Basic Electrical Engineering (TEE 101)

Lecture 12: Thevenin's Theorem and Norton's Theorem

Content

This lecture covers:

- Introduction to Thevenin's Theorem
- Introduction to Norton's Theorem
- Procedure to solve an Electrical Circuit using Thevenin's Theorem and Norton's Theorem

Introduction to Thevenin's Theorem

Like any other circuit analysis technique, Thevenin's Theorem is also used to solve the complex electrical networks

Using Thevenin's Theorem we can convert a complex electrical circuit into a simple one.

Thevenin's theorem was invented by a German Scientist, **Hermann Von Helmholtz** in 1853 and by **Leon Charles Thevenin** in 1883. **L. C Thevenin** was an Electrical Engineer at French Telegraph Services.

This theorem states that: *Any linear, bilateral network containing one or more energy sources and passive elements can be replaced by a simple network containing a single voltage source and a single resistance in series across the load terminals.*

Introduction to Thevenin’s Theorem cont..

That means the Thevenin’s equivalent of any electrical circuit consist of an independent voltage source and a series resistance across the load terminals.

The voltage source is known as Thevenin’s Voltage (or Open Circuit Voltage). It is represented by V_{th} or V_{oc}

The series resistance is known as Thevenin’s Resistance (denoted by R_{th})

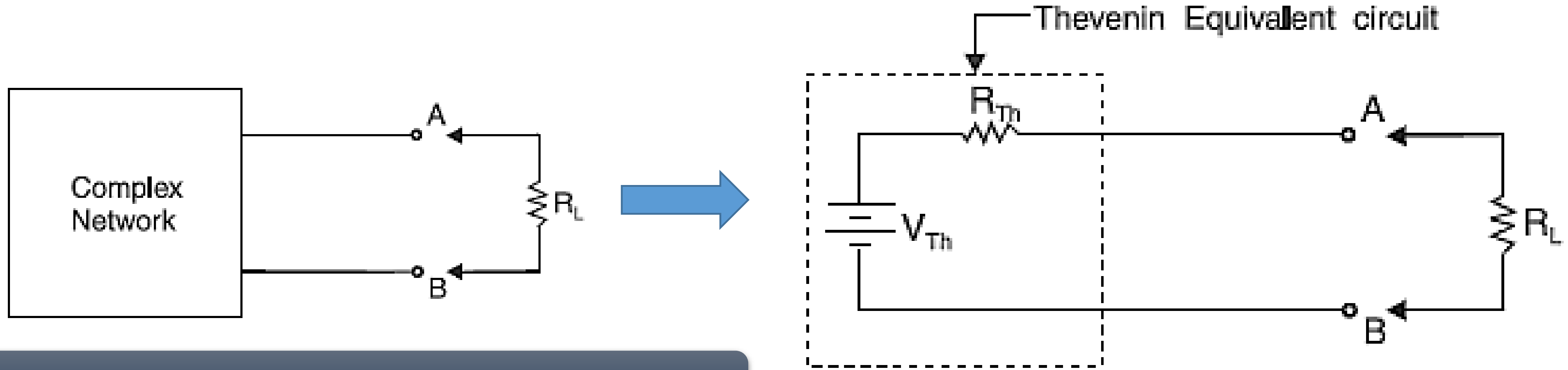
That implies, to obtain a Thevenin’s Equivalent of any linear bilateral circuit, we need:

1. Thevenin’s Voltage (V_{th}), and
2. Thevenin’s Resistance (R_{th})

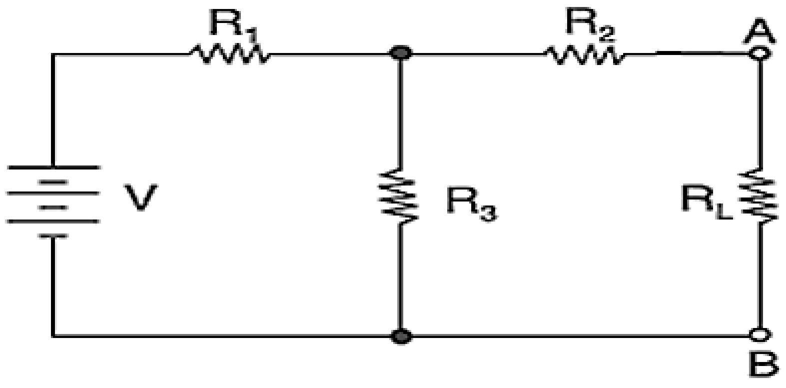
Thevenin’s Resistance is the equivalent resistance seen into the network from the open load terminals when all the sources in the circuit are replaced with their internal resistances.

