Name: ______________________________ (please print)

Signature: ___________________________

ECE 3455
Exam 1
March 7, 2009

Exam duration: 90 minutes

- You may have one 8 ½ x 11 in. "crib" sheet, written on both sides, during the quiz. You may have any calculator you choose, but no computers. No other notes or materials will be allowed.
- Show all work necessary to complete the problem on these pages. A solution without the work shown will receive no credit.
- Show units in intermediate and final results, and in figures.
- If your work is sloppy or difficult to follow, points will be subtracted.

This exam has 10 pages, including the cover sheet. Raise your hand if you are missing a page.

1 ________________/25

2 ________________/25

3 ________________/25

4 ________________/25

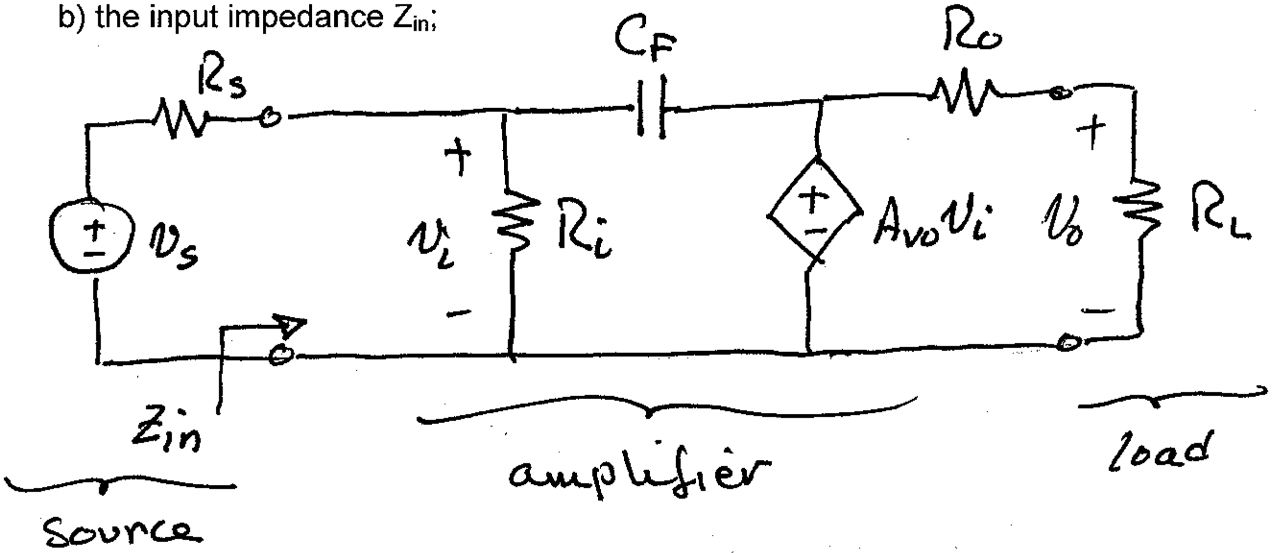
Total ________________/100

Room for Extra Work

1. (**25 points**) For the circuit shown below, find

+15 a) the transfer function $T(\omega) = \mathbf{V_o}/\mathbf{V_s}$;

+10 b) the input impedance Z_{in};



a) $\bar{V}_o = A_{vo}\bar{V}_i \frac{R_L}{R_L+R_o}$ $\quad \frac{\bar{V}_i}{R_i} + \frac{\bar{V}_i - A_{vo}\bar{V}_i}{1/j\omega C_F} + \frac{\bar{V}_i - \bar{V}_s}{R_s} = 0$

