Basic Electrical Engineering (TEE 101)

Lecture 3: Introduction to Electrical Energy Sources and source Transformation

Objective:

- **To discuss the various types of electrical energy sources**
- **Network Terminology**
- **Sign Convention**
- **Current Division and Voltage Division Rule**
- **To discuss the Source Transformation**

Electrical Energy Sources

Electrical energy sources are used to deliver electrical energy to the circuit.

Electrical Energy Sources are categorized on various basis. Such as:

1. DC sources
2. AC sources

DC Sources

Voltage Source / Current Source

Independent Voltage Source / Current Source

- Independent Ideal Voltage Source
- Independent Ideal Current Source
- Practical Voltage Source
- Practical Current Source

Dependent Voltage Source / Current Source

- Voltage Dependent Voltage Source
- Voltage Dependent Current Source
- Current Dependent Voltage Source
- Current Dependent Current Source

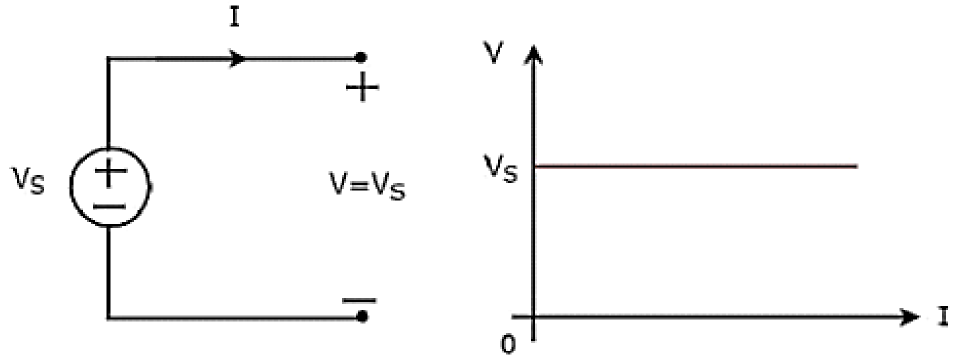
Independent Ideal Sources

Independent Ideal Voltage Sources

An independent voltage source produces a constant voltage across its two terminals.

This voltage is independent of the amount of current that is flowing through the two terminals of voltage source.

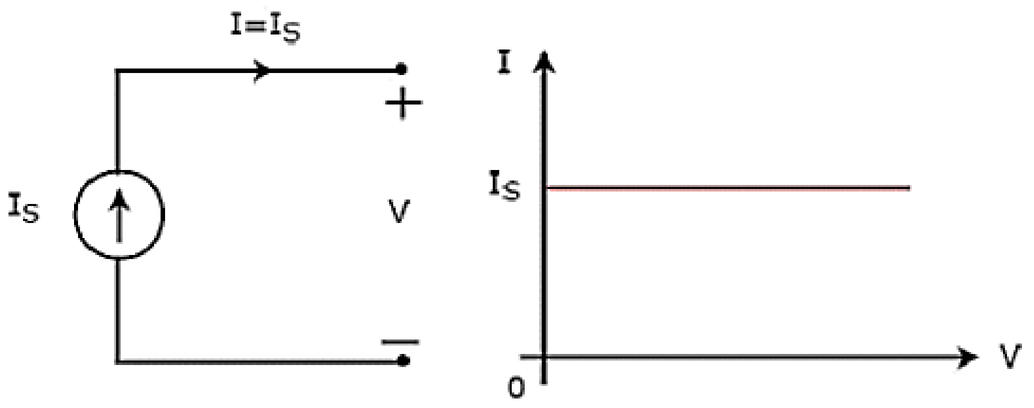
Independent **ideal voltage source** and its V-I characteristics are shown in the following figure.



- The **V-I characteristics** of an independent ideal voltage source is a constant line, which is always equal to the source voltage (VS) irrespective of the current value (I).
- So, the internal resistance of an independent ideal voltage source is zero Ohms.
- Hence, the independent ideal voltage sources **do not exist practically**, because there will be some internal resistance.

Independent Ideal Current Sources

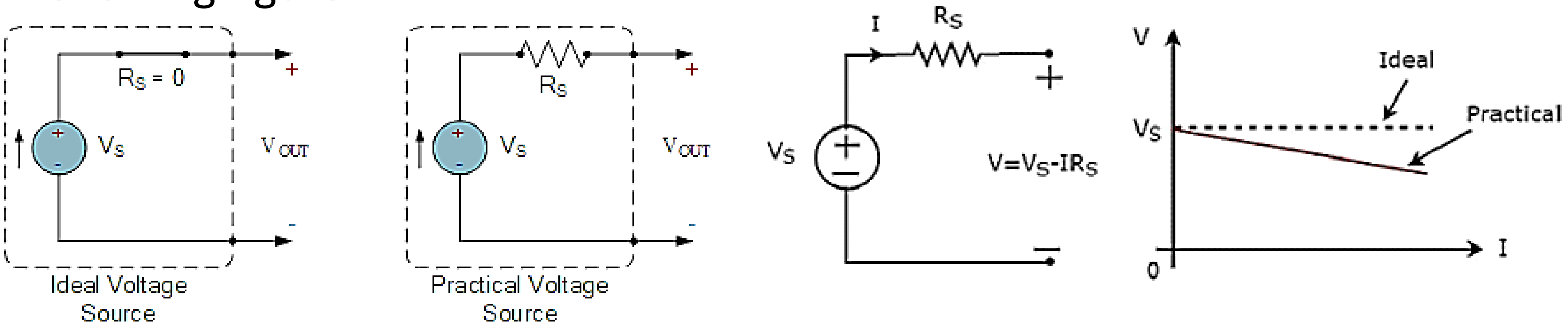
- An independent Ideal current source produces a constant current.
- This current is independent of the voltage across its two terminals.
- Independent **ideal current source** and its V-I characteristics are shown in the following figure.



