

EE313 ANALOG ELECTRONICS LABORATORY

2022-23 FALL TERM PROJECT

PROPOSAL REPORT

Introduction

In this project, we will examine the one of the modern communication systems: optical wireless communication system. The aim is to transmit the audio input signal that is generated by the microphone and to receive this information wirelessly. Then, the received signal is fed to the speaker at the final step while the quality of the signal is indicated by a single RGB LED. In general, the project can be grouped under two main units: Transmitter Unit and Receiver Unit. Also, each main part consists of different sub-units, and they are explained in detail in the following sections of the report.

Project Description

I. Transmitter Unit

A. Microphone Driver with Automatic Gain Control (AGC)

To transmit an audio signal using laser and photodiode, we need to detect this audio signal first. Therefore, to detect the audio signal we used a electret microphone. However, since the output voltage of the microphone is quite low, we cannot directly connect it to the rest of the circuit. In order to use this output, first, we should amplify it with a microphone driving circuit.

Apart from this, we should adjust the output signal because the output of the microphone is distance and frequency dependent, so the output amplitude of the microphone change with time as well as distance of the speaker (person) to it. Therefore, as it is stated in project definition, we need an automatic gain controller that controls gain and adjusts the amplitude of the microphone signal, so we will get a relatively constant amplitude audio signal. To achieve these, we used the microphone driver circuit with automatic gain control given in Figure 1.

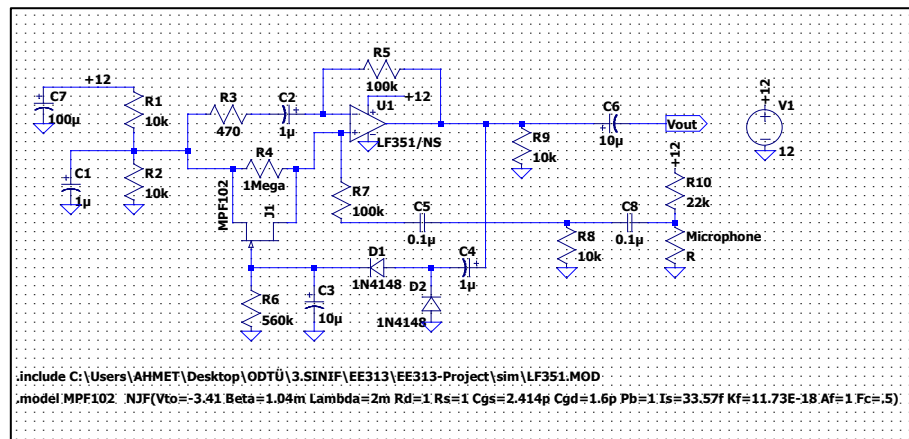


Figure 1: Microphone Driver Circuit Schematic with Automatic Gain Control

B. Low-Pass Filter

We will make use of the same low-pass filter circuit with the one that is used at the receiver part to attenuate higher frequency components at the output of the AGC circuit.

C. Summing Amplifier

Before transmitting the audio signal, we are going to add another signal namely reference signal so that at the receiver side, the amplitude of this signal will be treated as the measure of signal strength since it is constant. To sum up these two signals, we used a basic summing amplifier circuit.

D. Optical Transmitter

At the transmitter part, we need to convert the electrical signal to modulated light signal. To achieve this, we decided to use lasers rather than infrared or visible light LEDs because the visible light LEDs are very sensitive to the environmental noise whereas the infrared LEDs are not

observable by naked eye so that it is hard to check whether the system works properly. The light intensity of lasers is somewhat linearly dependent on the current, not the voltage. Therefore, the laser drive circuit is composed of the transconductance amplifier whose input voltage coming from the mixed signal.

II. Receiver Unit

A. Optical Receiver

At the receiver part, we decided to use a phototransistor to detect the incoming light. Phototransistor can be considered as a BJT whose base voltage is controlled by light. Therefore, we can convert the incoming light to electrical current by using a phototransistor.

B. Low-Pass and High-Pass Filter

After the conversion of light to current, we have both audio signal and reference signal. To obtain audio signal from the current, we decided to implement 3rd stage Butterworth Filter [1] with cut-off frequency at 3.5 kHz. To obtain reference signal, we decided to use the same circuit with capacitors and resistors are interchanged to use it as high-pass filter. The schematic of the low-pass filter is shown in Figure 2, below.

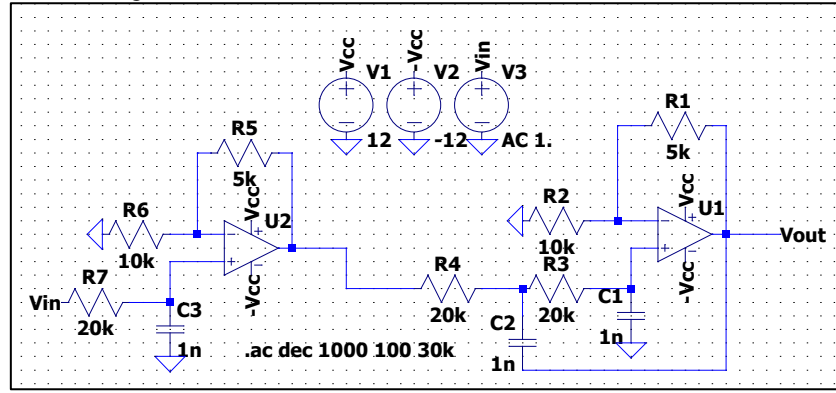


Figure 2: Low-Pass Filter Circuit Schematic

The output of the low-pass filter will be sent to the speaker through the power (audio) amplifier, and the output of the high-pass filter will be used for RGB led signal indicator.

C. Signal Level Indicator

The colors we decided to use for indicating the signal quality of the optical wireless communication system are shown in the Table 1, below.

Table 1: Signal Level Indicator Colors

	Signal Level	Color	R pin	G pin	B pin
1	No Signal	-	0	0	0
2	Weak Signal	Red	1	0	0
3	Moderate Signal	Yellow	1	1	0
4	Good Signal	Green	0	1	0
5	Excellent Signal	Blue	0	0	1

To determine the signal level, we decided to use 4 comparator circuits, each compares the amplitude of the signal with a reference value. The reference value is determined by precision peak detector circuit, and it corresponds to the peak voltage of the reference signal. Each comparator has a positive output voltage if the amplitude of the signal is higher than the reference signal, and negative or zero output if not. The red pin has positive voltage for the 1st and 2nd range, so that we feed the pin by the output obtained by subtracting the 3rd comparator's output from the 1st comparator's output. Similarly, the green pin is fed by the output obtained by subtracting the 4th comparator's output from the 2nd comparator's output. The blue pin is directly connected to the output of the last comparator. The overall circuit schematic is shown in Figure 3, below.

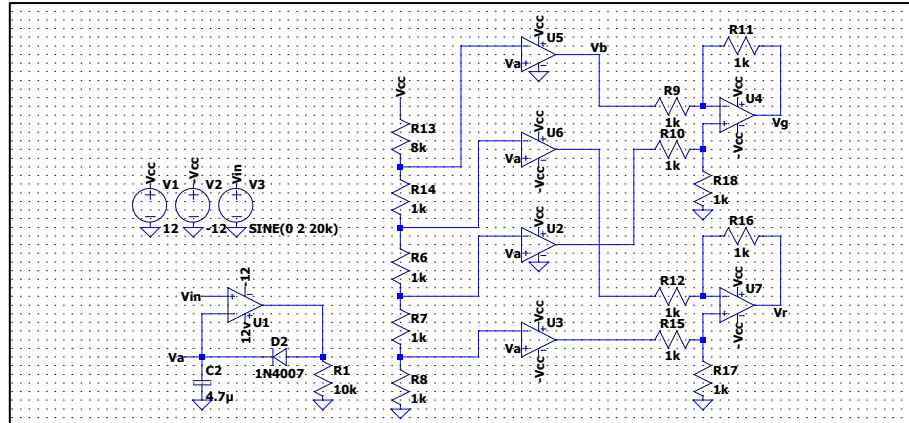


Figure 3: Signal Level Indicator Circuit Schematic

The output of the 1st comparator will be connected to gate terminal of a NMOS which is connected to the speaker in order to turn on the speaker if the received signal is higher than a threshold value.

D. Audio Amplifier

After filtering the audio signal from the received signal by using low-pass filter, we need to amplify the audio signal since the circuit will have high output resistance ($k\Omega$ - $M\Omega$) compared to the speaker internal resistance (8Ω). Thus, without using the audio amplifier, the volume of the speaker becomes so low that we cannot hear. To handle this, we considered to use a class B audio amplifier circuit which basically amplifies the audio signal. Also, at the beginning of the circuit we employed a buffer circuit to isolate the audio amplifier from the rest of the circuit. The circuit schematic of the audio amplifier can be seen in Figure 4.

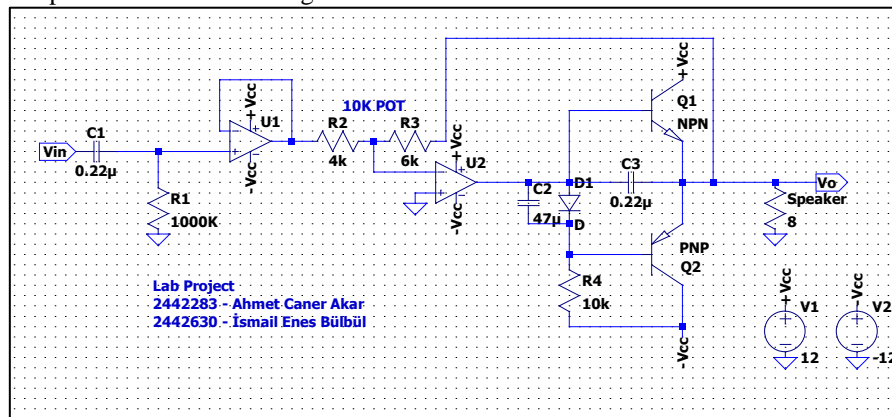


Figure 4: Class B Audio Amplifier Circuit Schematic

E. Clipped Indicator

We decided to use a comparator at the end of the audio amplifier to check whether the audio signal is clipped or not. We will connect 12 V to the negative terminal of the comparator and peak detector which is used to get the amplitude of the audio signal to the positive terminal of the output. If the audio signal is clipped, the comparator has positive output voltage and the LED which is connected to the output of the comparator will be indicating clipping.

Conclusion

To conclude, we have tried to design the overall system by using our knowledge obtained from EE311 course and EE313 experiments. In addition, sometimes we did a literature research about some circuit schematics and working principles such as Butterworth Filter and Automatic Gain Controller. Although we constructed some parts of the system in LTSpice, we couldn't add the simulation results due to page limitations.

References

- [1] "Low Pass Butterworth Filter Circuit Design and Applications," Electronics Hub, Feb. 11, 2019. <https://www.electronicshub.org/butterworth-filter/>