OP-AMP APPLICATIONS

CHAPTER 11

Common Op-Amp Applications

Constant-gain amplifier

Voltage summing

Voltage buffer

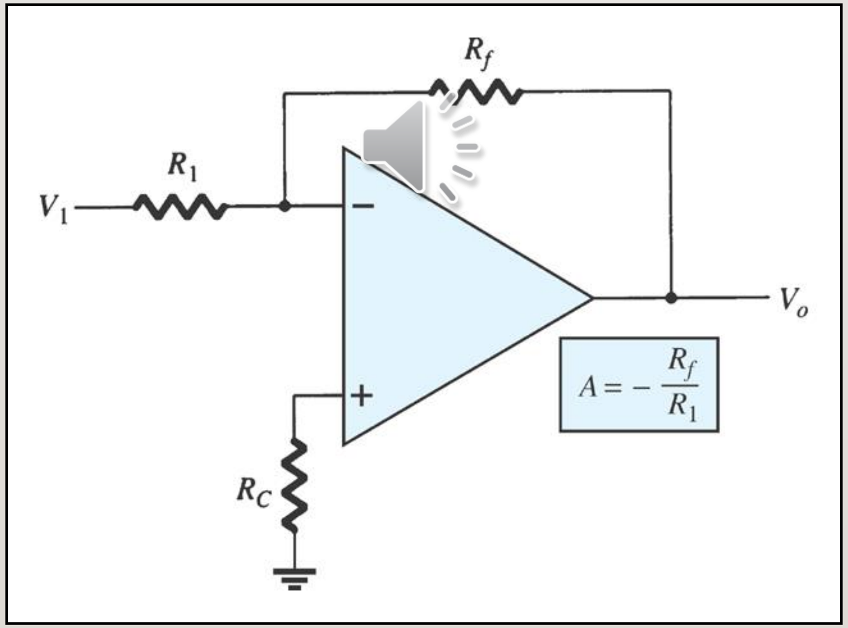
Controlled sources

Instrumentation circuits

Active filters

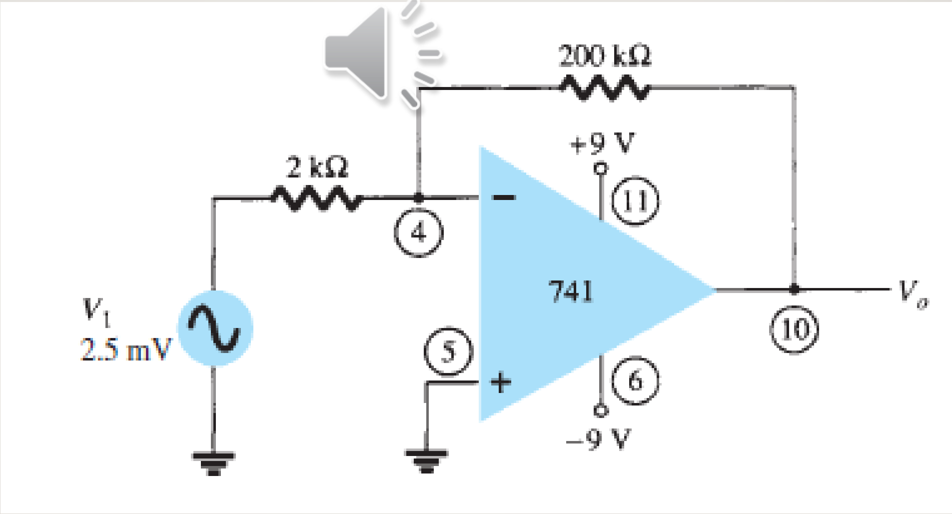
Constant-Gain Amplifier

Inverting amplifier



Constant-Gain inverting Amplifier

Example 11.1: Determine the output voltage of a given circuit with a sinusoidal input voltage of 2.5mV



Constant-Gain inverting Amplifier

Example 11.1 Solution: It is clear from the circuit that it is a constant gain inverting amplifier so

