University of California, Davis
Electrical and Computer Engineering

EEC 1/89D
Introduction to Electrical and Computer Engineering

Part 3: Sensors, Signals, and Systems
Optical Audio Transmitter and Receiver and Amplifiers

Lab 5: Signal Communication

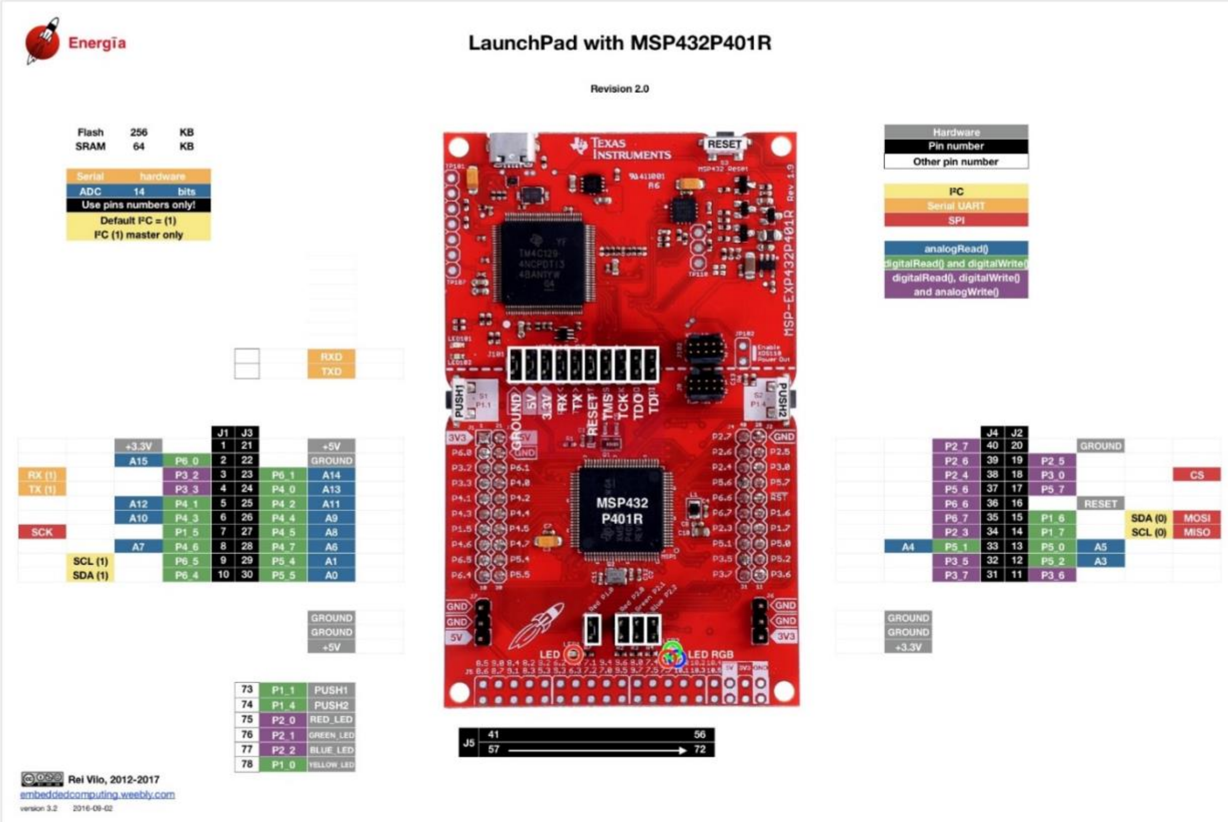
Introduction:

a. Purpose/ Scope

This lab is a direct continuation of the previous lab. Last time, we saw how we can switch between different forms of energy using transducers. We now wish to take this concept a step further and engineer an optical communication system. While the system design is limited in capability, the fundamental concepts behind its operation can be refined to make robust communication systems.

