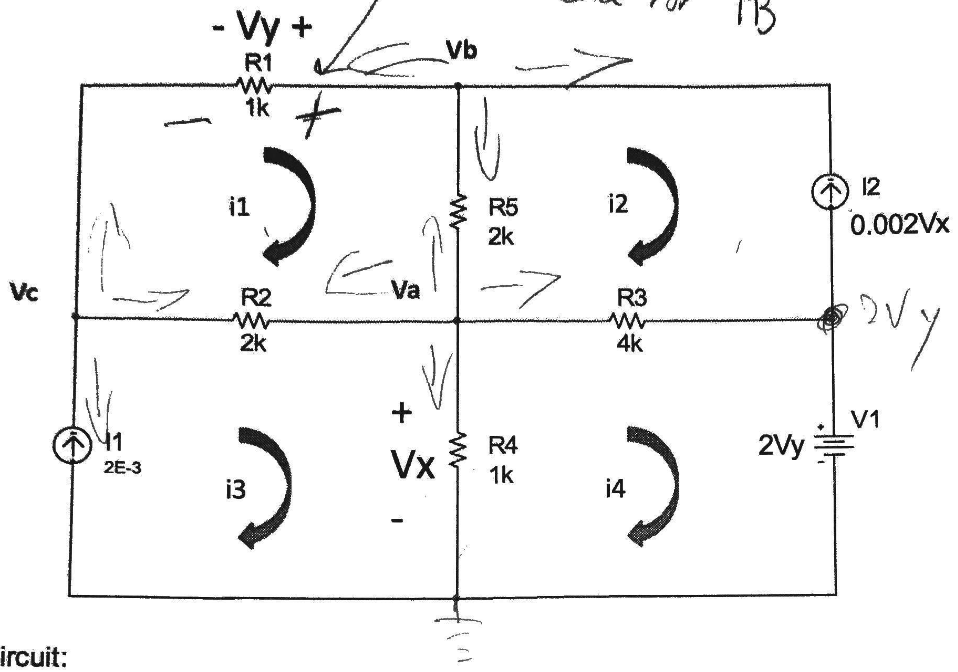
1) Mesh/Nodal Analysis with Dependent Sources

TAs this is my refence for 1B



In the above circuit:

a. Use mesh analysis to determine the voltage across R1 (Vy)

b. Verify your solution using node analysis.

$i_1 R_1 + i_1 R_5 - i_2 R_5 + i_1 R_2 - i_3 R_2 = 0$

$i_2 = -0.002 V_x$

$i_3 = 2\times10^{-3}$

$i_4 R_4 - i_3 R_4 + i_4 R_3 - i_2 R_3 + 2V_y = 0$

$V_x = i_3 R_4 - i_4 R_4$

$V_y = -i_1 R_1$

$i_1(R_1 + R_5 + R_2) - i_2 R_5 - i_3 R_2 = 0$

$i_2 + 0.002 V_x = 0$

$i_3 = 2\times10^{-3}$

$i_4(R_4 + R_3) - i_3 R_4 - i_2 R_3 + 2V_y$

$i_3 R_4 - i_4 R_4 - V_x = 0$

$-i_1 R_1 - V_y = 0$

$$\begin{array}{ccccc} i_1 & i_2 & i_4 & V_x & V_y \end{array}$$
$$\begin{bmatrix} 5000 & -2000 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0.002 & 0 \\ 0 & -4000 & 5000 & 0 & 2 \\ 0 & 0 & -1000 & -1 & 0 \\ -1000 & 0 & 0 & 0 & -1 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_4 \\ V_x \\ V_y \end{bmatrix} = \begin{bmatrix} 4 \\ 0 \\ 2 \\ -2 \\ 0 \end{bmatrix} \begin{bmatrix} 0.0019 \\ 0.0028 \\ 0.0034 \\ -1.39 \\ -1.91 \end{bmatrix}$$

$V_y = -(-i_1 R_1)$

$V_y = -1.913V$

$V_y = -V_{R_1}$

$\boxed{V_{R_1} = 1.913V}$

B: $\dfrac{V_C - V_b}{R_1} + \dfrac{V_C - V_a}{R_2} - 2\times10^{-3} = 0$

$\dfrac{V_b - V_c}{R_1} + \dfrac{V_b - V_a}{R_5} - 0.002V_x = 0$

$\dfrac{V_a - V_b}{R_5} + \dfrac{V_a - V_c}{R_2} + \dfrac{V_a}{R_4} + \dfrac{V_a - 2V_y}{R_3}$

