Common Op-Amp Circuits

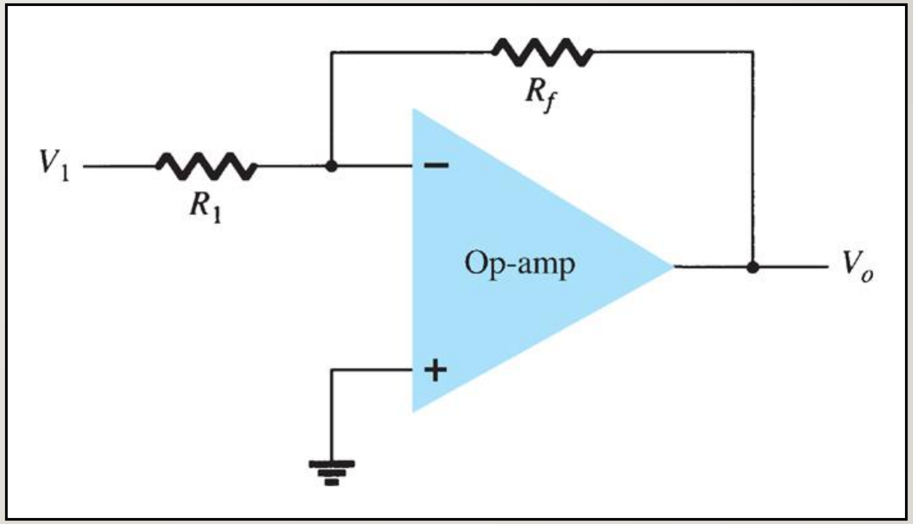
- Inverting amplifier
- Noninverting amplifier
- Unity follower
- Summing amplifier
- Integrator
- Differentiator

Inverting Op-Amp

The input signal is applied to the **inverting (–) input**

The **non-inverting input (+)** is grounded

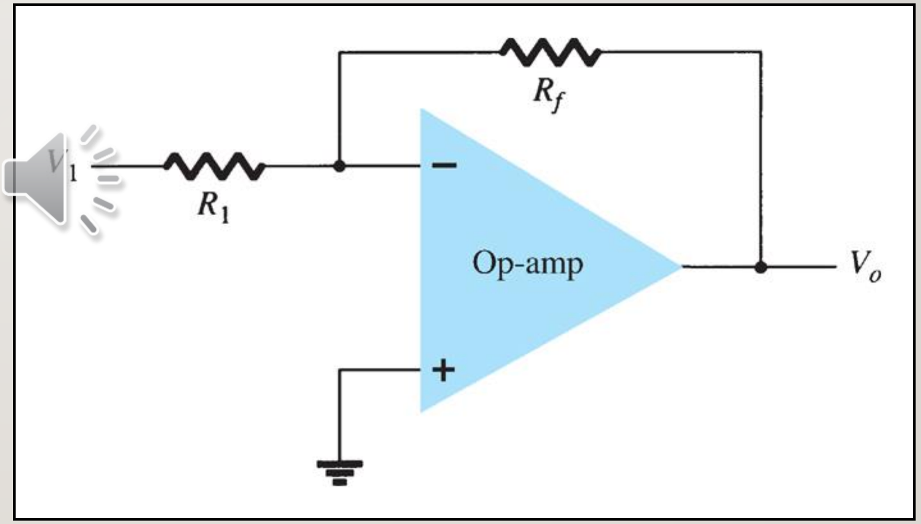
The **feedback resistor** (R_f) is connected from the output to the negative (inverting) input; providing *negative feedback*.



Inverting Op-Amp Gain

Gain is set using external resistors: R_f and R_1

$$A_v = \frac{V_o}{V_i} = \frac{R_f}{R_1}$$



Gain can be set to any value by manipulating the values of R_f and R_1.

Unity gain (A_v = 1):

$$R_f = R_1$$

$$A_v = \frac{-R_f}{R_1} = -1$$

The negative sign denotes a 180° phase shift between input and output.