b. Resources/Lab Materials

- breadboard x2
- MSP432 MCU x1
- wires
- LM358 operational amplifier x1
- LMC6482 operational amplifier x1
- photodiode x1
- red LED x1
- MAX9814 microphone x1
- Headphones (2 if possible)
- Audio Jack: Link
- Resistor: 100 Ω x1
- Resistor: 1 kΩ x3
- Resistor: 10 kΩ x1
- Resistor: 100 kΩ x1
- Resistor: 1 MΩ x1
- Resistor: 10 MΩ x1
- Capacitor: 100 μF x1



Pin layout of MSP432

<u>Exercise 1:</u> Sound to light

Description: We will now demonstrate how physically significant signals, such as sound, can be converted into useful forms and manipulated. In this exercise, you will use a microphone to convert sound to an electrical signal to be used to drive an LED and headphones.

The microphone you will be using is the MAX9814 and you will need to solder this with the help of the your lab TAs.

Fig. 1. (A) MAX9814 microphone

You'll notice the microphone has 5 holes in it labeled (from left to right): AR, Out, Gain, Vdd, and GND. Vdd and GND refer to power and ground respectively while Out references the pin producing the signal from the microphone. The other pin of importance is the Gain pin. How this pin is configured will determine the intensity of the output signal. If you look closely above the pin holes you can see a description of how to configure the gain pin hole for different degrees of amplification in units of dB.

Procedure:

1. Your TA will call you in groups to solder the microphone header pin. Once the header pin is soldered to the microphone, it can be mounted onto your breadboards for the remainder of the lab.

2. Construct the LED and microphone circuit shown in the diagram of Fig. 2.

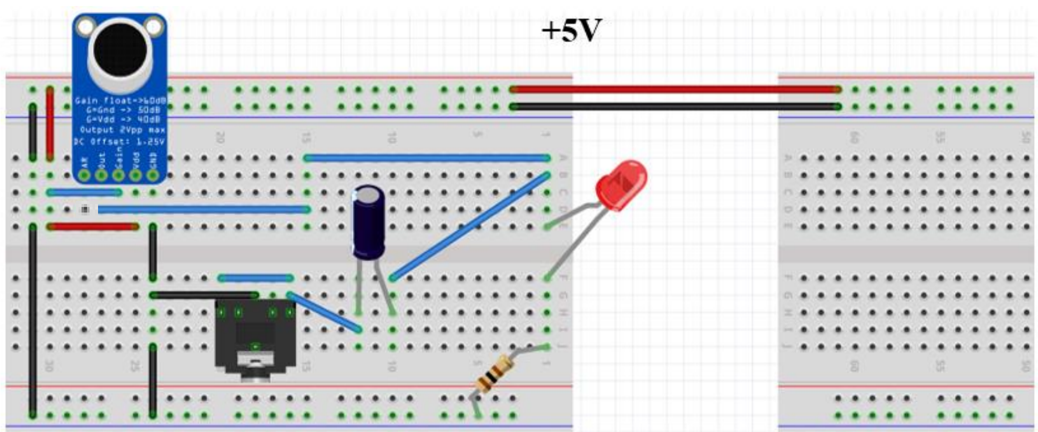


Fig. 2. Microphone-LED Circuit

If you can hear signals from the microphone you may go on and answer the following questions.

Questions: Submit answers to the following questions on Canvas.

1. We can hear that the electrical signal from microphone is a "good" representation of the original sound signal once we listen to it. We can also see an optical representation of the signal from the LED. Do you think the intensity fluctuations of the LED due to the microphone accurately represent the intensity fluctuations of the original sound signal? Why or why not?

2. Next we introduce the concept of gain which will be more thoroughly investigated in the following exercise. As mentioned previously, there are three configurations that will change the gain between 40, 50, and 60 dB. We are currently configured such that we are amplifying the signal by 40 dB. Move the wire connected to the gain pin from power to ground so that you are amplifying the signal by 50 dB. How does the sound change over the headphones between the two configurations?

3. Now remove the wire connected to the gain pin from the circuit. The pin is now said to be "floating." This configuration will produce a gain of 60 dB. Once again describe how the sound changes in quality and intensity.

