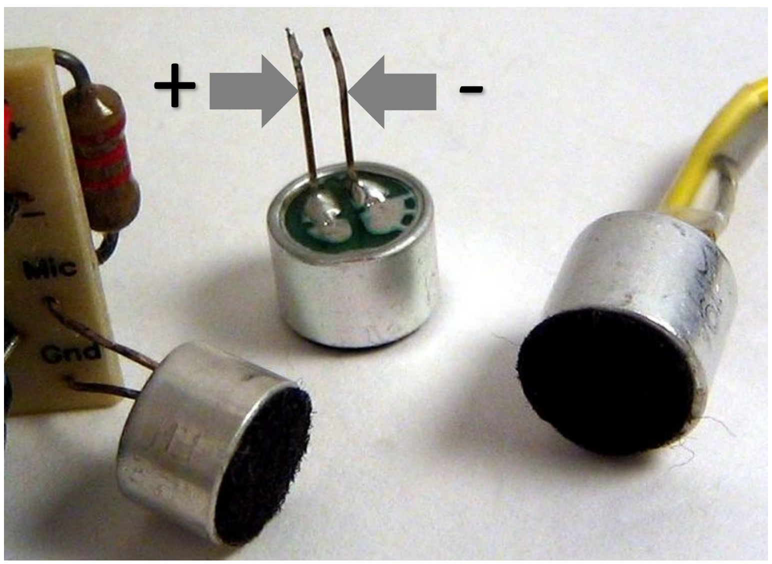
Microphone with Voltage Amplification

Laboratory Outline

An electret microphone with proper biasing (the way you apply voltages to power it and make it operate in a predictable manner) produces a response from ordinary sounds often measured only in the millivolts or tens-of-millivolts range. These voltages are small enough that typical electronic circuits would fail to capitalize on the sound information for typical sound applications like detection (did someone clap?), equalization (pump up the bass!), or even transmission over short distances (tiny signal + tiny noises = significant noise interference). For this reason, the electret microphone's output voltage should be immediately amplified to both preserve the original integrity (lowest noise) version of the signal and allow for additional electronics operations at voltage levels typical of basic electronic devices like diodes and transistors.



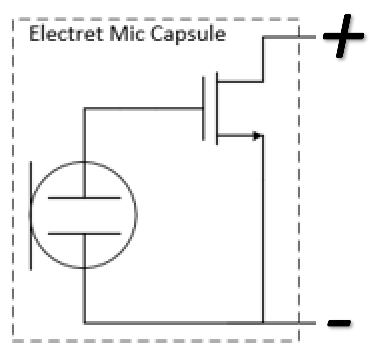


***Figure 1**: A photo and a model of the inner operation of the electret microphone capsule. Close examination of the photo shows the negative lead has metallic connections to the case or "can" of the mic capsule. Photo credit:*
https://upload.wikimedia.org/wikipedia/commons/5/57/Electret_condenser_microphone_capsules.jpg

Notes: This lab is deemed "very-challenging" by the TAs despite its procedural nature. This is because of the many parts and connections that must be made accurately. If you struggle when building circuits, often forgetting power and ground to ICs or have difficulties in mapping a circuit schematic to a physical breadboard, you may not want to tackle this exercise just yet.

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Prerequisites

- Recommended mini-project module 909: OpAmp Amplifier with Gain and Offset Control
- Knowing how to construct a breadboard circuit containing an IC.
- Understanding voltage division.
- Use of an oscilloscope.

Parts Needed

- (2) $1\ k\Omega$ resistor, (1) $10\ k\Omega$ resistor, (1) $1\ k\Omega$ potentiometer, (1 each) $0.1, 10, 1000\ \mu F$ capacitors
- (1) electret microphone capsule, (1) LM358 Operational Amplifier
- A battery with nominal voltage 6-9 volts

Learning Objectives

- To gain practical experience in circuit building and use of a microphone.
- To improve oscilloscope skills.
- To recognize the need for voltage gain and to be able to provide that voltage gain using an operational amplifier.

Procedure

Part of this construction may be done at home to save lab time for when you need access to the benchtop equipment.

