# OP-AMP APPLICATION

# Topic Outcomes

- Describe the different types of op-amp circuit
- Analyze the operation of the different applications of an op-amp

# Introduction

- The Module will provide knowledge about the principles, operation and characteristics of the opamp. The used of op-amps in variety of circuits and application (Comparator, Summing and Subtracting Amplifier, Integrator, Differentiator, ac and dc millivoltmeter, and Display Driver) is going to cover by this module.
- After finishing this module, students will learn to analyze op-amp circuit and used them to some application. They will learn how to design a comparator, summing amplifier, differentiator etc. based on the requirements. The plotting the output waveform from the op-amp circuit is also part of this topic. The ideas that students will earn here will serve as a stepping stone for the future topics (Filter, Oscillator and Linear IC)

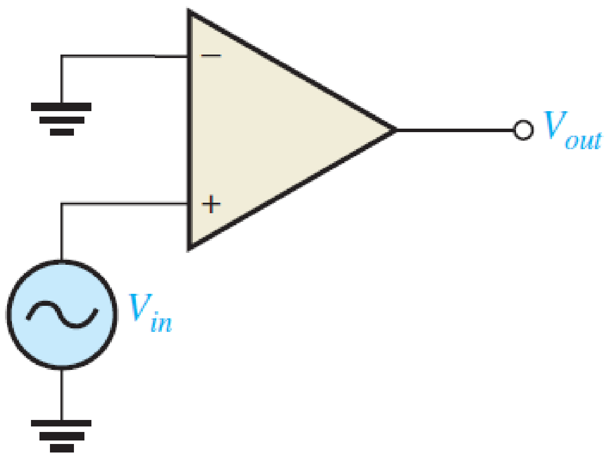
# Comparators

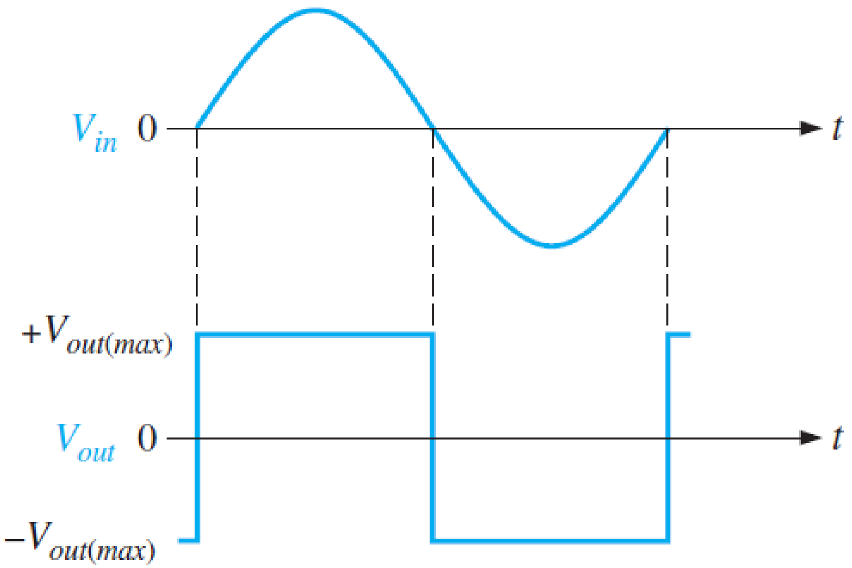
# Comparators

- A comparator is a specialized op-amp circuit in which the main function is to compare two input voltages, with the output always at either one of two states (high or low).
- Op-amp comparator provides very fast switching times that optimize the comparison function.
- It is also often used to interface between an analog and digital circuit. The following are the different types of op-amp as comparators circuit.
  - Zero-Level Detection
  - Nonzero-Level Detection
  - Output Bounding

# Zero Level Detection

- One application of an op-amp used as a comparator is to determine when an input voltage exceeds a certain level. The inverting input is connected to the ground to produce zero lever reference, and the input voltage is connected to the noninverting terminal. A very small difference in the input voltages will produce a saturation level at the output because of the high open-loop gain of the amplifier. You will also see in the figure that an input of sinusoidal voltage in the noninverting input drives the circuit to produce a square wave output voltage. When the sine wave is positive, the output is at maximum positive level and when it crosses to zero, the output goes to maximum negative level.



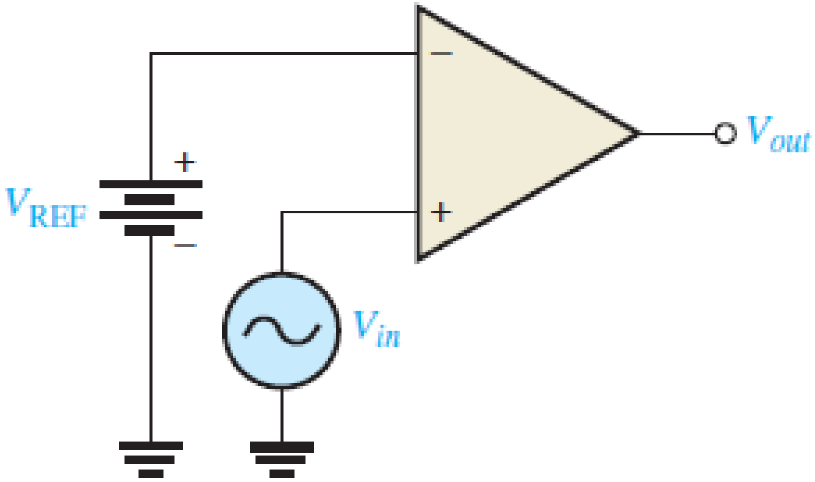



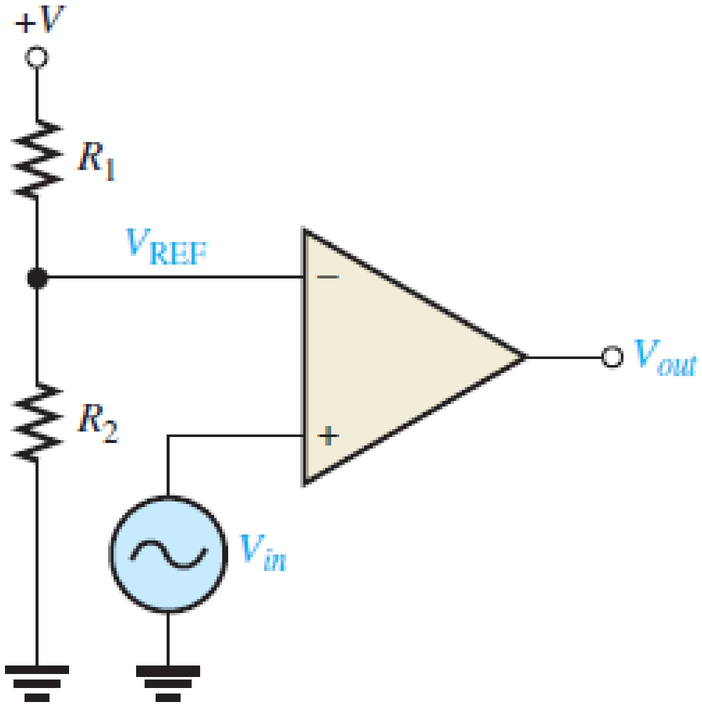
# Non-Zero Level Detection

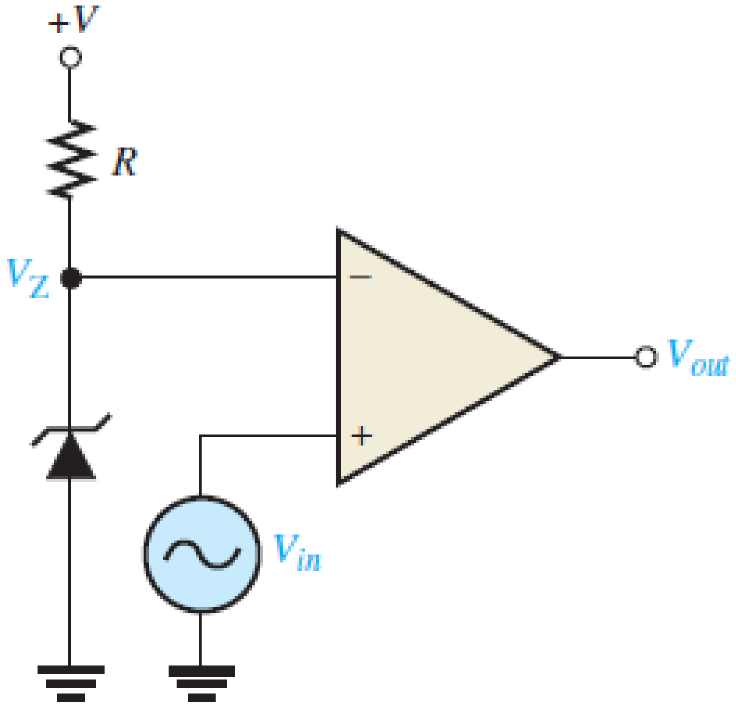
- The modified zero-level detector by applying fixed reference voltage source to the reference input terminal (the voltage reference is connected the inverting input).
- The reference voltage can be in the form of fixed dc voltage source, voltage divider, or the used of Zener diode.
- The voltage reference is defined by the equation: $V_{ref} = \frac{R_2}{R_1+R_2}(+V)$

  where $+V$ is the positive op-amp dc supply voltage.
- The circuit that uses a Zener diode to set the reference voltage ($V_{REF} = V_Z$).

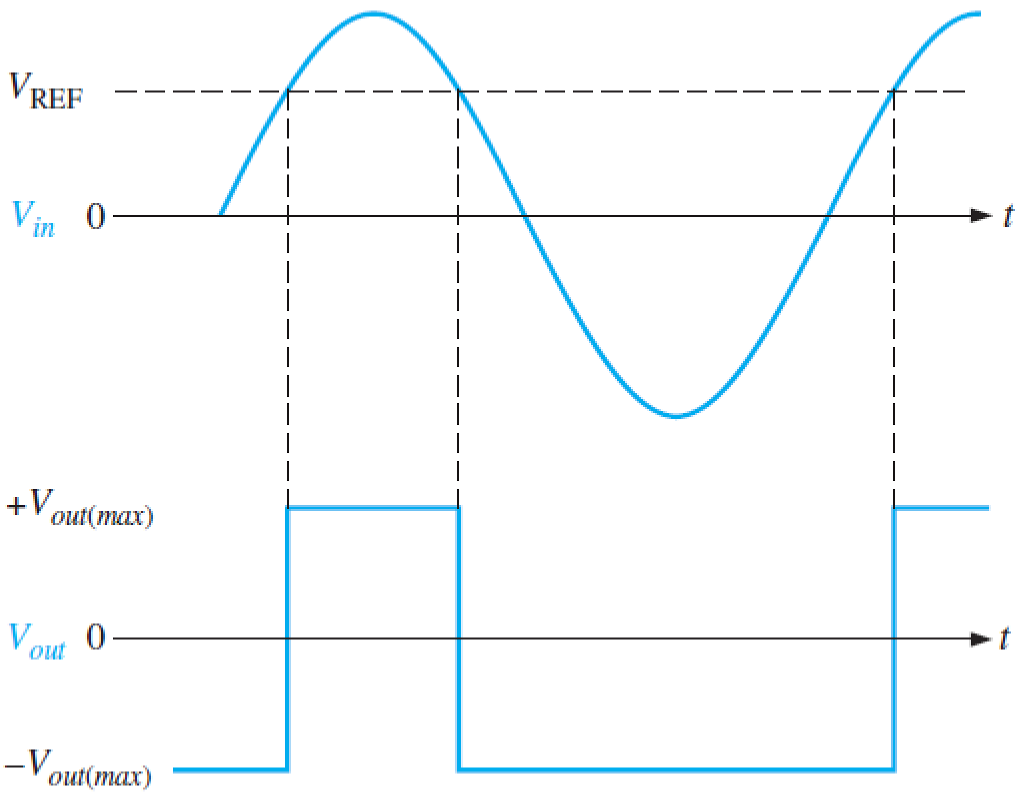
# Non-Zero Level Detection



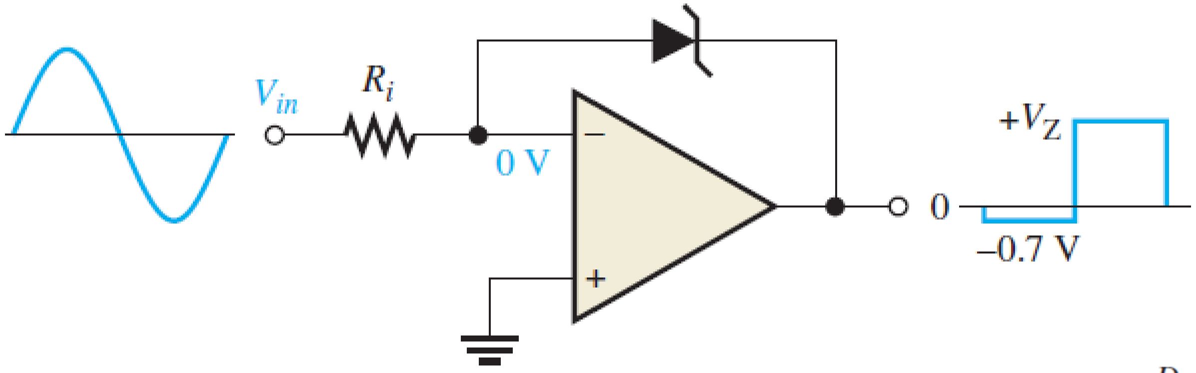



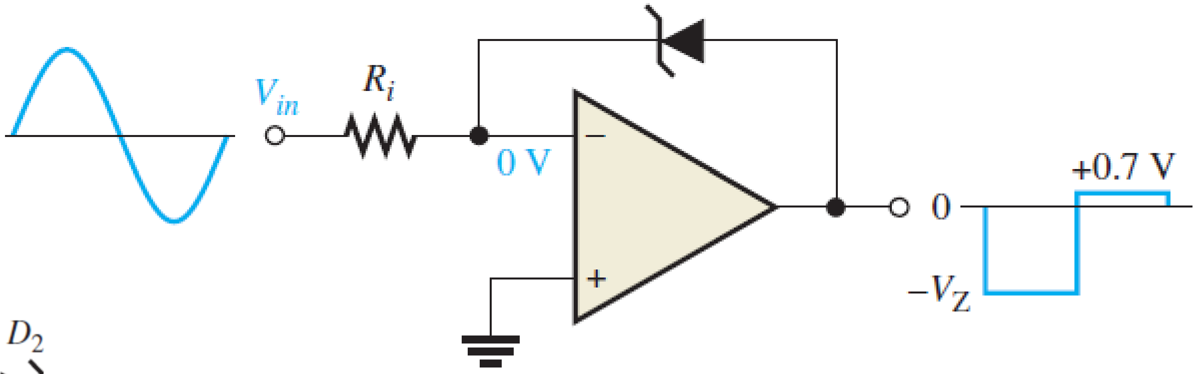
# Non-Zero Level Detection

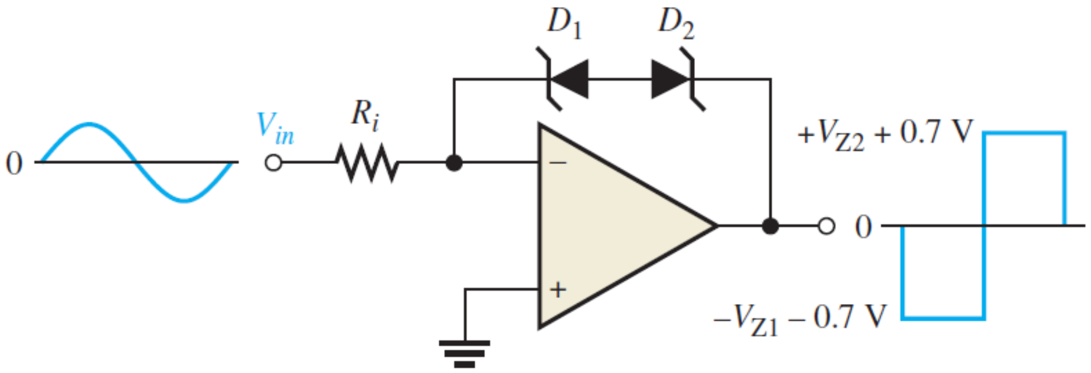


# Output Bounding

- In some applications, the output voltage levels of a comparator should be limit to some values that less than to the maximum output voltage level. Zener diode feedback is used to limit the output voltage range. The operation is as follows. Since the anode of the Zener is connected to the inverting (-) input, it is at virtual ground (> 0 V).



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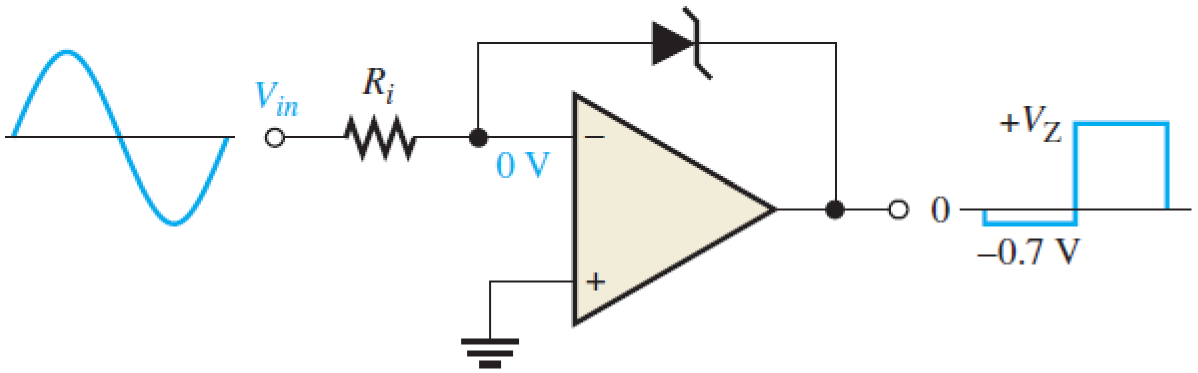


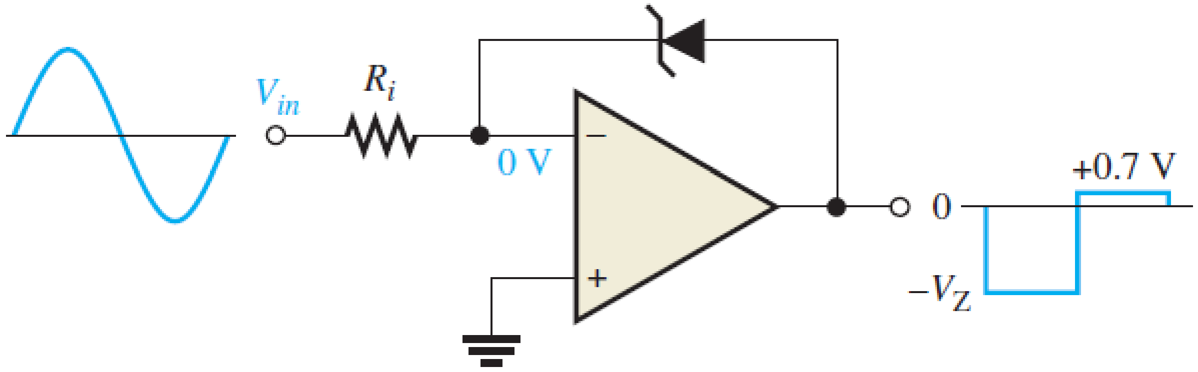

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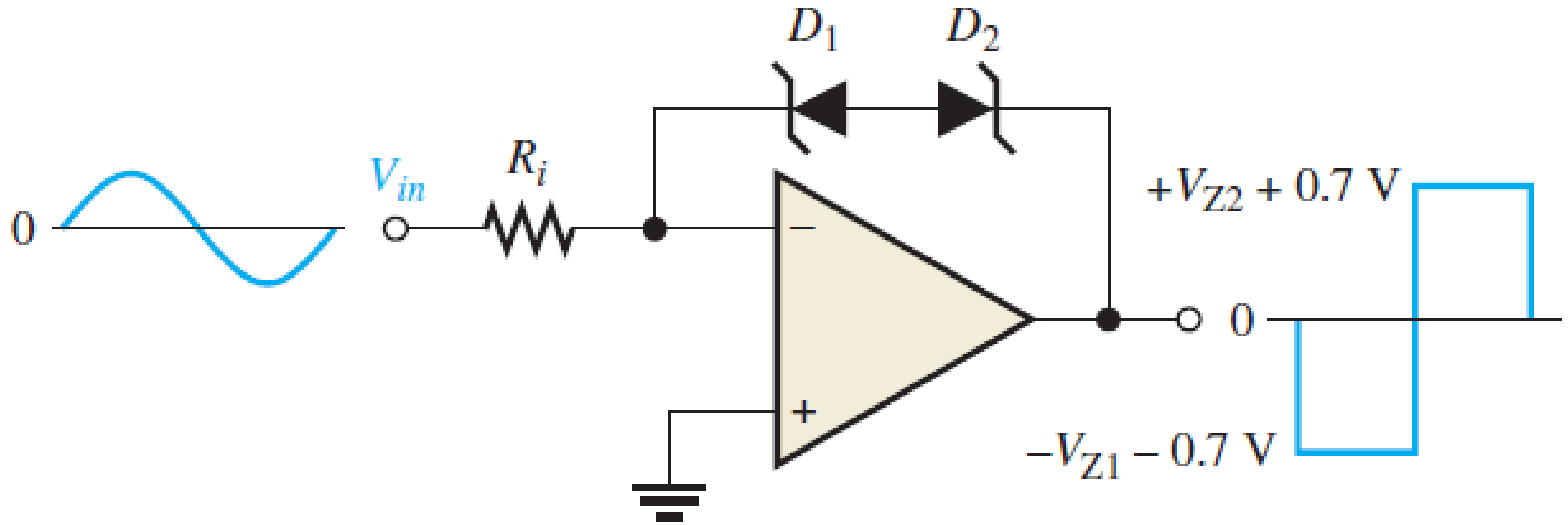
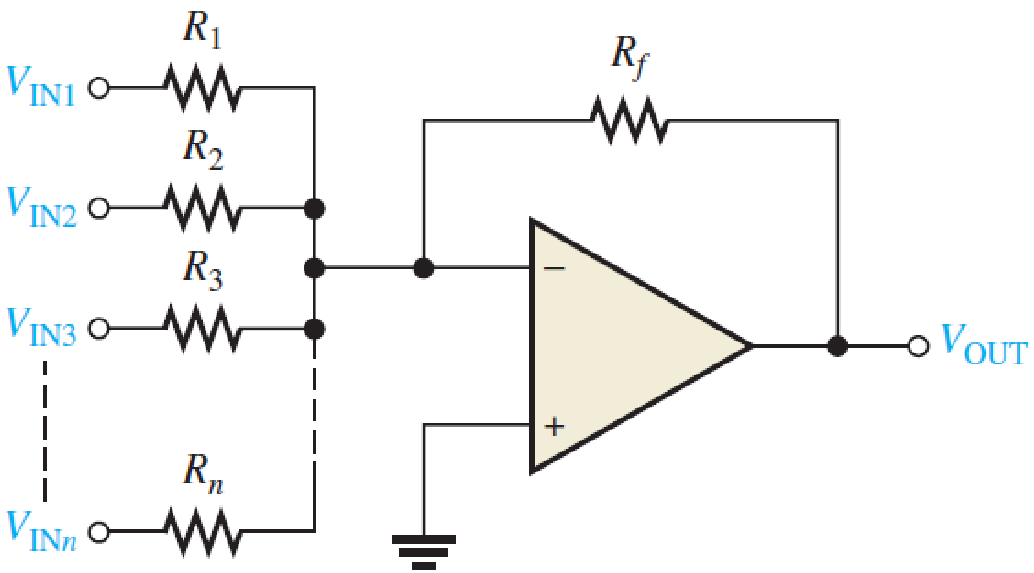


# Summing Amplifier

# Summing Amplifier

A summing amplifier has two or more inputs that provide a means of algebraically summing multiple voltages, each multiplied by a c

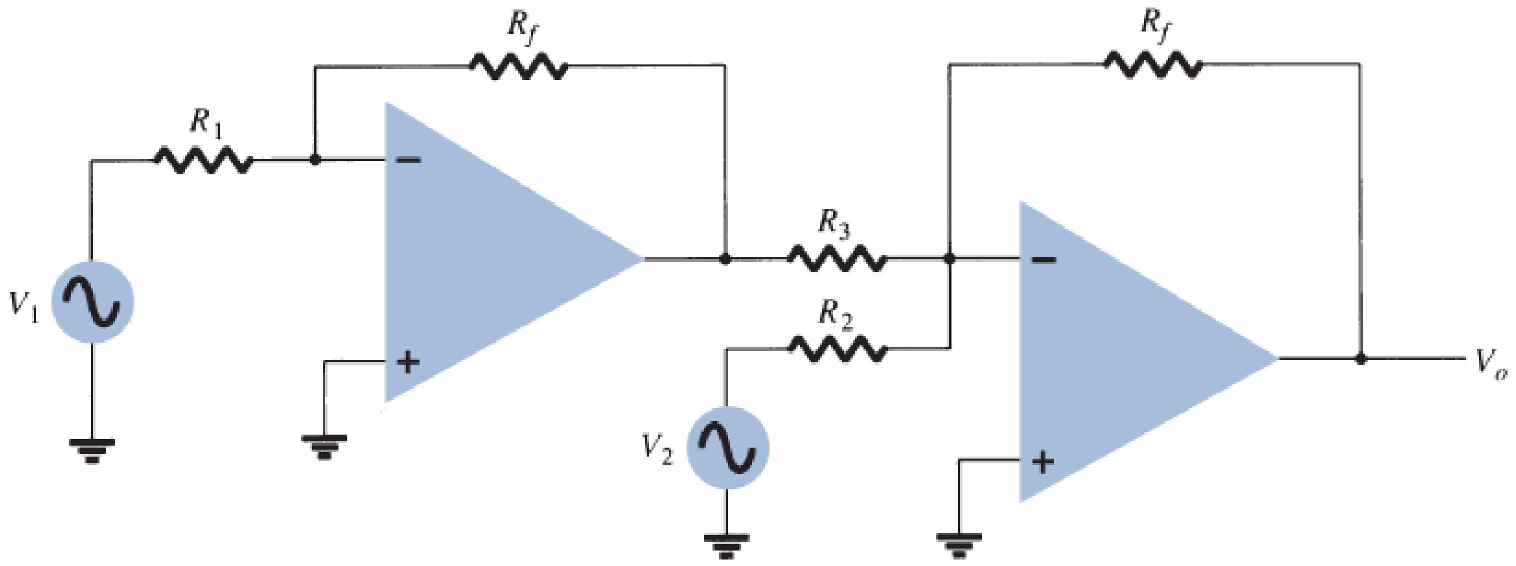



$$V_{OUT} = -\left(\frac{R_f}{R_1}V_{IN1} + \frac{R_f}{R_2}V_{IN2} + \frac{R_f}{R_3}V_{IN3} + \cdots + \frac{R_f}{R_N}V_{INn}\right)$$

# Voltage Subtraction

Two signals can be subtracted from one another in a number of ways. Figure below shows two op-amp stages used to provide subtraction of input signals. The resulting output is given by

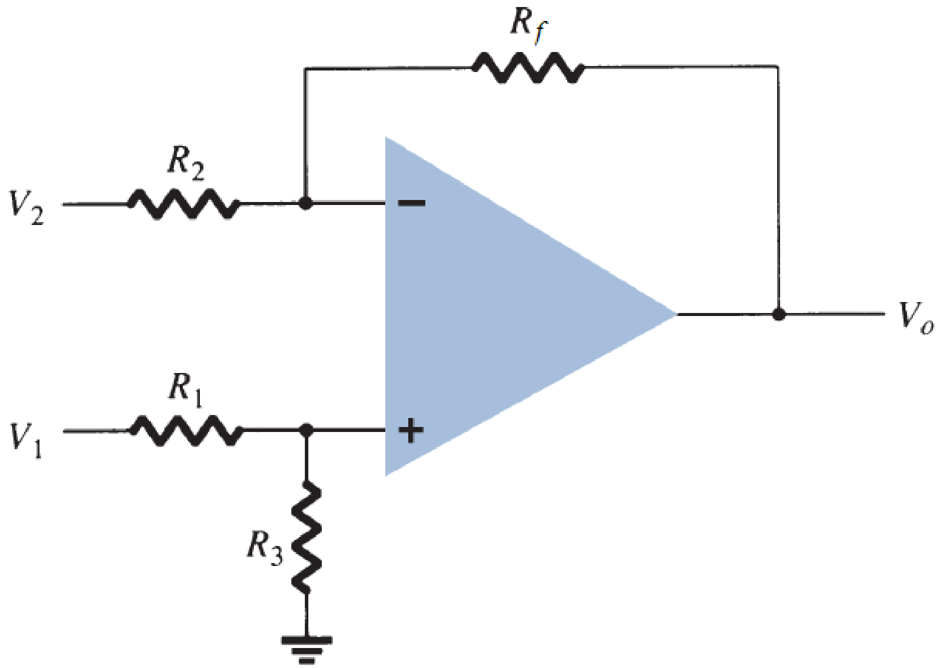
$$V_{O2} = -\left[\frac{R_f}{R_2}V_2 - \frac{R_f}{R_3}\left(\frac{R_f}{R_1}V_1\right)\right]$$



# Voltage Subtraction

Another circuit that can perform subtraction is shown in 9.11. Using superposition, the output voltage is

$$V_{out} = -\frac{R_3}{R_1 + R_3}\frac{R_2 + R_f}{R_2}V_{in1} - \frac{R_f}{R_2}V_{in2}$$

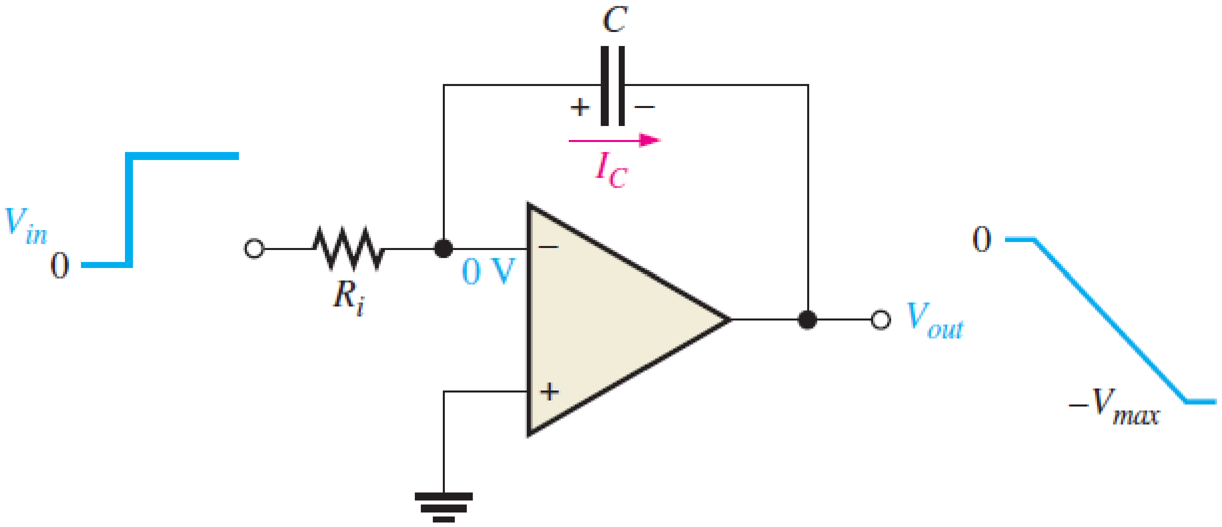


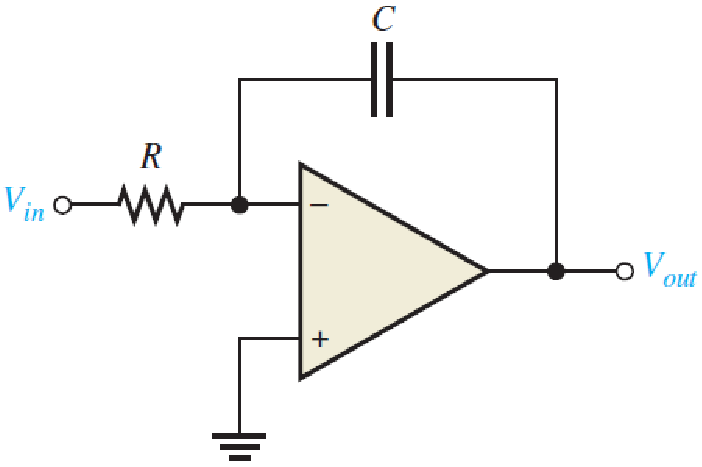
# Calculus Operations

# Integrator

An op-amp integrator simulates mathematical integration, which is basically a summing process that determines the total area under the curve of a function. An ideal integrator used capacitor as feeding element forms an RC circuit with the input resistor

$$V_{OUT} = -\frac{1}{RC}\int V_{in}(t)dt$$

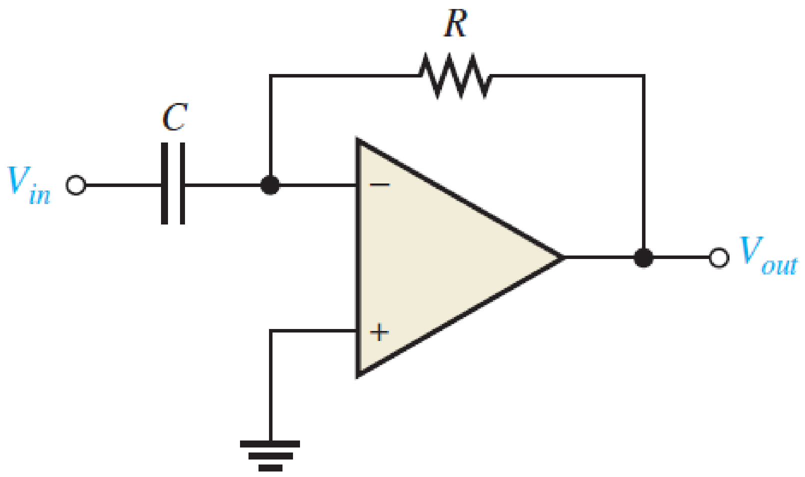


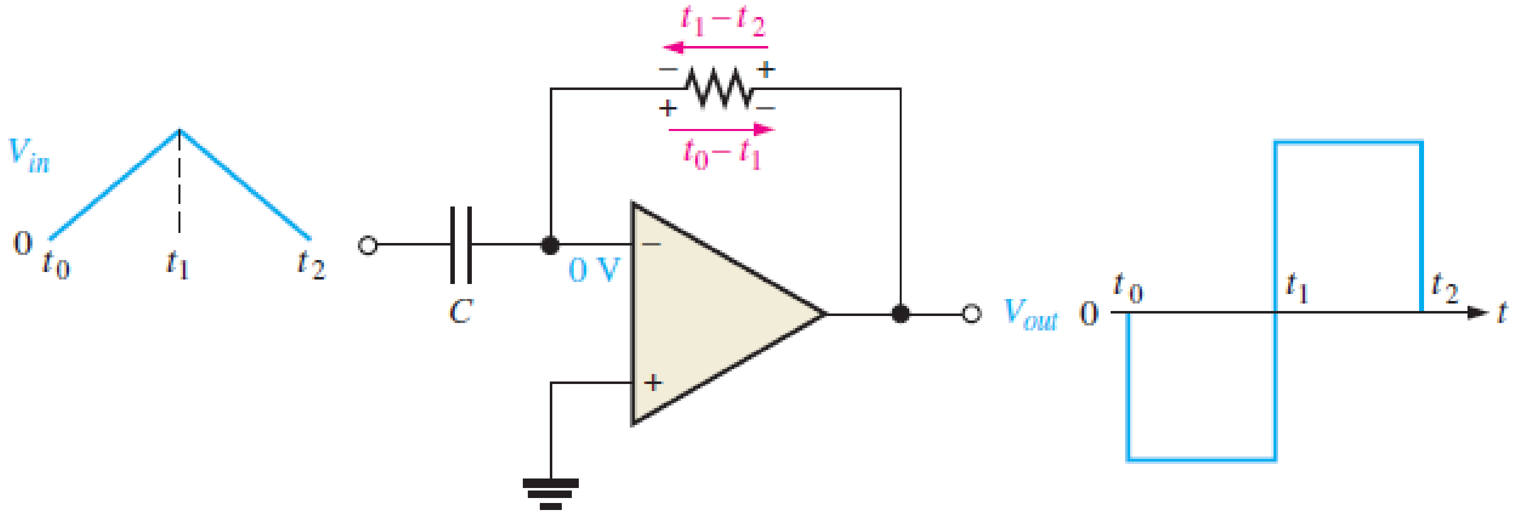



# Differentiator

The differentiator circuit consists of capacitor as input element and resistor as feedback element. The differentiator circuit produced an output that is proportional to the rate of change of the input voltage.

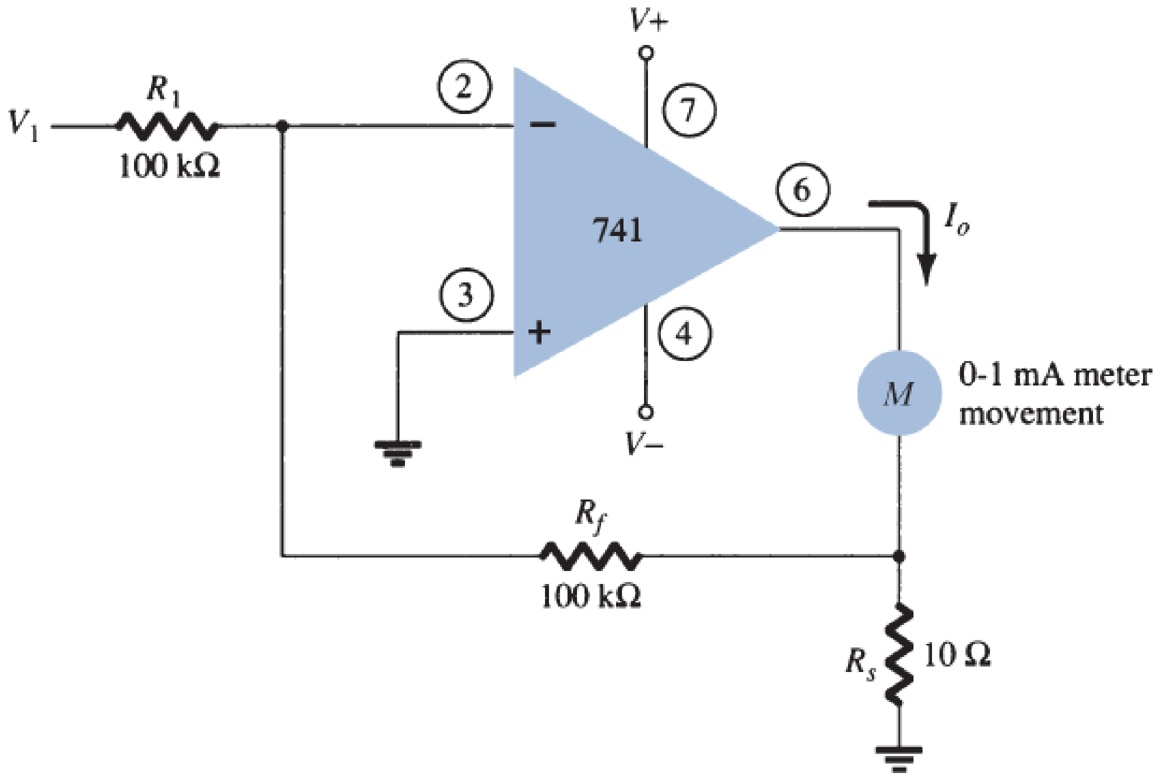
$$V_{OUT} = -RC\frac{d\,V_{IN}(t)}{dt}$$



# dc Millivoltmeter

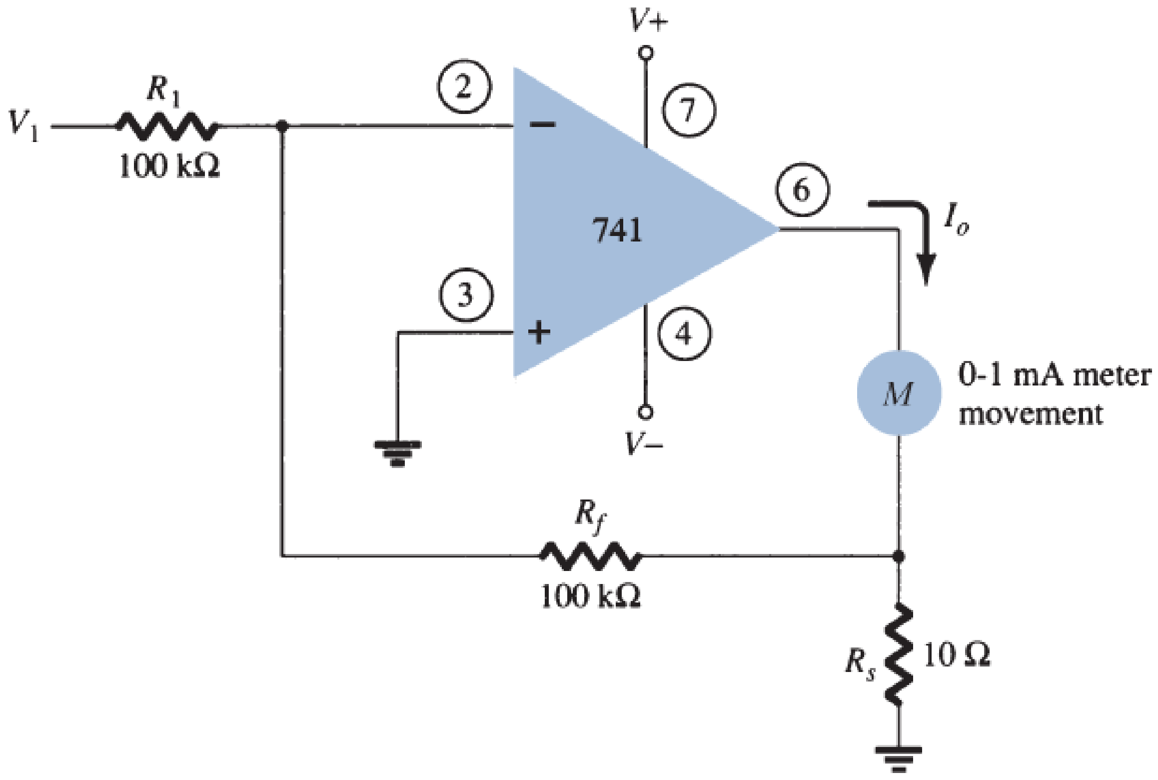
- Figure shows an op-amp used as basic dc millivoltmeter. The amplifier provides a meter with high $Zi$ and scale factors that dependent only on resistor value. The meter of the circuit represents millivolts range of signal at the input of the circuit. An analysis of the op-amp circuit provides the circuit transfer function




$$\left|\frac{I_o}{V_1}\right| = \frac{R_f}{R_1}\frac{1}{R_s} = \left(\frac{100k\Omega}{100k\Omega}\right)\left(\frac{1}{10\Omega}\right) = \frac{1mA}{10mV}$$

# dc Millivoltmeter

- It means that an input of 10$mV$ will result of 1$mA$ reading through the meter. If we change the input to 5 $mV$, the current that will flow to the meter will be 0.5$mA$, which is half-scale deflection. Changing the value of $Rf$ to 200$k\Omega$ will give us a full scale factor giving us a 5$mV$ full scale of the meter.



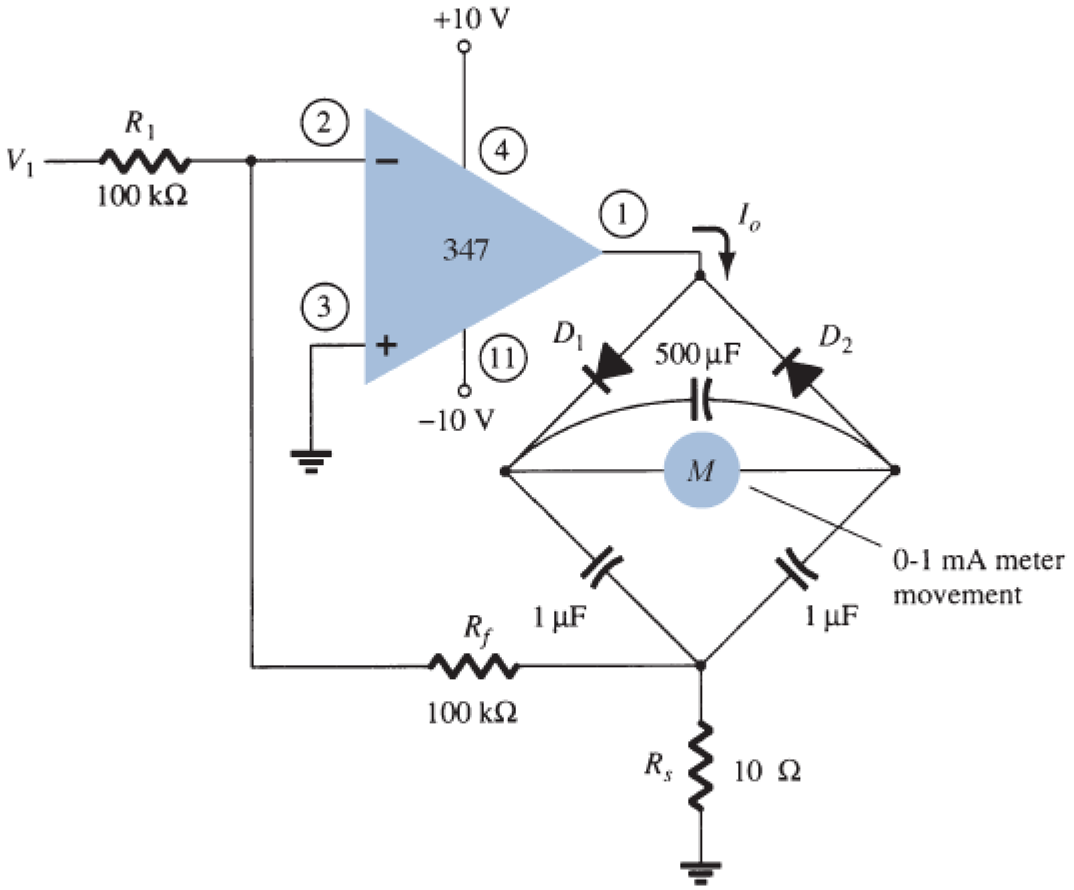

$$\left|\frac{I_o}{V_1}\right| = \frac{R_f}{R_1}\frac{1}{R_s} = \left(\frac{200k\Omega}{100k\Omega}\right)\left(\frac{1}{10\Omega}\right) = \frac{1mA}{5mV}$$

# ac Millivoltmeter

- Another application of op-amp is the ac millivoltmeter shown.The circuit transfer function is defined by

$$\left|\frac{I_o}{V_1}\right| = \frac{R_f}{R_1}\frac{1}{R_s} = \left(\frac{100k\Omega}{100k\Omega}\right)\left(\frac{1}{10\Omega}\right) = \frac{1mA}{10mV}$$

which appears the same as the dc millivoltmeter, except that in this case the signal handled is an ac signal. The full scale deflection of the meter is 10$mV$ ac input voltage. An ac input of 5 mV will result in half-scale deflection.



# End