4. If we were able to increase the gain further, how would you expect the quality of the audio signal to change?

<u>Exercise 2:</u> Amplifying Signals

Description: Sometimes signals from sensors are too weak or need to be properly conditioned before they can be worked with. One of the most widely used devices that is capable of this is the operational amplifier, more commonly known as the op-amp. In this exercise, you will combine another photo sensing device, a photodiode, with an op-amp to create a measurable signal.

Unlike the photoresistor, the photodiode will source a current when illuminated as opposed to controlling the voltage by varying it's resistance. Our goal is to take this current signal, amplify it, and convert it into a voltage that can be read by our MCU. To do this, we will construct an op-amp based circuit known as a transimpedance amplifier. A schematic of the transimpedance amplifier combined with the optical communication circuit can be seen below in Fig. 3.

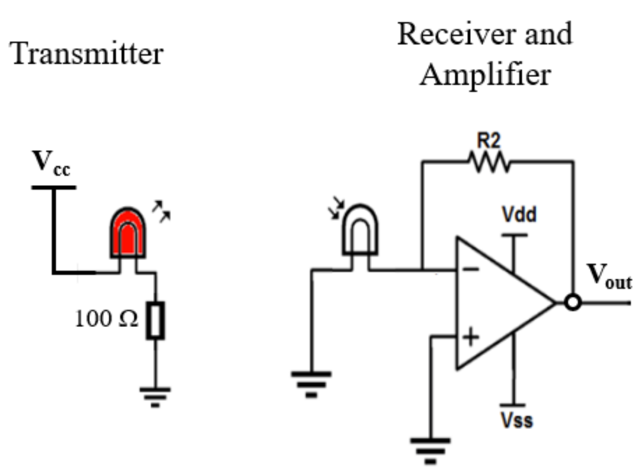


Fig. 3. Optical Communication Circuit with Transimpedance Amplifier

An important parameter for understanding an amplifying circuit is the gain. The gain of a circuit is defined as the ratio of the output over the input, if you only look at the receiver part of the circuit you can define the gain as the V_{out}/I_{in}, and that is proportional to R_2:

$$Receiver\ Gain = A_{rec} = \frac{V_{out}}{I_{in}} = -R_2$$

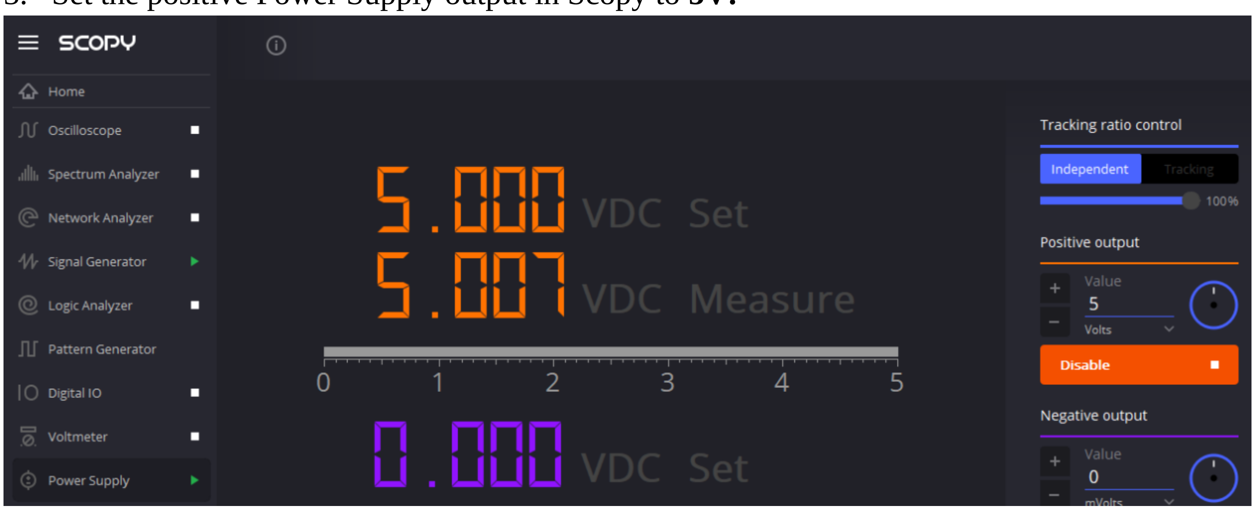
However, if you look at the entire circuit (transmitter + receiver) we can define the overall gain of our system as the ratio of V_{out}/V_{in}, where V_{in} is the value applied to the LED circuit by the function generator. In the following sections we will try to determine the overall gain of our communications system.

