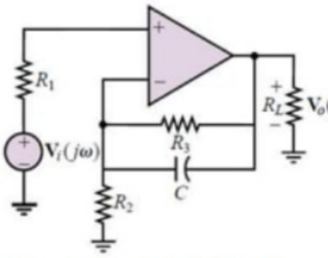
Question 1 30 out of 30 points

The circuit shown in the figure is an active filter with. Determine the cutoff frequency (ω_0) and pass-band gain (A_V) of the filter.



Given R_1=2kΩ,R_2=5kΩ,R_3=10kΩ,C=300nF.

$V_i = V^+$

$\frac{0-V^-}{R_2} = \frac{V^- - V_o}{R_3}$

$-\frac{V_i}{R_2} = \frac{V_i - V_o}{R_3}$

Ans: 9.54

$-\frac{R_3}{R_2} = \frac{V_i - V_o}{V_i}$

$\frac{V_o}{V_i} = \frac{R_3}{R_2} + 1$

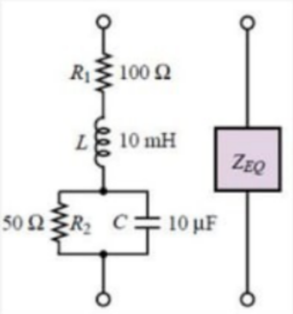
$|H(j\omega)| = \left|\frac{10k}{5k} + 1\right|$

$= 3$

$20\log_{10} 3 = 9.54$

Question 2 20 out of 20 points

Which of the following impedances best approximates the equivalent impedance of the following circuit, at frequency $\omega=10^4$ rad/sec?



Ans: $100 + j90\,\Omega$

$\frac{1}{Z} = \frac{1}{R_2} + \frac{1}{\frac{1}{j\omega C}}$

$= \frac{1}{R_2} + j\omega C$

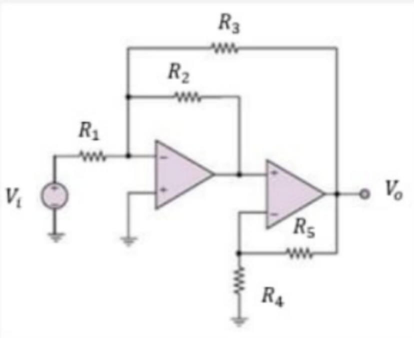
$Z = \frac{1}{\frac{1}{R_2} + j\omega C} \frac{\times R_2}{\times R_2}$

$= \frac{R_2}{1 + j\omega C R_2}$

$Z_{EQ} = R_1 + j\omega L + \frac{R_2}{1 + j\omega C R_2}$

Question 3 30 out of 30 points

The op-amps in the following circuit are ideal.



Given R_1=10Ω, R_2=10Ω, R_3=10Ω, R_4=20Ω, R_5=10Ω , determine the overall voltage gain $A_V=V_o/V_i$

$\frac{V_o}{V_i} = -\frac{10(10)(20+10)}{10(20\times10 + 10(20+10))}$

Ans: -0.6

$\frac{V_i - V}{R_1} = \frac{V - V}{R_2} + \frac{V - V_o}{R_3}$

$V_i R_2 R_3 - \cancel{V R_2 R_3} = \cancel{V R_2 R_3} - V R_1 R_3 + \cancel{V R_2 R_1} - V_o R_2 R_1$

$V_i R_2 R_3 = -V R_1 R_3 - V_o R_2 R_1$

$= -\left(\frac{R_4}{R_4+R_5} V_o\right) R_1 R_3 - V_o R_2 R_1$

$= \left(-\frac{R_4 R_1 R_3}{R_4+R_5} - R_2 R_1\right) V_o$

$\frac{V_o}{V_i} = R_2 R_3 \div \left(-\frac{R_4 R_1 R_3}{R_4+R_5} - R_2 R_1\right)$

$= R_2 R_3 \div -\left(\frac{R_4 R_1 R_3 + R_2 R_1 (R_4+R_5)}{R_4+R_5}\right)$

$= -\frac{R_2 R_3 (R_4+R_5)}{R_1(R_4 R_3 + R_2(R_4+R_5))}$

$\frac{0 - V}{R_4} = \frac{V - V_o}{R_5}$

$-\frac{V}{R_4} = \frac{V - V_o}{R_5}$

$-\frac{V}{R_4} = \frac{V}{R_5} - \frac{V_o}{R_5}$

$\frac{V}{R_5} + \frac{V}{R_4} = \frac{V_o}{R_5}$

$V\left(\frac{1}{R_5} + \frac{1}{R_4}\right)$ $\frac{R_4+R_5}{R_5 R_4}$

$V = \frac{V_o}{R_5} \div \left(\frac{1}{R_5} + \frac{1}{R_4}\right)$

$= \frac{V_o}{\cancel{R_5}} \times \frac{\cancel{R_5} R_4}{R_4+R_5}$

$= \frac{R_4}{R_4+R_5} V_o$

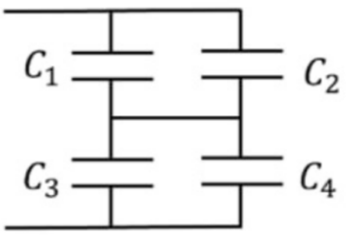
Question 4 10 out of 10 points

Evaluate (5 + 4*j) * (5 - 4*j) where *j* is the unitary imaginary number.

