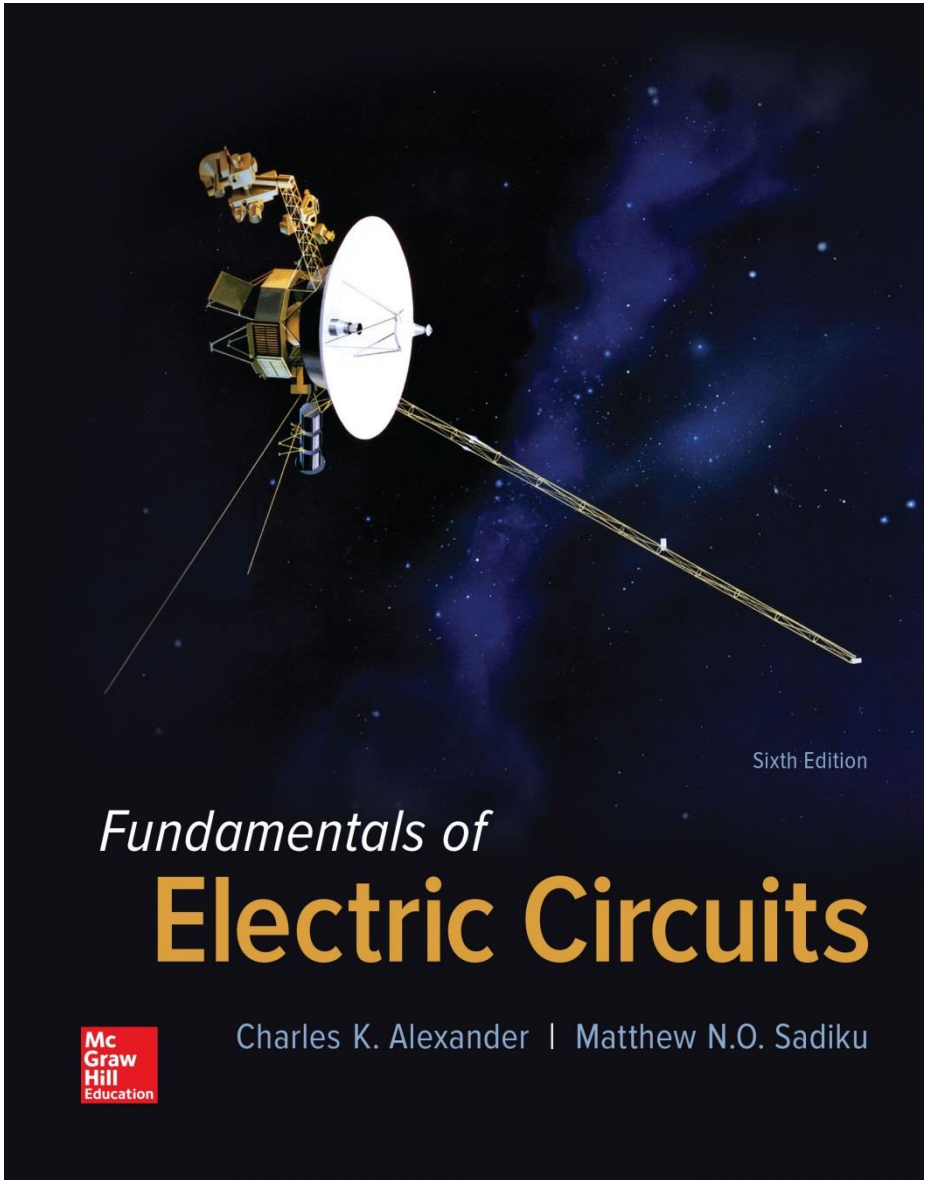
Fundamentals of Electric Circuits
Chapter 5



