SERIES RESONANT CIRCUIT

- **Circuit configuration– Resistor, Inductor and capacitor are connected in series**
- **Z= R + J Xl –J Xc**
- **Resonance occur when X l = Xc**
- **Xl = 2 ∏ f L   Xl= Inductive Reactance (Ω)**
- **f = frequency (HZ)**
- **L= Inductance (Henry)**

SERIES RESONANT CIRCUIT

- **Xc =** $\dfrac{1}{2 \pi f C}$

Where Xc = Capacitive reactance (Ω)

f = Frequency (HZ)

C= Capacitance (Farad)

Resonant Frequency & Quality Factor

- Resonant frequency (Fr) = $\dfrac{1}{2\pi\sqrt{LC}}$
- Quality Factor (Q) = $\dfrac{\text{Reactive Power}}{\text{Active Power}} = \dfrac{Xl}{R}$

Band Width

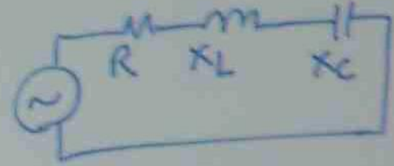
- Bandwidth (BW) = f 2 – f 1 = $\frac{fr}{Q}$

F1- Lower cut off frequency,

F2= Upper cut off frequency

Phf = Half power frequency = ½ P max

① SERIES RESONANT CIRCUIT



$$Z = R + jX_L - jX_C$$

$$X_L = 2\pi f L$$

$$X_C = \frac{1}{2\pi f C}$$

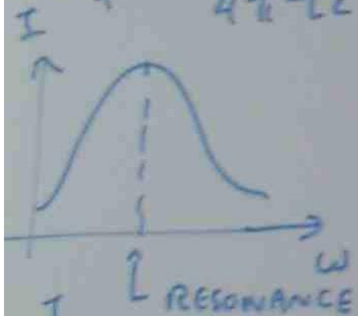
AT RESONANCE, $X_L = X_C \longrightarrow Z = R$

$$I = \frac{E}{Z} = \frac{E}{R} \quad \text{(MAXIMUM CURRENT)}$$

$$2\pi f L = \frac{1}{2\pi f C}$$

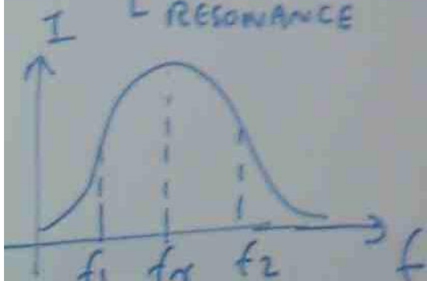
$$f^2 = \frac{1}{4\pi^2 LC} \longrightarrow f_r = \frac{1}{2\pi\sqrt{LC}}$$

f_r ← RESONANT FREQUENCY



QUALITY FACTOR

$$Q = \frac{\text{REACTIVE POWER}}{\text{AVERAGE POWER}} = \frac{X_L}{R}$$



$$BW = f_2 - f_1 = \frac{f_r}{Q}$$

$$P_{HPF} \text{ (HALF POWER FREQUENCY)} = \frac{1}{2} P_{MAX}$$

RLC Series Connection

- **RLC Series connection**

- **Z = R + j Xl – j Xc**

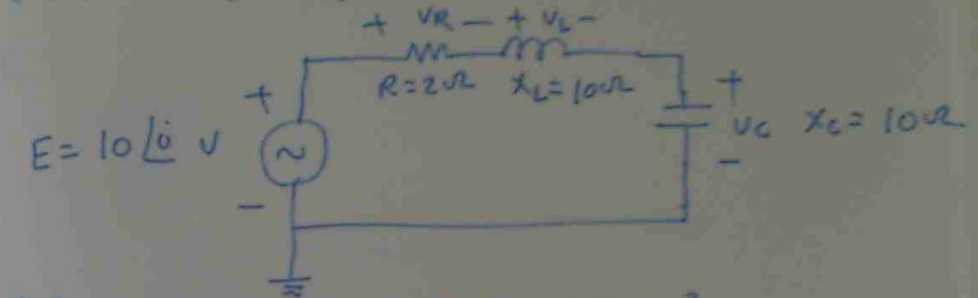
$$I = \frac{E}{Z}$$

Calculation of series RLC circuit

- **V l = I x X l**
- **Vc = I x Xc**
- **BW= f 2 – f 1 = $\frac{fr}{Q}$**
- **Phpf = ½ P max = ½ I max^2 R**

Pb. FOR THE GIVEN SERIES RESONANT CIRCUIT,

(a) FIND I, V_R, V_L AND V_C AT RESONANCE.



(b) WHAT IS Q OF THE CIRCUIT?

(c) IF RESONANT FREQUENCY IS 5000 HZ, FIND BANDWIDTH

(d) WHAT IS POWER DISSIPATED IN CIRCUIT AT HALF POWER FREQUENCY?