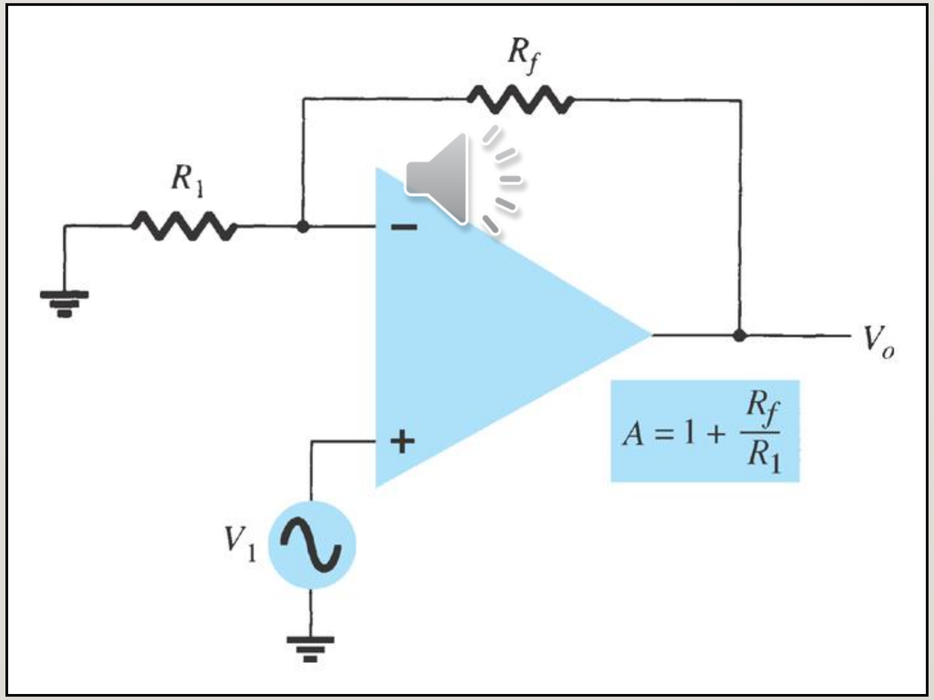
$$A = -\frac{R_f}{R_1} = -\frac{200\ \text{k}\Omega}{2\ \text{k}\Omega} = -100$$

The output voltage is then

$$V_o = AV_i = -100(2.5\ \text{mV}) = -250\ \text{mV} = \mathbf{-0.25\ V}$$

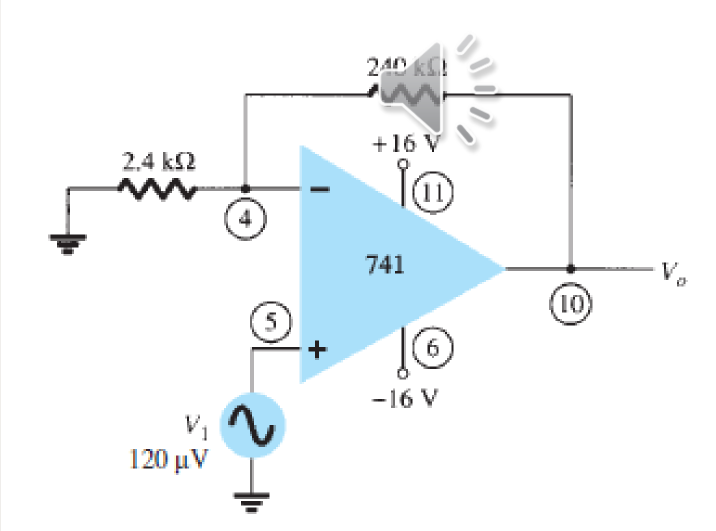
Constant-Gain Non inverting Amplifier

Noninverting amplifier



Constant-Gain non inverting Amplifier

Example 11.2: Determine the output voltage of a given circuit for an input voltage of 120μV



Constant-Gain non inverting Amplifier

Example 11.2 Solution: It is clear from the circuit that it is a constant gain non inverting amplifier so

$$A = 1 + \frac{R_f}{R_1} = 1 + \frac{240\ \text{k}\Omega}{2.4\ \text{k}\Omega} = 1 + 100 = 101$$