Thevenin’s Voltage is the open circuit voltage (V_{oc}) and is calculated across the open load terminals.

Procedure to solve an electrical network using Thevenin's Theorem



Consider and electrical circuit as shown below:



The whole procedure of solving an electrical circuit using Thevenin's Theorem can be completed in FOUR steps as listed below:

Step 1: Calculate Rth

Step 2: Calculate Vth

Step 3: Draw the Thevenin's Equivalent

Step 4: Calculate the Load Current (if required)

The procedure for using this theorem to solve d.c. networks is as under :

Step 1: Calculate the value of Thevenin's Resistance (R_{th})

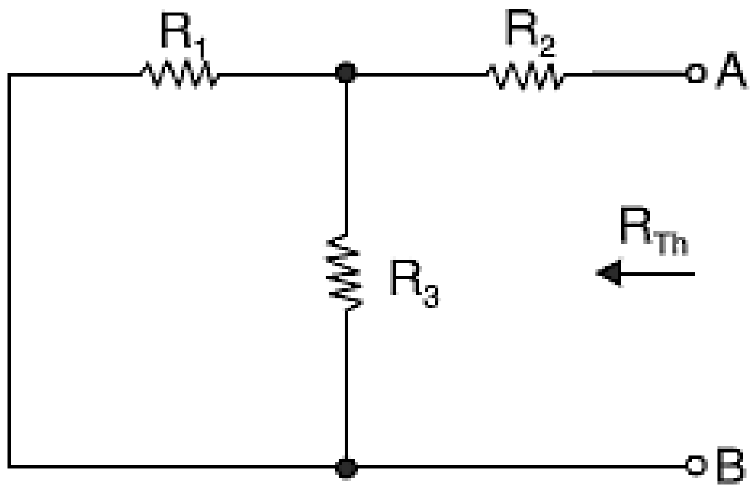
The value of R_{th} can be calculated by applying following steps on the given electrical circuit:

1 (a): Remove the load resistance and make the load terminals open. (ignore if the load terminals are already open)

1 (b): Now replace each energy source available in the given electrical circuit with its internal resistance**.

1(c): Now redraw the circuit after applying steps 1(a) and 1 (b).

1(d): Now apply the fundamental of equivalent resistance and calculate the value of R_{th} across open load terminals.



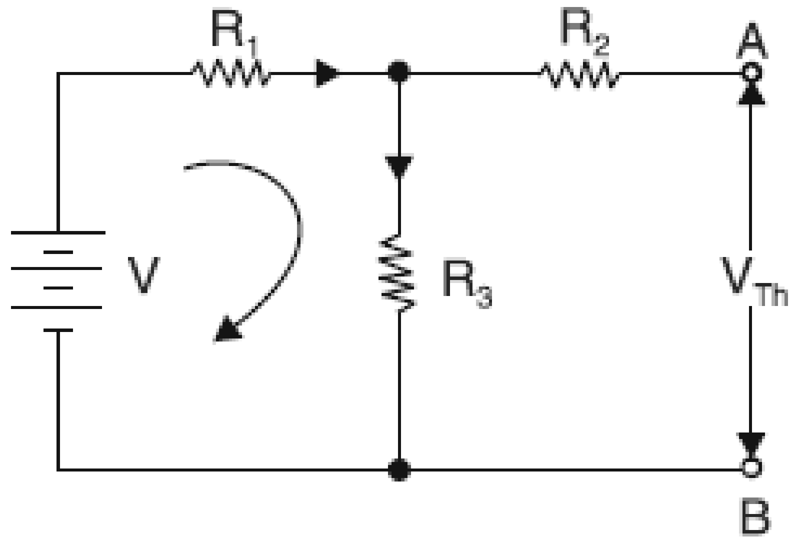
*****Note: The ideal voltage source is replaced with Short path or Short circuit and ideal current source is replaced with open path or open circuit (The reason is that: an ideal voltage source has ZERO resistance and an ideal current sources has INFINITE resistance)***

Step 2: Calculate the value of Thevenin's Voltage, Vth (or Open Circuit Voltage – Voc)

2(a): To calculate Vth, remove the load resistance and make the load terminals open. (ignore if the load terminals are already open)

