EE313 ANALOG ELECTRONICS LABORATORY PROJECT: PHOTOPHONE

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***Abstract*— This paper explains the "Photophone Project" that we prepared for Analog Electronics Laboratory. This project consists of two parts: Transmitter and Receiver. Transmitter part have 5 different circuits: Microphone Driver, Pre-Amplifier, Automatic Gain Controller, Muliplexer, Light Emitting End. Receiver Part also have 6 different circuits: Light Receiving End, Low-Pass Filter, High-Pass Filter, Power Amplifier and Speaker, Peak Detector, Comparator.**

***Index Terms*—automatic gain controller (AGC), microphone driver, multiplexer, power amplifier.**

I. INTRODUCTION

THIS project consists of two main parts. Transmitting the audio signal by light, using the 5 circuits designed, Microphone Driver, Pre-Amplifier, Automatic Gain Controller, Multiplexer, Light Emitting End. Then receiving the light and turning it into audio signal, using 6 other circuits we designed, Light Receiving End, Low-Pass Filter, High-Pass Filter, Power Amplifier and Speaker, Peak Detector, Comparator.

Any electrical signal might be transmitted with different ways of the electromagnetic waves. In this project we will use light as a transmitting wave. Created audio signal will be detected by microphone driver circuit, and this circuit turns audio signal to electrical signal. This signal will be amplified by pre-amplifier circuit, then the signal will be kept constant by AGC, preserving it from varying audio levels. Since the audio signal is low-frequency signal, it should be transmitted with increased frequency to make it non-dispersive. Multiplexer circuit adds a high frequency reference signal to audio signal. This modulated signal will be transmitted by laser light. At the receiving end, photodiode detects the light signal. Received signal should be separated from the high frequency part, before turning it into audio signal again. Using low-pass filter and amplifying the audio signal with speaker gives us the audio signal. To determine whether signal strength is enough and steady, we will use comparator circuit.

II. PROCEDURE

Project consists of two main parts: Transmitter, Receiver. Transmitting Circuit have 5 different parts:

A. Microphone Driver

Microphone Driver circuit is known for amplifying the audio signals created from the microphone component. Audio signals transferred to electrical signals from the microphone component and amplified from the circuit from Figure 1 below. We have used BC547 NPN as a transistor.

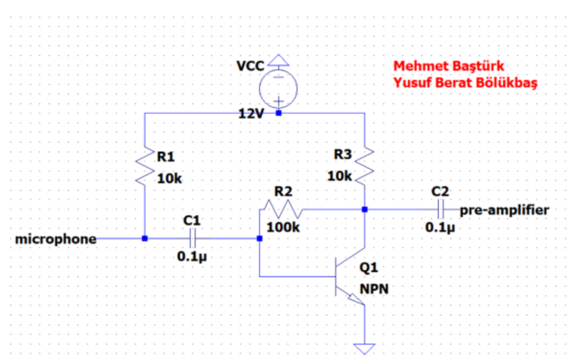

Figure 1: Microphone Driver Circuit

B. *Pre-Amplifier*

However, signals from the microphone driver circuit were very weak. We construct simple amplifier circuit using LM741 op-amp, with Gain = 10 V/V. Without this amplification, transmitting signals would be very weak so that no signal is captured from the receiver part.

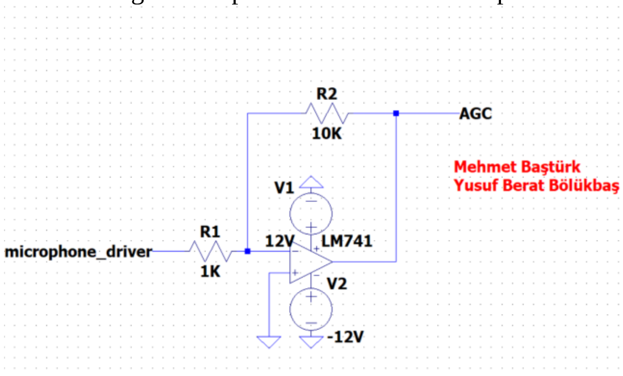

Figure 2: Pre-amplification Circuit

C. *Automatic Gain Control (AGC)*

Voice signals are a mixture of different frequency and amplitude signals. Pre-amplification circuit's output varies; thus, one should adjust the amplifier gain as a constant level although the input is fluctuating. Automatic Gain Control circuit sets the output as a constant while input amplitude varies. This makes us our circuit does not lose any signal whether it is too high or low in terms of amplitude.

