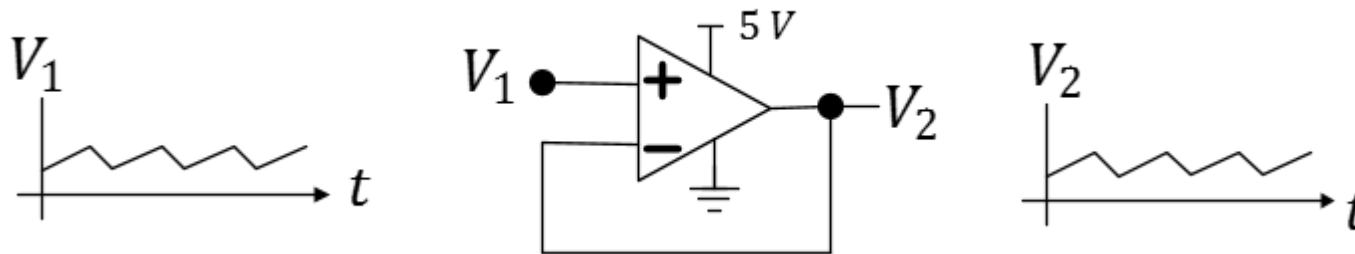


# The Voltage-Follower Buffer

## Laboratory Outline

An engineer working with circuits will encounter situations when a circuit, designed for some operation, was not simultaneously designed to “drive” the next stage of the system (often, it cannot source enough current to supply the power at its nominal voltage level). To combat this issue, we might “buffer” the signal. The buffer, as shown in Figure 1, has a high input **impedance** (much like a voltmeter) so that it doesn’t affect the voltage it is observing,  $V_1$  and low output impedance (closer to an ideal voltage source for most loads). In effect, we are not changing anything about the physical appearance of the signal, but rather replicating the waveform (as  $V_2$ ) using a buffer that will drive the next stage of the circuit without degrading the function of the previous stage. Often, this is part of a process called “signal conditioning” where the signal is conditioned to properly drive the next device within a system. This module will guide you through the procedure of using an LM358 operational amplifier to provide a buffer through a circuit called a “voltage follower” to a small voltage signal.

Notes: **Impedance** is much like resistance, but extends the idea of resistance to current flow to AC circuits. For an example of where resistance fails to describe a circuit element, consider a capacitor. A capacitor has a high impedance to DC current flow (it charges up quickly and resists the movement of further electrons), but has low resistance to higher-frequency AC current flow as the electrons continually change direction and therefore might never reach a charge point to resist electron flow.



*Figure 1: An Op Amp configured as a voltage follower.*

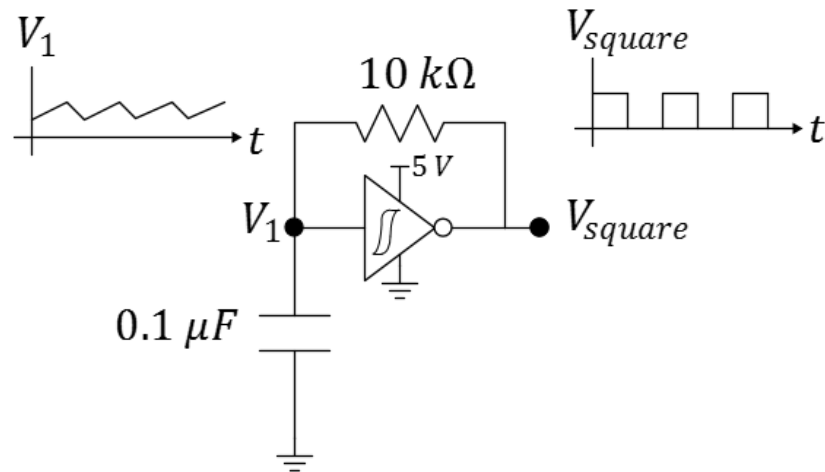
## Prerequisites

- Laboratory Exercise #5, the construction of a simple low-power oscillator circuit.
- Read *Explore More!* Module: The Relaxation Oscillator.