- The **V-I characteristics** of an independent ideal current source is a constant line, which is always equal to the source current (I_S) irrespective of the voltage value (V).
- So, the internal resistance of an independent ideal current source is infinite ohms.
- Hence, the independent ideal current sources **do not exist practically**, because there will be some internal resistance.

Non Ideal or Practical Voltage Source

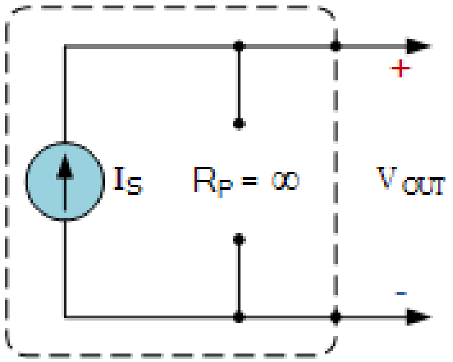
- Independent **practical voltage source** and its V-I characteristics are shown in the following figure.



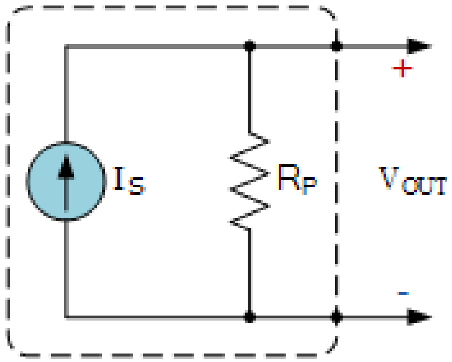
- There is a deviation in the V-I characteristics of an independent practical voltage source from the V-I characteristics of an independent ideal voltage source.
- This is due to the voltage drop across the internal resistance (R_S) of an independent practical voltage source.

Non Ideal or Practical Current Source

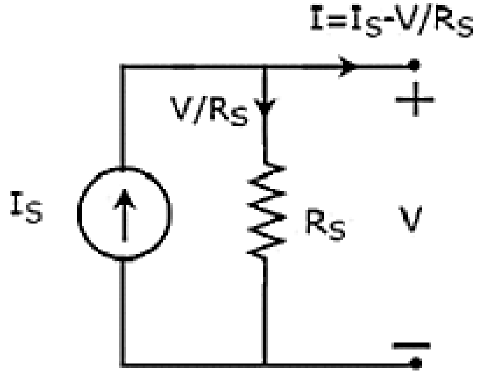
- Independent **practical current source** and its V-I characteristics are shown in the following figure.

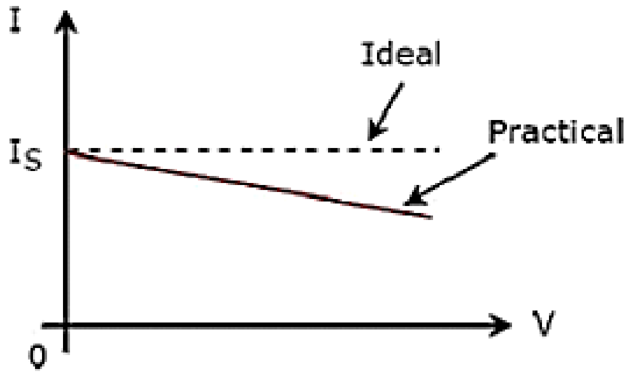


Ideal Current Source



Practical Current Source



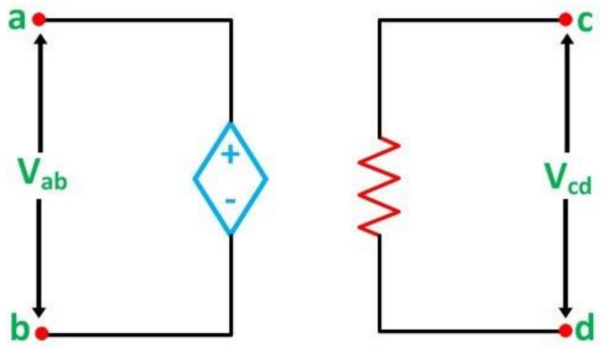


- There is a deviation in the **V-I characteristics** of an independent practical current source from the V-I characteristics of an independent ideal current source.
- This is due to the amount of current flows through the internal shunt resistance (R_S) of an independent practical current source.