$V_b - V_c = V_y$

$V_x = V_a$

$\dfrac{V_c}{R_1} + \dfrac{V_c}{R_2} - \dfrac{V_a}{R_2} - \dfrac{V_b}{R_1} = 2\times10^{-3}$

$\dfrac{V_b}{R_1} + \dfrac{V_b}{R_5} - \dfrac{V_c}{R_1} - \dfrac{V_a}{R_5} - 0.002V_x = 0$

$\dfrac{V_a}{R_5} + \dfrac{V_a}{R_2} + \dfrac{V_a}{R_4} + \dfrac{V_a}{R_3} - \dfrac{V_b}{R_5} - \dfrac{V_c}{R_2} - \dfrac{2V_y}{R_3}$

$V_b - V_c - V_y = 0$

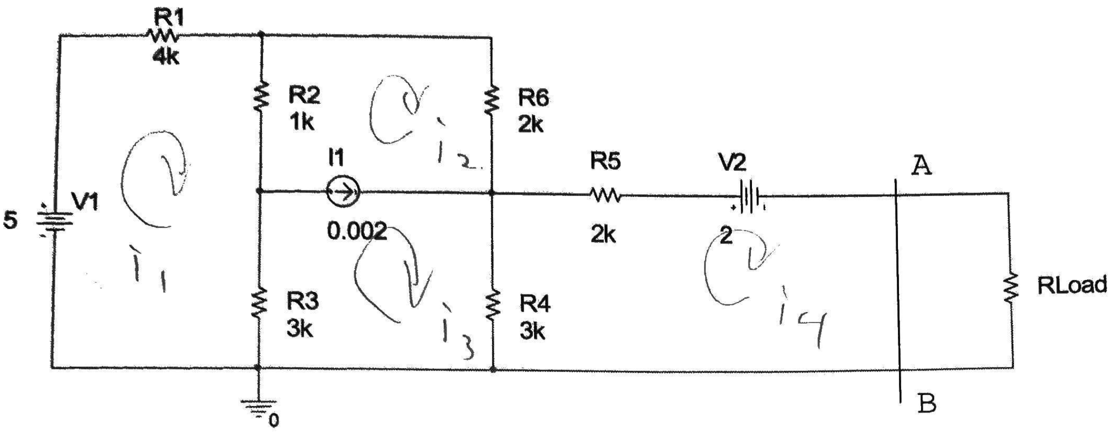
$\cancel{V_x - V_a}$ $V_x - V_a = 0$

$$\begin{array}{ccccc} V_a & V_b & V_c & V_x & V_y \end{array}$$
$$\begin{bmatrix} -\frac{1}{2000} & -\frac{1}{1000} & \frac{3}{2000} & 0 & 0 \\ -\frac{1}{2000} & \frac{3}{2000} & -\frac{1}{1000} & -0.002 & 0 \\ \frac{9}{4000} & -\frac{1}{2000} & -\frac{1}{2000} & 0 & -\frac{2}{4000} \\ 0 & 1 & -1 & 0 & -1 \\ -1 & 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \\ V_x \\ V_y \end{bmatrix} = \begin{bmatrix} 2\times10^{-3} \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} : \begin{bmatrix} -1.39 \\ -3.13 \\ -1.22 \\ -1.39 \\ -1.91 \end{bmatrix}$$

$V_b - V_c = V_{R_1}$

$-3.13 - (-1.22) = \boxed{-1.913\text{ V} = V_{R1}}$

2) Thevenin/Norton Equivalent Circuits



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a. Find the voltage between A and B if Rload has a resistance of 2kΩ.

b. Replace RLoad with an open circuit and find the voltage between A and B ($V_{Thevenin}$).

c. Replace RLoad with a short circuit and find the current from A to B, (INorton).

d. Find $R_{Thevenin}$ the resistance between A and B when looking to the left of th dashed line (RLoad detached)

e. Draw the Thevenin circuit with $V_{Thevenin}$, $R_{Thevenin}$, and R_{Load}.

f. In this two resistor circuit, verify that when RLoad is 2KΩ, the voltage between A and B is the same as your calculation from part a.

g. Draw the Norton circuit, with I_{Norton}, $RT_{hevenin}$ and R_{Load}.

h. In this two resistor circuit, verify that when RLoad is 2kΩ, the current through RLoad is the same as your calculation from part a.