Inverting Amplifier

Example 10.5: If Rf = 500kΩ and R1 = 100kΩ, what output voltage results for an input of V_1 = 2V

Solution:

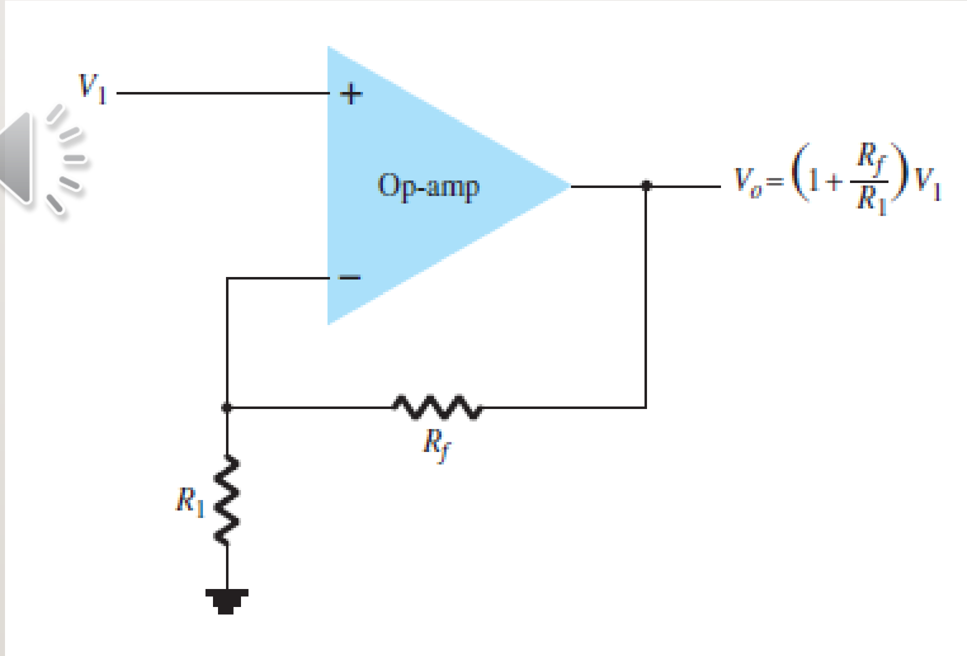
$$V_o = -\frac{R_f}{R_1} V_1 = -\frac{500\ \text{k}\Omega}{100\ \text{k}\Omega}(2\ \text{V}) = -10\ \text{V}$$

Non Inverting Op-Amp Gain

Gain is set using external resistors: R_f and R_1

Av = (1+ Rf/R1)

Gain can be set to any value by manipulating the values of R_f and R_1.



Non Inverting Amplifier

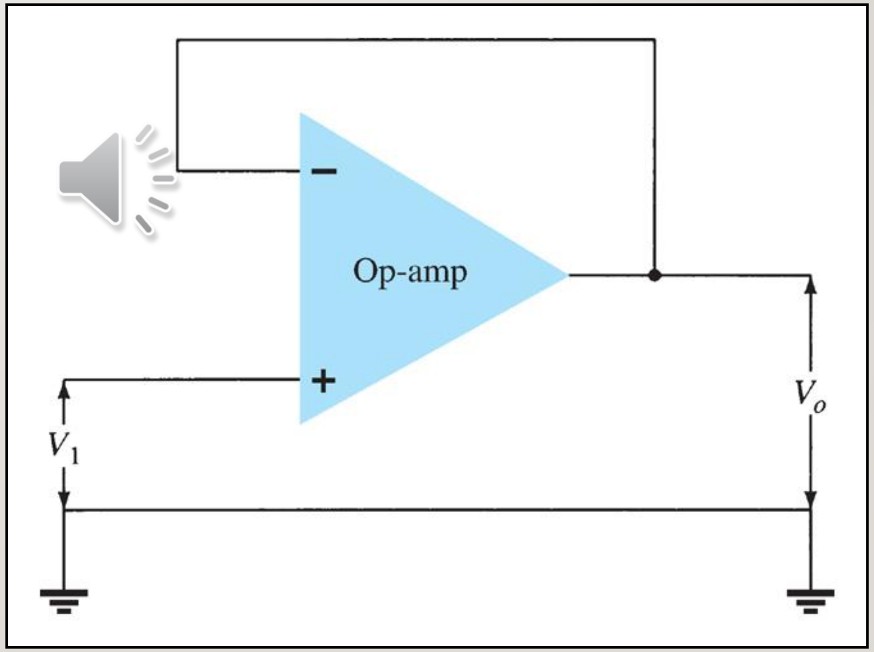
Example 10.6: Calculate the output voltage of a noninverting op-amp for values V1= 2V, Rf = 500kΩ and R1 = 100kΩ

