NASH, MICHAEL | CIRCUITS I | KEY CONCEPTS

RESISTANCE [Ω]

- $R_2 = R_1(1+\alpha(T_2-T_1))$ RESISTANCE CHANGE B4 TEMPERATURE CHANGE
- $R = \frac{\rho l}{A}$ RESISTANCE B4 LENGTH
  - ↳ $R = \rho l$ ($\rho = [\frac{\Omega}{1000ft}]$) IF GIVEN AWG
- $R = \frac{V}{I}$ (OHM'S LAW)
- $R = \frac{P}{I^2}$ (POWER)

★ INCREASE TEMP; l TO MAINTAIN R:

- $l = (\frac{1}{\rho})(R_1(1+\alpha(T_2-T_1)))(A)$

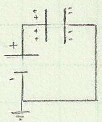
α = TEMP. COEF. $[\frac{1}{°C}]$

ρ = RESISTIVITY $[\Omega \cdot m]$ $[\frac{\Omega}{1000ft}]$

MIL CONVERT:
$(MILS)^2 = CM$
$l = A$
$\frac{in}{1000} = MILS$

CAPACITANCE [F]

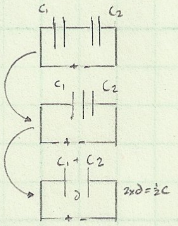
- $E = \frac{1}{2}V^2C$ ENERGY STORED IN A CAPACITOR
- $Q = V \cdot C$ CHARGE IN CAPACITOR (CHARGE ACROSS)
- $\Delta V = \frac{1}{C}(\Delta Q)$ CHANGE IN VOLTAGE
- $I_c = \frac{V_{in}}{R} \cdot e^{-t/RC}$ CURRENT IN LOW PASS FILTER AFTER t SECONDS
- $Q = I(\Delta t) = V \cdot C$ CHANGE IN CHARGE
- $V_c = V_{in}(e^{-\frac{t}{\tau}})$ CAPACITOR DISCHARGE
- CAPACITORS IN SERIES $\frac{1}{\frac{1}{C_1}+\frac{1}{C_2}+\ldots+\frac{1}{C_3}}$
- $V_c = V_{TOT}(\frac{C_{TOT}}{C_i})$ VOLTAGE ACROSS
- CAPACITORS IN PARALLEL $C_1 + C_2 + \ldots + C_n$
- $\bar{E}Q = F$ $\bar{E}$ IN A CAPACITOR
- $C = \varepsilon\frac{A}{\partial}$ CAPACITANCE BETWEEN PLATES
- $V_c = V_{in}(1-e^{-\frac{t}{\tau}})$ & $\tau = RC$ VOLTAGE IN CAPACITOR (CHARGE)



★ OPEN CAPACITORS IN STEADY STATE

HPF ★ SER. C BLOCKS DC

LPF ★ PAR. C BLOCKS AC



★ AC TO DC CONVERSION

★ E RELEASED AS A BURST

$V = IR$

$P = IV = I^2R = \frac{V^2}{R} = \frac{E}{t}$

$V = \frac{E}{Q} = \frac{ENERGY}{CHARGE} = \frac{[J]}{[C]}$

$A = \frac{Q}{t} = \frac{CHARGE}{TIME} = \frac{[C]}{[S]}$

$\varepsilon = \varepsilon_o \varepsilon_r$

$\varepsilon_o = 8.85 \times 10^{-12}$

$W = \bar{E}Q\partial$ WORK ON Q

$F = k\frac{Q_1Q_2}{r^2}$

INDUCTION [H]

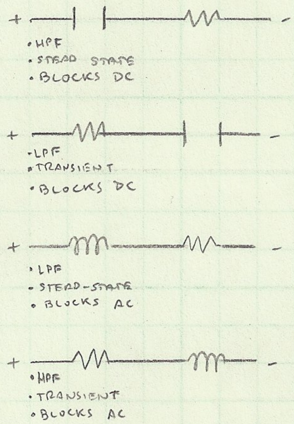
- $V = -N(\frac{\Delta\phi}{\Delta t})$ INDUCED VOLTAGE
- $\Delta V = -L(\frac{\Delta I}{\Delta t})$ VOLTAGE CHANGE B4 INDUCTION
- INDUCTORS IN SERIES $L_1 + L_2 + \ldots + L_n$
- INDUCTORS IN PARALLEL $\frac{1}{\frac{1}{L_1}+\frac{1}{L_2}+\ldots+\frac{1}{L_n}}$
- $E = \frac{1}{2}I^2L$ ENERGY STORED IN AN INDUCTOR
- $\tau = \frac{L}{R}$ INDUCTOR-RESISTOR TIME CONSTANT
- $V_L = V_s e^{-\frac{t}{\tau}}$
- $\mu = \frac{\Delta B}{\Delta H}$