Procedure:

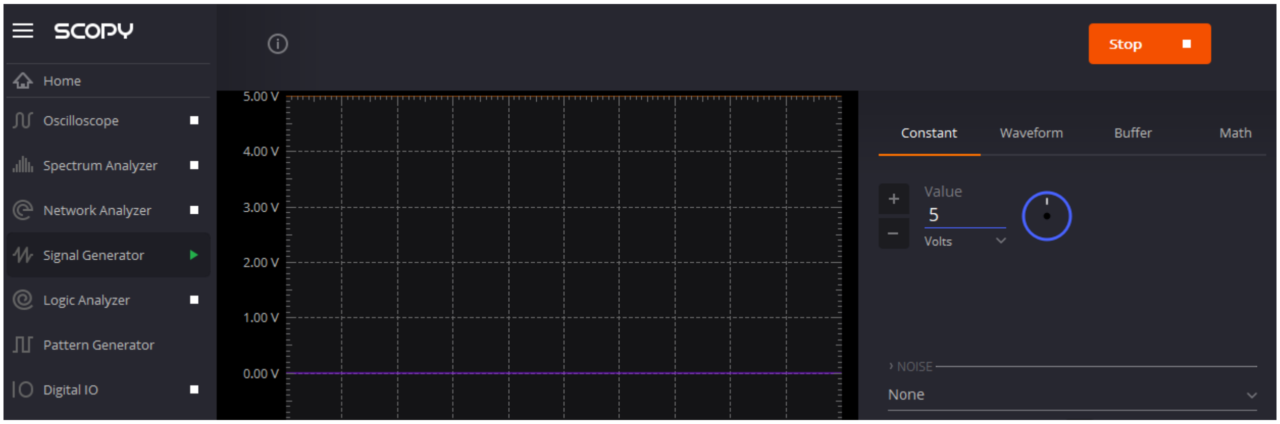
1. Build the transmitter/receiver circuit as shown in Fig. 4. Begin by using a 100 kΩ resistor for the R2 in the receiver circuit, and an op-amp. You will be provided with two op-amps and either can work as the pin layout for each is the same. The op-amps are the LM358 and the LMC6482. Keep in mind the following:

    1. The Transmitter circuit should be constructed on a separate breadboard as you will be measuring separation distance as in the previous lab.
    2. In the receiver circuit, the anode (the positive leg nearest the bump) of the photodiode is connected to ground.

    3. Set the positive Power Supply output in Scopy to **5V.**



4. Set the Signal generator to **Constant 5V**



We are using 2 separate supplies (V+ and W1 pins on ADALM) for the op amp and LEDs because we will want to change the supply voltage of only the op amp in later steps.

5. We will be measuring voltages larger than 3.3 V to start so we need the voltage divider circuit once again to scale the voltage before the measurement.
6. Use the Scopy Voltmeter with pin 1+