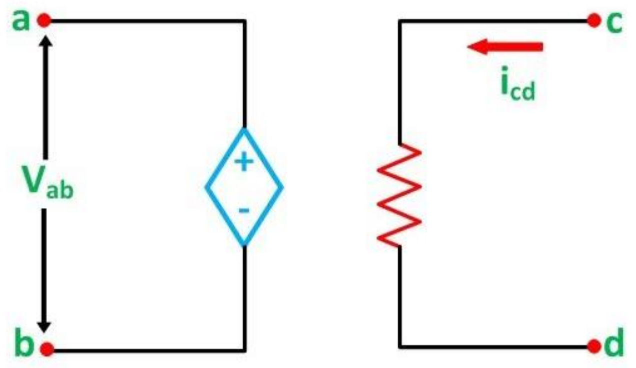
Dependent Sources

As the name suggests, dependent sources produce the amount of voltage or current that is dependent on some other voltage or current. Dependent sources are also called as **controlled sources**. Dependent sources can be further divided into the following two categories −

- **Dependent Voltage Sources**
- **Dependent Current Sources**



Voltage Dependent Voltage Source



Current Dependent Voltage Source

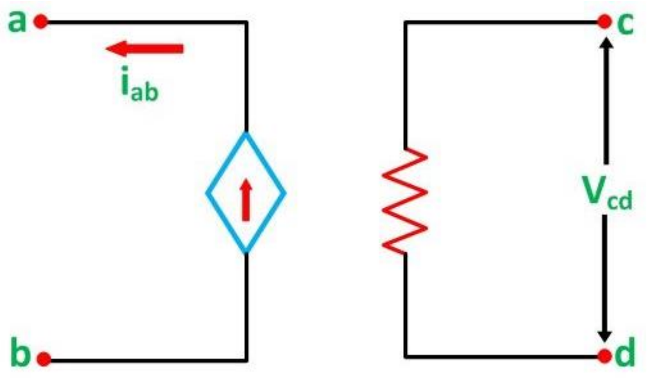
Dependent Voltage Sources

- A dependent voltage source produces a voltage across its two terminals.
- The amount of this voltage is dependent on some other voltage or current.
- Hence, dependent voltage sources can be further classified into the following two categories −
  - **Voltage Dependent Voltage Source (VDVS)**
  - **Current Dependent Voltage Source (CDVS)**

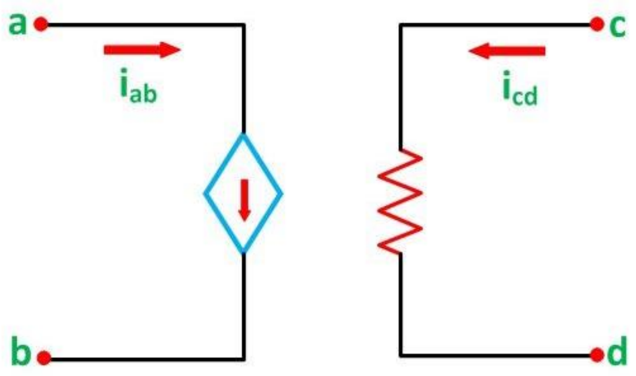
Dependent voltage sources are represented with the signs '+' and '-' inside a diamond shape. The magnitude of the voltage source can be represented outside the diamond shape.

Dependent Current Sources

- A dependent current source produces a current.
- The amount of this current is dependent on some other voltage or current.
- Hence, dependent current sources can be further classified into the following two categories –
  - **Voltage Dependent Current Source (VDCS)**
  - **Current Dependent Current Source (CDCS)**
- Dependent current sources are represented with an arrow inside a diamond shape.
- The magnitude of the current source can be represented outside the diamond shape.
- We can observe these dependent or controlled sources in equivalent models of transistors.



