# Lab 2

## Broken Engineers:

Matthieu Stogsdill, Makenna Maguire, Tim Evans, Austin Wittenburg

## 1. Introduction

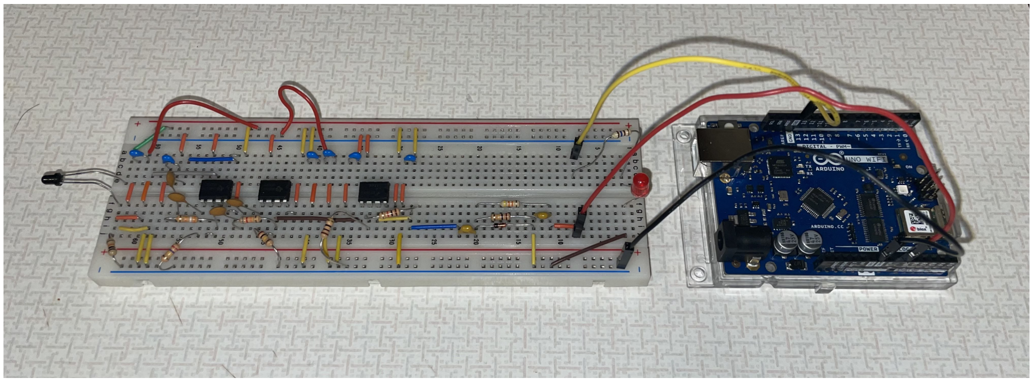


**Figure 1:** Final Prototype of "electric eye" light beam-interrupter safety system

The final design of the "electric eye" light beam-interrupter safety system consists of a transmitter provided to us and a receiver designed by our team which can be seen in **Figure 1**.The transmitter sends an infrared signal operating at a 50% duty cycle and 500 Hz frequency. Our infrared signal receiver consists of a photodiode to detect the transmitted signal followed by a buffer to keep our incoming signal from being altered by the detector. After the buffer the incoming signal is passed through our 4th order Butterworth high pass filter. The filter consists of two stages which are both 2nd order KRC/Sallen-Key high pass filters designed to filter out the noise of ambient light and the light from a 100W light bulb transmitting around 120 Hz and allowing the 500 Hz signal to pass through. After, the filter follows an amplifier to bring our filtered signal up to an appropriate level for the detector at the end of the circuit to recognize the difference between the signal being blocked and the signal being received. The signal is then passed through an envelope detector to convert the signal from AC to DC and then onto the arduino to be processed as a high or low signal and alert the user when the signal has been interrupted. When the signal has been interrupted an LED powered by the arduino initially in the off state will turn on for the duration that the signal is not being received and the arduino will send a text message to a predetermined phone number. The text will alert the user of a critical safety event with the hour, minute, second, and whether it is AM or PM of when the signal was interrupted.

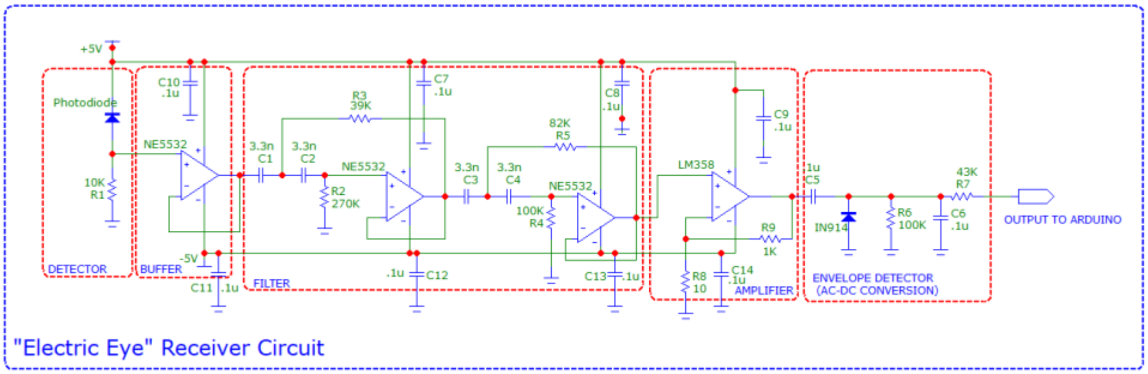


**Figure 2:** Final Schematic of "electric eye" light beam-interrupter safety system

## 2. Design Documentation

**Hardware:**

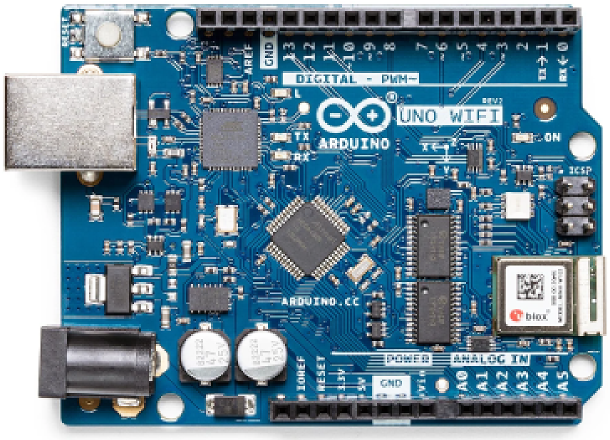


**Figure 3:** Arduino Uno Wifi Edition

The Arduino uno is the microcontroller used for this lab and handles sending the text messages and displaying whether or not the signal is being received or interrupted. In our design the arduino powers a red LED turning it on or off if the connection it has at the output of the envelope detector falls below a certain DC value.

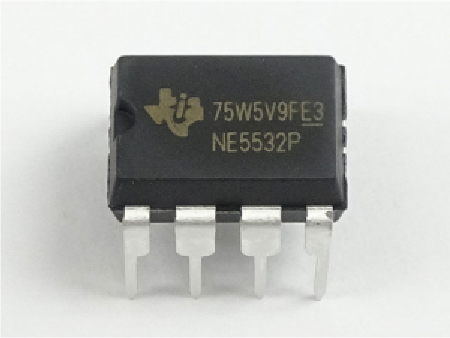


**Figure 4:** NE5532 Dual Low-Noise Operational Amplifier

One of the two operational amplifiers used in this lab is the NE5532. This amplifier was recommended by a professor as the filter design software recommended a different op-amp but this one works well and offers a dual op amp internal structure which is convenient for building two sections of the receiver in one IC. This chip is used to construct the buffer and the first stage of the filter. It is powered by a dual power supply at +/- 5V.

