Jimma University
College of Natural Sciences
Department of Physics

Lecture Notes : *Electronics I (Phys 2062)*

Chapter Five: Operational Amplifiers and Oscillations

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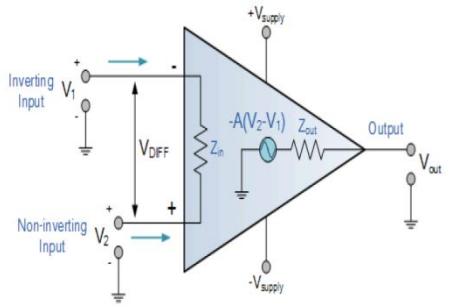

Outline of the Chapter

- Open loop Amplifiers,
- Ideal Amplifiers, Approximation Analysis Ope-loop Gain.
- The Ideal Op-Amp
- Analysis of Circuit Containing Ideal Op-Amps- Inverting Configuration
- Applications of the Inverting Configurations
- The Non-inverting Configuration
- Examples of Op-Amp Circuits
- Transistor amplifier, biasing points

Chapter Five: Operational Amplifiers and Oscillations

❖ Knowledge and Skill Outcomes

- ➢ This unit starts with the understanding of Amplifiers. It includes description of single and multi stage amplifiers and their characteristics.
- ➢ Concept of Positive Feedback and Negative Feedback is discussed.
- ➢ Damped and Undammed oscillations have been explained using suitable diagrams.
- ✓ Understanding of amplifier
- ✓ Understanding the single stage and multistage amplifier
- ✓ Knowledge about circuit diagram of single stage and multistage amplifiers.
- ✓ To know various types of characteristics of an amplifier.
- ✓ Understanding the concept of feedback in amplifiers.
- ✓ Understanding the sinusoidal, non-sinusoidal, damped and undamped oscillations.

Introduction: Amplifiers

- No electronic system can work without an amplifier. Can the voice of a singer reach everybody in the audience in a hall if PA system (Public Address system) fails?
- It is just because of the enlargement or the amplification of the signal picked up by microphone that we can enjoy a music orchestra.
- We are able to hear the news or football match on radio receiver and also we are able to watch and listen (Audio and Visual) programs on TV because the radio receiver or TV catches the weak signal through antenna and amplifies it.
- Amplification means enlargement of a weak signal by an electronic circuit without any distortion in the signal.
- The electronic circuit or device which amplifies the signal is known as Amplifier.

- We know if emitter-base junction of a transistor is forward biased and collector-base junction is reverse biased it can work in active region. This biasing is called DC biasing which is required for a transistor to work as an amplifier.
- Active region is the only region in which by carefully choosing the operating point transistor can amplify the input weak signal and produce the fruitful output without distortion.

Introduction: Amplifiers

- After proper DC biasing AC signal to be amplified is fed to the input of a transistor which is amplified by the transistor as per its configuration. Now the transistor works as an amplifier. Fig. 1 shows the circuit diagram of DC biasing for a transistor to work in active region. Fig. 2 shows the circuit diagram of a transistor amplifier which amplifies weak input signal.
- Amplifier is more precisely an electronic device that increases the voltage, current or power of an input signal with the aid of transistor by furnishing the additional power from a separate power source. At that time we can also say that it is a transistor amplifier.

