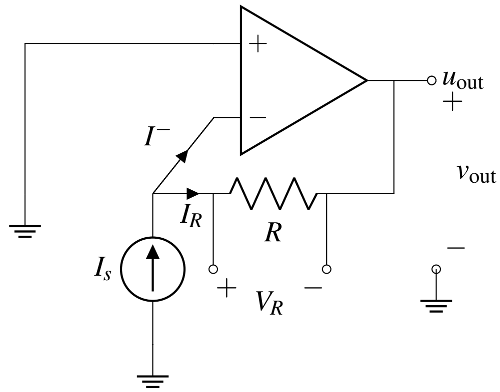
# EECS 16A Designing Information Devices and Systems I
# Fall 2019 Discussion 11B

**1. A Trans-Resistance Amplifier**




(a) Calculate $v_{\text{out}}$ as a function of $I_s$ and $R$.

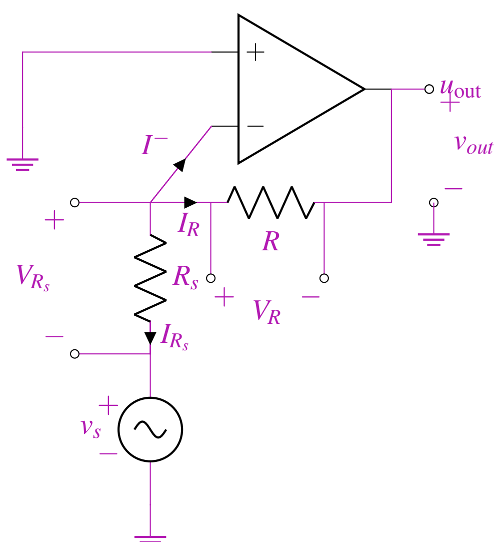
**Answer:**

$I^- = 0$, so $I_s = I_R$. Thus, $V_R = I_s R$.

Because the op-amp is in negative feedback, we also know that $u^+ = u^- = 0\,\text{V}$. Therefore, $v_{\text{out}} = u^- - V_R = -I_s R$.

(b) Implement the same behavior as the above circuit, but replace the current source with a voltage source and a resistor.

**Answer:**



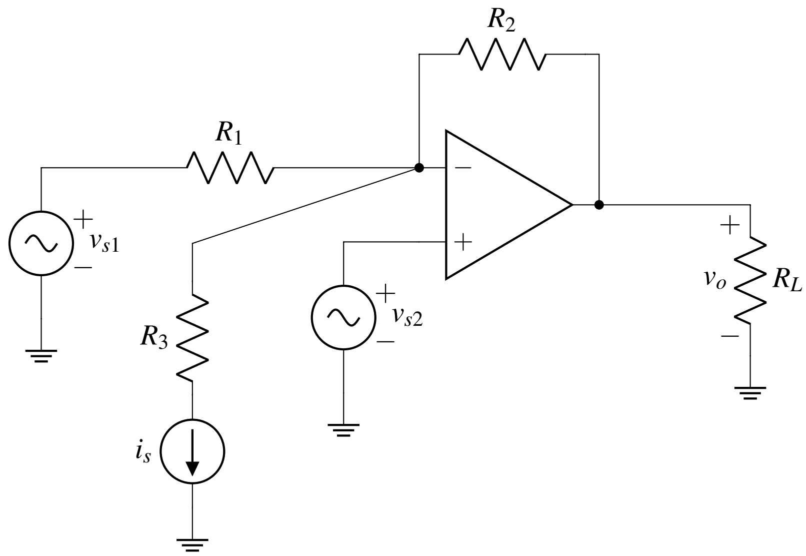

We know that $u^- = 0\,\text{V}$ because of the rules of op-amps in negative feedback. Applying KCL, we see that $I_{R_s} + I_R = 0 \Rightarrow I_{R_s} = -I_R$. In addition, applying Ohm's Law, $I_{R_s} = -\frac{v_s}{R_s}$, so $I_R = \frac{v_s}{R_s}$.

Hence, $v_{\text{out}} = -V_R = -\frac{v_s}{R_s} R = -\frac{R}{R_s} v_s$. This is the **inverting amplifier**.

**2. Node Voltage Analysis with Op-Amps**

Use node voltage analysis to find the output voltage $v_o$ for the circuit shown below.