(a) $Z = R + jX_L - jX_C = 2 + j10 - j10 = 2\,\Omega$

$I = \frac{E}{Z} = \frac{10\angle 0}{2\angle 0} = 5\angle 0$ Amp, $V_R = 5 \times 2 = 10\,V$

$V_L = I X_L = 5\angle 0 \times 10\angle 90 = 50\angle 90\,V$

$V_C = I X_C = 5\angle 0 \times 10\angle -90 = 50\angle -90\,V$

(b) $Q = \frac{X_L}{R} = \frac{10}{2} = 5$

(c) $BW = f_2 - f_1 = \frac{f_r}{Q} = \frac{5000}{5} = 1000\text{ Hz}$

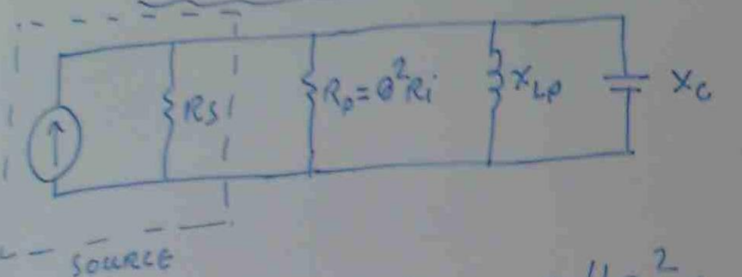
(d) $P_{HPF} = \frac{1}{2} P_{MAX} = \frac{1}{2} I_{MAX}^2 R$

$= \frac{1}{2} \times 5^2 \times 2 = 25\,W$

Parallel Resonant Circuit

- $$R_p = \frac{L}{R_l \times C}$$
- Ztp =Rs parallel with Rp= Rs parallel with $Q_l^2 R_l$
- $$F_p = f_s \sqrt{1 - \frac{1}{Q_l^2}}, \quad B_w = \frac{R_l}{2 \pi f L}$$

PARALLEL RESONANT CIRCUIT



$R_p = \frac{L}{R_L C}$, $Z_{Tp} = R_s // R_p = R_s // Q_L^2 R_L$

$f_p = f_s \sqrt{1 - \frac{1}{Q_L^2}}$, $BW = \frac{R_L}{2\pi f L}$

Q6 FOR THE GIVEN NETWORK WITH f_p PROVIDED,

(a) DETERMINE Q_L

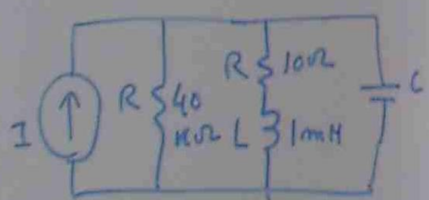
(b) DETERMINE R_P

(c) CALCULATE Z_{TP}

(d) FIND "C" AT RESONANCE

(e) FIND Q_p

(f) CALCULATE BW



$f_p = 0.04 MHz$

(a) $Q_L = \frac{X_L}{R_L} = \frac{2\pi f_p L}{R_L} = \frac{2 \times 3.14 \times 0.04 \times 10^6 \times 1 \times 10^{-3}}{10}$

$= 25.12$

(b) $R_p = Q_L^2 R_L = (25.12)^2 \times 10 = 6.31 \, k\Omega$

(c) $Z_{Tp} = R_s // R_p = \frac{R_s R_p}{R_s + R_p} = \frac{40 \times 6.31}{40 + 6.31}$

$= 5.45 \, k\Omega$

(d) $C = \frac{1}{4\pi^2 f^2 L} = \frac{1}{4 \times 3.14^2 \times (0.04 \times 10^6)^2 \times 1 \times 10^{-3}}$

$= 15.9 \times 10^{-9} F$

$= 15.9 \, nF$

(e) $Q_p = \frac{Z_{Tp}}{X_L} = \frac{5.45 \times 10^3}{2\pi f_p L} = \frac{5.45 \times 10^3}{2 \times 3.14 \times 0.04 \times 10^6 \times 1 \times 10^{-3}}$