**Figure 5:** LM358 Low Power, Dual-Operational Amplifier

The LM358 was the other of the two operational amplifiers used in this lab. Again this op-amp was recommended by a professor and was implemented as the gain amplifier for this lab to boost the signal after it was filtered. It is powered by a dual power supply at +/- 5 V.

**Figure 6:** Infrared Photodetector

The photodetector in this lab converts the incoming infrared signal from the receiver as well as ambient light from the room and other sources and creates a small photocurrent to be used by the receiver. This in pair with a resistor which is described in more detail later on will help us produce a signal voltage that will eventually find its way through the receiver and to the output.

**Miscellaneous Components**

There are a few components that are non-specific but still necessary for the successful operation of this device. These components are as follows

-Breadboard
-Jumper wires (male-male, female-male)
-Resistors (Values specified in schematic)
-Capacitors(Values specified in schematic)
-Red LED
-Diode (1N914)

**Software:**

The software components of our product consists of a script running on the laptop and arduino code running on the Arduino Uno Wifi Edition. The code on the laptop, main.py, consisted of an infinite while loop that continuously checks to see if the voltage output from the envelope detector went below the specified ADC value of 100. If it does, then a text message is sent indicating a critical safety event. The code on the arduino, lab2arduino.ino, consists of a loop that also continuously checks if the ADC voltage value goes below 100. If it does, then the code sets the output controlling the indication LED to high.

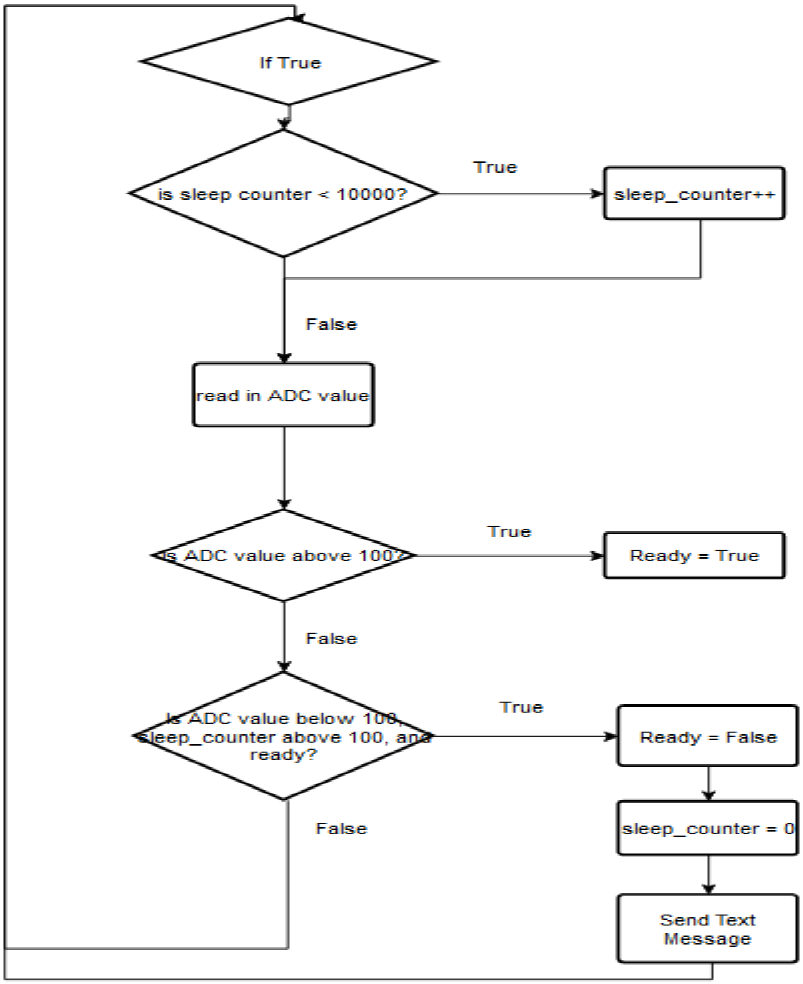


**Figure 7:** main.py logical flowchart

In main.py, we start by initializing a serial connection with the COM3 USB port that the Arduino is connected to with a baudrate of 9600. In the main loop, an infinite while loop is set up to check to see if the ADC voltage value drops below 100. This corresponded to a voltage of around 0.49V since we used ADC pins on the arduino that mapped analog voltage between 0-5V to decimal values 0-1024. The voltage is checked using the pyserial library to read input from the usb cable that the Arduino is connected with. If the voltage goes below an ADC value of 100, the counter is ready, and the receiver was previously not obstructed,  a text message with a timestamp is sent to indicate that the IR receiver has been obstructed. In the while loop, we sleep for 1 millisecond in order to give time to print out values for debugging purposes.

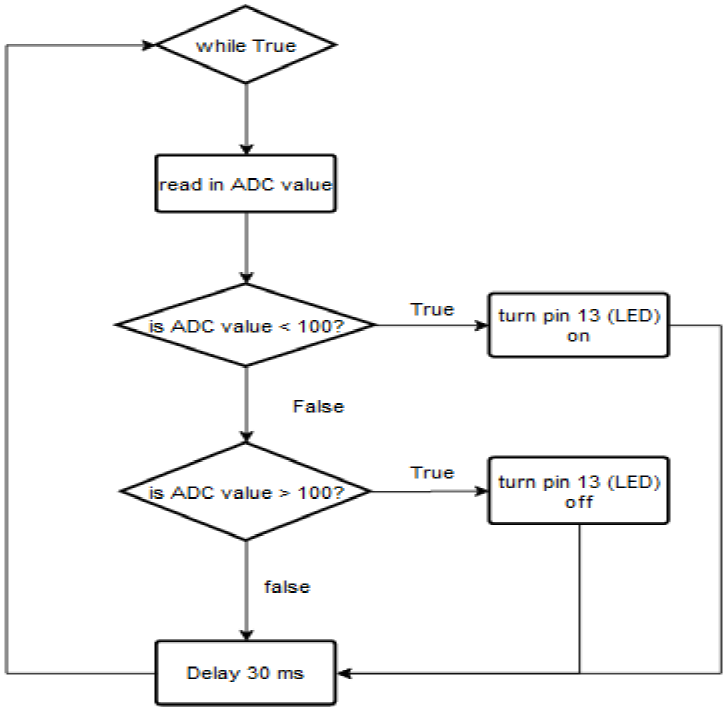


**Figure 8:** lab2arduino.ino logical flowchart

In lab2arduino.ino, we start by initializing A0 as an input pin in order to read ADC values from the output of the envelope detector. We initialize pin 13 to be an output pin for the indicator LED. We then start our serial connection with the USB port and then enter the main loop. In the main loop we read in the ADC value from A0 and check if it is below 100. If it is, we set pin 13 to high which turns on the indication LED. Else we set pin 13 to low in order to turn off the LED. We then delay for 30 milliseconds for output visibility.