$\Sigma A: -V_1 + i_1R_1 + iR_2 - i_2R_2 + i_1R_3 - i_3R_3 = 0$

$i_3 - i_2 = 0.002$

$i_2R_2 - i_1R_2 + i_2R_6 + i_3R_4 + i_3R_4 - i_4R_4 + i_3R_3 - i_1R_3 = 0$

$i_4R_4 - i_3R_4 + i_4R_5 + 2V + i_4R_{Load} = 0$

$$\begin{bmatrix} 8000 & -1000 & -3000 & 0 \\ 0 & -1 & 1 & 0 \\ -4000 & 3000 & 6000 & -3000 \\ 0 & 0 & -3000 & 7000 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \end{bmatrix} \begin{bmatrix} 5 \\ 0.002 \\ 0 \\ .2 \end{bmatrix} \begin{bmatrix} 9.562\times10^{-4} \\ -8.375\times10^{-4} \\ 0.00116 \\ 2.125\times10^{-4} \end{bmatrix}$$

$V_{AB} = V_{RLoad}$

$= i_4 R_{Load}$

$\boxed{V_{AB} = 0.425V}$

2 B: $-V_1 + i_1 R_1 + i_1 R_2 - i_2 R_2 + i_1 R_3 - i_3 R_3 = 0$

$i_3 - i_2 = 0.002$

$i_2 R_2 - i_1 R_2 + i_2 R_6 + i_3 R_4 + i_3 R_3 - i_1 R_3 = 0$

$$\begin{bmatrix} 8000 & -1000 & -3000 \\ 0 & -1 & 1 \\ -4000 & 3000 & 6000 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} 5 \\ 0.002 \\ 0 \end{bmatrix} : \begin{bmatrix} 9.107 \times 10^{-4} \\ -9.286 \times 10^{-4} \\ 0.00107 \end{bmatrix}$$

$V_{th} = V_{R4} - V_2$

$= 3.214 - 2$

$$\boxed{V_{th} = 1.214 \text{ V}}$$

2C: $-V_1 + i_1 R_1 + i_1 R_2 - i_2 R_2 + i_1 R_3 - i_3 R_3 = 0$

$i_3 - i_2 = 0.002$

$i_2 R_2 - i_1 R_2 + i_2 R_6 + i_3 R_4 - i_4 R_4 + i_3 R_3 - i_1 R_4 = 0$

$i_4 R_4 - i_3 R_4 + i_4 R_5 + 2V = 0$

$$\begin{bmatrix} 8000 & -1000 & 3000 & 0 \\ 0 & -1 & 1 & 0 \\ -4000 & 3000 & 6000 & -3000 \\ 0 & 0 & -3000 & 5000 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \end{bmatrix} = \begin{bmatrix} 5 \\ 0.002 \\ 0 \\ -2 \end{bmatrix} : \begin{bmatrix} 9.807 \times 10^{-4} \\ -7.885 \times 10^{-4} \\ 0.00121 \\ 3.269 \times 10^{-4} \end{bmatrix}$$

$i_4 = I_{AB}$

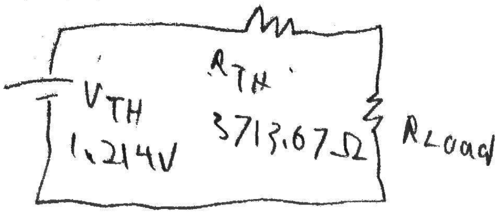
$I_{norton} =$

$$\boxed{3.269 \times 10^{-4} \text{ A}}$$

2D: $V_{th} = I_{norton} R_{th}$

$$\frac{V_{tH}}{I_{norton}} = R_{th} = \boxed{3713.67\ \Omega = R_{th}}$$

2E:

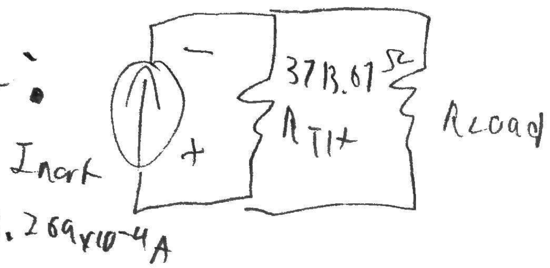


2F: $V_{AB} = V_{RLoad} = \dfrac{V_{TH}(R_{Load})}{R_{TH} + R_{Load}}$

$\boxed{V_{AB} = 0.425\text{ V}}$

Verified

2G:

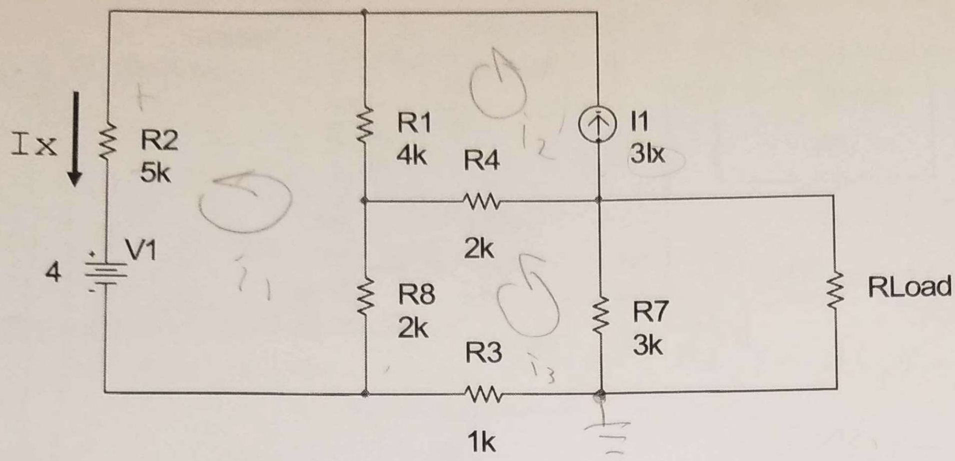


2H: $I_{RLoad} = \dfrac{I_{nort}(R_{TH})}{R_{TH} + R_{Load}}$

$\boxed{I_{RLoad} = 2.125 \times 10^{-4}\text{ A}}$

Verified

3. Thevenin/Norton Equivalent Circuits - Dependent Sources



a. Find VThevenin uisng the Open Circuit method

b. Find INorton using the Short Circuit method

c. Find $R_{Thevenin}$ using the test voltage/current method

3A:

$i_1 = I_x$

$i_2 = 3I_x = 3i_1$

$i_1R_2 + 4V + i_1R_8 - i_3R_8 + i_1R_1 - i_2R_1 = 0$

$i_3R_4 - i_2R_4 + i_3R_8 - i_1R_8 + i_3R_3 + i_3R_7 = 0$

$$\begin{array}{c} \begin{array}{cccc} i_1 & i_2 & i_3 & I_x \end{array} \\ \begin{bmatrix} 1 & 0 & 0 & -1 \\ -3 & 1 & 0 & 0 \\ 11000 & -4000 & -2000 & 0 \\ -2000 & -2000 & 8000 & 0 \end{bmatrix} \end{array} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \\ I_x \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ -4 \\ 0 \end{bmatrix} \quad \begin{bmatrix} 0.00133 \\ 0.004 \\ 0.00133 \\ 0.00133 \end{bmatrix}$$

