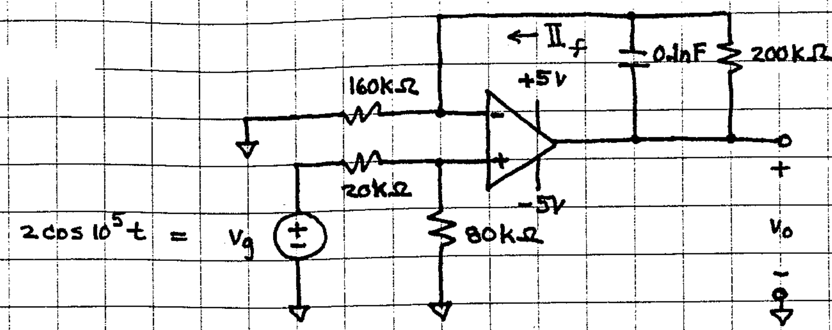
ex:



The op-amp is ideal

a) Find the steady-state expression for $v_o(t)$.
(In other words, solve in frequency domain to find sinusoidal expression for $v_o(t)$.)

sol'n: Same approach as with R's and DC sources, but use phasors for sources and complex impedances for L's and C's.

We still have rules: $V_n = V_p$ for phasor voltages and − and + inputs, and $I_n = I_p = 0$ for phasor currents into − and + inputs.

First, we find V_p, (as always with op-amp probs):

$$V_g = 2\angle 0^\circ \qquad V_p = V_g \cdot \frac{80\text{k}\Omega}{80\text{k}\Omega + 20\text{k}\Omega} = 2\angle 0^\circ \cdot \frac{4}{5} = 1.6\angle 0^\circ$$

$$V_n = V_p = 1.6\angle 0^\circ$$

Now equate feedback current, $\mathbb{I}_f$, with current in 160kΩ, since $I_n = 0$.

$$I_f = \frac{V_o - V_n}{200\text{k}\Omega \parallel Z_C} \qquad \text{where } Z_C = \frac{-j}{\omega C} = \frac{-j}{10^5 \cdot 0.1\text{n}} = -j\,100\text{k}\Omega$$

$$\text{and } I_f = \frac{V_n}{160\text{k}\Omega} \qquad \therefore \frac{V_o - V_n}{200\text{k}\Omega \parallel Z_C} = \frac{V_n}{160\text{k}\Omega}$$

$$\therefore V_o = V_n \left(1 + \frac{200\,k\Omega \parallel z_C}{160\,k\Omega}\right)$$

$$200\,k\Omega \parallel z_C = 200\,k\Omega \parallel -j100\,k\Omega = 100\,k\Omega \cdot 2 \parallel -j$$

$$= 100\,k\Omega \cdot \frac{-2j}{2-j}\,\frac{2+j}{2+j} = 100\,k\Omega\,\frac{2-j4}{2^2+1^2}$$

$$= 20\,k\Omega \cdot (2-j4)$$

$$= 40\,k\Omega - j\,80\,k\Omega$$

$$V_o = 1.6\angle 0^\circ \left(1 + \frac{40\,k\Omega - j80\,k\Omega}{160\,k\Omega}\right) \quad V$$

$$= \cancel{1.6}\angle 0^\circ \; \frac{160\,k\Omega + 40\,k\Omega - j\,80\,k\Omega}{\underset{100}{\cancel{160}}\,k\Omega} \quad V$$

$$= \frac{200\,k\Omega - j\,80\,k\Omega}{100\,k\Omega} = 2 - j0.8 \quad V$$

$$= \sqrt{2^2 + 0.8^2}\; e^{j\tan^{-1}\frac{-0.8}{2}} = 2.15\, e^{-j\,21.8^\circ} \; V \text{ or } 2.5\angle -21.8^\circ\, V$$

$$v_o(t) = 2.15 \cos(\omega t - 21.8^\circ)\; V \qquad \omega = 10^5 \text{ since } v_g = 2\cos 10^5 t$$

b) How large can amplitude of v_g be before the amplifier saturates? (i.e. before $v_o(t)$ exceeds $\pm 5\,V$ at some point during one cycle of sinusoid)

sol'n: The priciple of (linear) superposition tells us that the magnitude of $v_o(t)$ is directly proportional to the magnitude of $v_g(t)$. Furthermore, scaling $v_g(t)$'s magnitude leaves phase relationships unaffected.

For $v_g = 2\cos 10^5 t$ we have $v_o(t) = 2.15\cos(\omega t - 21.8^\circ)\,V$

$\therefore$ for $v_o(t) = 5\cos(\omega t - 21.8^\circ)\,V$ we have

$$v_g = \frac{5 \cdot 2}{2.15} \cos 10^5 t = 4.65 \cos 10^5 t \;\; V \quad \therefore \underline{4.65\,V} \text{ max}$$