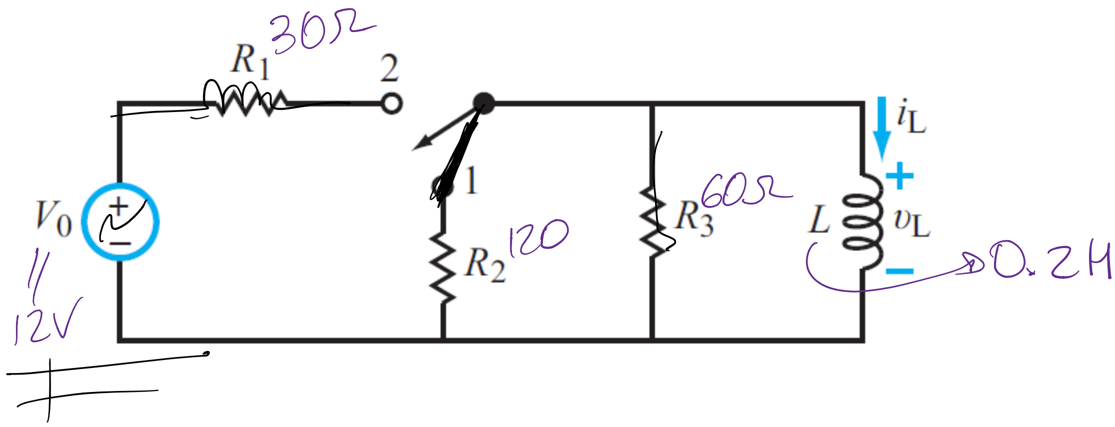
MT2 → Nov, 15 5:30–6:50 pm.
Modules 6–9.

MT2 Review

The switch was in position 1 for a long time, then at t = 0 was moved to position 2.
Given that V_0 = 12 V, R_1 = 30 Ω, R_2 = 120 Ω, R_3 = 60 Ω, and L = 0.2H, determine $v_L(t)$ and $i_L(t)$



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$$i_L(t) = i_L(\infty) + (i_L(0) - i_L(\infty))e^{-t/\tau}$$

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$$\tau = L/R_{EQ}$$

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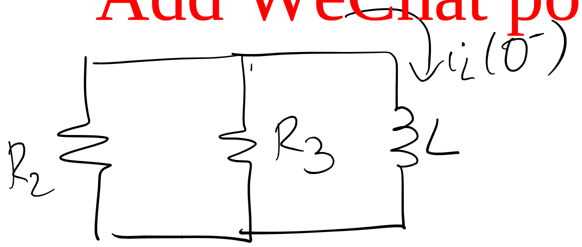
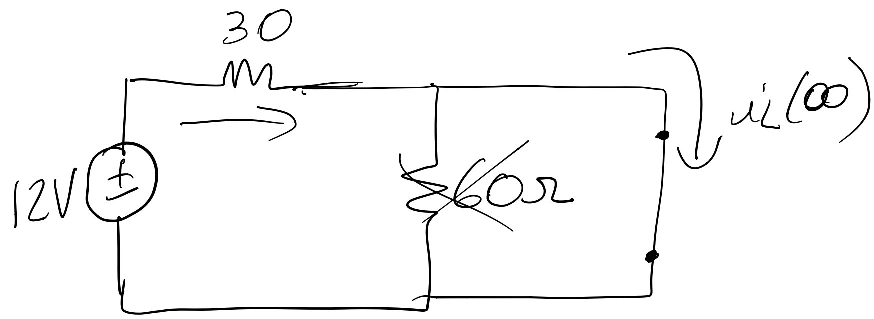
$t=0^-$:



