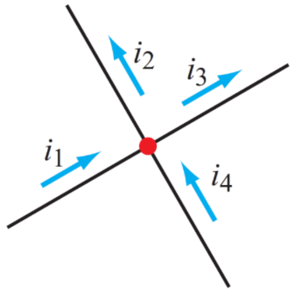
KIRCHHOFF'S CURRENT LAW, Sum of all currents entering a node is equal to zero

$$\sum_{n=1}^{N} i_n = 0 \quad (KCL)$$

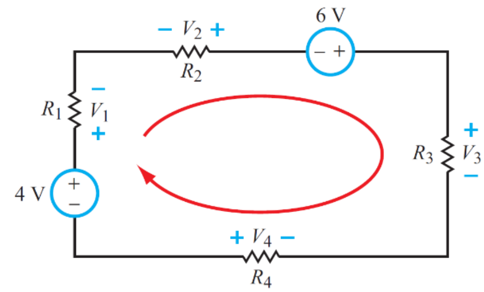
$$i_1 + i_4 - i_2 - i_3 = 0$$



KIRCHHOFF'S VOLTAGE LAW

Sum of all voltage drops in a closed loop is equal to zero

$$\sum_{n=1}^{N} v_n = 0 \quad (KVL)$$

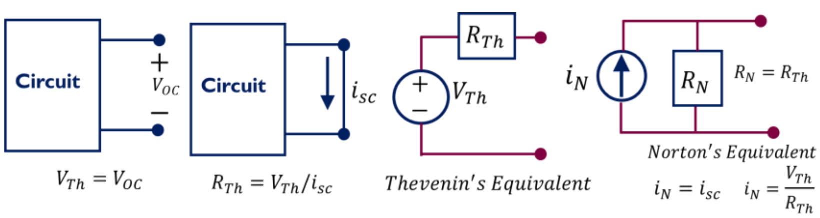


$$-4 + V_1 - V_2 - 6 + V_3 - V_4 = 0$$

OHM'S LAW $V = iR$

RESISTANCES IN PARALLEL : $\frac{1}{R_{eq}} = \sum_{i=1}^{N} \frac{1}{R_i}$ **RESISTANCES IN SERIES** $R_{eq} = \sum_{i=1}^{N} R_i$

THEVENIN'S EQUIVALENT CIRCUIT



$V_{Th} = open\ circuit\ voltage$
$R_{Th} = V_{th}/i_{sc}$
R_{Th} *is also the equivalent resistance seen between the terminals when all independent sources are set to zero*
Norton's Equivalent circuit can be obtained from Thevenin's equivalent circuit using source transformation

POWER ASSOCIATED WITH ANY CIRCUIT ELEMENT

$P = iV$

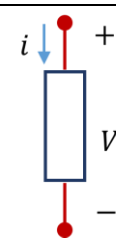
POWER DISSIPATED IN A RESISTOR

$$P = iV = i^2R = \frac{V^2}{R}$$

PASSIVE POWER CONVENTION

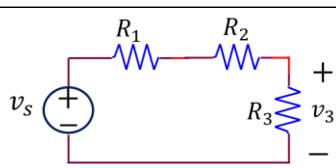
$$P = iV$$

positive P indicates absorbed power
negative P indicates delivered power

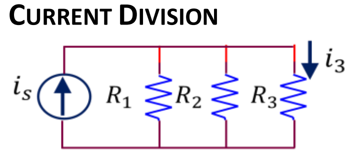


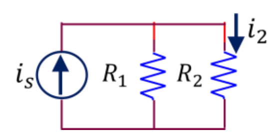
VOLTAGE DIVISION

$$v_3 = v_s \frac{R_3}{R_1 + R_2 + R_3}$$



CURRENT DIVISION





$$i_3 = i_s \frac{R_{eq}}{R_3} \qquad i_2 = i_s \frac{R_1}{R_1 + R_2}$$

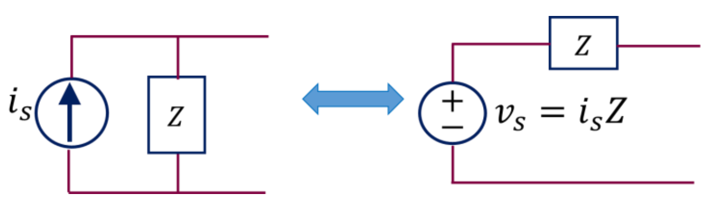
$$R_{eq} = R_1 || R_2 || R_3$$

PRINCIPLE OF SUPERPOSITION: For a linear system, the net response due to more than one input is the sum of the responses which would have been caused by each input individually.