## Parts Needed

- The completed oscillator circuit (Lab#5)
- (1) LM358 Operational Amplifier (there are 2 per IC, one IC in your kit)
- The Arduino to provide a 5-volt regulated power supply

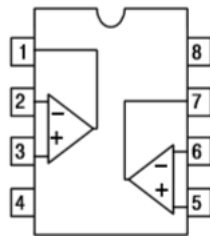
## At Home: Construction



**Figure 2:** Finding the triangular waveform from a common oscillator.

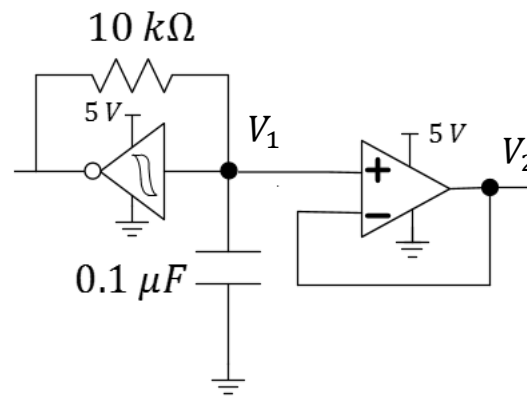
- ✓ Construct the oscillator (Figure 2) used to generate a square wave in the ECE110 lab (or use the same physical oscillator if you have it handy). You will use the triangular waveform  $V_1$  as your source to be buffered.
- ✓ Obtain the datasheet for the LM358 operational amplifier online.

**Question 1:** Use the datasheet to add the schematic symbols for power and ground to the LM358 pinout below. We will use the 5-volt regulated supply from the Arduino. What is the range of acceptable supply voltages?



**Question 2:** On the physical pinout diagram above, add the circuit-schematic symbols of the components used to construct the circuit buffer of **Figure 1 (not Figure 2)**.

- ✓ Construct the completed buffered triangular-waveform-generator circuit as shown in Figure 3.



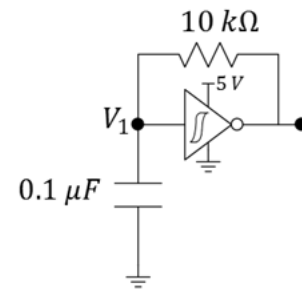
*Figure 3: Using a voltage follower to buffer the waveform  $V_1$  in producing  $V_2$ .*

### In the Laboratory: Analysis

To understand why the buffering is necessary, use a coaxial cable to view the unbuffered triangular waveform  $V_1$  on the oscilloscope. Change the channel input impedance from 1 MΩ to 50 Ω (this can be done by first pressing the highlighted channel number above the BNC input on the scope, then pressing the appropriate softkey).

**Question 3:** Describe what happens to the triangular signal,  $V_1$ , generated by the oscillator as viewed on the oscilloscope with the 50 Ω load.

**Question 4:** Model the oscilloscope load as a  $50\ \Omega$  resistor and add it to the schematic below. Use your understanding of relaxation oscillators to explain why the oscillator fails to oscillate when probed by the  $50\ \Omega$  load of the oscilloscope.



- ✓ Place the oscilloscope impedance to  $1\text{ M}\Omega$ .
- ✓ Using the triangular signal from the oscillator as input to the voltage follower, simultaneously monitor both the input  $V_1$  and the output  $V_2$  of the voltage follower on the scope (using channels 1 and 2, respectively).

**Question 5:** Describe what you see when both channels of the oscilloscope are set to  $1\text{ M}\Omega$ . **Include a plot.**

**Question 6:** Describe what happens as each channel is separately set to  $50\ \Omega$  while the other is  $1\text{ M}\Omega$ .

## Back at Home: Drawing Conclusions

**Question 7:** Think about the answers to the questions in this module. Which signal was insensitive to the change to  $50\ \Omega$ ? Does this match your understanding of a buffer? Comment on the effectiveness of your voltage follower.

## Learning Objectives

- To gain experience with the use of an operational amplifier in the voltage-follower buffer application.
- To improve oscilloscope skills pertaining to the trigger as well as the input impedance.
- To recognize the need for signal conditioning in the context of a buffering circuit.

## Explore Even More!

The oscillator and buffer are key components in ***Explore More! Module: The Voltage Comparator*** and ***Explore More! Module: PWM Control via an Active Sensor***.