$i_L(0^-) = 0$

$t \to \infty$



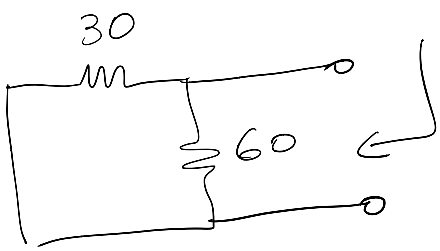
$v_L(t) = L\dfrac{di_L(t)}{dt}$ @ DC steady-state $\dfrac{di_L}{dt} = 0$

$v_L(t) = 0$ = short-circuit

$$i_L(\infty) = \frac{12}{30} = 0.4\,A$$

To find τ, we need REQ (from POV of L)

turn off all INDEP. sources



$$R_{EQ} = (30 \| 60) = \frac{30 \times 60}{30 + 60}$$

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$$R_{EQ} = 20\,\Omega \qquad \tau = \frac{L}{R_{EQ}} = \frac{0.2}{20} = 0.01$$

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$$i_L(t) = i_L(\infty) + [i_L(0^-) - i_L(\infty)]e^{-t/\tau}$$

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$$i_L(t) = 0.4 + [0 - 0.4]e^{-t/0.01}$$

$$i_L(t) = 0.4(1 - e^{-100t})\,A$$

$$v_L(t) = L\frac{di_L(t)}{dt} = 0.2 \times [0.4(0 - e^{-100t} \times (-100))]$$

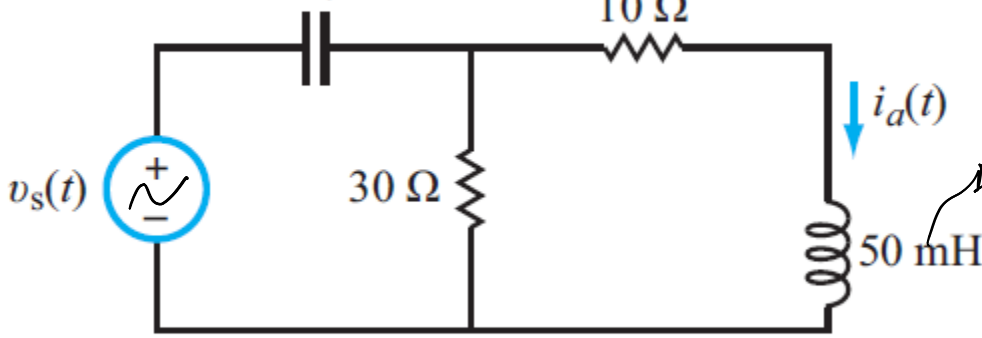
$$v_L(t) = 0.2 \times 0.4 \times 100 e^{-100t} = 8e^{-100t}\,V$$

$$v_L(0) = 8V$$

Find the current through the inductor and the power delivered by the source.

$v_s(t) = 40\sin(200t - 20°)\,V$

V_{max} $\quad \omega t \quad -\phi$



$\rightarrow \omega = 200!$

$$v_s(t) = 40\cos(200t - 110°)\,V$$

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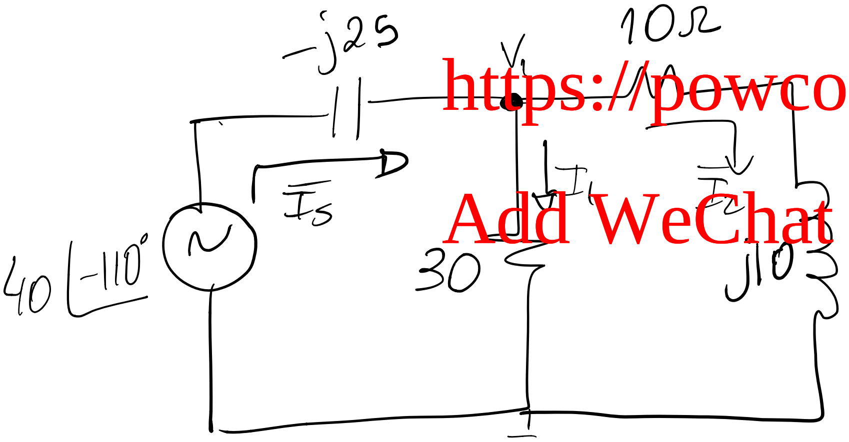