$= 21.68$

(f) $BW = \frac{f_p}{Q_p} = \frac{0.04 \times 10^6}{21.68} = 1.85 \, kHz$

STUDY EO2S |2| SLIDE 2 → 4

DO EXERCISES

Non sinusoidal circuits & Fourier Series

F(t) = Ao + A1 sin wt + A2 sin 2wt + -------

+ B1 cos wt + B2 cos 2wt+ --------

$$A_o = \frac{1}{T}\int_0^T f(t)\,dt \quad , \quad A_m = \frac{2}{T}\int_0^T f(t)\sin n\omega t\,dt$$

$$B_m = \frac{2}{T}\int_0^T f(t)\cos n\omega t\,dt$$

Calculation of effective voltage

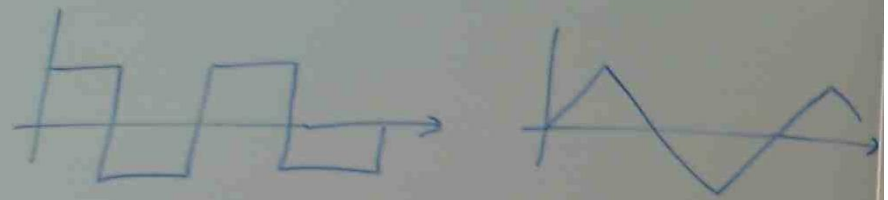
- $$V_{eff} = \sqrt{Vo^2 + \frac{V_{m1}^{\,2} + V_{m2}^{\,2} + \text{-----------------}}{2}}$$

- $$V_{eff} = \sqrt{V_o^{\,2} + V_{1\,eff}^{\,2} + V_{2\,eff}^{\,2} + \text{------------------}}$$

Total power

- $P_t = V_o I_o + V_1 I_1 \cos \theta_1 + V_2 I_2 \cos \theta_1 + ---$ $-------------------------- + V_n I_n \cos \theta_n$

② NON SINUSOIDAL CIRCUITS



FOURIER SERIES

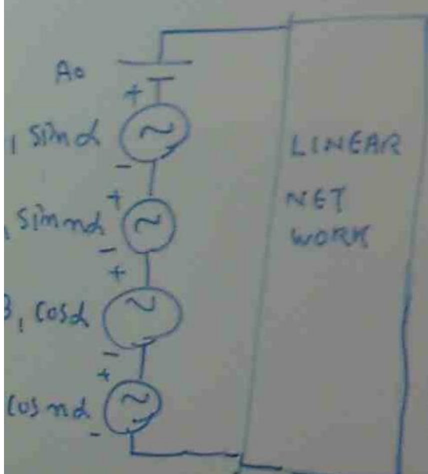
$$f(t) = A_0 + A_1 \sin\omega t + A_2 \sin 2\omega t + \cdots$$

DC (OR) AVERAGE VALUE

$$+ B_1 \cos\omega t + B_2 \cos 2\omega t + \cdots$$

$$A_0 = \frac{1}{T}\int_0^T f(t)\,dt, \quad A_n = \frac{2}{T}\int_0^T f(t)\sin n\omega t\,dt$$

$$B_n = \frac{2}{T}\int_0^T f(t)\cos n\omega t\,dt$$



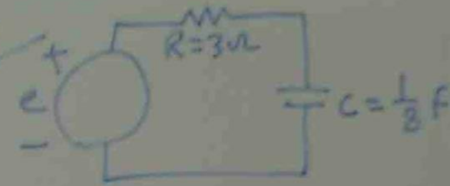
$$V_{eff} = \sqrt{V_0^2 + \frac{V_{m_1}^2 + V_{m_2}^2 + \cdots}{2}}$$

$$V_{eff} = \sqrt{V_0^2 + V_{1\,eff}^2 + V_{2\,eff}^2 + \cdots}$$

SIMILAR FOR I_{eff}

$$P_T = V_0 I_0 + V_1 I_1 \cos\theta_1 + \cdots + V_m I_m \cos\theta_m$$

Pb



THE INPUT TO THE CIRCUIT IS

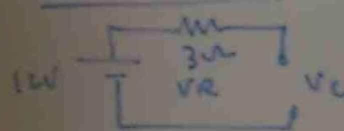
$e = 12 + 10 \sin 2t$

(a) FIND THE CURRENT i AND VOLTAGE V_R & V_C

(b) THE EFFECTIVE VALUE OF i, V_R, V_C

(c) FIND THE POWER DELIVERED TO THE CIRCUIT

FOR DC SUPPLY

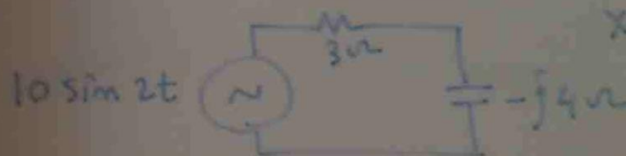


$V_R = 0$, $I = 0$, $V_C = 12V$

FOR 10 sin 2t SUPPLY

$\sin 2t \rightarrow \omega = 2$

$X_C = \frac{1}{\omega C} = \frac{1}{2 \times 1/8} = 4\Omega$



$Z = \sqrt{R^2 + X_C^2} \angle -\tan^{-1}\frac{X_C}{R} = \sqrt{3^2 + 4^2} \angle -\tan^{-1}\frac{4}{3}$

$= 5 \angle -53.2 \ \Omega$

$I = \frac{E}{Z} = \frac{10/\sqrt{2} \angle 0}{5 \angle -53.2} = 1.4142 \angle 53.2$ A

