Electronic Devices and Circuit Theory

Tenth Edition

Boylestad

Pearson

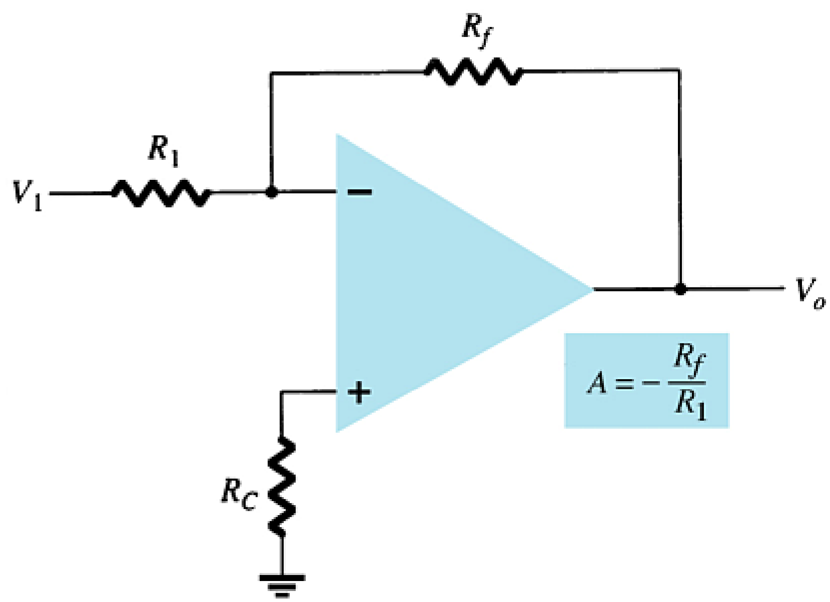
# Chapter 11
# Op-Amp Applications

# Op-Amp Applications

**Constant-gain multiplier**
**Voltage summing**
**Voltage buffer**
**Controlled sources**
**Instrumentation circuits**
**Active filters**