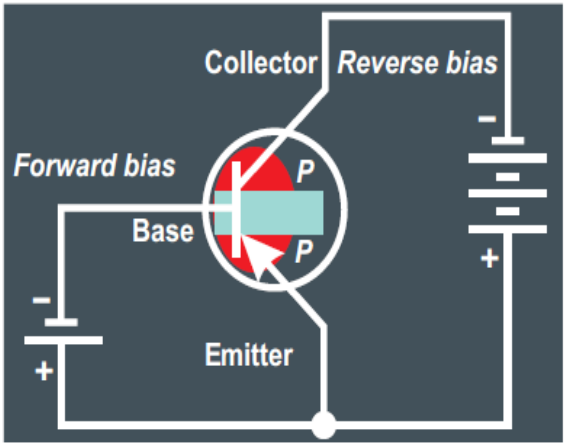

Figure-1

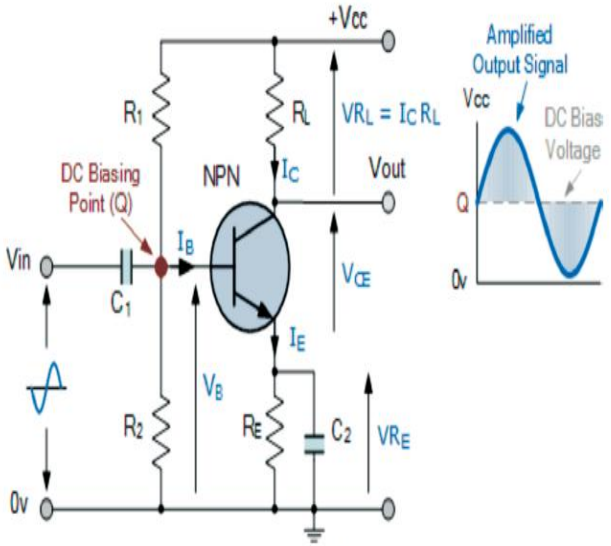

Figure-2

Single and Multistage Amplifiers

- When only one transistor is used in a transistor amplifier to amplify weak input signal then it is known as Single Stage Amplifier.
- A practical amplifier generally uses a number of stages for amplification and is known as Multistage Amplifier. Fig. 3 and Fig. 4 are examples of single and multistage amplifiers respectively
- In single stage amplifier the input signal is multiplied by the gain or amplification factor of a single amplifier. If input current is i then output current for CE amplifier will be b i that B B shall flow through output collector circuit.
- Here b is the current amplification factor for CE amplifier. If input voltage is v then output amplified voltage will be Axv where A is the voltage gain of the amplifier
- The amplified output voltage of amplifier will be 180 out of phase with its input voltage signal for CE amplifier circuit as shown in fig. 2 & 3.

