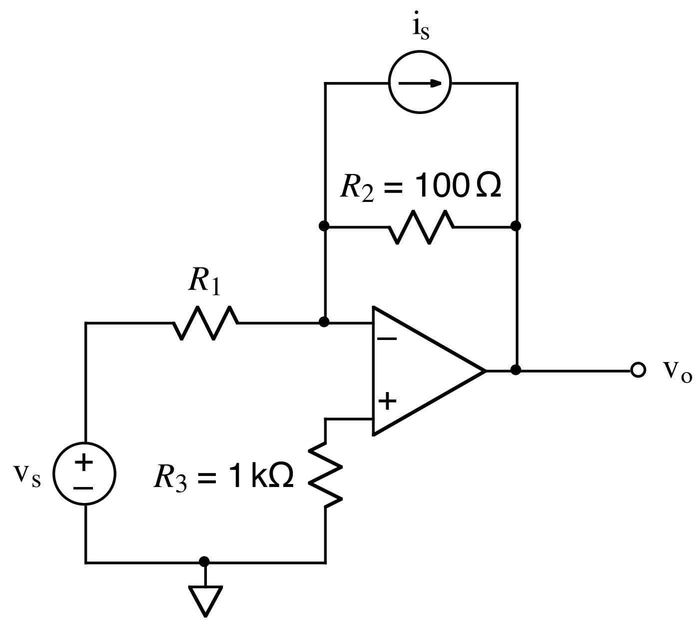
Ex:



Rail voltage = ±10 V

a) The above circuit operates in linear mode. Derive a symbolic expression for v_o. The expression must contain not more than the parameters i_S, v_S, R_1, R_2, and R_3.

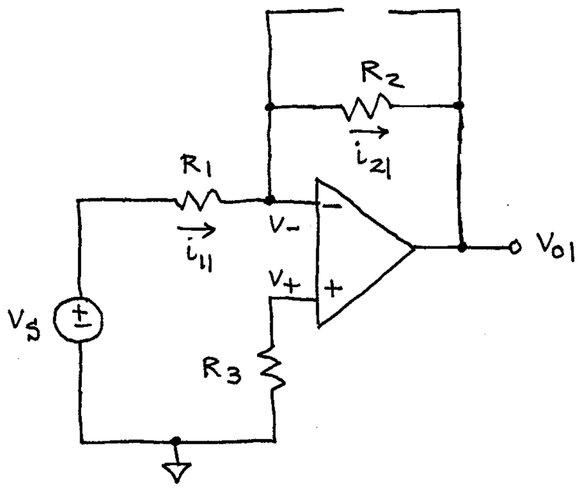
b) If $i_S = 0$ A, find the value of R_1 that will yield an output voltage of $v_o = -2$ V when $v_S = 1$ V.

c) Using the value of R_1 from part (a), find the value of i_S that will yield $v_o = 0$ V when $v_S = 1$ V.

d) Using the value of R_1 from part (a), calculate the input resistance, $R_{in} = v_S/i_1$.

Sol'n: We use superposition to find v_o.
We turn on one independent source at a time

Case I: v_S on, i_S off



First, we find v_+: $v_+ = 0\text{V}$ since no current flows into op-amp (or, therefore, thru R_3)

Second, we set $v_- = v_+$: $v_- = 0\text{V}$

Third, we find an expression for i_{11} flowing toward − input from the left. We use v_- in this expression:

$$i_{11} = \frac{v_S - v_-}{R_1} = \frac{v_S}{R_1}$$

Fourth, we find an expression for i_{21}, the total feedback current, flowing thru R_2. We use v_- in this expression:

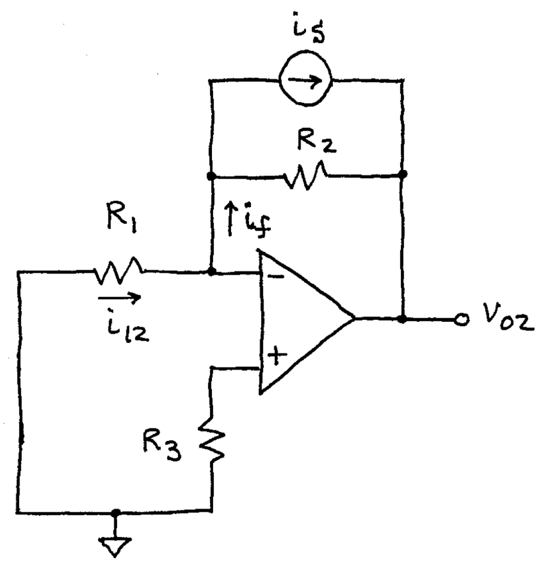
$$i_{21} = \frac{v_- - v_{o1}}{R_2} = \frac{-v_{o1}}{R_2}$$

Fifth, we set $i_{11} = i_{21}$ (since no current flows into op-amp) and solve for v_{O1}:

$$\frac{v_S}{R_1} = -\frac{v_{O1}}{R_2}$$

$$\therefore \quad v_{O1} = -v_S \frac{R_2}{R_1}$$

Case II: v_S off, i_S on



First, we find v_+: $v_+ = 0V$ since no current flows in R_3

Second, we set $v_- = v_+$: $v_- = 0V$

Third, we find an expression for i_{12} flowing toward − input from left:

$$i_{12} = \frac{0V - 0V}{R_1} = 0A$$

Fourth, we find an expression for i_f, the total current flowing in the feedback:

$$i_f = \frac{\overset{0V}{\overset{\shortparallel}{v_-}} - v_{o2}}{R_2} + i_s$$

Fifth, we set $i_{12} = i_f$ (since no current flows into op-amp) and solve for v_o:

$$0A = -\frac{v_{o2}}{R_2} + i_s$$

$$\therefore \; v_{o2} = i_s R_2$$

Now sum the results: $v_o = v_{o1} + v_{o2}$

$$v_o = -v_s \frac{R_2}{R_1} + i_s R_2$$

b) If $i_s = 0A$, we have the first case analyzed in part (a): $v_o = -v_s \dfrac{R_2}{R_1} = -2V$ (desired v)

For $v_s = 1V$ and $R_2 = 100\Omega$, we have

$$R_1 = \frac{-1V}{-2V} 100\Omega = 50\Omega$$

c) Now we turn on i_s and keep $v_s = 1V$:

$$0V = v_o = -v_s \frac{R_2}{R_1} + i_s R_2 = -1V \frac{100\Omega}{50\Omega} + i_s 100\Omega$$

or $\quad i_s = -2V/100\Omega = -20 \text{ mA}$

d) $i_1 = \dfrac{v_s - v_-}{R_1} = \dfrac{v_s}{R_1}$

Thus $R_{in} \equiv \dfrac{v_s}{i_1} = R_1$.