Voltage Dependent Current Source

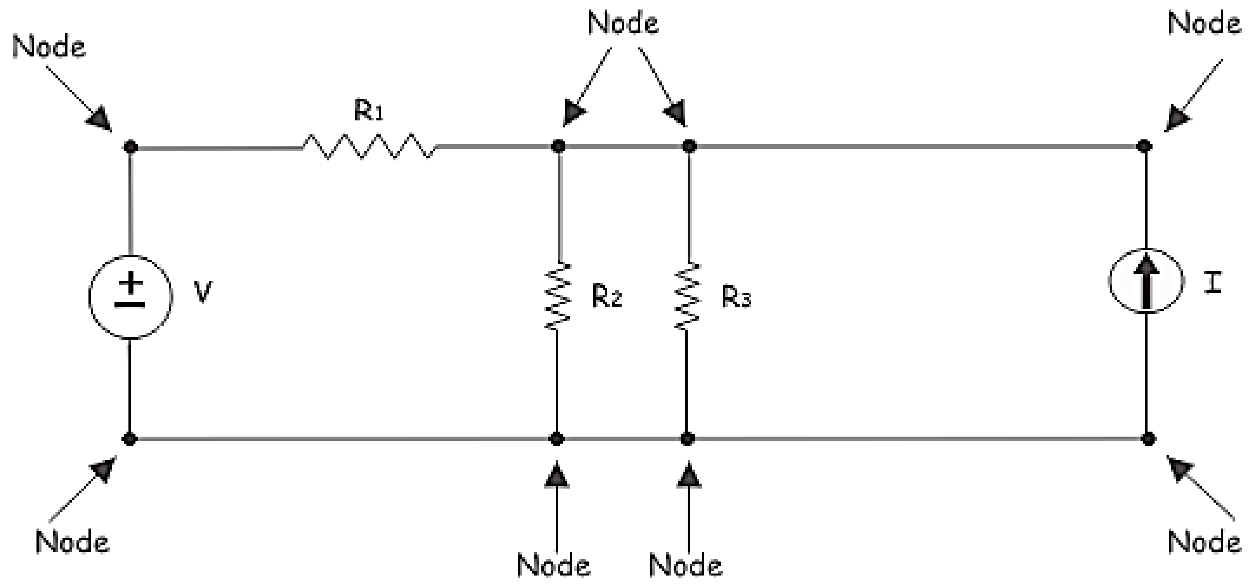


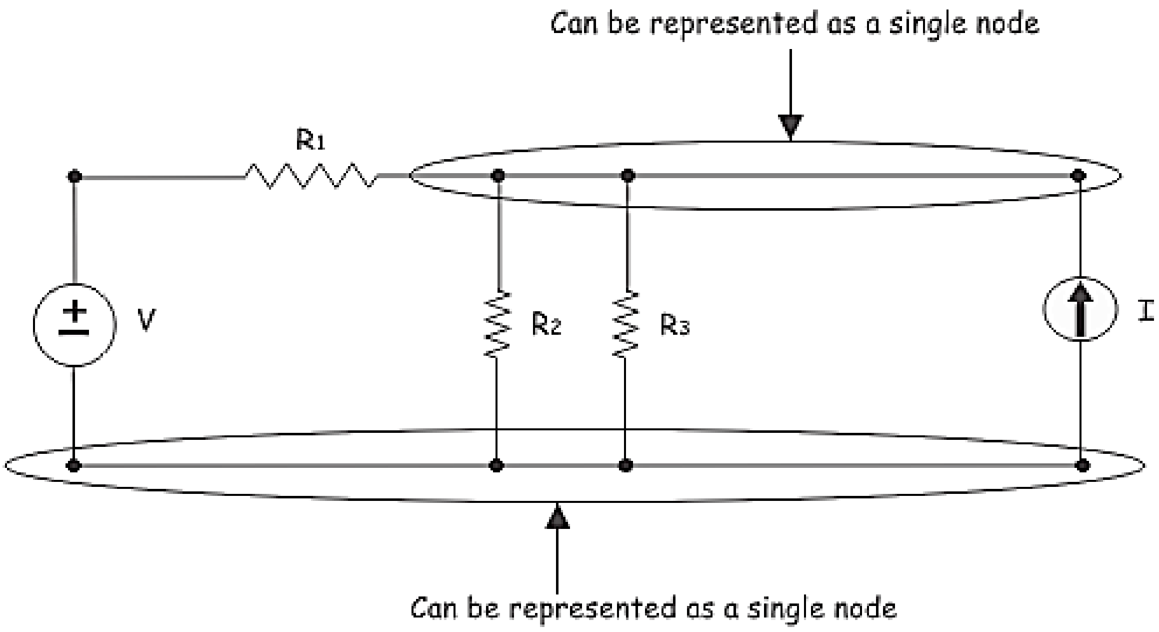
Current Dependent Current Source

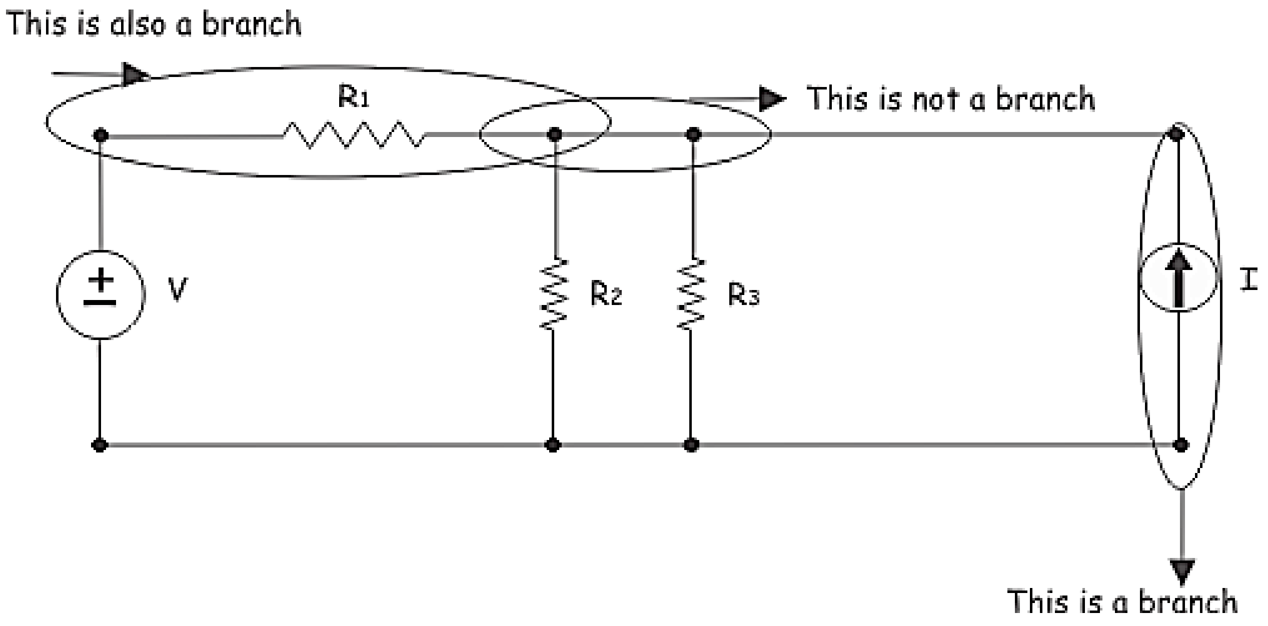
Network Terminology

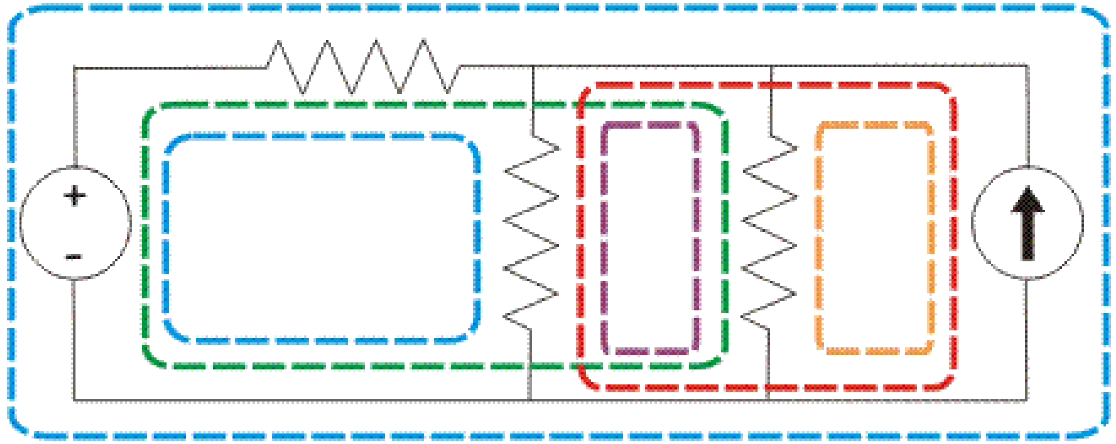
In order to describe the manner in which the elements are interconnected in a network, the following terms are used:

- **Node:** It is a point in an electrical network where two or more elements are connected
- **Junction:** It is a point in an electrical network where three or more elements are connected.
- **Branch:** A branch is a part of the electrical network which extends from one junction to another junction. A branch may contain one element or several elements in series.
- **Loop:** A closed path in an electrical network is called as loop.
- **Mesh:** The elementary loop of the network which further does not have any other loop in it is known as Mesh.


Node
Node
Node