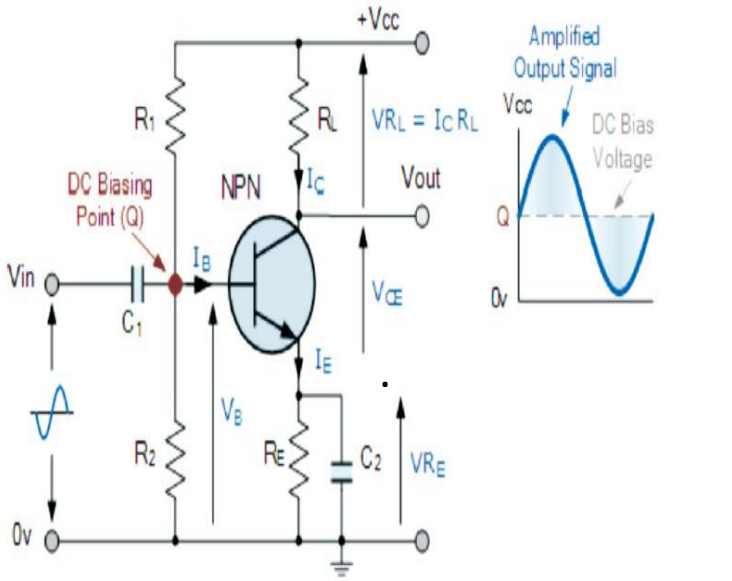

Figure-3

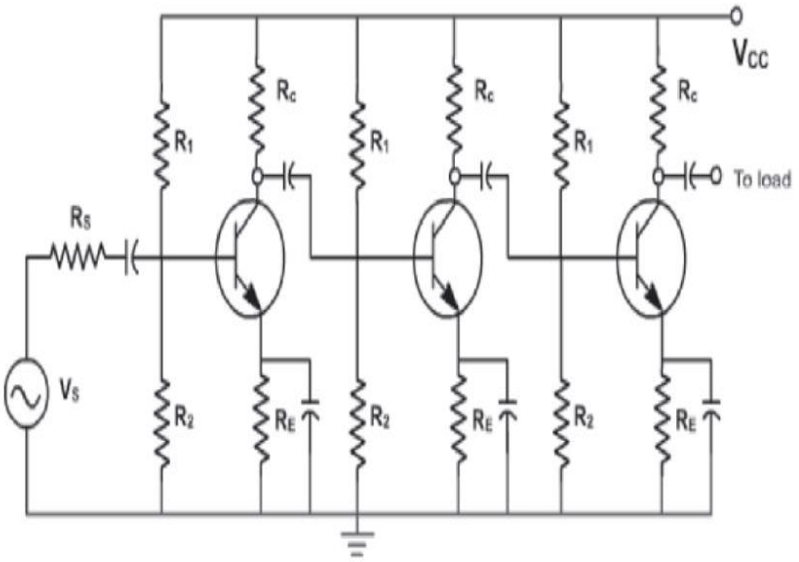

Figure-4

Single and Multistage Amplifiers

- The output from a single stage amplifier is usually not sufficient to drive an output device.
- In other words, the gain of a single amplifier is inadequate for practical purposes. Consequently, additional amplification over two or three stages is necessary.
- To achieve this, the output of each amplifier stage is coupled in some way to the input of the next stage.
- The resulting system is referred to as multistage amplifier. It may be emphasized here that a practical amplifier is always a multistage amplifier.
- For example, in a transistor radio receiver, the number of amplification stages may be six or more. A multistage amplifier is shown in Fig. 4

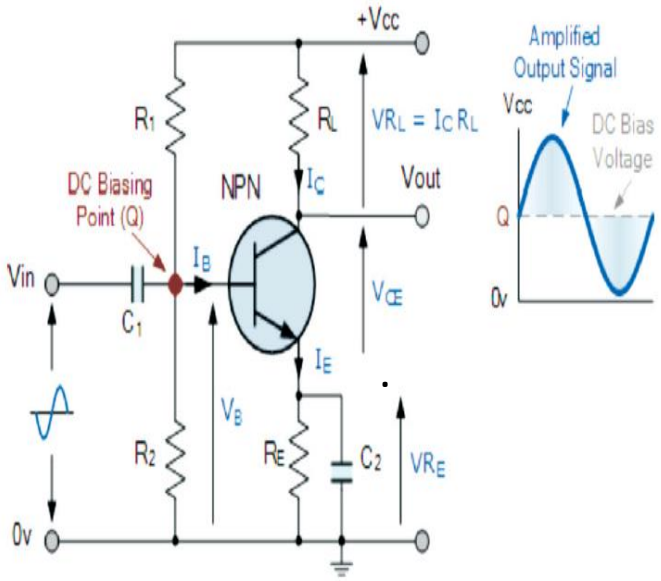

Figure-3

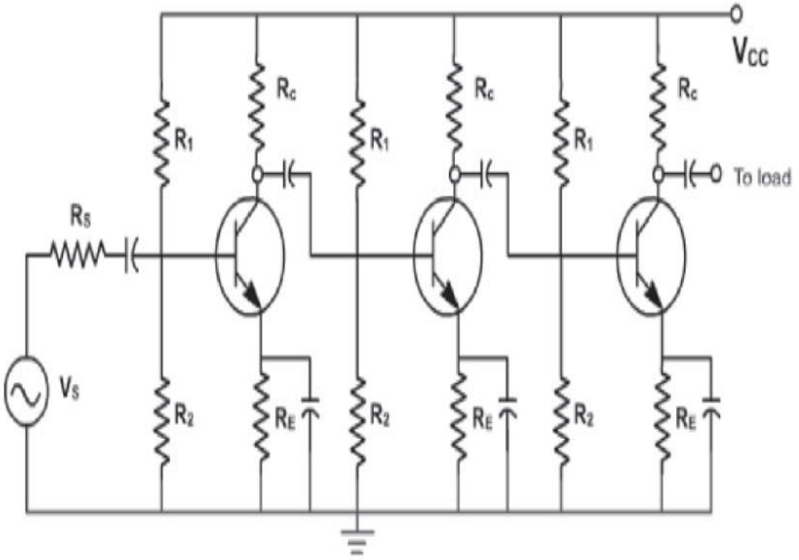

Figure-4

Feedbacks in Amplifiers

- Feedback : (Fig. 5) When a fraction of output is fed back to the input circuit, it is known as feedback.
- The fraction of output may either be current or voltage. A feedback amplifier consists of two parts: an amplifier and a feedback circuit.
- There are two types of feedback: (1) Positive feedback
  (2) Negative feedback.

(1) Positive Feedback: If the feedback voltage (or current) is so applied that it increases the input voltage (or current) then it is called positive feedback.

- ✓ In this case applied feedback voltage is in phase with input voltage.
- ✓ It is also known as regenerative or direct feedback.
- ✓ Positive feedback is used in oscillator circuits.