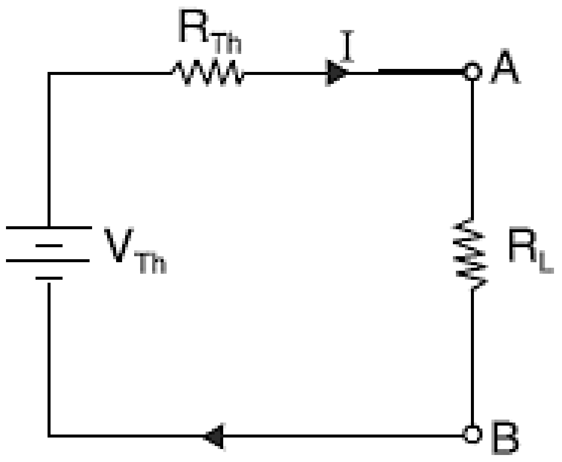
2(b): Now, across these open load terminals, calculate the value of Thevenin's voltage (Vth).

Because Vth is calculate across the open load terminals, that is why it is also known as open circuit voltage (Voc)



Step 3: Draw the Thevenin's Equivalent circuit:

- The Thevenin's equivalent circuit can be obtained by using the values of R_{th} and V_{th} obtained in steps 1 and 2 respectively.
- The Vth and R_{th} are connected in series across the load terminals.



Step 4: Calculate the load current (I_L) in the load resistance (R_L) by using the following equation:

$$I_L = \frac{V_{th}}{R_{th} + R_L}$$

Introduction to Norton's Theorem

Like Thevenin's Theorem, Norton's Theorem is also used to solve the complex electrical networks

Using Norton's Theorem we can convert a complex electrical circuit into a simple one.

Norton's theorem was independently derived in **1926** by **Siemens & Halske** researcher **Hans Ferdinand Mayer** (1895–1980) and Bell Labs engineer **Edward Lawry Norton** (1898–1983).

This theorem states that: *Any linear, bilateral network containing one or more energy sources and passive elements can be replaced by a simple network containing a single current source and a single resistance in parallel to current source across the load terminals.*

Introduction to Norton's Theorem cont..

That means the Norton's equivalent of any electrical circuit consist of an independent current source and a parallel resistance across the load terminals.

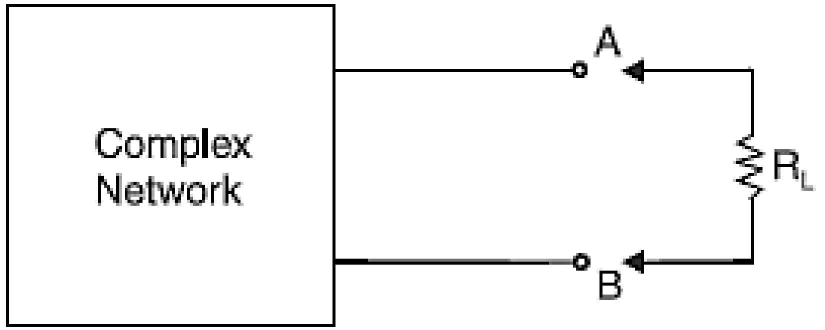
The current source is known as Norton's Current (or Short circuit current). It is represented by I_N or I_{SC}

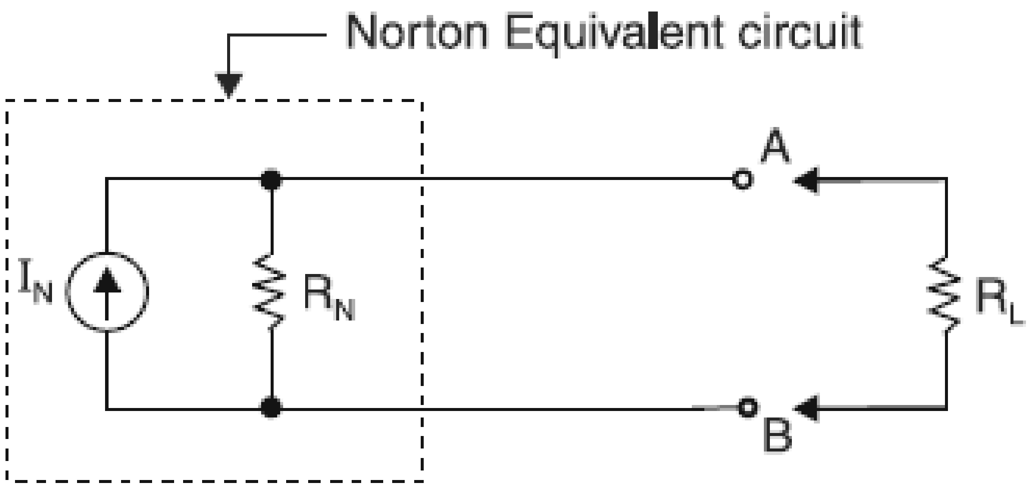
The parallel resistance is known as Norton's Resistance (denoted by R_N)