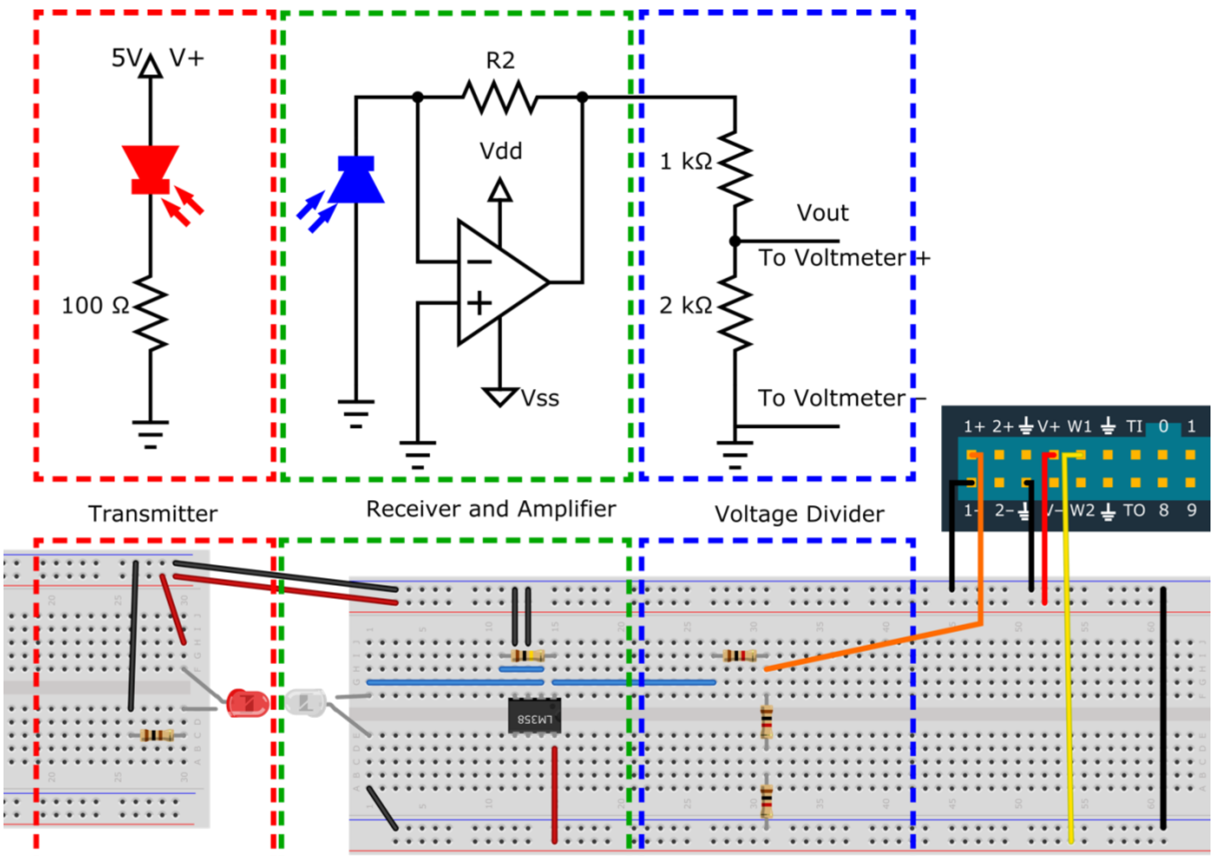


Fig. 4. Schematic for optical communication system and amplifier (Top) and breadboard implementation (Bottom)

7. Once complete, answer the following questions.

Questions: Submit answers to the following questions on Canvas.

1. Using a ruler systematically move the LED and the photodiode farther apart and measure the voltage at the output of the amplifier. For simplicity, assume Vin is the magnitude of the power supply across the LED. Plot the gain of the system as a function of the separation distance. Remember to include titles and units on your axes.

2. Why does the gain change with distance even though we are not changing any circuit components?

3. Put the LED and the photodiode as close together as possible to maximize the output signal. Next, change the resistor value R2 from 10k Ohm to 10 MOhm. In the table below record Vin, Vout, and Gain. Then plot the gain as a function of R_2. How does the gain change with resistance?

R_2	V_{in}	V_{out}	Gain
10 kΩ			
100 kΩ			
1 MΩ			
10 MΩ			

4. Repeat part 3, but first switch the power supply for the amplifier **ONLY** from 5 V to 3.3 V by changing the Signal Generator in Scopy to **3.3V.**