(2) Negative Feedback: If the feedback voltage (or current) is so applied that it reduces the amplifier input then it is called negative feedback.

- ✓ In this case applied feedback voltage is 180 degree out of phase with input voltage.
- ✓ It is also known as degenerative or inverse feedback.
- ✓ Negative feedback is frequently used in amplifier circuits.

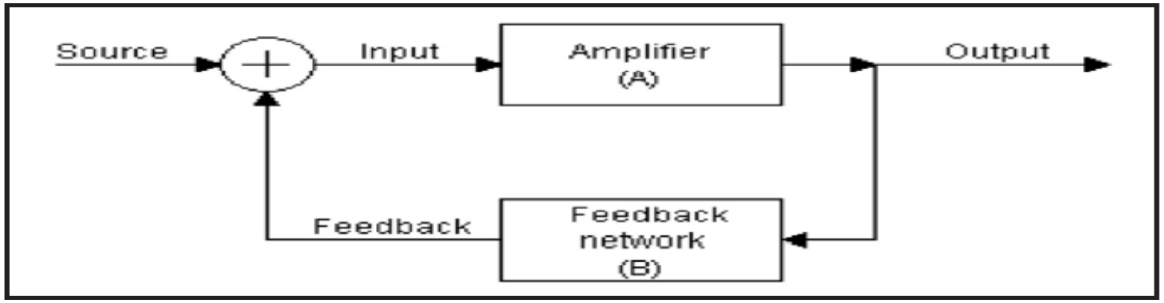

Figure-5

Amplifier Characteristics

❖ Any amplifier is characterized with its following characteristics:

- ✓ (1) Input Resistance
- ✓ (2) Output Resistance
- ✓ (3) Voltage Gain
- ✓ (4) Current Gain
- ✓ (5) Power Gain
- ✓ (6) Phase Reversal

Introduction to Oscillators

- The op-amp astable oscillator covered in Section 6.5 was our first example of an oscillator – a circuit that produces a periodic output signal without an input signal.
- These types of circuits have some kind of feedback mechanism that allows them to oscillate spontaneously.
- We can categorize oscillators into two broad groups: *relaxation oscillators* and *sinusoidal oscillators*
- The relaxation oscillators are characterized by non-sinusoidal output waveforms, timing that is set by capacitor charging and discharging, and the non-linear operation of its active components
- On the other hand, sinusoidal oscillators, as the name implies, have sinusoidal output waveforms and linear operation of the active components, and the analysis is done in the frequency domain (i.e., by considering how the circuit responds to different frequencies)

Introduction to Oscillators

- Any circuit that generates an alternative voltage is called an oscillator.
- Output of an oscillator may be a sine wave, square wave, sawtooth wave or pulses. Electronic oscillators may be broadly divided into following two groups:
  - ✓ **(i) Sinusoidal (or Harmonic) Oscillators:** Which produce an output having sine wave form.
  - ✓ **(ii) Non-Sinusoidal Oscillators:** They produce an output which has rectangular, square or saw tooth waveform or is of pulse shape.
- Sinusoidal Oscillators may be damped and undamped.
  - ✓ **(i) Damped Oscillations:** Oscillations whose amplitude keeps decreasing (or decaying) with time are called damped or decaying oscillations. Wave form of such oscillations are shown in Fig.6(a)
  - ✓ **(ii) Undamped Oscillations:** Oscillations whose amplitude remains constant i.e. does not change with time are called undamped oscillations. Such oscillations are shown in Fig.6(b)

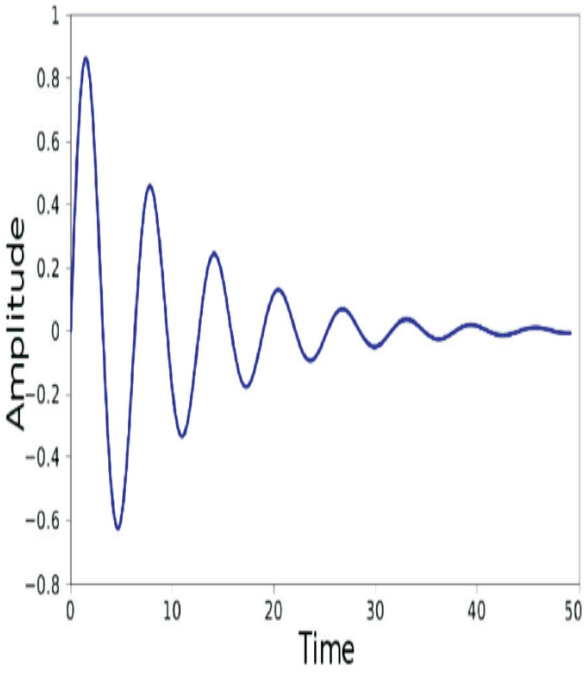

Figure-6(a)