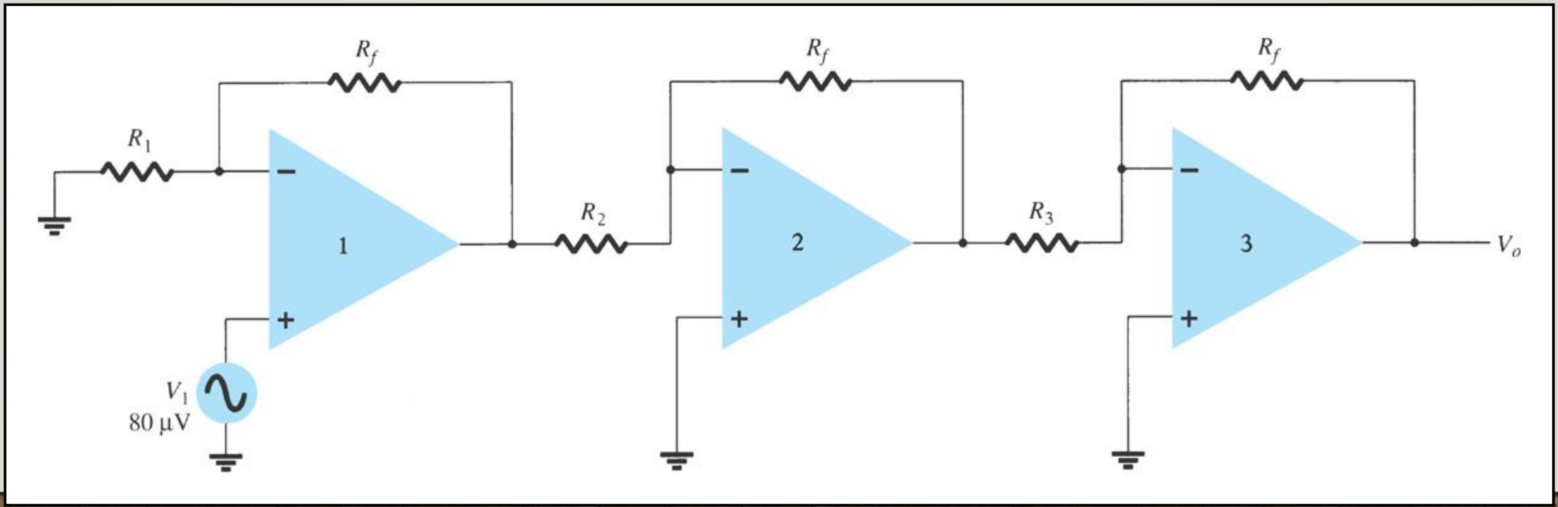
The output voltage is then

$$V_o = AV_i = 101(120\ \mu\text{V}) = \mathbf{12.12\ mV}$$

Multiple-Stage Gains

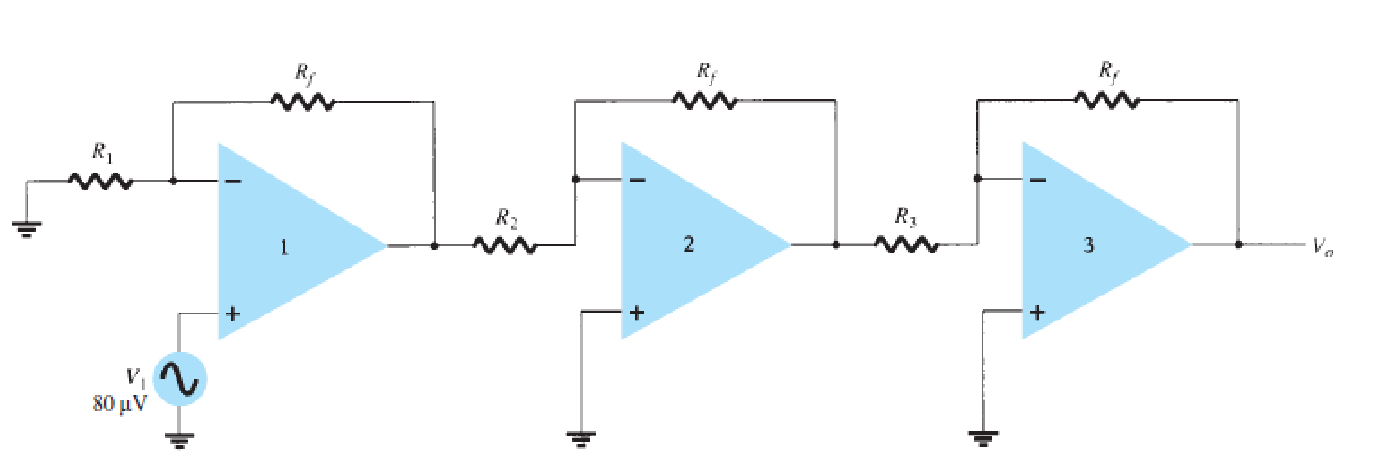
The total gain (3-stages) is given by: $A = A_1 A_2 A_3$