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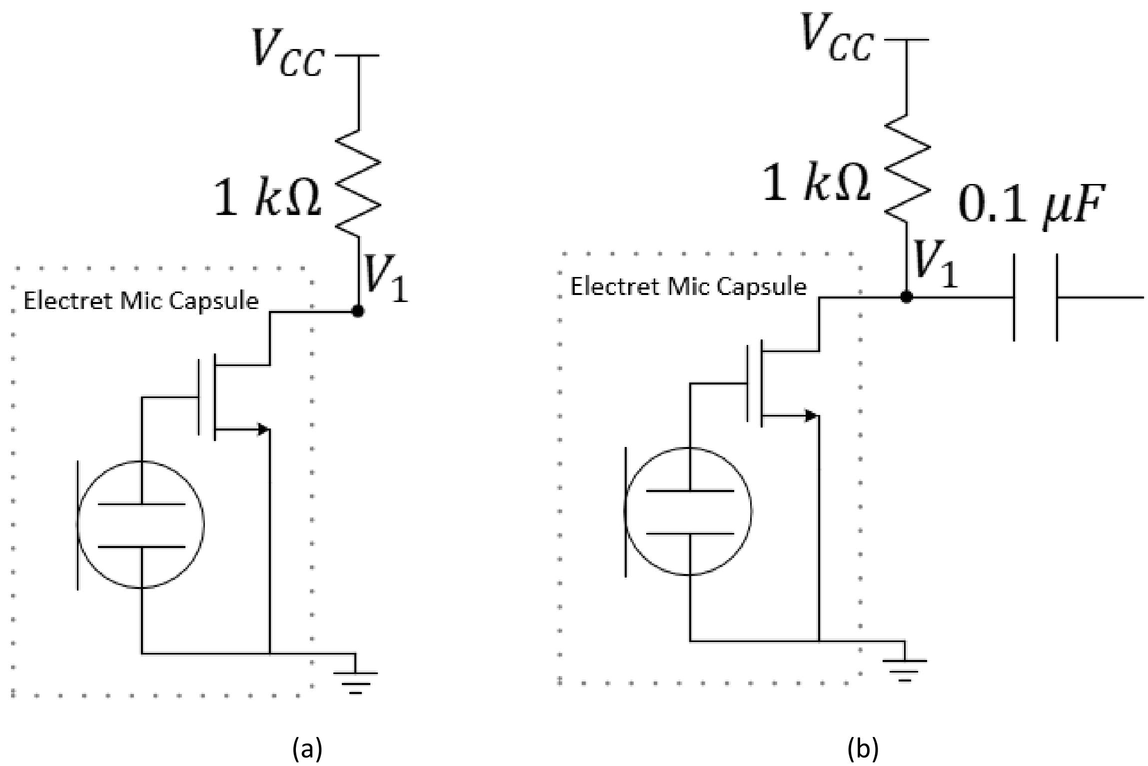

***Figure 2**: (a) A resistor provides bias to the internal MOSFET of the capsule. (b) An AC-coupling capacitor removes the DC component of V_1 before sending the microphone signal to the next component.*

"Bias" the Mic: Please be aware that the microphone is NOT symmetric. The internal MOSFET is a transistor that must be biased properly as discussed in lecture and shown in Figure 2. A close observation of the electret microphone capsule (Figure 1) will allow you to determine which of the two leads should be attached to the negative side of the battery (shown in Figure 2 as ground). Build Figure 2 (b). ***Do not actually attach a battery yet.*** Instead, just make the connections for V_{CC} and ground to the power rails of the breadboard.

Quick Check: If you want, you can now connect one channel of your oscilloscope to view the output after the $0.1\ \mu F$ capacitor (relative to ground). If you connect the battery and adjust your oscilloscope settings (horizontal and vertical), you should be able to see a (very-small voltage) sinusoid when you whistle into the mic. Disconnect your battery and continue.