## 3. Design Process & Experimentation

### Design Process:

For our filter design, we had to compare four different types of filters to see which would give us the output we wanted. These four types were optical, electronic, software, and matched filtering. For optical filters, the two main types are absorptive and dichroic. In the absorptive filters, the compounds used absorb or block specific wavelengths while allowing others. Dichroic filters do the opposite, they reflect the selected wavelengths and transmit the non reflected. Electronic filters work by allowing specific frequencies to pass through. This works by isolating a designated frequency and allowing the signal to pass using circuits to remove unwanted wavelengths. Software filtering is similar to electronic filtering however, instead of using hardware to digitize the output from a photodetector software will be used by the use of a microcontroller. A matched filter is the last type of filter considered. This filter is mainly seen in radar signal detecting, and is used to detect a piece of a signal and it will maximize the signal to noise ratio of the detected signal. These four filter types were evaluated based on their advantages and disadvantages for this lab and we then designed our filter.

In the end we decided to go with electronic filtering as the IC's were cheap and readily available to us. We used an online website Analog Filter Wizard to help us design the filter. We ended on a 4th order Butterworth high pass filter which can be seen below along with the bode plots for its stopband and passband tolerances. It was designed to allow the 500 Hz infrared signal through while filtering out ambient light and the light from a 100W light bulb which transmits around 120 Hz. The design also included an amplifier and an envelope detector. When designing the receiver, it was clear that in order to get the correct output it needed to be amplified so we added the amplifier to the output of the second op amp. Following this, we needed a way to convert from AC to DC to detect the signal using the Arduino. As a result we first designed a bridge rectifier and then when we added the rectifier to the full circuit we did not get the correct output on the serial monitor. So we switched to an envelope detector which used a diode, capacitor, and resistor and this was successful.

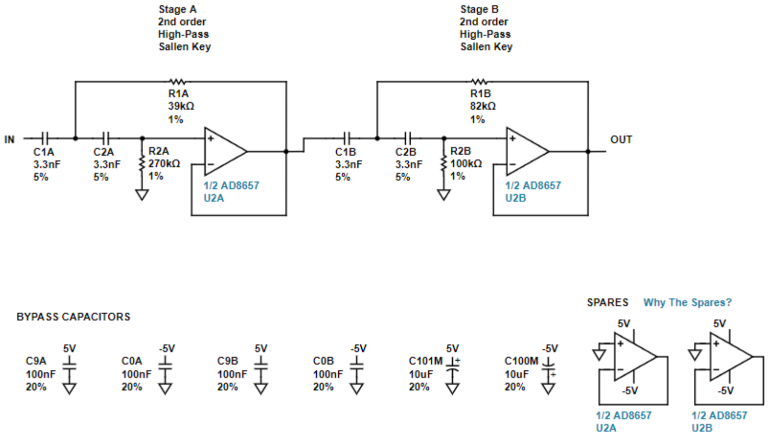


**Figure 9:** Schematic of 4th Order Butterworth High Pass Filter

## Experimental Design:

After the design of the circuit was completed a series of tests needed to be conducted. We conducted these tests starting with the first phase of the circuit. We used two main tools to accomplish these tests: a signal generator and an oscilloscope. Using a signal generator at 500 Hz we tested to make sure the receiver at the first pass of the filter was reading 500 Hz. Following this we did the same for the second pass of the filter. We added this phase because even though the first pass could have been enough to filter out the signal we wanted to add this pass to make sure we got the correct output. We also checked with an oscilloscope at the output of the second pass of the filter to make sure the waveform was a square wave. Once we had the filter phase done, we realized we needed to amplify the output in order for the Arduino to pick up the signal. We initially started with a small gain and quickly realized that the gain was not big enough for the Arduino to pick up, so we changed the gain to 100 and this worked well. The last piece of the circuit was the envelope detector. We tested this piece separately before adding it to the full circuit. We used the oscilloscope to see if the output through the detector would work with the Arduino to send a text message alert. Lastly, was the final test which was to make sure it all worked when the receiver was together and with the receiver. We tested it following the test plan below, which shows how we conducted the series of tests to check if the receiver was correct.