AGC circuit's response over different signals and amplitude can be seen from Figure 4.

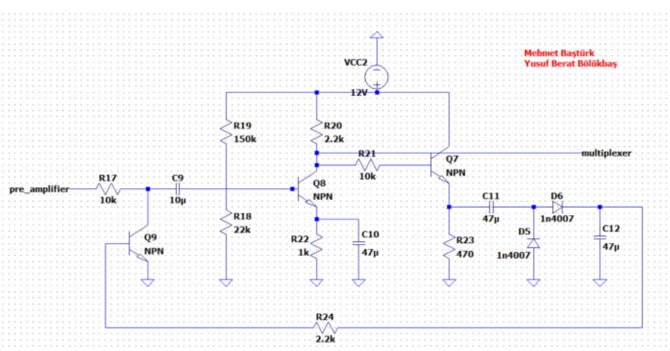

Figure 3: Automatic Gain Controller

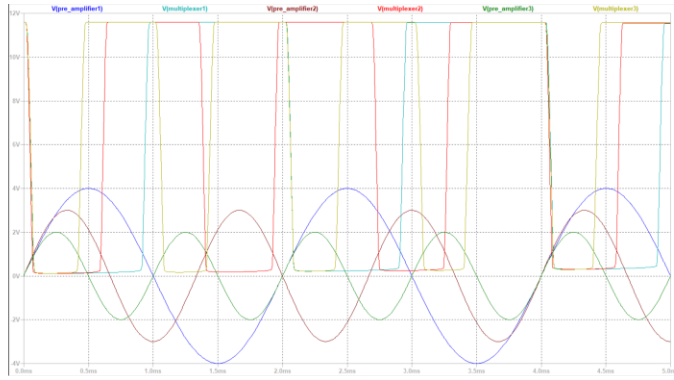

Figure 4: AGC Response to Varying Inputs

D. *Multiplexer (Summing Amplifier)*

One of the main problems in this project is that audio signals have low frequency, which makes them prone to be dispersive. Summing audio signals with high frequency signal will reduce the signal loss during the transmission significantly.

Adding audio signal to reference signal can be done easily with an op-amp circuit given below Figure 5. We have used LM741 op-amp in this circuit.

Multiplexer circuits are widely used in Audio Mixer applications. It has similar principles to AM modulation techniques in signal processing.

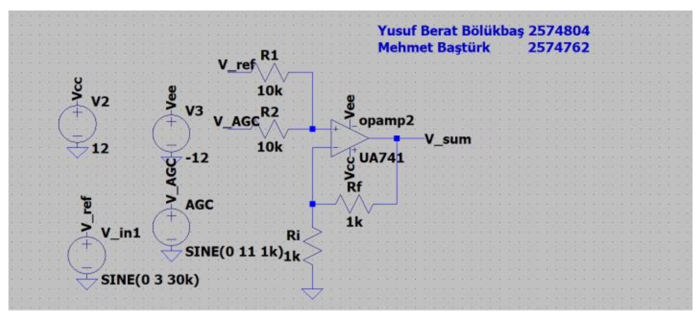

Figure 5: Summing Amplifier (Multiplexer)

E. *Light Emitting End*

Multiplexed signal at the output end of the op-amp circuit is taken as a high frequency input of the laser. Our 0.5W laser takes our electrical signal and transmits it as a light signal to the receiver end.

Laser has two probes: positive probe should be connected to DC supply; negative probe should be connected to the output end of the summing amplifier circuit.

In our lab, there were very strong lights. In order to reduce losses during the light transmitting, we have used a simple black plastic pipe, connecting laser with photodiode in receiver end.

Light emitting circuit is basically a transconductance amplifier circuit, since laser takes inputs as current and summing amplifier gives output as voltage.

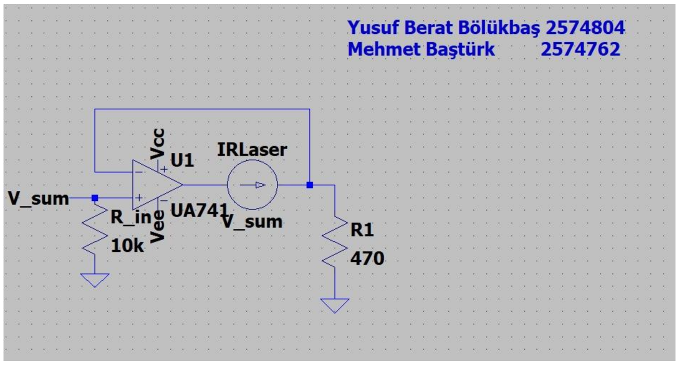

Figure 6: Laser Circuit

Receiver Circuit consists of 6 different circuits:

A. Light Receiver

Light Receiver circuit is the first element of our receiver part. Light signals carrying our audio information should be converted into electrical signals again. In order to accomplish this, we have used photodiode which converts light signals into both AC and DC current.