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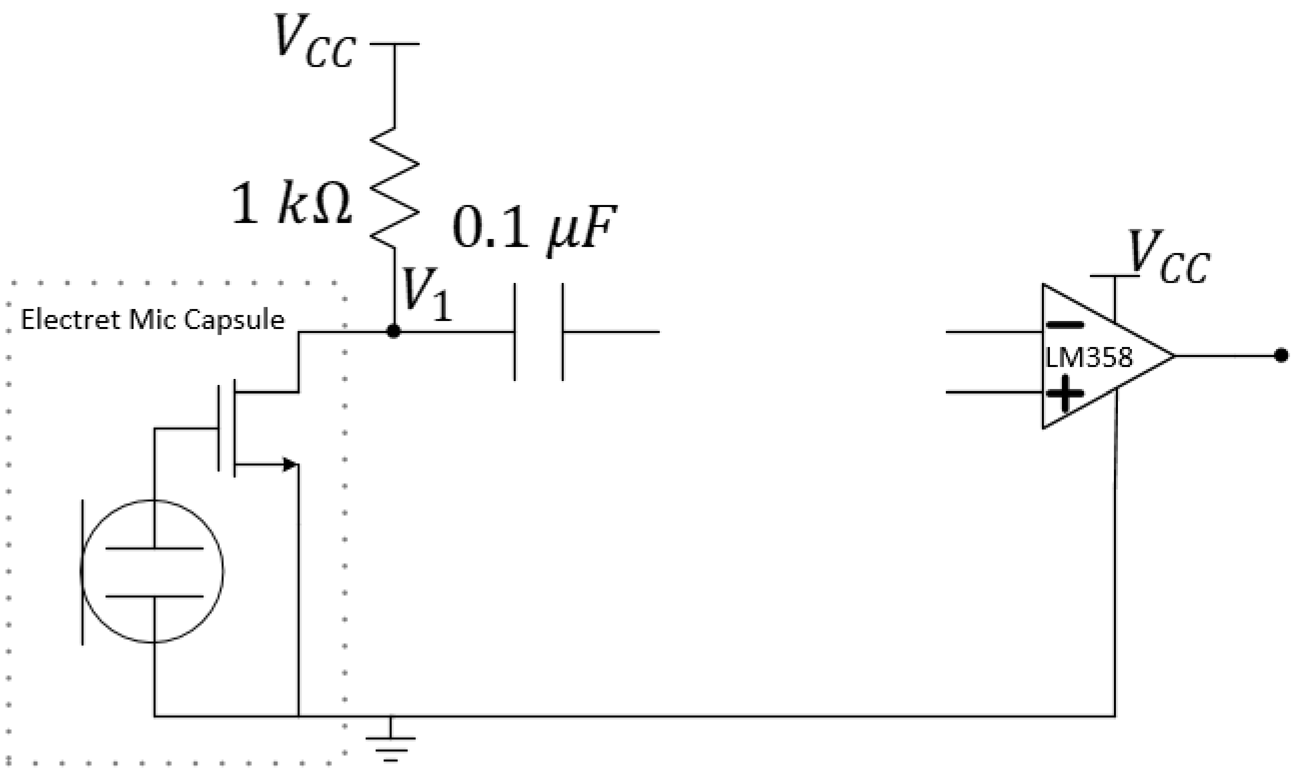

***Figure 3**: Powering the LM358 Op Amp.*

Obtain the datasheet for the LM358 operational amplifier online (http://www.ti.com/lit/ds/symlink/lm158-n.pdf). We will use the LM358 op amp to provide voltage gain to the very-small voltage coming from the microphone. In Figure 3, we see that the op amp is an “active device” that requires battery voltage for correct operation. You will connect pin 4 of the op amp to ground and pin 8 of the op amp to the positive side of the battery.

Use the datasheet to determine the maximum rated supply voltage of the LM358.

Answer Question 1 on the summary page.