or: $$A = \left(1 + \frac{R_f}{R_1}\right)\left(-\frac{R_f}{R_2}\right)\left(-\frac{R_f}{R_3}\right)$$



Multiple Stage Gain Amplifier

Example 11.3: Determine the output voltage using the given circuit below for resistor components of value Rf = 470kΩ , R1 = 4.3kΩ, R2 and R3 = 33kΩ for an input voltage of 80μV



Multiple Stage Gain Amplifier

Example 11.3 Solution:

The amplifier gain is calculated to be

$$A = A_1A_2A_3 = \left(1 + \frac{R_f}{R_1}\right)\left(-\frac{R_f}{R_2}\right)\left(-\frac{R_f}{R_3}\right)$$

$$= \left(1 + \frac{470\text{ k}\Omega}{4.3\text{ k}\Omega}\right)\left(-\frac{470\text{ k}\Omega}{33\text{ k}\Omega}\right)\left(-\frac{470\text{ k}\Omega}{33\text{ k}\Omega}\right)$$

$$= (110.3)(-14.2)(-14.2) = 22.2 \times 10^3$$

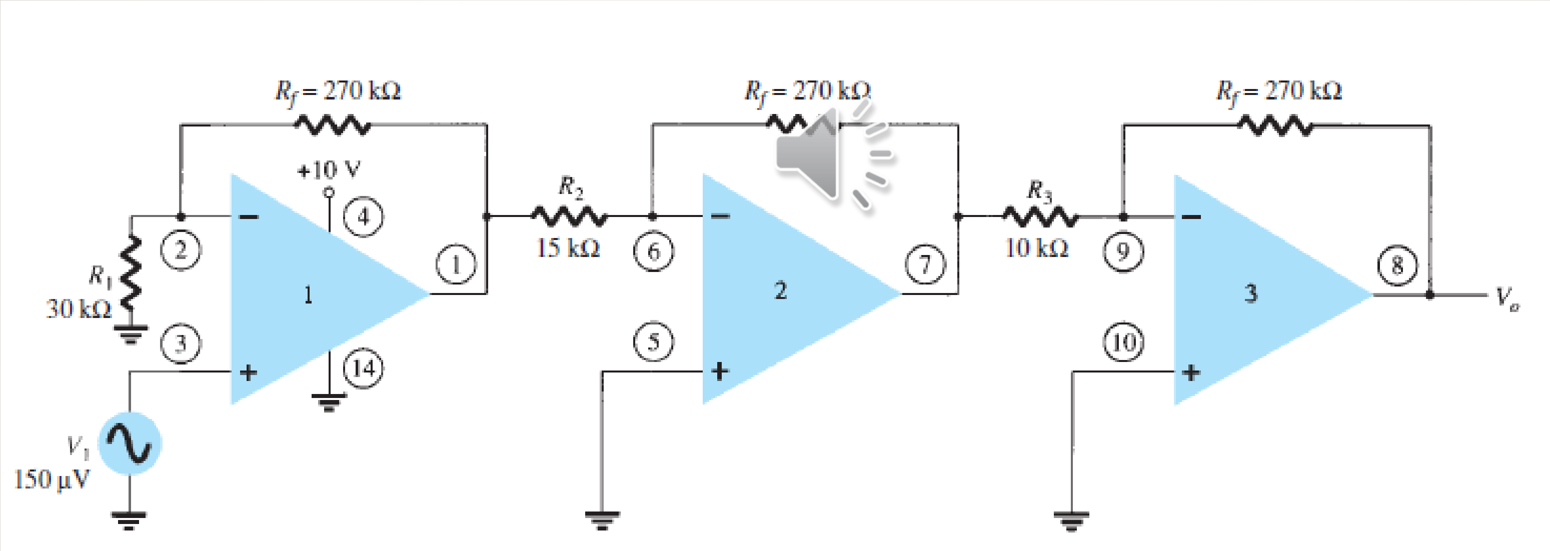
$$V_o = AV_i = 22.2 \times 10^3(80\ \mu\text{V}) = \mathbf{1.78\ V}$$

