Final Exam Useful Information

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$C = \frac{Q}{V}$ $\quad$ $\text{farad} = \frac{\text{coul}}{\text{volt}} = \frac{\text{amp}\cdot\text{sec}}{\text{volt}}$ $\quad$ $v_C = \frac{1}{C}\cdot\int_{-\infty}^{t} i_C\,dt = \frac{1}{C}\cdot\int_{0}^{t} i_C\,dt + v_C(0)$ (initial voltage) $\quad$ $i_C = C\cdot\frac{d}{dt}v_C$

parallel: $C_{eq} = C_1 + C_2 + C_3 + \ldots$ $\quad$ **series:** $C_{eq} = \dfrac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots}$

$W_C = \frac{1}{2}\cdot C\cdot V_C^2$ $\quad$ Capacitor voltage **cannot** change instantaneously

$\text{henry} = \frac{\text{volt}\cdot\text{sec}}{\text{amp}}$ $\quad$ $i_L = \frac{1}{L}\cdot\int_{-\infty}^{t} v_L\,dt = \frac{1}{L}\cdot\int_{0}^{t} v_L\,dt + i_L(0)$ (initial current) $\quad$ $v_L = L\cdot\frac{d}{dt}i_L$

$W_L = \frac{1}{2}\cdot L\cdot I_L^2$ $\quad$ Inductor current **cannot** change instantaneously

Resonance: $\omega_o = \dfrac{1}{\sqrt{L_{eq}\cdot C_{eq}}}$

For all first order transients: $x(t) = x(\infty) + (x(0) - x(\infty))\cdot e^{-\frac{t}{\tau}}$ $\quad$ $\tau = R_{Th}\cdot C$ OR $\frac{L}{R_{Th}}$

Steady-state sinusoidal AC Impedances: $Z_C = \frac{1}{j\cdot\omega\cdot C} = \frac{-j}{\omega\cdot C}$ $\quad$ $Z_L = j\cdot\omega\cdot L$ $\quad$ $\omega = 2\cdot\pi\cdot f$

Poles come from denominator of transfer function, zeroes from numerator. Bode slopes: -20, 0, or +20 dB/decade

dB is $20\cdot\log_{10}(|H(\omega)|)$

Overdamped $\quad$ $b^2 - 4\cdot k > 0$ $\quad$ s_1 and s_2 are real and negative

$X(t) = X(\infty) + B\cdot e^{s_1\cdot t} + D\cdot e^{s_2\cdot t}$ $\quad$ $X(0) = X(\infty) + B + D$ $\quad$ $\frac{d}{dt}X(0) = B\cdot s_1 + D\cdot s_2$

Critically damped $\quad$ $b^2 - 4\cdot k = 0$ $\quad$ $s_1 = s_2 = -\frac{b}{2} = s$ $\quad$ s_1 and s_2 are real, equal and negative

$X(t) = X(\infty) + B\cdot e^{s\cdot t} + D\cdot t\cdot e^{s\cdot t}$ $\quad$ $B = X(0) - X(\infty)$ $\quad$ $D = \frac{d}{dt}X(0) - B\cdot s$

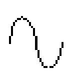
$\frac{d}{dt}i_L(0) = \frac{v_L(0)}{L}$

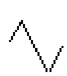
Underdamped $\quad$ $b^2 - 4\cdot k < 0$ $\quad$ $s = \alpha \pm j\omega$ $\quad$ complex s_1 and s_2

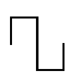
$X(t) = X(\infty) + e^{\alpha\cdot t}\cdot(B\cdot\cos(\omega\cdot t) + D\cdot\sin(\omega\cdot t))$ $\quad$ $B = X(0) - X(\infty)$ $\quad$ $D = \dfrac{\frac{d}{dt}X(0) - B\cdot\alpha}{\omega}$

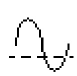
$\frac{d}{dt}v_C(0) = \frac{i_C(0)}{C}$

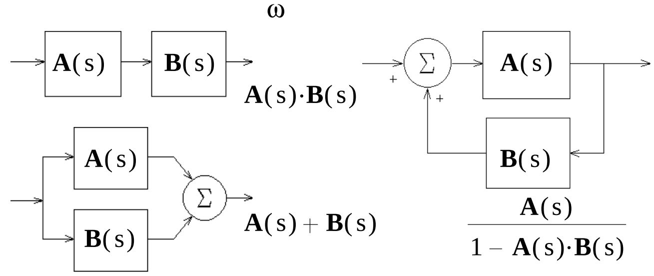
$V_{rms} = \sqrt{\frac{1}{T}\cdot\int_{0}^{T}(v(t))^2\,dt}$ $\quad$ **R**oot **M**ean (average) **S**quare