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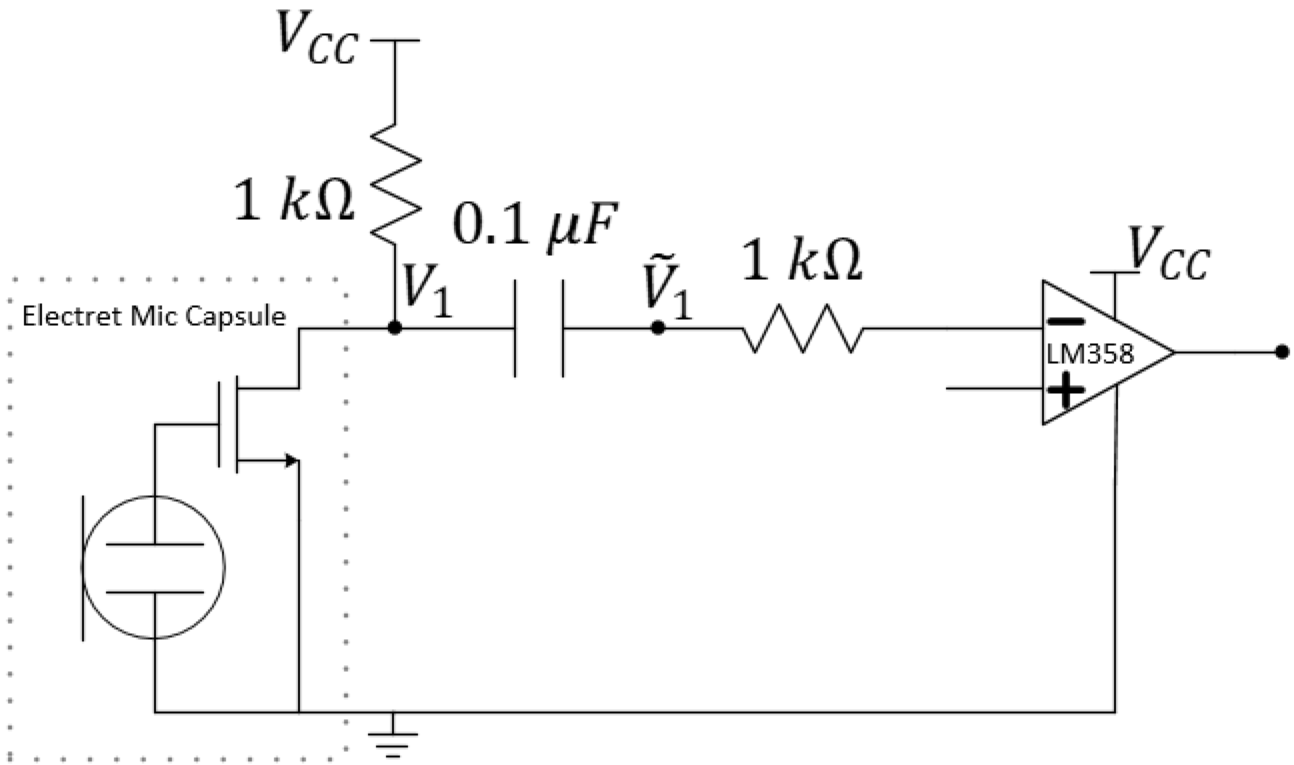

Figure 4*: Attach a resistor to the negative input of the LM358.*

Amplifying the Voltage: With the battery properly connected to the op amp, we can now add two resistors that will set the voltage gain of the op amp-based voltage gain amplifier. From the capacitor to the negative (-) input of the LM358 (pin 2), add a $1\ k\Omega$ resistor.

