# Unit 42 Adder circuits

- The output from a two input noninverting adder is given by:

$$V_{out} = V_1 + V_2$$

- The output from an inverting adder is given by:

$$V_{out} = -R_f \left( \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \ldots \right)$$

The addition of two voltage signals to get a single output sum is a very common operation in electronics. We will first look at a noninverting simple adder as it is a good example of circuit analysis techniques where a given circuit can be split into its component parts in order to analyze the operation of the circuit. The circuit is shown in Figure 42.1.

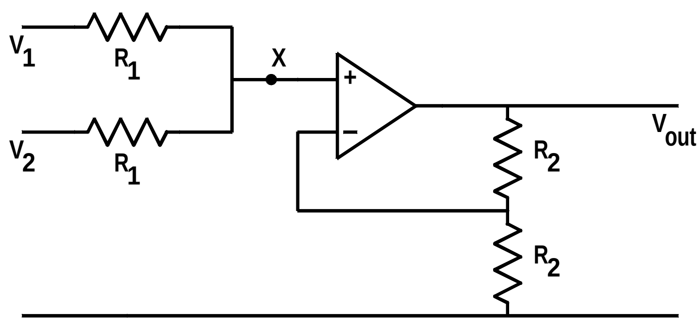


Figure 42.1: Two input noninverting adder.

The two input voltages, $V_1$ and $V_2$, are specified with respect to ground and are applied to the ends of two equal resistors of value $R_1$, connected in series. Since no current flows into the input terminals of the op-amp, current only flows in the resistors. The current in the two $R_1$ in series is given by:

$$I = \frac{V_1 - V_2}{2 \times R_1}$$

The voltage, $V_X$, at the mid point, X, of the resistors is given by:

$$V_X = V_1 - I \times R_1 = V_1 - \frac{V_1 - V_2}{2 \times R_1} \times R_1 = V_1 - \frac{V_1}{2} + \frac{V_2}{2} = \frac{V_1 + V_2}{2}$$

In other words, $V_X$ is the average of $V_1$ and $V_2$.

The noninverting amplifier has a gain of $A_V = 1 + \frac{R_2}{R_2} = 2$. The output of the circuit is then given by:

$$V_{out} = \frac{V_1 + V_2}{2} \times 2 = V_1 + V_2$$

which is the sum of the two input voltages. The disadvantage of this adder is that no more than two input signals can be added.

The inverting adder is a much more versatile type of adder circuit and a typical circuit configuration is shown in Figure 42.2.

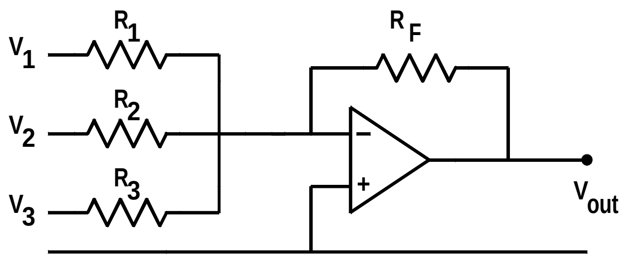


Figure 42.2: Inverting adder.

This particular circuit has three input signals but any number of inputs can be used.

The key to the analysis of this circuit is the first rule for op-amps (Unit 39) that the voltage at the inverting input is the same as the voltage at the noninverting input. In this case the noninverting, (+), input is at zero volts because it is connected to ground. Therefore the voltage at the inverting, (−), input is at approximately zero volts. This is called a *virtual earth* or *virtual ground*.

Now calculate the current which flows in each of the input resistors. The voltage difference across $R_1$ is $V_1 - 0 = V_1$ and the current is therefore $\frac{V_1}{R_1}$. A similar calculation is carried out for each of the other inputs.

