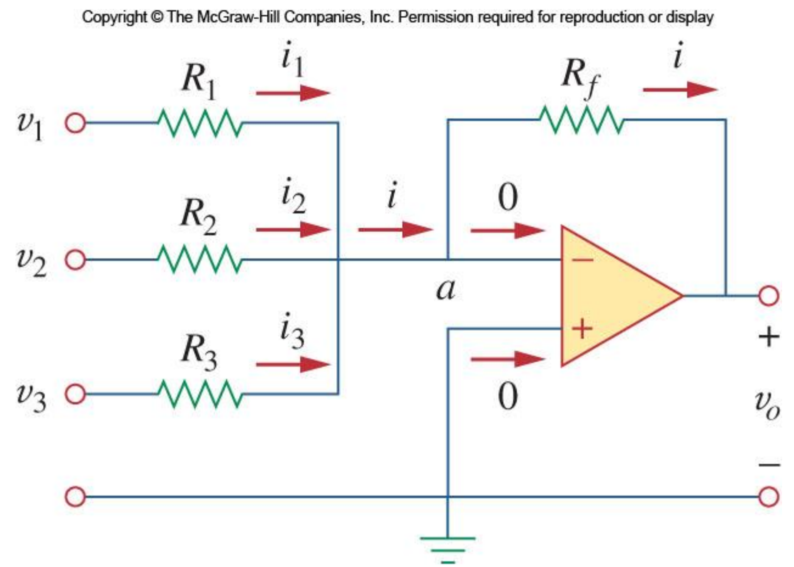
Summing amplifier

- **Aside from amplification, the op-amp can be made to do addition very easily.**
- **If one takes the inverting amplifier and combines several inputs each via its own resistor:**
  - **The current from each input will be proportional to the applied voltage and the input resistance**



$$i_1 = \frac{(v_1 - v_a)}{R_1} \quad i_2 = \frac{(v_2 - v_a)}{R_2} \quad i_3 = \frac{(v_3 - v_a)}{R_3}$$

Summing amplifier II

- **At the inverting terminal, these currents will combine to equal the current through the feedback resistor**

$$i_a = \frac{(v_a - v_o)}{R_f}$$

- **This results in the following relationship:**

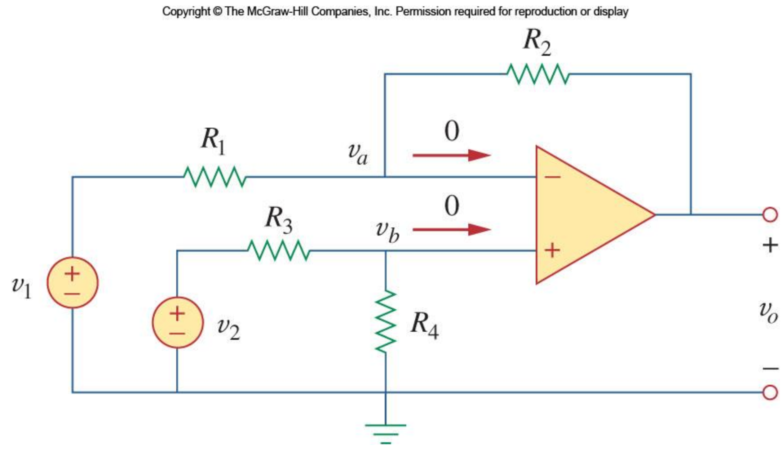
$$v_o = -\left(\frac{R_f}{R_1} v_1 + \frac{R_f}{R_2} v_2 + \frac{R_f}{R_3} v_3 \right)$$

- **Note that the output is a weighted sum of the inputs.**
- **The number of inputs is not limited to three.**

Difference amplifier

- **Subtraction should come naturally to the op-amp since its output is proportional to the difference between the two inputs.**
- **Applying KCL to node a in the circuit shown gives:**

$$v_o = \left(\frac{R_2}{R_1} + 1 \right) v_a - \frac{R_2}{R_1} v_1$$



Difference amplifier II

- **Applying KCL to node b gives:**

$$v_b = \frac{R_4}{R_3 + R_4} v_2$$

- **With the negative feedback present, we know that $v_a = v_b$ resulting in the following relationship:**

$$v_o = \frac{R_2\left(1 + R_1/R_2\right)}{R_1\left(1 + R_3/R_4\right)} v_2 - \frac{R_2}{R_1} v_1$$

Common mode rejection

- **It is important that a difference amplifier reject any signal that is common to the two inputs.**
- **For the given circuit, this is true if:**

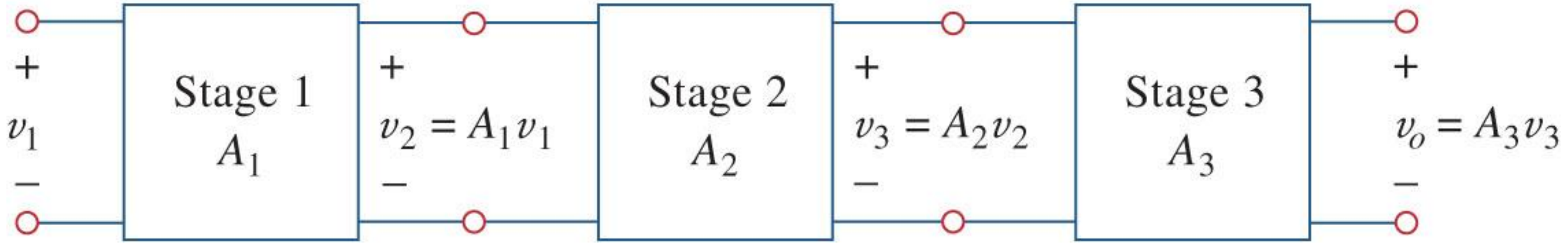
$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

