Optical Wireless Communication System

Yunus ÇAY, Ege Ekin CANSIZ
Middle East Technical University
Department of Electrical and
Electronics Engineering
Ankara,Turkey
e223156@metu.edu.tr,
e2166148@metu.edu.tr

***Abstract*—This report contains the overall results of the EE313 Analog Electronics Laboratory project. Project's name is Optical Wireless Communication System. Results and content of this project is included in this report.**

Keywords—optical, wireless, communication, photophone

I. Introduction

Communication and interaction with societies has been a very essential need for human since the ancient times. Many methods have developed in order to communicate between distant locations. Smoke signals, carrier pigeons , letters, telegraph … etc used in the past. However, today, the most widespread way for communication is telephone invented by Graham Bell.

Today, communication with telephone is very common and everyone has a phone number. This communication is based on RF signals; on the other hand, there is a one more method for communication invented by Graham Bell with phone. This is called as photophone, modulated visible or invisible light beams are used for transmitting. Graham Bell point out this invention as the greatest invention he has ever made.

Graham Bell introduced optical wireless communication system, 19 years before the first radio transmission. OWC is not popular and does not satisfy some basic requirements; distance, easy-distribution (clouds, rain...). However, OWC has some advantages compared to today's phone communication. These are wide spectrum range and speed. In this report, all details are revealed about the photophone project has made based on Graham Bell invention.

II. Components and Constraints

A. Constraints

- Narrowband telephony is used. 300 Hz - 3.4 kHz.
- Laser or light source must be lower than 5mW.
- Signal indicator should identify the quality of transmission with 5 different color.
- 1mW should be obtained from the output of the power amplifier.
- When input is very low, there should be clipping.

B. Components

- Electret microphone
- LM358 Op-Amp
- 5mV visible laser
- Photodiode
- Transistors and Power Transistors
- RGB Led
- Diode
- Relay
- Various Capacitors
- Various Resistors
- Power Supply, Signal Generator

III. Project Parts

A. Microphone with pre-amplifier

In the project, we used an electret microphone, which is a simple type of microphone. We used 2-pin electret microphone, where one pin is *ground* and the other pin is *signal out* pin. In its internal parts, there is an amplifying transistor, NPN JFET type. *Source of NPN* is the ground pin, d*rain of NPN* is signal out pin & *gate of NPN* is pick-up plate, whose duty is to form a capacitance with electrostatically charged membrane and transform sound signals to electric signals. We can say that the transistor can be on common source configuration with the signal output is connected to DC source, resistor and an isolation capacitor for small signals. However, the small signal is not in desirable magnitude and it is amplified with another common source configuration amplifier to desired size for transmission.

B. Automatic Gain Controller (AGC)

Audio information is converted to electrical signal with microphone and preamplifier. Following part is AGC, which stands for automatic gain controller.

Amplitude of the output of the microphone can change with distance between source and microphone. Constant amplitude signal is needed for stable circuit since signal with changing amplitude may result in information loss. AGC is a part of the circuit provides constant amplitude with feedback.

