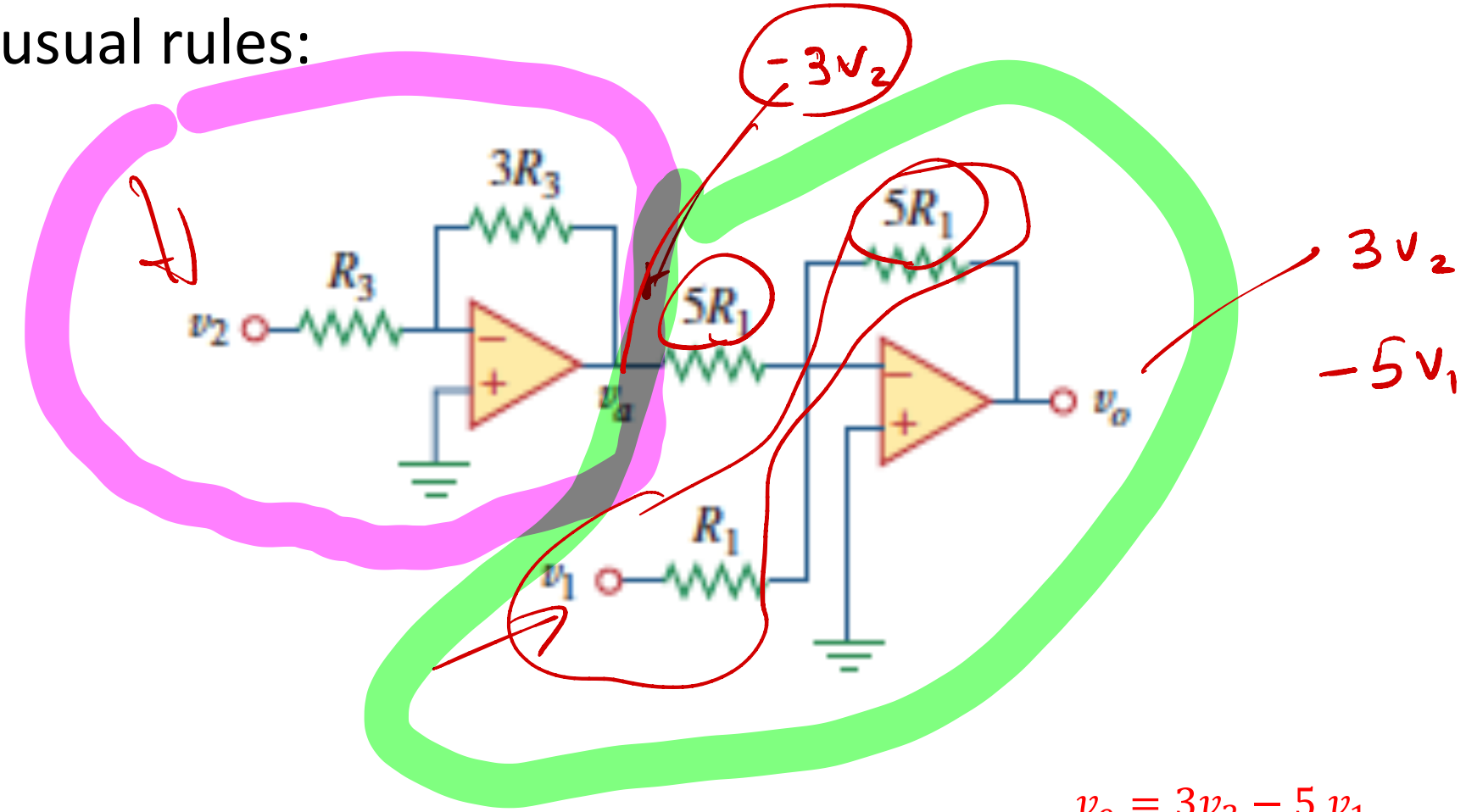
Op Amps – 3

multiple op amps, AC

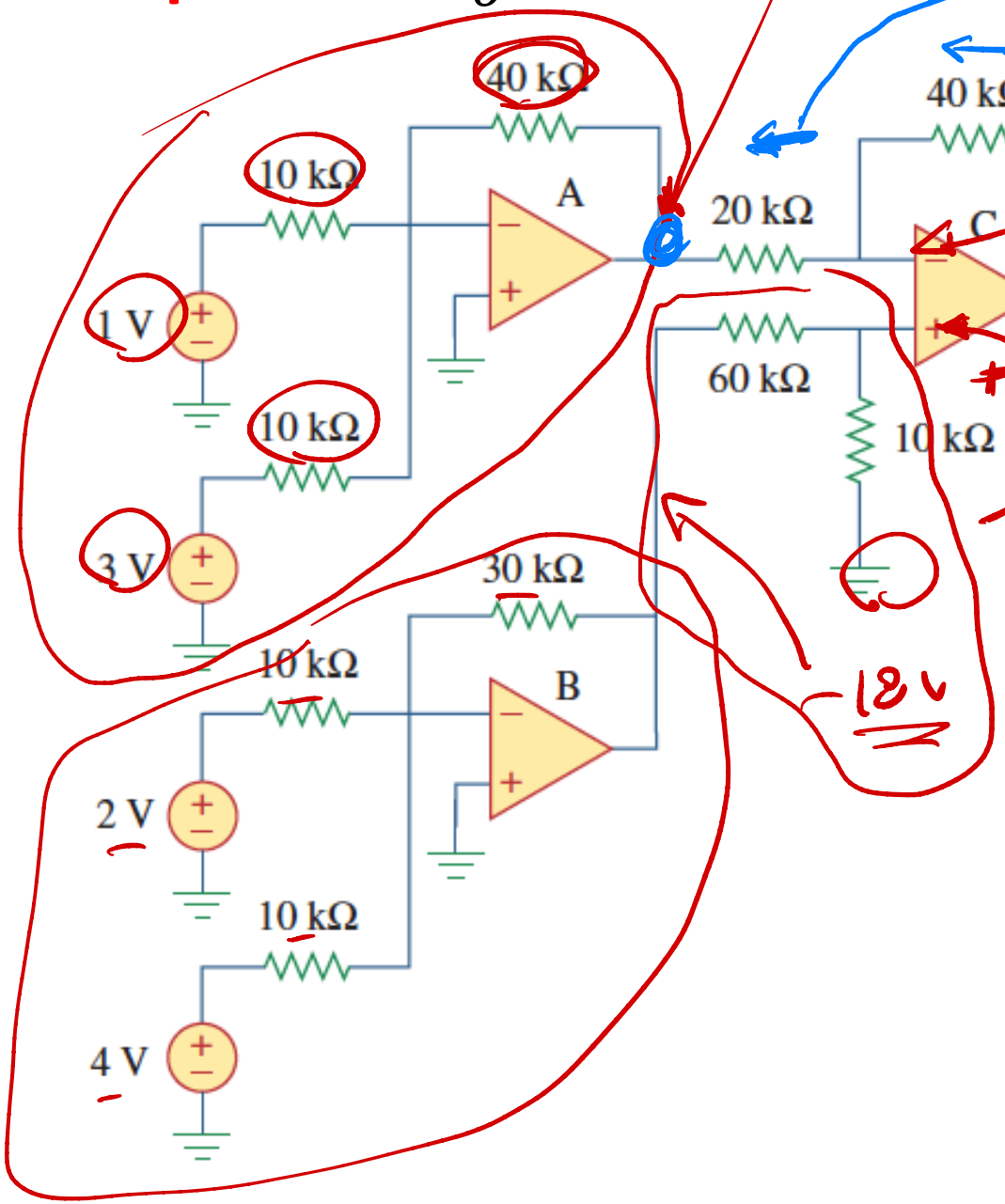
Now what?

