LECTURE NOTES

ON

BASIC ELECTRICAL ENGINEERING

II B. Tech I semester

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COMPUTER SCIENCE AND ENGINEERING

UNIT-I

Introduction to Electrical Engineering

Ohms Law: At constant temperature potential difference across the conductor is directly proportional to current flowing through the conductor is called ohms law.

$$V \propto I$$

V=IR

where the constant of proportionality R is called the resistance or electrical resistance, measured in ohms (Ω). Graphically, the $V - I$ relationship for a resistor according to Ohm's law is depicted in Figure

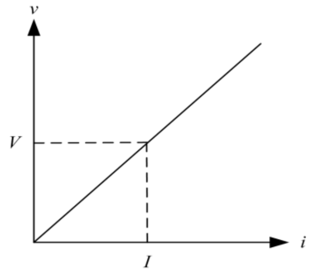
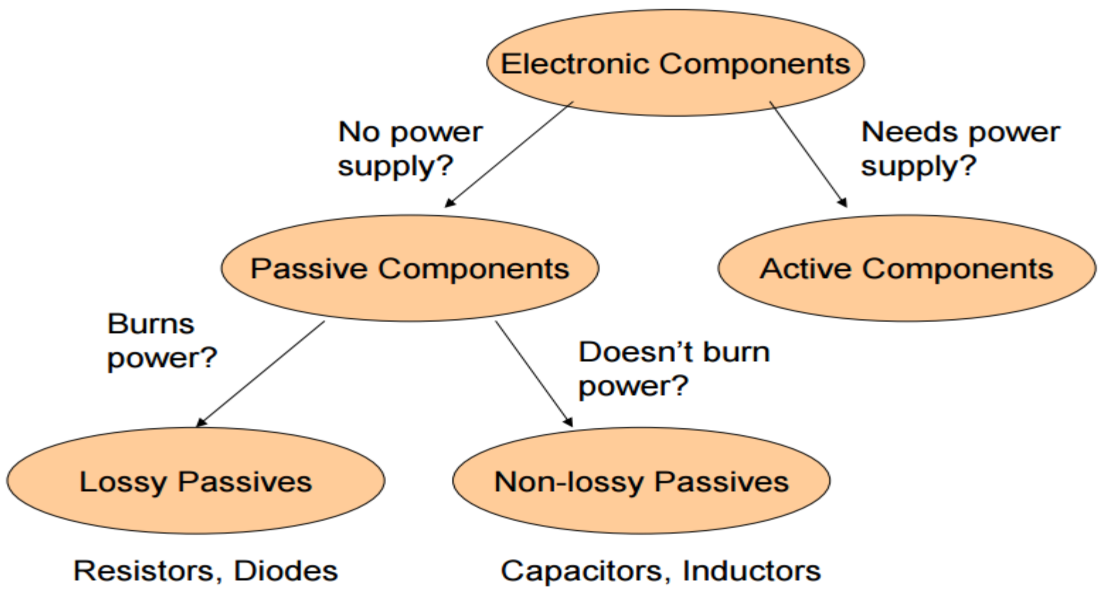


Figure $V - I$ relationship for a resistor according to Ohm's law.

At any given point in the above graph, the ratio of voltage to current is always constant

basic circuit components:



Circuit Element	Voltage	Current
Resistor	$V = IR$	$I = \frac{V}{R}$
Inductor	$v = L\frac{di}{dt}$	$i = \frac{1}{L}\int_0^t v\,dt$
Capacitor	$v = \frac{1}{C}\int_0^t i\,dt + v(0)$	$i = C\frac{dv}{dt}$, $i = 0$ for DC

$V - I$ relationships for a resistor, inductor and capacitor.

Kirchhoff's Voltage Law (KVL)

Kirchhoff's Voltage Law states that the algebraic sum of voltages around each loop at any instant of time is zero

Σ voltage drops = Σ voltage rises

Kirchhoff's Current Law (KCL)

Kirchhoff's Current Law states that The algebraic sum of currents a node at any instant is zero.