That implies, to obtain a Norton's Equivalent of any linear bilateral circuit, we need:
1. Norton's Current, (I_N) and
2. Norton's Resistance (R_N)

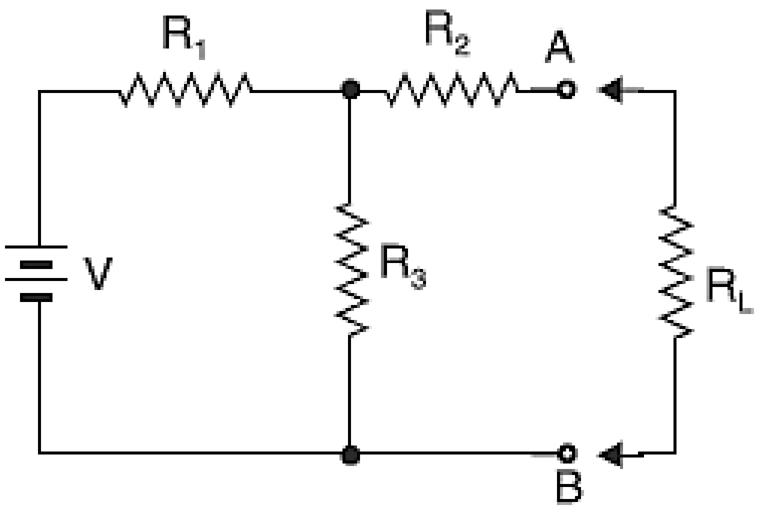
Norton's Resistance is the equivalent resistance seen into the network from the open load terminals when all the sources in the circuit are replaced with their internal resistances.
Norton's Current is the short circuit current (I_{SC}) and is calculated through the short load terminals.

Procedure to solve an electrical network using Norton's Theorem





Consider and electrical circuit as shown below:



The whole procedure of solving an electrical circuit using Norton's Theorem can be completed in FOUR steps as listed below:

Step 1: Calculate R_N

Step 2: Calculate I_N

Step 3: Draw the Norton's Equivalent

Step 4: Calculate the Load Current (if required)

The procedure for using this theorem to solve d.c. networks is as under :

Step 1: Calculate the value of Norton's Resistance (R_N)

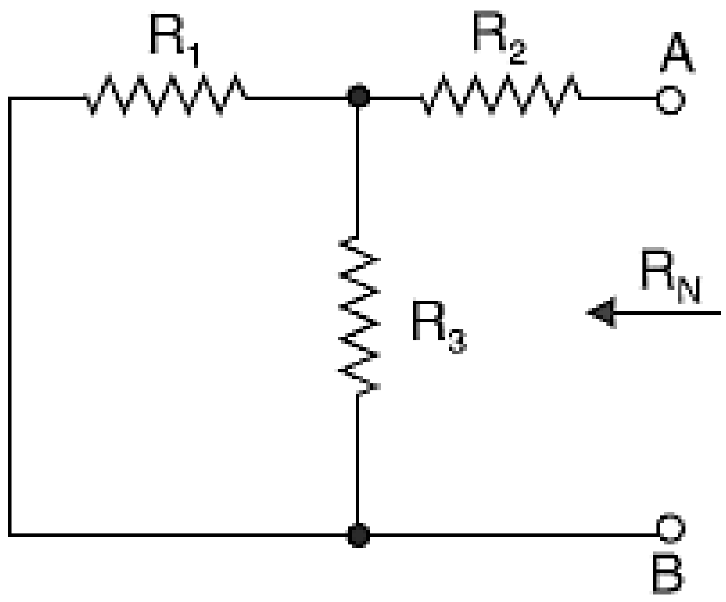
The value of $\mathbf{R_N}$ can be calculated by applying following steps on the given electrical circuit:

1 (a): Remove the load resistance and make the load terminals open. (ignore if the load terminals are already open)

1 (b): Now replace each energy source available in the given electrical circuit with its internal resistance**.

1(c): Now redraw the circuit after applying steps 1(a) and 1 (b).