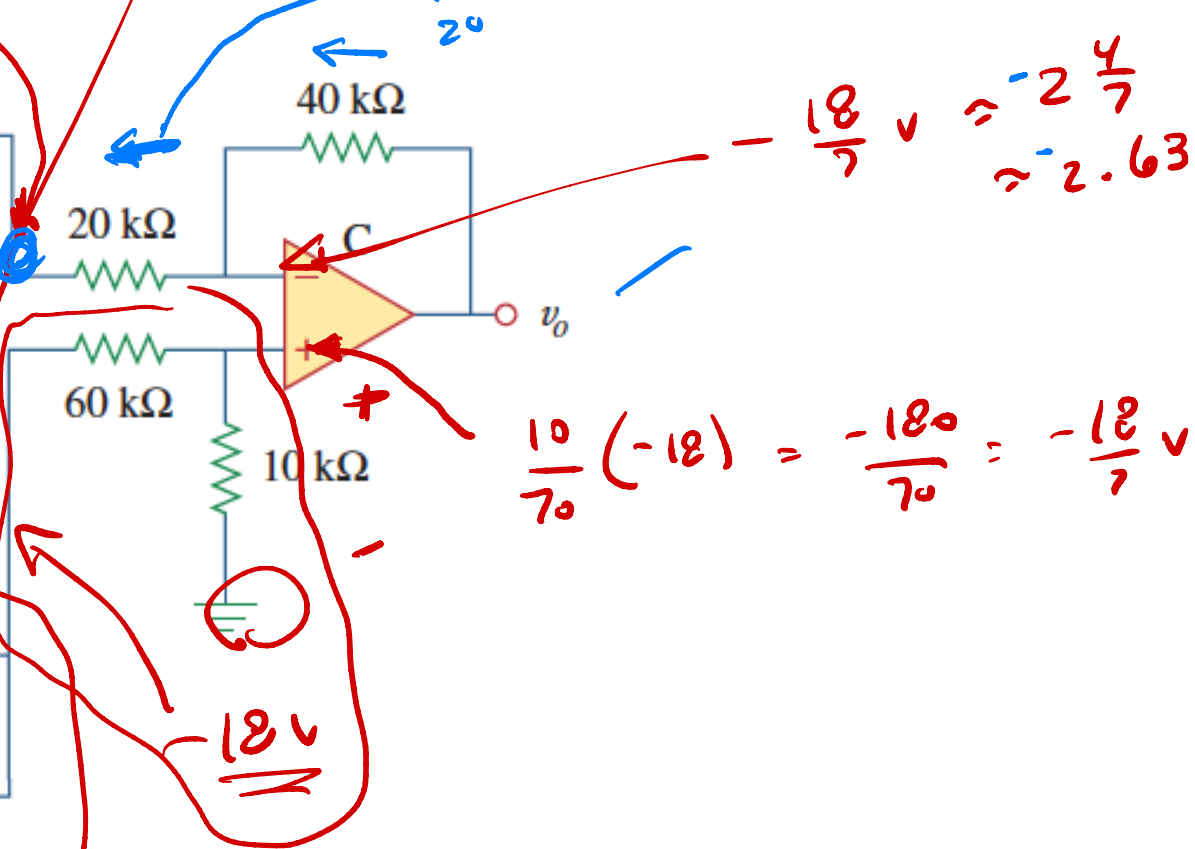
- Method is to exploit known forms and/or apply the usual rules:



$$v_o = 3v_2 - 5\,v_1$$

Example: find v_o





$-4-12=-16\,V$

$\frac{13.4}{20}\,mA$

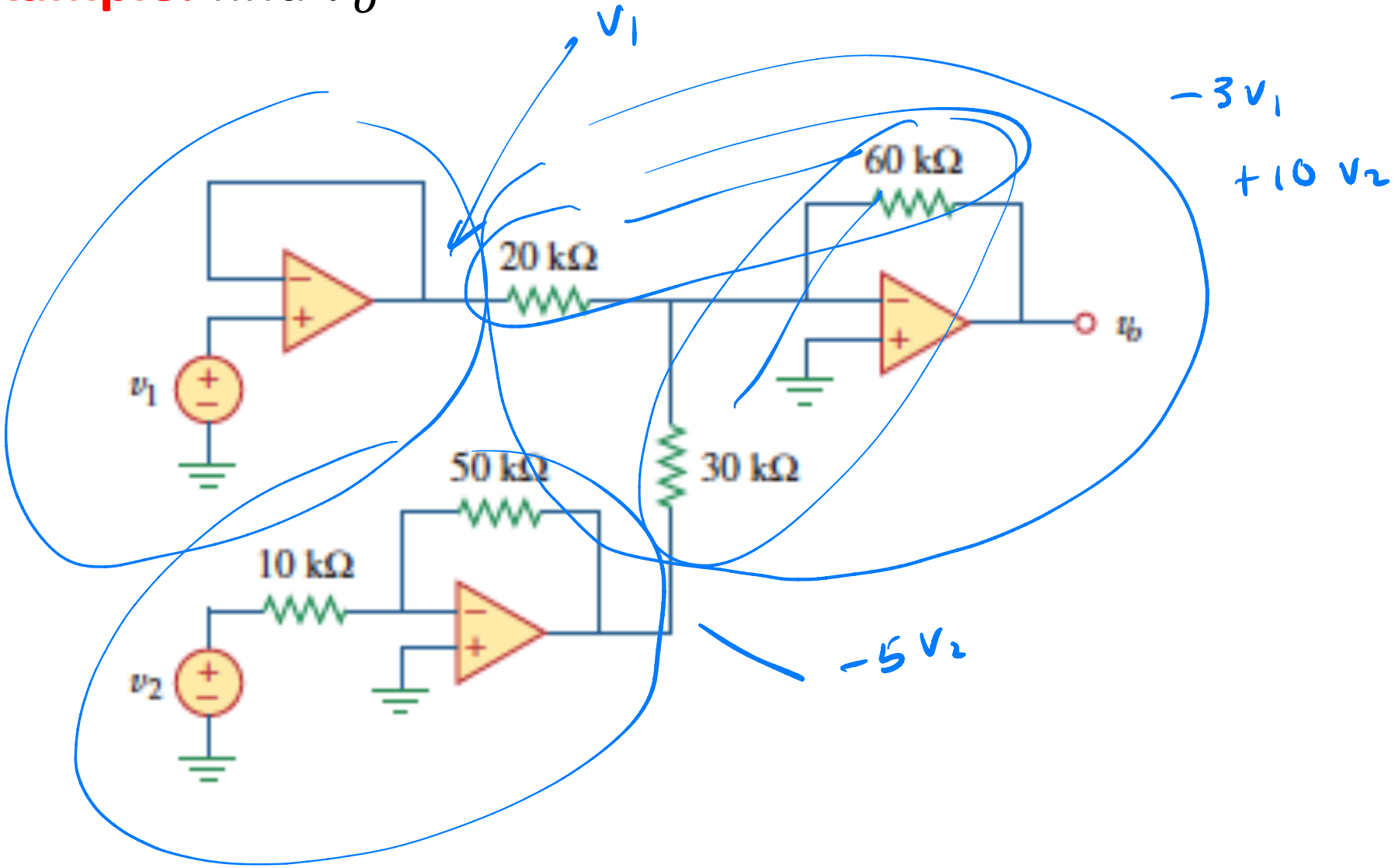
$-\frac{18}{7}\,V \approx -2\frac{4}{7} \approx -2.63$