Simple circuit can be seen from Figure 6 below. A coupling capacitor should be added to separate DC levels of the two distinct circuits.

Light receiver circuit is basically transresistance amplifier circuit, since photodiode takes light signal and converts it into current. After that, this current is converted to voltage by transresistance amplifier

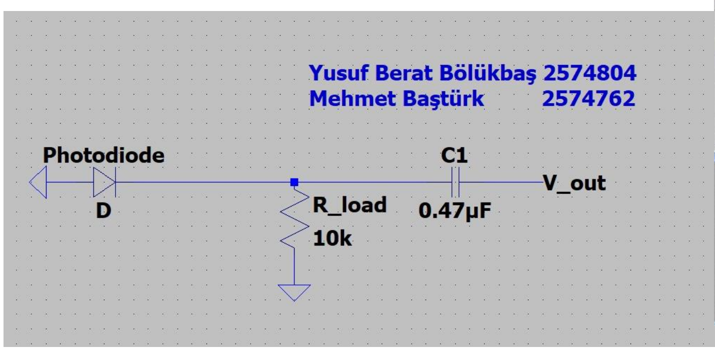

Figure 7: Light Receiver Circuit

B. Low-Pass Filter

Since two different frequencies summed at the multiplexer phase. One should separate low frequency audio signal from high frequency reference signal. We have designed a simple passive low-pass filter, RC filter with cut-off frequency 1kHz. The output of this filter is directly connected to the power amplifier.

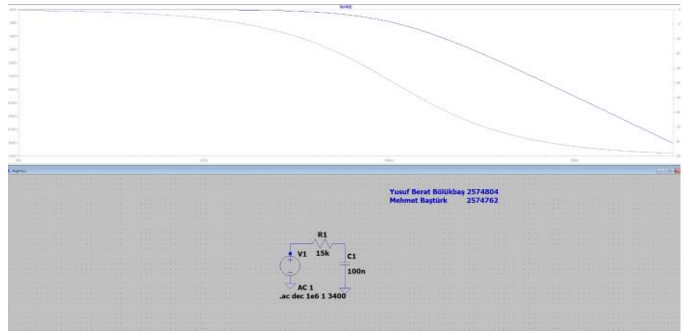

Figure 8: Low-Pass Filter

C. Power Amplifier

Extracted audio signals have very low amplitudes. In order to hear sound, one should amplify it first. We have designed a Class AB power amplifier, which is a combination of Class A and B. This combination allows us to have characteristics of both A, 50% efficiency but low distortion, and B, 80% efficiency but higher distortion.

It can be seen that in Figure 9 circuit has push pull configuration using NPN and PNP transistors. Class AB amplifiers are widely used in audio applications and at medium power levels they exhibit better power efficiency.

Power Amplifier circuit is directly connected to the 1W 16Ω speaker.

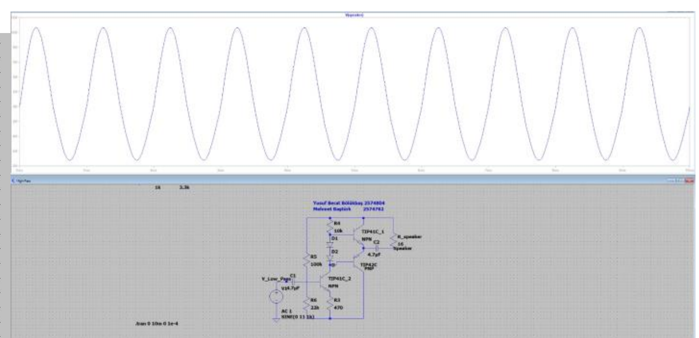

Figure 9: Power Amplifier Circuit

D. High-Pass Filter

As we stated above in low-pass filter, two added signals (reference and audio) should be separated. Although extracting low frequency signal is enough to hear it with speaker, since audible frequencies are at the range of 30-20kHz, one should know whether the multiplexer is working or not.

We have designed simple passive RC filter, selecting 1kΩ and 1nF. We have measured the cut-off frequency at 15kHz.