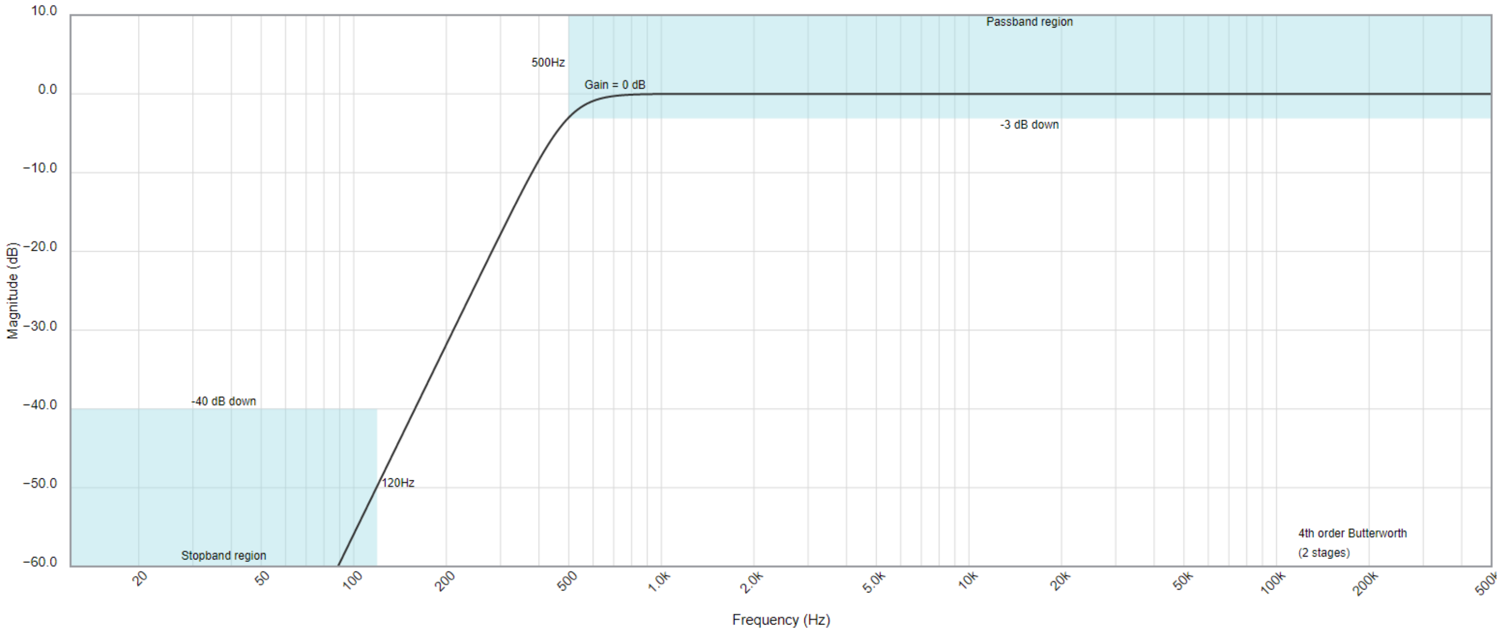


**Figure 10:** Magnitude Plot for 4th Order Butterworth High Pass Filter

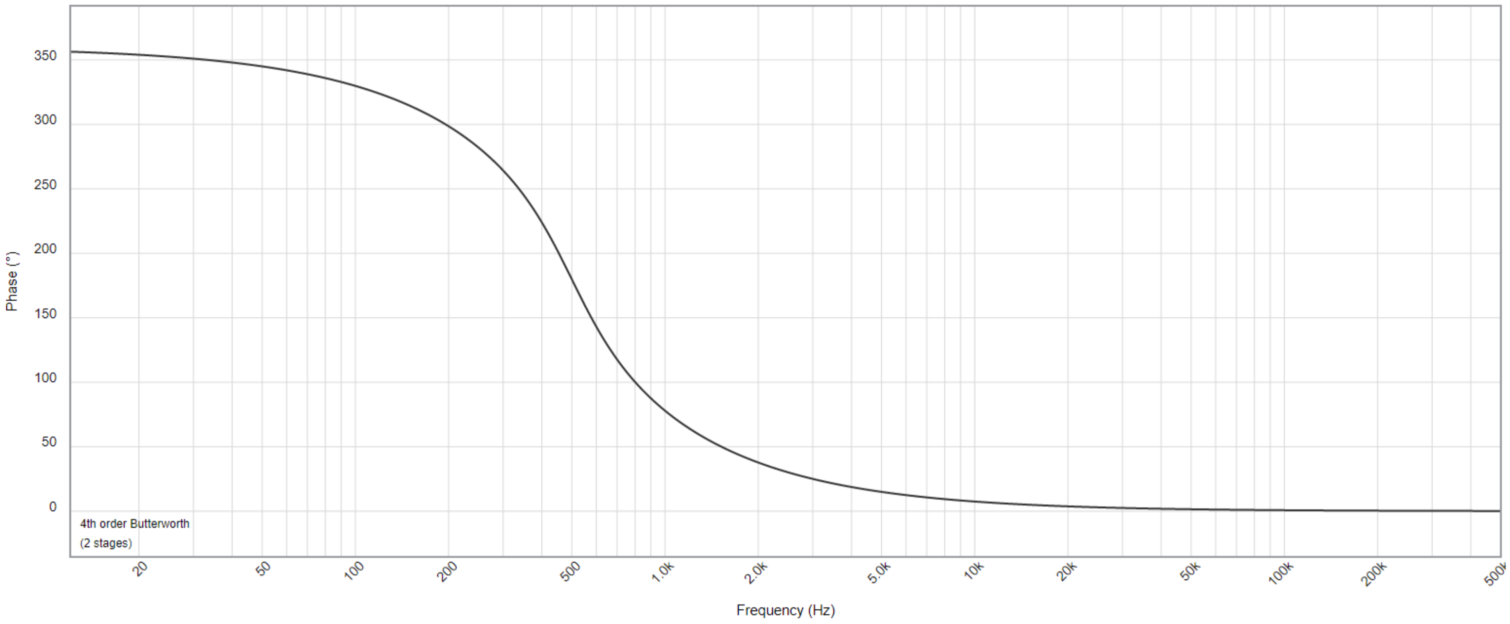


**Figure 11:** Phase Plot for 4th Order Butterworth High Pass Filter

**Data Analysis:**

Along the way of the design and testing process there were several points where the data being received needed to match up with design criteria. One way we tested our design as the transmitter was in high demand was to use a signal generator and replace the detector circuit with an input straight from the signal generator. We used the signal generator to input a square wave of multiple different frequencies to initially test the buffer. Using an oscilloscope we tested that the signal being put into the buffer was the same signal coming out of the buffer at multiple frequencies and that it was indeed still a square wave. After verifying that the buffer was not giving us anything other than the input signal we tested each stage of the filter using the sweep feature on the signal generator to sweep through a range of frequencies starting around 10 Hz up to 3kHz and using the oscilloscope to confirm that the output was still a square wave transmitting at 500 Hz and being cut off at the 120 Hz range. This same test was conducted at the output of the amplifier as well as comparing the DC voltage at the output of the second stage of the fitler and making sure the output of the amplifier was our gain multiplied by that DC voltage.

## 4. Test Report

| **Test Procedure** | **Expected Result** | **Pass/Fail** | **Value** |
|---|---|---|---|
| Put the receiver and transmitter in low light and point them at each other | The receiver’s LED should remain off | Pass | |
| Turn the lights back on and using a 100 W light bulb, move the light closer and closer to the receiver until it fails then measure the distance | The receiver should remain functional when the lightbulb is near the system | Pass | 6 in |
| Turn off the 100 W light bulb and break the signal from the transmitter to the receiver | The receiver's LED should turn on and a text message should be sent to a predetermined phone number | Pass | |
| Examine the format of the text message | The message should be in the format: HH:MM XX, where HH is the hour between 00 and 12, MM is the minute between 00 and 60, and XX is AM or PM | Pass | |
| Break the signal from the receiver once more and keep it broken for some time | The receiver should send only one text message until the signal is restored | Pass | |
| Move the transmitter and receiver further apart but maintain the signal until it cannot be maintained, then measure the distance between them | The receiver should be able to be placed at least three feet apart and remain functional | Pass | 3 ft 3 in |
| Remove the receiver from the system and, using a signal generator, send a range of signals less than 500 Hz into the filter and measure the output with an oscilloscope | The output of the filter should be roughly 0 Hz when the incoming signal is $< 500$ Hz | Pass | 0 Hz |
| Now set the signal to 500 Hz and slowly increase the signal | The output of the filter should be roughly 500 Hz for all input signals $\geq$ 500 Hz | Pass | 501.8 Hz |
| Remove the signal generator and supply the envelope detector with 5 volts of AC power and measure the output with an oscilloscope | The output of the detector should be a DC voltage of at least 1 volt so that the arduino can better distinguish from a high and low signal | Pass | 1.5 V |

