1.8.2: Selected Operational Amplifier Circuits

Overview

This module provides an overview of a number of operational amplifier based circuits which can be used to perform commonly used mathematical operations. The circuits provided in this module all perform algebraic operations (addition, subtraction, multiplication). There are many op-amp based circuits to perform other operations (integration, differentiation, etc.) – these are presented in later modules.

The governing equations for several of the circuits presented here have been previously derived in Module EA-191. Other circuits provided here are similar to but slightly more general than previously derived circuits. The governing equations for the circuits presented here are not derived in this module, they are simply presented as potentially useful reference material.

Before beginning this module, you should be able to:

- Analyze circuits containing ideal operational amplifiers (Chapter 1.8.1)

After completing this module, you should be able to:

- Identify operational amplifier circuits which add or subtract two signals
- Sketch a voltage follower circuit
- Design operational amplifier circuits to provide a given multiplicative constant

This module requires:

- N/A

The following subsections provide operational amplifier-based circuits which perform the basic mathematical operations of addition, subtraction, and multiplication. In the circuits shown below, the ground symbol, $\frac{1}{\text{ground}}$, is used to denote the reference voltage from which all other voltages are measured. The op-amp power supply voltages, $V^+$ and $V^-$, are also shown explicitly on the circuits shown below. Recall that the output voltage from an operational amplifier is restricted to be between $V^+$ and $V^-$. 

Doc: XXX-YYY  page 1 of 4

Copyright Digilent, Inc. All rights reserved. Other product and company names mentioned may be trademarks of their respective owners.
1. **Inverting Amplifier Circuit**

The circuit shown in Figure 1 is called an inverting amplifier. $v_{in}$ is the applied (input) voltage to the circuit. $v_{out}$ is the output voltage from the circuit. The relationship between $v_{in}$ and $v_{out}$ for this circuit is:

$$v_{out} = -\frac{R_2}{R_1} v_{in}$$

Thus, the output voltage is an **inverted** (due to the sign change) and **amplified or scaled** (due to the multiplicative factor $\frac{R_2}{R_1}$) version of the input voltage. The scaling factor $\frac{R_2}{R_1}$ is sometimes called the **gain** of the amplifier. Note that if $R_1$ and $R_2$ are the same, the output voltage is simply the negative of the input voltage.

![Inverting amplifier circuit](image)

Figure 1. Inverting amplifier circuit.

2. **Difference Amplifier Circuit**

The circuit shown in Figure 2 is called a difference amplifier. The output of the circuit ($v_{out}$ in Figure 2) is proportional to the difference between the two inputs, $v_a$ and $v_b$. With the four independent resistances ($R_1$, $R_2$, $R_3$, and $R_4$) shown in Figure 2, the input voltages can be scaled independently. In order to apply the same scaling factor to both inputs, we can apply a requirement to the choice of the resistances. If we choose

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

then the expression for the output voltage becomes:

$$v_{out} = \frac{R_2}{R_1} (v_b - v_a)$$
1.8.2: Selected Operational Amplifier Circuits

The output voltage is, then, a scaled version of the difference between the two input voltages. Note that if \( v_a \) is zero, the circuit is a non-inverting amplifier. (The output is a scaled version of the single input \( v_b \), with no sign change.) Also note that if \( R_1 = R_2 = R_3 = R_4 \), the circuit simply subtracts the voltage \( v_a \) from the voltage \( v_b \).

![Figure 2. Difference amplifier circuit.](image)

3. Summing Amplifier Circuit

The circuit shown in Figure 3 is a summing amplifier circuit. The output voltage is an inverted and scaled version of the sum of the input voltages, \( v_a \) and \( v_b \). If \( R_1 = R_2 \), the input voltages are not individually scaled and the output voltage is:

\[
v_{out} = -\frac{R_3}{R_1} (v_a + v_b)
\]

Note that if, in addition, \( R_3 = R_1 \), the output voltage is simply the sum of the two input voltages.

![Figure 3. Summing amplifier circuit.](image)
4. Voltage Follower

The circuit shown in Figure 4 is called a voltage follower. For this circuit, the output voltage is the same as the input voltage:

\[ V_{\text{out}} = V_{\text{in}} \]

The advantage of this circuit is that the input current to the circuit is approximately zero. Thus, the circuit provides an output voltage with essentially no power requirements at the input node (any power at the output is provided by the op-amp’s positive and negative power supplies \( V^+ \) and \( V^- \)). This circuit is useful for decoupling different subsystems from one another.

![Voltage Follower circuit](image)

Figure 4. Voltage Follower circuit