$\frac{10}{70}(-18) = -\frac{180}{70} = -\frac{18}{7}\,V$

$-18\,V$

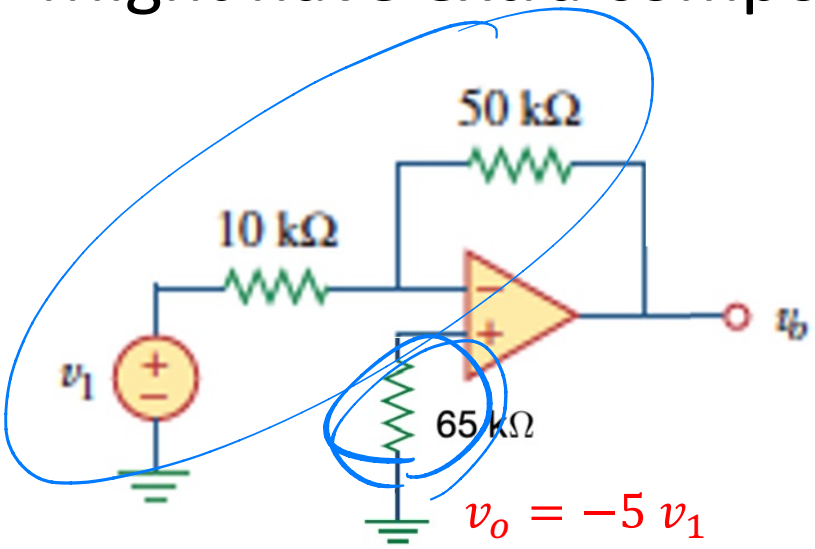
$v_o = 25.1\,V$

Example: find v_o

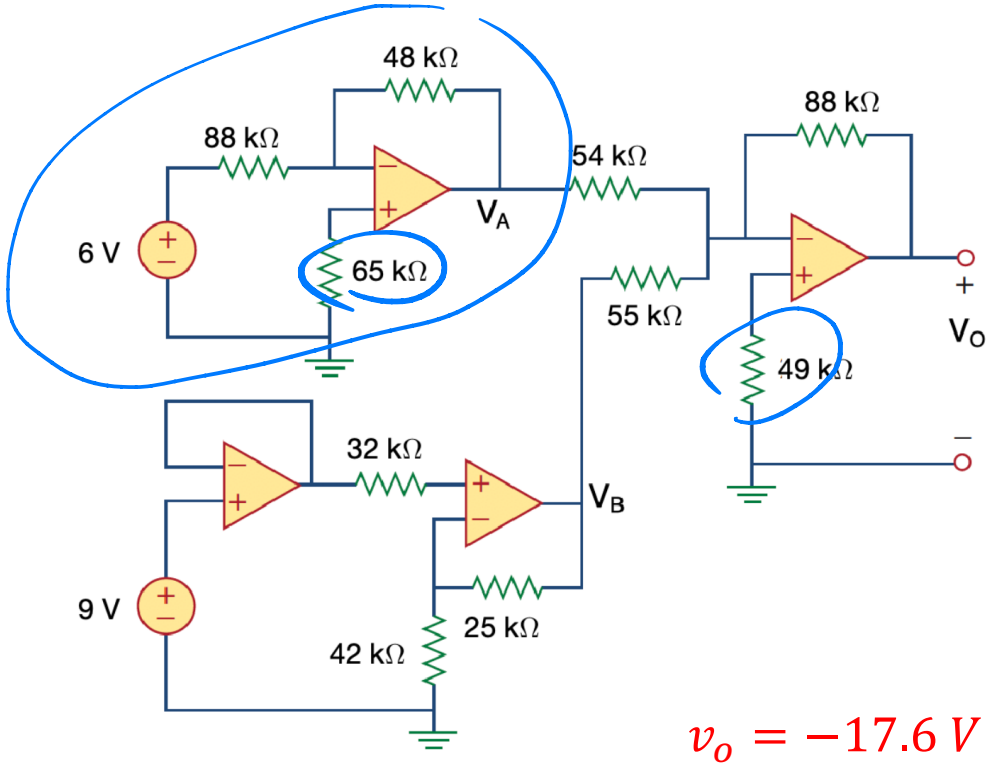


$v_o = 10v_2 - 3v_1$

Might have extra components:

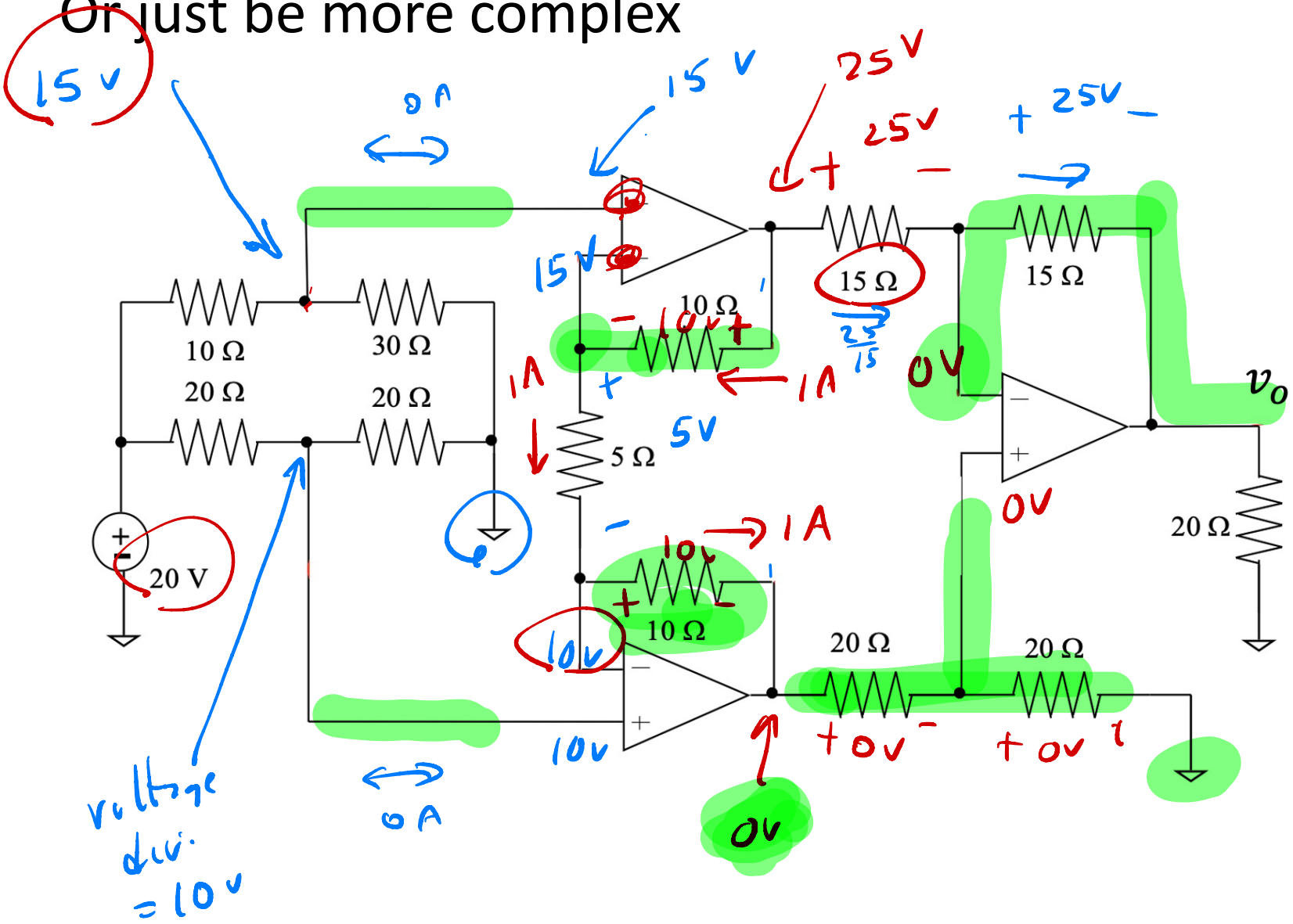


$v_o = -5\ v_1$



$v_o = -17.6\ V$

Or just be more complex

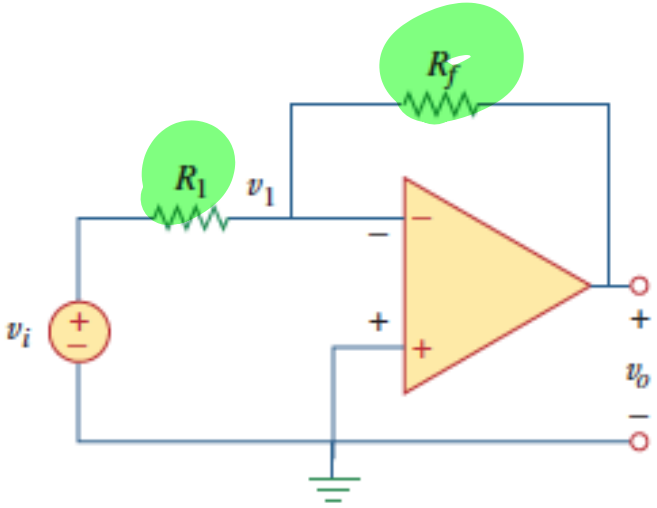


$v_o = -25\ V$

Op Amps and AC

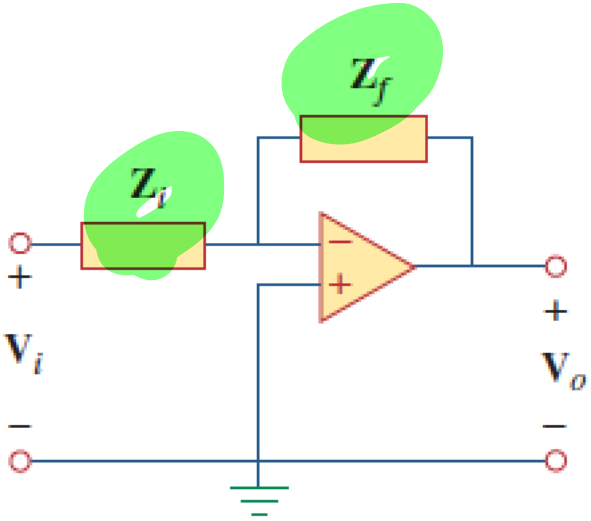
- Recall the inverting amplifier

$$\text{gain} = -\frac{R_f}{R_i}$$

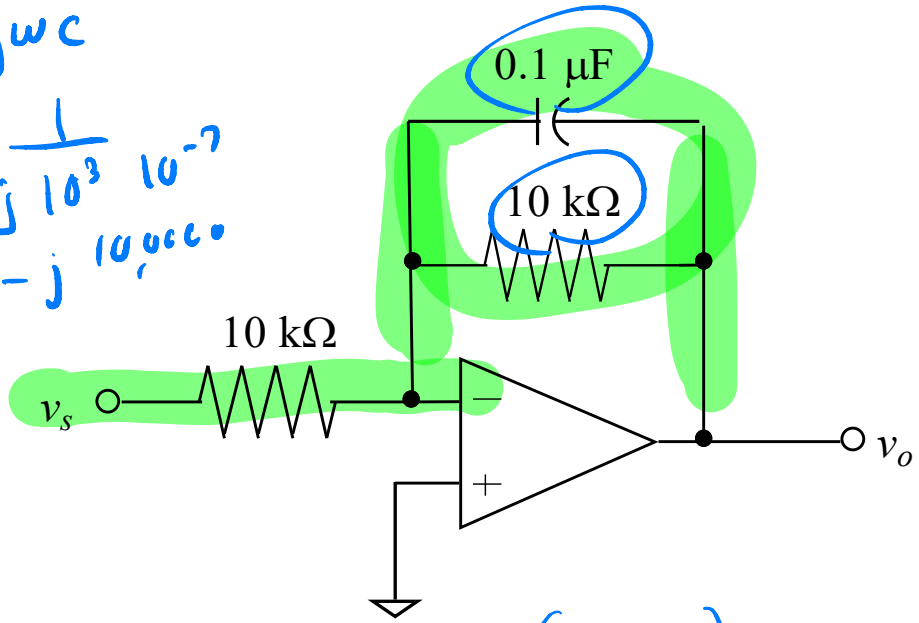


- Now, an "active" filter

$$H(\omega) = -\frac{Z_f}{Z_i}$$



Example: find v_o if $v_s(t) = 2\cos 1000t$ V



$Z_C = \frac{1}{j\omega C} = \frac{1}{j\,10^3\,10^{-7}} = -j\,10000$

$Z_i = 10\text{ k}$

$Z_F = \frac{(10^4)(-j10^4)}{10^4(1-j)}$

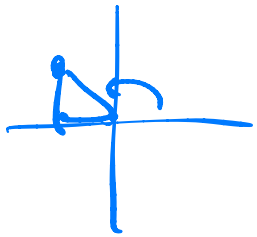
$= -10^4\,\frac{j}{(-j)}\,\frac{1+j}{1+j}$