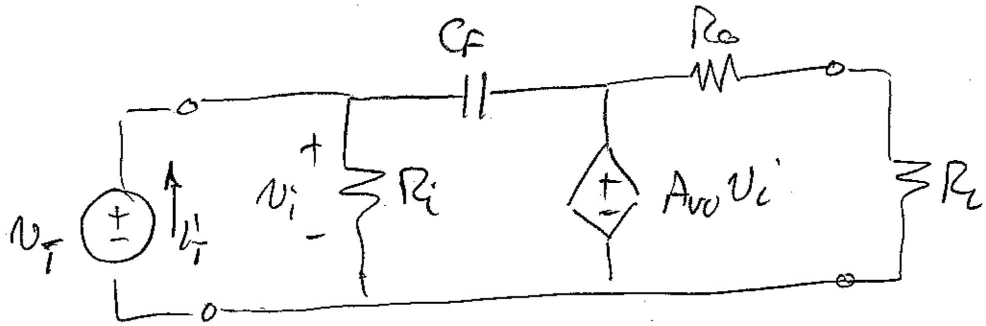
+10

$$\bar{V}_i\left(\frac{1}{R_i} + \frac{1}{R_s} + (1-A_{vo})j\omega C_F\right) = \frac{\bar{V}_s}{R_s}$$

+5 $$\bar{V}_i\left(\frac{R_s}{R_i} + 1 + R_s(1-A_{vo})j\omega C_F\right) = \bar{V}_s$$

$$\boxed{\frac{\bar{V}_o}{\bar{V}_s} = A_{vo}\frac{R_L}{R_L+R_o} \cdot \frac{1}{R_s/R_i + 1 + j\omega C_F R_s (1-A_{vo})}}$$

b)



Room for extra work

+6 $$\bar{I}_T = \frac{\bar{V}_i}{R_i} + \frac{\bar{V}_i(1-A_{vo})}{1/j\omega C_F} = \bar{V}_i\left(\frac{1}{R_i} + j\omega C_F(1-A_{vo})\right)$$

$$\bar{V}_i = \bar{V}_T \Rightarrow \frac{\bar{V}_T}{\bar{I}_T} = \frac{1}{\frac{1}{R_i} + j\omega C_F(1-A_{vo})}$$

+4 $$\boxed{Z_{in} = \frac{R_i}{1 + j\omega C_F R_i(1-A_{vo})}}$$

Any correct algebraic expressions for $\bar{V}_o/\bar{V}_s$ and Z_{in} that are written in terms of R_L, R_o, C_F, R_i, and A_{vo} are acceptable for full credit.

2. (**25 points**) The transfer function T(ω) for a certain amplifier is shown below. It is known that the magnitude of the transfer function at ω = 300 rad/sec is approximately 0 dB.

We are given that $R_1C_1 = 5 \times 10^{-5}$ s; $R_2C_2 = 3.333 \times 10^{-4}$ s; $R_3C_3 = 1.667 \times 10^{-3}$ s; and $R_4C_4 = 10^{-3}$ s. (*Note that the value for R_3C_3 is slightly modified from that on the recent quiz.*)

$$T(\omega) = K\frac{\left(\frac{1}{R_1C_1} + j\omega\right)\left(j\omega R_4C_4\right)^2}{\left(1 + j\omega R_2C_2\right)^2\left(\frac{1}{R_3C_3} + 3j\omega\right)}$$

Using the paper provided on the next page, draw the straight-line approximation to the **phase** Bode plot for this transfer function.

We have zeros at 0 (double) and $1/R_1C_1 = 20\,000$ rad/s

We have poles at $\frac{1}{3R_3C_3} = 200$ rad/s and

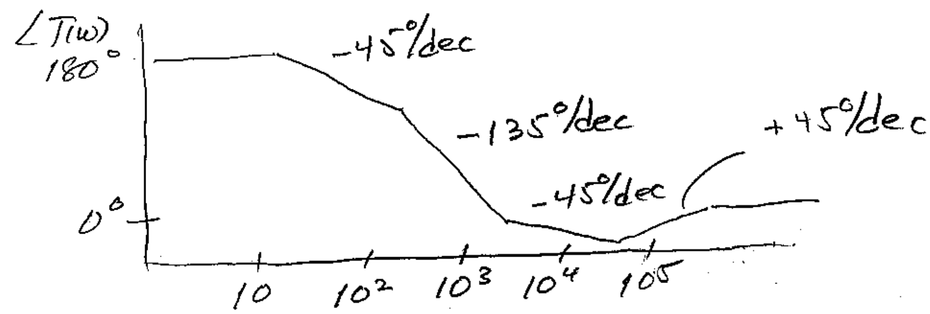
$1/R_2C_2 = 3000$ rad/s (double).

