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Rajasthan RVUNL

Electrical Engineering

Electric Circuits

Formula Notes

IMPORTANT FORMULAS TO REMEMBER

Current: Electric current is the time rate of change of charge flow.

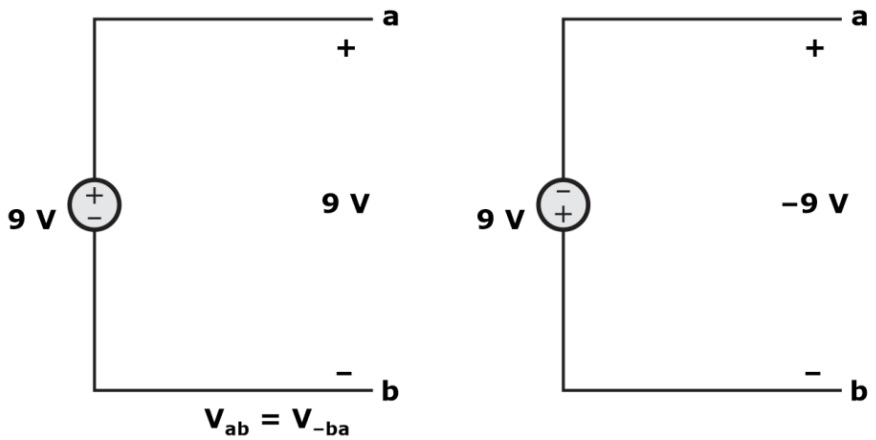
$$i = \frac{dq}{dt} \text{ (Ampere)}$$

Charge transferred between time t_0 and t

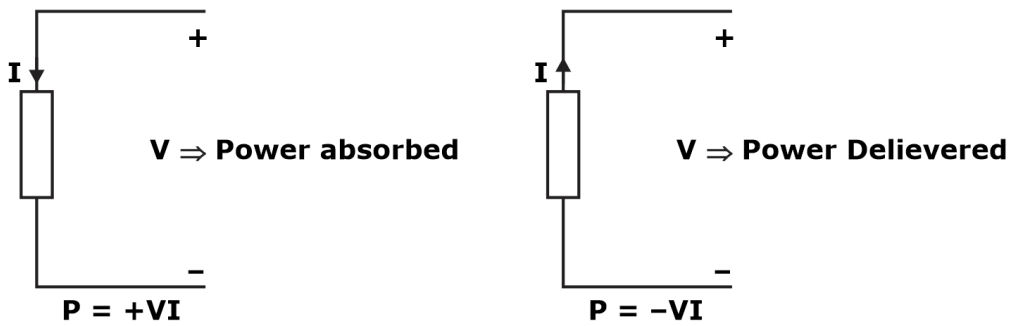
$$q \int_{t_0}^{t} i dt$$

Sign Convention: A negative current of -5A flowing in one direction is same a current of +5A in opposite direction.

Voltage: Voltage or potential difference the energy required to move a unit charge through an element, measured in volts.



Power: It is time rate of expending or absorbing energy.



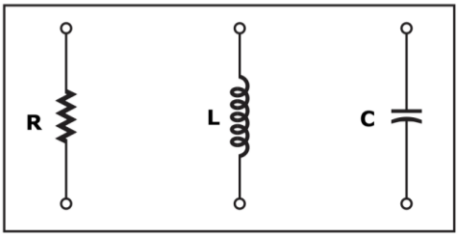
- Law of conservation of energy must be obeyed in any electric circuit.
- Algebraic sum of power in a circuit, at any instant of time, must be zero.

  i.e. $\sum P = 0$

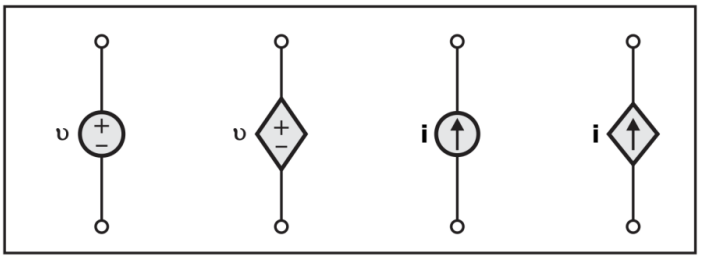
Circuit Elements:

Passive element: If it is not capable of delivering energy, then it is passive element.