$V_{TH} = V_{R7}$

$= i_3 R_7$

$\boxed{V_{TH} = 4V}$

3B: $i_1 = I_x$

$i_2 = 3I_x = 3i$

$i_1R_2 + 4V + i_1R_8 - i_3R_8 + i_1R_1 - i_2R_1 = 0$

$i_3R_4 - i_2R_4 + i_3R_8 + i_3R_3 + i_3R_7 - i_4R_7 = 0$

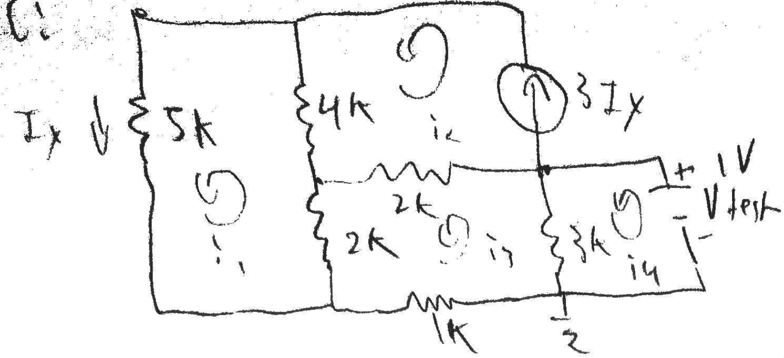
$i_4R_7 - i_3R_7 = 0$

$$\begin{bmatrix} 1 & 0 & 0 & -1 & 0 \\ -3 & 1 & 0 & 0 & 0 \\ 11000 & -4000 & -2000 & 0 & 0 \\ -2000 & -2000 & 8000 & 0 & -3000 \\ 0 & 0 & -3000 & 0 & 3000 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \\ I_x \\ i_4 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ -4 \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} 9.52\times10^{-4} \\ 0.0028 \\ 0.0015 \\ 9.52\times10^{-4} \\ 0.0015 \end{bmatrix}$$

i_4: $\boxed{I_{Norton} = 0.001524 A}$

3c:



$i_1 = I_x$

$i_2 = 3I_x = 3i_1$

$i_1 11k - i_3 2k - i_2 4k = 0$

$i_3 8k - i_1 2k - i_2 2k - i_4 3k$

$i_4 3k - i_3 3k = 1$

$$\begin{array}{ccccc} i_1 & i_2 & i_3 & i_4 & I_x \end{array}$$
$$\begin{bmatrix} 1 & 0 & 0 & 0 & -1 \\ -3 & 1 & 0 & 0 & 0 \\ 11000 & -4000 & -2000 & 0 & 0 \\ -2000 & -2000 & 8000 & -3000 & 0 \\ 0 & 0 & -3000 & 3000 & 0 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \\ I_x \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} -9.52\times10^{-5} \\ -2.85\times10^{-4} \\ 4.76\times10^{-5} \\ 3.8\times10^{-4} \\ -9.52\times10^{-5} \end{bmatrix}$$

$i_4 = I_{test}$

$= 3.8095\times10^{-4}$ A

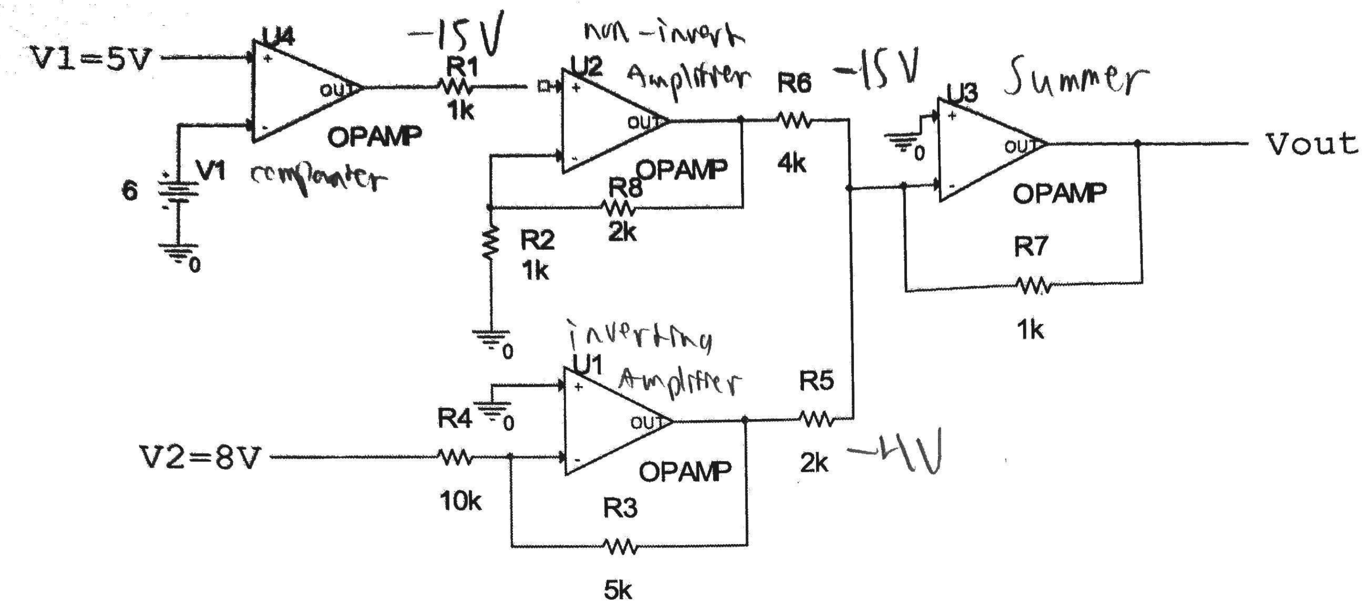
$\frac{V_{Test}}{I_{Test}} = \boxed{R_{TH} = \frac{1}{3.8095\times10^{-4}} = 2625.003\ \Omega}$