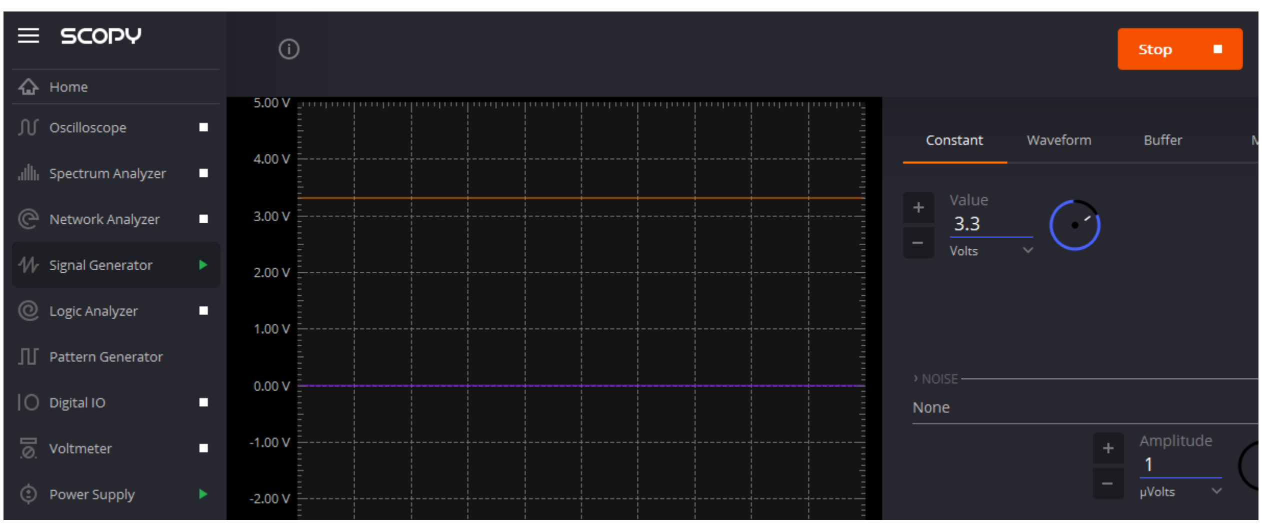


Fig. 5. Switching op amp power supply to 3.3V

Once this is done, complete the chart again with under the same circumstances.

R_2	V_{in}	V_{out}	Gain
10 kΩ			
100 kΩ			
1 MΩ			
10 MΩ			

5. What happens when the gain becomes very large? Will the output voltage become infinite?

6. What sets the maximum output signal achievable for an amplifier? Knowing this, explain why the microphone in exercise 1 sounded like it did when set to higher gain values.

<u>Exercise 3:</u> IR transmitter with microphone and speaker

Description: We will now combine all aspects of the previous labs into a single device to construct an optical communication system. For this exercise your main challenge will be to appropriately choose the parameters/components of the circuit below to create as loud and clear signal as possible. Thus far, we have (1) analyzed the gain associated with the microphone by changing the configuration of the gain pin, (2) analyzed the dependence of gain on separation distance between the LED and photodiode, and (3) changed the resistance of the op-amp to manipulate the gain. Your job is to manipulate these parameters to optimize the signal to the best of your ability.