R1
V
R2
R3
I
Node
Node
Node
Node


Can be represented as a single node
R1
V
R2
R3
I
Can be represented as a single node

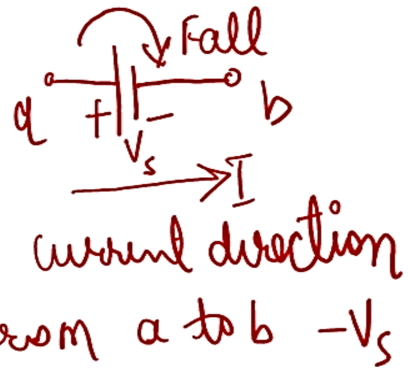

This is also a branch
R1
This is not a branch
V
R2
R3
I
This is a branch

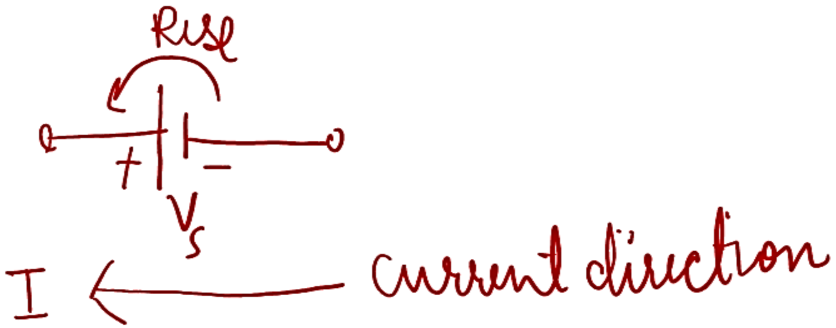


Sign Convention for sources and passive components

Polarity of Voltage Source

- Polarity of the voltage source is fixed and is independent of the direction of current.
- The positive (+) terminal is at a higher potential and negative (-) is at lower potential
- Consider a voltage source as shown in figure below:

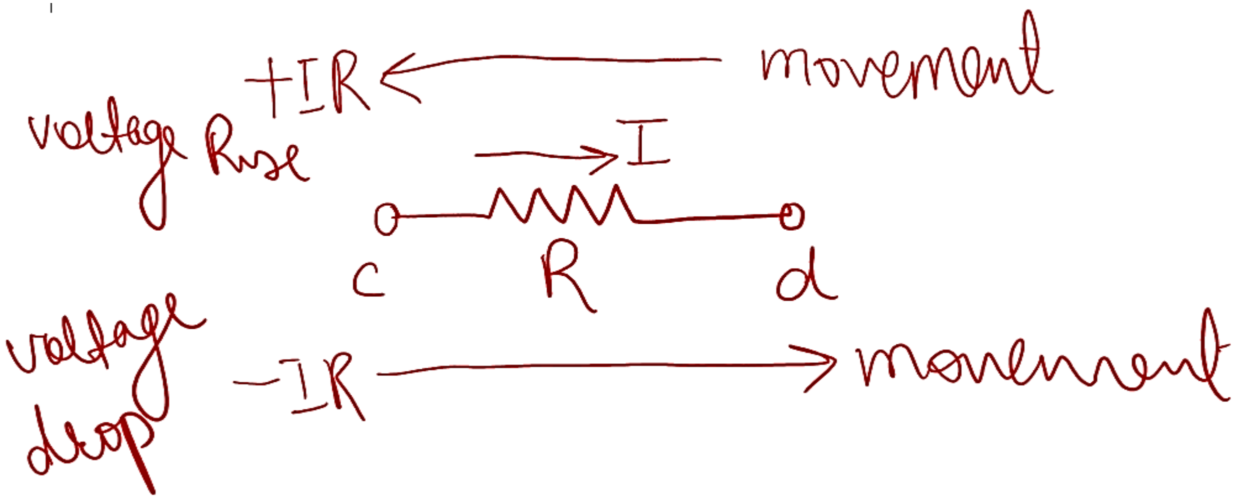




- When we go from “a” to “b” (i.e +ve terminal to –ve terminal), then there is a **voltage drop**
- When we go from “b” to “a” (i.e. –ve terminal to +ve terminal), then there is a **voltage rise**
- **Voltage Rise** indicates positive voltage and **Voltage Drop** indicates the negative voltage

