Lecture 5

Operational Amplifiers:
- The Weighted Summer
- The Non-Inverting Configuration
- The Difference Amplifier
Today’s Objectives

- Define and analyze a weighted-summer circuit.
- Identify the **non-inverting** configuration of an op-amp.
- Analyze non-inverting op-amp circuits.
The Weighted Summer
What is a “Weighted Summer?”

Simply put, it is an op-amp configured to produce the **weighted sum** of two or more voltage inputs...

\[
v_0 = - \left( \frac{R_f}{R_1} v_1 + \frac{R_f}{R_2} v_2 + \cdots + \frac{R_f}{R_n} v_n \right)
\]
Analysis of a Weighted Summer

Use **superposition** to analyze the following weighted summer (i.e., write an expression for $v_o$ in terms of the input voltages and input and feedback resistors).

$$v_o = -\left(\frac{R_f}{R_1}v_1 + \frac{R_f}{R_2}v_2 + \cdots + \frac{R_f}{R_n}v_n\right)$$
Solution

\[ i_1 = \frac{v_1}{R_1}, \quad i_2 = \frac{v_2}{R_2}, \quad \ldots \quad i_n = \frac{v_n}{R_n} \]

\[ i_f = i = i_1 + i_2 + \ldots + i_n \]

Where: \[ i = \frac{0-v_o}{R_f} \quad \Rightarrow \quad v_o = -iR_f \]

\[ \therefore \quad v_o = -\left( \frac{R_f}{R_1} v_1 + \frac{R_f}{R_2} v_2 + \ldots + \frac{R_f}{R_n} v_n \right) \]
The Non-Inverting Configuration

How to derive the closed-loop gain ($v_o/v_I$) for this configuration:
Closed-Loop Gain Derivation

Ohm's law:
\[ i_1 = \frac{v_I - v_1}{R_1} = \frac{v_I - 0}{R_1} = \frac{v_I}{R_1} \]

KVL:
\[ v_o - v_I - i_1 R_2 = 0 \]

Thus:
\[ A_{vcl} = \frac{v_o}{v_I} = 1 + \frac{R_2}{R_1} \]

Observe: \( A_{vol} \equiv \infty \)
Design a non-inverting op-amp where the gain is +10 and the total resistance is 150kΩ. Sketch the final circuit.
Solution

\[ R_1 + R_2 = 150k\Omega \]

\[ 1 + \frac{R_1}{R_2} = 10 \]

\[ R_1 = 15k\Omega \]

\[ R_2 = 135k\Omega \]
The Difference Amplifier
A Difference amplifier combines features of the inverting amplifier and the non-inverting amplifier. It is the complement of the summing amplifier and allows the subtraction of two voltages or, as a special case, the cancellation of a signal common to the two inputs.
Use superposition...

- set $v_1 = 0$, solve for $v_o$ (i.e., this is a **non-inverting** amp)
- set $v_2 = 0$, solve for $v_o$ (i.e., this is an **inverting** amp)
Result of setting $v_1 = 0$ and then solving for $v_o$ (non-inverting configuration):

$$v_{o2} = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4}{R_3 + R_4}\right)v_2$$
Result of setting \( v_2 = 0 \) and then solving for \( v_o \) (inverting configuration):

\[
\dot{v}_{o1} = -\frac{R_2}{R_1} v_1
\]
Add the two results...

\[ v_o = v_{o1} + v_{o2} \]