**Answer:**

We check if the op-amp is in negative feedback, and if it is ideal. We can see that the op-amp is in negative feedback because there is a path from the output back to the minus terminal, and we assume that the op-amp is ideal. Because both of these conditions are met, we can use the node voltage analysis for op-amp rules.

We write three equations for the op-amp: two KCL equations (one at the plus terminal, and one at minus terminal), and one equation setting $v^+ = v^-$. (Note that no current flows into or out of the op-amp's plus or minus terminals). First, we write the KCL equation for the minus terminal of the op-amp. All currents are defined as flowing out of the minus terminal:

$$i_{R_1} + i_{R_2} + i_{R_3} = 0.$$

Second, we note that $I_{v_{s2}} = 0$ because no current can enter the plus terminal. We do not need this equation because $v^+$ is set by the independent source $v_{s2}$.

Third, we set $v^+ = v^-$ which means that $v^- = v_{s2}$.

Because of the independent current source, we know:

$$i_{R_3} = i_s$$

By Ohm's law, we know:

$$i_{R_1} = \frac{v^- - v_{s1}}{R_1}$$

and

$$i_{R_2} = \frac{v^- - v_o}{R_2}$$

Then, substituting back into the original KCL equation, we have:

$$\frac{v^- - v_{s1}}{R_1} + \frac{v^- - v_o}{R_2} + i_s = 0$$

and substituting $v^- = v_{s2}$, we have:

$$\frac{v_{s2}-v_{s1}}{R_1}+\frac{v_{s2}-v_o}{R_2}+i_s=0$$

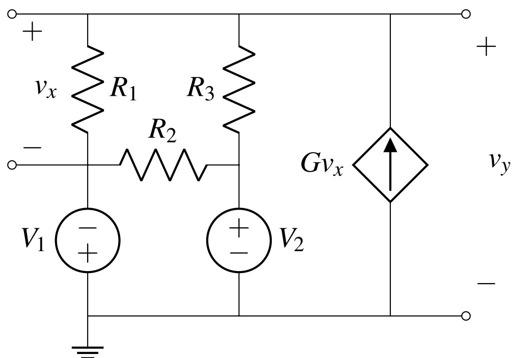
which we rearrange to find $v_o$, giving:

$$v_o = v_{s2}\left(1+\frac{R_2}{R_1}\right)+i_s\cdot R_2-\left(\frac{R_2}{R_1}\right)v_{s1}$$

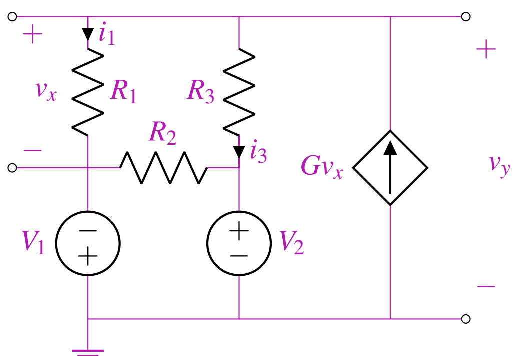
**3. Take Node of the Voltage Sources**

Use nodal analysis to solve for the voltages $v_x$ and $v_y$. Use the following values for numerical calculations. **Note the polarity on the voltage sources.**

$$V_1 = 5\,\text{V} \quad R_1 = 10\,\Omega$$
$$V_2 = 5\,\text{V} \quad R_2 = 50\,\Omega$$
$$G = \tfrac{1}{4}\,\text{S} \quad R_3 = 40\,\Omega$$




**Answer:**




Applying KCL at the node $v_y$:

$$i_1+i_3-Gv_x = 0\,\text{A}$$

$$\frac{v_y+5\,\text{V}}{10\,\Omega}+\frac{v_y-5\,\text{V}}{40\,\Omega}-(\frac{1}{4}\text{S})(v_y+5\,\text{V}) = 0\,\text{A}$$

$$4(v_y+5\,\text{V})+(v_y-5\,\text{V})-10(v_y+5\,\text{V}) = 0\,\text{V}$$

$$4v_y + 20\,\text{V} + v_y - 5\,\text{V} - 10v_y - 50\,\text{V} = 0\,\text{V}$$
$$-5v_y - 35\,\text{V} = 0\,\text{V}$$
$$v_y = -7\,\text{V}$$
$$v_x = v_y + 5\,\text{V} = -7\,\text{V} + 5\,\text{V} = -2\,\text{V}$$

Finally, we arrive at:

$$v_x = -2\,\text{V}$$
$$v_y = -7\,\text{V}$$