CONFIRM ★

HPF ★ PAR. L BLOCKS DC

LPF ★ SER. L BLOCKS AC

★ SHORT INDUCTORS IN STEADY STATE



ϕ: MAGN. FLUX [Wb]

B: ϕ DENSITY $[\frac{Wb}{m^2}]$, [T]

μ: PERMEABILITY

H: MAGN. FIELD INTENSITY

L: INDUCTANCE [H]

τ: TIME CONST.

μ_r: PERMEAB. OF AIR

μ_o: MAT. PERMEAB.

N: # OF COILS/LOOPS

FIELDS

- $B = \mu H = \mu(\frac{N}{l})I = \frac{I}{r}(2\times10^{-7})$ MAGN. FLUX DENSITY: "PRESSURE" OF ϕ
- $B = \mu_r \mu_o H$ MAGN FLUX DENSITY (FERROMAGNETIC)
- $B = \frac{\phi}{A}$ MAG FIELD DENSITY (UNITS)
- $F = k\frac{Q_1Q_2}{r^2}$ FORCE ON A CHARGE (IN NEWTONS)
- $W = \bar{E}Q\partial = VQ = F\partial$ WORK ON CHARGE

• MAX P TRANSFER THM.
MAX TRANSFER WHEN $R_L = R_{TH}$

• KIR. VOLTAGE LAW (KVL)
$V_{DROP} = V_{RISE}$ (SERIES)

• KIR. CURRENT LAW (KCL)
$I_{IN} = I_{OUT}$ (NODAL)

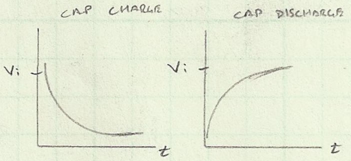
MESH ANALYSIS

$$\begin{array}{c|c}
 & \begin{matrix} A & B & C & D & E \end{matrix} \\
\begin{matrix} A \\ B \\ C \\ D \\ E \end{matrix} &
\begin{bmatrix} A & -AB & -AC & -AD & -AE \\ -AB & B & -BC & -BD & -BE \\ -AC & -BC & C & -CD & -CE \\ -AD & -BD & -CD & D & -DE \\ -AE & -BE & -CE & -DE & E \end{bmatrix} \cdot \begin{bmatrix} I_A \\ I_B \\ I_C \\ I_D \\ I_E \end{bmatrix} = \begin{bmatrix} V_A \\ V_B \\ V_C \\ V_D \\ V_E \end{bmatrix}
\end{array}$$

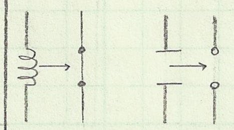
RESISTANCE | CURRENT | VOLTAGE

= BARRIER R'S
= SUM R'S

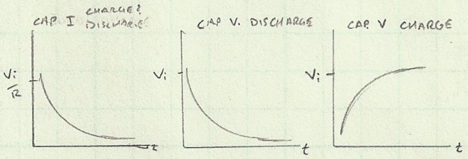
HPF

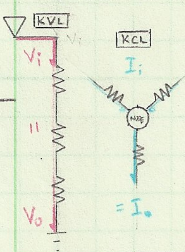


D-C STEADY STATE



LPF





$\mu_r = 4\pi \times 10^{-7}$

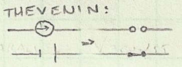
$k = 9 \times 10^9$

1 COULOMB $= 6.242 \times 10^{18}$ e^-'s

$\varepsilon_o = 8.85 \times 10^{-12}$

- IN SERIES: I CONSTANT
  $V = \Sigma V_{DROPS}$
- PARA: V CONSTANT
  $I = \Sigma$ BRANCH CURR.

