Lecture 8
Op Amps
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

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 $V_{EE}$. 
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

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

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

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

\[ \begin{align*}
    i_{in} & = \frac{v_{in}}{R_1} \\
    i_{out} & = -\frac{v_{out}}{R_2} \\
    i_{in} & = i_{out} \quad \Rightarrow \quad \frac{v_{in}}{R_1} = -\frac{v_{out}}{R_2} \\
    \frac{v_{out}}{v_{in}} & = -\frac{R_2}{R_1}
\end{align*} \]
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.