Ans: 41

Question 5 10 out of 10 points

Capacitors in series/parallel.



$\frac{1}{C_{eq}} = \frac{1}{20} + \frac{1}{30}$

$C_{eq} = 12\text{ mF}$

With reference to the figure, determine the equivalent capacitance when C1 = 4 mF, C2 = 16 mF, C3 = 5 mF, C4 = 25 mF.

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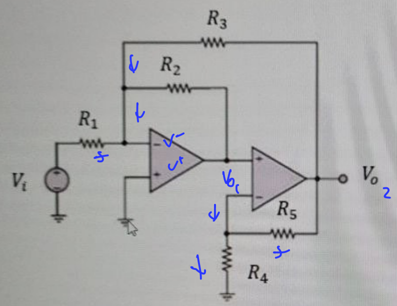
The op-amps in the following circuit are ideal.



Given $R_1=10\Omega$, $R_2=10\Omega$, $R_3=10\Omega$, $R_4=20\Omega$, $R_5=10\Omega$, determine the overall voltage gain $A_V=V_o/V_i$

- a. $A_V=+0.6$
- b. $A_V=+1.5$
- c. $A_V=-0.6$
- d. $A_V=-1.5$

$$i_1 + i_2 + i_3 = i_{in} = 0$$

$$\frac{V_s - V^-}{R_1} + \frac{V_{out,1} - V^-}{R_2} + \frac{V_{out,2} - V^-}{R_3} = 0$$

$$V^+ = V^- = 0$$

$$\frac{V_s}{R_1} + \frac{V_{out,2}}{R_3} = -\frac{V_{o1}}{R_2}$$

$$-R_2\left(\frac{V_s}{R_1} + \frac{V_{o2}}{R_3}\right) = V_{o1} \quad \text{— (1)}$$

$$i_{in} = i_5 + i_4$$

$$\frac{V^-}{R_4} = -\frac{(V^- - V_{o2})}{R_5}$$

$$V^- = V^+ = V_{o1}$$

$$V_{o1}\left(\frac{1}{R_5} + \frac{1}{R_4}\right) = \frac{V_{o2}}{R_5}$$

$$V_{o1} = \frac{V_{o2}}{\cancel{R_5}}\left(\frac{R_4 \cancel{R_5}}{R_5 + R_4}\right) \quad \text{— (2)}$$

Sub (1) into (2)

$$-R_2\left(\frac{V_s}{R_1} + \frac{V_{o2}}{R_3}\right) = V_{o2}\left(\frac{R_4}{R_5 + R_4}\right)$$

$$\frac{V_s}{R_1} + \frac{V_{o2}}{R_3} = V_{o2}\left(\frac{R_4}{(R_5 + R_4)(-R_2)}\right)$$

$$\frac{V_s}{10} + \frac{V_{o2}}{10} = -\frac{V_{o2}}{15}$$

$$\frac{V_s}{10} = \frac{V_{o2}}{6}$$

$$\frac{V_{o2}}{V_s} = -\frac{6}{10} = -0.6$$

$$\frac{V_2^-}{R_4} = \frac{V_o}{R_5 + R_4}$$

$$\therefore V_2^- = \frac{R_4}{R_5 + R_4} V_o$$

$$= \frac{20}{10+20} V_o$$

$$= \frac{2}{3} V_o$$

$$V_2^+ = V_2^- = \frac{2}{3} V_o$$

$$V_1^+ = V_1^- = 0$$

$$I_1 + I_2 + I_3 = 0$$

$$\frac{V_i - V_1^-}{R_1} + \frac{V_2^+}{R_2} + \frac{V_o}{R_3} = 0$$

$$\frac{V_i}{10} + \frac{2}{3} V_o \left(\frac{1}{10}\right) + \frac{V_o}{10} = 0$$

$$\frac{V_i}{10} + \frac{V_o}{6} = 0$$

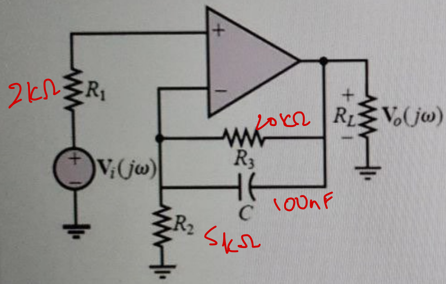
$$\frac{V_o}{V_i} = -\frac{6}{10}$$

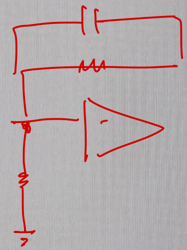
$$= -0.6$$

⚠ Moving to the next question prevents changes to this answer.