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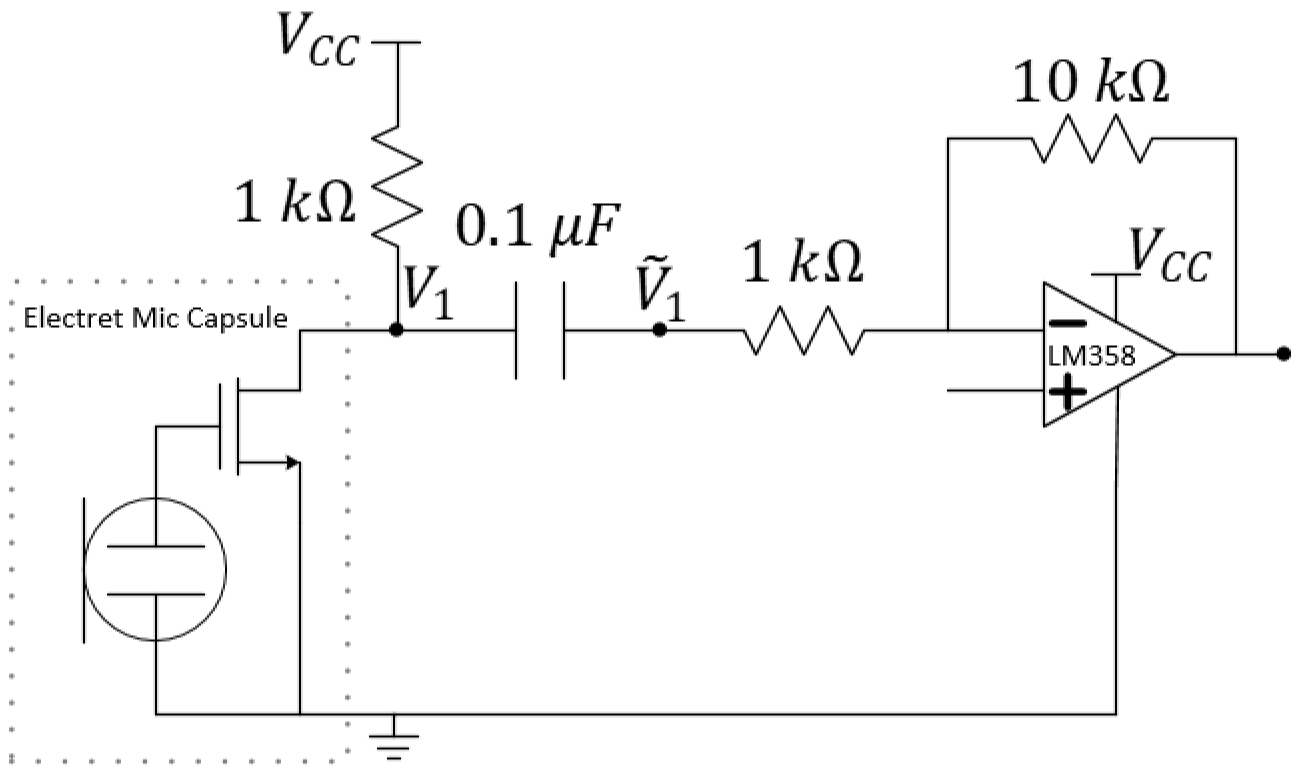


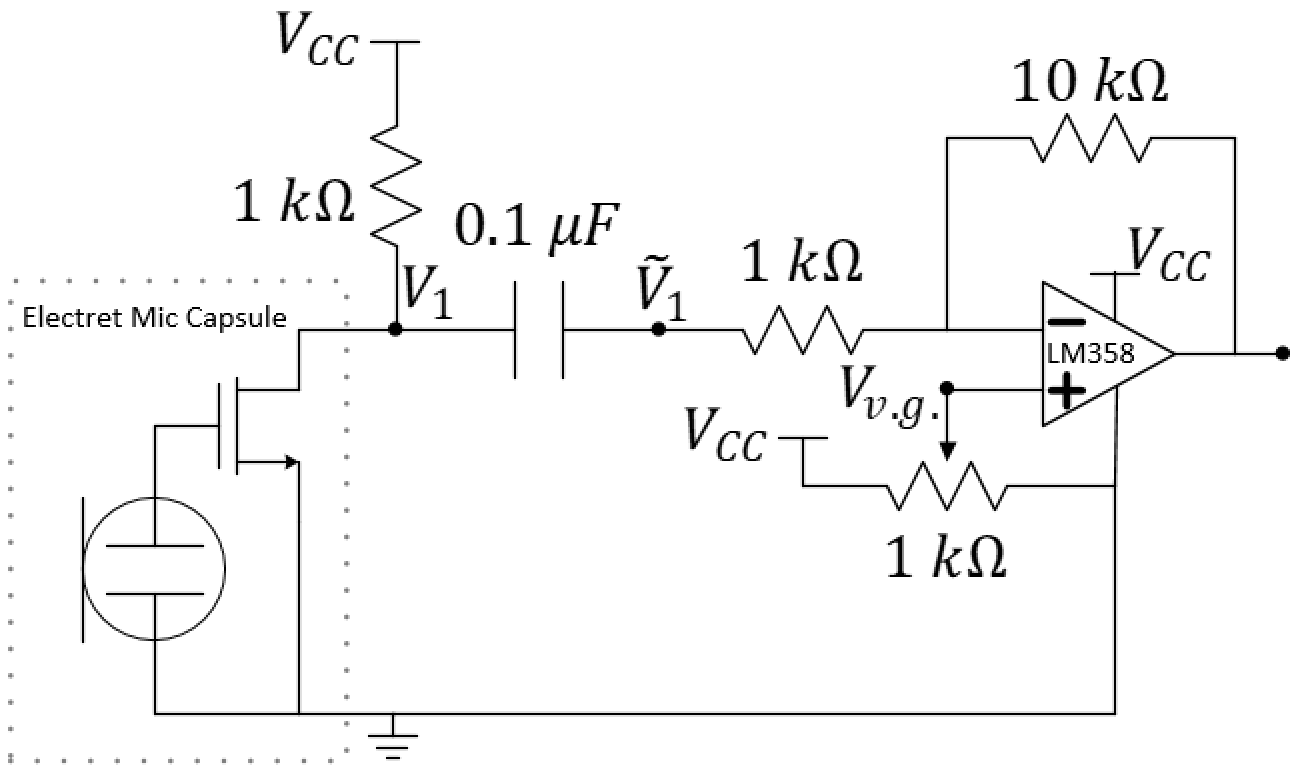
***Figure 5**: Adding a feedback resistor for gain.*