Solution:

$$V_o = \left(1 + \frac{R_f}{R_1}\right)V_1 = \left(1 + \frac{500\text{ k}\Omega}{100\text{ k}\Omega}\right)(2\text{ V}) = 6(2\text{ V}) = \mathbf{+12\text{ V}}$$

Unity Follower

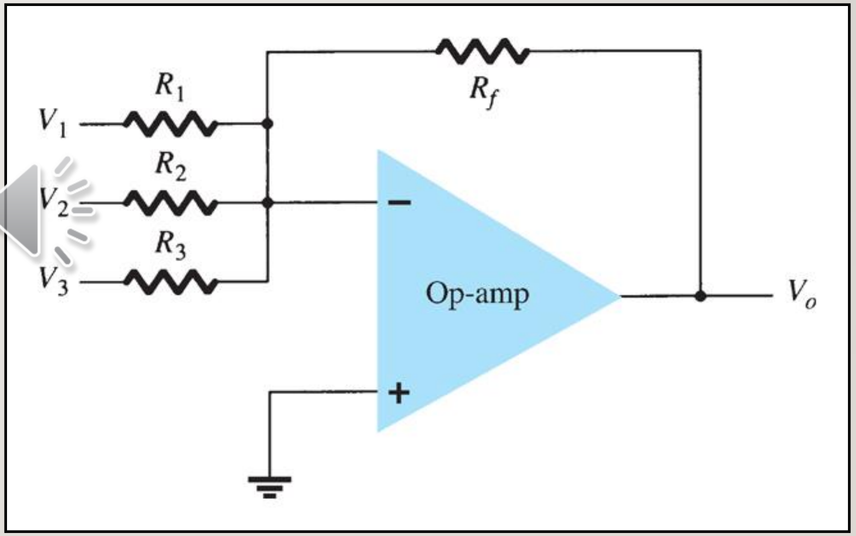
$$V_o = V_1$$



Summing Amplifier

Because the op-amp has a high input impedance, the multiple inputs are treated as separate inputs.

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



Summing Amplifier

Example 10.7: Calculate the output voltage of an op-amp summing amplifier for the following set of voltages. Use $R_f = 1 M\Omega$ in all cases.

a. $V_1 = +1\text{ V}, V_2 = +2\text{ V}, V_3 = +3\text{ V}, R_1 = 500\text{ k}\Omega, R_2 = 1\text{ M}\Omega, R_3 = 1\text{ M}\Omega.$

b. $V_1 = -2\text{ V}, V_2 = +3\text{ V}, V_3 = +1\text{ V}, R_1 = 200\text{ k}\Omega, R_2 = 500\text{ k}\Omega, R_3 = 1\text{ M}\Omega.$