Filtered signal is directly transmitted to peak detector circuit to indicate whether the signal is transmitted well with light signals.

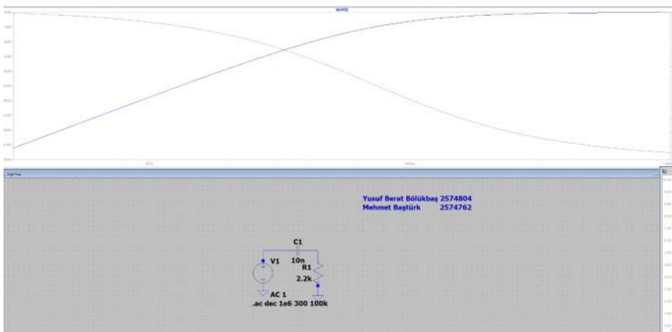

Figure 10: High Pass Filter

E. Peak Detector

Peak detector circuit simply takes the peak values of given AC signals. In our design, we have used a simple diode-capacitor circuit which extracts the ripple values of the input AC signal. Also, diode rectifiers can be used to collect peak values of the AC input.

High frequency input signal, reference signal, was given as 6Vpp in our laboratory trials. Thus peak detector gives output 3V DC. Measured 3V DC voltage is directly connected to comparator circuit, which indicates the voltage level by LED colors.

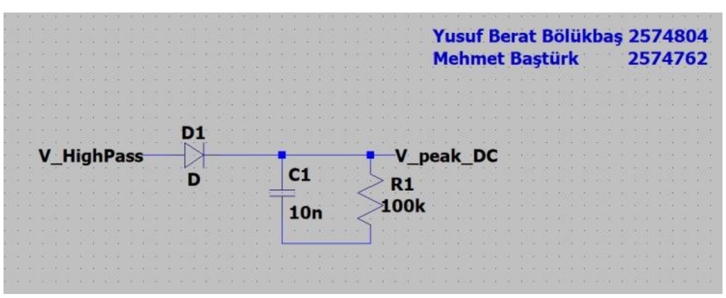

Figure 11: Peak Detector

F. Comparator Circuit

We have designed a comparator circuit that controls common anode RGB LED. Firstly, we have a main comparator op-amp which has a peak detector input (+) and V_ref input (-) , by using voltage divider. When we have a lower voltage than the reference voltage, first op-amp will get the Vee value so that LED will be off. If V_peak > V_ref, we will get Vcc output in the first op-amp.

After getting Vcc, we will have 3 more comparators, which will be connected to the LED probes from their output. For each op-amp, when thein V_in input is bigger than the Vref voltage, they will get a Vcc output so that the corresponding LED color will be on. Note that multiple colors can be off or on for corresponding respective. By using the voltage divider, we will lower and lower our input. For the lowest V_in value, we will connect the most positive color (blue) so that this voltage will guaranteed to exceed the reference signal.

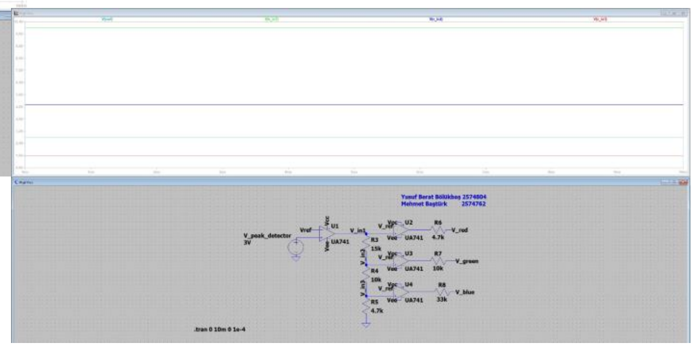

Figure 12: Comparator Circuit

III. Conclusion

In the term ending project of the Analog Laboratory, we successfully designed and constructed "Photophone" communicating system, which is similar to Graham Bell's first telephone prototypes. This system takes the audio input, transmits into electrical signals, converts it to light signal, receives it as light and converts it to electrical signals and lastly converts it into vibrations.

Overall system can be considered as two main parts, transmitter and receiver. The main purpose of this project was to demonstrate information can be transferred with different types of waveforms, including light by non-conducting medium. During this system, audio signal is transmitted into electrical, light, electrical and vibration signals respectively. Cascaded transmitter part circuits were, microphone driver, pre-amplifier, automatic gain control, multiplexer, and light-emitting end. On the receiver end, light receiver, filters, power amplifier, and comparator circuits are used.