$V_{R\,eff} = I \times R = 1.4142 \angle 53.2 \times 3 \angle 0 = 4.24 \angle 53.2$ V

$V_{C\,eff} = I X_C = 1.4142 \angle 53.2 \times 4 \angle -90 = 5.64 \angle -36.8$

$I_{eff} = \sqrt{0^2 + 1.414^2} = 1.414$ Amp | $P_{eff} = I_{eff}^2 R = 1.414^2 \times 3 = 6W$ | $V_{C\,eff} = \sqrt{12^2 + 5.64^2} = 13.67$ V

PULSE WAVEFORM & RC RESPONSE

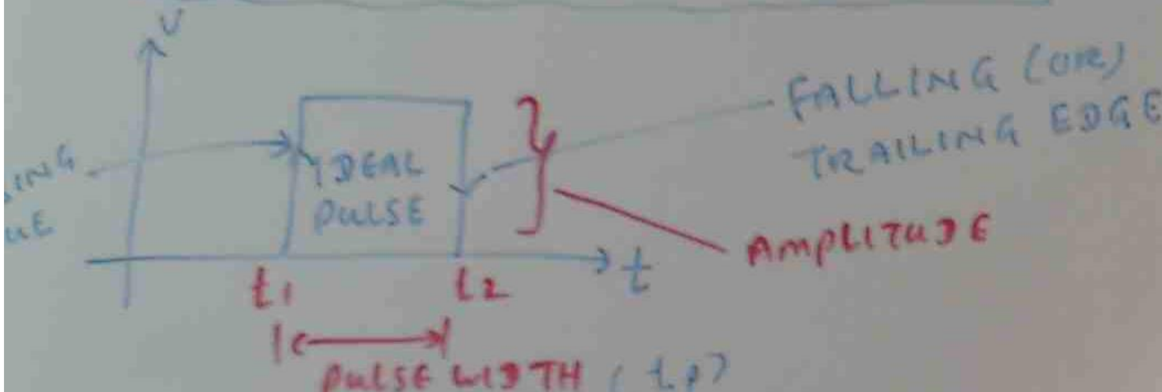
- **% Tilt =** $\dfrac{V1 - V2}{V}$

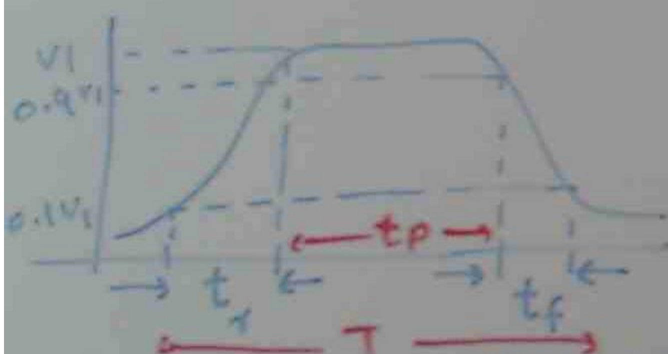
- **V =** $\dfrac{V1 + V2}{2}$

DUTY CYCLE

- $\text{Duty cycle} = \dfrac{\text{Pulse width}}{\text{Period}} = \dfrac{tp}{T}$
- $\text{Frequency} = \dfrac{1}{\text{Period}}, \quad f = \dfrac{1}{T}$

③ PULSE WAVE FORMS AND RC RESPONSE





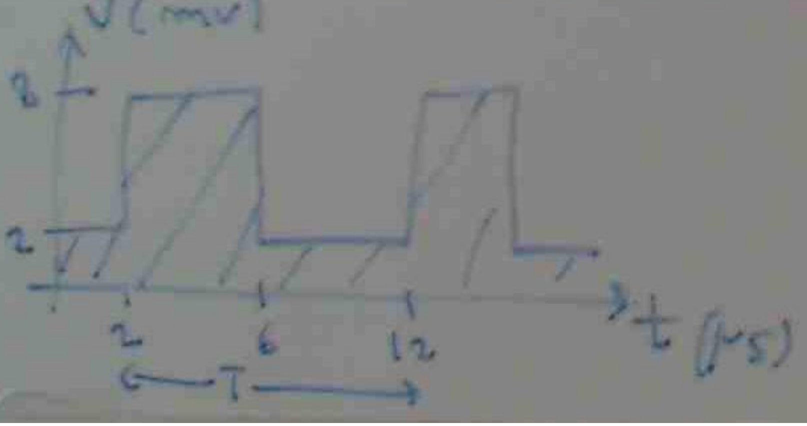
$$\% \text{ TILT} = \frac{V_1 - V_2}{V}$$