$= -5000(-1+j)$

$= 5000 - 5000j$

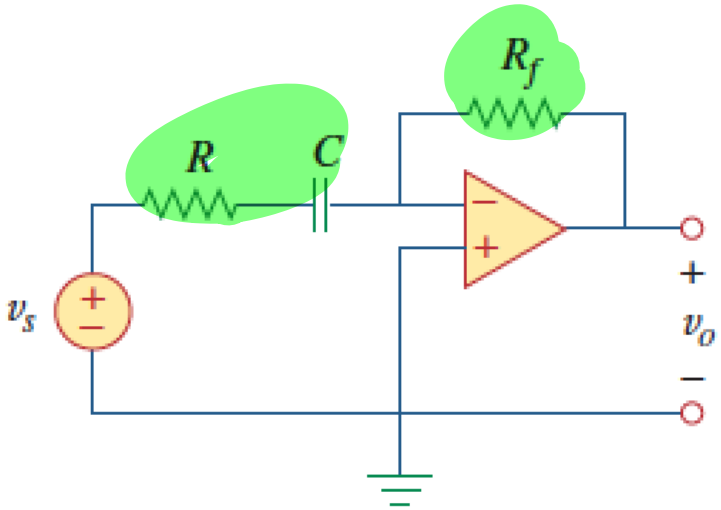
$-\frac{5000(1-j)}{10000}\,2$

$V_o = -1 + j \rightarrow \sqrt{2}\angle 135°$



$v_o(t) = \sqrt{2}\cos(\omega t + 135°)$ V

Example: find v_o if $v_i(t) = A\cos\omega t\ V$ Is the result low pass, bandpass, or highpass?



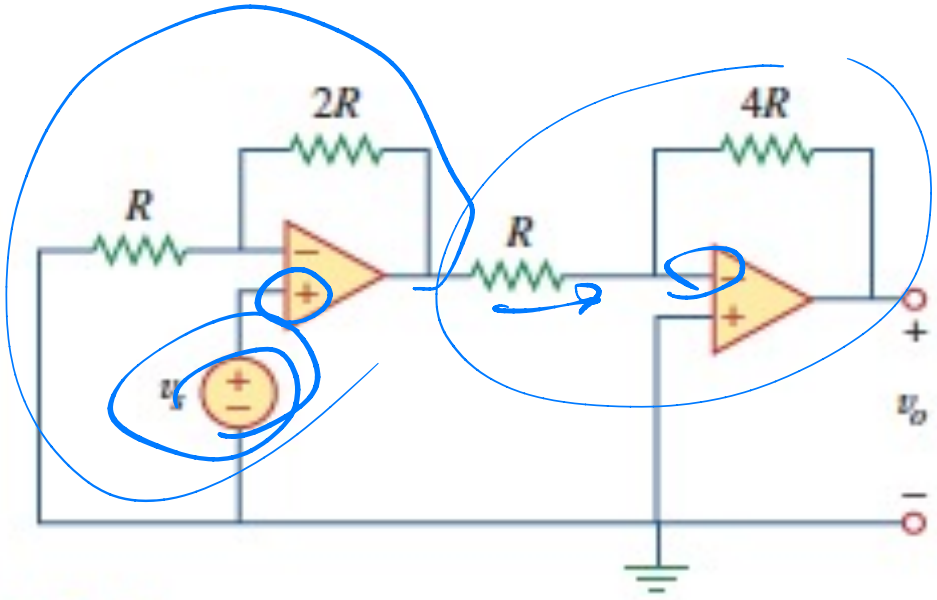
$$V_o = -\frac{V_i}{A}\,\frac{R_F}{R_F + \frac{1}{j\omega C}}$$

$$= \frac{A R_F}{\sqrt{R_F^2 + \frac{1}{\omega^2 C^2}}}\ \angle \tan^{-1}\frac{1/\omega C}{R_F}$$

$v_o(t)$

$$v_o(t) = \frac{A\omega R_f C}{\sqrt{1+\omega^2 R_i{}^2 C^2}}\cos(\omega t + 180° - \tan^{-1}(\omega R_i C))\ \text{V}$$