Solution:

$$\text{a. } V_o = -\left[\frac{1000\text{ k}\Omega}{500\text{ k}\Omega}(+1\text{ V}) + \frac{1000\text{ k}\Omega}{1000\text{ k}\Omega}(+2\text{ V}) + \frac{1000\text{ k}\Omega}{1000\text{ k}\Omega}(+3\text{ V})\right]$$

$$= -[2(1\text{ V}) + 1(2\text{ V}) + 1(3\text{ V})] = -7\text{ V}$$

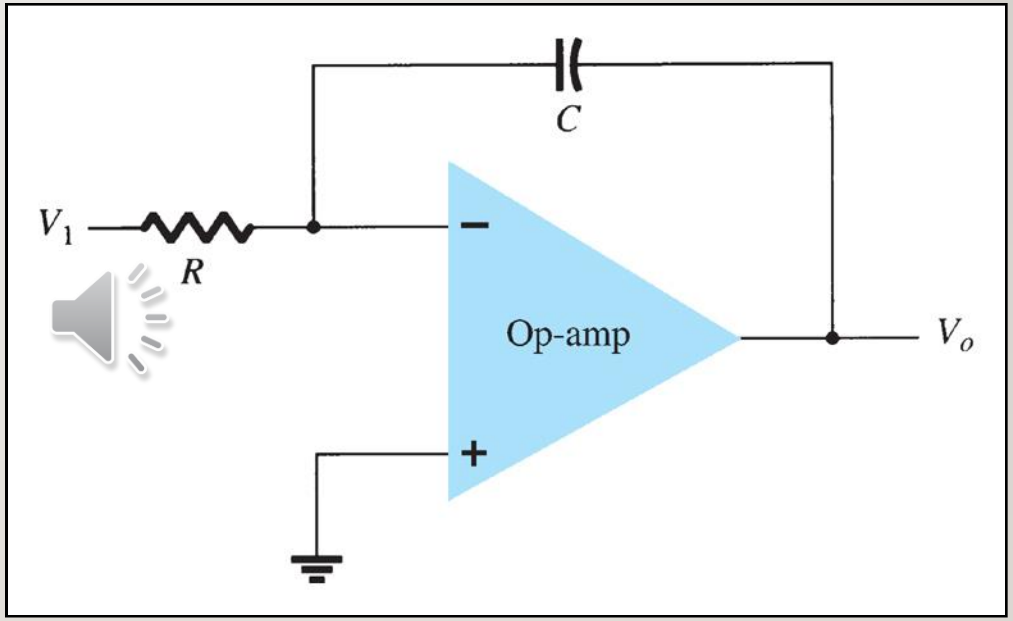
$$\text{b. } V_o = -\left[\frac{1000\text{ k}\Omega}{200\text{ k}\Omega}(-2\text{ V}) + \frac{1000\text{ k}\Omega}{500\text{ k}\Omega}(+3\text{ V}) + \frac{1000\text{ k}\Omega}{1000\text{ k}\Omega}(+1\text{ V})\right]$$

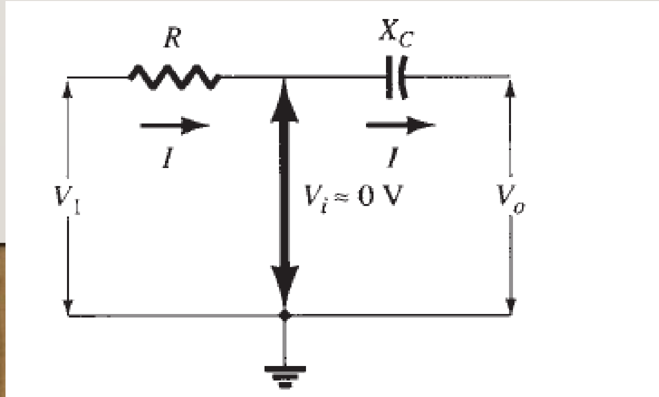
$$= -[5(-2\text{ V}) + 2(3\text{ V}) + 1(1\text{ V})] = +3\text{ V}$$