## 5. Project Retrospective

### a. Project Outcome

Overall, the project went well and we stuck with the original plan well. From our first meeting to final check off we stayed on track and were able to complete the lab at a good pace. The design of our filter stayed consistent throughout the lab. Our choice to use the NE5532 op-amp with the photodetector was a great choice for our design since after this all we included was an amplifier to amplify the output and an envelope detector for the AC-DC converter. The slight issue we had in our design and testing was the wiring of our op amps. The input and output wires of the circuit were wired wrong and therefore our output was screwed, however, once this was changed the output was clear and we were able to finish the lab. We believe that we did extensive testing on the filter to make sure the signal we were getting was not only correct, but also accurate. We wanted to create a receiver that could detect a signal from far away and we were successful with this. The receiver detected a signal from the transmitter from over a meter, which was our goal.

### b. Changes for Future Labs

For future labs, we believe making sure the wiring on our circuit was correct would have saved us ample amount of time when testing. The issue we were facing was the input and outputs of the op amp were incorrect so the receiver was not getting the correct signal. When we went to test the output at the first phase we were getting a crazy looking graph on the oscilloscope. We were not sure where the error was, but after double checking the data sheet for the NE5322 op amp we realized the mistake and quickly switched it. If we would have done this earlier the filter could have been completed quicker. This is the only change we would make for future labs: read the data sheets correctly.

### c. Roles and Responsibilities

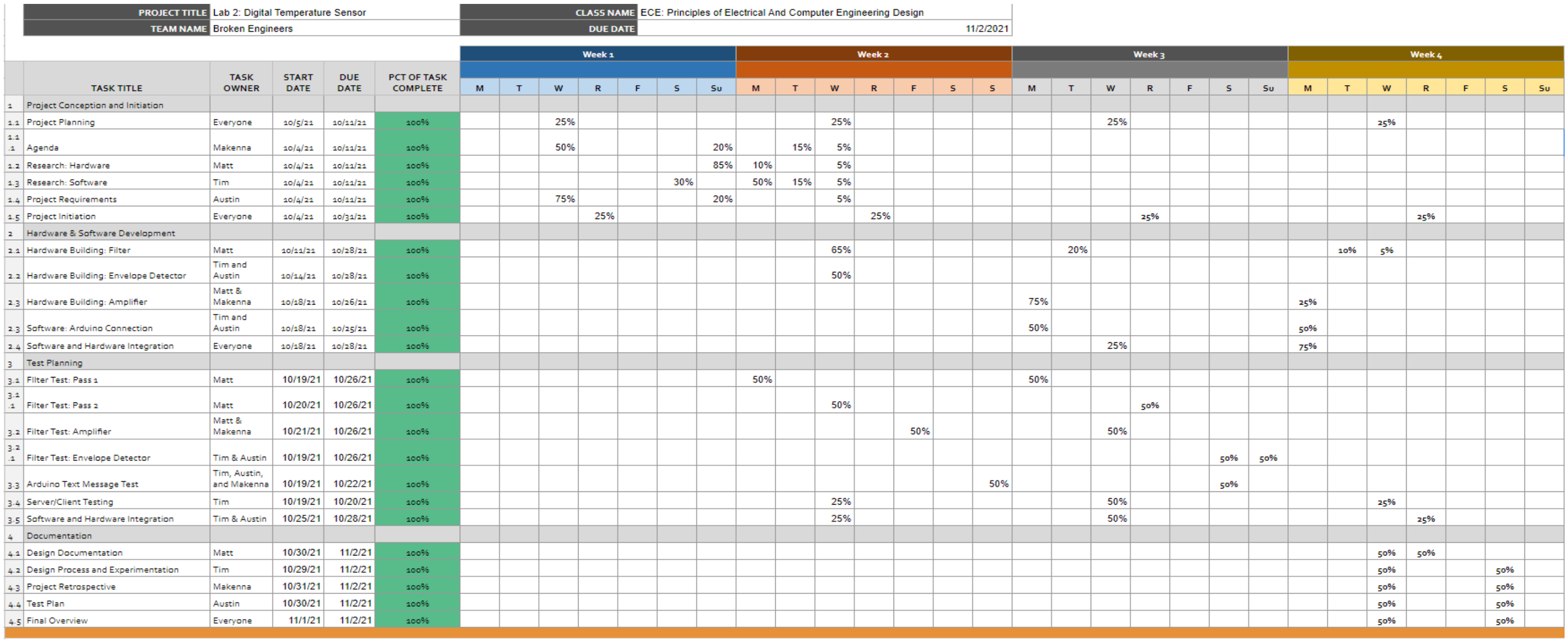
Throughout this lab, it was mainly electrical so Matt was in charge of most of the filter components. The first few times we met, we discussed the design of the circuit and were able to come to an agreement of which hardware pieces we would be using after we did some research. We decided that the two pieces of hardware that would work best for us would be either the NE5322 op amp or the LM158P op amp. We ultimately decided on the NE5322 op amp. He was able to put together the first pass of the filter using the NE5322 op amp and the photodetector to get the correct output from this part. After Matt had the first part set up, using the signal generator and an oscilloscope we all tested the filter to see if we got the correct output. When we were not getting the output we wanted, Tim looked over the circuit again and found the error in the wiring of the NE5322 and was able to make the circuit function correctly. The second pass of the filter included a second NE5322 op amp wired similarly to the first and then Matt and Makenna spent the time testing this part to make sure the signal output was correct. While Matt and Makenna were working on the circuit, Austin and Tim first built a bridge detector for the AC to DC converter and tested it. They tested it and it was giving us the correct output, however, when attached to the rest of the circuit we were not given the correct results. This led us to the idea of the envelope detector, which Austin built and we all tested to make sure it was correct. We realized the signal was not as strong and would need an amplifier to make sure we got the correct output. Matt and Makenna worked together to find the correct gain for this amplifier to make sure the output we were getting was amplified enough for the detector. Finally piecing the whole circuit together we were able to get the transmitter and receiver to work together. The final part was the text message alert, which Tim, Austin, and Makenna worked on to modify the code from lab 1 to fit the criteria of lab two. We had to add a few lines of code to make sure it would work and then used Arduino's serial monitor along with PySerial to get the correct outputs for the text messages. Lastly we had to attach the LED to the Arduino to make sure it was active low and would turn off if the signal was lost or interrupted. Overall, we were able to work together to get the lab done and used the strengths of each other to perfect the receiver as best as we could.