$\frac{V_p}{\sqrt{2}}$


$\frac{V_p}{\sqrt{3}}$


V_p


$\sqrt{V_{rmsAC}^2 + V_{DC}^2}$



$\mathbf{A}(s)\cdot\mathbf{B}(s)$ $\quad$ $\mathbf{A}(s) + \mathbf{B}(s)$ $\quad$ $\dfrac{\mathbf{A}(s)}{1 - \mathbf{A}(s)\cdot\mathbf{B}(s)}$

$pf = \cos(\theta) = \frac{P}{|\mathbf{S}|}$

All voltages and current below are RMS

$P = (|\mathbf{I_R}|)^2\cdot R = \frac{(|\mathbf{V_R}|)^2}{R}$ for resistors or $P = |\mathbf{V}|\cdot|\mathbf{I}|\cdot\cos(\theta) = |\mathbf{S}|\cdot pf = (|\mathbf{I}|)^2\cdot|\mathbf{Z}|\cdot\cos(\theta) = \frac{(|\mathbf{V}|)^2}{|\mathbf{Z}|}\cdot\cos(\theta)$ (where $\cos(\theta)$ is pf)

capacitors -> - Q $\quad$ $Q_C = (|\mathbf{I_C}|)^2\cdot X_C = \frac{(|\mathbf{V_C}|)^2}{X_C}$ $\quad$ $X_C = -\frac{1}{\omega\cdot C}$ and is a negative number causes leading pf

inductors -> + Q $\quad$ $Q_L = (|\mathbf{I_L}|)^2\cdot X_L = \frac{(|\mathbf{V_L}|)^2}{X_L}$ $\quad$ $X_L = \omega\cdot L$ and is a positive number causes lagging pf

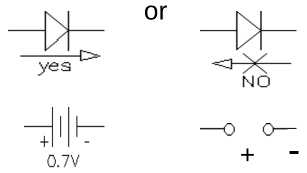
or Q = Reactive "power" $= |\mathbf{V}|\cdot|\mathbf{I}|\cdot\sin(\theta)$ $\quad$ units: VAR, kVAR, etc. "volt-amp-reactive"

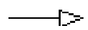
S = Complex "power" $= \mathbf{V}\cdot\overline{\mathbf{I}}$ (complex congugate) $= P + jQ = |\mathbf{V}|\,|\mathbf{I}|\,\angle\theta = |\mathbf{S}|\,\angle\theta$ $\quad$ units: VA, kVA, etc. "volt-amp"

S = Apparent "power" $= |\mathbf{S}| = |\mathbf{V}|\cdot|\mathbf{I}| = \sqrt{P^2 + Q^2}$ $\quad$ **Transformer:** $\frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}$ $\quad$ $\mathbf{Z_{eq}} = \left(\frac{N_1}{N_2}\right)^2\cdot\mathbf{Z_2}$

Diodes

conducting | not conducting

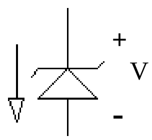




current

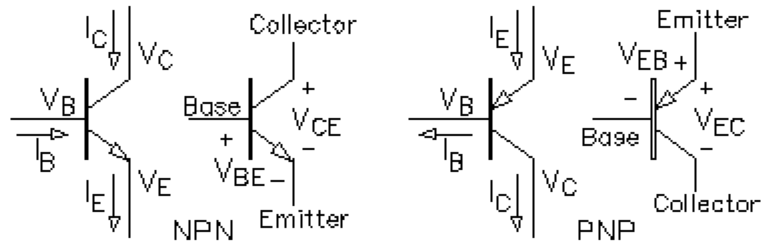
$V_d < 0.7V$ Check

LEDs: 2V



V_Z = zener voltage

Transistors



$v_{BE} = v_B - v_E$

$v_{CE} = v_C - v_E$

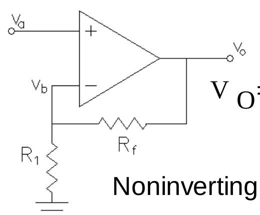
Replace v_{BE} with v_{EB} and v_{CE} with v_{EC} in equations below

