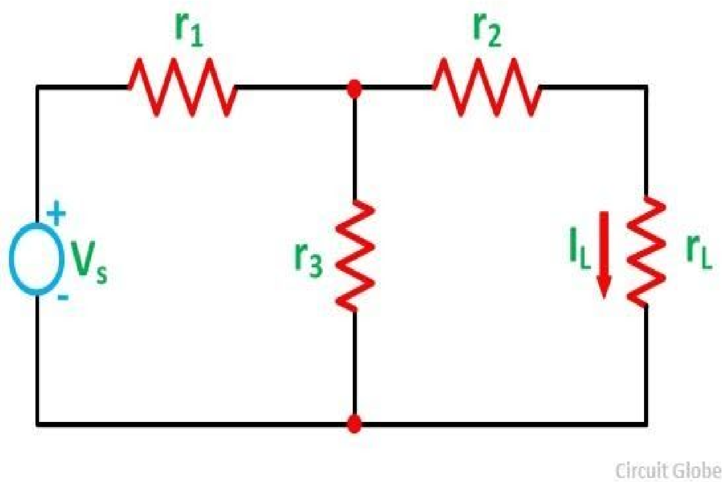
A more general statement of Thevenin’s Theorem is that any linear active network consisting of independent or dependent voltage and current source and the network elements can be replaced by an equivalent circuit having a voltage source in series with a resistance.

Where the voltage source being the open-circuited voltage across the open-circuited load terminals and the resistance being the internal resistance of the source.

In other words, the current flowing through a resistor connected across any two terminals of a network by an equivalent circuit having a voltage source E_{th} in series with a resistor R_{th}. Where E_{th} is the open-circuit voltage between the required two terminals called the Thevenin voltage and the R_{th} is the equivalent resistance of the network as seen from the two-terminal with all other sources replaced by their internal resistances called Thevenin resistance.

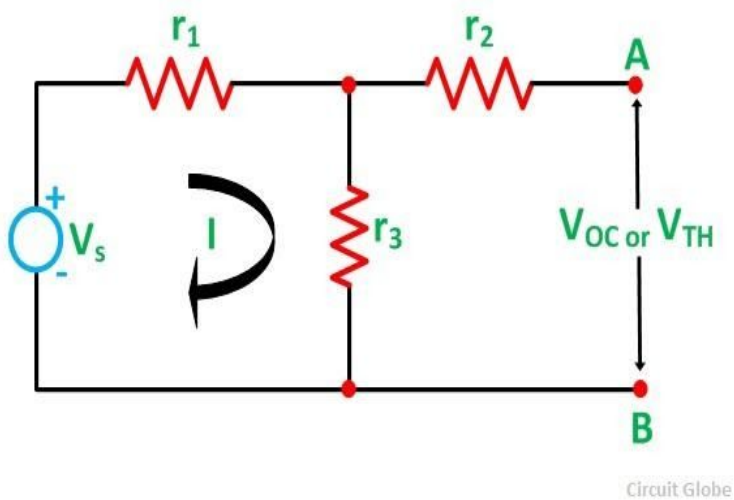
Explanation of Thevenin’s Theorem

The Thevenin’s statement is explained with the help of a circuit shown below:



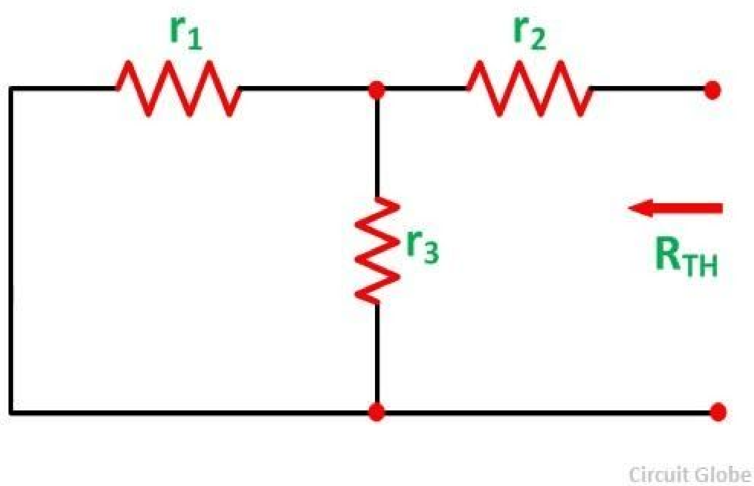
Let us consider a simple DC circuit as shown in the figure above, where we have to find the load current $\mathbf{I_L}$ by the Thevenin's theorem.

In order to find the equivalent voltage source, $\mathbf{r_L}$ is removed from the circuit as shown in the figure below and $\mathbf{V_{oc}}$ or $\mathbf{V_{TH}}$ is calculated.

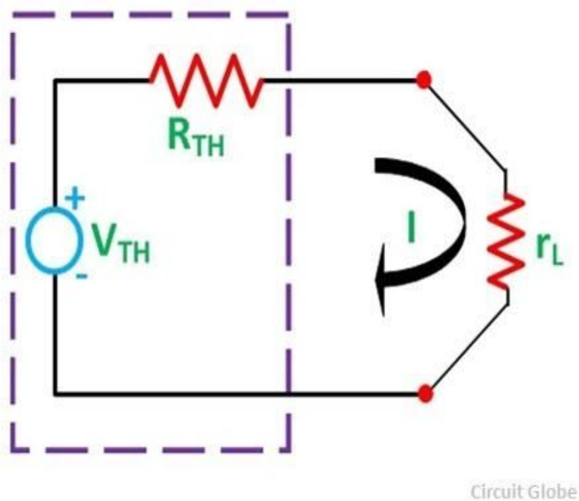


$$V_{OC} = I\, r_3 = \frac{V_S}{r_1 + r_3} r_3$$

Now, to find the internal resistance of the network (Thevenin's resistance or equivalent resistance) in series with the open-circuit voltage $\mathbf{V_{OC}}$, also known as Thevenin's voltage $\mathbf{V_{TH}}$, the voltage source is removed or we can say it is deactivated by a short circuit (as the source does not have any internal resistance) as shown in the figure below:



$$R_{TH} = r_2 + \frac{r_1 r_3}{r_1 + r_3}$$



As per Thevenin's Statement, the load current is determined by the circuit shown above and the equivalent Thevenin's circuit is obtained.
The load current $\mathbf{I_L}$ is given as:

$$I_L = \frac{V_{TH}}{R_{TH} + r_L}$$

Where,

V_{TH} is the Thevenin's equivalent voltage. It is an open circuit voltage across the terminal AB known as **load terminal**
R_{TH} is the Thevenin's equivalent resistance, as seen from the load terminals where all the sources are replaced by their internal impedance
r_L is the **load resistance**

Steps for Solving Thevenin's Theorem

Step 1 – First of all remove the load resistance **r_L** of the given circuit.

Step 2 – Replace all the sources by their internal resistance.

Step 3 – If sources are ideal then short circuit the voltage source and open circuit the current source.

Step 4 – Now find the equivalent resistance at the load terminals, known as Thevenin's Resistance (R_{TH}).

Step 5 – Draw the Thevenin's equivalent circuit by connecting the load resistance and after that determine the desired response.

This theorem is possibly the most extensively used networks theorem. It is applicable where it is desired to determine the current through or voltage across any one element in a network. Thevenin's Theorem is an easy way to solve a complicated network.

<u>REFRENCES-</u>

1)-www.circuitglobe.com

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