Polarity of a Resistor

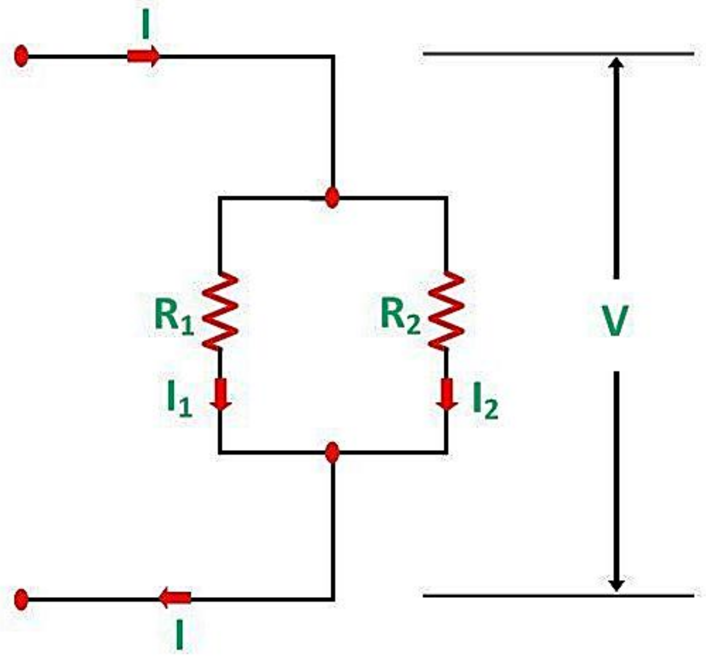
- Current flows from higher potential point to a lower potential point in a circuit or through an element
- As illustrated in figure given below:



- Since the current "I" flows from point "c" to "d", the point "c" is at a higher potential and the point "d" is at lower potential.
- When we move from "c" to "d", that is, along the direction of current, there is a voltage drop (i.e. Vcd = -IR)
- When we go from "d" to "c", that is, opposite to the flow of current, there is a voltage rise (i.e. Vdc = +IR)
- The following rule is to be remembered while taking sign convention in case of passive elements:
  - **"Movement along the flow of current gives –ve voltage (i.e. voltage drop)", and**
  - **"Movement opposite to the flow of current gives +ve voltage (i.e. voltage rise)"**

Current Division Rules

- A parallel circuit acts as a current divider as the current divides in all the branches in a parallel circuit, and the voltage remains the same across them.
- The current division rule determines the current across the circuit impedance.
- The current division is explained with the help of the circuit shown below:



The current I has been divided into I_1 and I_2 into two parallel branches with the resistance R_1 and R_2 and V is the voltage drop across the resistance R_1 and R_2.

V = IR ……..(1)

Then the equation of the current is written as: $I_1 = \frac{V}{R_1}$ and $I_2 = \frac{V}{R_2}$

Let the total resistance of the circuit be R and is given by the equation shown below:

$$R = \frac{R_1 R_2}{R_1 + R_2} \dots\dots\dots\dots(2)$$

Equation (1) can also be written as: **I = V/R** ………(3)

Now, putting the value of R from the equation (2) in the equation (3) we will get

$$I = \frac{V\,(R_1 + R_2)}{R_1 R_2} \ldots\ldots\ldots.(4)$$

But $$V = I_1 R_1 = I_2 R_2 \ldots\ldots\ldots\ldots.(5)$$

Putting the value of $V = I_1R_1$ from the equation (5) in equation (4), we finally get the equation as:

$$I = \frac{I_1 R_1 (R_1 + R_2)}{R_1 R_2} = \frac{I_1}{R_2}(R_1 + R_2) \ldots\ldots..(6)$$

And now considering $V = I_2R_2$ the equation (4) will be:

$$I = \frac{I_2 R_2 (R_1 + R_2)}{R_1 R_2} = \frac{I_1}{R_1}(R_1 + R_2) \ldots\ldots..(7)$$

Thus, from the equation (6) and (7) the value of the current I_1 and I_2 respectively is given by the equation below:

$$I_1 = I\,\frac{R_2}{R_1 + R_2} \quad \text{and} \quad I_2 = I\,\frac{R_1}{R_1 + R_2}$$

Thus, in the current division rule, it is said that the current in any of the parallel branches is equal to the ratio of opposite branch resistance to the total resistance, multiplied by the total current.