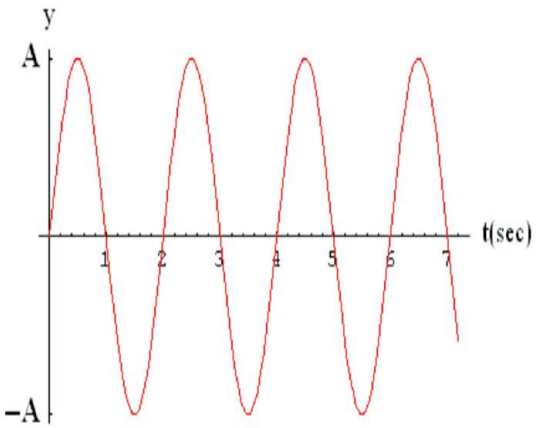

Figure-6(b)

Operational Amplifiers (Op-Amp)

- **Operational Amplifiers**, or **Op-amps** as they are more commonly called, are one of the basic building blocks of Analogue Electronic Circuits
- Operational amplifiers (OpAmps) are general purpose voltage amplifiers employed in a variety of circuits.
- OpAmps are DC amplifiers with a very large gain, high input impedance and low output resistance .
- They are constructed as a difference amplifiers, i.e., the output signal is proportional to the difference between the two input signals.
- An OpAmp chip should be powered for it to work, i.e., power supply attachments are necessary. These connections, however, are not usually shown in the circuit diagram
- *Operational amplifiers* are linear devices that have all the properties required for nearly ideal DC amplification and are therefore used extensively in signal conditioning, filtering or to perform mathematical operations such as add, subtract, integration on and differentiation.
- An **Operational Amplifier**, or op-amp for short, is fundamentally a voltage amplifying device designed to be used with external feedback components such as resistors and capacitors between its output and input terminals

Operational Amplifiers (Op-Amp)

- An **Operational Amplifier**, or op-amp for short, is fundamentally a voltage amplifying device designed to be used with external feedback components such as resistors and capacitors between its output and input terminals.
- These feedback components determine the resulting function or “operation” of the amplifier and by virtue of the different feedback configurations whether resistive, capacitive or both, the amplifier can perform a variety of different operations, giving rise to its name of “Operational Amplifier”.
- An *Operational Amplifier* is basically a three-terminal device which consists of two high impedance inputs. One of the inputs is called the **Inverting Input**, marked with a negative or “minus” sign, (–).
- The other input is called the **Non-inverting Input**, marked with a positive or “plus” sign (+).
- The output voltage signal from an Operational Amplifier is the difference between the signals being applied to its two individual inputs.
- In other words, an op-amps output signal is the difference between the two input signals as the input stage of an Operational Amplifier is in fact a differential amplifier as shown below
  - Amplifiers are two-port networks in which the output voltage or current is directly proportional to either input voltage or current. Four different kinds of amplifiers exit:

✓ Voltage amplier: Av = Vo=Vi = constant
✓ Current amplifier: Ai = Io=Ii = consant
✓ Transconductance amplier: Gm = Io=Vi = constant
✓ Trans resistance amplifier: Rm = Vo=Ii = constant