Overview

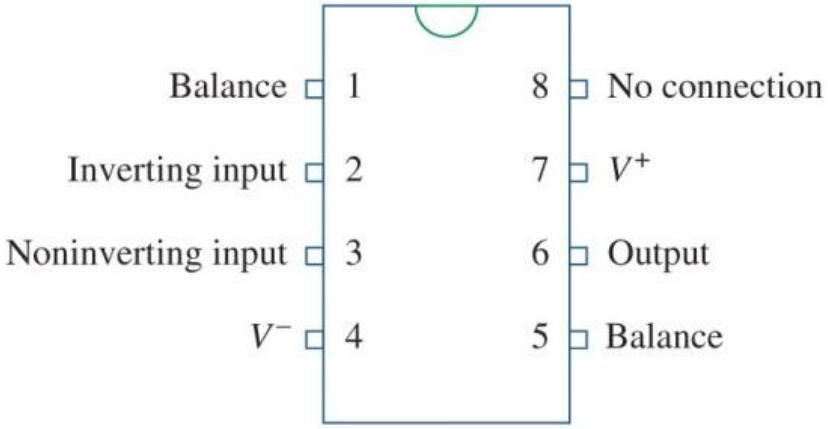
- **In this chapter, the operation amplifier will be introduced.**
- **The basic function of this useful device will be discussed.**
- **Examples of amplifier circuits that may be constructed from the operation amplifier will be covered.**
- **Instrumentation amplifiers will also be discussed.**

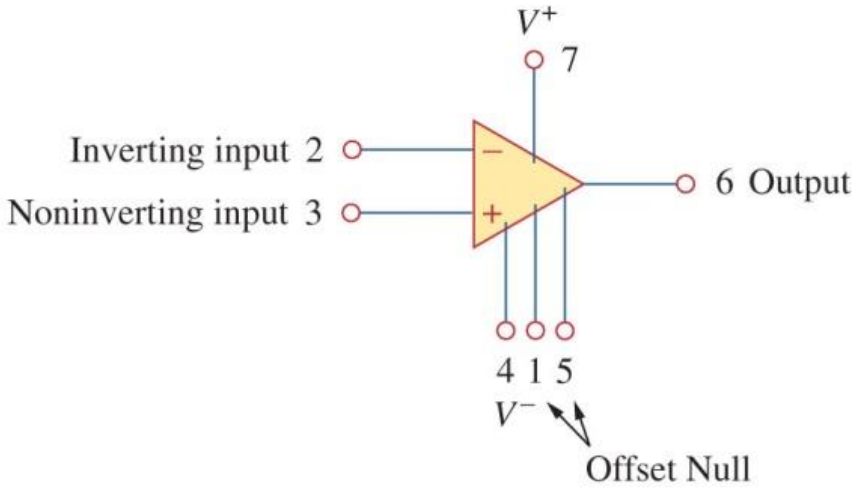
Operational Amplifier

- **Typically called ‘Op Amp’ for short**
- **It acts like a voltage controlled voltage source**
- **In combination with other elements it can be made into other dependent sources**
- **It performs mathematical operations on analog signals**

Operational Amplifier II

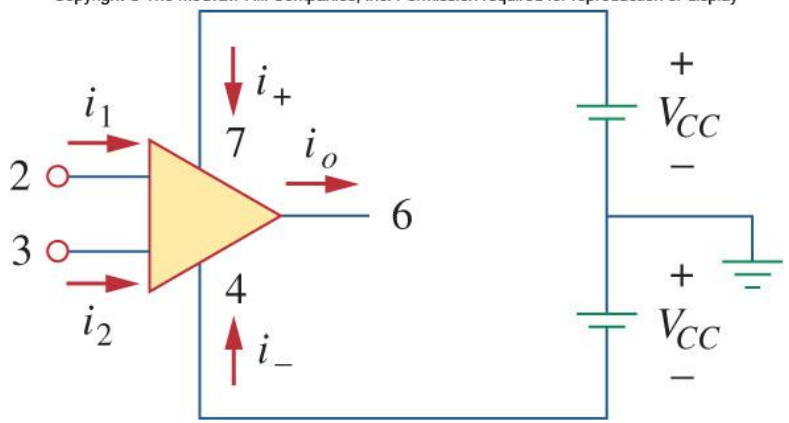
- **The op amp is capable of many math operations, such as addition, subtraction, multiplication, differentiation, and integration**
- **There are five terminals found on all op-amps**
  - **The inverting input**
  - **The noninverting input**
  - **The output**
  - **The positive and negative power supplies**





Powering an Op-amp

- As an active element, the op-amp requires a power source
- Often in circuit diagrams the power supply terminals are obscured
- It is taken for granted that they must be connected
- Most op-amps use two voltage sources, with a ground reference between them
- This gives a positive and negative supply voltage



Output Voltage

- **The voltage output of an op-amp is proportional to the difference between the noninverting and inverting inputs**

$$v_o = Av_d = A(v_2 - v_1)$$

- **Here, *A* is called the open loop gain**
- **Ideally it is infinite**
- **In real devices, it is still high: 10^5 to 10^8 volts/volt**

TABLE 5.1

Typical ranges for op amp parameters.

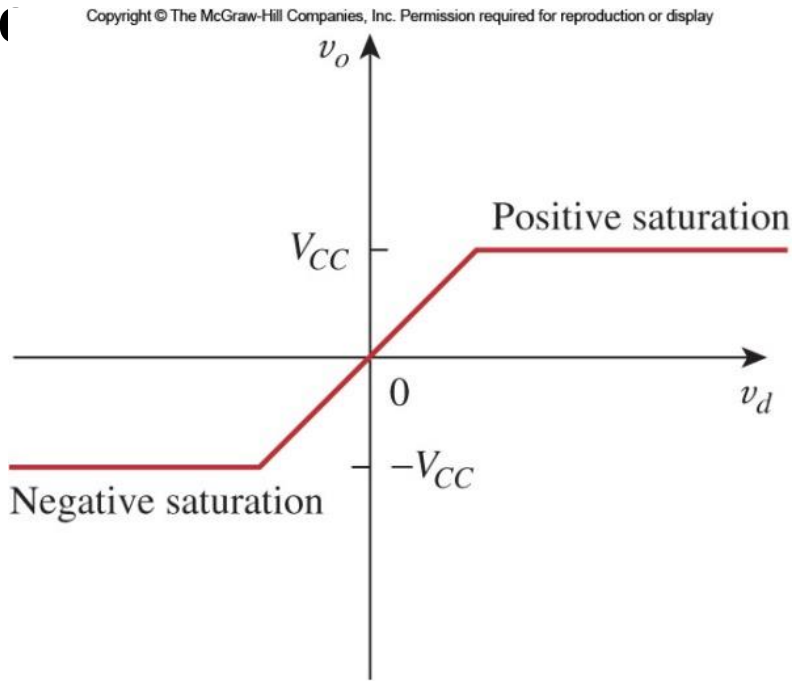
Parameter	Typical range	Ideal values
Open-loop gain, A	10^5 to 10^8	∞
Input resistance, R_i	10^5 to $10^{13}\ \Omega$	$\infty\ \Omega$
Output resistance, R_o	10 to 100 Ω	$0\ \Omega$
Supply voltage, V_{CC}	5 to 24 V	

Feedback

- **Op-amps take on an expanded functional ability with the use of feedback**
- **The idea is that the output of the op-amp is fed back into the inverting terminal**
- **Depending on what elements this signal passes through the gain and behavior of the op-amp changes**
- **Feedback to the inverting terminal is called “negative feedback”**
- **Positive feedback would lead to oscillations**

Voltage Saturation

- As an ideal source, the output voltage would be unlimited
- In reality, one cannot expect the output to exceed the supply voltages
- When an output should exceed the possible voltage range, the output remains at either the maximum or minimum supply voltage
- This is called saturation
- Outputs between these limiting voltages are referred to as the linear region

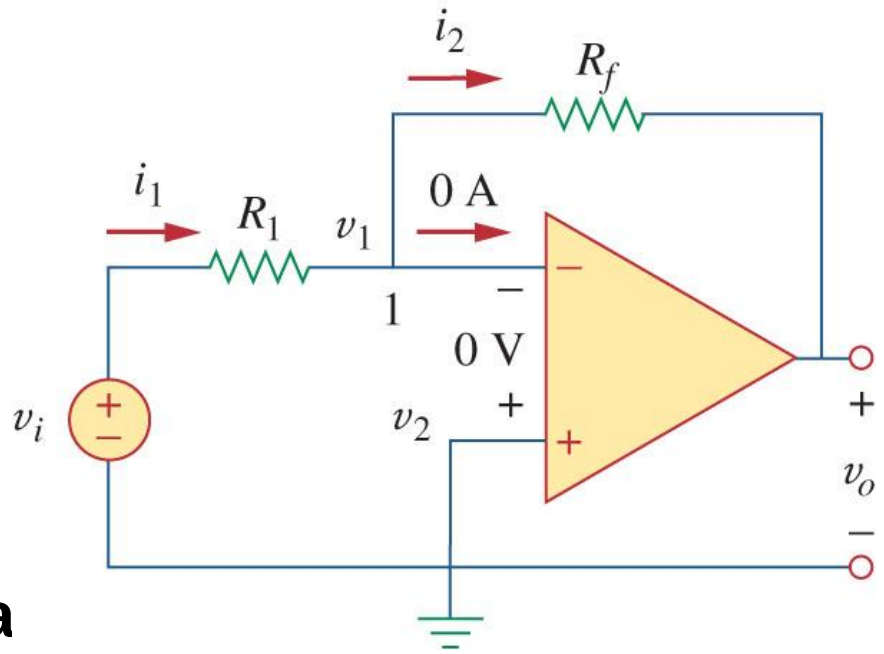


Ideal Op Amp

- We give certain attributes to the ideal op-amp
- As mentioned before, it will have an infinite open-loop gain
- The resistance of the two inputs will also be infinite
- This means it will not affect any node it is attached to
- It is also given zero output impedance
- From Thevenin's theorem one can see that this means it is load independent

Inverting Amplifier

- The first useful op-amp circuit that we will consider is the inverting amplifier
- Here the noninverting input is grounded
- The inverting terminal is connected to the output via a feedback resistor, R_f
- The input is also connected to the inverting terminal via another resistor, R_1



Inverting Amplifier III

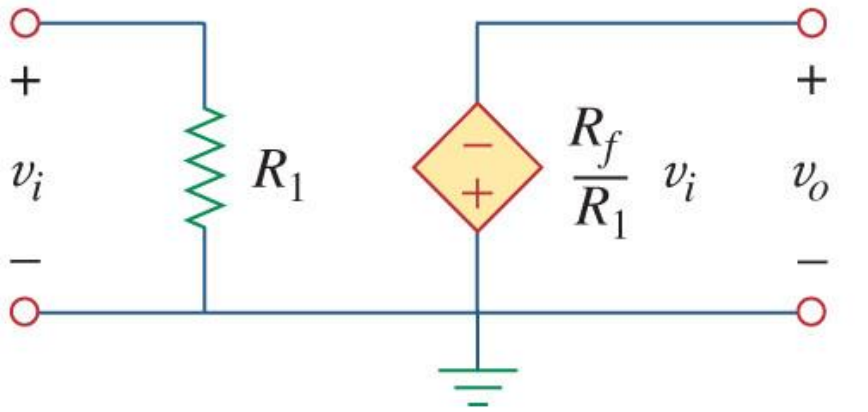
- **This can be rearranged to show the relationship between the input and output voltages**

$$v_o = -\frac{R_f}{R_1} v_i$$

- **From this one can see that:**
  - **The gain is the ratio of the feedback resistor and R_1**
  - **The polarity of the output is the reverse of the input, thus the name “inverting” amplifier**

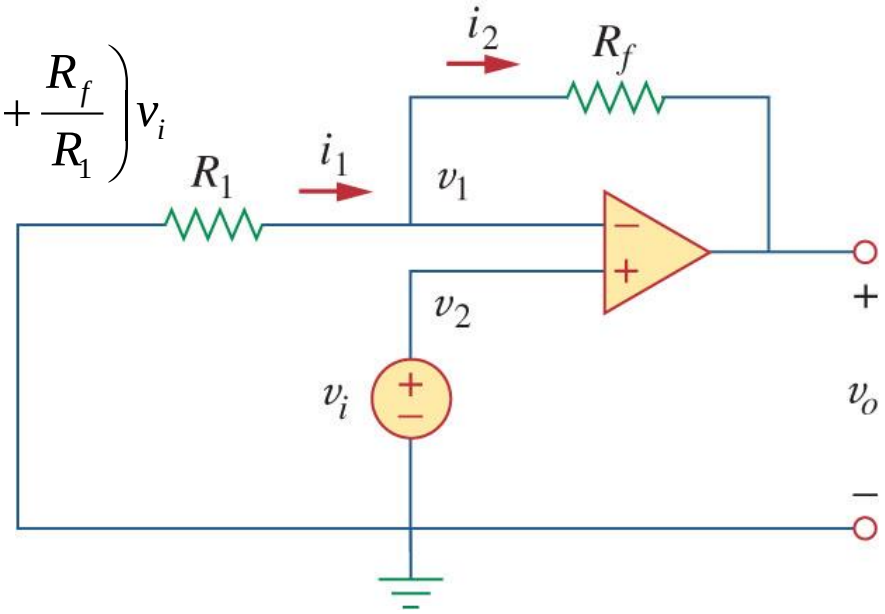
Equivalent Circuit

- The inverting amplifier's equivalent circuit is shown here
- Note that it has a finite input resistance
- It is also a good candidate for making a current-to-voltage converter



Non-Inverting Amplifier

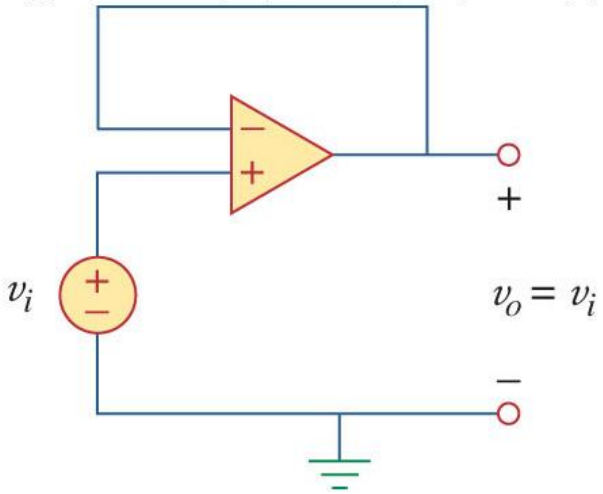
$$v_o = \left(1 + \frac{R_f}{R_1}\right) v_i$$



- **Another important op-amp circuit is the noninverting amplifier**
- **The basic configuration of the amplifier is the same as the inverting amplifier**
- **Except that the input and the ground are switched**

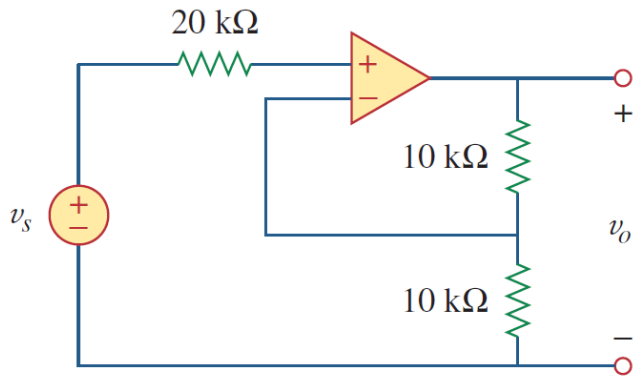
Non-inverting Amplifier II

- Note that the gain here is positive, thus the amplifier is noninverting
- Also note that this amplifier retains the infinite input impedance of the op-amp
- One aspect of this amplifier's gain is that it can never go below 1.
- One could replace the feedback resistor with a wire and disconnect the ground and the gain would still be 1
- This configuration is called a voltage follower or a unity gain amplifier
- It is good for separating two circuits while allowing a signal to pass through.



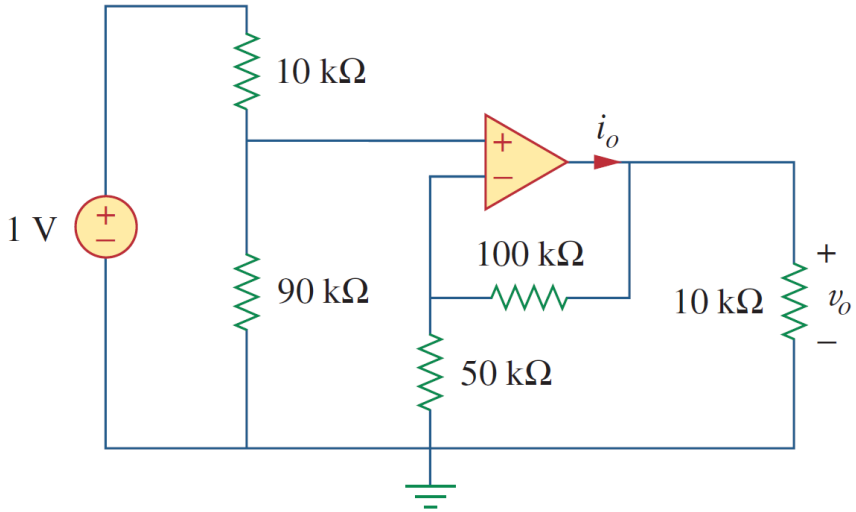
Ejemplo

- **Encuentre la ganancia**



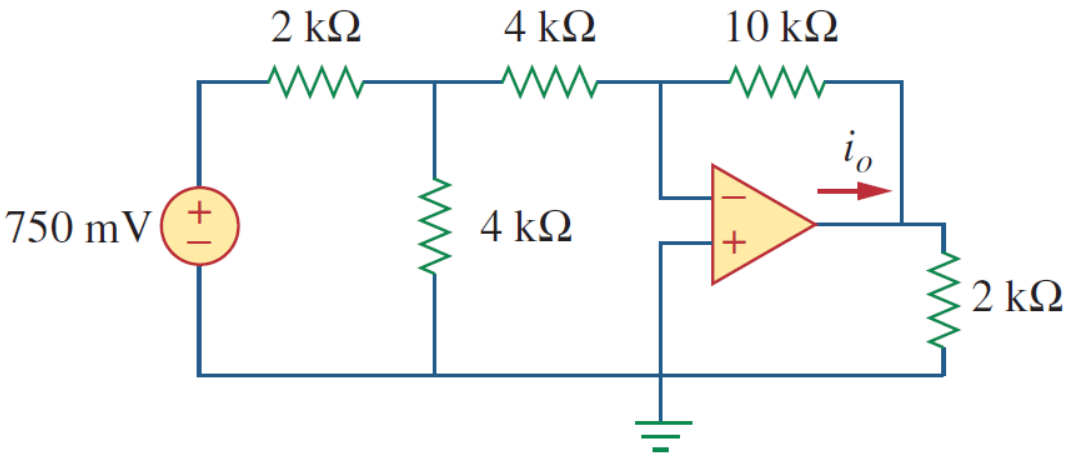
Ejemplo

- **Encuentre V_o e I_o**



Ejemplo

- **Encontrar** i_0



Ejemplo

- **Encontrar v_0 cuando $v_s = 2\ V$**