Voltage Division Rule

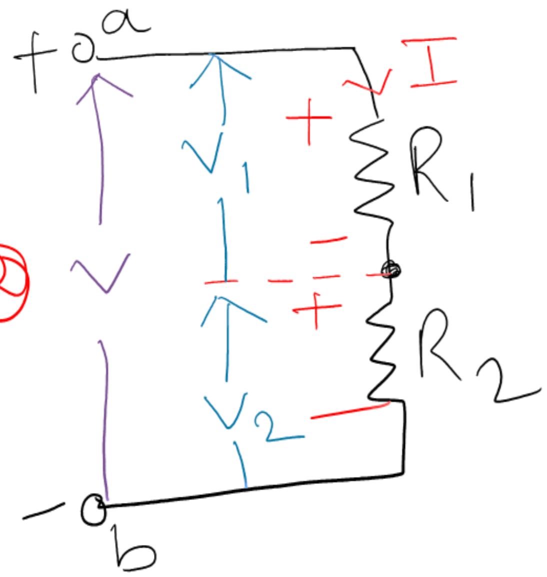
Voltage division between two resistors:

- When there are only two resistors in series (as shown in figure below), the voltage division between them can be found as follows:
- Total current in the circuit

$$I = \frac{V}{R_1 + R_2} \quad \text{①}$$

- By Ohm's Law

$$V_1 = I R_1 \quad \text{or} \quad \boxed{V_1 = \frac{V}{R_1 + R_2} \times R_1} \quad \text{②}$$



- Similarly

$$V_2 = I R_2 ; \quad \text{or} \quad \boxed{V_2 = \frac{V}{R_1 + R_2} \times R_2} \quad \text{③}$$

- Thus, the voltage across either of the series resistors is equal to the applied voltage times the ratio of that resistance to the total resistance.
- Hence, the use of voltage-divider equation eliminates calculations for current when determining voltage across resistors

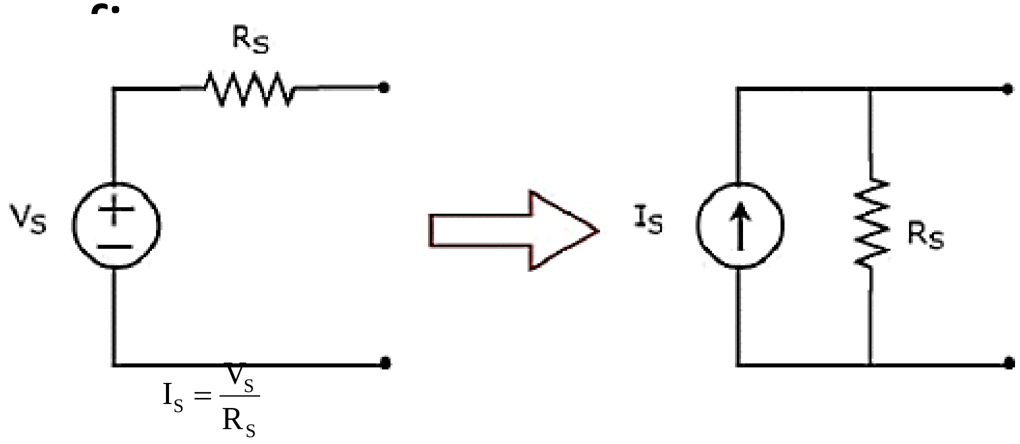
Source Transformation

- A non-ideal or practical voltage source an be transformed to an equivalent non-ideal or practical current source.
- Vice-versa is also true
- Replacing one source by an equivalent source is often called as source transformation.
- It is a fictional change in the type of source (i.e. it is a mathematical equivalence in terms of equations in the circuits)
- This transformation techniques serves as a powerful tool to simplify the analysis of circuits specially with mixed sources
- A practical voltage source and practical current source are said to be equivalent if their V-I relations are the same for all terminal conditions.
- For equivalence of the two sources, the following conditions should be satisfied:

1. The open circuit voltages at their terminals are equal
2. The short circuit currents at their terminals are equal

Transformation of Practical voltage source into a practical current source

- The transformation of practical voltage source into a practical current source is shown in the followi

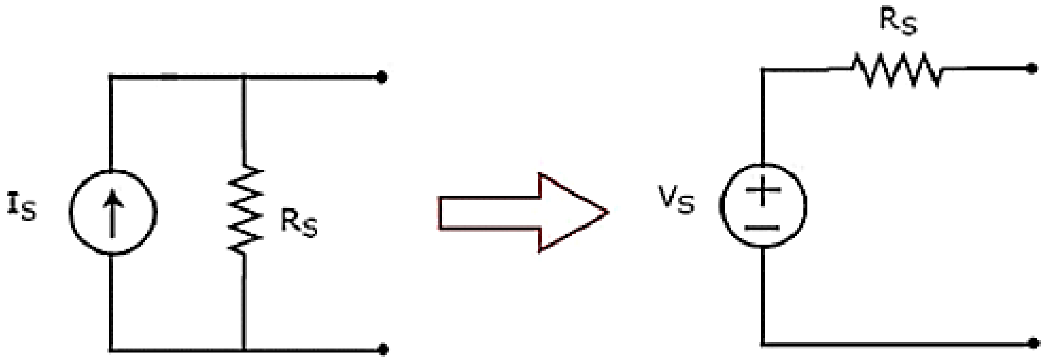


- **Practical voltage source** consists of a voltage source (V_S) in series with a resistor (R_S).
- This can be converted into a practical current source as shown in the figure.
- It consists of a current source (I_S) in parallel with a resistor (R_S).
- The value of I_S will be equal to the ratio of V_S and R_S. Mathematically, it can be represented as

$$I_S = \frac{V_S}{R_S}$$

Transformation of Practical current source into a practical voltage source

- The transformation of practical current source into a practical voltage source is shown in the following figure.