$$V = \frac{V_1 + V_2}{2}$$

$$\text{DUTY CYCLE} = \frac{\text{PULSE WIDTH}}{\text{PERIOD}} = \frac{t_p}{T}$$

$$\text{FREQUENCY} = \frac{1}{\text{PERIOD}}, \quad f = \frac{1}{T}$$

DETERMINE THE AVERAGE VALUE FOR PERIODIC PULSE WAVE FORM



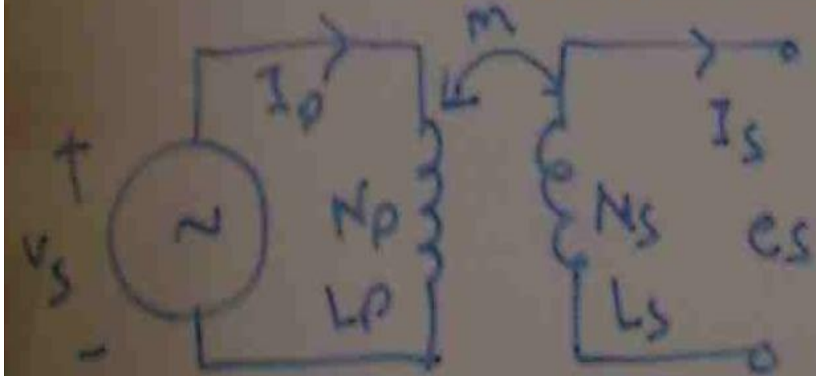
AVERAGE VALUE (G) = $\frac{\text{AREA UNDER CURVE}}{T}$

$$G = \frac{8(6-2) + 2(12-6)}{12-2} = \frac{8 \times 4 + 2 \times 6}{10}$$

$$= \frac{44}{10} = 4.4\,mV$$

DUTY CYCLE = $\frac{t_p}{T} = \frac{6-2}{12-2} = \frac{4}{10} = 0.4$

4) TRANSFORMER

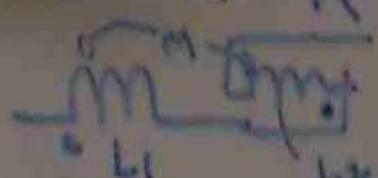


$$e_p = L_p \frac{di_p}{dt}$$

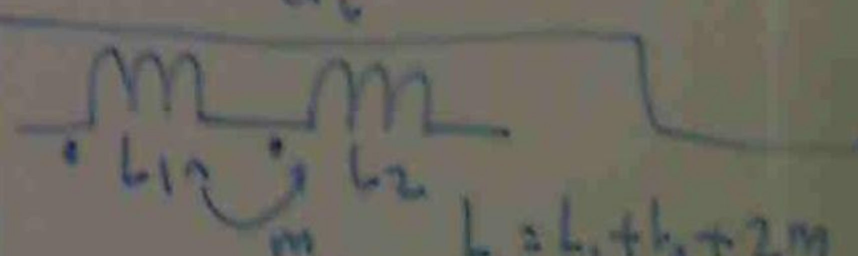
$$e_p = N_p \frac{d\phi_p}{dt}$$

$$e_s = L_s \frac{dI_s}{dt}, \quad e_s = N_s \frac{d\phi_s}{dt}$$

$$m = K\sqrt{L_p L_s}$$

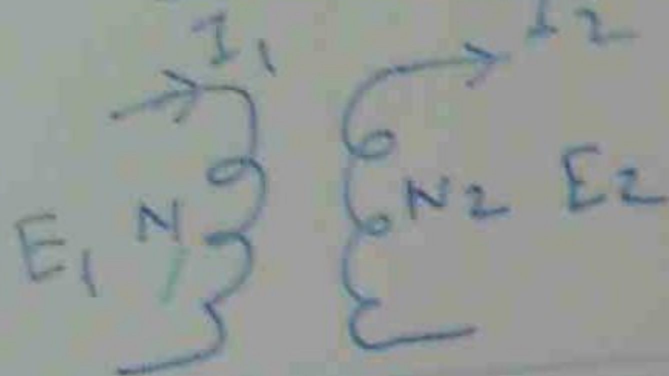


$$L_T = L_1 + L_2 - 2m_{12}$$



$$L_T = L_1 + L_2 + 2m_{12}$$

TRANSFORMER



$$\frac{E_1}{E_2} = \frac{N_1}{N_2}$$

$$E_1 = 4.44 f N_1 \phi_m$$

ϕ_m = FLUX

f = FREQUENCY

N_1 = PRIMARY TURN

N_2 = SECONDARY TURN

E_1 = PRIMARY VOLTAGE

E_2 = SECONDARY VOLTAGE

I_1 = PRIMARY CURRENT

I_2 = SECONDARY CURRENT

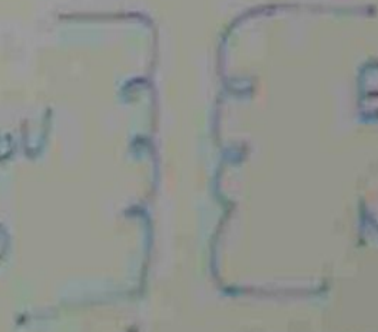
$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} = a$$

a = TURN RATIO

Pb

$E_p = 200V$

$N_p = 50$



$E_s = 2400V$

$N_s = ?$

$f = 60Hz$

CALCULATE

(a) MAXIMUM FLUX ϕ_m

(b) SECONDARY TURN N_s

$$E_p = 4.44\, N_p\, f\, \phi_m$$

$$\phi_m = \frac{E_p}{4.44 \times N_p \times f} = \frac{200}{4.44 \times 50 \times 60} = 15.02 \times 10^{-3}\, wb$$