1(d): Now apply the fundamental of equivalent resistance and calculate the value of $\mathbf{R_N}$ across open load terminals.



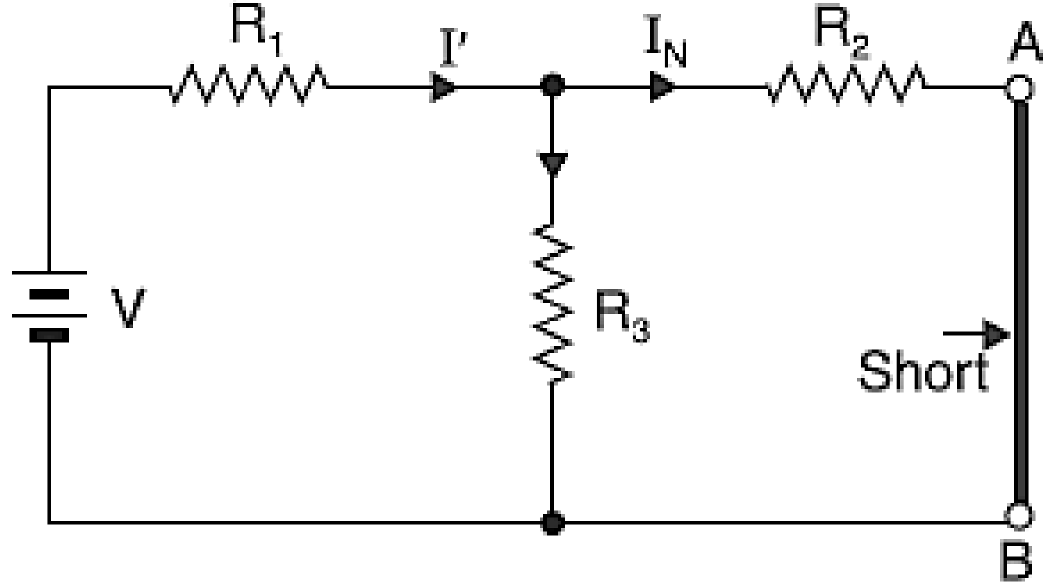
***Note: The ideal voltage source is replaced with Short path or Short circuit and ideal current source is replaced with open path or open circuit (The reason is that: an ideal voltage source has ZERO resistance and an ideal current sources has INFINITE resistance)*

Step 2: Calculate the value of Norton's Current I_N (or Short Circuit Current – I_{SC})

2(a): To calculate $\mathbf{I_N}$, remove the load resistance and make the load terminals Short.

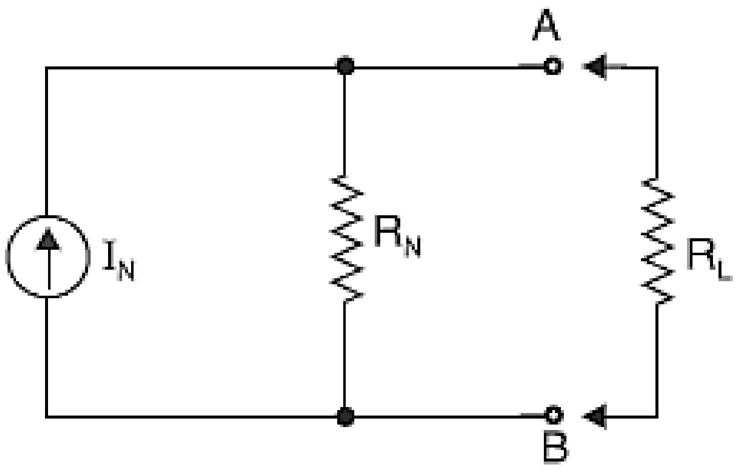
2(b): Now, through these short load terminals, calculate the value of Norton's Current ($\mathbf{I_N}$).

Because $\mathbf{I_N}$ is calculate across the short load terminals, that is why it is also known as short circuit current ($\mathbf{I_{SC}}$)



Step 3: Draw the Norton's Equivalent circuit:

- The Norton's equivalent circuit can be obtained by using the values of $\mathbf{R_N}$ and $\mathbf{I_N}$ obtained in steps 1 and 2 respectively.
- The $\mathbf{I_N}$ and $\mathbf{R_N}$ are connected in parallel across the load terminals. (as shown in figure below)



Step 4: Calculate the load current (I_L) in the load resistance (R_L) by using the current division rule:

$$I_L = \frac{I_N R_N}{R_N + R_L}$$

Thank You