Σ currents in = Σ currents out

Basic Definitions:

Current: the directed flow of electrons (charge) called current. It is denoted by I. units are Amps

Electrical potential: charged body capacity to do work is known as its electrical potential.

Potential difference: difference in potentials of two charged bodies is called Potential difference

Power: the rate at which an electrical work done in electrical work is called power. It is denoted by P. units are Watt

Electrical work: Electrical work is said to be done when there is transfer of charge. It is denoted by W. units are joules.

Energy: capacity to do work is called energy.

Electrical Network: A combination of various electric elements (Resistor, Inductor, Capacitor, Voltage source, Current source) connected in any manner what so ever is called an electrical network

Classification of element:

We may classify circuit elements in two categories, passive and active elements.

Passive Element: The element which receives energy (or absorbs energy) and then either converts it into heat (R) or stored it in an electric (C) or magnetic (L) field is called passive element.

Active Element: The elements that supply energy to the circuit is called active element. Examples of active elements include voltage and current sources, generators

Bilateral Element: Conduction of current in both directions in an element (example: Resistance; Inductance; Capacitance) with same magnitude is termed as bilateral element

Unilateral Element: Conduction of current in one direction is termed as unilateral (example: Diode, Transistor) element

Linear Circuit: Roughly speaking, a linear circuit is one whose parameters do not change with voltage or current. More specifically, a linear system is one that satisfies (i) homogeneity property (ii) additive property

Non-Linear Circuit: Roughly speaking, a non-linear system is that whose parameters change with voltage or current. More specifically, non-linear circuit does not obey the homogeneity and additive properties.

DC Sources

In general, there are two main types of DC sources

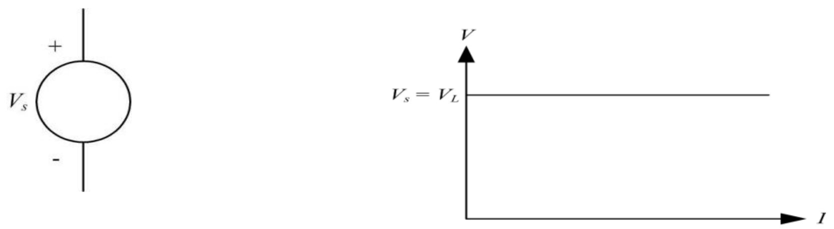
1. Independent (Voltage and Current) Sources
2. Dependent (Voltage and Current) Sources

An independent source produces its own voltage and current through some chemical reaction and does not depend on any other voltage or current variable in the circuit. The output of a dependent source, on the other hand, is subject to a certain parameter (voltage or current) change in a circuit element. Herein, the discussion shall be confined to independent sources only.

DC Voltage Source

This can be further subcategorised into ideal and non-ideal sources.

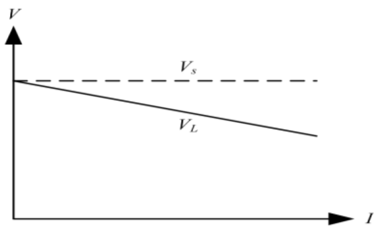
The Ideal Voltage Source An ideal voltage source, shown in Figure has a terminal voltage which is independent of the variations in load. In other words, for an ideal voltage source, the sup- ply current alters with changes in load but the terminal voltage, V_L always remains constant. This characteristic is depicted in Figure.

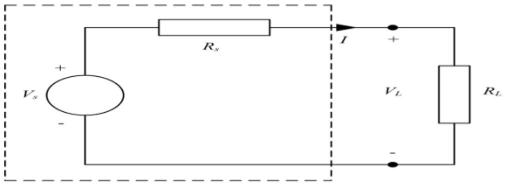


(a) An ideal voltage source. (b) $V - I$ characteristics of an ideal voltage source.