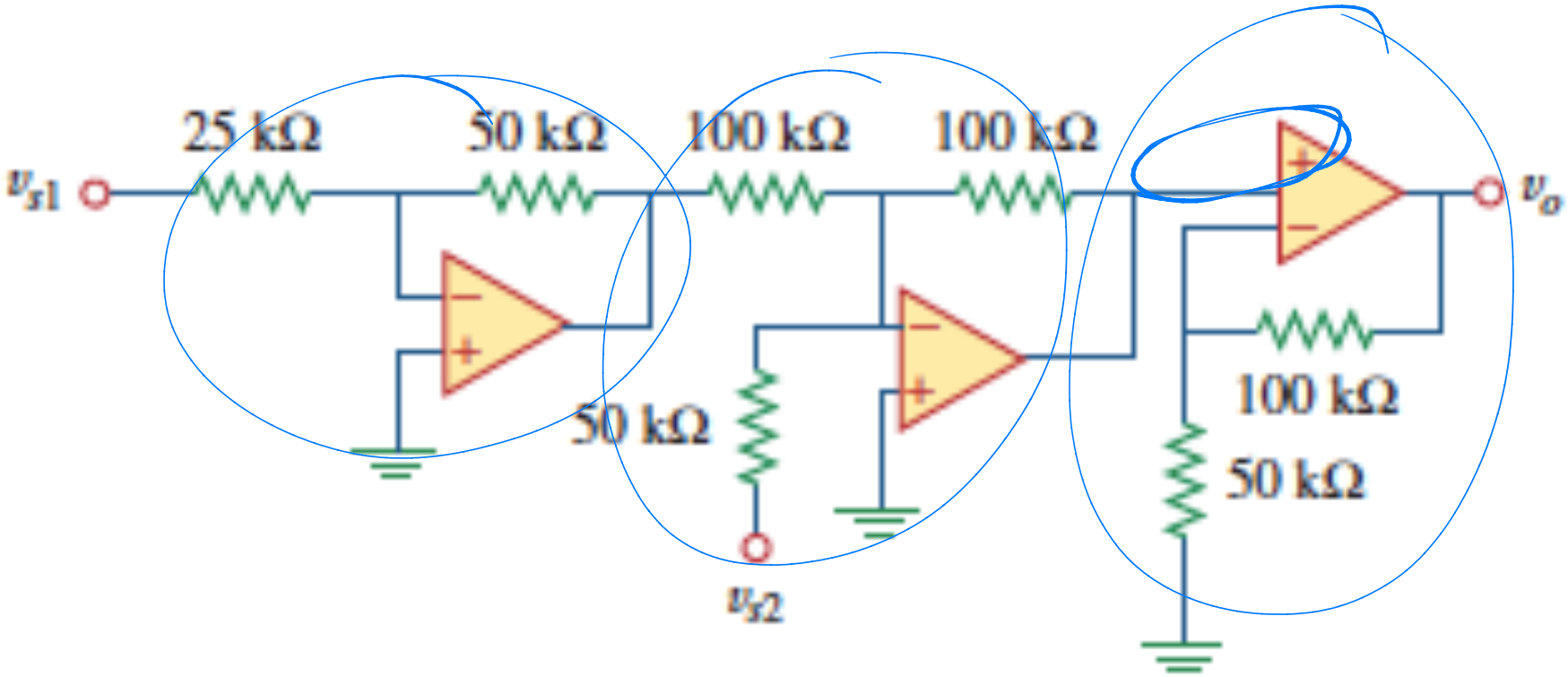
Practice problem: find v_o



$v_o = -12\ v_s$

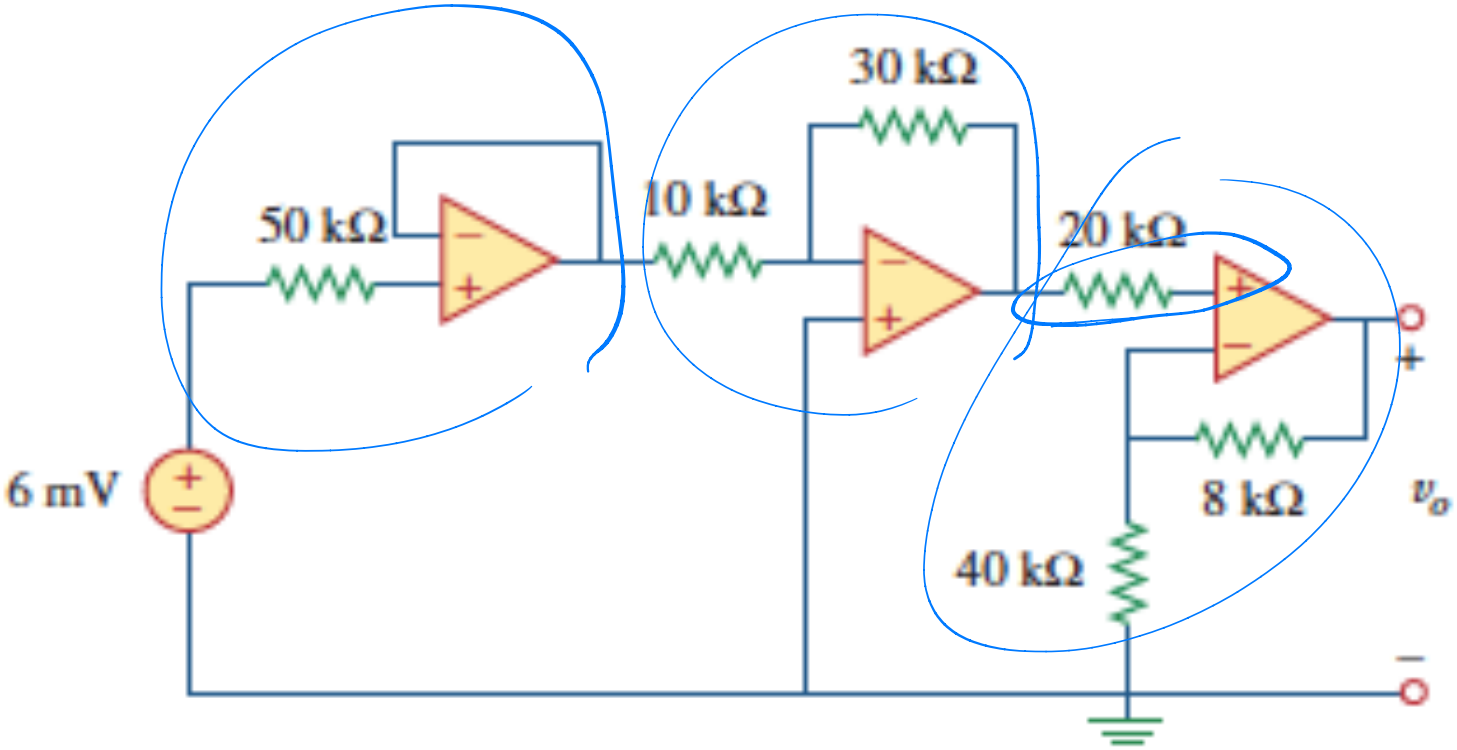
$v_o = 6(v_1 - v_2)$

Practice problem: find v_o



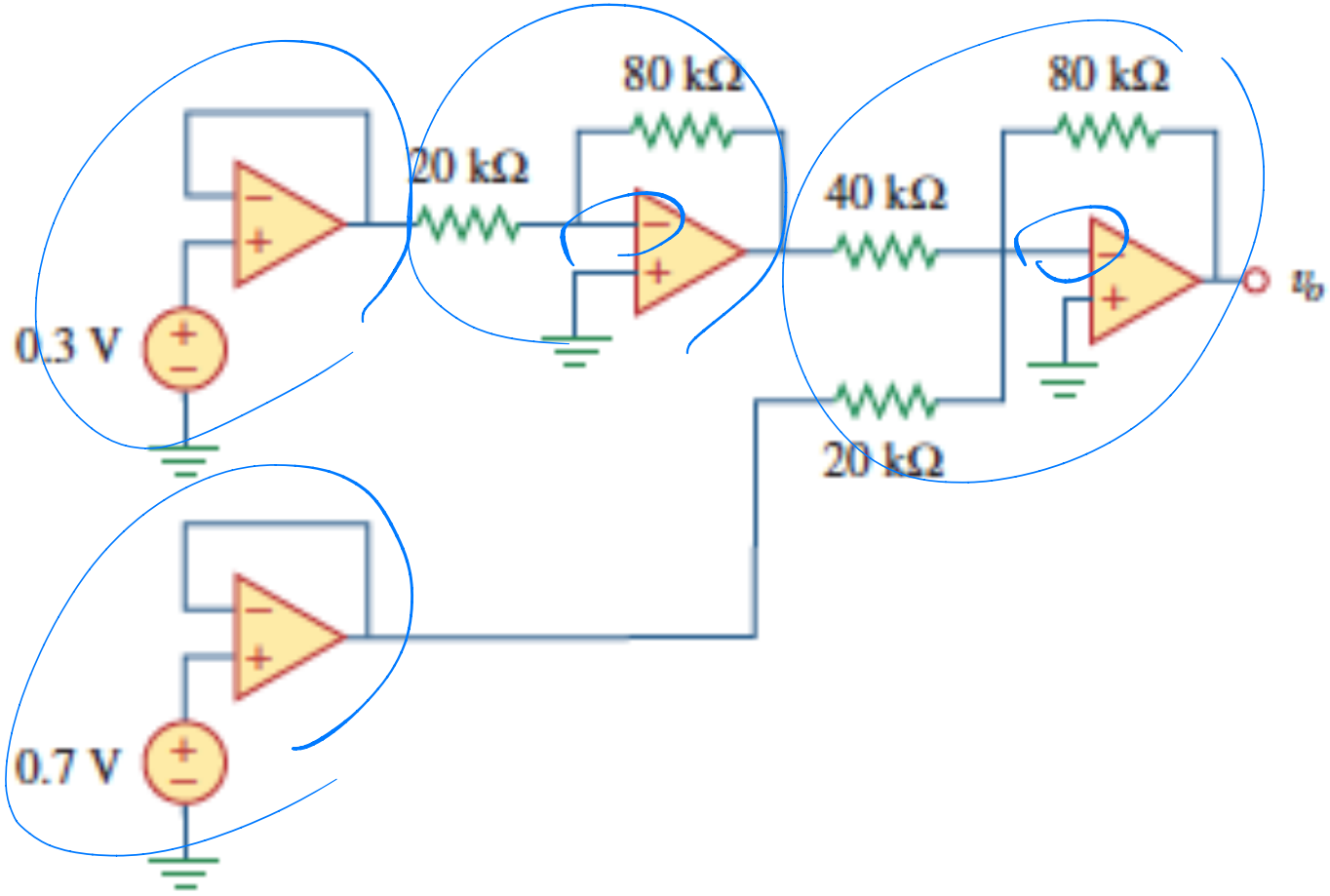
$v_o - 21.6\ mV$

Practice problem: find v_o



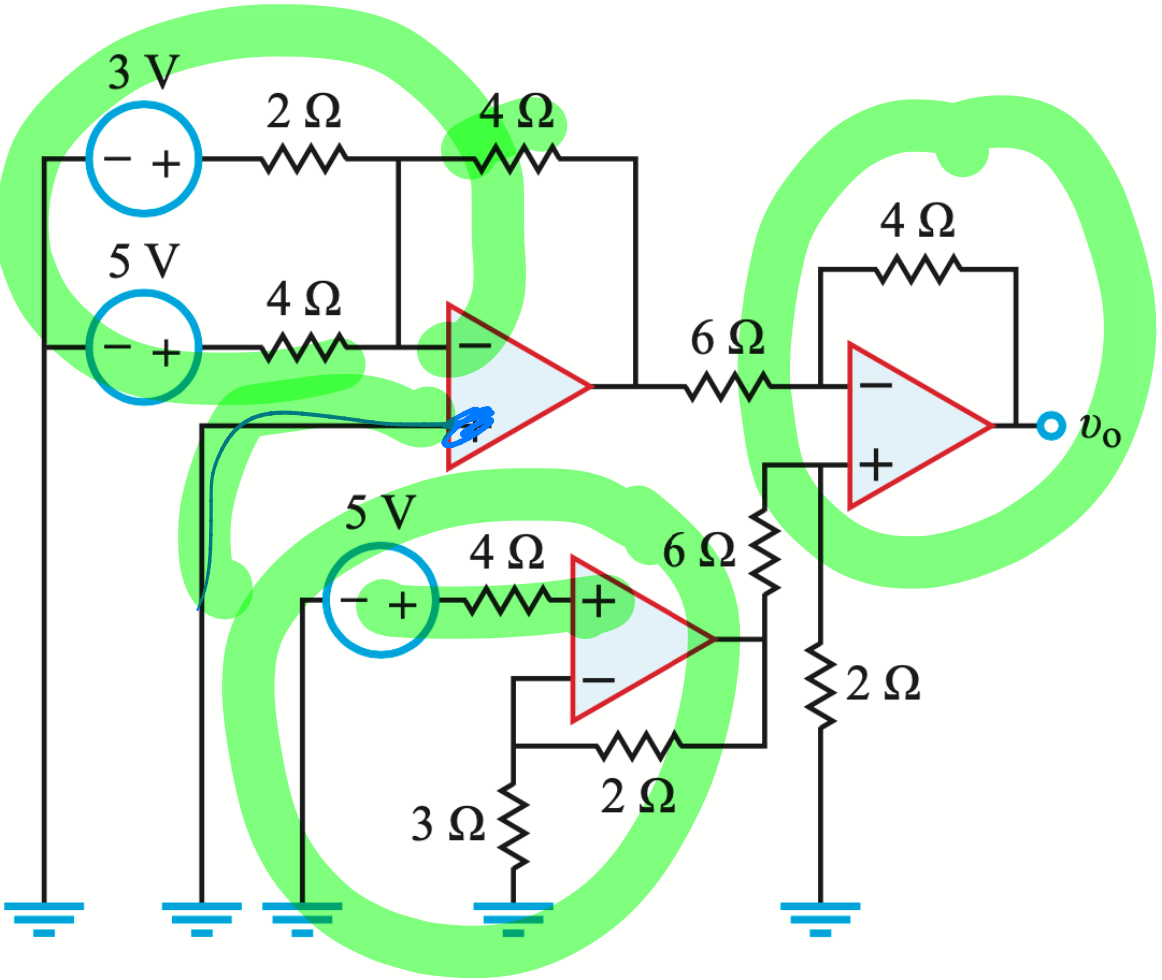
$v_o = -0.4\ V$

Practice problem: find v_o