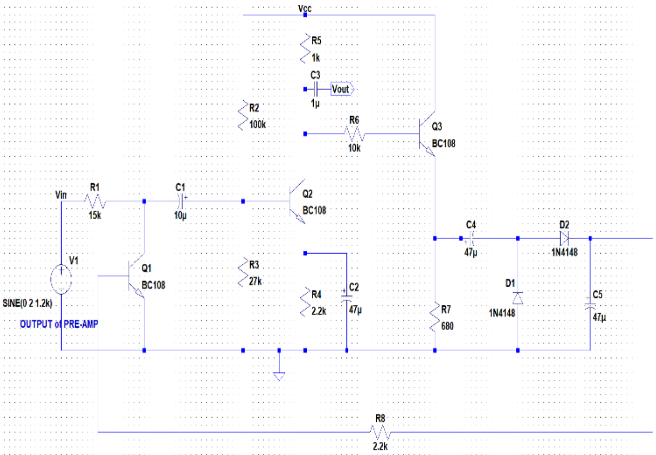

Figure 1: AGC Circuit

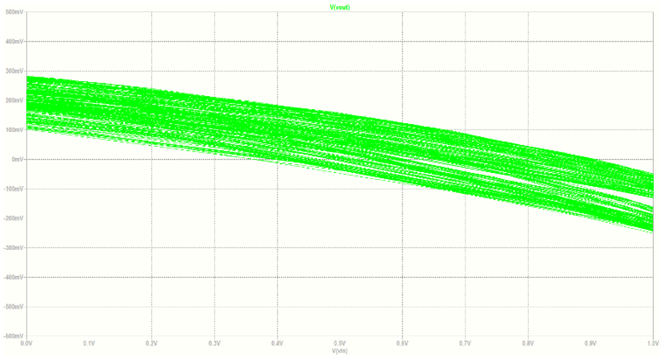
Figure 2: Simulation of AGC Circuit

In this circuit, main amplifier is the Q2 and Q3 is the emitter follower is fed with output signal. Then, after capacaitor on the emitter of the Q3 isolated the AC & DC signal, peak rectifier provides a base current to Q1. When output signal is high, Q1 sinks more current and input current is decreased and output signal decrease. With this feedback circuit, constant amplitude signal can be obtained. According to simulations we get 400 mV peak-to-peak signal.

Circuit is constructed on the board and measured the output signal. However, proper results could not be seen. Therefore, we cannot compare theoretical and experimental results.

Whether we didn't AGC part or not, we expected some discrepancies because of Ro resistances, internal capacitances of transistors, tolerance values of resistances. These dicrepancies would cause to change in value of constant amplitude, efficiency of AGC.

C. Band-pass filter

While people can give sound which have 20 Hz – 18 kHz frequency range, narrowband telephony uses the range between 300 Hz and 3.4 kHz. Therefore, filtering the signal is necessity with band-pass filter.

Passive band-pass filter is seperated to two part with buffer to get rid of loading. Transfer functions are not the same with buffer and without buffer. First section is high-pass which determines the high cutoff frequency. Second section is low-pass section. With these cutoff frequencies, out of the narrowband telephony frequencies are attenuated.

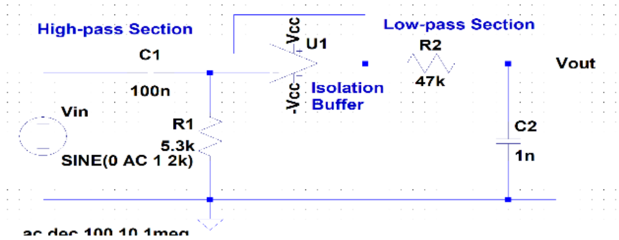

Figure 3: Band-pass Filter

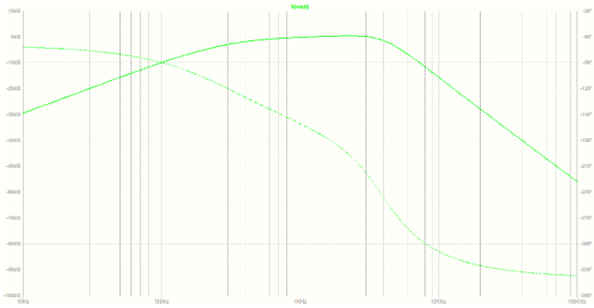
Figure 4: Simulation of Band-pass Filter

$$H(s) = \frac{s}{s + \frac{1}{R_1 C_1}}$$

$$f_c = \frac{1}{2\pi RC}$$

$$H(s) = \frac{\frac{1}{R_2 C_2}}{s + \frac{1}{R_2 C_2}}$$

Figure 5: Frequency Response of equations of Band-pass Filter

D. Summing amplifier

The photophone uses laser to generate modulated signal and uses indicator to determine quality of transmission. To generate modulated light, DC offset is required to drive laser. For signal indicator, reference signal that have frequency out of the narrowband telephony range is needed. To combine these signals, summing amplifier is used.