Integrator

The output is the integral of the input; i.e., proportional to the area under the input waveform. This circuit is useful in low-pass filter circuits and sensor conditioning circuits.

$$v_o(t) = -\frac{1}{RC}\int v_1(t)dt$$

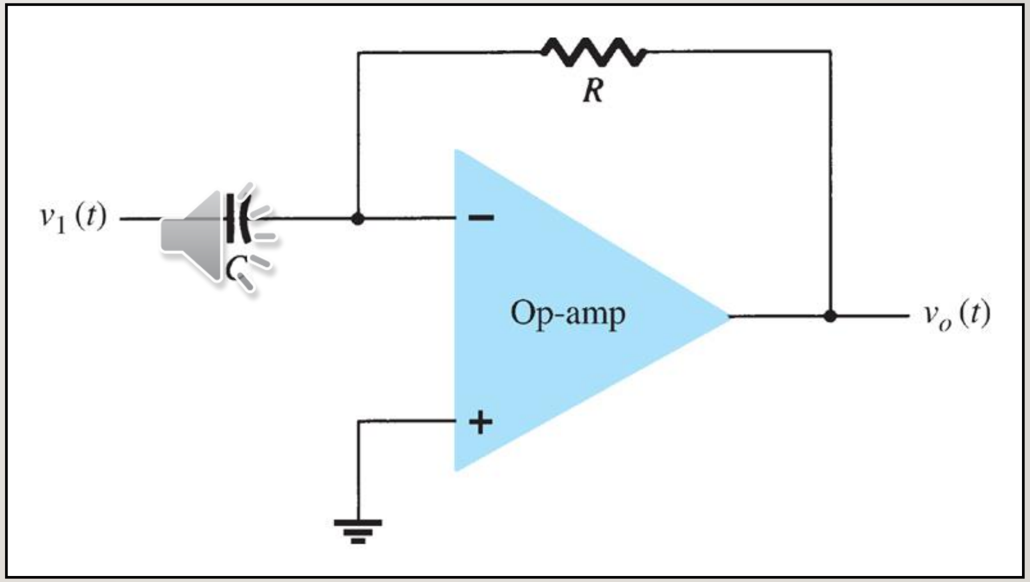




Differentiator

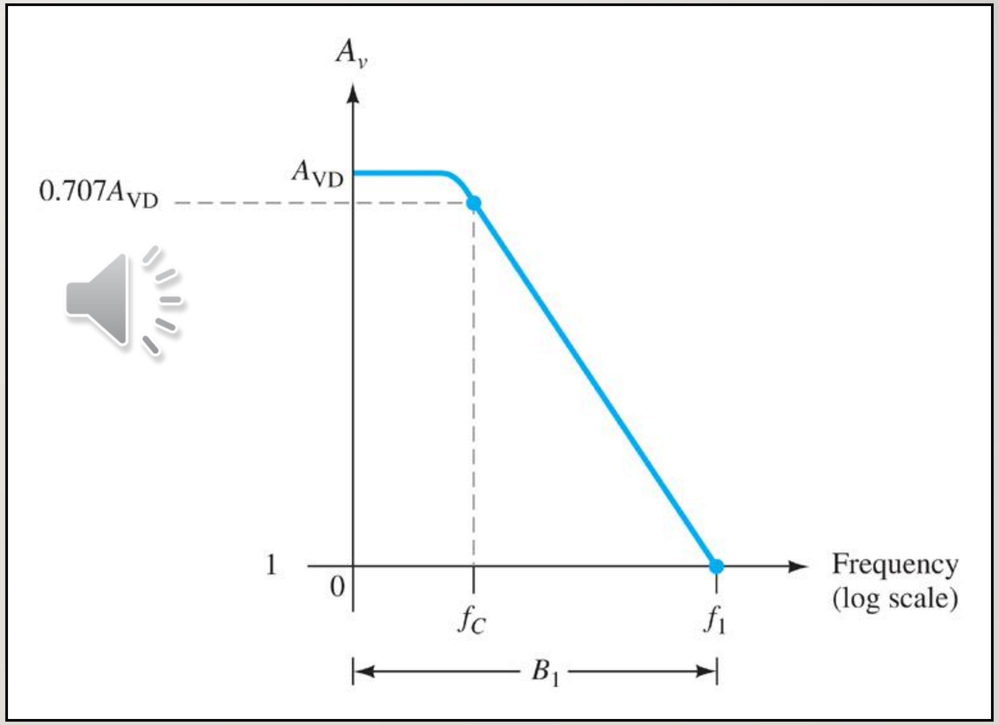
The differentiator takes the derivative of the input. This circuit is useful in high-pass filter circuits.