<u>Procedure:</u>

1. Construct the circuit shown in Figure 6 below as shown.

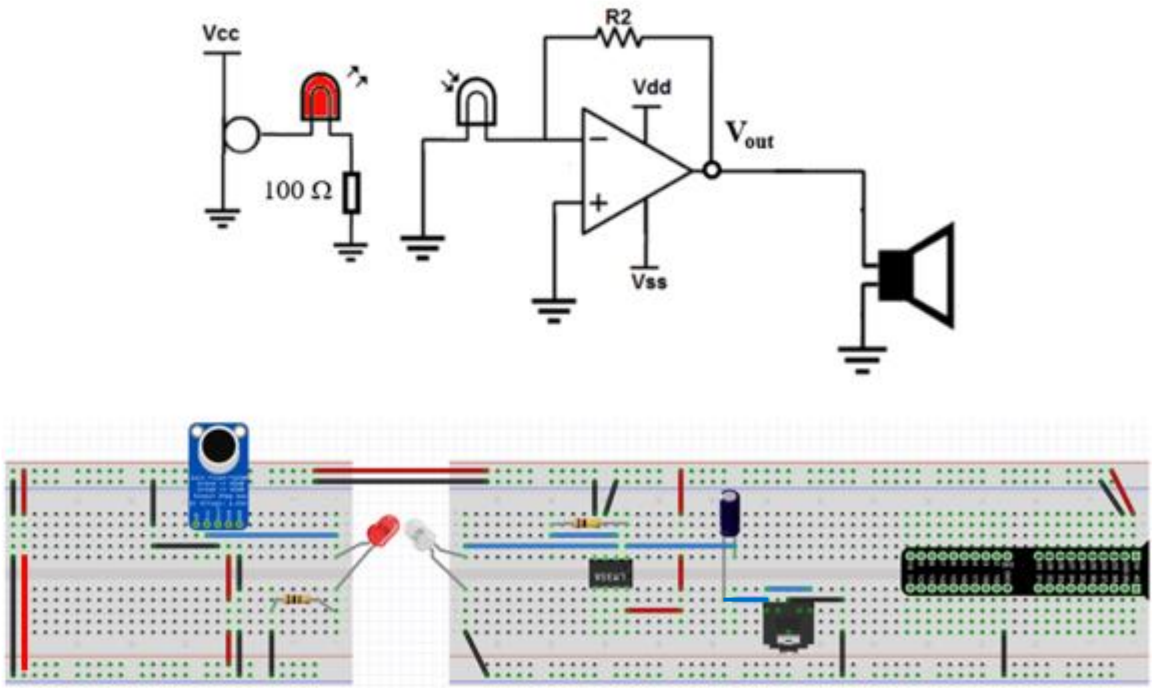


Fig. 6. IR transmitter with microphone and speaker schematic (top) and breadboard implementation (bottom)

2. After assembling the circuit, connect your headphones to the audio jack to see if you can hear through the microphone. You should at least be able to hear a buzzing sound through the headphones.

3. Once you verify the circuit is working, begin optimizing each of the three aspects discussed above. Start by determining how close the LEDs should be to each other to maximize gain. Then change the configurations of the microphone and the op-amp resistor to achieve the clearest signal. To test the signal quality, use the following link to generate a sound signal across different frequencies Link . If you have an extra set of headphones, plug them into your computer and put them up against the microphone to generate the signal. Otherwise, you will need to use your speakers and the signal will be harder to hear. Be sure to test the quality of the signal over a range of frequencies as you will be asked to comment on this later.

4. Once you are satisfied with the signal quality, answer the following questions.

Questions: Submit answers to the following questions on Canvas.

1. How far apart did you place the LED and photodiode and why?

2. How high did you set the gain on the microphone (40, 50, or 60 dB) and why?

3. What resistor did you choose to use in the op-amp circuit and why?

4. Was there any change in the signal intensity for specific frequencies? If so, specify the range of frequencies in which the communication system performed the best.

5. In the figure below, draw the pathway from the output of the microphone to ground through the LED and resistor.

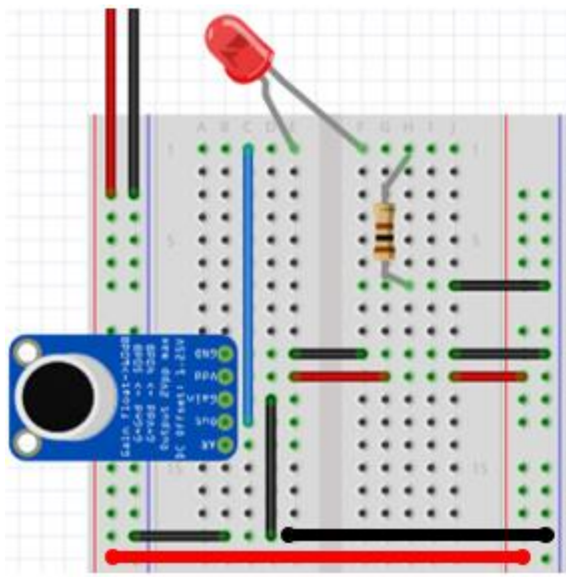


Fig. 7. Schematic for problem 2 of exercise 3.