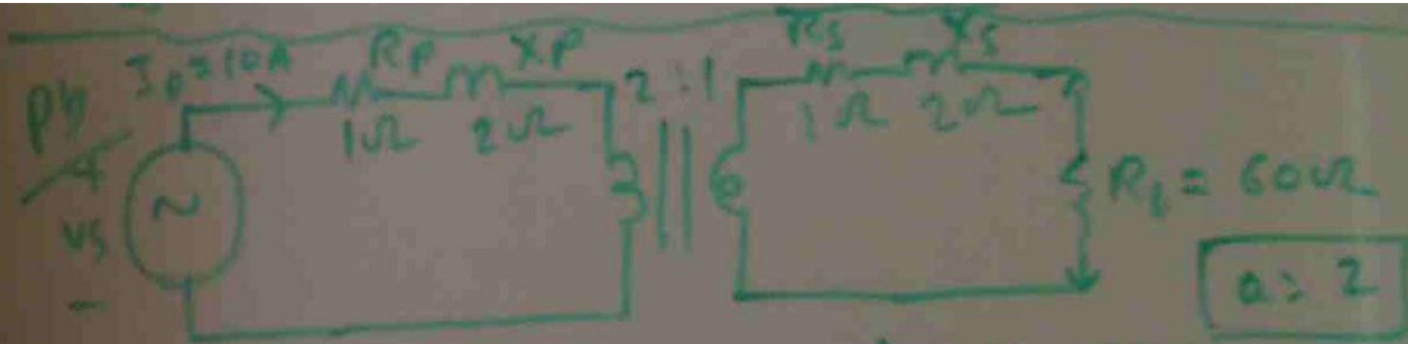
$15.02\ m\,wb$

$$\frac{E_p}{E_s} = \frac{N_p}{N_s} \rightarrow N_s = \frac{E_s N_p}{E_p} = \frac{2400 \times 50}{200} = 600 \text{ TURNS}$$

REFLECTED IMPEDANCE & POWER

$R_s' = a^2 R_s$, $X_s' = a^2 X_s$, $Z_s' = a^2 Z_s$

R_s' = SECONDARY RESISTANCE REFER TO PRIMARY
X_s' = SECONDARY REACTANCE REFER TO PRIMARY
Z_s' = SECONDARY IMPEDANCE REFER TO PRIMARY