Capacitor	Inductor
$\boldsymbol{i = C\frac{dv}{dt} \qquad v = \frac{1}{C}\int_{t=t_0}^{t} i(t)dt + v(t_0)}$ $\boldsymbol{P = iv \quad w = \frac{1}{2}Cv^2}$	$v = L\frac{di}{dt} \qquad i = \frac{1}{L}\int_{t=t_0}^{t} v(t)dt + i(t_0)$ $P = iv \quad w = \frac{1}{2}Li^2$
Transient analysis for first order RC , general solution $\boldsymbol{v(t) = V_F + (V_0 - V_F)e^{-\frac{t}{\tau}} \qquad t \geq 0}$ $\boldsymbol{i(t) = I_0 e^{-\frac{t}{\tau}} \qquad t \geq 0^+}$	Transient analysis for first order RL circuits, general solution $v(t) = V_0 e^{-\frac{t}{\tau}} \qquad \boldsymbol{t \geq 0^+}$ $i(t) = I_F + (I_0 - I_F)e^{-\frac{t}{\tau}} \qquad \boldsymbol{t \geq 0}$
$\boldsymbol{\tau = RC}$	$\tau = \frac{L}{R}$
$\boldsymbol{\Longrightarrow v(0^-) = v(0) = v(0^+) = V_0}$	$i(0^-) = i(0) = i(0^+) = I_0$
Sinusoidal steady state analysis	
$\boldsymbol{\tilde{V} = Z\tilde{I} \qquad Z = \frac{1}{j\omega C}}$	$\tilde{V} = Z\tilde{I} \qquad Z = j\omega L$
$\boldsymbol{v(t) = V_m cos\,(\omega t)}$, $\boldsymbol{i(t) = I_m \cos(\omega t + 90^o)}$	$i(t) = I_m \cos(\omega t) \qquad v(t) = V_m cos\,(\omega t + 90^o)$
Current leads voltage by $\boldsymbol{90^o}$	*Current lags voltage by* 90^o
Capacitors in parallel $\boldsymbol{C_{eq} = \Sigma C_i}$	*Inductors in parallel* $\frac{1}{L_{eq}} = \boldsymbol{\Sigma \frac{1}{L_i}}$
Capacitor in series $\frac{1}{C_{eq}} = \Sigma \frac{1}{C_i}$	*Inductors in series* $L_{eq} = \Sigma L_i$

$$v(t) = V_m cos(\omega t + \theta_v) \xLeftrightarrow{\text{Phasor transform}} \tilde{V} = V_m \angle \theta_v = V_m e^{j\theta_v}$$

SOURCE TRANSFORMATION



SAMPLING AND QUANTIZATION

Sampling rate $f_s \geq 2f_{max}$, minimum sampling rate is called the Nyquist rate

$N = number\ of\ \ bits, \quad L = number\ of\ quantization\ Levels$

$\Delta = quantization\ step, \quad q_e = quantization\ error$

$V_{FS} = full\ scale\ range\ of\ the\ analog\ to\ digital\ converter, A/D$

For a digital system of N bits, the number of discrete levels $L = 2^N$

$Quantization\ step \qquad \Delta = \frac{V_{FS}}{L} = \frac{V_{FS}}{2^N}$

V_{FS} *is the full scale range of A/D* $\qquad V_{FS} = V_{max} - V_{min}$

V_{max} is the maximum allowed input level for A/D

V_{min} is the minimum allowed input level for A/D

$Quantization\ error \quad q_e \leq \frac{\Delta}{2}$ if signal is within A/D range

If the signal exceeds the A/D full scale range, the error will be given by

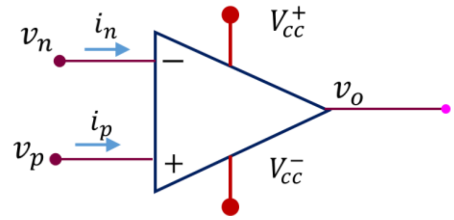
$$q_e = V_{signal} - \left(V_{max} - \frac{\Delta}{2}\right) \qquad for\ V_{signal} > V_{max}$$

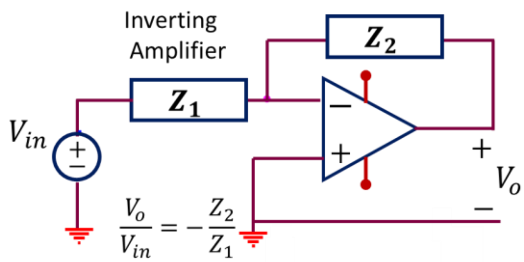
$q_e = \left(V_{min} + \frac{\Delta}{2}\right) - V_{signal} \quad for\ V_{signal} < V_{min}$

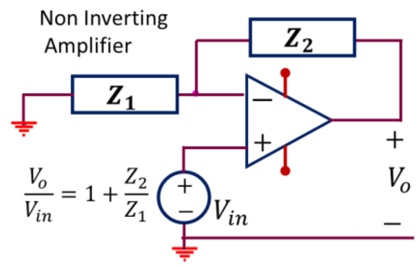
For an A/D that has an allowed input range of $from - 10V\ to\ 10V,\ then\ V_{FS} = 10 - (-10) = 20V$

IDEAL OPERATIONAL AMPLIFIER

- $\boldsymbol{i_n = 0, i_p = 0} \qquad \boldsymbol{v_n = v_p}$
- Infinite resistance looking into the inverting or non-inverting terminal
- Infinite bandwidth
- For linear mode of operation $V_{cc}^- \leq v_0 \leq V_{cc}^+$







TRANSFER FUNCTIONS AND THE FREQUENCY RESPONSE OF LINEAR SYSTEMS

$H(j\omega) = \frac{V_o}{V_{in}}$