The voltage across the feedback resistor, $R_f$, is $0 - V_{out} = -V_{out}$ and therefore the feedback current is $I_f = \frac{-V_{out}}{R_f}$. Since no current flows in the input terminal of the op-amp (Rule 2, Unit 39) we get $I_1 + I_2 + I_3 = I_f$ and therefore:

$$\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} = -\frac{V_{out}}{R_f}$$

The advantage of this inverting adder is that it allows us to carry out a scaled or weighted addition to get an output of the form:

$$V_{out} = -\left(3.9V_1 + 4.0V_2 + 1.0V_3\right)$$

The inversion is easily reversed by using an inverter circuit having a gain of −1.

If an output of the form:

$$V_{out} = 3.1V_1 - 2.4V_2 - 5.0V_3$$

is required, then an inverter can be used on the $V_1$ input signal before it is applied to the inverting adder so that the effective equation is:

$$V_{out} = -\left(3.1(-V_1) + 2.4V_2 + 5.0V_3\right)$$

## 42.1 Examples

42.1 Derive the equation for the output voltage from the circuit shown in Figure 42.3.

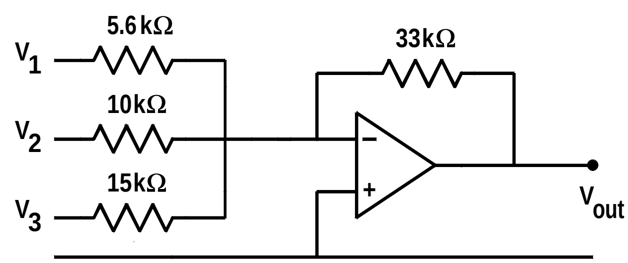


Figure 42.3: Example 42.1.

The equation for the output is:

$$\begin{aligned} V_{out} &= -\left(\frac{33}{5.6} \times V_1 + \frac{33}{10} \times V_2 + \frac{33}{15} \times V_3\right) \\ &= -5.9V_1 - 3.3V_2 - 2.2V_3 \end{aligned}$$

42.2 A circuit such as that in Figure 42.3 has been constructed. Design a systematic test procedure for the circuit.

There are three inputs to the circuit so each of these three input channels must be tested separately and the measured output compared with the calculated output. Possible test voltages are zero volts, and small positive and negative voltages. Only after the individual channels have been tested should test signals be applied to two or more channels.

A test matrix such as that shown below should be prepared and the specified measurements carried out and filled into the column marked

Measured $V_{out}$. It is only by carrying out systematic testing that you can ever be sure that a circuit you design and construct actually works to specification.

The equation describing the circuit to be tested is:

$$V_{out} = -5.9V_1 - 3.3V_2 - 2.2V_3$$

| Test no. | $V_1$ | $V_2$ | $V_3$ | Calculated $V_{out}$ | Measured $V_{out}$ |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | |
| 2 | 1 | 0 | 0 | −5.9 | |
| 3 | 0 | 1 | 0 | −3.3 | |
| 4 | 0 | 0 | 1 | −2.2 | |
| 5 | −1 | 0 | 0 | +5.9 | |
| 6 | 0 | −1 | 0 | +3.3 | |
| 7 | 0 | 0 | −1 | +2.2 | |
| 8 | −1 | 1 | 1 | +0.4 | |
| 9 | 1 | −1 | 1 | −4.8 | |

## 42.2 Problems

42.1 Explain the function of each of the tests in the test matrix in Example 42.2. What is being tested and what section of the circuit would you examine in the event of a discrepancy between the Calculated $V_{out}$ and the Measured $V_{out}$?

42.2 Apply the principle of superposition (Unit 21) to analyze the noninverting adder shown in Figure 42.1.

42.3 Design an adder circuit which will have an output given by:

$$V_{out} = -\left(2.8V_1 + 3.2V_2 + 1.0V_3 + 1.9V_4\right)$$

Design a test matrix, similar to that in Example 42.2, for this circuit and calculate the expected outputs for each test input.

42.4 The output voltage from an inverting adder circuit is given by:

$$V_{out} = -1.3V_1 - 2.9V_2$$

If the signals $V_1$ and $V_2$ are $V_1 = 2.1\sin(400t)\,\text{V}$ and $V_2 = 0.6\,\text{V}$, where $t$ is the time in seconds, give a scaled sketch of the output voltage waveform from the adder.