THEVENIN:



$P_{MAX} = V_L I_L = \frac{V_{TH}^2}{4R_{TH}}$

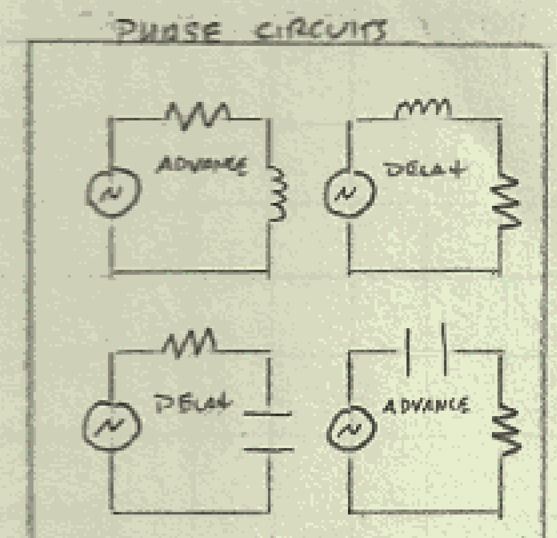
$V_L = V_{TH} R_{TH} (R_L)(\frac{1}{R_L + R_{TH}})$

SMALL R_L → LARGE I, SMALL V

LARGE

$I_L = V_{TH}(\frac{1}{R_{TH}+R_L})$

PHASE CIRCUITS



VOLTAGE

$V(t) = V_+ \sin(2\pi f t + \theta)$

$V_+ \angle \theta$ (f MUST BE CONSTANT)

$V_{rms} = \sqrt{\frac{1}{T}\sum V_{+x}^2 \cdot \Delta t_x}$ (SQUARE/TRIANGLE WAVES)

$V_{rms} = \frac{1}{\sqrt{2}} V_+$ (SINUSOIDAL WAVES)

$V_{AVG} = \frac{1}{T}\int_0^T V_+ \sin(\omega t)\,\partial t$ (SINUSOIDAL) ☆ MULTIPLY BY $\frac{1}{2}$ IF HALF-WAVE

$V_{AVG} = (\sum V_x \cdot t_x)(\sum t_x)$ (SQUARE/TRIANGULAR)

IMPEDANCE

$X_L = j(2\pi f L) = 2\pi f L \angle 90°$

$X_C = -j(2\pi f C)^{-1} = 2\pi f C \angle -90°$

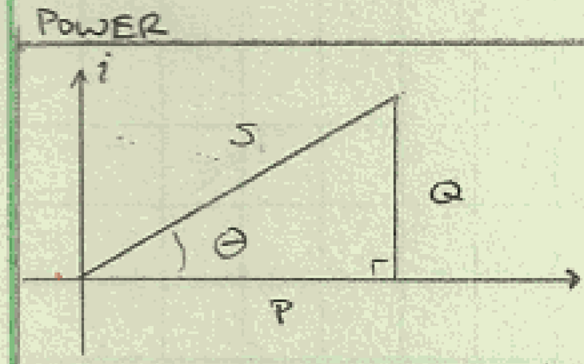
$Z = \sum R_x + j(X_{Lx} - X_{Cx}) = \|Z\| \angle \theta$; $\theta = \arctan\left(\frac{X_L - X_C}{R}\right)$

$f_r = \frac{1}{2\pi\sqrt{LC}}$

$\omega = \frac{1}{\sqrt{LC}}$

$V = I \cdot Z$; $V\angle\theta = (I \cdot \|Z\|)\angle(\theta_I + \theta_Z)$

POWER



$S = \sqrt{P^2 + Q^2}$

$P = S\cos\theta$

$Q = S\sin\theta$

$P = VI \quad P = I^2 Z$

$P = \frac{V^2}{Z^2}$

$PF = \cos\theta$ (IDEAL = 1)

ALSO IDEAL WHEN $Z_L = Z_{TH} \angle \emptyset°$

BANDWIDTH

$BW = f_2 - f_1 = \frac{f_0}{Q} = \Delta f$; $\frac{1}{2}$ POWER FREQ $= (\frac{1}{2}\sqrt{2} \cdot I_{max})^2 R = \frac{1}{2}P_{max}$