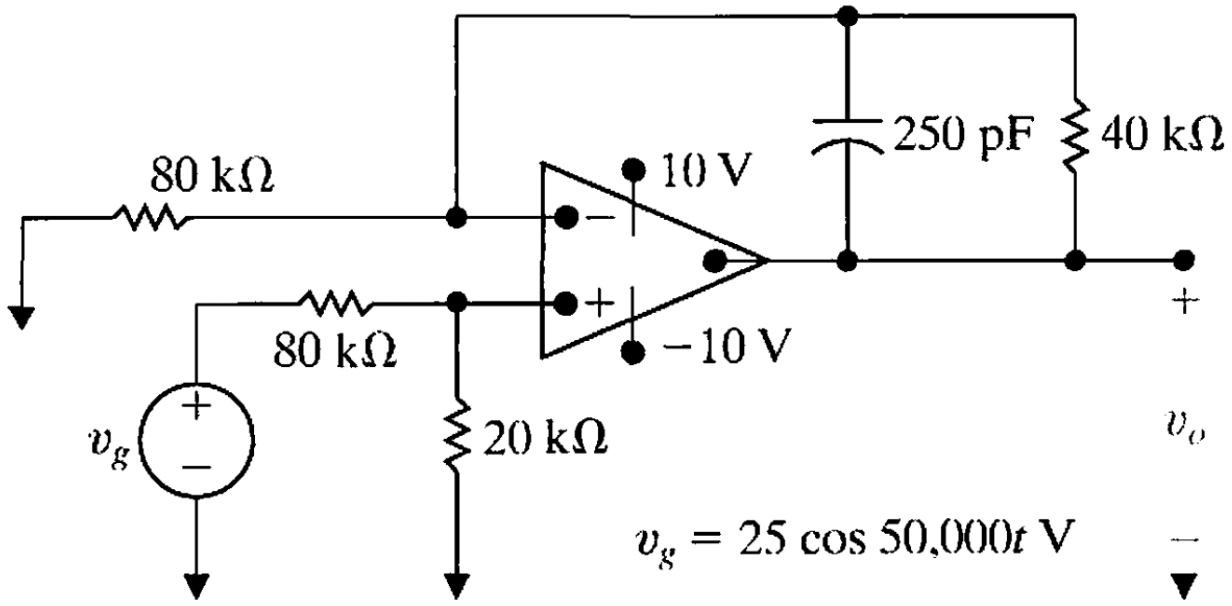


$v_o = 21.8\ V$

Practice problem: find v_o

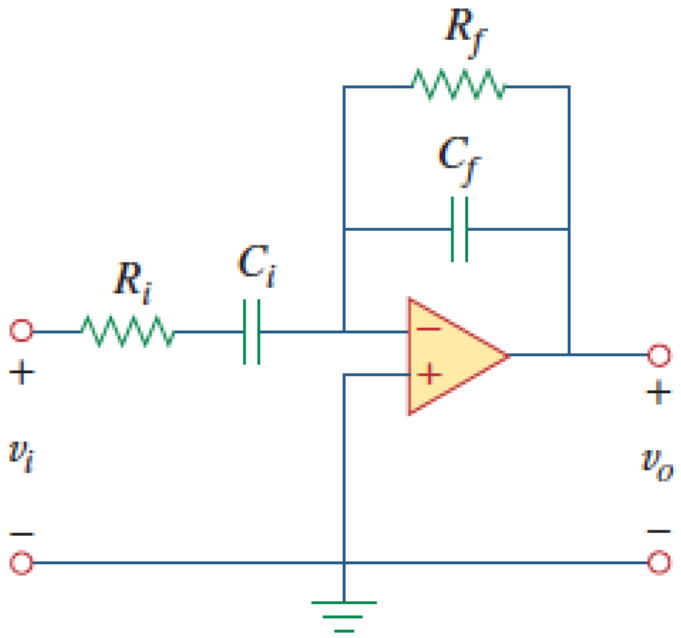


Practice problem: find $v_o(t)$



$v_o(t) = 0.707 \cos(50{,}000t - 8.13°)$ V

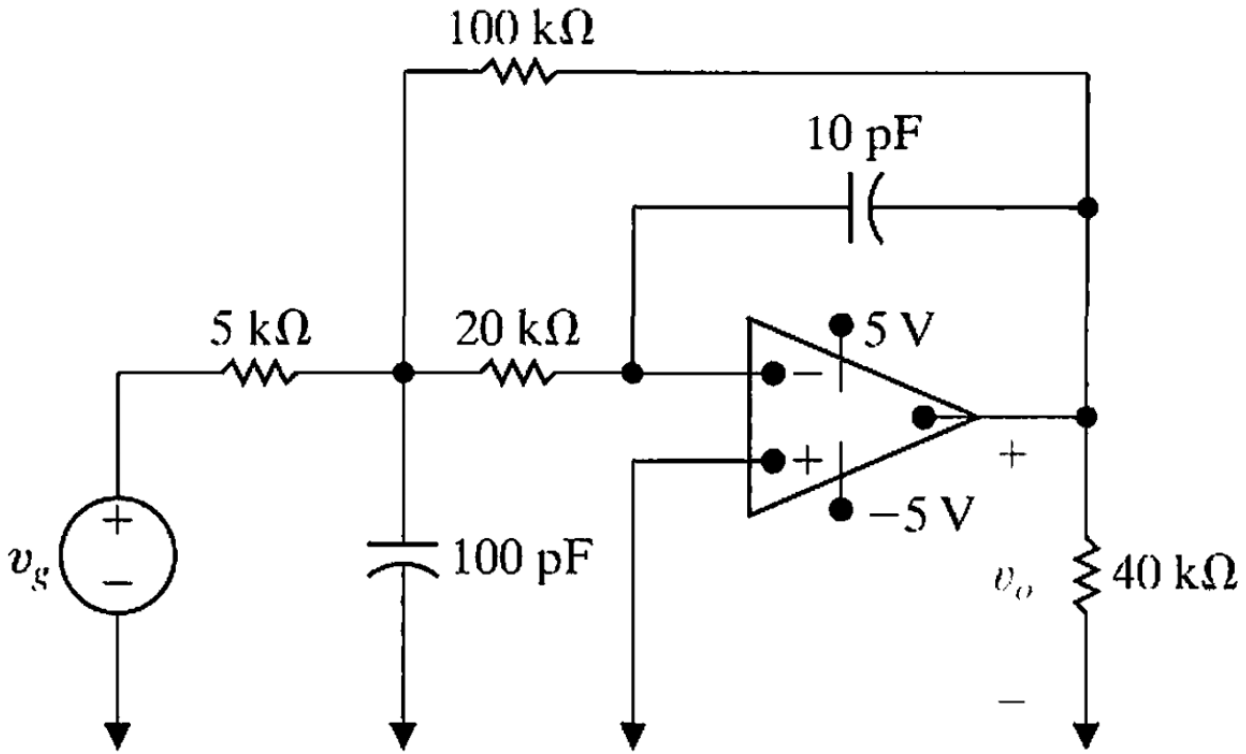
Practice problem: find v_o if $v_i(t) = A\cos\omega t\ \ V$



$$v_o(t) = \frac{A\omega R_f C_i}{\sqrt{1+\omega^2 {R_i}^2 {C_i}^2}\sqrt{1+\omega^2 {R_f}^2 {C_f}^2}}\cos\left(\omega t + 270° - \tan^{-1}(\omega R_i C_i) - \tan^{-1}\left(\omega R_i C_f\right)\right)\ \text{V}$$

Practice problem:

2. Find the steady state output voltage (across the 40 k ohm resistor) if the source $v_g(t) = 2\cos 10^6 t$ volts.



$v_o(t) = 9.26\cos(1{,}000{,}000t + 76.6°)$ V