Figure: Schematic and characteristics of an ideal voltage source

Practical Voltage Source For a practical source, the terminal voltage falls off with an increase in load current. This can be shown graphically in Figure. This behavior can be modeled by assigning an internal resistance, R_S, in series with the source as shown in Figure





Practical Voltage Source

Where R_L *represents* the load resistance. The characteristic equation of the practical

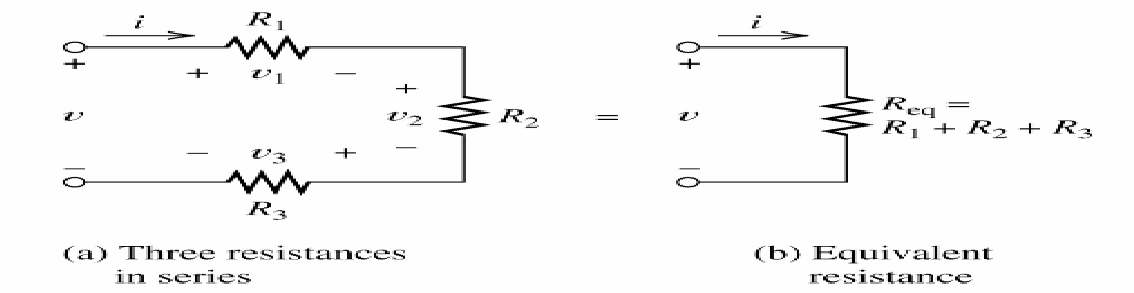
voltage source can be written as

$$V_L = V_S - R_S I$$

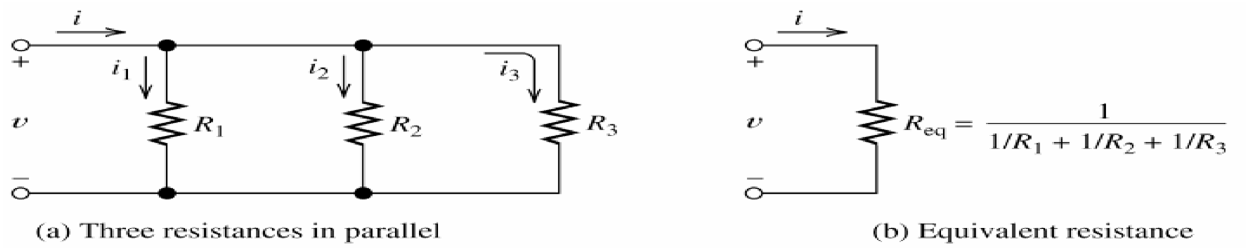
For an ideal source, $R_s = 0$ and therefore $V_L = V_S$.