$Q = \frac{f_0}{BW}$; $Q = \frac{X_L}{R} = \frac{\omega L}{R}$; $Q = \frac{X_C}{R} = \frac{1}{\omega RC}$

$f_1 = f_0 - \frac{1}{2}BW$; $f_2 = f_0 + \frac{1}{2}BW$; $f_0 = f_1 + \frac{1}{2}BW$

CAPACITANCE

$B_L = -j(2\pi f L)^{-1}$

$B_C = j(2\pi f C)^{-1}$ $\quad Y = \sum G_x + j(B_C - B_L)$

$G = \frac{1}{R}$

KEY CONCEPTS

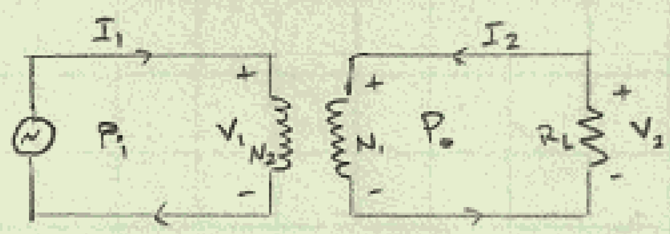
$\theta = \frac{\Delta t}{T} \cdot 2\pi = \frac{\Delta t}{T} \cdot 360$

$\omega = 2\pi f = (360)f$

$\theta = -\omega t_1$

	UNITS
ω = ANGULAR FREQUENCY	rad/s
V_{pp} = VOLTAGE PEAK TO PEAK (AMPLITUDE)	V
V_+ = VOLTAGE MAX	V
f = FREQUENCY (CYCLES/SEC)	Hz
T = PERIOD	ms
θ = PHASE SHIFT	rad
V_{rms} = rms VOLTAGE	V
V_{AVG} = AVERAGE VOLTAGE	V
R = RESISTANCE	Ω
X_C = CAPACITIVE REACTANCE	Ω
X_L = INDUCTIVE REACTANCE	Ω
Z = IMPEDANCE $= \sum X + R$	Ω
f_r = RESONANCE	Hz
I = CURRENT	–
S = APPARENT POWER	V·A
R = REAL POWER	W
Q = REACTIVE POWER	V·A·R
PF = POWER FACTOR	–
P = POWER	W
BW = BANDWIDTH	Hz
f_1 = LOW FREQ ($\frac{1}{2}$ POWER)	Hz
f_2 = HIGH FREQ ($\frac{1}{2}$ POWER)	Hz
f_0 = CENTER FREQ (P = max) $f_r = f_0$ = RES. FREQ	Hz
B_C = CAPACITIVE SUSCEPTANCE	S, ℧
B_L = INDUCTIVE SUSCEPTANCE	S, ℧
Y = ADMITTANCE $= \sum B + G$	S, ℧
G = CONDUCTANCE	S, ℧
Q = QUALITY	–
$Z = \frac{1}{Y}$	
V_{RIP} = RIPPLE VOLTAGE	V
V_D = DIODE VOLTAGE DROP	V

TRANSFORMERS



$\frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2}$

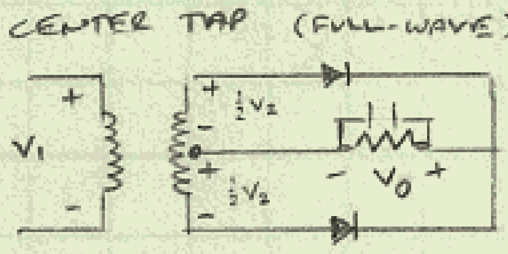
☆ MAY BE USED TO MAX POWER TRANSFER IF $R_L \neq R_{TH}$

$P_i = V_1 \cdot I_1$

$P_o = V_2 I_2$

RECTIFIERS

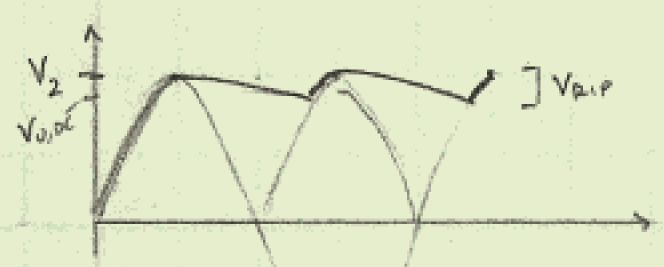
CENTER TAP (FULL-WAVE)



