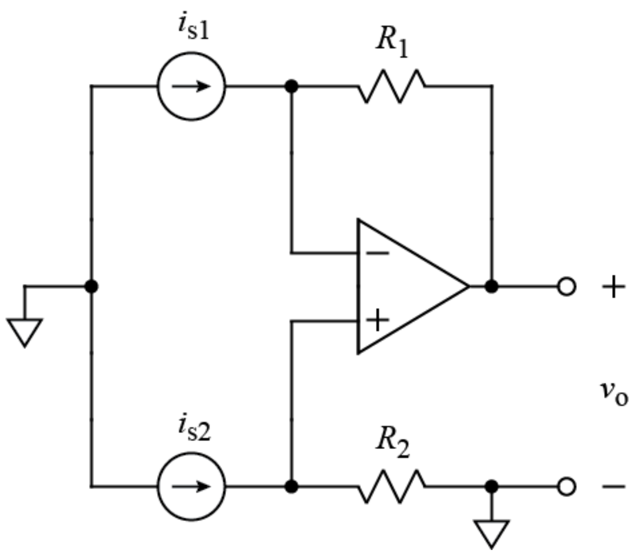
Ex:



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_{s1}, i_{s2}, R_1, and R_2.

b) Derive a symbolic expression for v_o in terms of common mode and differential input currents:

$$i_{cm} \equiv \frac{(i_{s2} + i_{s1})}{2} \quad \text{and} \quad i_{dm} \equiv i_{s2} - i_{s1}$$

The expression must contain not more than the parameters i_{cm}, i_{dm}, R_1, and R_2. Write the expression as i_{cm} times a term plus i_{dm} times a term.

c) What condition must be satisfied in order for the above circuit to amplify only i_{dm}?

SOL'N: a) We first determine the voltage at the + input of the op-amp. No current flows into the op-amp, so i_{s2} flows through R_2 to produce v_+.

$$v_+ = i_{s2} R_2$$

The negative feedback causes the voltage at the – input to be the same as the voltage at the + input.

$$v_- = v_+ = i_{s2} R_2$$

We equate the current flowing toward the – input from the left and right sides. (No current flows into the – input.)

$$i_{s1} = \frac{v_- - v_o}{R_1}$$

We solve the above equation for v_o.

$$v_o = v_- - i_{s1}R_1 = i_{s2}R_2 - i_{s1}R_1$$

b) We write the current sources in terms of the common mode and differential mode currents.

$$i_{s1} = i_{cm} - \frac{i_{dm}}{2} \quad \text{and} \quad i_{s2} = i_{cm} + \frac{i_{dm}}{2}$$

We substitute these expressions into the expression for v_o.

$$v_o = \left(i_{cm} + \frac{i_{dm}}{2}\right)R_2 - \left(i_{cm} - \frac{i_{dm}}{2}\right)R_1$$

Rearranging terms yields the desired answer.

$$v_o = i_{cm}(R_2 - R_1) + \frac{i_{dm}}{2}(R_2 + R_1)$$

c) The common-mode term is eliminated by setting R_1 equal to R_2.

$$R_1 = R_2$$