Now, add a feedback resistor of value $10\ k\Omega$ from the output (pin 1) of the LM358 op amp to the - input (pin 2). The voltage gain of the amplifier will be given by

$$G_V = \frac{10\ k\Omega}{1\ k\Omega} = 10$$

This voltage gain is unit-less, but also might be said to have units of volts/volts. That is, for every one volt the input $\tilde{V}_1$ varies, the output pin of the LM358 will vary by 10 volts, thus demonstrating a voltage gain on the time-varying signal. However, the LM358 is not quite ready for operation yet. We still need to do something with the positive (+) input, pin 3.

Answer Question 2 in the summary.



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In Figure 6, we have added a potentiometer of 1 $k\Omega$ used as a voltage divider for the battery voltage. The divided voltage (appearing at the wiper, the middle pin, of the potentiometer) is fed to the positive (+) input of the LM358. This requires a little more explanation…

Virtual Ground for Single-Battery Operation: The LM358 *could* use both a positive and a negative voltage provided by two batteries in series. The ground of the microphone capsule would then be connected to the center of the two batteries as would the positive (+) input of the LM358. The positive voltage of the microphone circuit would be provided by the "upper" battery. However, we would rather have the convenience of using only one battery! We can do this by creating a virtual ground at the positive input of the LM358. Setting the voltage divider near $\frac{V_{CC}}{2}$ allows us to use the configuration in Figure 6 while artificially raising the time-varying signal coming from the capacitor with a DC voltage that allows it to swing up and down within the

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voltage range of a single battery. It is not critical that you understand this. You can finish the exercise even if not clear on the concept.

Start by adjusting your potentiometer to the center of its mechanical range. Tune the potentiometer gently as it can be easy to damage when forcing it near its bounds. Use the oscilloscope to adjust the voltage at the positive input of the LM358 to one-half of the battery voltage.