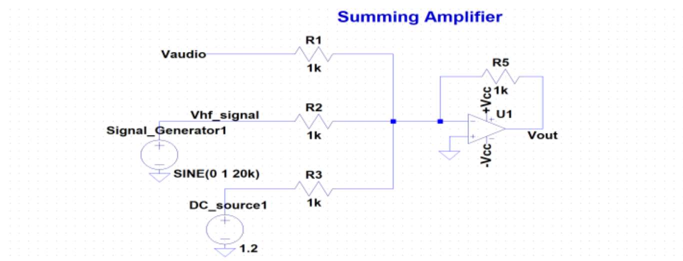

Figure 6: Summing Amplifier Circuit

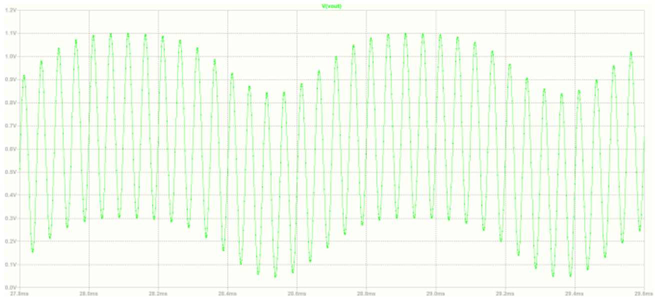

Figure 7:Simulation of Summing Amplifier

$$-Vout = \frac{R_5}{R_1}\{V_{audio} + V_{hf} + V_{DC}\}$$

Figure 8: Calculation of Voltage Sums

As seen on the figure, signals are combined and transconductance amplifier is the next step to modulate light. This process is also called as frequency multiplexing.

E. Photodiode with transconductance amplifier

Photodiode is employed for sensing the light signal received from the laser. Photodiode that used in this project is a silicon-based photodiode, where the narrowband telephony signals are received. Photoconductive mode of photodiode is used where it continuously operates in reverse bias. Similar with laser diode, photodiode converts received flux signal to current. Then, a transimpedance amplifier is connected to photodiode such that current to voltage transition is applied. Transimpedance amplifier consists of a resistor and a capacitor between the noninverting input and output. Capacitor is employed for increasing the stability of output.

F. Power Amplifier

After low-pass filter extracts the audio signal it needs to be amplified to large sizes in order to be heared from the speaker. Typical amplifier topologies such as common source could be used in power amplifiers but it would not be energy efficient and may lead to overheating problems since the gain will be in large amounts. Those typical amplifiers (common source, common emitter etc.) are called Class A amplifiers.

There are times when input signal is near to zero and in Class A amplifiers, transistors are always biased so there is always energy consumption. What is needed at audio amplifiers is that the transistors should be at such a topology that when there is little signal at the input, they should have no biasing. One solution to this problem is putting two transistors in a complimentary pair (NPN at upper, PNP at lower) and connecting their bases. While one transistor amplifies above zero part of the input signal where other amplifies the below zero part. It is called Class B Amplifier and is illustrated in Figure-1 below.

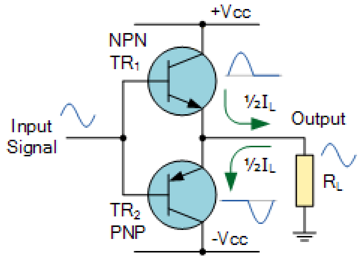

Figure 9: Class B Amplifier

However, the output at Class B is not exact replica of the input because there is a distortion occurring where input is crossing on zero and transistors switch to “ON” between themselves. It is called crossover distortion. There are loses in the audio signal in this area. There is an easy way to reduce distortion in this area by applying additional biasing to the input signal. As we can see from the Figure-2, biasing point is changed with the addition of two bias sources. In this project, we used two diodes for biasing. This type of amplifiers are called Class AB amplifiers and their efficiency is between Class A and Class B.

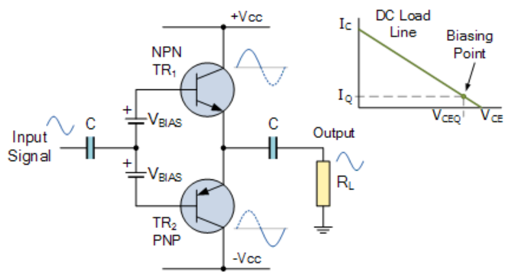

Figure 10: Class AB amplifier

G. Signal Level Indicator

After high-pass filter extracts the signal generator’s signal, AC signal of the signal generator needs to be converted into DC signal. Because since AC signal is always changing, we cannot compare its values. A circuit called peak detector does this process. It is simply a series connection of a diode and a capacitor, which has an output of DC voltage equal to the peak value of the applied AC signal. It can be better if an op-amp is used additionally.

Since the DC value of high-pass signal is obtained reference points are needed for the comparating part. Peak detector circuit obtains these reference voltages where input is the high frequency signal gathered directly from the signal generator. These reference voltages are equally divided in voltage divider circuit. For the indicator part, an RGB LED is used. Following two paragraphs describes the comparating scenario where there are five colors for five different signal strength.