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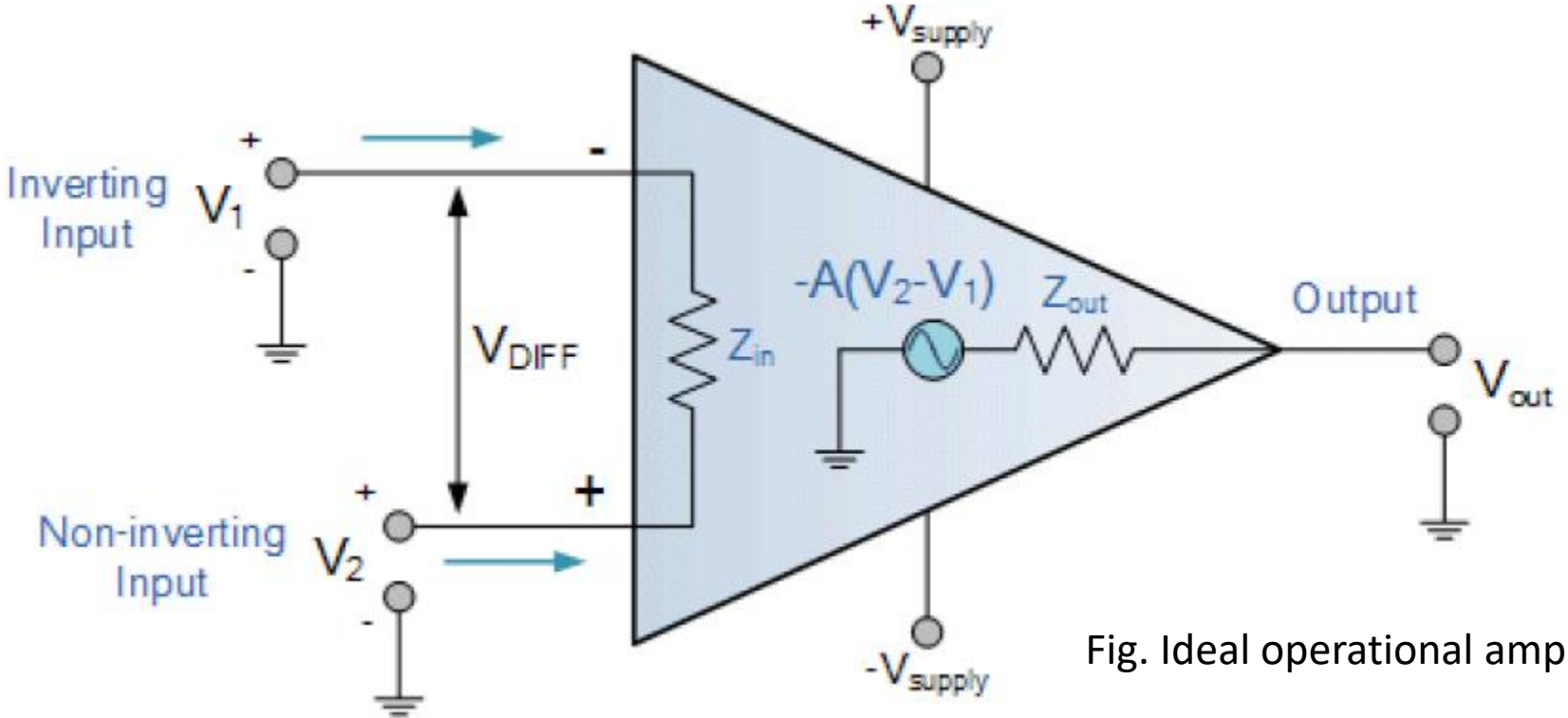


Fig. Ideal operational amplifier

The ideal op-amp

- To facilitate the understanding of op amp circuits, we will assume ideal op amps.
- An op amp is ideal if it has the following characteristics :
  1. Infinite open-loop gain,
  2. Infinite input resistance,
  3. Zero output resistance, *Ro* 0.
- No current flows into the input terminals of the device. This is equivalent to having an infinite input resistance *Ri*=∞. In practical terms this implies that the amplifier device will make no power demands on the input signal source.
- Have a zero output resistance (*Ro=0*). This implies that the output voltage is independent of the load connected to the output.
- In addition the ideal op-amp model will have infinite open loop gain ($A \rightarrow \infty$). The ideal op-amp model is shown schematically on Figure 4.