$$v_o(t) = -RC\frac{dv_1(t)}{dt}$$



Gain and Bandwidth

The op-amp's high frequency response is limited by its internal circuitry. The plot shown is for an open loop gain (*A_{OL}* or *A_{VD}*). This means that the op-amp is operating at the highest possible gain with no feedback resistor.



In the open loop mode, an op-amp has a narrow bandwidth. The bandwidth widens in closed-loop mode, but the gain is lower.

Slew Rate (SR)

Slew rate (SR): The maximum rate at which an op-amp can change output without distortion.

$$SR = \frac{\Delta V_o}{\Delta t} \quad \text{(in V/}\mu\text{s)}$$

The SR rating is listed in the specification sheets as the V/μs rating.

Maximum Signal Frequency

The slew rate determines the highest frequency of the op-amp without distortion.

$$f \leq \frac{SR}{2\pi V_p}$$

where V_P is the peak voltage

Frequency Parameters

An op-amp is a wide-bandwidth amplifier. The following factors affect the bandwidth of the op-amp:

Gain

Slew rate

Absolute Ratings

These are common maximum ratings for the op-amp.

Absolute Maximum Ratings

Supply voltage	±22 V
Internal power dissipation	500 mW
Differential input voltage	±30 V
Input voltage	±15 V

Electrical Characteristics

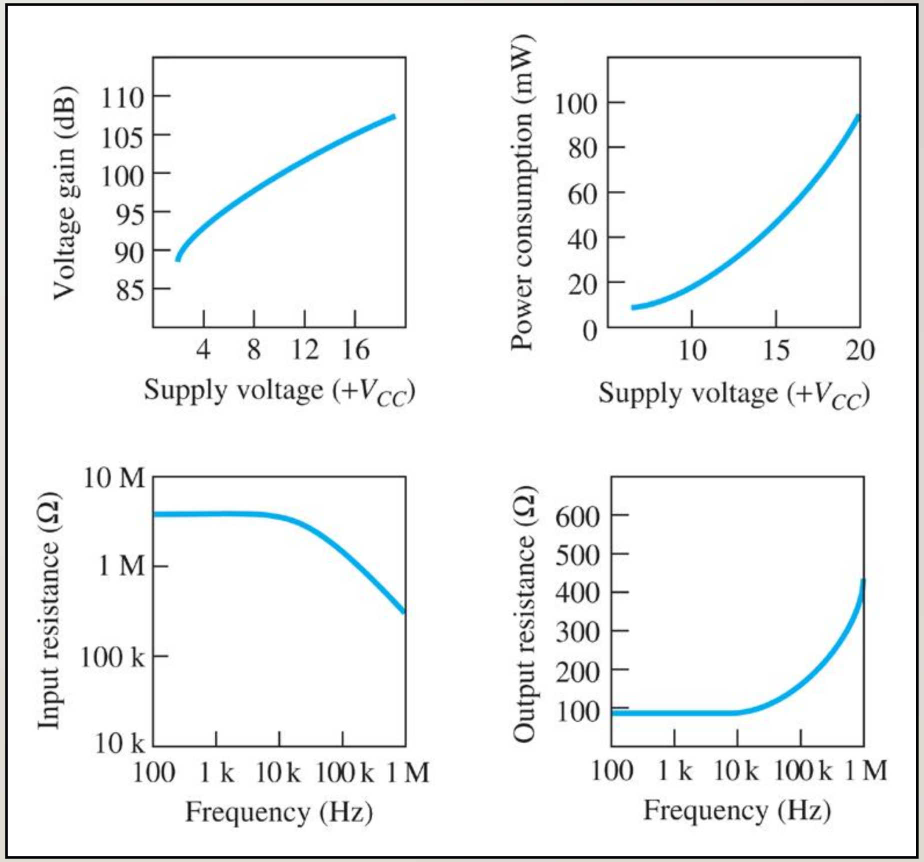
μA741 Electrical Characteristics: $V_{CC} = \pm 15$ V, $T_A = 25°C$