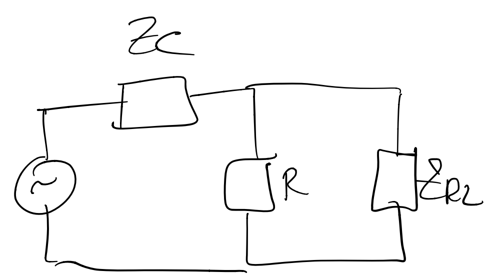
$Z_R = R$

$Z_L = j\omega L$

$Z_L = j \times 200 \times 50 \times 10^{-3}$

$Z_L = j10$

$$Z_C = \frac{1}{j\omega C} = \frac{1}{j200 \times 200 \times 10^{-6}} = -j25$$

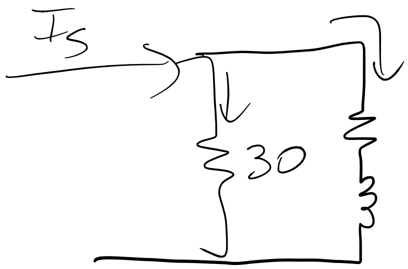


$$Z_{eq} = (10 + j10) \,//\, 30 + (-j25)$$

$$Z_{eq} = \frac{(10 + j10) \times 30}{40 + j10} + (-j25)$$

$$Z_{eq} = 21.6\angle -65.87°$$

$$\bar{I}_S = \frac{V_S}{Z_{eq}} = \frac{40\angle -110^\circ}{21.6\angle -65.87^\circ} = 1.85\angle -44.12^\circ \text{ A}$$



current division:

$$\bar{I}_2 = \frac{\bar{I}_S \times 30}{40+j10} = 1.34\angle -58.15^\circ \text{ A}$$

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$$i_L(t) = 1.34\cos(200t - 58.15^\circ) \text{ A}$$

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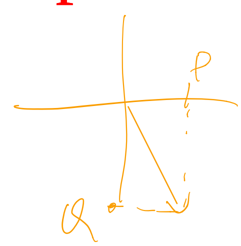

$$\bar{S}_S = \frac{\bar{V}_S \bar{I}_S^*}{2} = \frac{40\angle -110^\circ \times 1.85\angle +44.12^\circ}{2}$$

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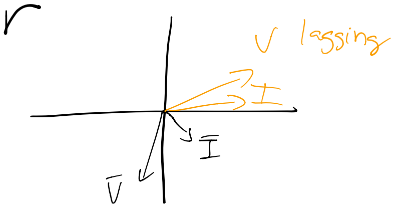
$$\bar{S}_S = 37\angle -65.88 = 15.12 - j33.77 \text{ VA}$$

$$P = 15.12 \text{ W} \qquad Q = 33.77 \text{ VAr}$$



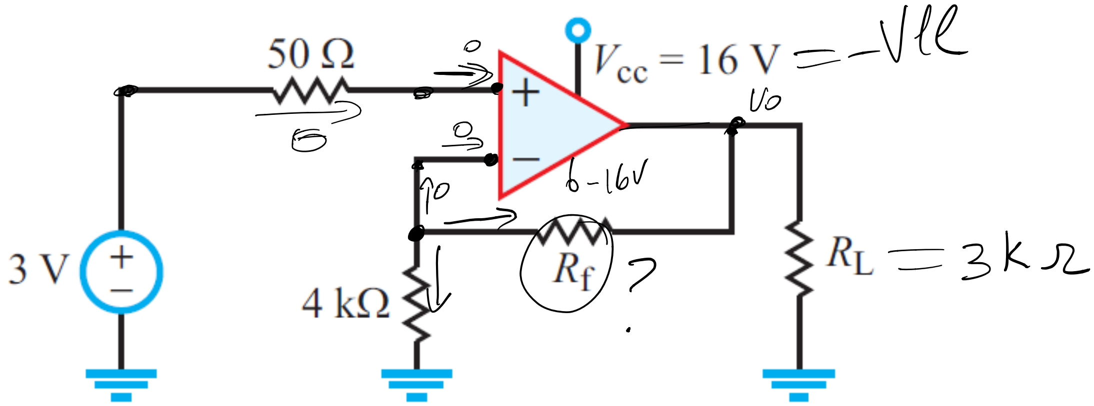
$$pf = \frac{P}{S} = \frac{15.12}{37} = 0.4$$