Although the "block" circuits are very simple and easy to construct, driving the whole system as one part was difficult. We have gained hands-on experience with signal amplifications, frequency modulations and their design.

References

[1] R. C. Jaeger and T. N. Blalock, *Microelectronic Circuit Design*, 6th ed. New York, NY, USA: McGraw-Hill, 2022.

[2] A. S. Sedra and K. C. Smith, *Microelectronic Circuits*, 7th ed. New York, NY, USA: Oxford Univ. Press, 2014.

IV. Appendix

Figure 13: Microphone Driving Circuit Experimental Output

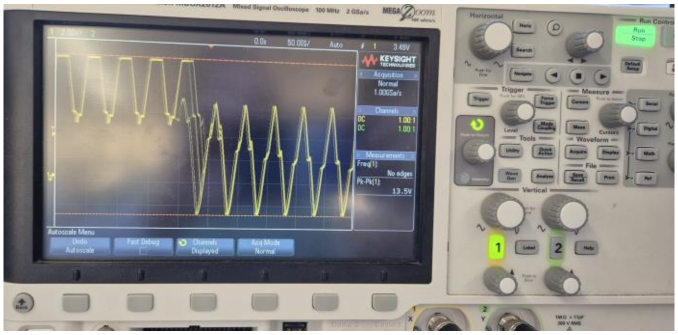

Figure 14: Pre-Amplifier Circuit Experimental Output

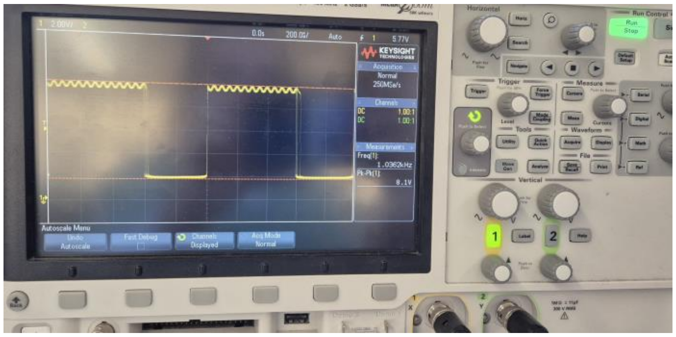

Figure 15: AGC Experimental Output

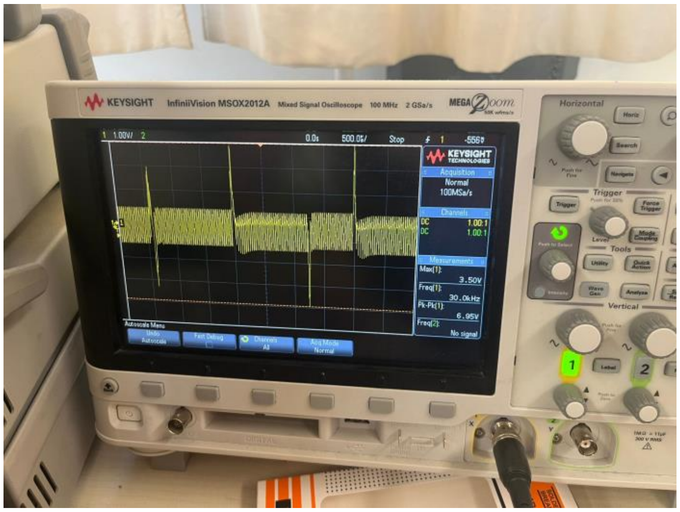

Figure 16: High Pass Filter Experimental Output

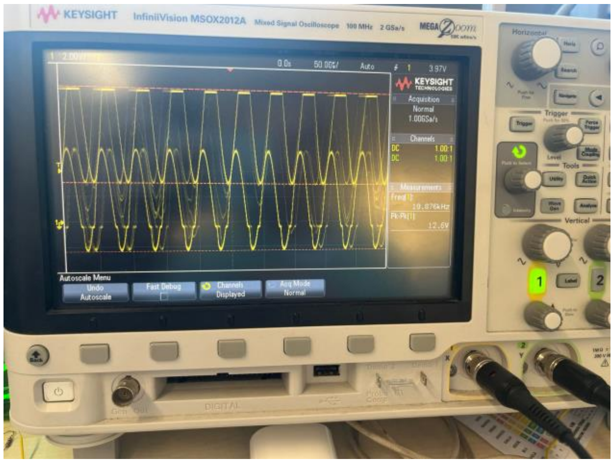

Figure 17: Summing Amplifier Experimental Output