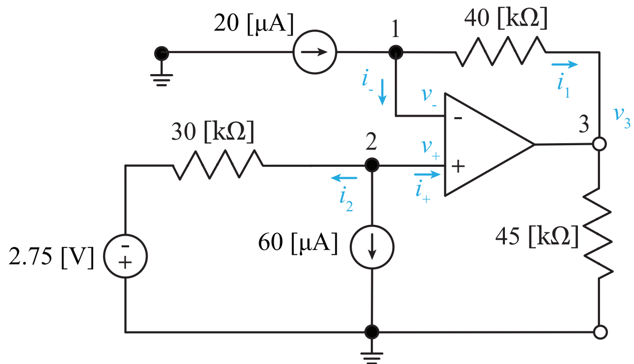
Op-amp Worksheet

MEMS 0031 - Electrical Circuits

June 17th, 2020

Problem #1

Determine the reading of the voltmeter in the circuit shown below.
To find the reading of the voltmeter, NVA will need to be used to determine the nodal voltage at the output of the op-amp. Node voltages are defined as 1, 2, and 3 in the circuit shown.



The op-amp is assumed to be ideal. Therefore, it can be said that:

$$(\mathrm{v}_+) = (\mathrm{v}_-); \quad \mathrm{i}_+ = 0; \quad \mathrm{i}_- = 0$$

Nodes 1 and 2 have nodal voltage values of v_- and v_+ respectively. Applying KCL to node 1:

$$20\,[\mu\mathrm{A}] = i_1 + i_- \implies 20\,[\mu\mathrm{A}] = \frac{V_1 - V_3}{40\,[\mathrm{k}\Omega]} + \cancelto{0}{i_-}$$

Applying KCL to node 2:

$$i_+ + i_2 + 60\,[\mu\mathrm{A}] = 0 \implies \cancelto{0}{i_+} + \frac{V_2 - (-2.75\,[\mathrm{V}])}{30\,[\mathrm{k}\Omega]} + 60[\mu\mathrm{A}] = 0$$

We see the V_2 is found directly from our second KCL equation to be:

$$V_2 = -4.55\,[\mathrm{V}]$$

And we know $V_1 = V_2 = -4.55\,[\mathrm{V}]$.