$$pf = \cos(\theta_V - \theta_I) = \cos(-65.88) = 0.4$$

power angle
imped angle

$pf = 0.4$ leading

The supply voltage of the op amp is 16 V. If R_L = 3kΩ, find R_f such that the circuit delivers 75 mW of power to R_L.



$$\frac{V_o^2}{R_L} = P_{out} = 75\times10^{-3} W \Rightarrow V_o = \sqrt{3\times10^{3} \times 75\times10^{-3}}$$

$$V_o = 15V < 16V \checkmark$$

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$$v^+ = v^- = 3V$$

KVL @ v^- : $\frac{v^- - 0}{4K} + \frac{v^- - V_o}{R_f} + 0 = 0$

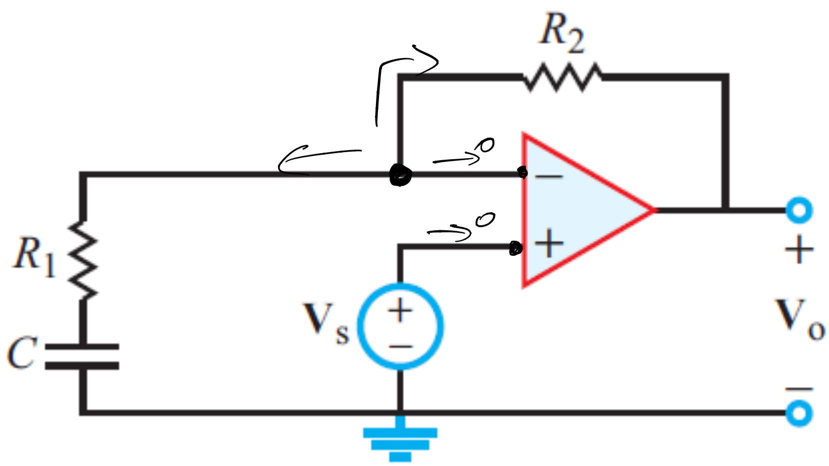
$$\frac{3}{4K} + \frac{3-15}{R_f} = 0 \qquad \frac{12}{R_f} = \frac{3}{4\times10^{3}} \Rightarrow \boxed{R_f = 16k\Omega}$$

OR: recognize it's a non-inverting amplifier:

$$V_o = \left(\frac{R_1+R_2}{R_2}\right) v_s \Rightarrow \underset{15}{V_o} = \left(\frac{4K+R_f}{R_f}\right) \underset{3}{v_s}$$

find $R_f = 16k\Omega$

Obtain an expression for H(ω) = Vo/Vs.



$$V^- = V^+ = V_s$$

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KCL @ V^-: $\dfrac{V_s - 0}{R_1 + \frac{1}{j\omega C}} + \dfrac{V_s - V_o}{R_2} + 0 = 0$