Resistive Circuits

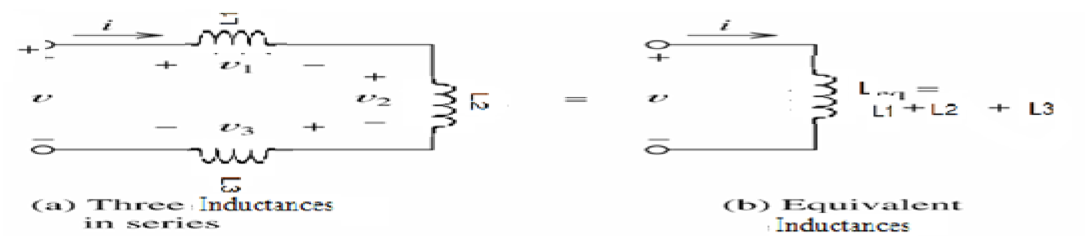
Series Resistors



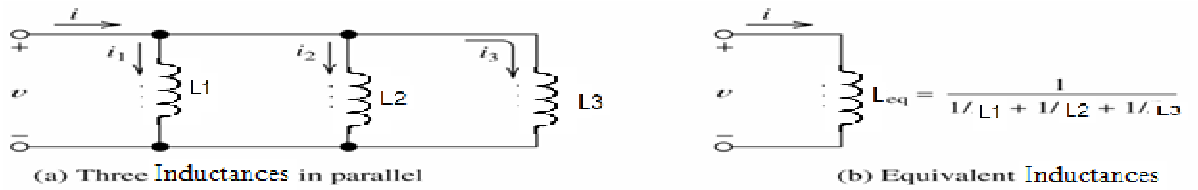
Parallel Resistors



Series Inductors

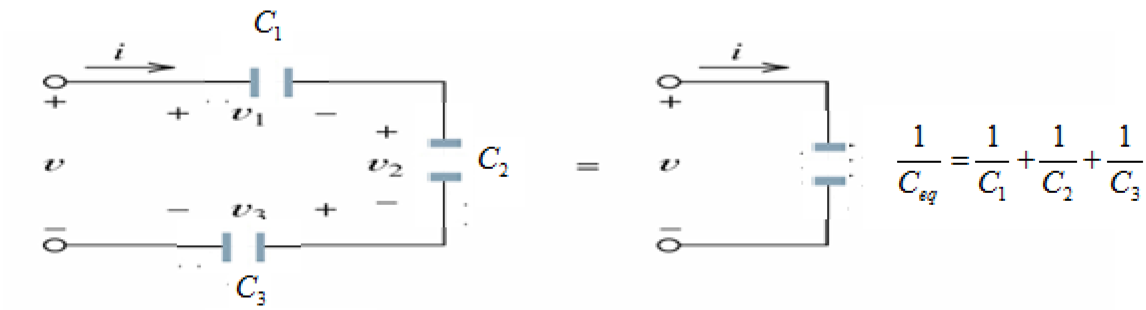


Parallel Inductors



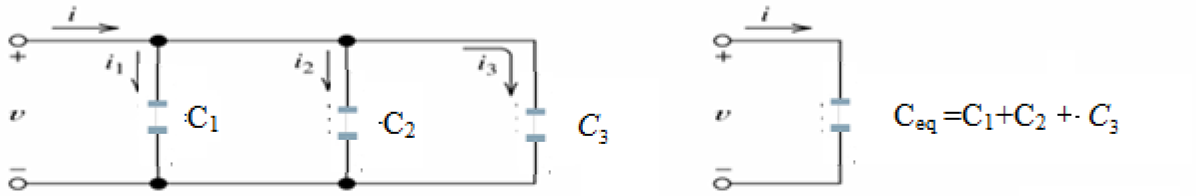
(a) Three Inductances in parallel (b) Equivalent Inductances

Series Capacitors



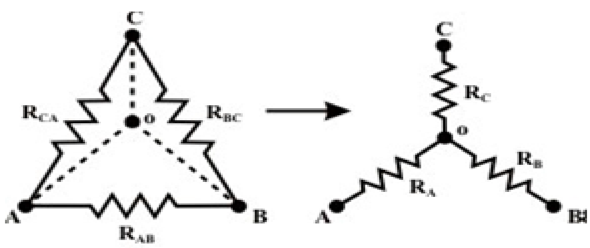
(a) Three capacitances in series (b) Equivalent capacitance

Parallel Capacitors



(a) Three capacitance in parallel (b) Equivalent capacitance

Delta – Star Conversion

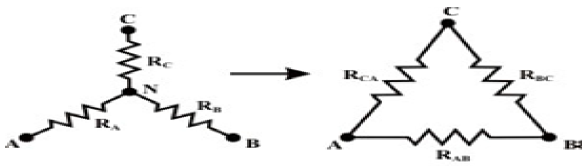


$$R_A = \frac{R_{AB}R_{CA}}{R_{AB} + R_{BC} + R_{CA}}$$

$$R_B = \frac{R_{AB}R_{BC}}{R_{AB} + R_{BC} + R_{CA}}$$

$$R_C = \frac{R_{BC}R_{CA}}{R_{AB} + R_{BC} + R_{CA}}$$

Star -Delta Conversion



$$R_{AB} = R_A + R_B + \frac{R_A R_B}{R_C}$$

$$R_{AC} = R_A + R_C + \frac{R_A R_C}{R_B}$$

$$R_{BC} = R_B + R_C + \frac{R_B R_C}{R_A}$$

Superposition Theorem

Superposition theorem is extremely useful for analysing electric circuits that contains two or more active sources. In such cases, the theorem considers each source separately to evaluate the current through or voltage across a component. The resultant is given by the algebraic sum of all currents or voltages caused by each source acting independently. Superposition theorem can be formally stated as follows

"*The current through or voltage across any element in a linear circuit containing several sources is the algebraic sum of the currents or voltages due to each source acting alone, all other sources being removed at that time.*"

Linearity is a necessary condition for the theorem to apply. Fortunately, the *v*, *i* relationship for *R*, and *C* are all linear.The sources can be removed using the following methodology

1. Ideal voltage sources are short-circuited
2. Ideal current sources are open-circuited

In general, practical sources are replaced by their internal resistances.