$\boxed{\text{Verify: } \frac{V_{TH}}{I_{norton}} = R_{TH} \qquad \frac{4}{0.001524} = 2625\ \Omega}$

$\boxed{R_{TH} \text{ is verified}}$

4. Amplifier Circuits

R1 should be attached to U2....



a. For the above circuit, determine the output voltage, Vout. The voltages supplied to the op-amps are 15V and -15V, as appropriate.

$V \text{ at } R_6 = \left(\frac{R_8}{R_2} + 1\right) - 15\,V$

$\left(\left(\frac{2}{1}\right) + 1\right) - 15\,V$

$-15 \cdot 3 = V \text{ at } R_6$

$-45 =$

$\downarrow$

limit

$-15\,V = V \text{ at } R_6$

$V \text{ at } R_5 = \frac{-R_3}{R_4}\, 8\,V$

$= \frac{-5}{10}\, 8\,V$

$= -\frac{1}{2}\, 8\,V$

$V \text{ at } R_5 = -4\,V$

$V_{out} = -\frac{1K}{2K}(-4V) - \frac{1K}{4K}(-15V)$

$2V + \frac{15}{4}V$

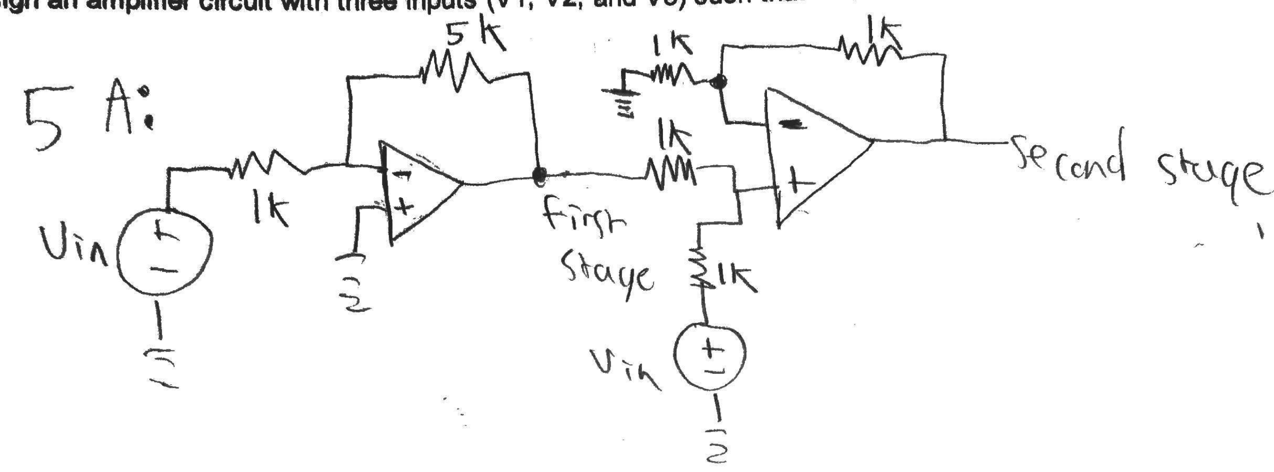
$2V + 3.75V = \boxed{5.75V = V_{out}}$

5. Amplifier Circuits: Design

a. Design a two stage amplifier such that the output of the first stage is V1 = -5Vin and the output of the second stage is Vout = -4V1

b. Design an amplifier circuit with three inputs (V1, V2, and V3) such that Vout = V1 - 2V2 - 4V3

5 A:



5B: