Infrared Transmitter and Receiver

EE 230 Final Project

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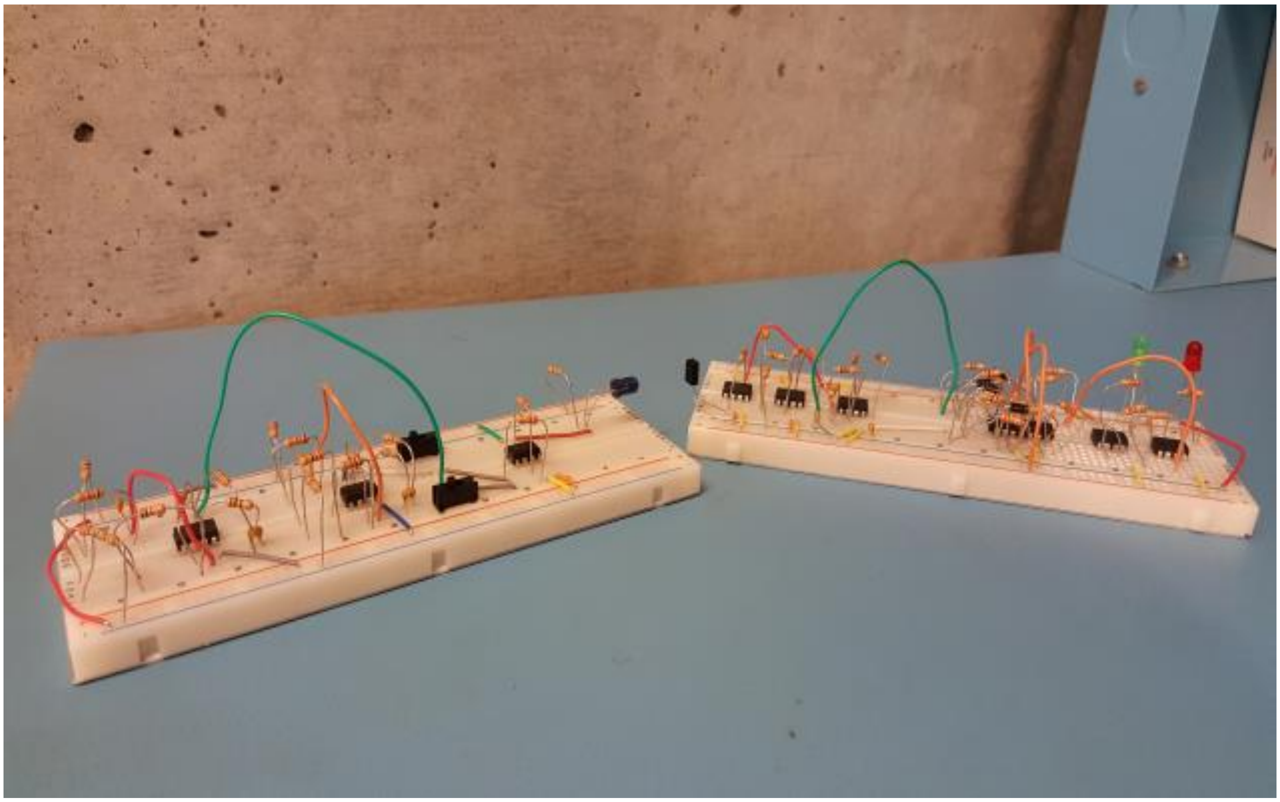


Introduction

In the final project of the year, we are to design a device that either turns on a red LED or green LED, based off of a user input. There will need to be two circuits: the first one will be to transmit a signal of varying frequencies through an infrared LED, and the other will be to take that signal and amplify it so that we can light up the designated LED for that frequency. The transmitting circuit will have two oscillators, an amplifier and an infrared transmitter. The receiving circuit will be comprised of an infrared receiver, bandpass filters, full-wave rectifiers, and comparator circuits for each of the different frequencies that need to be transmitted. To put all of this into one device, we will need to create multiple sub-circuits that have a specific function. The plan is to build each step one at a time according to our calculations and then test the section to make sure it is working properly. Once each section is complete we will combine them all to create our final product. If we use these sub-circuits effectively, we will be able to fulfill the goals of this project, and do it in a relatively quick manner.

Method

We started this lab with the intention of building a circuit that generates two different signals at two separate frequencies then transmits, receives, and filters the signal. Then based on the frequency that is received lights up a specific LED. We were to do this using only a triple volt power supply. To accomplish this we separated the circuit into two parts and started with a Wien Bridge Oscillator on the transmission side. A Wien Bridge Oscillator uses an operational amplifier to make a sinusoidal signal at a frequency biased on the resistor and capacitor values in the circuit. In order to generate two different frequencies we made two separate oscillators set at our required frequencies, 1 kHz and 10 kHz. Once the signal is generated it is controlled by switch to a simple inverting operational amplifier to increase the peak-to-peak value of the signal. The increase is necessary to get the signal to transmit effectively. Now the amplified oscillated signal is transmitted using an infrared LED. Because it is a diode, the transmission will be a half wave that is either always positive or always negative depending on the directionality of the diode. We only need to transmit a few millivolts in order for our receiver to pick up the signal. Below are the equation and values of resistors and capacitors we used in our oscillators:

$f = 1$ kHz; $f = \frac{1}{2\pi RC}$; RC = $\frac{1}{2000\pi}$ = 1.59×10^{-4}; Chose R= 1.6 kΩ Chose C= 0.1 µF

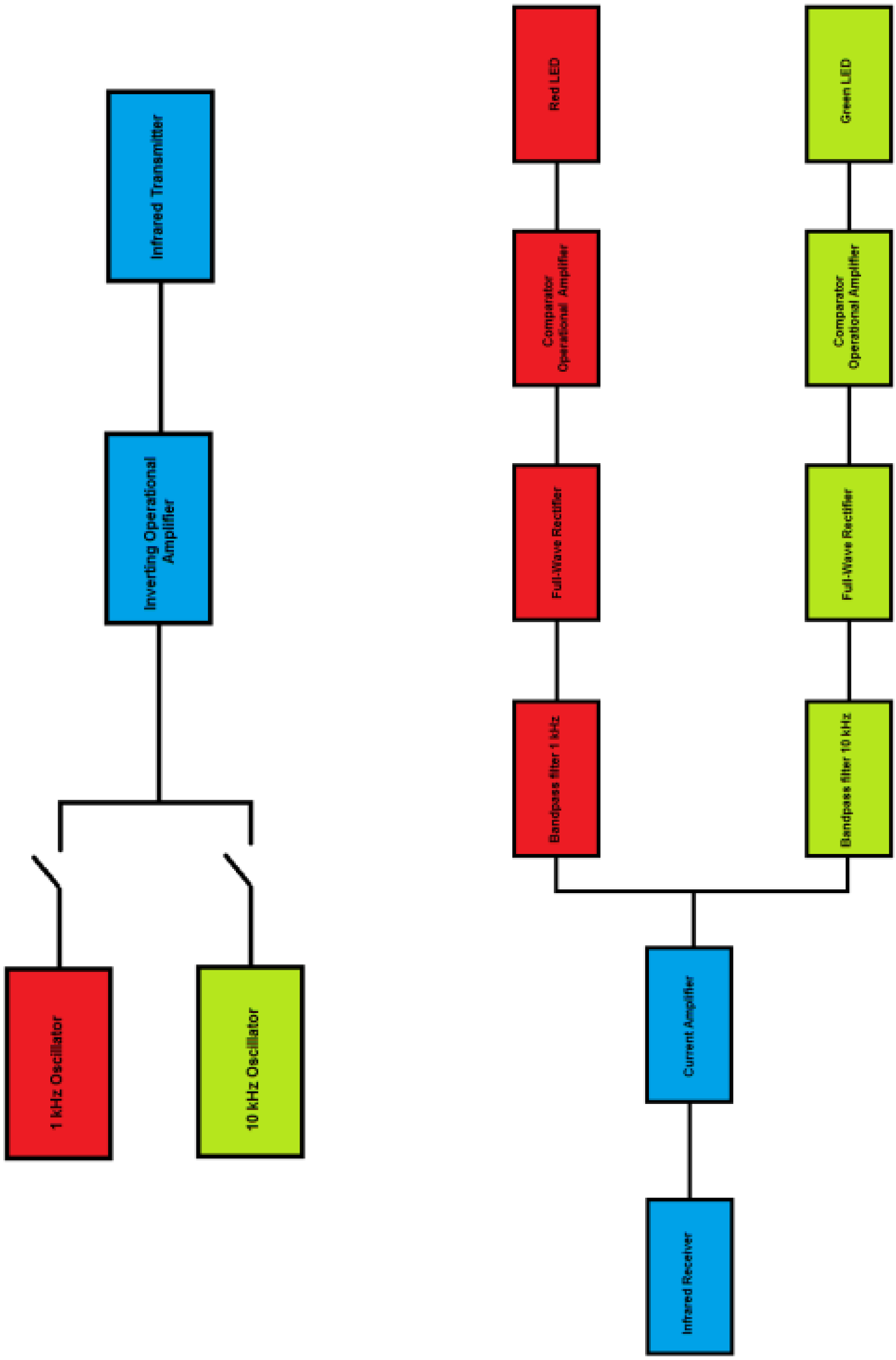
$f = 10$ kHz; $f = \frac{1}{2\pi RC}$; RC = $\frac{1}{20000\pi}$ = 1.59×10^{-5} ; Chose R= 1.6 kΩ Chose C = 0.01 µF

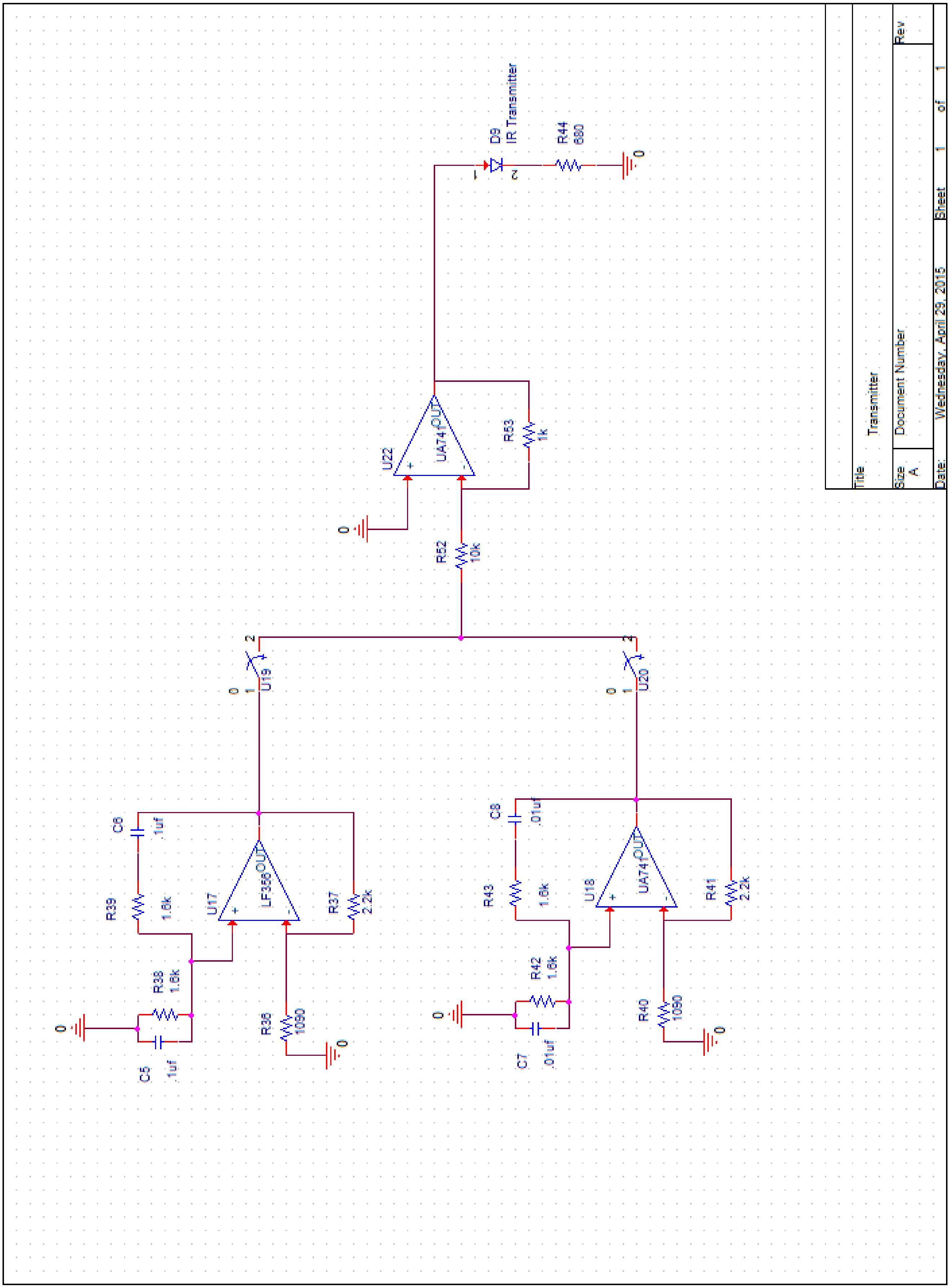
On the receiving side of the circuit we started by receiving the signal set by the infrared LED with an infrared receiver. Immediately following the receiver we used a current amplifier with a gain of one thousand volt per volt because the received signal is very small. This was necessary in order for us to be able to get a useable signal into the two band pass filters. At the output of the current amplifier we have two different active band pass filters.

The active band pass filters include both an amplifier and a band pass filter that is a series combination of resistors and capacitors. There is one for the 1 kHz frequency and one for the 10 kHz frequencies so that we passed only the desired frequencies. The filtering creates two separate signals from here on, one that is close to zero and the other that is comparatively large based on the transmitted frequency. To find out what components to use, we used the equation $f_{-3dB} = \frac{1}{2\pi * RC}$ to make a pass band for each frequency. For the 1 kHz passband, we chose 2 capacitors with a value of 10^{-7} mF. The math then told us to use a 6.8 kW resistor for the high pass section and a resistor of 680 W for the low pass part. This gave us a pass band from 234 Hz to 2340 Hz meaning the needed value of 1000 Hz is in the pass band. For the 10 kHz passband, we chose 2 capacitors with a value of 10^{-8} F. This gave us resistor values of 2.2 kW and 1 kW for the high pass and low pass filters respectively. This gave us a passband of 7234 Hz to 15915 Hz. Again; the 10 kHz frequency we need to pass will be included in that passband. Next the signals are sent through a full wave rectifier that makes the signal positive and upright using diodes and an operational amplifier. After the signal is positive it is sent to a comparator.

The comparator uses positive feedback to take a sinusoidal type input and makes it a DC pulse signal or square wave like signal. The comparator is necessary to create a DC signal for the final LED and allows us to set a reference voltage. The reference voltage means that when the input signal is less than it the comparator does not turn on. Setting the reference voltage allows us to make sure that any of the unwanted signal that passed through the filter unexpectedly does not turn on the wrong LED.

Finally, once the signal goes through the comparator the LED lights up letting us know that we have successfully generated, transmitted, received, and filtered the signal.


1 kHz Oscillator
10 kHz Oscillator
Inverting Operational Amplifier
Infrared Transmitter
Infrared Receiver
Current Amplifier
Bandpass filter 1 kHz
Full-Wave Rectifier
Comparator Operational Amplifier
Red LED
Bandpass filter 10 kHz
Full-Wave Rectifier
Comparator Operational Amplifier
Green LED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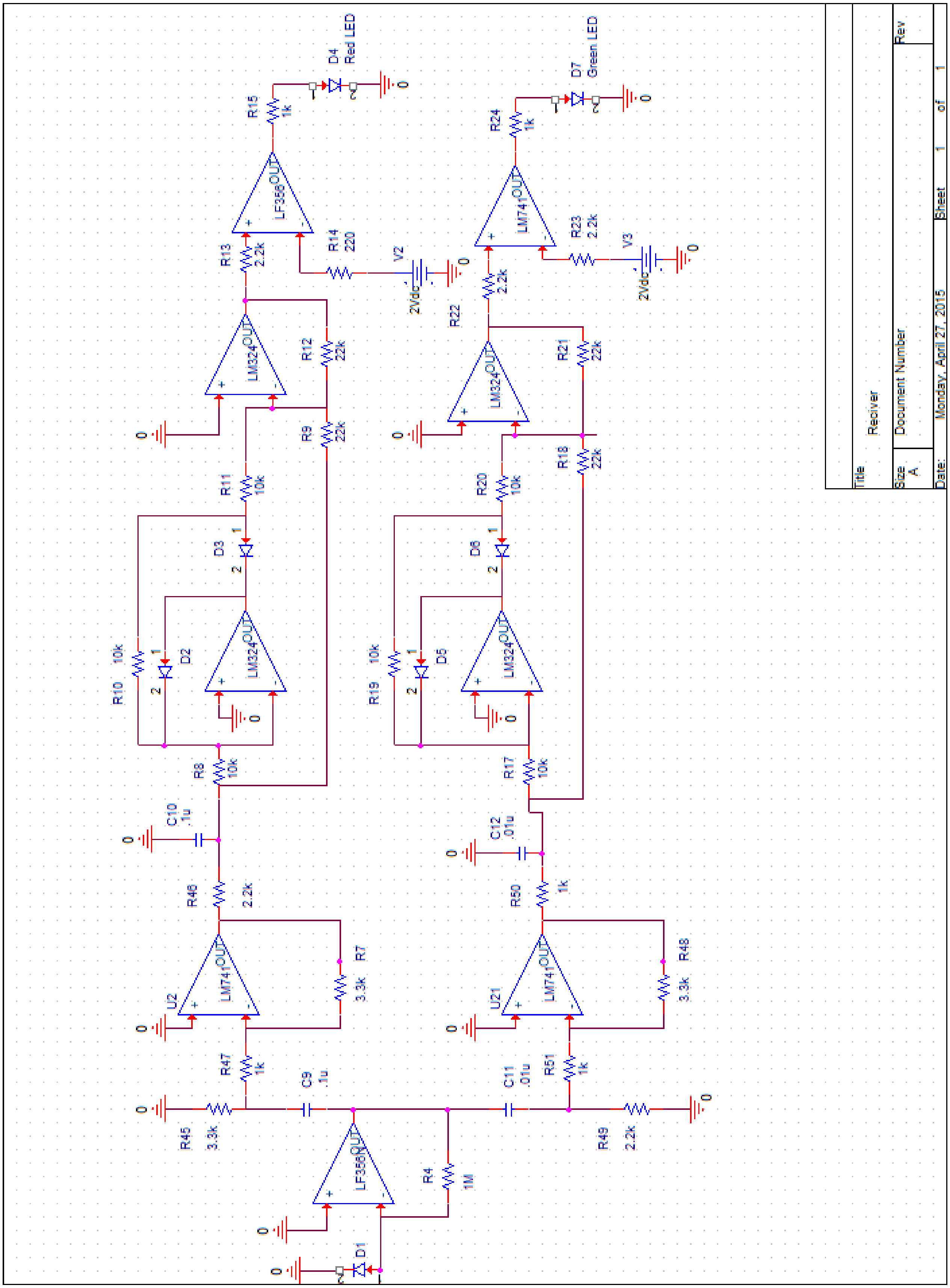
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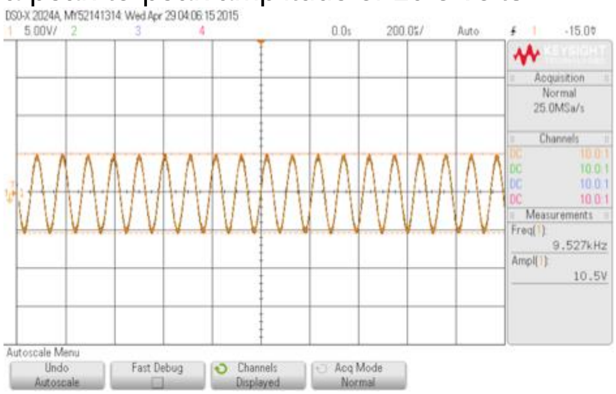
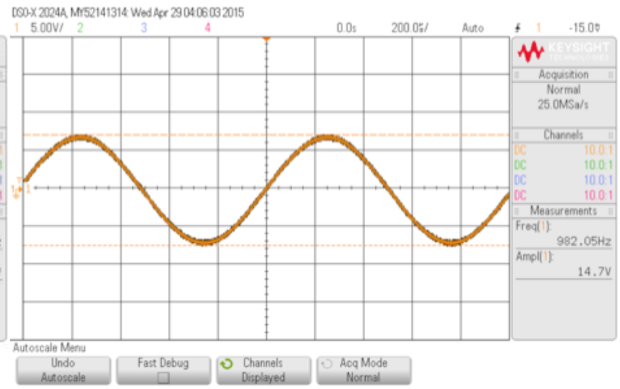
R15
1k
D4
Red LED
R49
2.2k
C11
.01u
R51
1k
U21
LM741
R48
3.3k
R50
1k
C12
.01u
R17
10k
R19
10k
D5
D6
R20
10k
R18
22k
R21
22k
R22
2.2k
R23
2.2k
V3
2Vdc
R24
1k
D7
Green LED

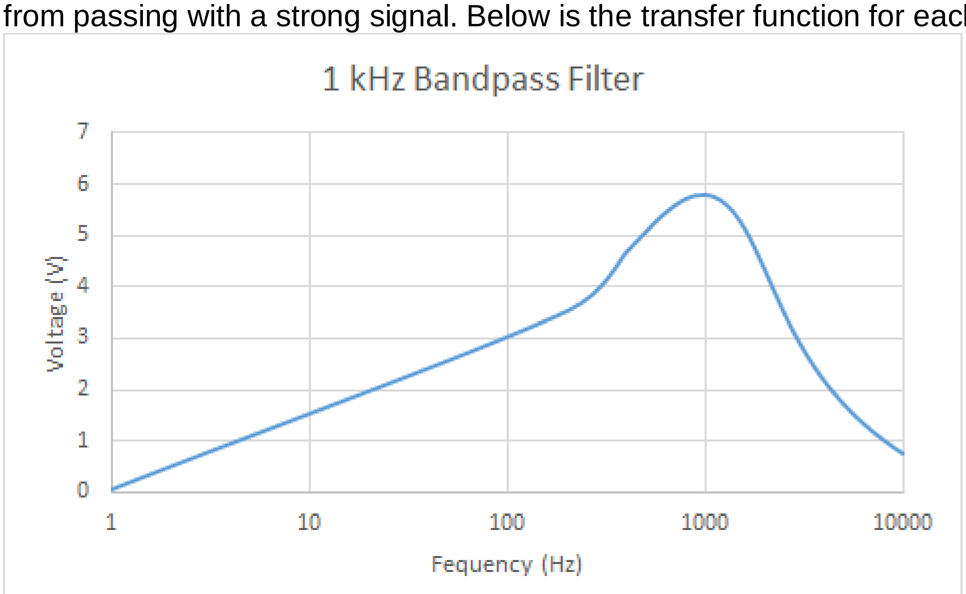
Results

The outputs of our oscillators were more or less exactly where we wanted them. As shown above, the first oscillator produced a sinusoidal signal at 982 Hz with a peak-to-peak amplitude of 14.7 volts. The second oscillator produced a sinusoidal signal at 9527 Hz and a peak-to-peak amplitude of 10.5 volts.

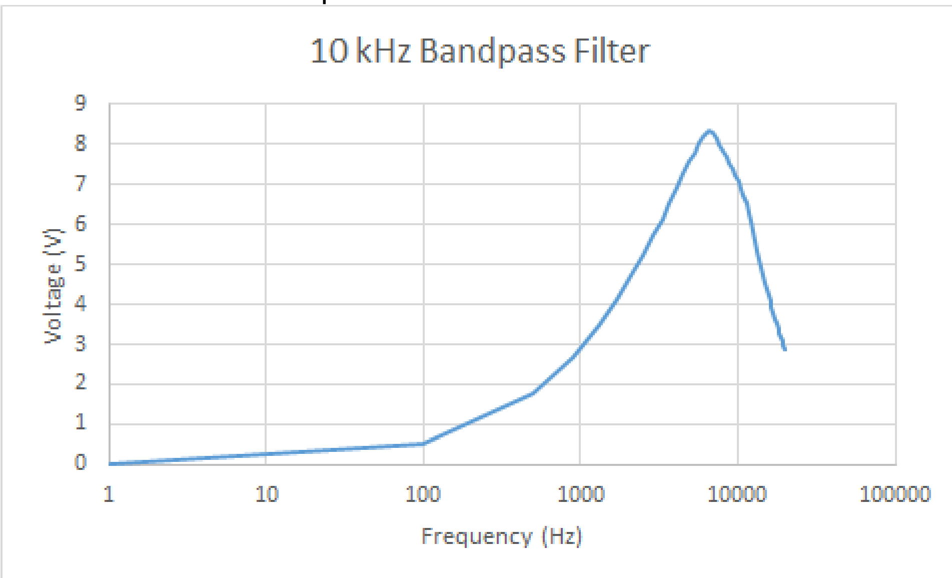




Our bandpass filters were a key part in our design. When the 1 kHz signal was sent, the output at the 1 kHz filter was about 1.7 V and the output at the 10 kHz filter was 0.5 V. When the 10 kHz signal was sent, the output at the 1 kHz filter was 0.3 V and the output at the 10 kHz filter was about 2 V. These are the results that we are looking for. The filters are doing their job and passing the correct frequency, while stopping the opposite frequency from passing with a strong signal. Below is the transfer function for each filter:



The 1 kHz transfer function looks just as we expect it to. It peaks at 1 kHz and filters out frequencies outside of the passband. More importantly, the voltages at 1 kHz and 10 kHz have much different outputs.



The 10 kHz transfer function shows that the passband is a little off. It peaks around 9 kHz and still passes the 10 kHz signal. The 1 kHz signal is filtered out quite a bit, which is just enough for the LED to not light up. Overall, our bandpass filters are fulfilling their purpose, as we can see in the above transfer functions.

Finally, when we used our completed circuit we were able to turn on one switch for the 1 kHz signal and the red LED lit up. Then we were able to turn off the switch and turn on the other switch to the 10 kHz signal and have the green LED light up. Our 1 kHz signal transmitted better and would light up the red LED from a distance of about 3-5 inches however our 10 kHz signal needed to be closer and worked from only about 1-2 inches away.