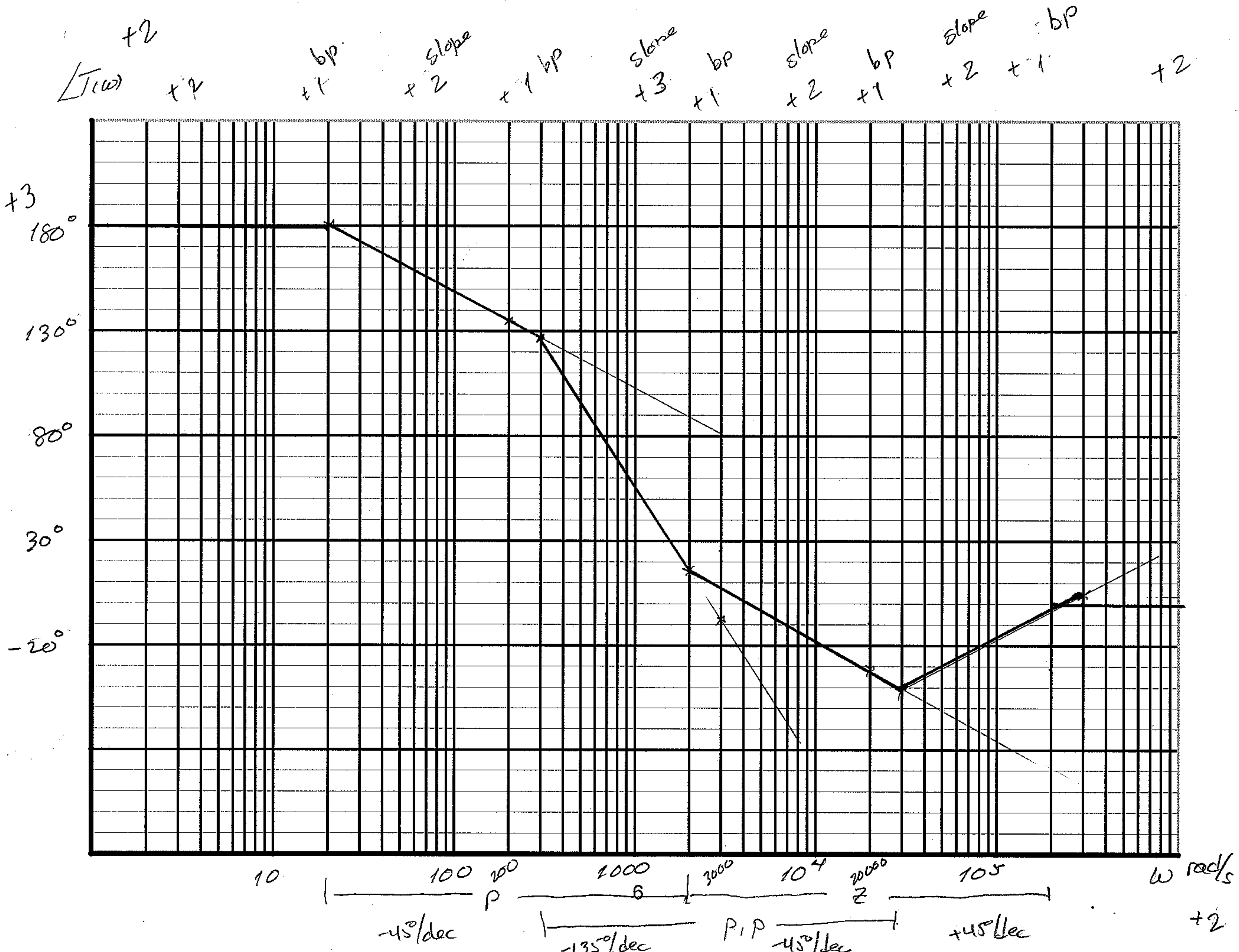
The zeros at 0 have no affect on the slopes of the phase Bode plot.

The phase plot enters at $\angle T(\omega \to 0) \to (j\omega R_4C_4)^2$

$\to 180°$.