- **At which point, the output is:**

$$v_o = \frac{R_2}{R_1}\left(v_2 - v_1\right)$$

Cascaded op amps

- It is common to use multiple op-amp stages chained together.
- This head to tail configuration is called "cascading"
- Each amplifier is then called a "stage"

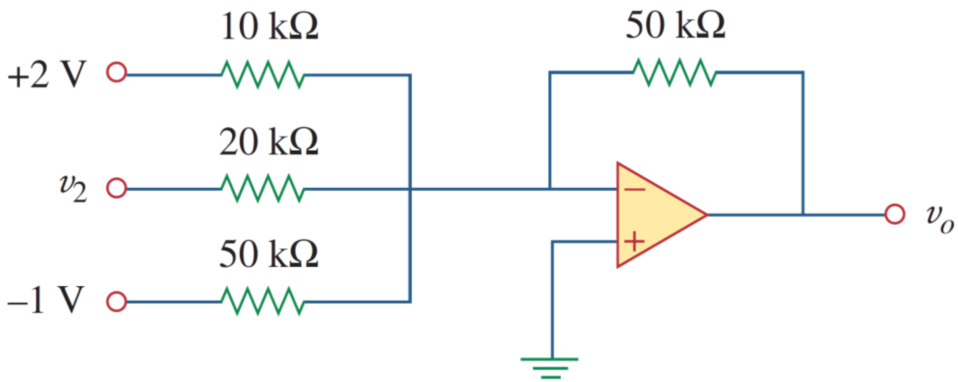


Cascaded op amps II

- **Due to the ideal op-amps' input and output impedance, stages can be chained together without impacting the performance of any one stage.**
- **One reason for cascading amplifier stages is to increase the overall gain.**
- **The gain of a series of amplifiers is the product of the individual gains:**

$$A = A_1 A_2 A_3$$

5.39 For the op amp circuit in Fig. 5.76, determine the value of v_2 in order to make $v_o = -16.5$ V.

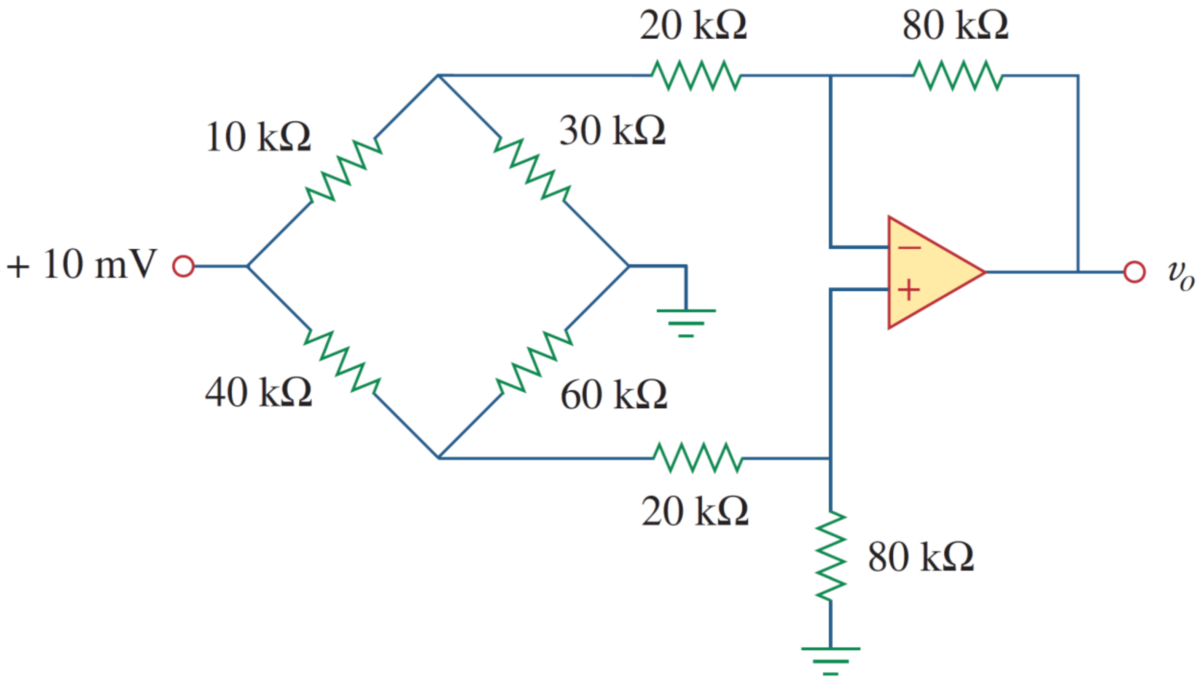


A four-input summing amplifier has $R_1 = R_2 = R_3 = R_4 = 80\ \mathrm{k\Omega}$. What value of feedback resistor is needed to make it an averaging amplifier?

Design an op amp circuit to perform the following operation:

$$v_o = 3v_1 - 2v_2$$

All resistances must be $\leq 100\ \mathrm{k}\Omega$.


20 kΩ
80 kΩ
10 kΩ
30 kΩ
+ 10 mV
v_o
40 kΩ
60 kΩ
20 kΩ
80 kΩ