Discussion

Transmitter
The production of the oscillator circuits did not give us a lot of problems. We first built the 1 kHz oscillator and had trouble getting a clean output wave. This issue occurred because the gain on our oscillator was too large and the oscillator was outputting a saturated signal. We fixed this by temporarily replacing R_4 with a potentiometer, which helped find exact values for R_4 and R_3, since these resistors control the gain of the circuit. We adjusted the potentiometer until we had a perfect non-saturated sinusoid signal outputted from the oscillator. We built a 10 kHz oscillator using this same process. Later on, we had trouble transmitting the signal to the receiver. To make sure we were sending a strong enough signal, we added an inverting amplifier to boost the signal. For an unknown reason, after we had been successfully testing the oscillators for a few days, the 10 kHz wave began to act strangely by alternating the amplitude, causing our LED to pulse. To fix this, we changed out the amplifier because we suspected that there was something wrong with it. As it turned out we were correct and changing the amplifier fixed the problem.

LED Physics
Originally we had our LED transmitter and receiver connected to a DC voltage. The DC voltage was intended to make the diodes be in forward bias or “on” and then our signal would be transmitted on top of the extra voltage. What we found in practice was that our signal was overpowered by the DC component and we could not see the signal when we received it. We decided to take out the extra DC signal, which caused our transmission length to drop, but we were actually able to find the signal. In order to compensate for the lower voltage we added an extra amplifier to boost the signal going to the LED and compensate for not having a DC component.

Receiver
At first, to amplify the signal we received, we built a simple non-inverting amplifier. Since we tested our circuit with the function generator, rather than the actual infrared receiver, this section of the circuit worked fine at the beginning stages of testing. However, the infrared receiver acts as a current source rather than a voltage source, which led to a problem in the later stages of testing where we would use the infrared receiver as the source. We realized this problem later on in the development process and built a current amplifier rather than a non-inverting amplifier.

On our first attempt at building the bandpass filter, we built an inverting band pass filter with cutoff frequencies ranging from 500 Hz- 1.5 kHz and 7 kHz - 13 kHz. Once built, we found the range of the filter to be slightly larger than expected (the range was too large) and the 1 kHz and 10 kHz signals slightly interfered. Since the range was a bit too large, we built an active band pass filter in an attempt to fix this problem. This method ended up working perfectly for the 1 kHz filter. It was better for the 10 kHz filter, but was still slightly too large. It didn’t pass the 1 kHz signal; so, for the purpose of this project, it will suffice.

At first, we ran into a couple problems when building the full-wave rectifier. The first problem was that we forgot to ground the non-inverting inputs. Our other problem was connecting a resistor in the wrong node. These were easy fixes after analyzing the circuitry. We noticed when the frequency is higher at 10 kHz, the output voltage is a little distorted. This happens because the diodes can't handle higher frequencies very well. This distortion will not affect the final outcome.

The comparator circuit gave us the least amount of trouble. It was fairly easy to set up and didn't give us any problems. We expected a DC voltage on the output, and we got a signal that was close to a DC signal, since it had a slight fluctuation. This is acceptable though and doesn't cause any problems with our circuit.

Once we had all of these sub-circuits constructed and functioning on their own, we connected all of these steps and tested it out. We ran into quite a bit of trouble at this stage. We first could not get the signal to transmit at all. We fixed this by putting a different infrared transmitter in our circuit. This new transmitter sent a stronger and more direct signal to the receiver. We also had issues with the receiver circuit. We kept running into occurrences when only one of the signals was working, while the other wasn't. We tried to debug this issue by analyzing each section. Whenever we altered the circuit, we kept on running into different problems. These problems accumulated so we just deconstructed the entire receiver circuit and reassembled it. This method worked well, as our new circuit was functioning flawlessly.

Conclusion

This lab proved to be both challenging and rewarding. It took a lot of work and hours in order for us to make the circuit work to the level we expected. We came into the project expecting it to be very difficult because we did not know where to start, but it ended up going very smoothly and we got a lot accomplished that first day. After that, as we started to perfect the circuit, we took a lot longer and ran into a few speed bumps. These speed bumps helped us come together as a team and problem solve together. It was a lot of fun and was really rewarding at the end of the project to flip those switches and watch the LED turn on.