Example: Resistor, Inductor, and capacitor



Active element: If an element is capable of delivering energy independently, then it is called active element. Example: Voltage source, and current source.



Linear and Non-linear elements: If voltage and current across an element are related to each other through a constant coefficient then the element is called as linear element otherwise it is called as it is as non-linear.

Unidirectional and Bidirectional: When elements characteristics are independent of direction of current then element is called bi-directional element otherwise it is called as unidirectional.

- R, L & C are bidirectional
- Diode is a unidirectional element.
- Voltage and current sources are also unidirectional elements.
- Every linear element should obey the bi-directional property but vice versa as is not necessary.

Resistor: Linear and bilateral (conduct from both direction)

- In time domain V(t) = I(t)R
- In s domain: V(s) = RI(s)

  $R = \frac{\rho l}{A}$ ohm

- l = length of conductor, ρ= resistivity, A = area of cross section
- Extension of wire to 'n' times results in increase in resistance:

  $R' = n^2 R$

- Compression of wire results in decrease in resistance:

$$R' = \frac{R}{n^2}$$

Capacitor: All capacitors are linear and bilateral, except electrolytic capacitor which is unilateral.

- Time Domain:

$$i(t) = \frac{Cdv(t)}{dt} \qquad v(t) = \frac{1}{C}\int_{-\infty}^{t} i(t)dt$$

- In s-domain:

$$I(s) = s\,CV(s) \quad V(s) = \frac{1}{sC}I(s)$$

- Capacitor doesn't allow sudden change of voltage, until impulse of current is applied.
- It stores energy in the form of electric field and power dissipation in ideal capacitor is zero.

Impedance:

$Z_c = -jX_c\,\Omega$ & $X_c = \frac{1}{\omega C}$; $X_c \rightarrow$ Capacitive reactance ; $\omega = 2\pi f$

Inductor: Linear and bilinear element

Time Domain: $V(t) = L\frac{di(t)}{dt}$

$$i(t) = \frac{1}{L}\int_{\infty}^{t} v(t)dt$$

Impedance $Z_L = j\,X_L\,\Omega$ & $X_L = \omega L$

In s-domain $V(s) = sL\,I(s)$

$$I(s) = \frac{1}{sL}V(s)$$

- Inductor doesn't allow sudden change of current, until impulse of voltage is applied. It stores energy in the form of magnetic field.
- Power dissipation in ideal inductor is zero.

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FORMULAS FOR THE BASIC CIRCUIT COMPONENTS					
Circuit Element	Impedance		Volt- Amp Equations		Energy (Dissipated on R or Stored in L, C)
	Absolute Value	Complex form	instantaneous values	RMS values for sinusoidal signals	
Resistance	R	R	V = iR	$V_{rms} = I_{rms}R$	$E = I_{rms}^2Rt$
Inductance	$2\Pi fL$	$j\omega L$	V = Ldi/dt	$V_{rms}=I_{rms}x2\Pi fL$	$E = li^2/2$
Capacitance	$1/(2\Pi fC)$	$1/j\omega C$	i=Cdv/dt	$V_{rms}=I_{rms}/(2\Pi fC)$	$E = Cv^2/2$

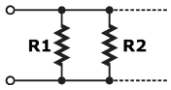
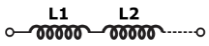
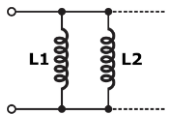
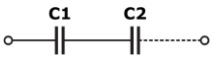
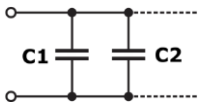
Notes:

R- resistance in ohms, - inductance in henrys, C- capacitance in farads, f – frequency in Hertz, t- time in seconds, $\pi \approx 3.14159$,

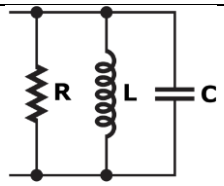
$\omega = 2\pi f$ – angular frequency

j – imaginary unit ($j^2=-1$)