Multiple Stage Gain Amplifier

Example 11.4: Show the connection of an LM124 quad op-amp as a three stage amplifier with gains of +10, -18. and -27. Use a 270kΩ feedback resistor for all three circuits. What output voltage will result for an input voltage of 150μV

Multiple Stage Gain Amplifier

Example 11.4 Solution:



Multiple Stage Gain Amplifier

Example 11.4 Solution:

For the gain of +10,

$$A_1 = 1 + \frac{R_f}{R_1} = +10$$

$$\frac{R_f}{R_1} = 10 - 1 = 9$$

$$R_1 = \frac{R_f}{9} = \frac{270\,\text{k}\Omega}{9} = 30\,\text{k}\Omega$$

For the gain of −18,

$$A_2 = -\frac{R_f}{R_2} = -18$$

$$R_2 = \frac{R_f}{18} = \frac{270\,\text{k}\Omega}{18} = 15\,\text{k}\Omega$$

Multiple Stage Gain Amplifier

Example 11.4 Solution:

For the gain of −27,

$$A_3 = -\frac{R_f}{R_3} = -27$$

$$R_3 = \frac{R_f}{27} = \frac{270\ \text{k}\Omega}{27} = 10\ \text{k}\Omega$$

The circuit showing the pin connections and all components used is given in Fig. 11.6. For an input of $V_1 = 150\ \mu\text{V}$, the output voltage is

$$V_o = A_1A_2A_3V_1 = (10)(-18)(-27)(150\ \mu\text{V}) = 4860(150\ \mu\text{V})$$
$$= 0.729\ \text{V}$$

Multiple Stage Gain Amplifier

Example 11.5: Show the connection of an LM348 to provide outputs that are 10, 20 and 50 times larger than the. Use a 200kΩ feedback resistor for all three stages.

Multiple Stage Gain Amplifier

Example 11.5 Solution:

The resistor component for each stage is calculated to be

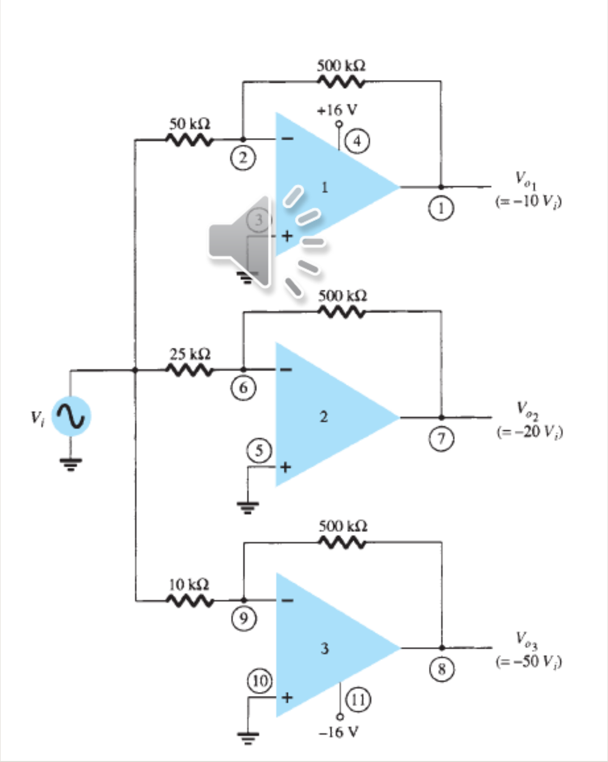
$$R_1 = -\frac{R_f}{A_1} = -\frac{500\text{ k}\Omega}{-10} = 50\text{ k}\Omega$$