Thévenin's Theorem

Th´evenin's theorem provides a useful tool when solving complex and large electric circuits by reduc- ing them to a single voltage source in series with a resistor. It is particularly advantageous where a single resistor or load in a circuit is subject to change.

Formally, the Thévenin's theorem can be stated as

"*Any two-terminal linear electric circuit consisting of resistors and sources, can be re- placed by an equivalent circuit containing a single voltage source in series with a resistor connected across the load.*"

In the circuit diagrams shown in Figure, the current I_L through the load resistance R_L is the same. Hence the circuits are equivalent as far as the load resistor R_L is concerned.

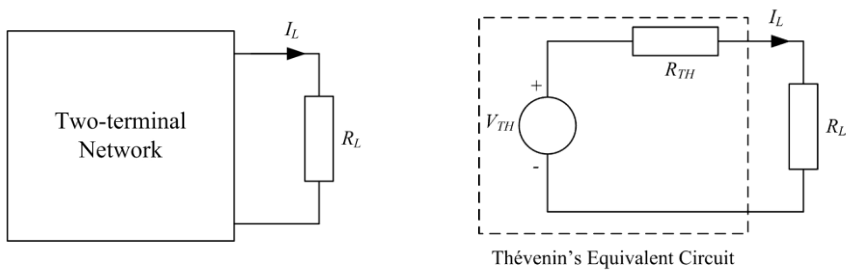


Figure : Illustration of Thévenin's theorem.

The following steps outline the procedure to simplify an electric circuit using Thévenin's theorem where VTH and RTH are the Thévenin's voltage and Theévenin's resistance respectively.

1. Remove the load resistance RL.
2. VTH is the open circuit (OC) voltage across the load terminals and
3. RTH is the resistance across the load terminals with all sources replaced by their internal resis- tances.

Alternatively, measure the OC voltage across, and the short circuit (SC) current through the load terminals. Then

$VTH = V_{OC}$ and $RT = V_{OC}/I_{SC}$

Maximum Power Transfer Theorem

As discussed in the section on Th´evenin's theorem, any DC network of sources and resistances can be replaced by a single voltage source in series with a resistance connected across the load (see Figure). The maximum power transfer theorem states that the power delivered to the load is maximum when the load resistance, RL is equal to the internal (source) resistance, R_S of the DC power supply. In other words, it can be said that the load resistance must match the Th´evenin's resistance for maximum power transfer to take place i.e.,

$$(R_S = RTH) = RL$$

When this occurs, the voltage across the load resistance will be $\frac{V_S}{2}$ and the power delivered to the load is given by

The above equation is plotted in Figure which clearly demonstrates maximum power delivered when $R_S = RL$. Under this condition, the maximum power will be

$$\boxed{P_{max} = \frac{V_S^2}{4R_S}}$$

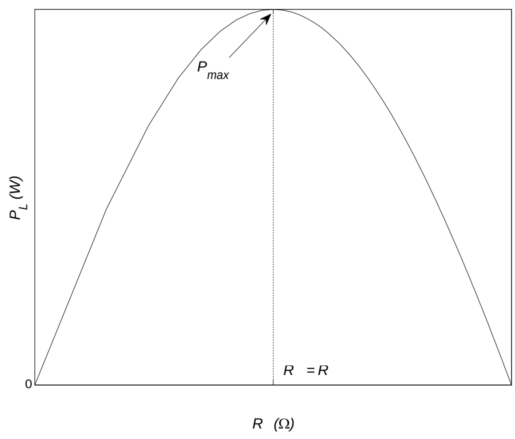


Figure: Illustration of maximum power transfer theore