Euler's formula: $e^{jx} = \cos x + j\sin x$

EQUATIONS FOR SERIES AND PARALLEL CONNECTIONS				
Circuit Element	Series Connection		Parallel Connection	
Resistors		$R_{series} = R1+R2+...$		$R_{parallel} = \frac{1}{(1/R1+1/R2+...)}$
Inductors		$L_{series} = L1+L2=...$		$R_{parallel} = \frac{1}{(1/R1+1/R2+...)}$
Capacitors		$C_{series} = \frac{1}{(1/C1+1/C2+...)}$		$C_{parallel} = C1+C2+C3...$

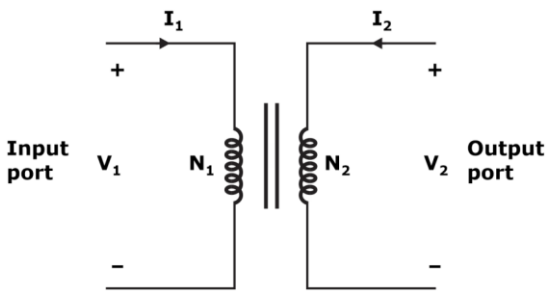
Rules of series	Rules of parallel
$V_{eq} = V_1 + V_2 + V_3$	$i_{eq} = i_1 + i_2 + i_3$
$R_{eq} = R_1 + R_2 + R_3$	$R = \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}}$
$C_{eq} = \frac{1}{\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}}$	Ceq = C1 + C2 + C3

CALCULATIONS OF EQUIVALENT RLC IMPEDANCES		
Circuit Connection	Complex Form	Absolute Value
 Series	Z=R+jωL+1/ωC	$Z=\sqrt{R^2+(\omega L-\frac{1}{\omega C})^2}$
 Parallel	Z=1/(1/R+1/jωL+jωC	$Z=\frac{1}{\sqrt{\frac{1}{R^2}+\left(\omega C-\frac{1}{\omega L}\right)^2}}$

Mesh Analysis:

- Path – A set of elements that may be traversed in order, without passing thru the same node twice
- Loop – a closed path
- Mash – A loop that does not contain any other loop within it.
- Planar Circuit – A circuit that may be drawn on a plane surface in such a way that there are no branch crossovers
- Non-Planar Circuit – A circuit that is not planar, ie. some branches pass over some other branches (cannot use Mesh Analysis)

Transformer: 4 terminal or 2-port devices.



- $N_1 > N_2$: Step down transformer

  $$\frac{V_1}{V_2}=\frac{N_1}{N_2}$$

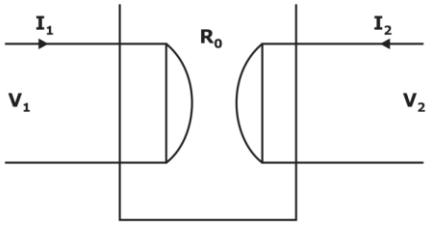
- $N_2 > N_1$: Step up transformer

  $$\frac{I_1}{I_2}=\frac{N_2}{N_1}$$

Where $\frac{N_1}{N_2} = K \rightarrow$ Turns ratio.

- Transformer does not work as amplifier because current decreases in same amount power remain constant.

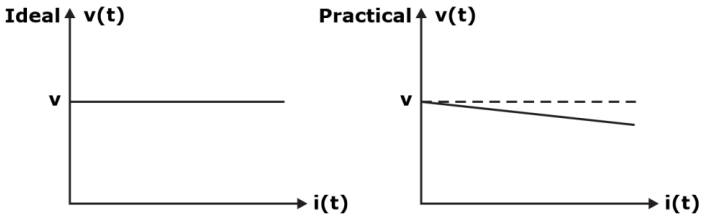
Gyrator:



- R_0 = Coefficient of Gyrator
- V1 = R0 I2
- V2 = R0 I2
- If load is capacitive then input impedance will be inductive and vice versa.
- If load is inductive then input impedance will be capacitive.
- It is used for simulation of equivalent value of inductance.