### d. Project Management

Throughout the lab we implemented a waterfall and test driven methodology to complete most of the lab. This was because we completed most of the lab in phases and we needed to make sure testing was conducted after each phase. In phase one we wired the first pass of the circuit which was the main part of the filter. After wiring, this is where the test drive methodology was implemented. We used the signal generator to make sure the output we were getting from the transmitter was the same as the output of the photodetector. After this we then measured the output at the output of the first pass of the filter. After they checked out, we moved on to the second pass of the filter. Following the same steps we did before we tested the output. Then we moved on to stage two which was building the amplifier of the circuit. Using a diode, resistors, and capacitor we built the amplifier and tested to make sure we were getting the same signal as before. Then following this, in part three the envelope detector was added and tested to make sure the AC to DC converter was correct. In this part we tried two different detectors: the bridge rectifier and the envelope detector. We decided to pick the envelope detector as it gave more accurate readings on the serial monitor. After completion of this the final stage was adding the LED and text message alert. The testing for this was simple and we had to tweak a few lines of code to make sure the delay for the text message matched correctly when the receiver was not detecting the transmitter. Overall, the management of this lab was not bad and the outcome showed it as we had a strong and successful receiver that picked up the transmitter at a far distance.

### e. Gantt Chart

Attached below is the Gantt chart we created on the first meeting we had as a group. We believe we stuck to this chart well and it was a major reason for our success in this lab. Throughout the lab we would add our efforts for the day to make sure we were on task and did not fall behind like we thought we did on the last lab. We think throughout this lab, we had better time management and we were able to complete the lab in a shorter period of time because we always knew what we wanted to accomplish that day. The one place where we had a small delay was right at the beginning of the filter design where we struggled with the incorrect wiring of the op amp. This set us back slightly on the testing of the first pass of the filter, however, once we completed this the rest of the circuit came easy. For the next lab or future projects that have circuits to be built we need to be more keen on the data sheet in order to stay on track with our goals. Overall, we were able to mostly stick with our original Gantt chart and it helped us complete the lab in a timely manner.



| | | | |
|---|---|---|---|
| **PROJECT TITLE** | Lab 2: Digital Temperature Sensor | **CLASS NAME** | ECE: Principles of Electrical And Computer Engineering Design |
| **TEAM NAME** | Broken Engineers | **DUE DATE** | 11/2/2021 |

| | | | | | | Week 1 | | | | | | | Week 2 | | | | | | | Week 3 | | | | | | | Week 4 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TASK TITLE | TASK OWNER | START DATE | DUE DATE | PCT OF TASK COMPLETE | M | T | W | R | F | S | Su | M | T | W | R | F | S | S | M | T | W | R | F | S | Su | M | T | W | R | F | S | Su |
| 1 | Project Conception and Initiation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.1 | Project Planning | Everyone | 10/5/21 | 10/11/21 | 100% | | | 25% | | | | | | | 25% | | | | | | | 25% | | | | | | | 25% | | | | |
| 1.1.1 | Agenda | Makenna | 10/4/21 | 10/11/21 | 100% | | | 50% | | | | 20% | | 15% | 5% | | | | | | | | | | | | | | | | | | |
| 1.2 | Research: Hardware | Matt | 10/4/21 | 10/11/21 | 100% | | | | | | | 85% | 10% | | 5% | | | | | | | | | | | | | | | | | | |
| 1.3 | Research: Software | Tim | 10/4/21 | 10/11/21 | 100% | | | | | | 30% | | 50% | 15% | 5% | | | | | | | | | | | | | | | | | | |
| 1.4 | Project Requirements | Austin | 10/4/21 | 10/11/21 | 100% | | | 75% | | | | 20% | | | 5% | | | | | | | | | | | | | | | | | | |
| 1.5 | Project Initiation | Everyone | 10/4/21 | 10/31/21 | 100% | | | | 25% | | | | | | | 25% | | | | | | | 25% | | | | | | | 25% | | | |
| 2 | Hardware & Software Development | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.1 | Hardware Building: Filter | Matt | 10/11/21 | 10/28/21 | 100% | | | | | | | | | | 65% | | | | | | 20% | | | | | | | 10% | 5% | | | | |
| 2.2 | Hardware Building: Envelope Detector | Tim and Austin | 10/14/21 | 10/28/21 | 100% | | | | | | | | | | 50% | | | | | | | | | | | | | | | | | | |
| 2.3 | Hardware Building: Amplifier | Matt & Makenna | 10/18/21 | 10/26/21 | 100% | | | | | | | | | | | | | | | 75% | | | | | | | 25% | | | | | | |
| 2.3 | Software: Arduino Connection | Tim and Austin | 10/18/21 | 10/25/21 | 100% | | | | | | | | | | | | | | | 50% | | | | | | | 50% | | | | | | |
| 2.4 | Software and Hardware Integration | Everyone | 10/18/21 | 10/28/21 | 100% | | | | | | | | | | | | | | | | | 25% | | | | | 75% | | | | | | |
| 3 | Test Planning | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3.1 | Filter Test: Pass 1 | Matt | 10/19/21 | 10/26/21 | 100% | | | | | | | | 50% | | | | | | | 50% | | | | | | | | | | | | | |
| 3.1.1 | Filter Test: Pass 2 | Matt | 10/20/21 | 10/26/21 | 100% | | | | | | | | | | 50% | | | | | | | | 50% | | | | | | | | | | |
| 3.2 | Filter Test: Amplifier | Matt & Makenna | 10/21/21 | 10/26/21 | 100% | | | | | | | | | | | | 50% | | | | | 50% | | | | | | | | | | | |
| 3.2.1 | Filter Test: Envelope Detector | Tim & Austin | 10/19/21 | 10/26/21 | 100% | | | | | | | | | | | | | | | | | | | | 50% | 50% | | | | | | | |
| 3.3 | Arduino Text Message Test | Tim, Austin, and Makenna | 10/19/21 | 10/22/21 | 100% | | | | | | | | | | | | | | 50% | | | | | | 50% | | | | | | | | |
| 3.4 | Server/Client Testing | Tim | 10/19/21 | 10/20/21 | 100% | | | | | | | | | | 25% | | | | | | | 50% | | | | | | | 25% | | | | |
| 3.5 | Software and Hardware Integration | Tim & Austin | 10/25/21 | 10/28/21 | 100% | | | | | | | | | | 25% | | | | | | | 50% | | | | | | | | 25% | | | |
| 4 | Documentation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.1 | Design Documentation | Matt | 10/30/21 | 11/2/21 | 100% | | | | | | | | | | | | | | | | | | | | | | | | 50% | 50% | | | |
| 4.2 | Design Process and Experimentation | Tim | 10/29/21 | 11/2/21 | 100% | | | | | | | | | | | | | | | | | | | | | | | | 50% | | | 50% | |
| 4.3 | Project Retrospective | Makenna | 10/31/21 | 11/2/21 | 100% | | | | | | | | | | | | | | | | | | | | | | | | 50% | | | 50% | |
| 4.4 | Test Plan | Austin | 10/30/21 | 11/2/21 | 100% | | | | | | | | | | | | | | | | | | | | | | | | 50% | | | 50% | |
| 4.5 | Final Overview | Everyone | 11/1/21 | 11/2/21 | 100% | | | | | | | | | | | | | | | | | | | | | | | | 50% | | | 50% | |