$$R_2 = -\frac{R_f}{A_2} = -\frac{500\text{ k}\Omega}{-20} = 25\text{ k}\Omega$$

$$R_3 = -\frac{R_f}{A_3} = -\frac{500\text{ k}\Omega}{-50} = 10\text{ k}\Omega$$

Multiple Stage Gain Amplifier

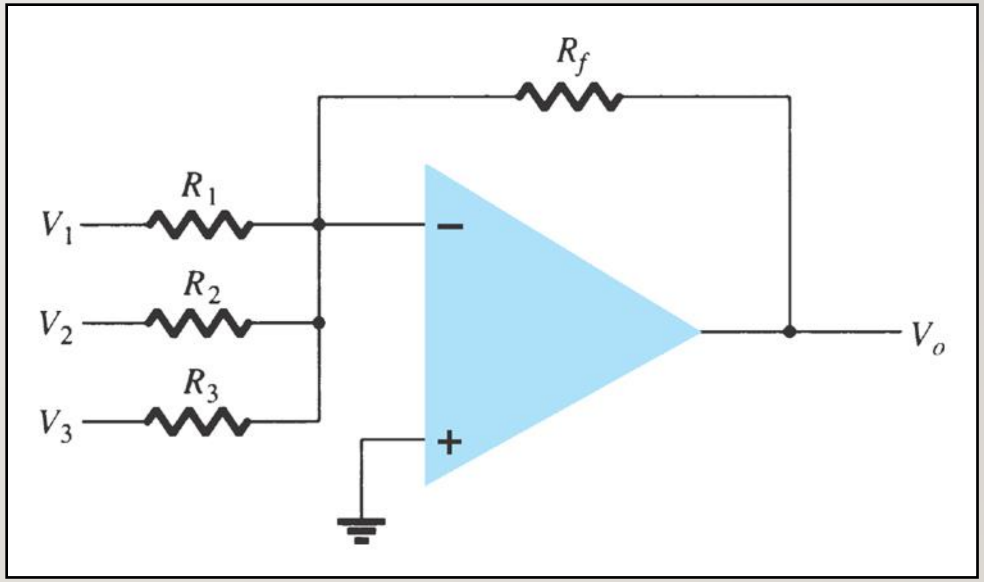
Example 11.5 Solution:



Voltage Summing

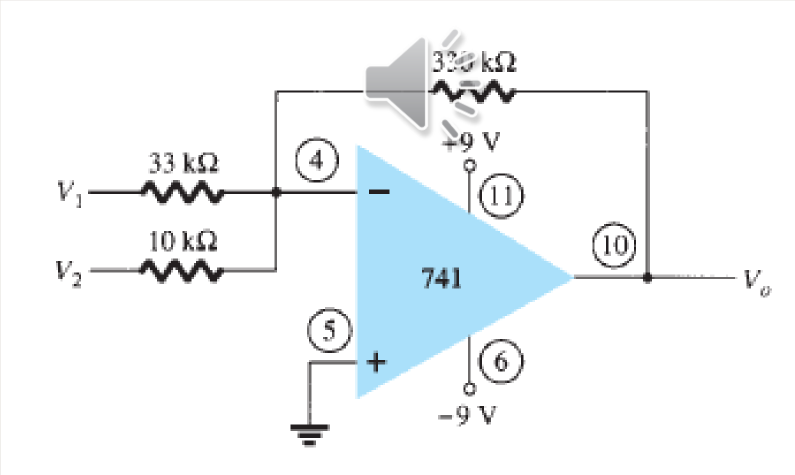
The output is the sum of individual signals times the gain:

$$V_o = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3\right)$$



Voltage Summing Amplifier

Example 11.6: Calculate the output voltage of the given circuit. The inputs are V1 = 50mVsin(1000t) and V2 = 10mVsin(3000t)



Voltage Summing Amplifier

Example 11.6 Solution:

The output voltage is

$$V_o = -\left(\frac{330\text{ k}\Omega}{33\text{ k}\Omega}V_1 + \frac{330\text{ k}\Omega}{10\text{ k}\Omega}V_2\right) = -(10\,V_1 + 33\,V_2)$$

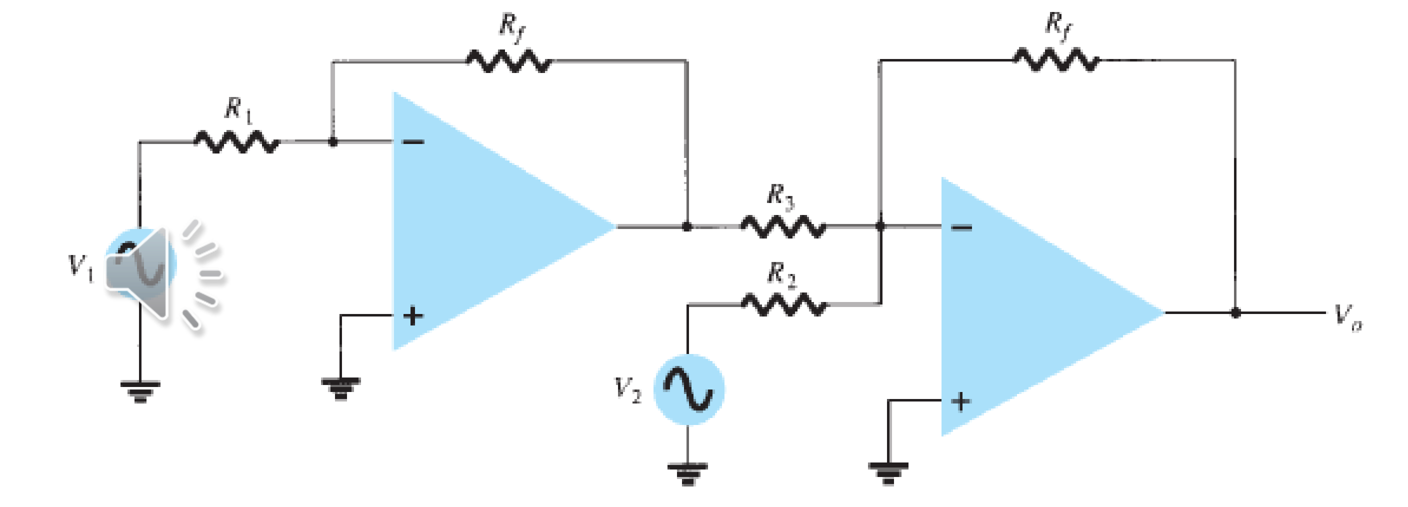
$$= -[10(50\text{ mV})\sin(1000t) + 33(10\text{ mV})\sin(3000t)]$$

$$= -[0.5\sin(1000t) + 0.33\sin(3000t)]$$

Voltage Subtractor

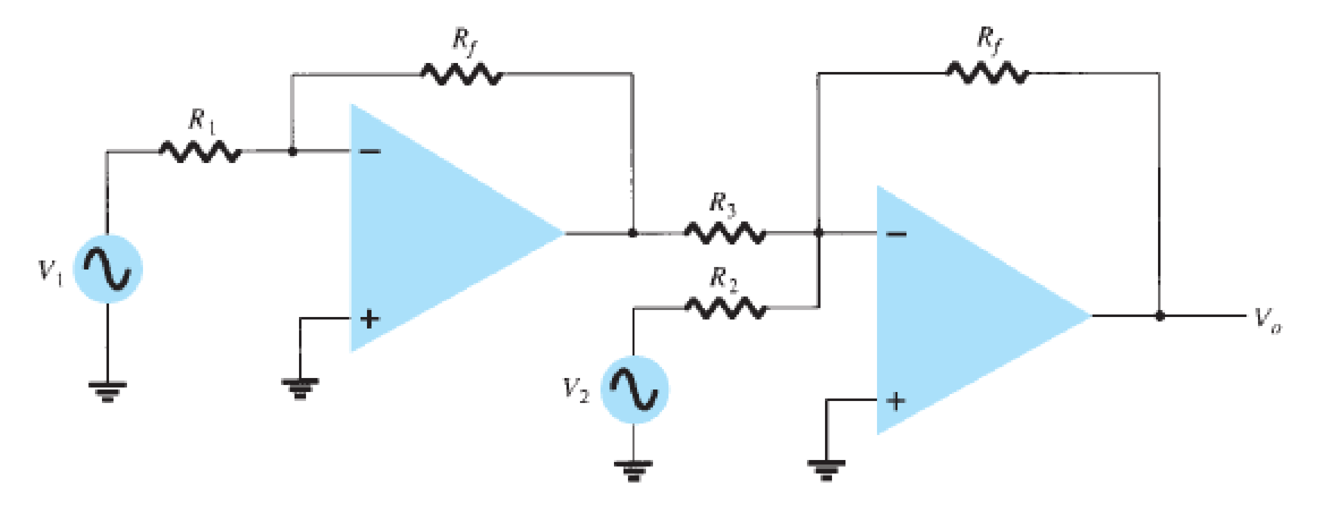
Two signals can be subtracted from one another in a number of ways. Figure shows two op-amp stages used to provide subtraction of input signals