DETERMINE (a) R_e, X_e, (b) V_L, V_S

(a) $R_e = R_p + a^2 R_S = 1 + 2^2 \times 1 = 5\Omega$

$X_e = X_p + a^2 X_S = 2 + 2^2 \times 2 = 10\Omega$

(b) $a V_L = I_p \times a^2 R_L = 10 \times 2^2 \times 60 = 2400V$

$V_L = \frac{2400}{a} = \frac{2400}{2} = 1200V$

$V_S = I_p (R_e + a^2 R_L + j X_e)$

$= 10(5 + 2^2 \times 60 + j10)$

$= 10(245 + j10) = 10 \times \sqrt{245^2 + 10^2} = 2452.04V$

(6) DECIBEL, FILTERS, BODE PLOTS

VOLTAGE GAIN $= \frac{V_2}{V_1}$, POWER GAIN $= \frac{P_2}{P_1}$

CURRENT GAIN $= \frac{I_2}{I_1}$

DECIBEL

$$dB_{\text{POWER GAIN}} = 10 \log_{10} \frac{P_2}{P_1}$$

$$dB_{\text{VOLTAGE GAIN}} = 20 \log_{10} \frac{V_2}{V_1}$$

$$dB_{\text{CURRENT GAIN}} = 20 \log_{10} \frac{I_2}{I_1}$$

Pb IF A SYSTEM HAS A VOLTAGE GAIN OF 36 dB, FIND THE APPLIED VOLTAGE IF OUTPUT VOLTAGE IS 6.8V

$$dB_{\text{VOLTAGE}} = 20 \log \frac{V_o}{V_i}$$

$$36 = 20 \log_{10} \frac{6.8}{V_i}$$

$$\frac{36}{20} = \log_{10} \frac{6.8}{V_i} \rightarrow$$

$$1.8 = \log_{10} \frac{6.8}{V_i}$$

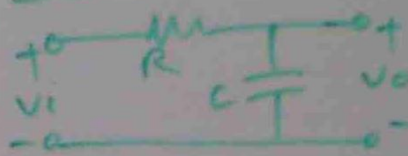
$$\frac{6.8}{V_i} = 10^{1.8}$$

$$V_i = \frac{6.8}{10^{1.8}}$$

$$= 0.109V$$

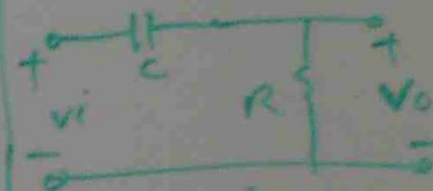
FILTERS

RC LOW PASS FILTER



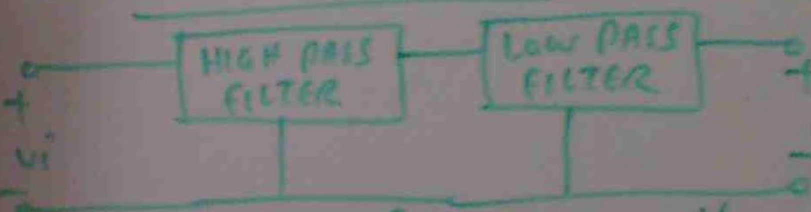
$$V_o = \frac{V_i}{\sqrt{\left(\frac{R}{X_C}\right)^2 + 1}}$$

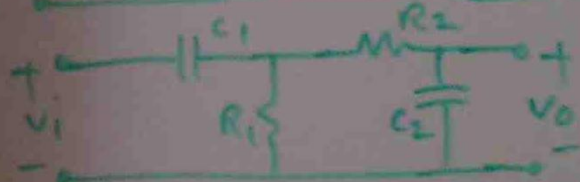
RC HIGH PASS FILTER

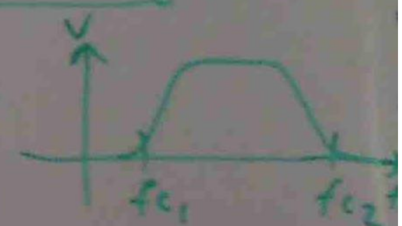


$$V_o = \frac{V_i}{\sqrt{\left(\frac{X_C}{R}\right)^2 + 1}}$$

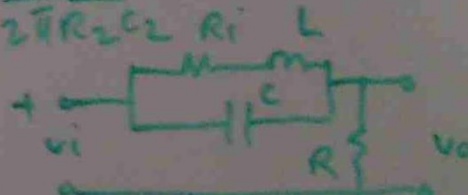
BAND PASS FILTER



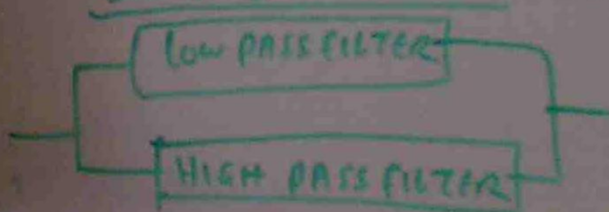


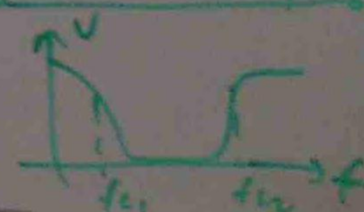


$$f_{c_1} = \frac{1}{2\pi R_1 C_1}, \quad f_{c_2} = \frac{1}{2\pi R_2 C_2}$$

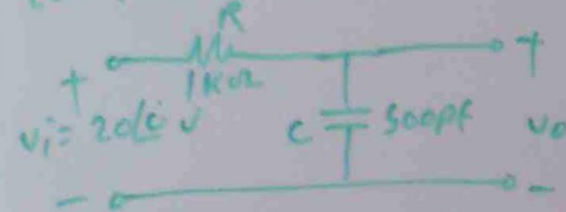


BAND STOP FILTER





Pb SKETCH THE OUTPUT VOLTAGE V_o VERSUS FREQUENCY FOR GIVEN LOW PASS FILTER



$$f_c = \frac{1}{2\pi RC} = \frac{1}{2 \times 3.1416 \times 1\times10^{3} \times 500\times10^{-12}}$$

$$= 318.31 \text{ kHz}$$

$$V_o = \frac{V_i}{\sqrt{\left(\frac{R}{X_c}\right)^2 + 1}} = \frac{V_i}{\sqrt{(2\pi f c R)^2 + 1}}$$