Modes or regions of operation

(v_{BE} and v_{CE} are approximate)

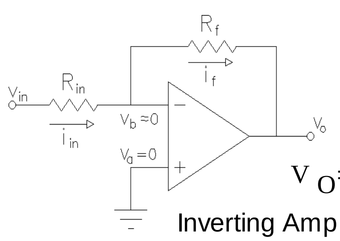
Cutoff (off)	Active (partially on)	Saturation (fully on)
$v_{BE} < 0.7V$	$v_{BE} \simeq 0.7V$	$v_{BE} \simeq 0.7V$
$i_B = 0$	$i_B > 0$	$i_B > 0$
	$v_{CE} \geq 0.2V$	$v_{CE} \simeq 0.2V$
$i_C = 0$	$i_C = \beta i_B = \alpha i_E$ $\alpha \simeq 1$ controlled by the transistor	$i_C < \beta i_B$ limited by something outside of the transistor

Op-amps



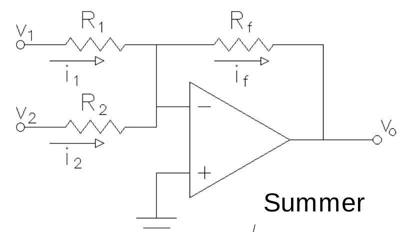
$$V_O = \left(\frac{R_f}{R_1} + 1\right) \cdot Va$$

Noninverting Amp



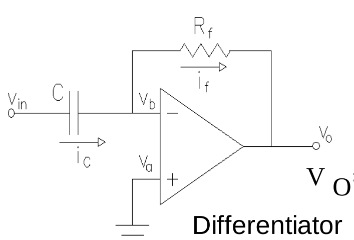
$$V_O = -\frac{R_f}{R_{in}} \cdot V_{in}$$

Inverting Amp



Summer

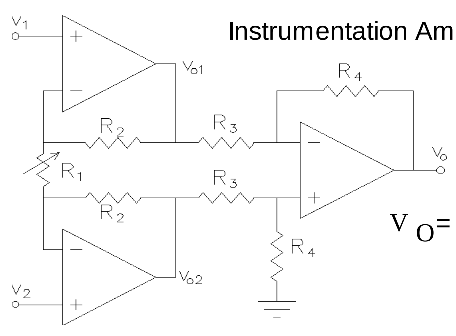
$$V_O = -\left(\frac{R_f}{R_1} \cdot V_1 + \frac{R_f}{R_2} \cdot V_2\right)$$



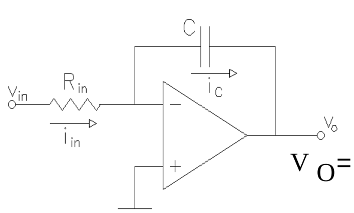
$$V_O = -R_f \cdot C \cdot \frac{d}{dt} V_{in}$$

Differentiator

Instrumentation Amp

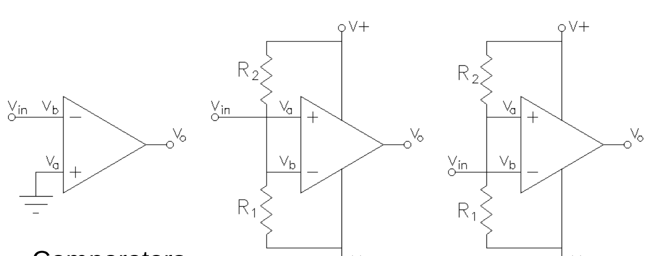


$$V_O = \left(1 + \frac{2 \cdot R_2}{R_1}\right) \cdot \frac{R_4}{R_3} \cdot (V_2 - V_1)$$

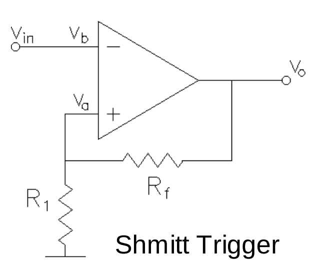


$$V_O = -\frac{1}{R_{in} \cdot C} \cdot \left(\int V_{in}\, dt\right)$$

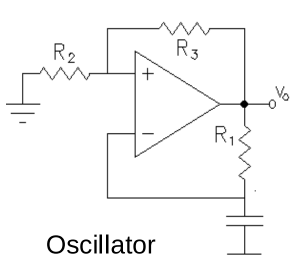
Integrator



Comparators



Shmitt Trigger



Oscillator