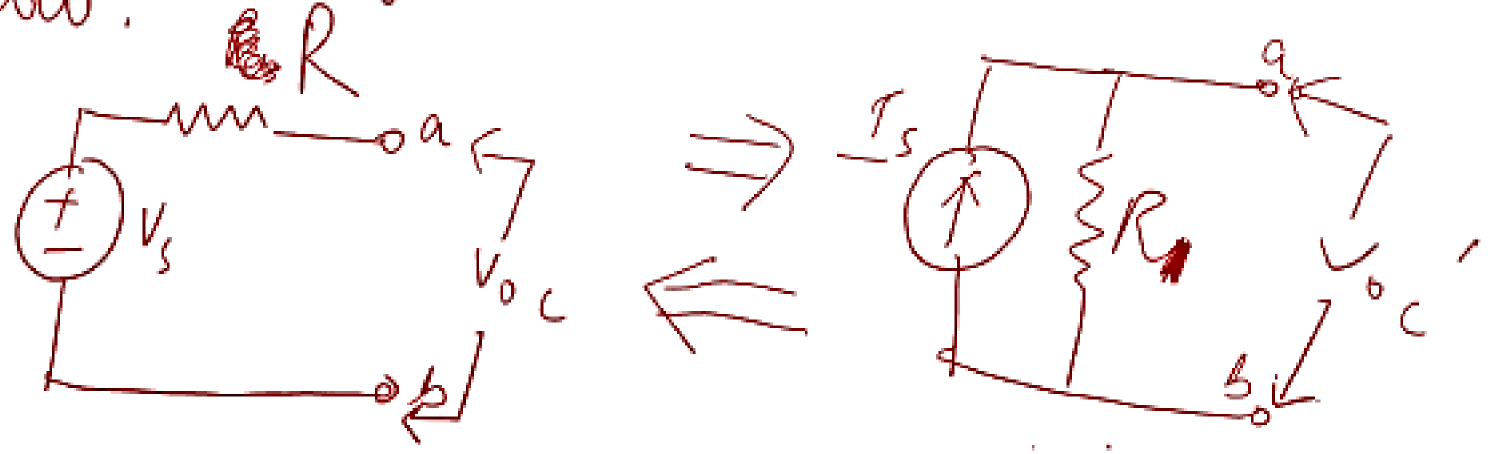


- Practical current source consists of a current source (I_S) in parallel with a resistor (R_S).
- This can be converted into a practical voltage source as shown in the figure.
- It consists of a voltage source (V_S) in series with a resistor (R_S).
- The value of V_S will be equal to the product of I_S and R_S.
- Mathematically, it can be represented as

$$V_S = I_S R_S$$

Let us prove the source transformation

Consider a voltage source with internal resistance as shown below:



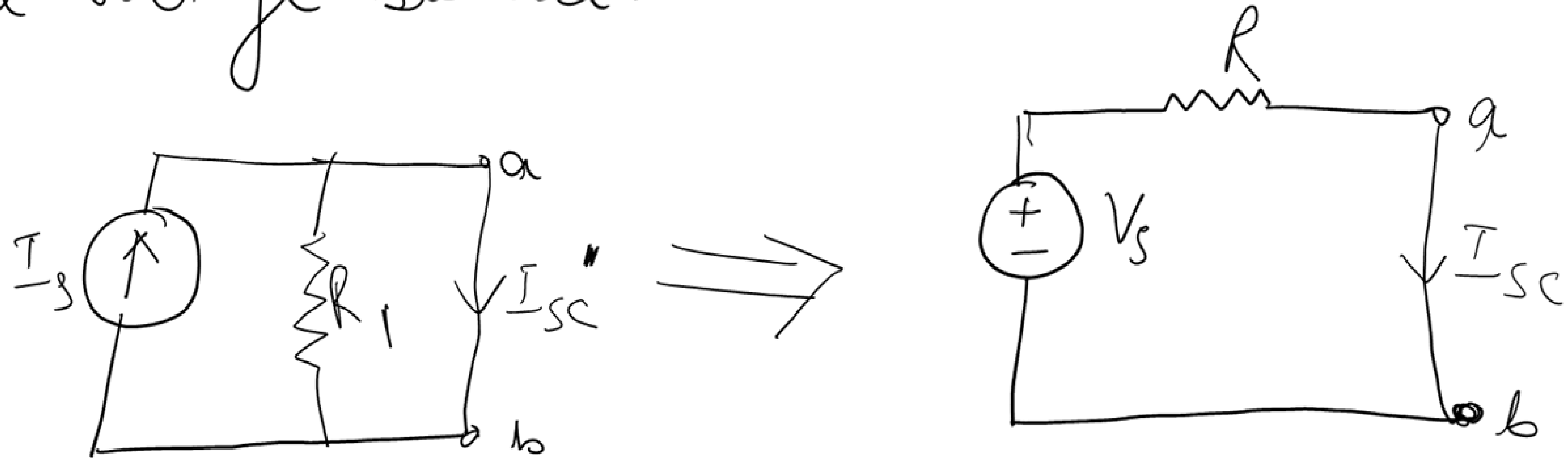
$V_{oc}' = I_s R_s$

$\boxed{V_{oc} = V_s}$

$V_{oc} = V_{oc}'$

$V_s = I_s R_s$ or $I_s = \frac{V_s}{R_s}$

Now let us transform the current source back to the voltage source.



$$I_{sc} = I_{sc}'$$

$$I_{sc} = \frac{V_s}{R}$$

$$I_{sc}' = I_s$$

So; $I_s = \dfrac{V_s}{R}$

or $V_s = I_s R$

Thank You