Characteristic	Minimum	Typical	Maximum	Unit
V_{IO} Input offset voltage		1	6	mV
I_{IO} Input offset current		20	200	nA
I_{IB} Input bias current		80	500	nA
V_{ICR} Common-mode input voltage range	±12	±13		V
V_{OM} Maximum peak output voltage swing	±12	±14		V
A_{VD} Large-signal differential voltage amplification	20	200		V/mV
r_i Input resistance	0.3	2		MΩ
r_o Output resistance		75		Ω
C_i Input capacitance		1.4		pF
CMRR Common-mode rejection ratio	70	90		dB
I_{CC} Supply current		1.7	2.8	mA
P_D Total power dissipation		50	85	mW

Note: These ratings are for specific circuit conditions, and they often include minimum, maximum and typical values.

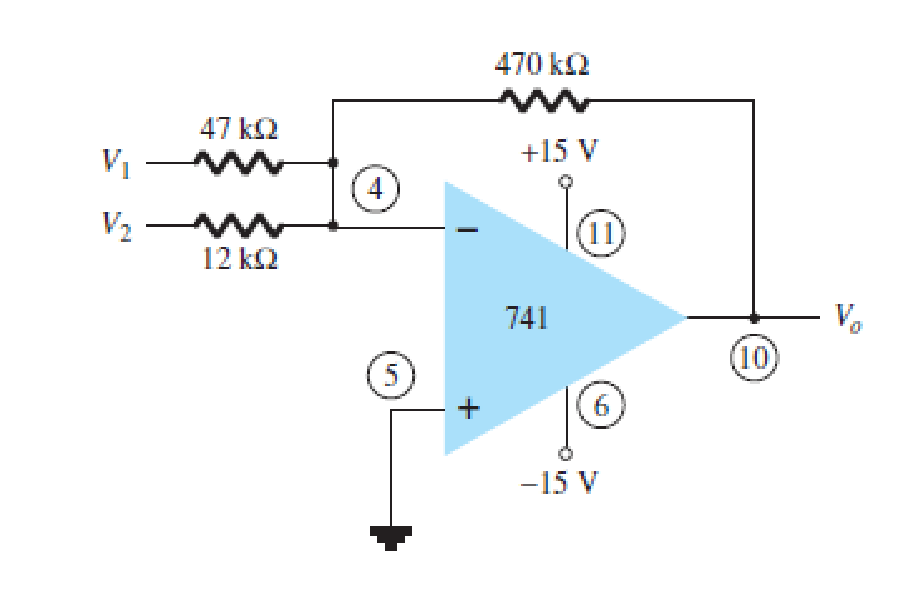
Op-Amp Performance

The specification sheets will also include graphs that indicate the performance of the op-amp over a wide range of conditions.



ASSIGNMENT TASK

Analyse the Op Amp configuration to calculate the output voltage for the circuit of Figure below with inputs of V_1 =40 mV rms and V_2 =20 mV rms.



ASSIGNMENT TASK

- Analyze the op Amp circuit to determine the output voltage for the circuit of Figure below .