# Constant-Gain Amplifier

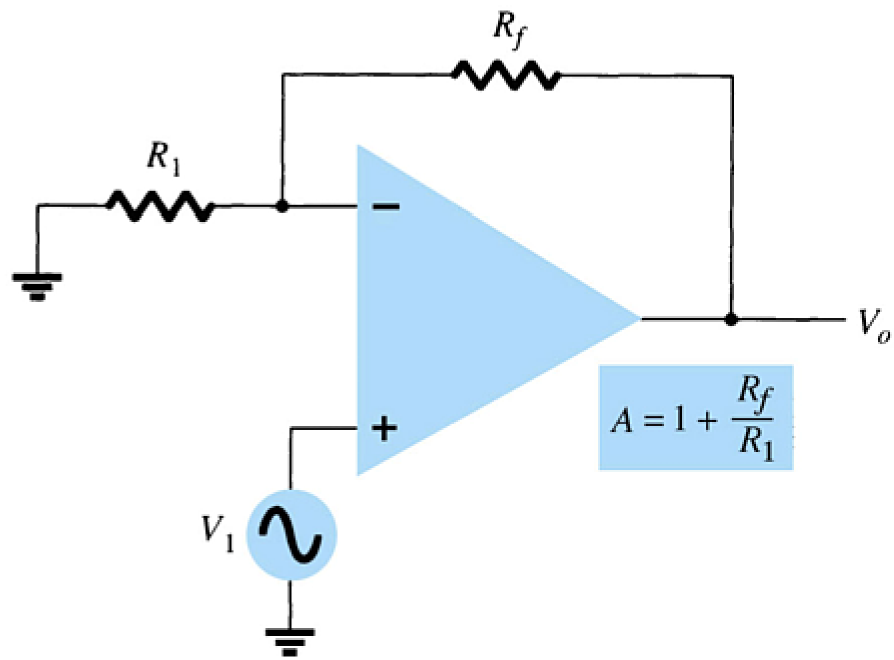
## Inverting Version




more…

# Constant-Gain Amplifier

## Noninverting Version



# Multiple-Stage Gains

**The total gain (3-stages) is given by:**

$$A = A_1 A_2 A_3$$

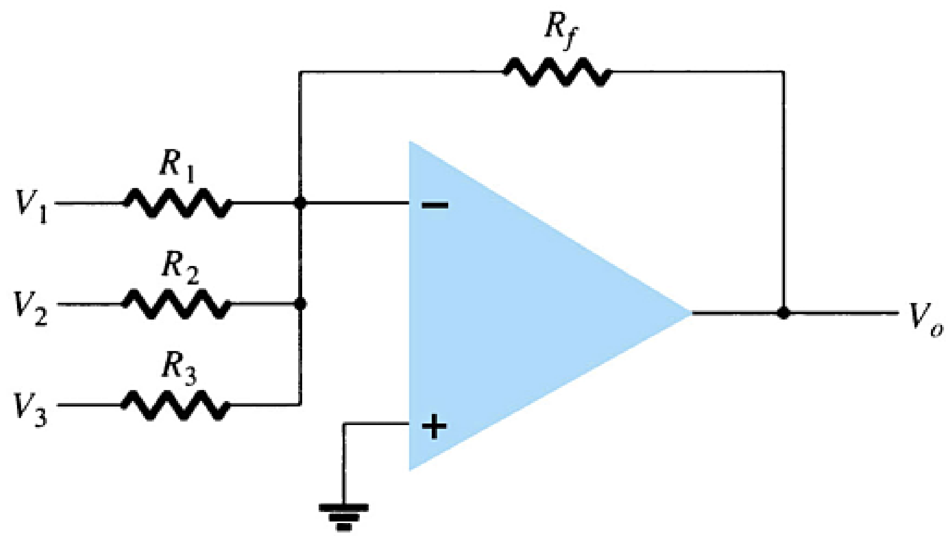
**or**

$$A = \left(1 + \frac{R_f}{R_1}\right)\left(-\frac{R_f}{R2}\right)\left(-\frac{R_f}{R3}\right)$$

# Voltage Summing

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

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



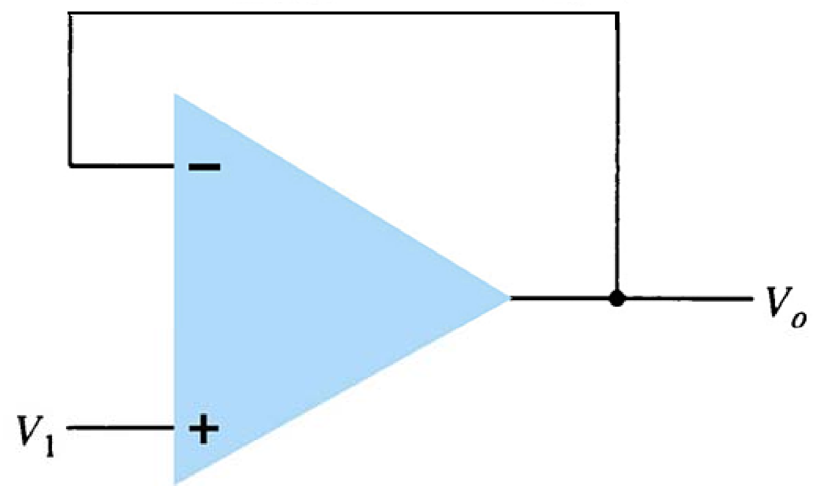

[Formula 14.3]

# Voltage Buffer

**Any amplifier with no gain or loss is called a unity gain amplifier.**
**The advantages of using a unity gain amplifier:**

- **Very high input impedance**
- **Very low output impedance**

**Realistically these circuits are designed using equal resistors ($R_1 = R_f$) to avoid problems with offset voltages.**



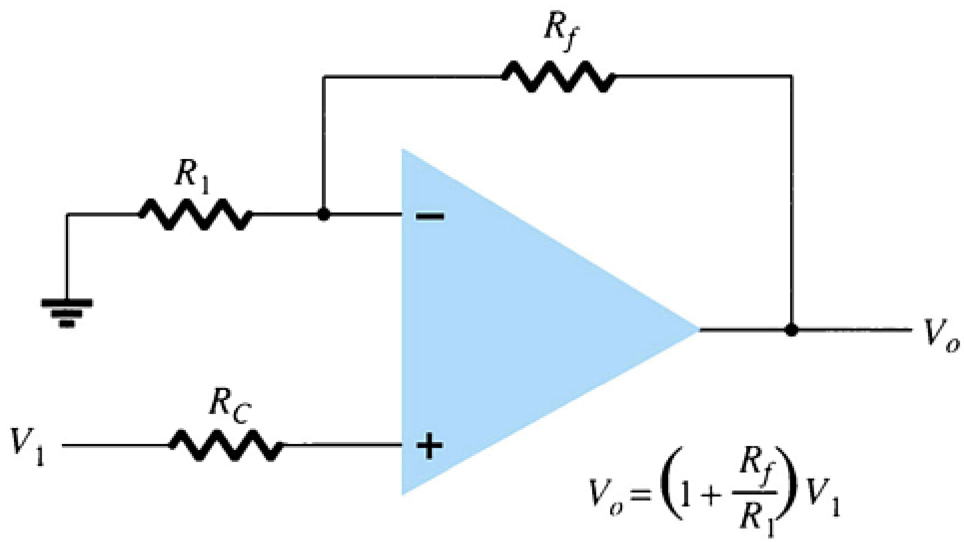
# Controlled Sources

**Voltage-controlled voltage source**
**Voltage-controlled current source**
**Current-controlled voltage source**
**Current-controlled current source**

# Voltage-Controlled Voltage Source

**The output voltage is the gain times the input voltage. What makes an op-amp different from other amplifiers is its impedance characteristics and gain calculations that depend solely on external resistors.**

**Noninverting Amplifier Version**

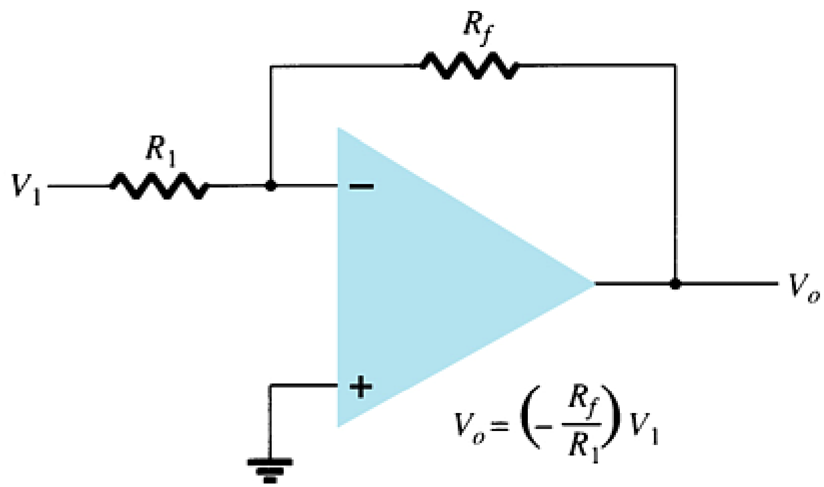



**more…**

# Voltage-Controlled Voltage Source

**The output voltage is the gain times the input voltage. What makes an op-amp different from other amplifiers is its impedance characteristics and gain calculations that depend solely on external resistors.**

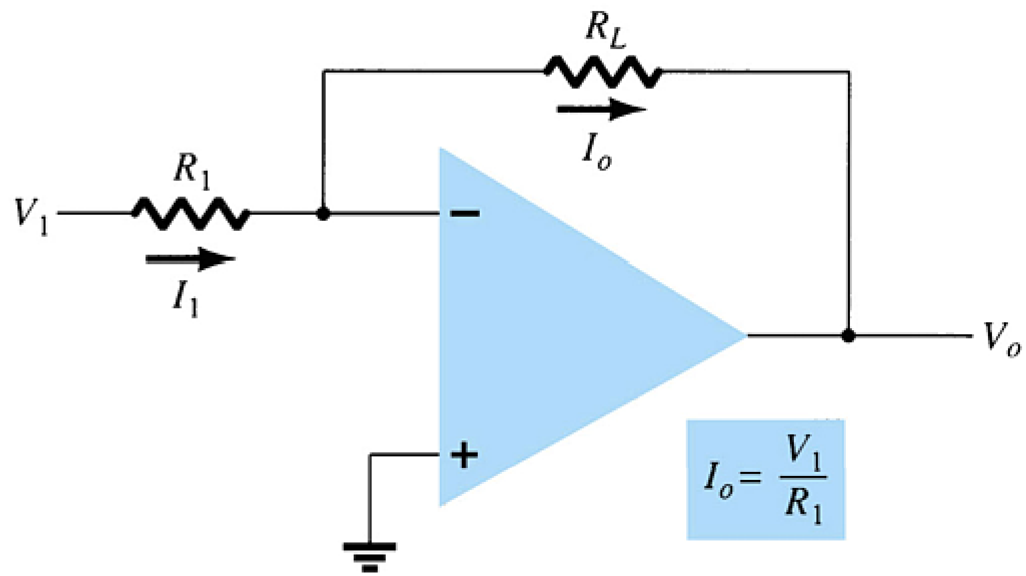
**Inverting Amplifier Version**



# Voltage-Controlled Current Source

**The output current is:**

$$I_o = \frac{V_1}{R_1} = kV_1$$



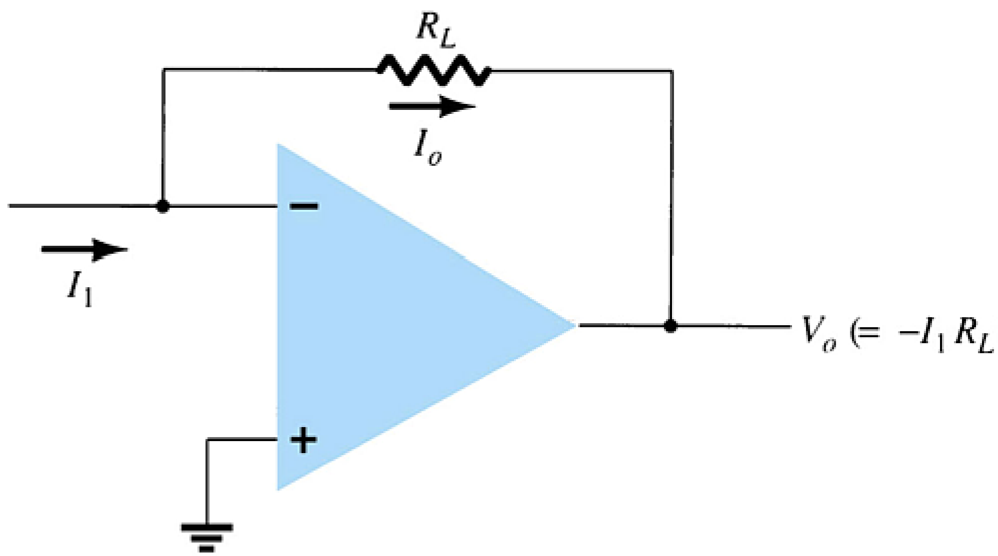
# Current-Controlled Voltage Source

This is simply another way of applying the op-amp operation. Whether the input is a current determined by $V_{in}/R_1$ or as $I_1$:

$$V_{out} = \frac{-R_f}{R_1} V_{in}$$

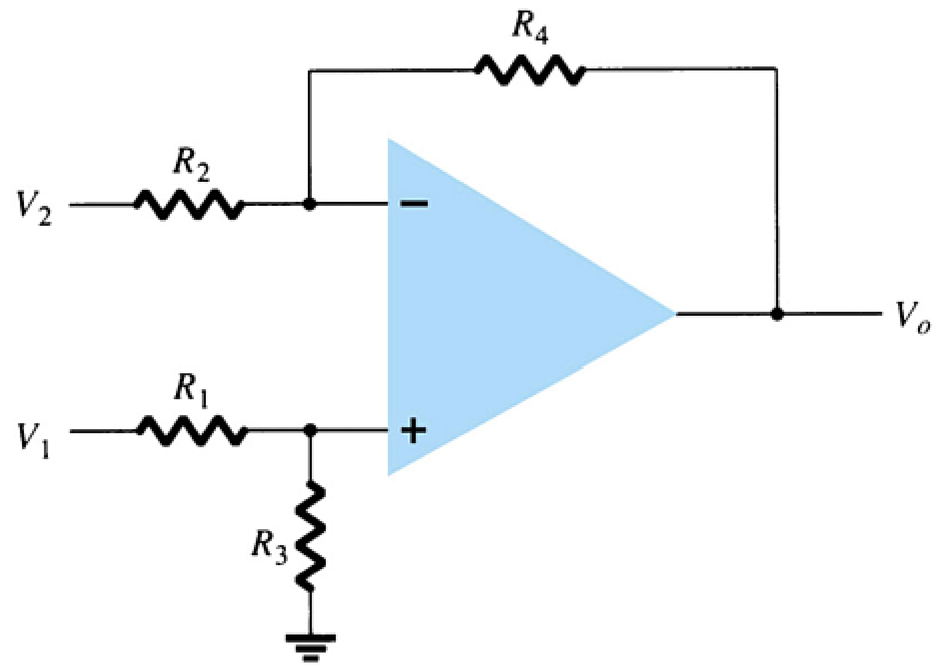
or

$$V_{out} = -I_1 R_L$$



# Current-Controlled Current Source

**This circuit may appear more complicated than the others but it is really the same thing.**




$$V_{out} = -\left(\frac{R_f}{R_{in}}\right)V_{in}$$

$$\frac{V_{out}}{R_f} = -\frac{V_{in}}{R_1 \parallel R_2}$$

$$\frac{V_{out}}{R_f} = -\frac{V_{in}}{R_{in}}$$

$$I_o = -\frac{V_{in}}{R_1 \parallel R_2}$$

$$I_o = -V_{in}\left(\frac{R_1 + R_2}{R_1 \times R_2}\right)$$

$$I_o = -\frac{V_{in}}{R_1}\left(\frac{R_1 + R_2}{R_2}\right)$$

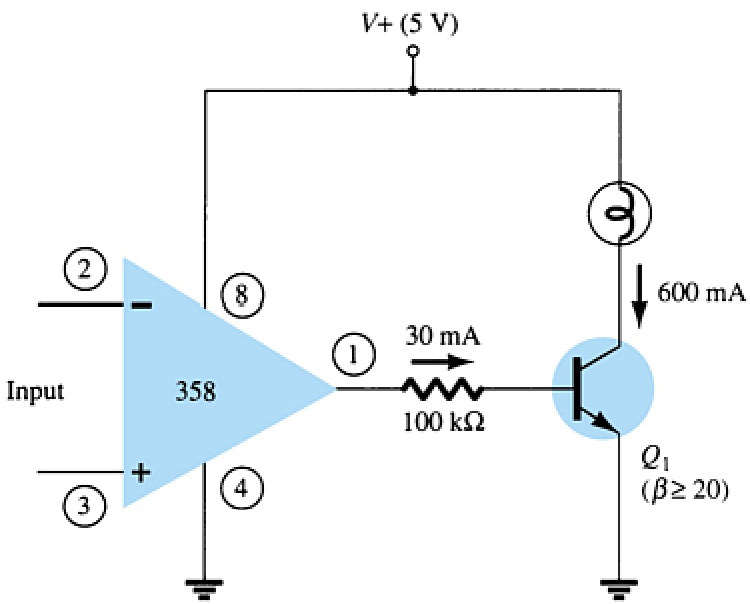
$$I_o = -I\left(1 + \frac{R_1}{R_2}\right) = kI$$

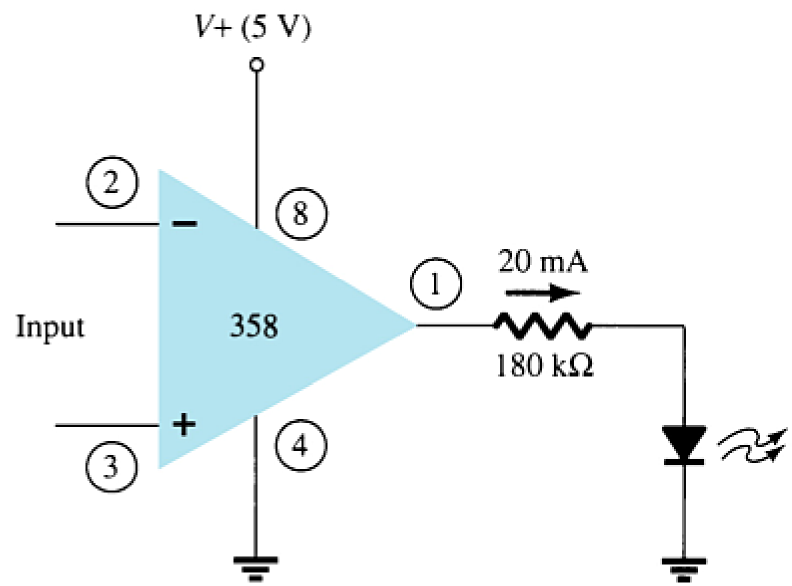
# Instrumentation Circuits

**Some examples of instrumentation circuits using op-amps:**

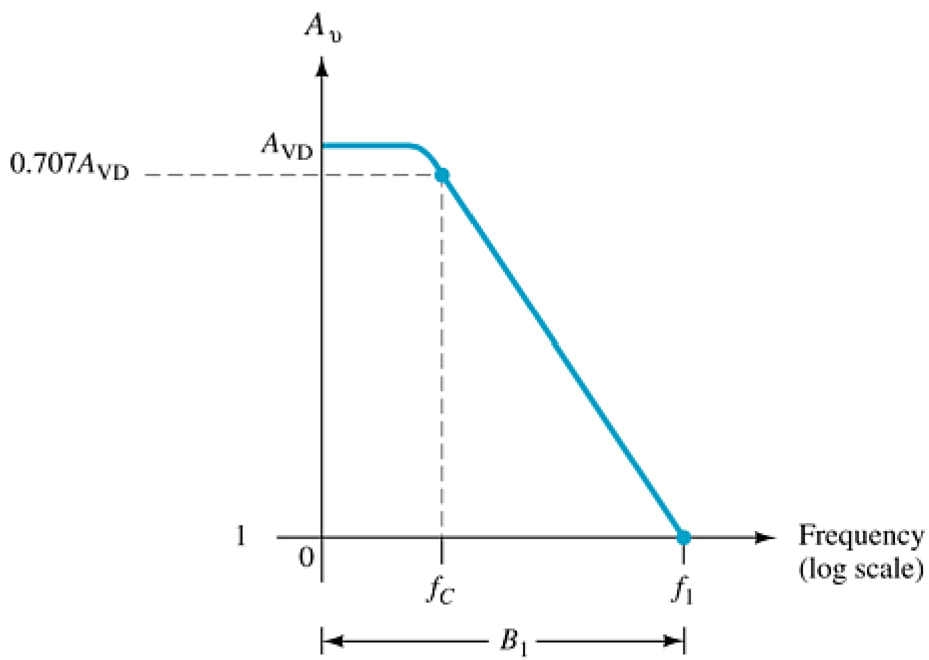
- **Display driver**
- **Instrumentation amplifier**

# Display Driver



# Instrumentation Amplifier




**For all Rs at the same value (except $R_p$):**

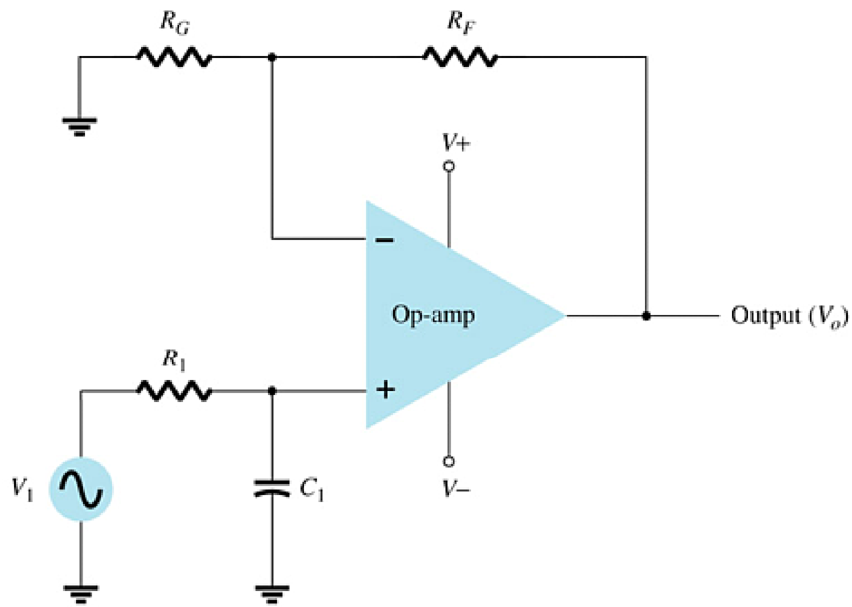
$$V_o = \left(1 + \frac{2R}{R_P}\right)(V_1 - V_2) = k(V_1 - V_2)$$

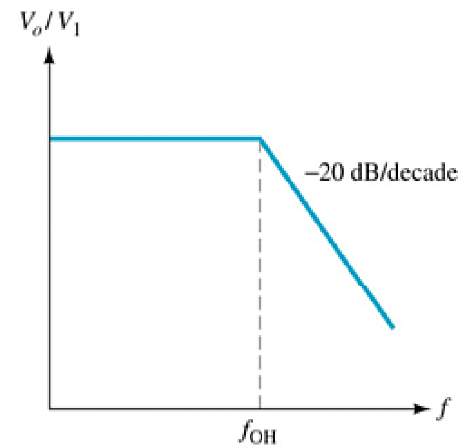
# Active Filters

**Adding capacitors to op-amp circuits provides external control of the cutoff frequencies. The op-amp active filter provides controllable cutoff frequencies and controllable gain.**

- **Low-pass filter**
- **High-pass filter**
- **Bandpass filter**

# Low-Pass Filter—First-Order



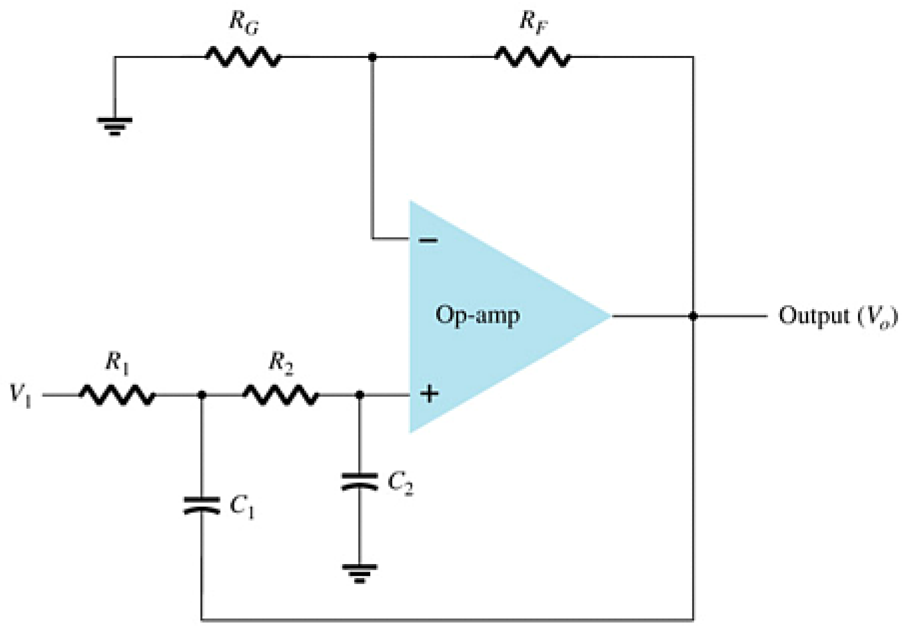



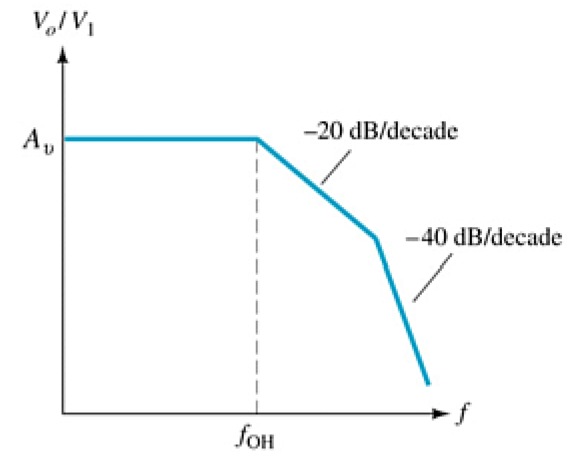

**The upper cutoff frequency and voltage gain are given by:**

$$f_{OH} = \frac{1}{2\pi R_1 C_1}$$

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

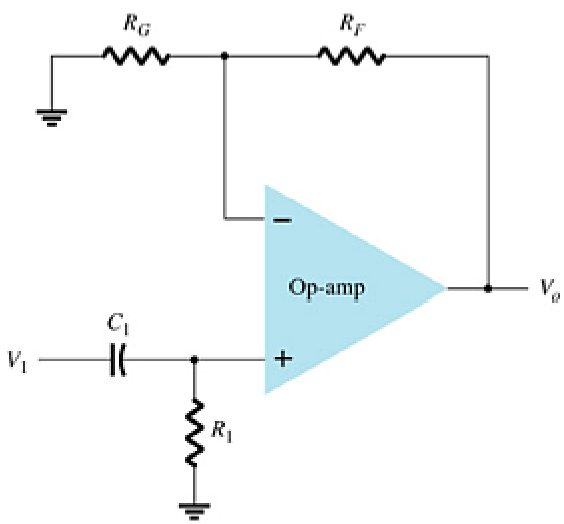
# Low-Pass Filter—Second-Order

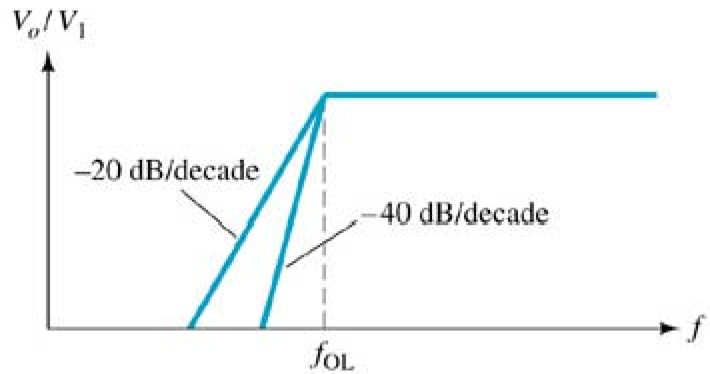



**The roll-off can be made steeper by adding more RC networks.**

# High-Pass Filter




**The cutoff frequency is determined by:**

$$f_{OL} = \frac{1}{2\pi R_1 C_1}$$

# Bandpass Filter

**There are two cutoff frequencies: upper and lower. They can be calculated using the same low-pass cutoff and high-pass cutoff frequency formulas in the appropriate sections.**