## 6. Appendix & Resources

## A. Circuits

### 1. Detector

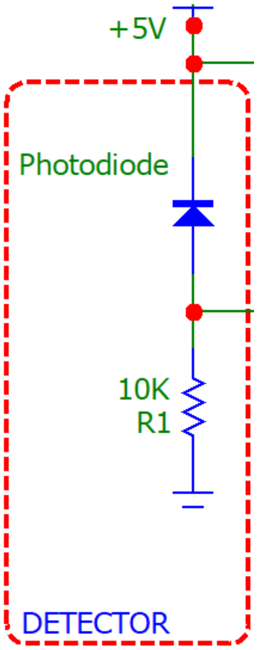


**Figure A-1:** Detector Section of the Receiver

The detector section of the receiver is made up of a photodiode where the transmitted signal is received and the photodetector in this case acts as a small current source. The resistor R1 converts the photocurrent to a small voltage. As we increase the value of R1 the DC voltage across it also increases, however if the value becomes too large the resistor can saturate and the DC voltage will approach our power supply.

2. Buffer

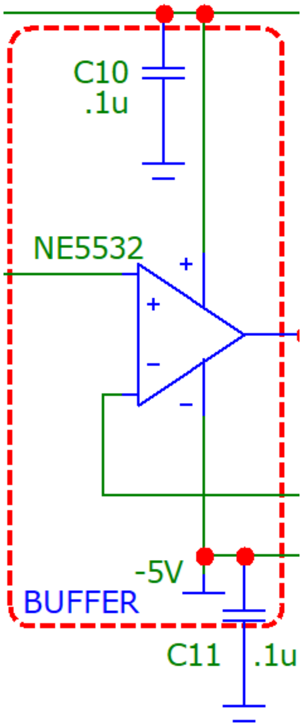


**Figure A-2:** Buffer Section of Receiver

In the last section of the receiver we described the issue of saturation with the resistor. In this section we address another issue that the resistor brings up which is that of altering the time constant of the filter. The section following this one has precise capacitor resistor pair values that give us a cutoff frequency of 120 Hz and a passband of 500 Hz. That filter sees the resistor in the detector section which causes issues for the time constant and to fix this we implement the buffer. The buffer is a unity gain amplifier which sees the detector as only an ideal voltage source and does not alter our signal or filtering. We use one side of the NE5532 Op-amp and simply input the signal to the non-inverting input and connect the inverting input to the output. The power supply for the op-amp is decoupled with .1uF capacitors on both the positive and negative 5V rails.

## 3. Filter

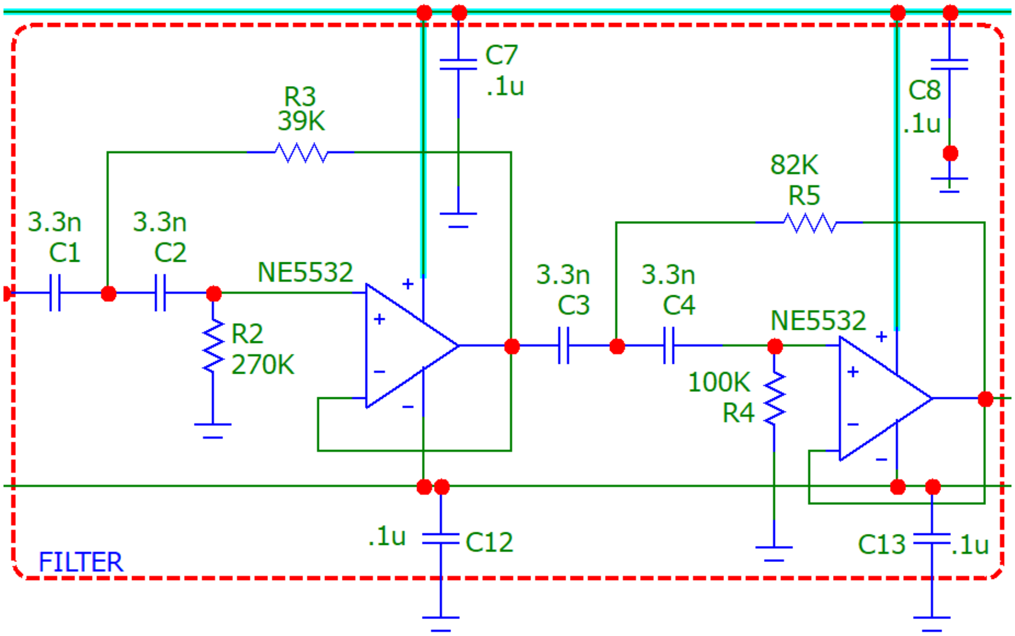


**Figure A-3:** Filter Section of Receiver Circuit

The filter of this circuit like stated above in this report is a 4th order Butterworth high pass filter. It consists of two stages each of which are a 2nd order KRC/Sallen-Key high pass filter. They are designed to allow the passage of frequencies of 500 Hz and above while filtering out all other light from the room that may cause noise in the system around 120 Hz. It may have been possible that this circuit filtered out the 120 Hz with only the first stage of this design; however it doesn't hurt to have two stages, one that can handle a majority of the filtering while the other cleans up and smooths out the signal. The filter is made from the remaining side of the NE5532 op amp for the first stage while the second stage is fed into a second NE5532 IC. There are .1uF decoupling capacitors attached close to the dual voltage supply rails on each of the op-amps to reduce any noise that may come from our power supply.