If the received HF signal is greater than the 4th reference signal then the signal received is “very strong” (5th case). If the signal is less than 4th ref. but greater then 3rd ref. then the signal is “strong” (4th case). If the signal is less than 3rd ref. but greater than 2nd ref. then the signal is “normal” (3rd case). If the signal is less than 2nd ref. but greater than 1st ref. then the signal is “weak” (2nd case). If the signal is less than 1st ref. then the we can say “no signal” (1st case).

Red pin is activated until the received signal level is greater than the 3rd reference signal. Thus; 1st case, 2nd case and 3rd case has red color. Green pin is activated when the received signal is less than the 4th reference signal & greater than the 1st reference signal. Thus; 2nd case, 3rd case and 4th case has green color. Blue pin is activated when the received signal is greater than the 2nd reference signal. Thus; 3rd case, 4th case and 5th case has blue color. Therefore; case 1 is indicated by red color, case 2 is indicated by green+red=yellow color, case 3 is indicated by green+red+blue=white color, case 4 is indicated by green+blue=cyan color, case 5 is indicted by blue color.

REFERENCES

[1] Electret Microphone, E. (2019). Electronics: Fun & Fundamentals — The Eclectic Electret Microphone | Make:. [online] Make: DIY Projects and Ideas for Makers. Available at: https://makezine.com/2014/05/12/electronics-fun-fundamentals-the-eclectic-electret-microphone/ [Accessed 22 Jan. 2019].

[2] ElProCus - Electronic Projects for Engineering Students. (2019). Working Principle of Photodiode, Characteristics And Applications. [online] Available at: https://www.elprocus.com/photodiode-working-principle-applications/ [Accessed 22 Jan. 2019].

[3] Anon, (2019). [online] Available at: https://www.electronics-tutorials.ws/amplifier/class-ab-amplifier.html [Accessed 22 Jan. 2019].

APPENDIX A:

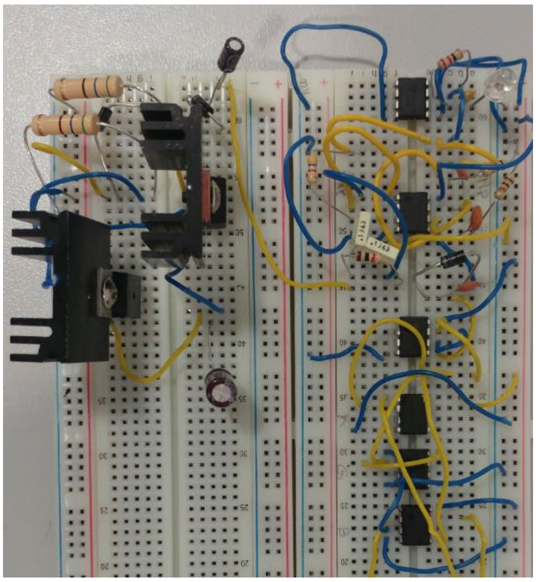

Figure 11: Audio Amplifier Part (Left), Transimpedance amplifier with photodiode (Upper Right), Comparator Part with Peak detector (Lower Right)

APPENDIX B:

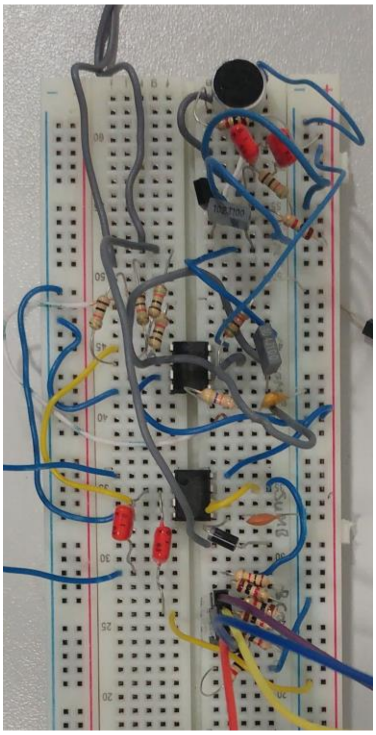

Figure 12: Microphone Part with preamplifier (Up), band-pass filter part with voltage dividing circuits (Down)