Lecture 9
Op Amps
Amplifiers

Figure 11.1 Electronic amplifier.

Input & Output Impedance

Figure 11.4 Source, amplifier, and load for Example 11.1.
Inverting versus Non-inverting Amplifiers

Inverting amplifiers have negative voltage gain, and the output waveform is an inverted version of the input waveform. Non-inverting amplifiers have positive voltage gain.
Figure 11.2 Input waveform and corresponding output waveforms.
Negative Feedback

![Negative Feedback Diagram](image-url)
Negative Feedback
Chapter 14
Operational Amplifiers

1. List the characteristics of ideal op amps.

2. Identify negative feedback in op-amp circuits.

3. Analyze ideal op-amp circuits that have negative feedback using the summing-point constraint.
IDEAL OPERATIONAL AMPLIFIERS

\[ v_o = A_{OL}(v_1 - v_2) \]

**Figure 14.1** Circuit symbol for the op amp.
The input signal of a differential amplifier consists of a differential component and a common-mode component.

\[ v_{id} = v_1 - v_2 \]

\[ v_{icm} = \frac{1}{2}(v_1 + v_2) \]
Characteristics of Ideal Op Amps

- Infinite gain for the differential input signal
- Zero gain for the common-mode input signal
- Infinite input impedances
- Zero output impedance
- Infinite bandwidth
Figure 14.2 Equivalent circuit for the ideal op amp. The open-loop gain \( A_{OL} \) is very large (approaching infinity).
Figure 14.3 Op-amp symbol showing the dc power supplies, $V_{CC}$ and $V_{EE}$. 
SUMMING-POINT CONSTRAINT

Operational amplifiers are almost always used with negative feedback, in which part of the output signal is returned to the input in opposition to the source signal.
In a negative feedback system, the ideal op-amp output voltage attains the value needed to force the differential input voltage and input current to zero. We call this fact the **summing-point constraint**.
Ideal op-amp circuits are analyzed by the following steps:

1. Verify that *negative* feedback is present.

2. Assume that the differential input voltage and the input current of the op amp are forced to zero. (This is the summing-point constraint.)
3. Apply standard circuit-analysis principles, such as Kirchhoff’s laws and Ohm’s law, to solve for the quantities of interest.
The Basic Inverter

Figure 14.4 The inverting amplifier.
Verify Negative Feedback

\[ v_{in} > 0 \rightarrow v_{out} << 0 \]

\[ v_{in} < 0 \rightarrow v_{out} >> 0 \]
Applying the Summing Point Constraint

\[ i_1 = \frac{v_{\text{in}}}{R_1} \]

**Figure 14.5** We make use of the summing-point constraint in the analysis of the inverting amplifier.
Applying the Summing Point Constraint

\[ i_{in} = \frac{v_{in}}{R_1} \]
\[ i_{out} = \frac{-v_{out}}{R_2} \]
\[ i_{in} = i_{out} \implies \frac{v_{in}}{R_1} = \frac{-v_{out}}{R_2} \]
\[ \frac{v_{out}}{R_2} = -\frac{v_{in}}{R_1} \]
Inverting Amplifier

\[ A_v = \frac{v_o}{v_{in}} = -\frac{R_2}{R_1} \]
Inverting Amplifier

\[ i_{in} = \frac{v_{in}}{R_1} \rightarrow Z_{in} = R_1 \]
Inverting Amplifier

\[ v_{out} = -\frac{R_2}{R_1} v_{in} \]

Independent of load resistance

\[ R_L \rightarrow \text{output impedance } Z_{out} = 0 \]
**Figure 14.6** An inverting amplifier that achieves high gain magnitude with a smaller range of resistance values than required for the basic inverter. See Example 14.1.