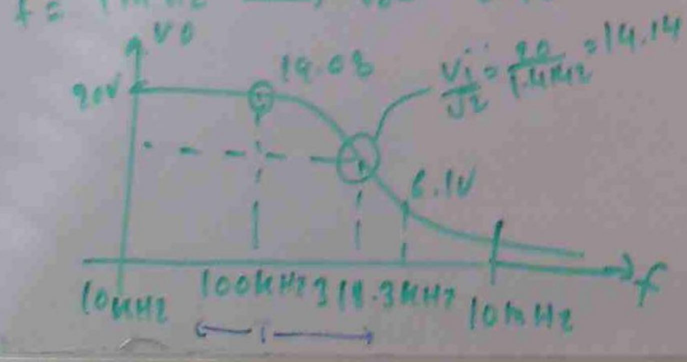
f = 10 kHz → 100 kHz → 1 MHz → 10 MHz

$$f = 10\text{ kHz } (V_o) = \frac{20}{\sqrt{(2\times3.14\times10\times10^{3}\times500\times10^{-12}\times1\times10^{3})^2 + 1}}$$

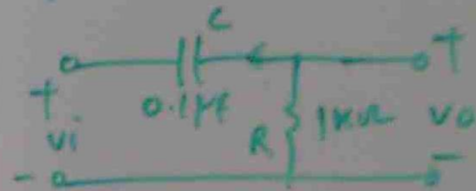
$$\simeq 20\text{V}$$

f = 100 kHz ⟶ V_o = 19.08 V   f = 10 MHz → $V_o \simeq 0$

f = 1 MHz ⟶ V_o = 6.1 V



P6) SKETCH $A_{v\,dB}$ FOR GIVEN HIGH PASS FILTER CIRCUIT



$$f_c = \frac{1}{2\pi RC}$$

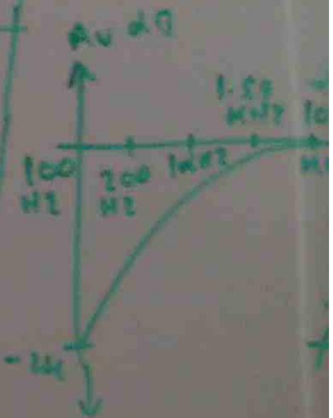
$$= \frac{1}{2 \times 3.14 \times 1 \times 10^{3} \times 0.1 \times 10^{-6}}$$

$$= 1592.36\ Hz$$

$$|A_{v\,dB}| = 20 \log_{10} \frac{1}{\sqrt{1 + \left(\frac{f_c}{f}\right)^2}}$$

f: 100 Hz → 200 Hz → 1 kHz → 1.59 kHz → 10 kHz

f	$A_{v\,dB}$	dB
100 Hz	$20 \log_{10} \frac{1}{\sqrt{1+\left(\frac{1592}{100}\right)^2}}$	-24
200	$20 \log_{10} \frac{1}{\sqrt{1+\left(\frac{1592}{200}\right)^2}}$	-20
1kHz → 1000	$20 \log_{10} \frac{1}{\sqrt{1+\left(\frac{1592}{1000}\right)^2}}$	-6
1.59 kHz	$20 \log_{10} \frac{1}{\sqrt{1+\left(\frac{1592}{1592}\right)^2}}$	-3
10 kHz	$20 \log_{10} \frac{1}{\sqrt{1+\left(\frac{1592}{10000}\right)^2}}$	0



80 sin ωt

$\omega = 250$ rad/sec

$X_L = 2\pi f L$
$= 250 \times 0.2 = 50\Omega$

$Z = \sqrt{R^2 + X_L^2}$
$= \sqrt{20^2 + 50^2}$
$= 53.85\ \Omega$

$\theta = \tan^{-1}\frac{50}{20} = 68.2^\circ$

$I = \frac{E}{Z} = \frac{80}{53.85} = 1.49$, $I = \frac{1.49}{\sqrt{2}} \sin(250t - 68.2)$
$= 1.05 \sin(250t - 68.2)$

20 sin 3ωt

$X_L = 3\omega L = 3 \times 250 \times 0.2$
$= 150\Omega$

$Z = \sqrt{20^2 + 150^2} = 151.3\Omega$

$\theta = \tan^{-1}\frac{150}{20} = 82.4^\circ$

$I = \frac{E}{Z} = \frac{20}{151.3} = 0.132$, $I = \frac{0.132}{\sqrt{2}} \sin(750t - 82.4)$

$I = 0.093 \sin(750t - 82.4)$

$E_{rms} = \sqrt{25^2 + \left(\frac{80}{\sqrt{2}}\right)^2 + \left(\frac{20}{\sqrt{2}}\right)^2} = 63.5V$

$$I_{rms} = \sqrt{1.25^2 + \left(\frac{1.44}{\sqrt{2}}\right)^2 + \left(\frac{0.132}{\sqrt{2}}\right)^2} = 1.64\ A$$

$$\text{TOTAL POWER} = 1.25^2 \times 20 + 1.05^2 \times 20 + 0.093^2 \times 20$$

$$= 53.5\ \text{WATT}$$