Rough sketch:





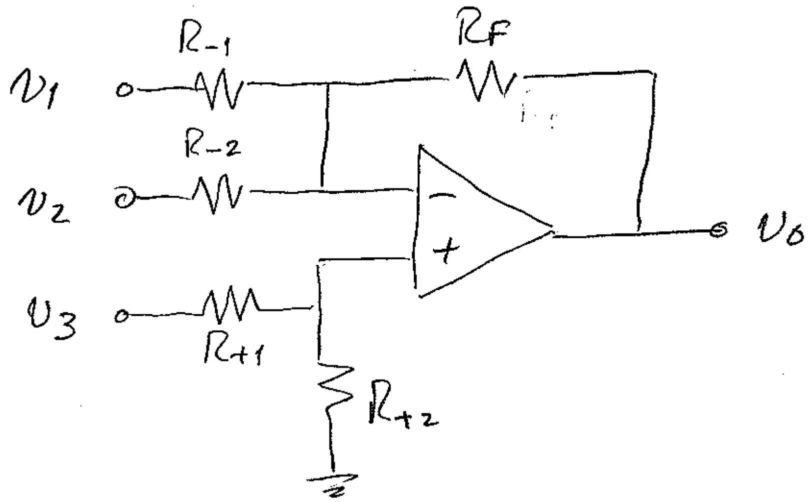
$\angle T(\omega)$
+2
+2
bp
+1
slope
+2
+1 bp
slope
+3
bp
+1
slope
+2
bp
+1
slope
+2
+1
bp
+2
+3
180°
130°
80°
30°
-20°
10
100
200
1000
3000
10^4
20000
10^5
ω rad/s
p
6
z
+2
-45°/dec
-135°/dec
p, p
-45°/dec
+45°/dec

3. **(25 points)** Use "ideal" op amps to generate a voltage output given by

$$v_O = -0.4v_1 - 0.8v_2 + 0.2v_3$$

where v_1, v_2, and v_3 are independent input sources.

<u>For partial credit (10 points)</u>, use any number of op amps to generate the required output.
<u>For full credit (25 points)</u>, use only one op amp to generate the required output.



+12: basic configuration

R_F/R_{-1} +4

R_F/R_{-2} +4

$\left.\begin{matrix} R_{+1} \\ R_{+2} \end{matrix}\right\}$ +5

Using superposition, we set $v_2 = v_3 = 0$, Then we have a simple inverting configuration:

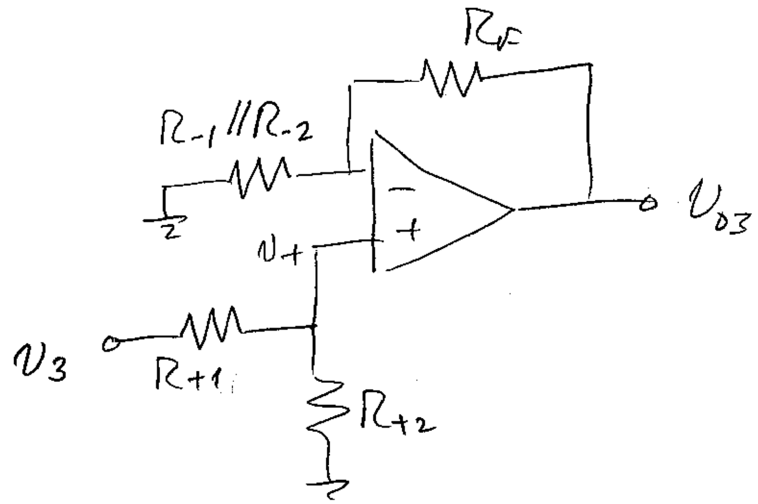
$$v_{O1} = -\frac{R_F}{R_{-1}} v_1$$

Clearly we will have the same thing for $v_1 = v_3 = 0$ and

$$v_{O2} = \frac{-R_F}{R_{-2}} v_2$$

Room for extra work

Set $v_1 = v_2 = 0$ and re-draw:



Summary:

$R_{-1} = 25\ k\Omega$

$R_{-2} = 12.5\ k\Omega$

$R_F = 10\ k\Omega$

$R_{+1} = 10\ k\Omega$

$R_{+2} = 1\ k\Omega$

$$v_{o3} = v_+\left(1 + \frac{R_F}{R_{-1} \| R_{-2}}\right) \qquad v_+ = v_3 \frac{R_{+2}}{R_{+1} + R_{+2}}$$

$$v_{o3} = v_3 \frac{1}{\frac{R_{+1}}{R_{+2}} + 1}\left(1 + \frac{R_F}{R_{-1} \| R_{-2}}\right)$$

Choose $R_F = 10\ k\Omega$ (arbitrary). Then

$$\frac{R_F}{R_{-1}} = 0.4 \Rightarrow R_{-1} = \frac{R_F}{0.4} = 25\ k\Omega$$

$$\frac{R_F}{R_{-2}} = 0.8 \Rightarrow R_{-2} = \frac{R_F}{0.8} = 12.5\ k\Omega$$

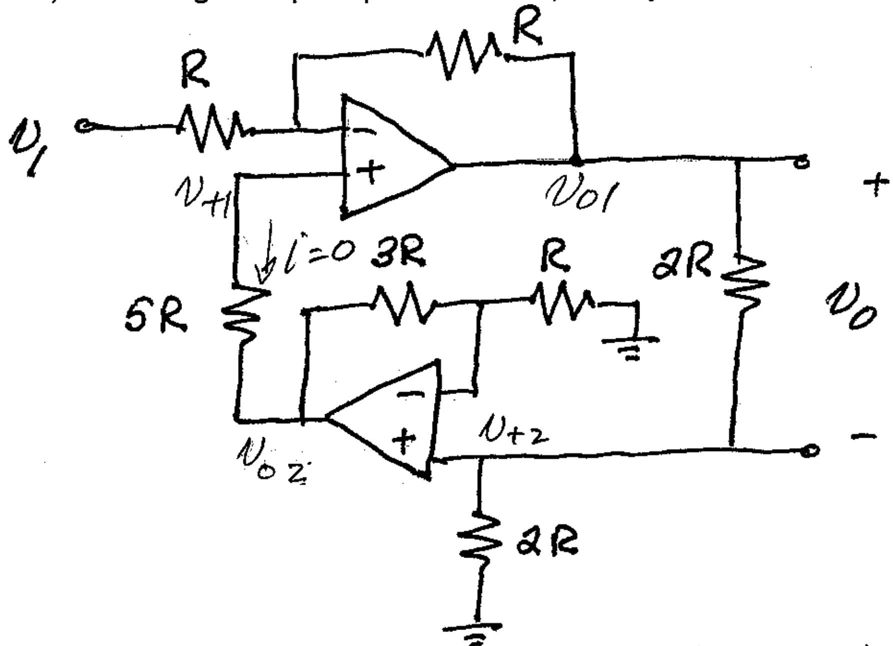
$$\Rightarrow 1 + R_F / R_{-1} \| R_{-2} = 1 + \frac{10}{25 \| 12.5} = 2.2$$

$$\frac{1}{\frac{R_{+1}}{R_{+2}} + 1} \cdot 2.2 = 0.2 \Rightarrow \frac{R_{+1}}{R_{+2}} = 10$$

Choose $R_{+1} = 10\ k\Omega$

$R_{+2} = 1\ k\Omega$

4. (**25 points**) Assuming the op amps are "ideal", find v_o.



non-inv. analysis + 6
inv analysis + 6
coupling + 13

non inv

$$v_{+1} = v_{o2} = v_{+2}\left(1+\frac{3R}{R}\right) = 4v_{+2}$$

inv.

$$v_{o1} - v_{+1} + \frac{v_1 - v_{+1}}{R}\cdot R = 0$$

$$v_{o1} = 2v_{+1} - v_1 = 4v_{+2} - v_1$$

$$v_{+2} = v_{o1}\frac{2R}{2R+2R} = \frac{1}{2}v_{o1}$$

coupling

$$\therefore v_{o1} = 2v_{o1} - v_1 \Rightarrow v_{o1} = \frac{1}{3}v_1$$

$$v_o = \frac{2R}{2R+2R}v_{o1} = \frac{1}{2}v_{o1}$$

$$\boxed{v_o = \frac{1}{6}v_1}$$

Room for extra work