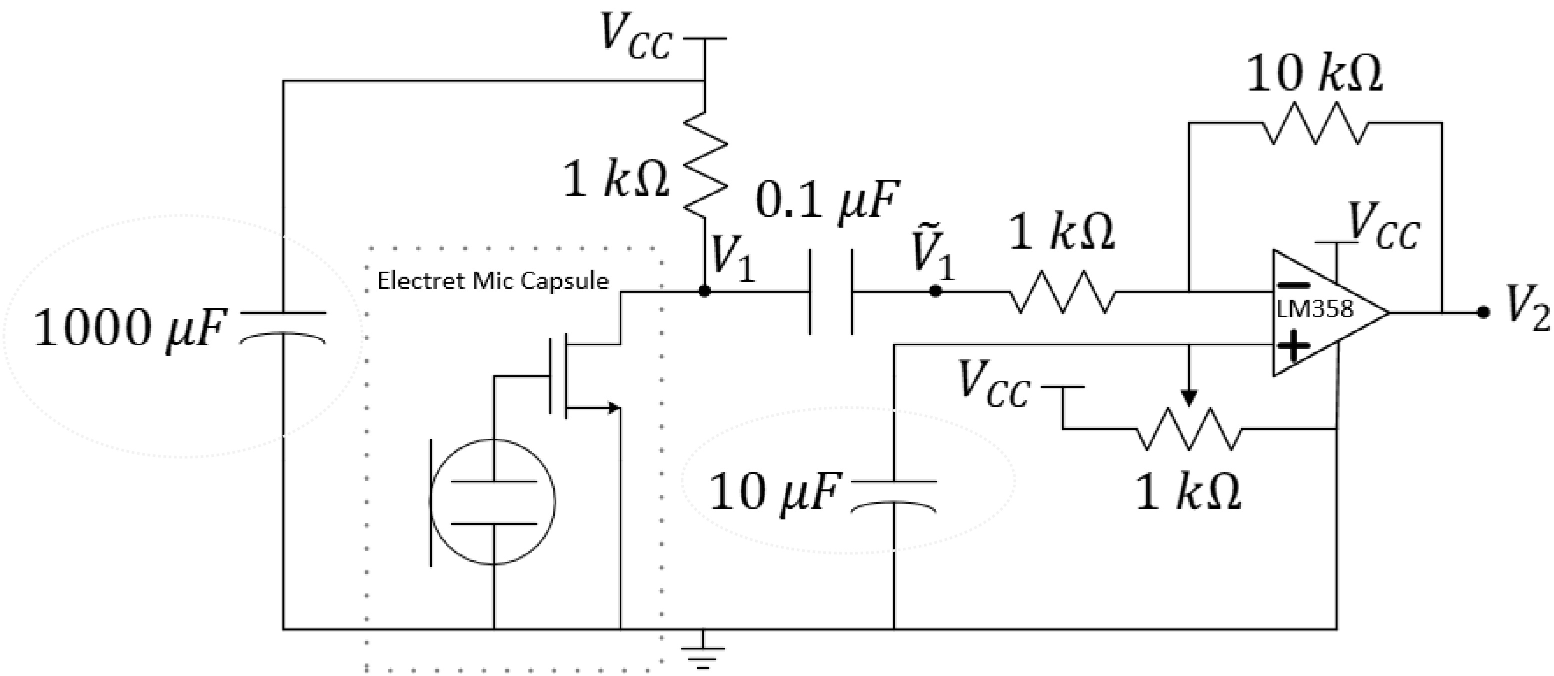

Figure 7: Finding the triangular waveform from a common oscillator.

Limiting Voltage Swings and Avoiding Unstable amplifiers: Finally, we will add two capacitors as in Figure 7. Since capacitors resist large fluctuations in voltage (they require a time to charge and discharge that is proportional to the value of C), placing a $10\ \mu F$ capacitor at the positive input of the LM358 will stabilize that voltage and placing $1000\ \mu F$ across the battery will practically eliminate voltage changes there as well. The capacitor across the battery can also reject accidental oscillations that can happen due to complex circuit behavior at higher frequencies. That is to say, any device with gain will have feedback paths not always controlled or even modelled that can cause strong output signals to find their way back to the input where they are

Comment: Amplifiers can accidentally become oscillators if not careful to avoid un-intended circuit paths from the output to the input.

further amplified. The amplified signal again finds its way back to the input where the process continues until undesired oscillation occurs! A large capacitor across the battery can help eliminate one or more of these potential feedback paths.

Analysis

Turn on the oscilloscope and monitor the battery voltage V_{CC} to ground. Supply the battery to your breadboard and turn it on while monitoring the oscilloscope. If the oscilloscope does not show the battery voltage, shut off your battery and look over your circuit for a short-circuit path from V_{CC} to ground.