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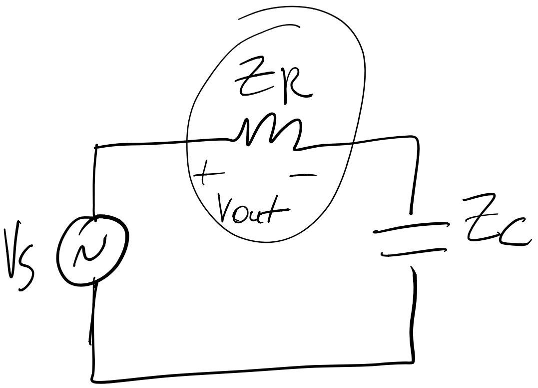
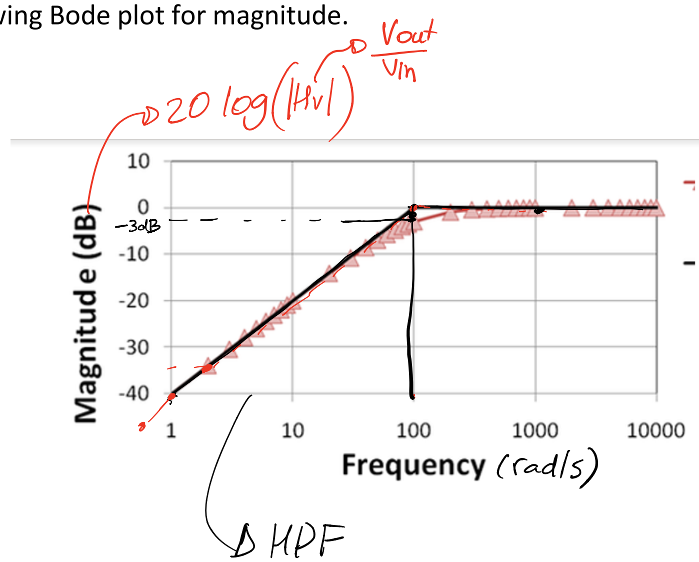
$$V_s\left(\frac{1}{R_1 + \frac{1}{j\omega C}} + \frac{1}{R_2}\right) = \frac{V_o}{R_2}$$

$$\frac{V_o}{V_s} = R_2\left[\frac{1}{R_1 + \frac{1}{j\omega C}} + \frac{1}{R_2}\right] = \cancel{R_2}\left[\frac{R_2 + R_1 + \frac{1}{j\omega C}}{\cancel{R_2}\left(R_1 + \frac{1}{j\omega C}\right)}\right]\frac{\times j\omega C}{\times j\omega C}$$

$$= \frac{R_2 j\omega C + R_1 j\omega C + 1}{R_1 j\omega C + 1} = \frac{1 + (R_1 + R_2) j\omega C}{1 + jR_1\omega C}$$

Design the circuit below to be a filter with the following Bode plot for magnitude.





$$\frac{V_R}{V_S} = \frac{Z_R}{Z_R+Z_C} = \frac{R}{R+\frac{1}{j\omega C}} = \frac{1}{1-\frac{j}{\omega RC}}$$

$\omega \to 0$: $\frac{V_R}{V_S} \to 0$

$\omega \to \infty$: $\frac{V_R}{V_S} \to 1$

} HPF

We need to choose output as the voltage through the resistor.

$$\cancel{\frac{V_C}{V_S} = \frac{1/j\omega C}{R+1/j\omega C} = \frac{1}{jR\omega C+1}}$$

$\cancel{\omega \to 0 : \frac{V_R}{V_S} = 1}$

$\cancel{\omega \to \infty : \frac{V_R}{V_S} = 0}$

~~} LPF~~

$$H_V(\omega) = \frac{1}{1-\frac{j}{\omega RC}} = \frac{1}{1-j\frac{\omega_C}{\omega}}$$

$$\omega_C \to \frac{P_{out}}{P_{in}} = \frac{1}{2} \to |H_V| = \frac{1}{\sqrt{2}}$$

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$\omega_c = 100 \text{ rad/s}$

$$\omega_c = \frac{1}{RC} = 100$$

so, $$\frac{1}{C} = 100R$$

$C = 1 \times 10^{-6} F = 1 \mu F$

$R = 10 k\Omega$

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