Question 3

The circuit shown in the figure is an active filter with. Determine the cutoff frequency (ω_0) and pass-band gain (A_V) of the filter.





Given R_1=2kΩ, R_2=5kΩ, R_3=20kΩ, C=100nF.

- ✓ ω_0 = 500 rad/sec; A_V = 13.98 dB.
- ○ ω_0 = 500 rad/sec; A_V = 8.22 dB.
- ○ ω_0 = 2000 rad/sec; A_V = 8.22 dB.
- ○ ω_0 = 2000 rad/sec; A_V = 13.98 dB.

⚠ Moving to the next question prevents changes to this answer

Look @ non inverting. amp

$$A_{HP} = 1 + \frac{Z_F}{Z_S}$$

$$Z_F = R_3 \,//\, \frac{1}{j\omega C_F} = \frac{R_3}{1 + j\omega C R_3}$$

$$Z_S = R_2$$

$$A_{HP} = 1 + \frac{R_3}{R_2} \cdot \frac{1}{1 + j\omega C R_3}$$

$$|A_{HP}| = 1 + \frac{20}{5} \cdot \frac{1}{\sqrt{1 + \omega^2 C^2 R_3^2}}$$

$\omega = 0 \rightarrow 5 = 20\log 5 = 13.98\,dB$ //

$\omega = \infty \rightarrow 0$

$$\omega_0 = \frac{1}{CR_3}$$

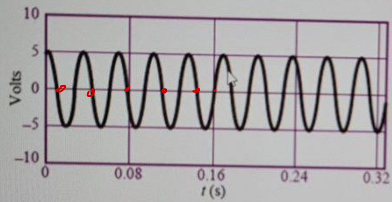
$$= \frac{1}{1\times10^{-7} \times 20\times10^{3}}$$

$$= 500$$

Moving to the next question prevents changes to this answer.

Question 2

The following figure represents a sinusoidal voltage in a Voltage vs. Time graph, where time is expressed in second.



Which of the following options best represents the frequency of the following sinusoidal signal?

- a. 30 Hz
- b. 3.10 Hz
- c. 0.32 Hz
- d. 12.5 Hz

Moving to the next question prevents changes to this answer.

$$\frac{0.08}{2.5} = 0.032$$

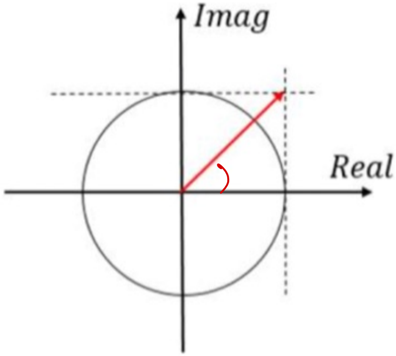
$$f = \frac{1}{T} = \frac{1}{0.0032}$$

$$= 31.25$$

$$\approx 30\,Hz$$

Question 3

The figure below represents the complex plane and, in it, a vector (arrow) and the unitary circle.



Which of the following complex numbers best represents the vector?

- [x] a. $e^{j\pi/4}$
- [ ] b. $\sqrt{2}e^{j\pi/4}$
- [ ] c. $\sqrt{2}e^{j\pi}$
- [ ] d. $\sqrt{2}$

$\pi = 180^\circ$

$45^\circ = \frac{\pi}{4} \Rightarrow e^{j\pi/4}$

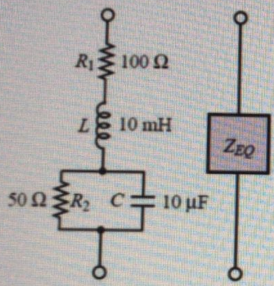
$e^{i\theta} = \cos\theta + i\sin\theta$

$= \frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}}j$

$Re + Im = a + jb$

Question 4

Which of the following impedances best approximates the equivalent impedance of the following circuit, at frequency $\omega = 10^4$ rad/sec?



- a. $Z_{EQ} = j100\ \Omega$
- b. $Z_{EQ} = 100 + j90\Omega$
- c. $Z_{EQ} = 100\ e^{j\pi/2}\Omega$
- d. $Z_{EQ} = 100 + 100\ e^{j\pi}\Omega$

$\omega = 10^4$ rad/sec

$(a+b)(a-b)$

$= a^2 - b^2$

$$Z_{eq} = R_1 + L + C // R_2$$

$$= 100 + j\omega L + \left(\frac{1}{R_2} + \frac{1}{\frac{1}{j\omega c}}\right)^{-1}$$