Once you are sure there is no short, move the Channel 1 probe to measure V_1 to ground. Channel 1 should be DC coupled (see the Notice on the right). The voltage shown should be somewhere between $\frac{1}{4}V_{CC}$ and $\frac{3}{4}V_{CC}$. Clapping your hands near the microphone may not show any visible change in the signal. Change the oscilloscope from “DC coupled” to “AC coupled”. The voltage shown at V_1 should now be near 0 volts. Adjust the vertical scale until the voltage displayed becomes a visibly “broader” line. Now when you clap near the microphone, you should see some sharp transitions in the voltage displayed. Adjust the trigger level to be about ¾ of the way up the oscilloscope’s screen and adjust the horizontal scale to be on the order of tens of milliseconds. Change these settings until a clap of the hands is clearly visible on the oscilloscope’s screen. You can also try whistling into the mic.

About AC coupling: The reason AC coupling on the oscilloscope had this effect was because it essentially places a capacitor in series with the probe being used to measure V_1. A capacitor will effectively remove the DC component of V_1 while only allowing the AC component to pass through to the oscilloscope’s display.

Do not change the display settings of the oscilloscope but change Channel 1 of the oscilloscope back to DC Coupling and then move your channel 1 *positive* probe to the other side of the $0.1\ \mu F$ capacitor of Figure 7 to measure $\tilde{V}_1$. The $0.1\ \mu F$ capacitor will block the DC component and the oscilloscope doesn’t need to! Clapping your hands while viewing this signal with DC Coupling (the $0.1\ \mu F$ capacitor removed the DC) should produce nearly the same result seen as when you saw V_1 with AC Coupling (the oscilloscope removed the DC).

Answer Question 3 of the summary.

[Optional: You can help to reduce signal distortion caused by your amplifier by tuning your virtual ground. Use two channels of the oscilloscope to measure (DC coupled) the virtual ground on the positive (pin 3) input of the LM358 ($V_{v.g.}$ on Channel 1) as well as the output signal V_2 (Channel 2). Clap your hands or whistle into the microphone. Adjust the settings of Channel 2 until you can clearly see the signal. Tune the potentiometer such that the variation of V_2 is balanced between 0 and V_{CC} so that

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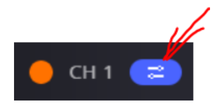
Notice: This lab was written for the oscilloscope in 1001 ECEB and not the M2k. Use the wire harness from the M2k and your 9-volt battery. DC/AC coupling can be found by clicking on the measurements next to the channel and scrolling down on the ensuing menu.



For other items, play around or ask your teammates/TAs for help.

Notes:

distortion in the signal is minimized. Whistling into the microphone (or using a $1\ kHz$ sinusoid from YouTube on your cell phone) is a great way to do this.**]**

Finally, simultaneously monitor V_1 and V_2 with both channels AC Coupled.

Answer Questions 4 and 5 of the summary.

Explore Even More!

An op amp is a (hidden) component in a voltage comparator. If available, consider completing a module on **The Voltage Comparator**.

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To gain credit for this module, you will need to submit a video that states your name and section, shows your circuit, and then demonstrates the response of V_2 to a clap and/or whistle. Comment on the voltage level and whether it is high enough to drive, say, a diode-based half-wave rectifier.

Completion of the questions on the final page are for your own benefit and not collected in Fall 2021.

Name:____________________ UIN: | | | | | | | | | | Section AB/BB: [ ]

Notes:

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Question 1: What maximum supply voltage can be safely applied between pins 8 and 4 of the LM358N? Note that the maximum voltage is a single value even if stated in the one-supply or the two-supply manner.

Question 2: What change(s) to the circuit might you make to increase the voltage gain from 10 to 20?

Question 3: In your own words, what does AC coupling on the oscilloscope accomplish?

Question 4: Estimate the voltage gain of the LM358. You might do this based on a 1 kHz sinusoid played from your cell phone into the microphone.

Question 5: Create a short video verifying the operation of your circuit with an oscilloscope.