Voltage Source:

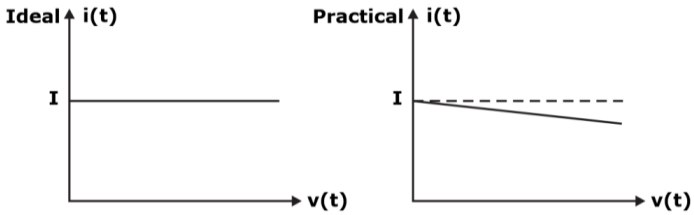
- In practical voltage source, there is small internal resistance, so voltage across the element varies with respect to current.



- Ideal voltmeter, R_V is infinite (Internal resistance)

Current Source:

- In practical current source, there is small internal resistance, so current varies with respect to the voltage across element.



- Ideal Ammeter, R_a is 0 (Internal resistance)
- Internal resistance of voltage source is in series with the source.
- Internal resistance of ideal voltage source is zero.
- Internal resistance of current source is in parallel with the source.
- Internal resistance of ideal current source is infinite.

Independent source: Voltage or current source whose values doesn't depend on any other parameters

- Example: Generator

Dependent Source: Voltage or current source whose values upon other parameters like current, voltage.

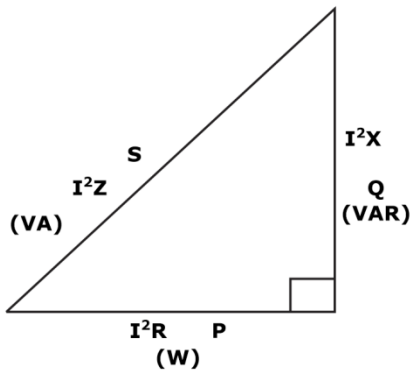
Dependent Source: Voltage or current source whose values upon other parameters like current, voltage.

Lumped Network: Network in which all network elements are physically separable is known as lumped network.

Distributed Network: A network in which the circuit elements like resistance, inductance etc, are not physically separate for analysis purpose, is called distributed network. Example: Transmission line.

Thevenin's Theorem: Any linear network can be replaced by an independent voltage sources in series with an impedance such that the current voltage at the terminals is unchanged.

Norton's Theorem: Identical to thevenin's statement except that the equivalent circuit is an independent current source in parallel with. ($Z_s = R_{Th}$)

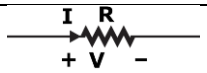
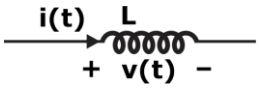
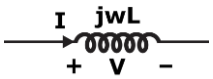
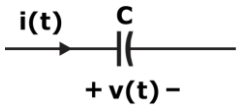
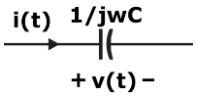
Average Power	**Max. power Transfer**
$P_{Avg} = \frac{V_m}{\sqrt{2}} - \frac{I_m}{\sqrt{2}} \cos(\theta)$ $= V_{rms} I_{rms} \cos(\theta)$	$Z_L = R_L + jX_L$ $= R_{Th} - jX_{Th} = Z_{Th}$
Power Factor $PF = \cos(\theta)$ $\theta = \theta_v - \theta_i$	**True Power** $P = I^2 R$ 
Reactive Power $Q = V_{rms} I_{rm} \sin(\theta)$ Measured VARs Volt Amperes Reactive $P^2 + Q^2 = (V_{rms} I_{rm})^2$	
Apparent Power (s) $S = V_{rms} I_{rms} = Va$ $S = P + jQ$ $S = I^2 Z$	

Root Mean Square:

Average of a signal that is symmetric about the horizontal axis:

$V_{rms} = \frac{V_m}{\sqrt{2}}$ $\quad$ $I_{rms} = \frac{I_m}{\sqrt{2}}$

$V_{eff} = V_{rms}$ $\quad$ $I_{eff} = I_{rms}$

Time Domain		Frequency Domain	
	$v = Ri$	$V = RI$	
	$V = L\frac{di}{dt}$ $\frac{di}{dt}$	$V = j\omega LI$	
	$v = \frac{1}{C}\int idt$	$v = \frac{1}{jwC}I$	

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