Basic Electronic Circuits (IEC-103)

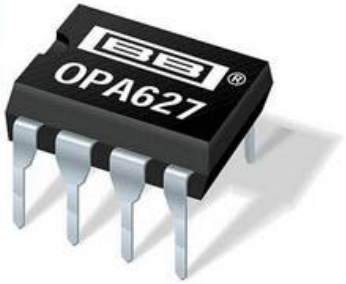
Lecture-03

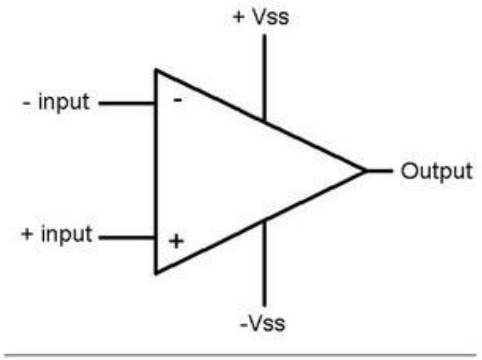
Operational Amplifiers

Operational Amplifier

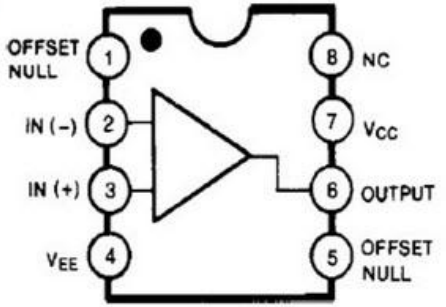
- Typically called 'Op Amp' for short.
- Used in large variety of electronic circuits.
- It acts like a voltage controlled voltage source.
- In combination with other elements it can be made into other dependent sources
- It performs mathematical operations on analog signals

741 Op Amp IC

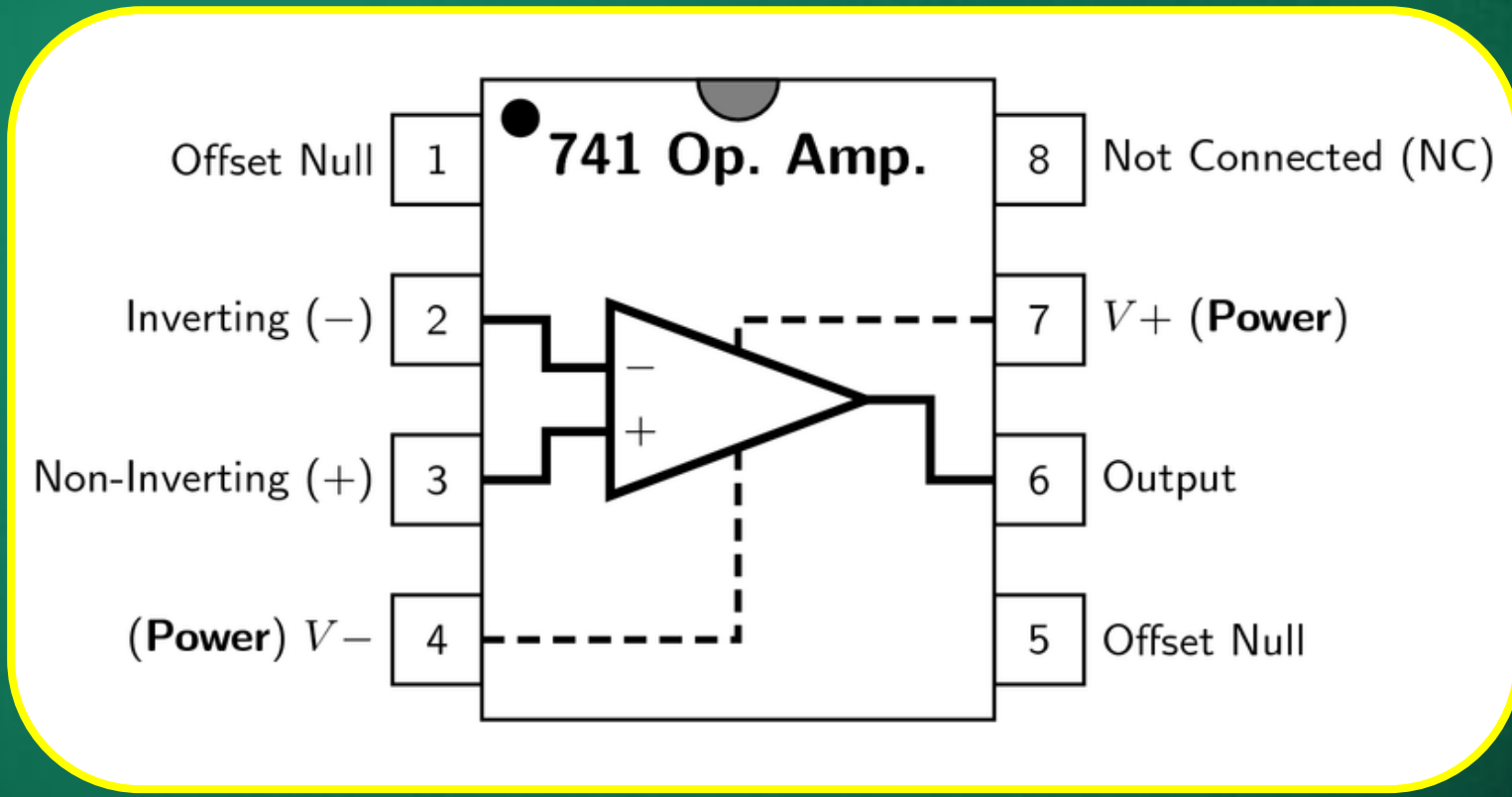




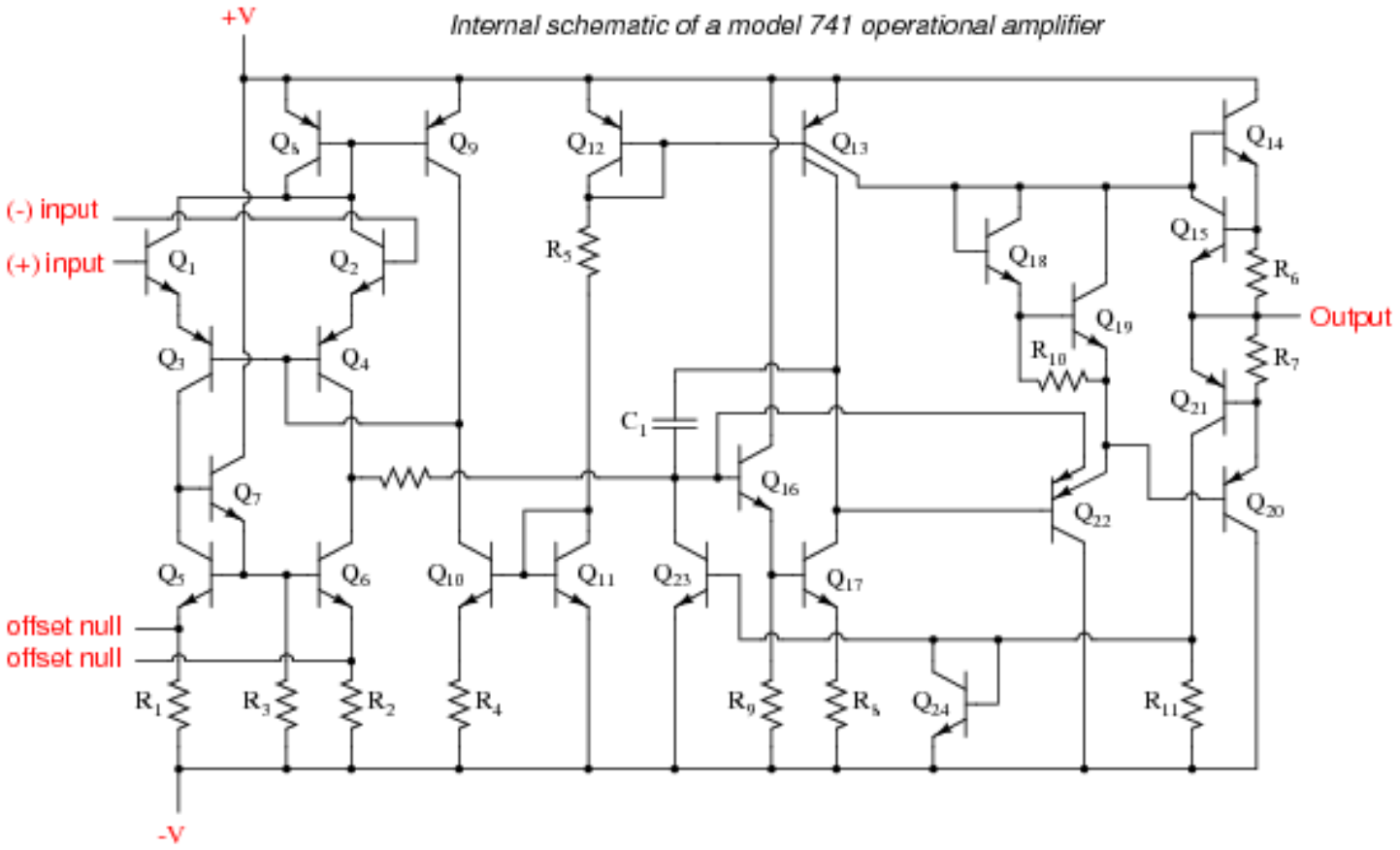
OP-AMP



741 Op Amp IC (Pin Diagram)



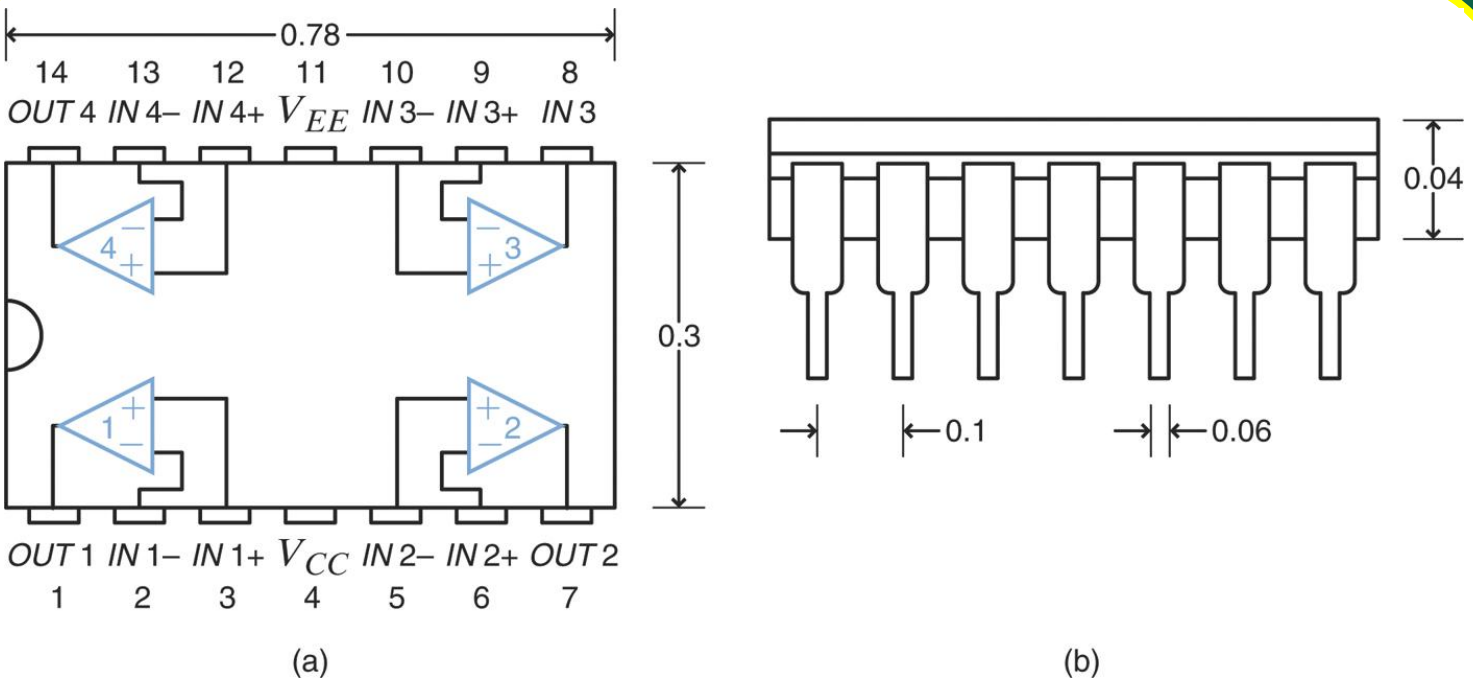
741 Op Amp IC (Circuit Diagram)



741 Op Amp IC

- It is most versatile IC available.
- It is a linear amplifier.
- It is an 8 Pin Chip.
- Applications – Filters, ECG amplification, strain gauges, signal conditioning in transducers, control systems.
- Available in 2 configurations – 8 Pin and 14 Pin.

14 Pin Op-amp Chip



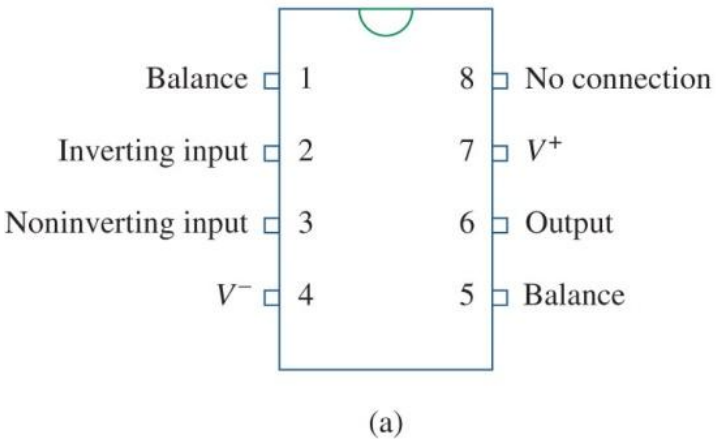
Operational Amplifiers

The op amp is capable of many math operations, such as addition, subtraction, multiplication, differentiation, and integration.

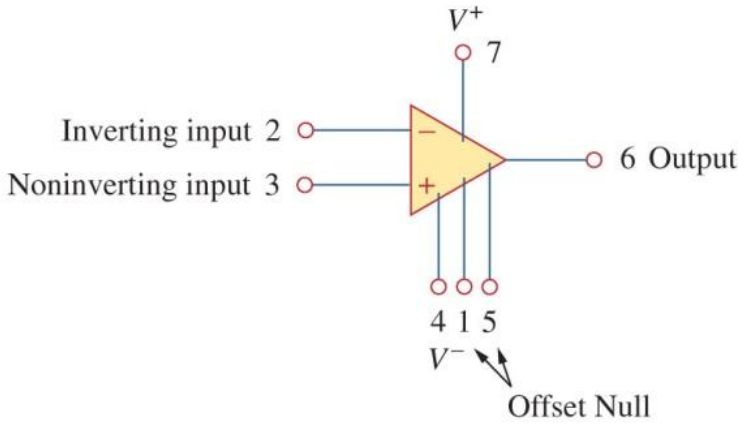
There are five terminals found on all op-amps

- The inverting input
- The noninverting input
- The output
- The positive and negative power supplies.

Operational Amplifier



(a)



(b)

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.

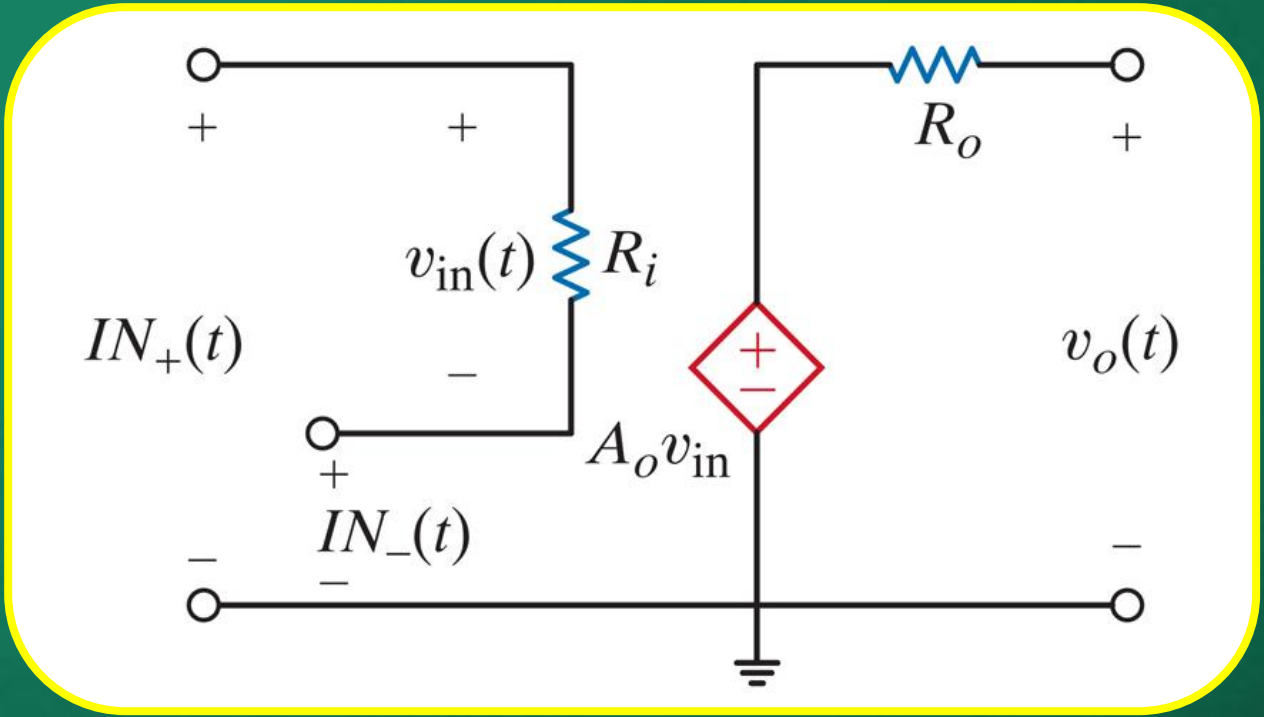
Output Voltage of an Op-amp

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

$$v_o = Av_d = A(v_+ - v_-)$$

- 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

Equivalent Circuit of an Op-amp



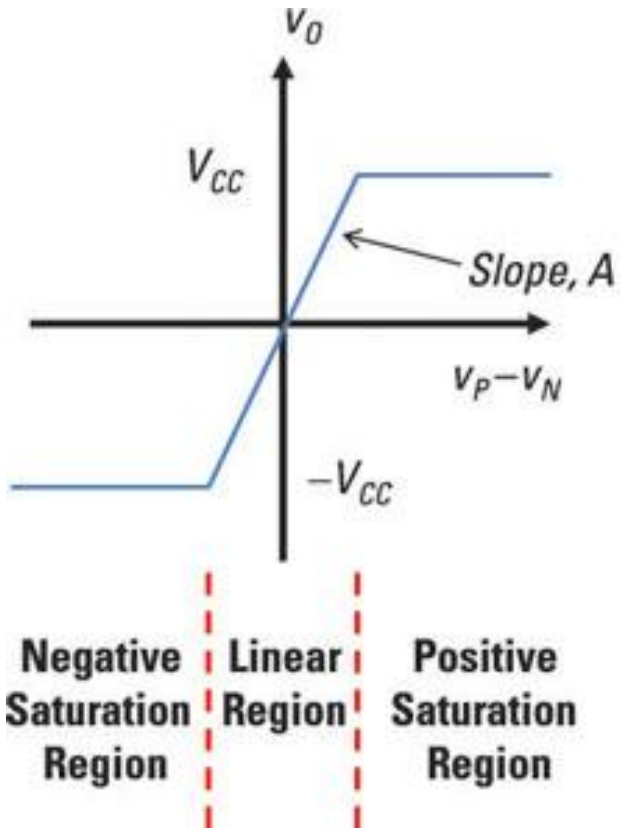
Typical Ranges of Op-amp Parameters

TABLE 5.1

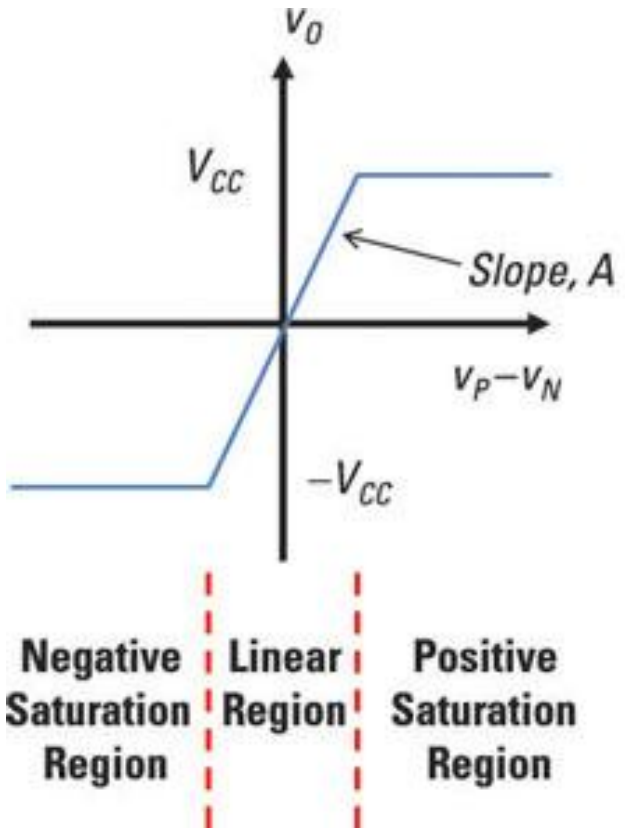
Typical ranges for op amp parameters.

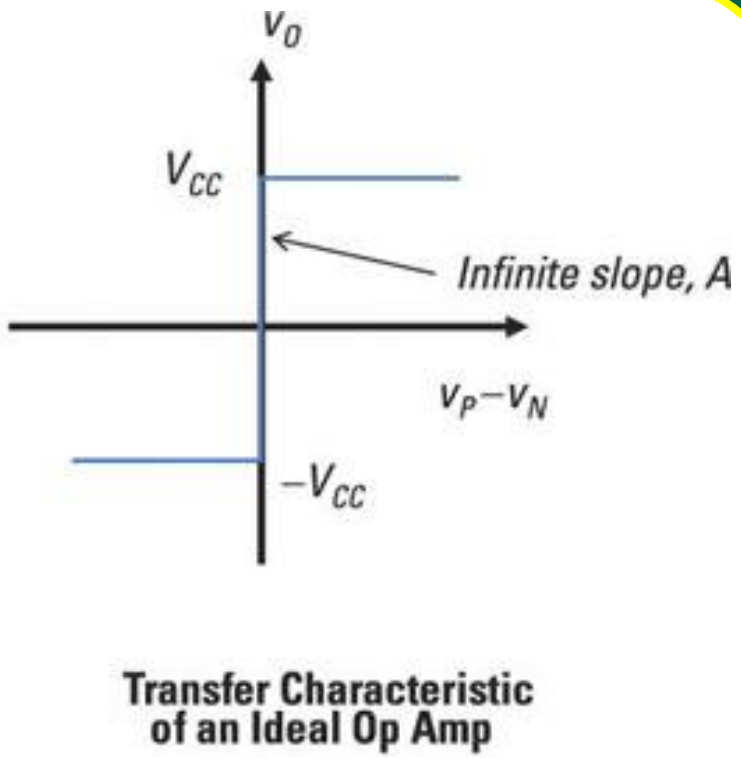
Parameter	Typical range	Ideal values
Open-loop gain, A	10^5 to 10^8	∞
Input resistance, R_i	10^5 to $10^{13}\ \Omega$	$\infty\ \Omega$
Output resistance, R_o	10 to 100 Ω	0 Ω
Supply voltage, V_{CC}	5 to 24 V	

Transfer Characteristics of an Op-amp



Transfer Characteristics of an Op-amp





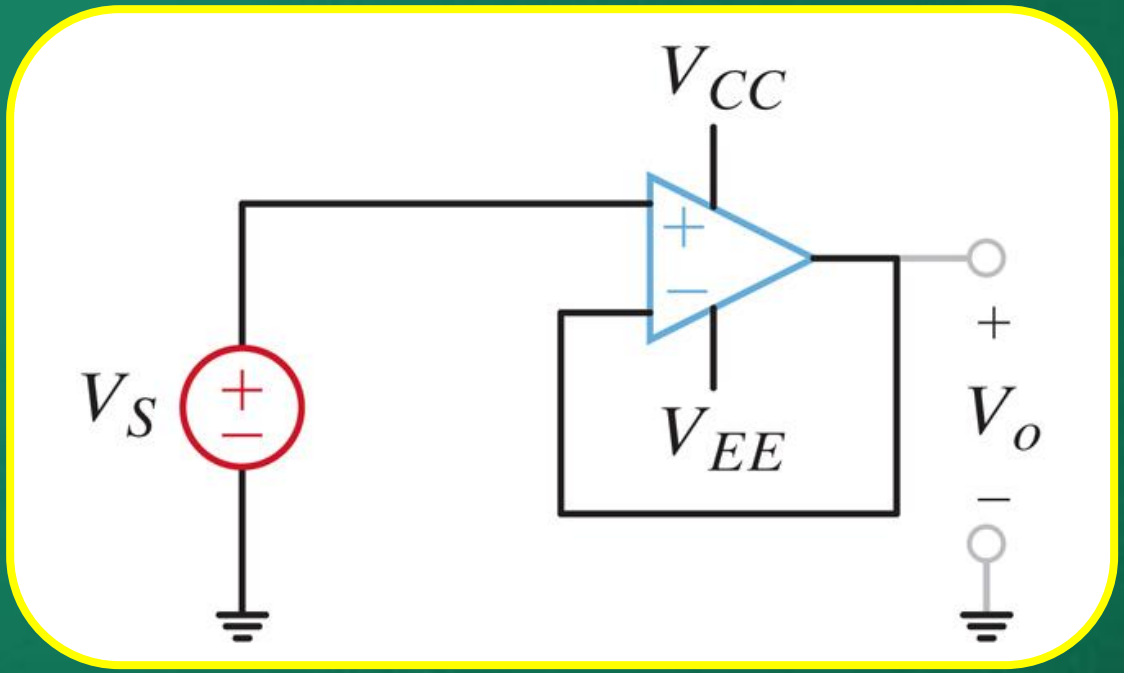
Transfer Characteristic of an Ideal Op Amp

Feedback

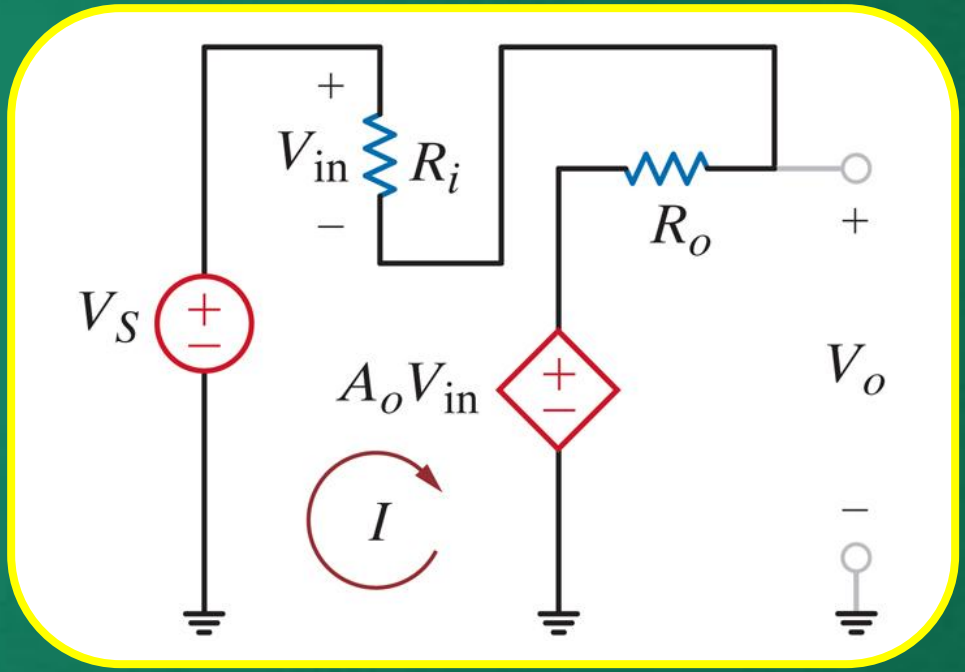
- Op-amps take on an expanded functional ability with the use of feedback.
- The idea is that the output of the op-amp is fed back into the inverting terminal.
- Depending on what elements this signal passes through the gain and behavior of the op-amp changes.
- Feedback to the inverting terminal is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

Op-amp Analysis

Unity Gain Buffer



Analysis using Circuit Model



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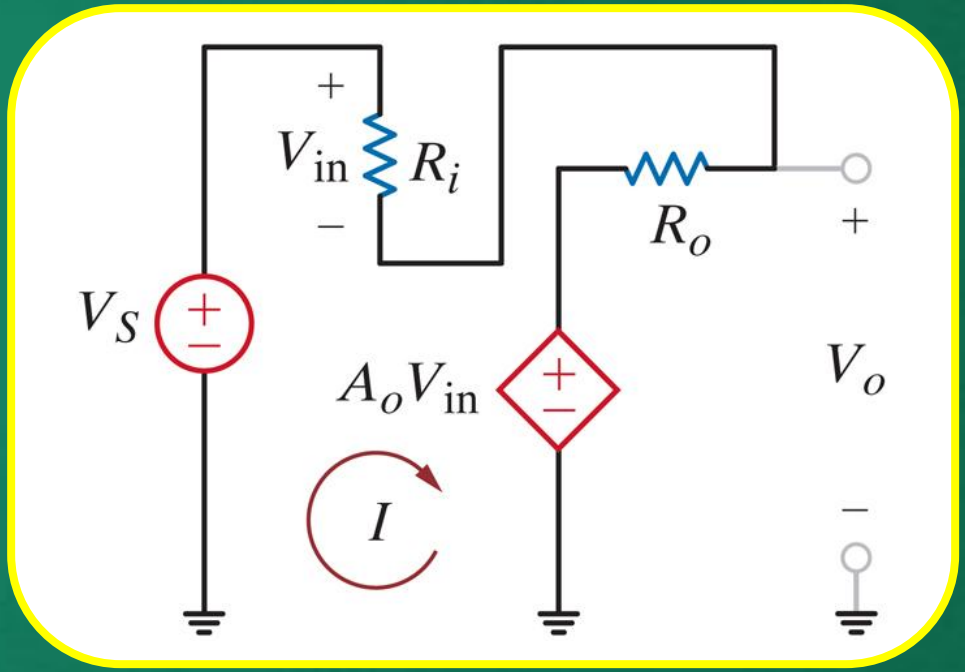

$$\frac{V_o}{V_s} = \frac{1}{1 + \frac{R_i}{R_O + A_O R_i}}$$

Ideal Op-amp Rules

- No current ever flows into either of the input terminals.

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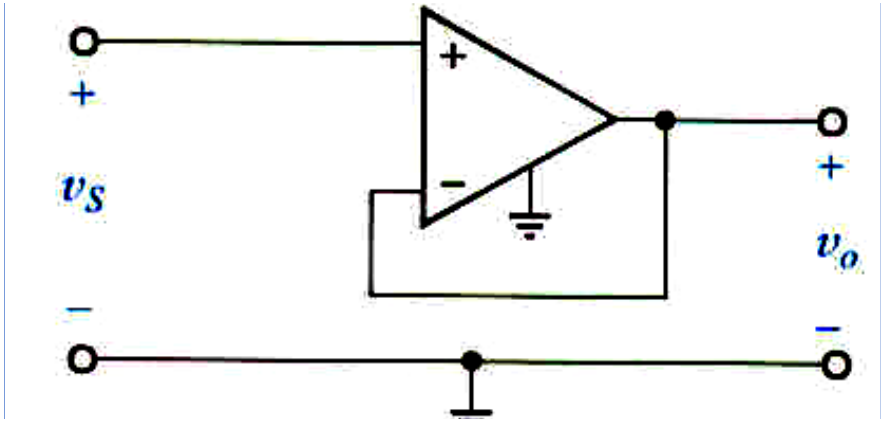
- There is no voltage difference between the two input terminals.

Analysis using Ideal Op-amp



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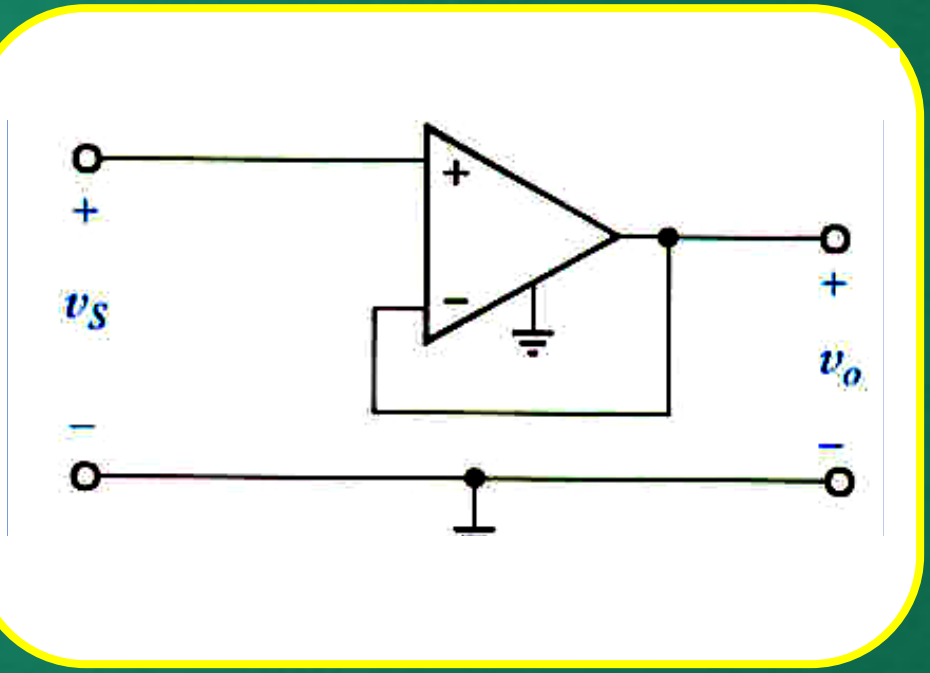
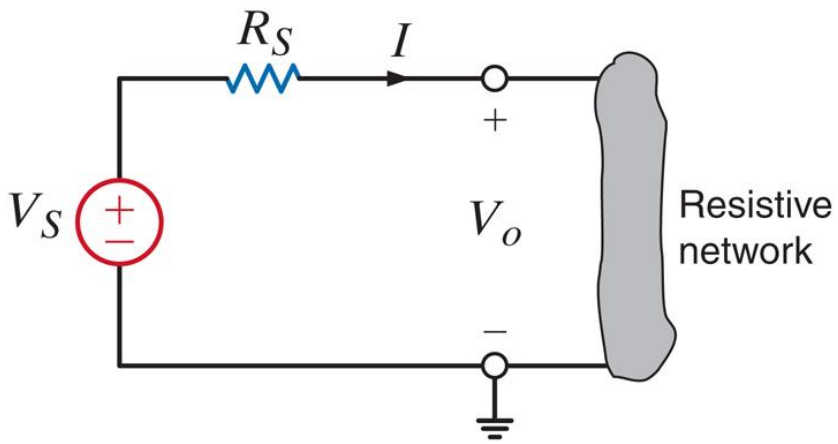


$$\frac{V_o}{V_s} = 1$$

Advantages of Buffer



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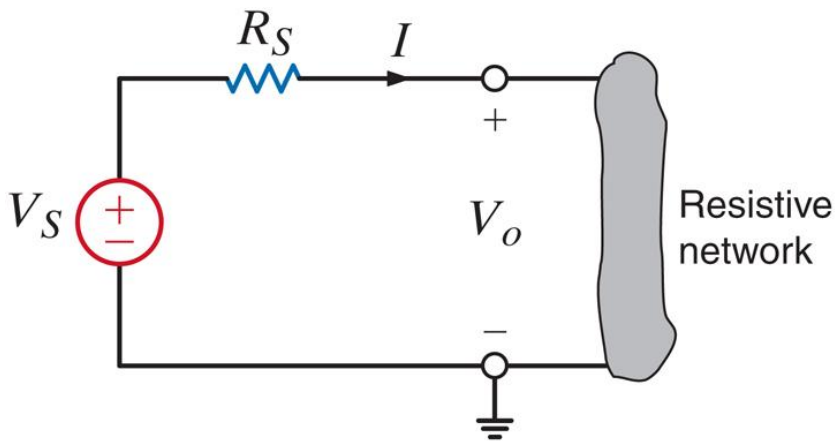

$$V_o = V_s - R_s I$$

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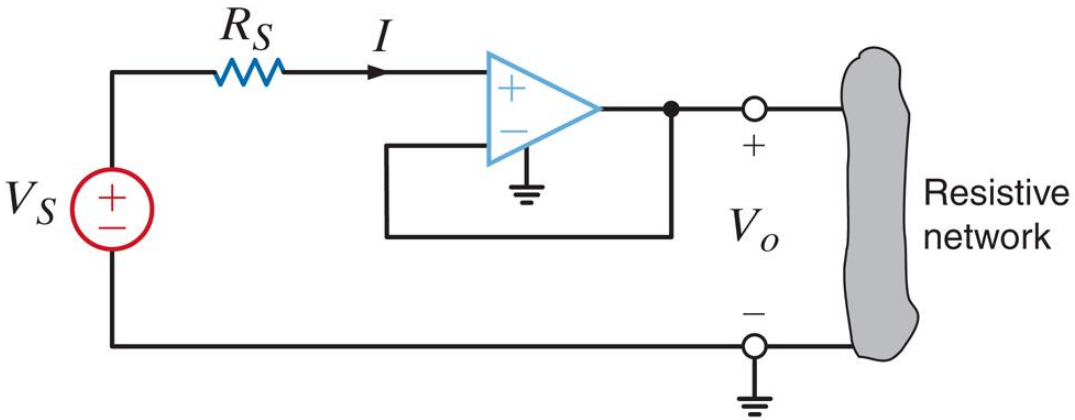

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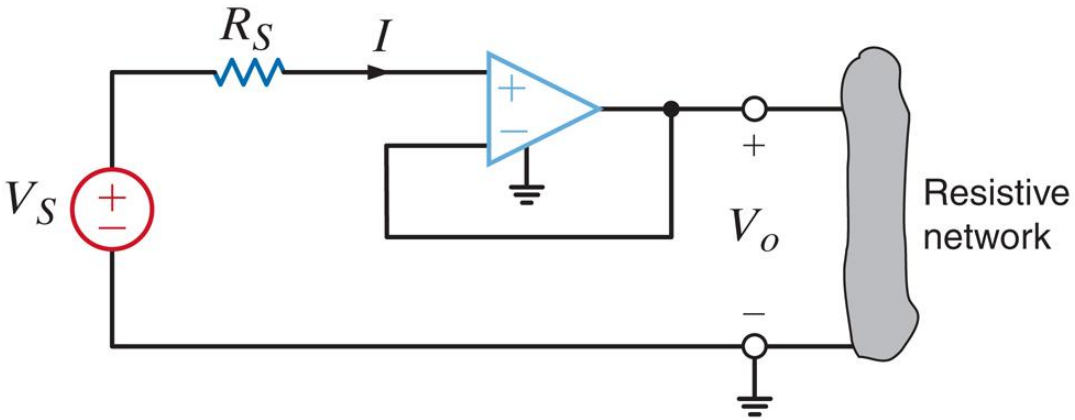
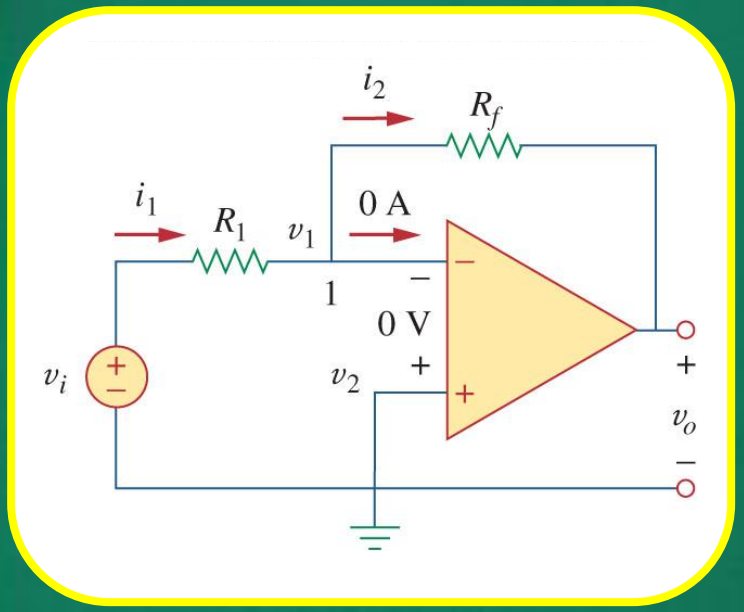


$$V_o = V_s$$

Inverting Amplifier



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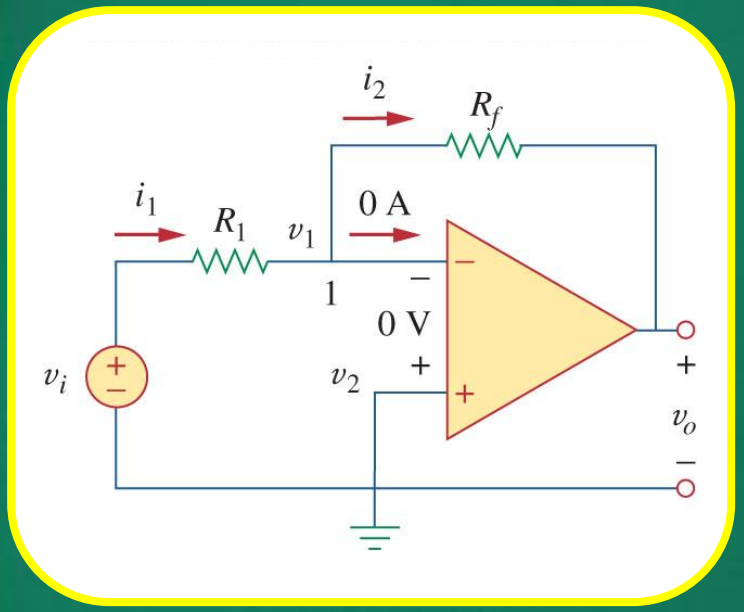

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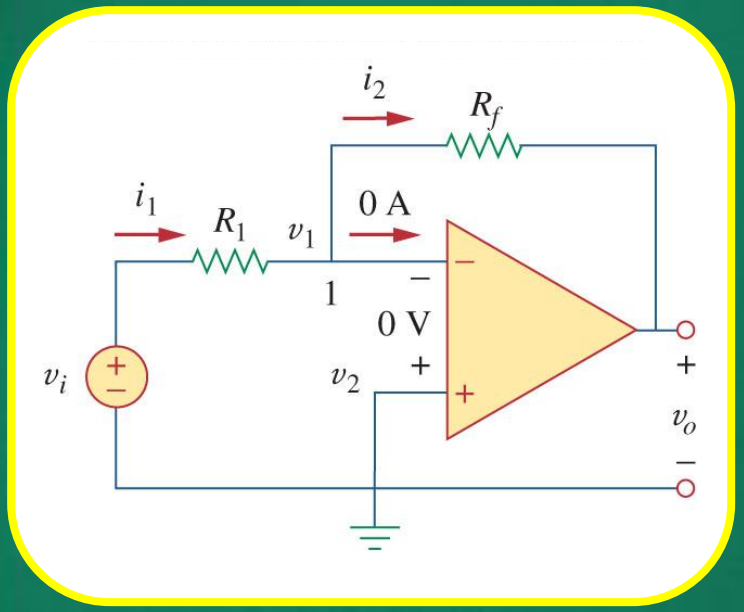

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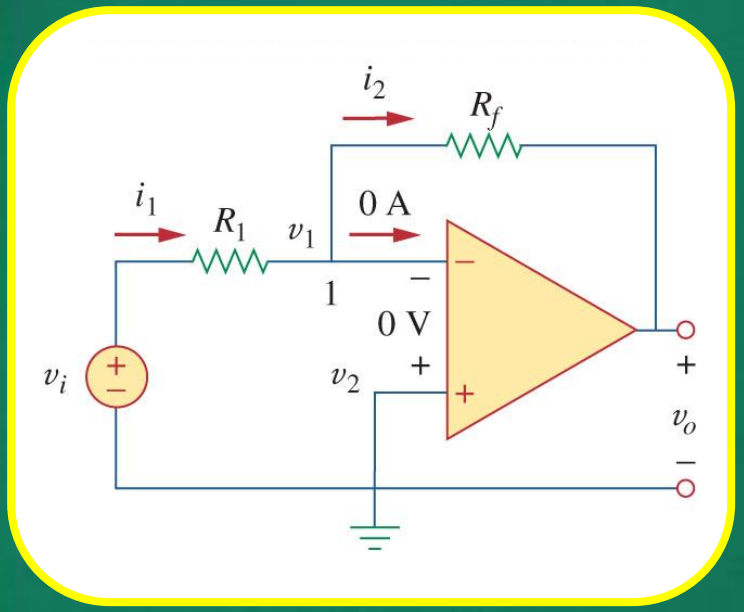

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- The inverting terminal is connected to the output via a feedback resistor, R_f.

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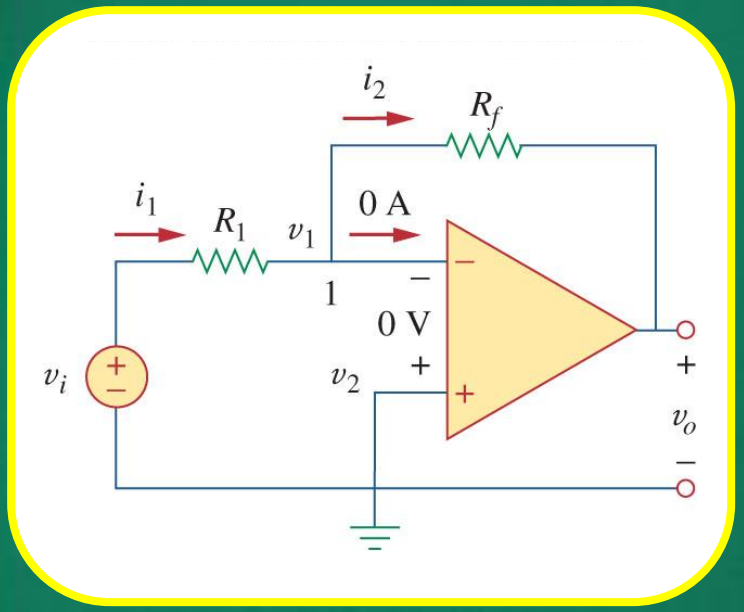

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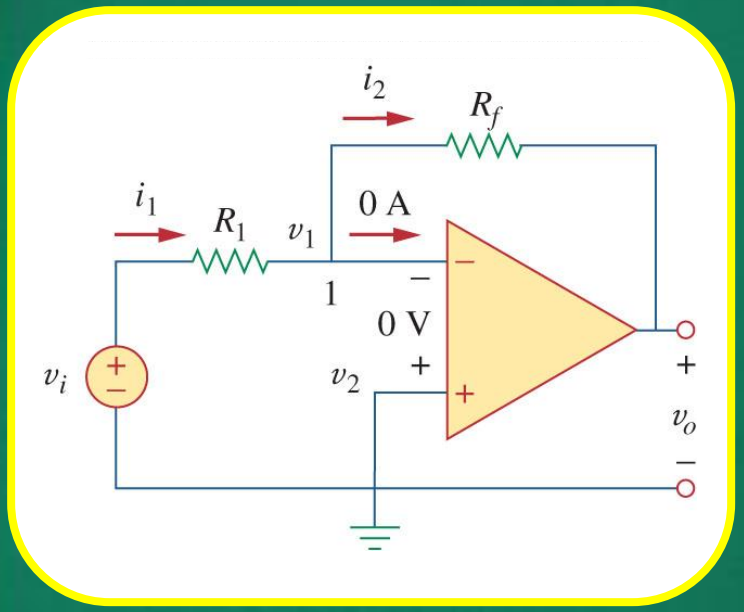

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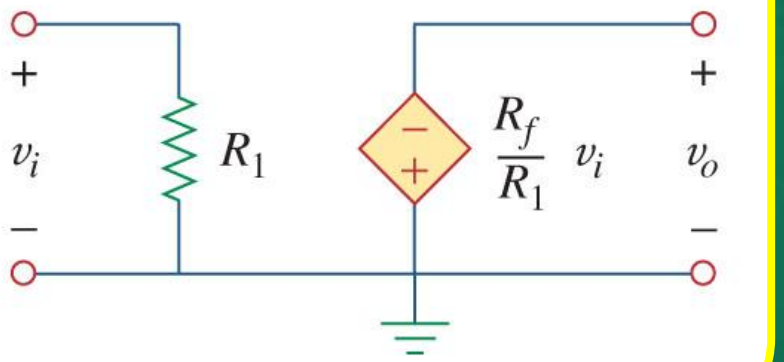
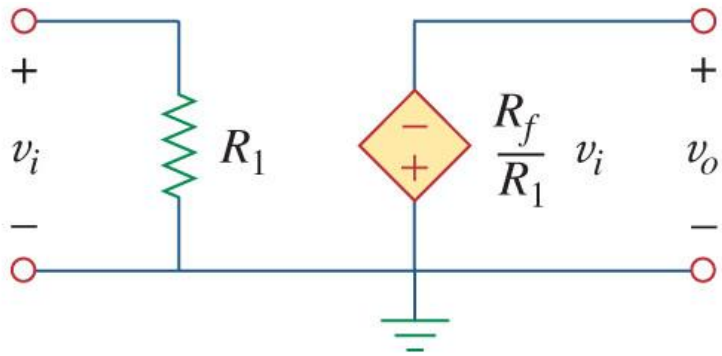
$$v_o = -\frac{R_f}{R_1} v_i$$

Inverting Amplifier



Inverting Amplifier

- The inverting amplifier's equivalent circuit is shown here.



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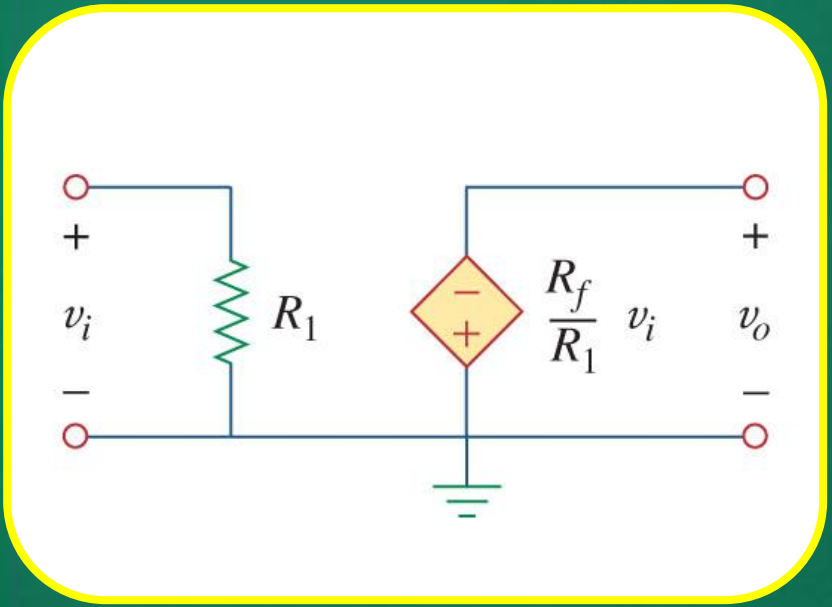

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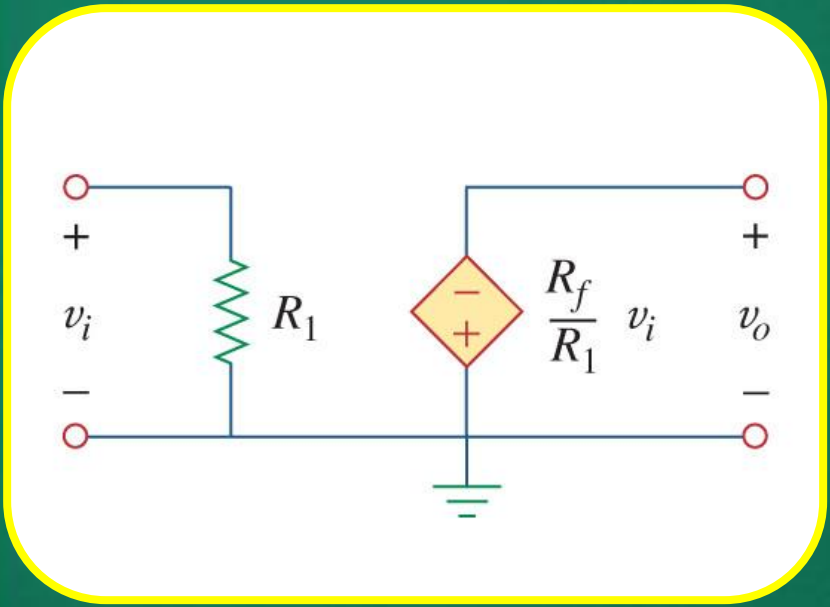
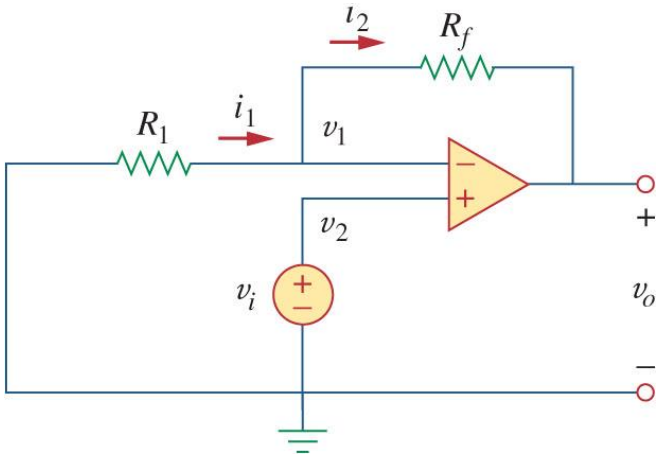
- Note that it has a finite input resistance.

Inverting Amplifier



- 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



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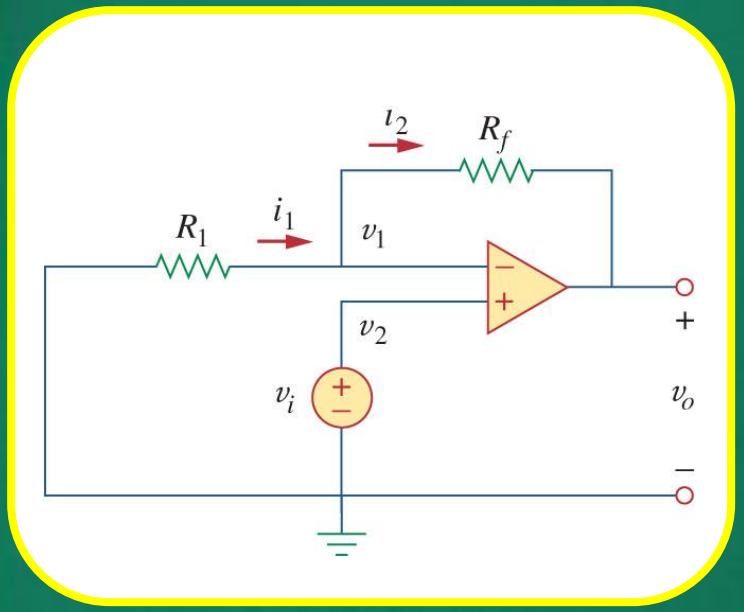
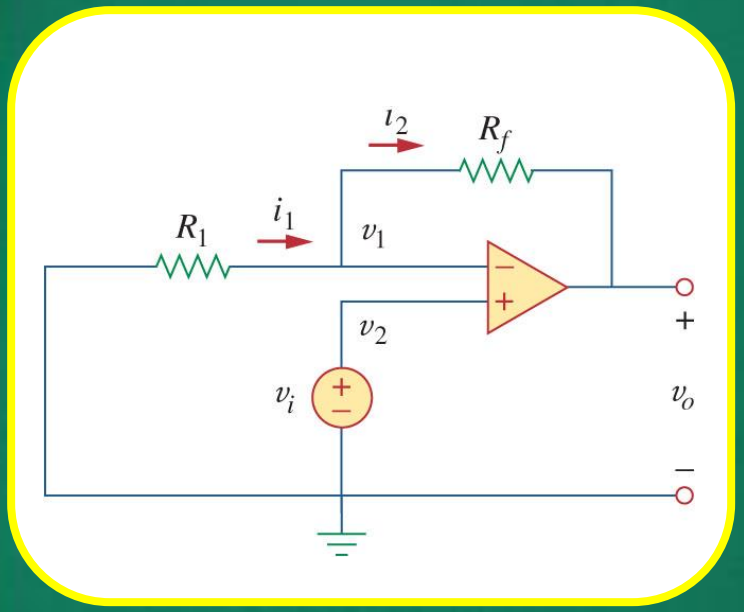


- Another important op-amp circuit is the noninverting amplifier.

Non-Inverting Amplifier



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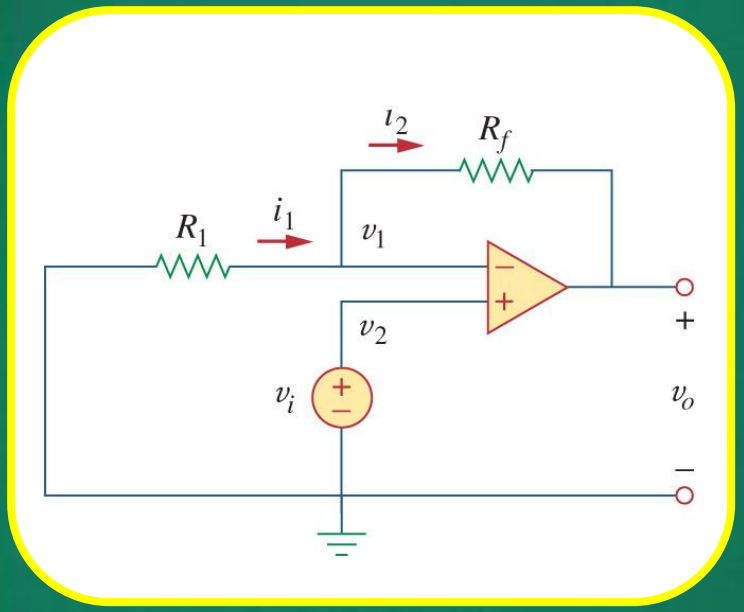
- The basic configuration of the amplifier is the same as the inverting amplifier

Non-Inverting Amplifier



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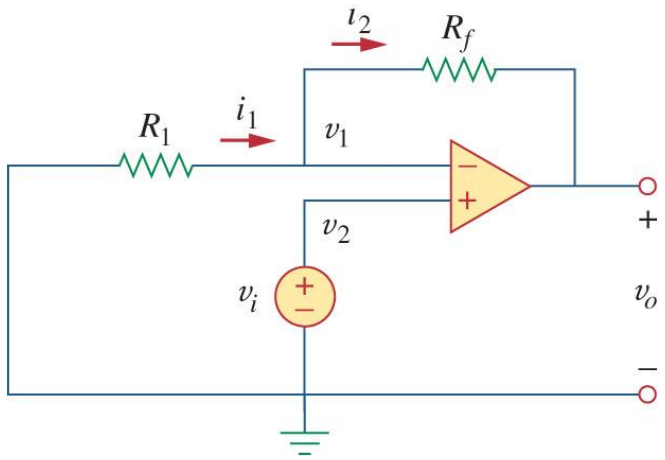
Non-Inverting Amplifier



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- Except that the input and the ground are switched

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

Non-Inverting Amplifier

- Gain here is positive, thus the amplifier is noninverting.

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- 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 (voltage follower).