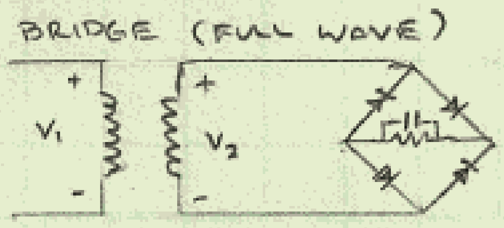
$V_{0,DC} = V_0 - \frac{1}{2}V_{RIP}$ (DC)

$V_0 = (V_2 - V_D)$ (PEAK OUTPUT)

$V_{RIP} = V_0 \cdot (2fRC)^{-1}$ (RIPPLE V)



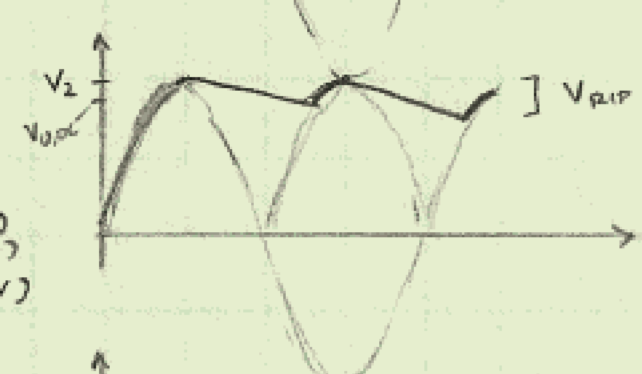
BRIDGE (FULL WAVE)



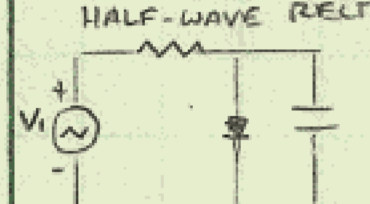
$V_{0,DC} = V_0 - \frac{1}{2}V_{RIP}$ (DC OUT)

$V_0 = (V_2 - 2 \cdot V_D)$ (PEAK V OUT)

$V_{RIP} = V_0 \cdot (2fRC)^{-1}$ (RIPPLE V)



HALF-WAVE RECTIFIER (SMOOTHED VOLTAGE)

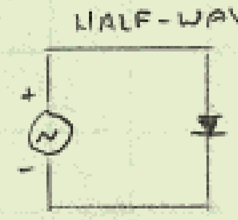


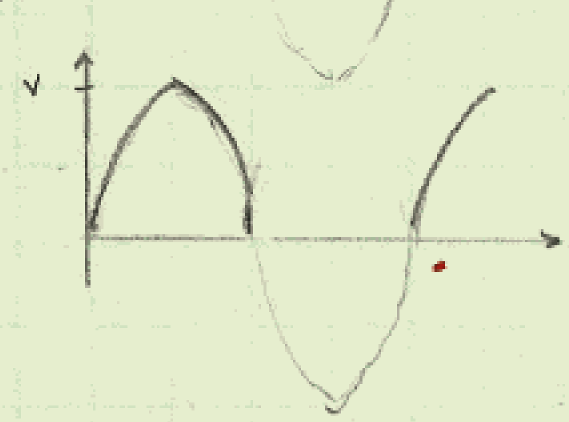
$V_0 = V_1 - V_D$ (PEAK V OUT)

$V_{RIP} = V_0 (fRC)^{-1}$ (RIPPLE V)

$V_{0,DC} = V_0 - \frac{1}{2}V_{RIP}$ (DC OUT)

HALF-WAVE RECTIFIER



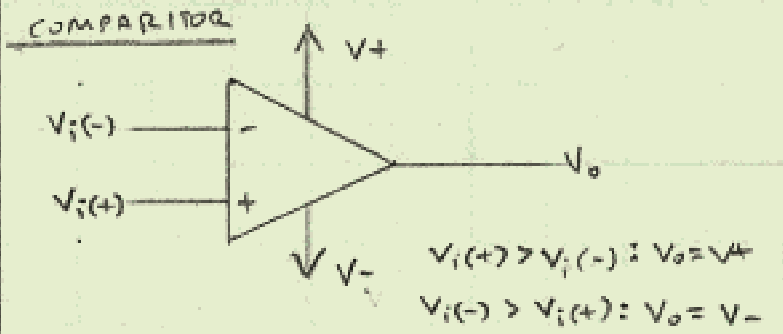


☆ $\eta = \frac{P_o}{P_i}$ (EFFICIENCY)