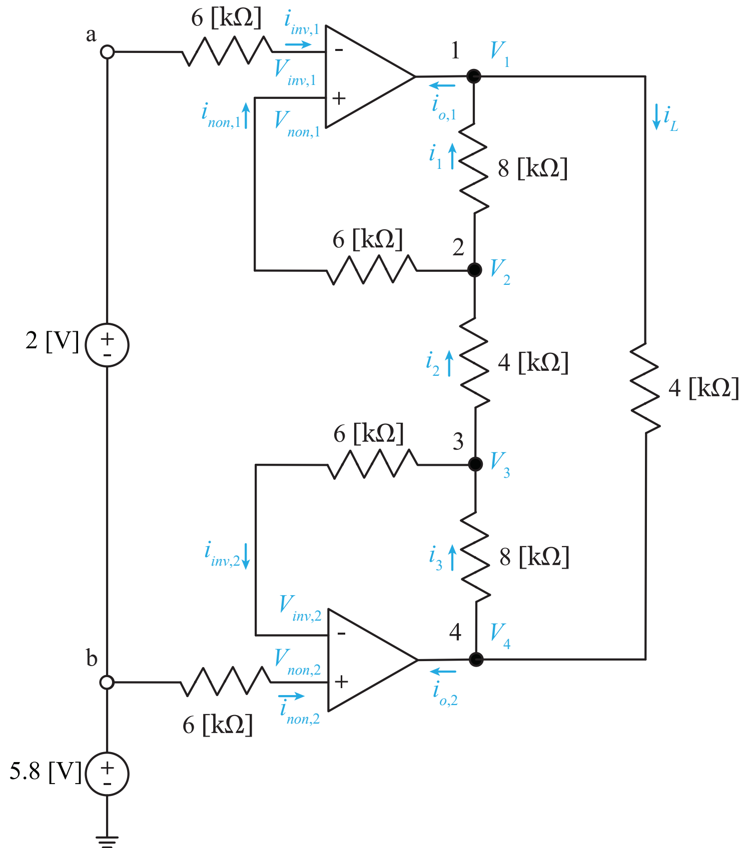
$$(\mathrm{v}_+) - (\mathrm{v}_-) = 0$$

With V_1 known, we can solve V_3 from our first KCL equation: $V_3 = -5.35\,[\mathrm{V}]$

Problem #2

In the circuit shown below, determine the current i_o. Assume that the operational amplifiers are ideal. To do such, we need to determine the node voltages V_1 and V_4.

The current i_L can be determine by finding the voltage drop across the 4 [kΩ] resistor.



The op-amps used are assumed to be ideal. Therefore:

$$\mathrm{V}_{non,1} = \mathrm{V}_{inv,1}; \quad \mathrm{V}_{non,2} = \mathrm{V}_{inv,2}; \quad \mathrm{i}_{non,1} = \mathrm{i}_{inv,1} = 0; \quad \mathrm{i}_{non,2} = \mathrm{i}_{inv,2} = 0$$

We note the node voltage V_b=5.8 [V], and that:

$$V_a - V_b = 2\,[\mathrm{V}] \implies V_a = 7.8\,[\mathrm{V}]$$

Top op-amp:

Since $i_{inv,1}$ is equal to zero, $V_{inv,1} = V_a$. This also means $V_{non,1} = V_{inv,1} = V_a$. Since $i_{non,1}$ is equal to zero, $V_2 = V_{non,1} = V_a$. Therefore, the voltage at node 2 is 7.8 [V].

Bottom op-amp:

Since $i_{non,2}$ is equal to zero, $V_{non,2} = V_b$. This also means $V_{inv,2} = V_{non,2} = V_b$. Since $i_{inv,2}$ is equal to zero, $V_3 = V_{inv,2} = V_b$. Therefore, the voltage at node 3 is 5.8 [V].

With the V_2 and V_3 known, we can work toward solving V_1 and V_4. First, we will find i_2:

$$i_2 = \frac{V_3 - V_2}{4\,[\mathrm{k}\Omega]} = \frac{(5.8 - 7.8)\,[\mathrm{V}]}{4\,[\mathrm{k}\Omega]} = -0.5\,[\mathrm{mA}]$$

Applying KCL at node 2:

$$i_2 = \cancelto{0}{i_{non,1}} + i_1 \implies i_1 = -0.5\,[\mathrm{mA}]$$

Solving for V_1:

$$i_1 = \frac{V_2 - V_1}{8\,[\mathrm{k\Omega}]} \implies V_1 = V_2 - i_1(8\,[\mathrm{k\Omega}]) = 7.8\,[\mathrm{V}] - (-0.5\,[\mathrm{mA}])(8\,[\mathrm{k\Omega}]) = 11.8\,[\mathrm{V}]$$

Applying KCL at node 3:

$$i_3 = \cancelto{0}{i_{inv,2}} + i_2 \implies i_3 = -0.5\,[\mathrm{mA}]$$

Solving for V_4:

$$i_3 = \frac{V_4 - V_3}{8\,[\mathrm{k\Omega}]} \implies V_4 = V_3 + i_3(8\,[\mathrm{k\Omega}]) = 5.8\,[\mathrm{V}] + (-0.5\,[\mathrm{mA}])(8\,[\mathrm{k\Omega}]) = 1.8\,[\mathrm{V}]$$

Therefore, the current i_L can be found via Ohm's law:

$$i_L = \frac{V_1 - V_4}{4\,[\mathrm{k\Omega}]} = \frac{(11.8 - 1.8)\,[\mathrm{V}]}{4\,[\mathrm{k\Omega}]} = 2.5\,[\mathrm{mA}]$$