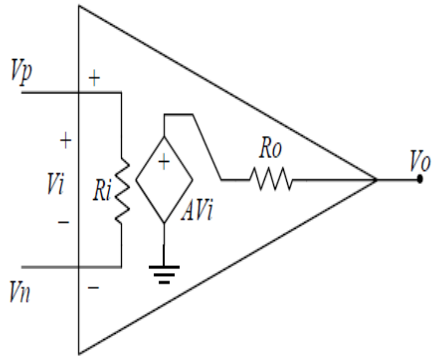


Figure 2. Equivalent circuit model of op-amp device

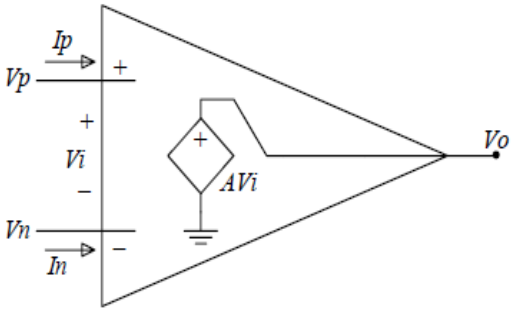


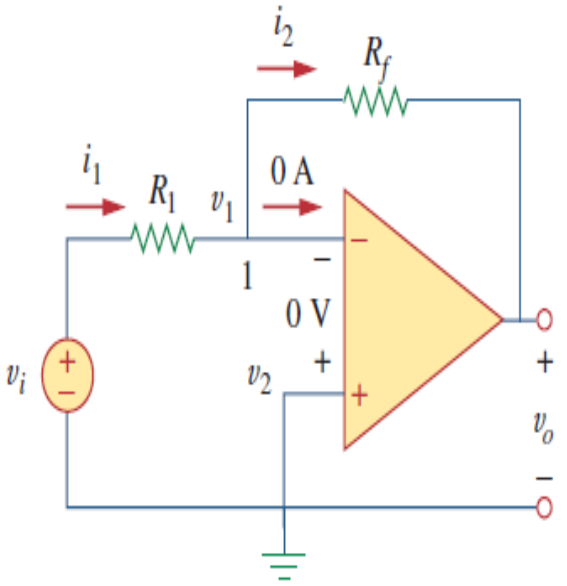
Figure 4. Ideal op-amp model.

In summary, the ideal op-amp conditions are:

$I_p = I_n = 0$	No current into the input terminals
$R_i \rightarrow \infty$	Infinite input resistance
$R_0 = 0$	Zero output resistance
$A \rightarrow \infty$	Infinite open loop gain

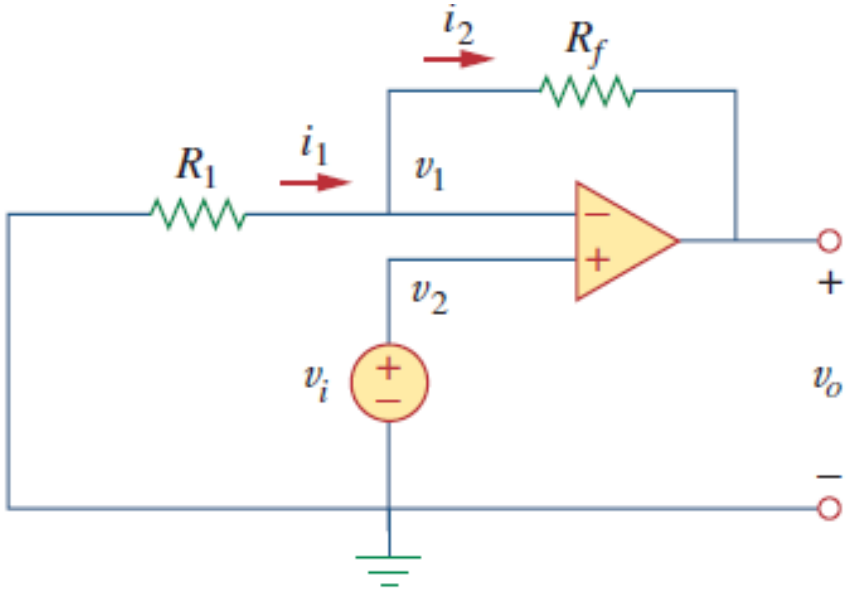
Inverting Amplifier

- It is a useful op amp circuits that often serve as modules for designing more complex circuits.
- An inverting amplifier reverses the polarity of the input signal while amplifying it
- A key feature of the inverting amplifier is that both the input signal and the feedback are applied at the inverting terminal of the op amp.
- Notice that the gain is the feedback resistance divided by the input resistance which means that the gain depends only on the external elements connected to the op amp
- The inverting amplifier is used, for example, in a current-to-voltage converter



Noninverting Amplifier

- Another important application of the op amp is the noninverting amplifier shown in Figure
- A noninverting amplifier is an op amp circuit designed to provide a positive voltage gain
- In this case, the input voltage *vi* is applied directly at the noninverting input terminal
- The gain depends only on the external resistors



Thank you