☆ RIPPLE % $= \left(\frac{V_{RIP}}{V_0}\right)$%

OP AMPS

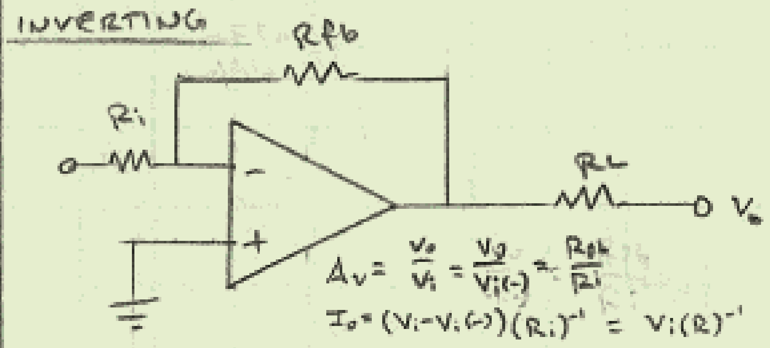
COMPARATOR



$V_i(+) > V_i(-)$: $V_0 = V+$

$V_i(-) > V_i(+)$: $V_0 = V-$

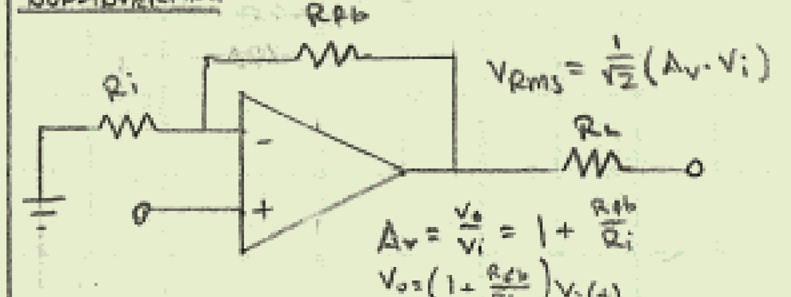
INVERTING



$A_V = \frac{V_0}{V_i} = \frac{V_0}{V_i(-)} = \frac{R_{fb}}{R_i}$

$I_0 = (V_i - V_i(-))(R_i)^{-1} = V_i(R)^{-1}$

NON-INVERTING



$V_{Rms} = \frac{1}{\sqrt{2}}(A_V \cdot V_i)$

$A_V = \frac{V_0}{V_i} = 1 + \frac{R_{fb}}{R_i}$

$V_0 = (1 + \frac{R_{fb}}{R_i})V_i(+)$

• VIRTUAL GROUND: $\frac{V_0}{V_i(+) - V_i(-)} \approx \infty$

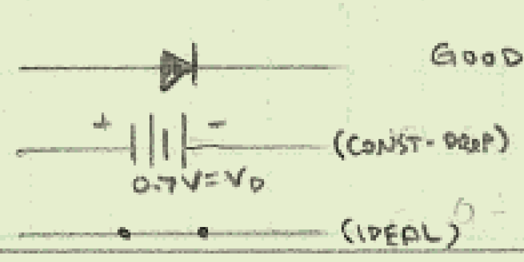
$\therefore V_i(+) - V_i(-) \approx \emptyset$

• $\sum$ AMPS: $I = \sum I_n = \sum\left(\frac{V_n}{R_n}\right)$

- VOLTAGE FOLLOWERS USED TO MATCH THEVENIN HIGH R INPUT SIGNALS TO LOW R LOADS

DIODES

FOWARD BIAS



GOOD IN ANALYSIS IF:

$I_D > \emptyset A$

$V_D = \emptyset.7V$

REVERSE BIAS

GOOD IF:

$I_D \leq \emptyset$

$V_D = \emptyset$

MISC

→ $R_1 \| R_2 = \frac{R_1 R_2}{R_1 + R_2}$

→ RESONANCE WHEN $|X_L| = |X_C|$