$$V_o = -\left(\frac{R_f}{R_2}V_2 - \frac{R_f}{R_3}\frac{R_f}{R_1}V_1\right)$$



Voltage Subtractor Amplifier

Example 11.7: Calculate the output voltage of the given circuit with components R_f = 1MΩ, R_1 = 100kΩ,, R_2 = 50kΩ,, R_3 = 500kΩ,



Voltage Subtractor Amplifier

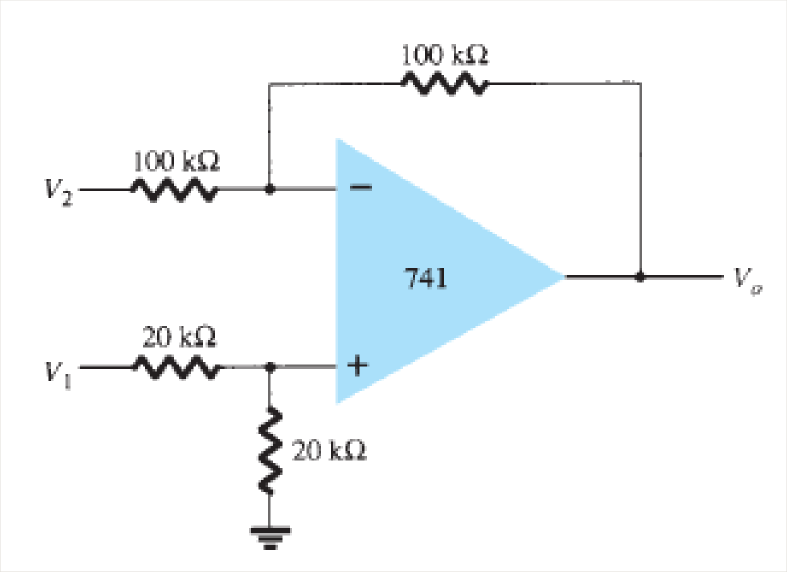
Example 11.7 Solution:

$$V_o = -\left(\frac{1\,\text{M}\Omega}{50\,\text{k}\Omega}V_2 - \frac{1\,\text{M}\Omega}{500\,\text{k}\Omega}\frac{1\,\text{M}\Omega}{100\,\text{k}\Omega}V_1\right) = -(20\,V_2 - 20\,V_1) = \mathbf{-20(V_2 - V_1)}$$

The output is seen to be the difference of V_2 and V_1 multiplied by a gain factor of -20.

Voltage Subtractor

Example 11.8: Determine the output voltage of the given circuit



Voltage Subtractor

Example 11.8 Solution:

$$V_o = \left(\frac{20\,\text{k}\Omega}{20\,\text{k}\Omega + 20\,\text{k}\Omega}\right)\left(\frac{100\,\text{k}\Omega + 100\,\text{k}\Omega}{100\,\text{k}\Omega}\right)V_1 - \frac{100\,\text{k}\Omega}{100\,\text{k}\Omega}V_2$$

$$= V_1 - V_2$$

The resulting output voltage is seen to be the difference of the two input voltages.