## 4. Amplifier

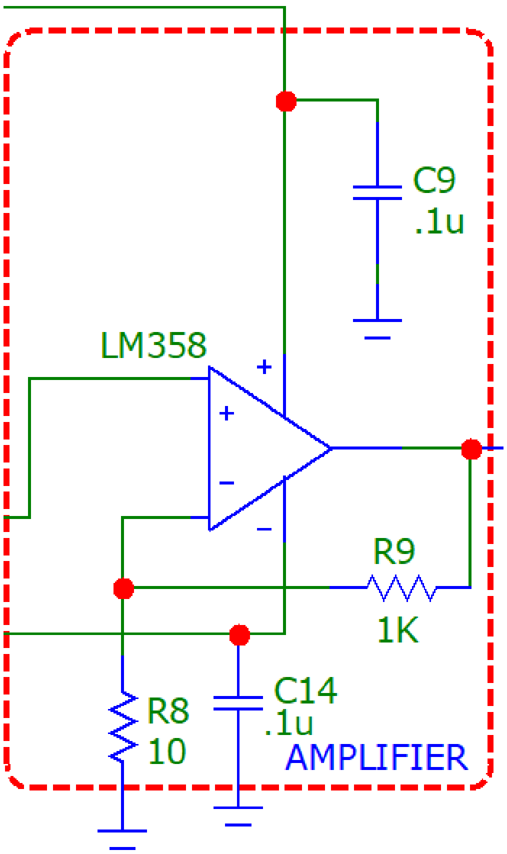


**Figure A-4:** Amplifier Section of Receiver Circuit

The amplifier circuit of this receiver was built with a single LM358 IC. The amplifier was set up as a non-inverting op-amp with a gain of 101. The equation used to find this gain is simply $A = 1 + (R9/R8)$. The gain was originally much smaller than 100 but through testing and design this was not enough to bring the signal up to a level that the arduino could distinguish as high or low depending on whether the signal was blocked. The LM358 is powered by a dual power supply with positive and negative 5V and decoupled with .1uF capacitors at each power supply rail.

5. Envelope Detector

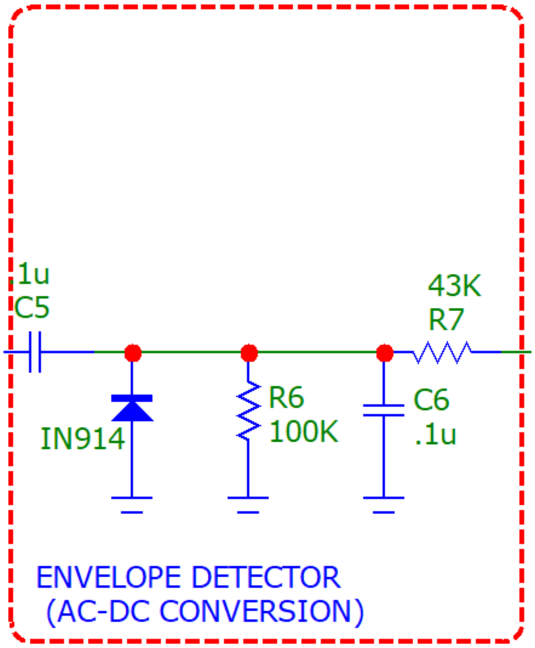


**Figure A-5 :** Envelope Section of Receiver Circuit

The envelope detector circuit takes the output of the amplifier and converts it into a DC signal that the Arduino can read in order to determine whether or not the LED should be on or off. The output of the amplifier is connected in series to a 0.1 µF capacitor, which leads to a 1N914 diode (the clamp), a 100 kΩ resistor, and a 43 kΩ resistor. The diode and 100 kΩ resistor both lead to ground while the 43 kΩ resistor leads to a second 0.1 µF capacitor (the low-pass filter) that leads to ground, as well as the output signal for the circuit.

### 6. Arduino

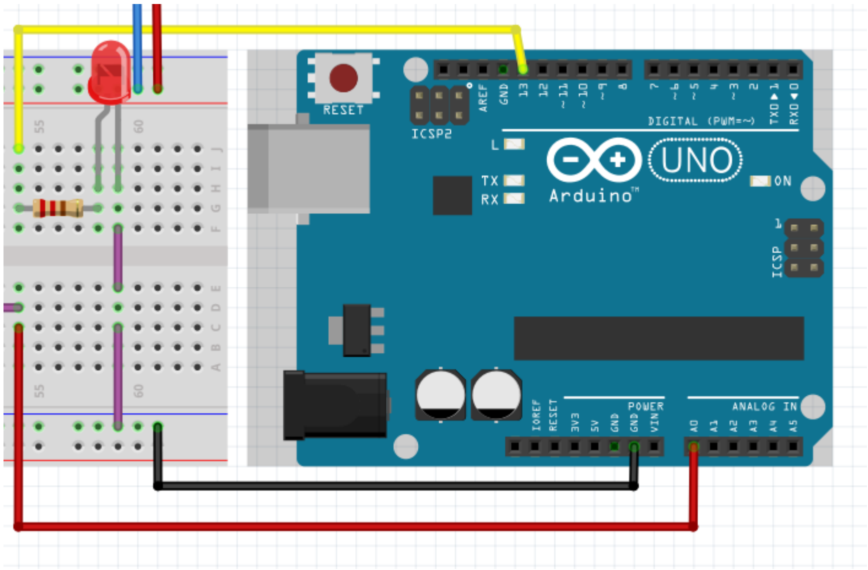


**Figure A-6 :** Arduino Section of Receiver Circuit

The Arduino is powered independently by the computer and only serves to power the LED on or off. The output of the envelope detector leads to pin A0, an analog input pin capable of handling the incoming signal and determining if the voltage is low enough to constitute a break in the signal from the transmitter. If so, the Arduino will set pin 13 high and power the LED acknowledging the loss of signal from the transmitter. The LED is connected to a 220 Ω resistor.

## B. Datasheets & Other Resources

LM358 Datasheet

https://www.ti.com/document-viewer/LM158/datasheet/GUID-A1978388-D344-4F0E-9158-A27B65FCCF55#TITLE-SLOS068SLOS0682966

NE3552 Datasheet

https://www.ti.com/document-viewer/NE5532/datasheet

1N914 Datasheet

https://www.onsemi.com/pdf/datasheet/1n914-d.pdf

Analog Filter Wizard

https://tools.analog.com/en/filterwizard/