ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

Electrical and Electronics Engineering Department

EE213 - Electrical Circuits Laboratory

Fall, 2019-2020

Final Report
Displaying Sound Level System

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Submission Date: 27.12.2019

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1. Introduction

This report is about the discussion and explanation of the details of a displaying sound level system and the aim of its design. In the second part, a design for the ideal case will be explained thoroughly with reasoning for the aim of each subunit. Then in third part for a working implementation of the system the changes we had to make and real world factors which should be considered will be listed**.**

1.1 Properties of an Displaying Sound Level System

Lots of people complain about the noise of the city in which they are living. Noise damages cognitive functions, including attention, concentration, memory, reading ability, and sound discrimination. However, these aren't the only disadvantages of urban noise. It also causes psychological stress, poor quality sleeps, and harms children's development. To solve this problem, we want to create a feedback mechanism that gives a signal. The system will take the external noise as input and provide an output, which shows that if the place is appropriate to live.

Figure 1: Mrphamchi, "Chăm Sóc Tai – Page 30," [Accessed: 27-Dec-2019]

Also desibelmeters (Figure 2) are used to detect the sound level of environment. On the other hand, not everyone can reach this kind of device easily. The circuit which we will be creating is going to be cheaper and simpler so that everyone could afford this circuit.

Figure 2: "Voltcraft SL-200 Digital Sound Level Meter," Available. [Accessed: 27-Dec-2019]

To accomplish that, we designed this circuit that will give feedback by lightning a LED with three different duty cycle. The level of noises will be proportional with the time that LED is lightning. First, the sound that is collected by a microphone will be changed into a corrected DC voltage. Then, this voltage will be compared with three different levels and as output 3 levels of voltage values will be obtained. After that, this output will compared with the triangular wave that is created from another part of the circuit by using a square wave input, and the resultant voltage will give the time that is necessary for the LED to lighten.

1.2 Abstract

First we will establish the microphone unit by amplifying and correcting the AC output of microphone. Then we will convert this AC voltage to DC voltage by using full-wave rectifier. After that, we will classify this voltages by using comparator unit which includes five comparator operational amplifiers. At the same time, we will be creating triangular waves whose peak to peak value is 12V and frequency is 1Hz which is obtained by using an integrator amplifier at the output of the square wave generator. Finally the LED unit we will be comparing this triangular wave with the output voltage of comparator unit. This will let us to have duty cycle values which will determine how much time LED will lighten.

1.3 Concerns about the differences between real and ideal application

For the reasons and designs to be explained in later parts of this report we must either use circuit components which have too low tolerances so that we will obtain the exact voltages and currents we want or we should use adjustable components. Since even the highest quality components will have significant tolerance percentages which are still too large for us to ignore, one clearly sees that the second option is easier to apply to the design and more applicable to adapt the changes due to external conditions. For example, in the simulation we've used ideal operational amplifiers at some parts of the circuit. On the other hand, in reality the operational amplifiers we will use to design this system have type of LM741 which are operating not ideally. Therefore we may need to change values of resistors and capacitors.

2. Designing of Displaying Sound Level System

A displaying sound level system contains:

- Microphone Unit
    - Microphone Corrector Unit
    - Microphone Amplifier and Transformer Unit

- Comparator Unit
- Triangular Wave Creator Unit
- Voltage Source Unit
- Led Unit

Figure 3 represents a simple block diagram of this system.

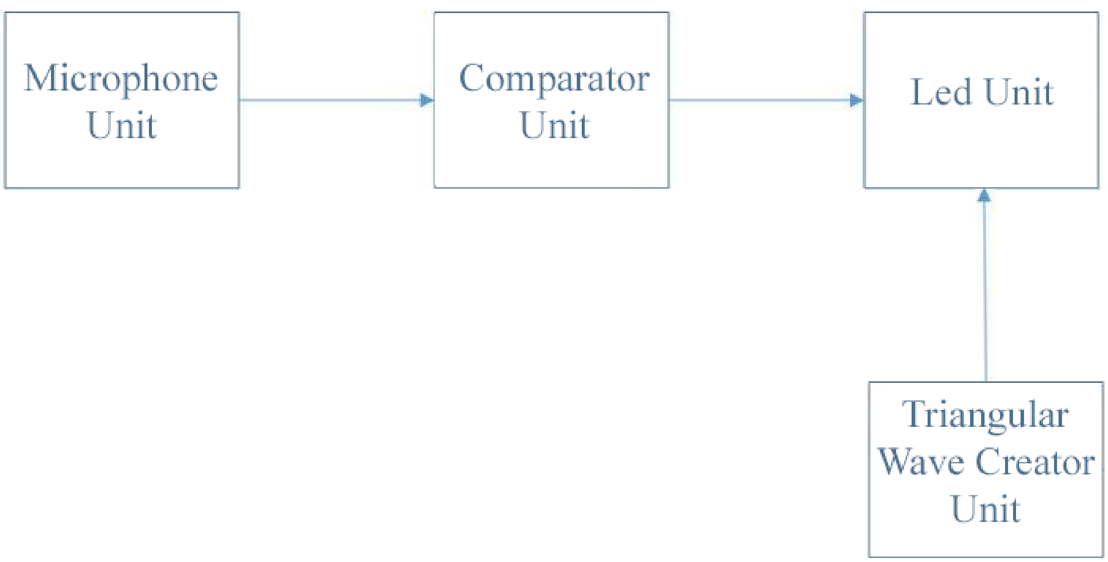

Figure 3: A basic block diagram for the desired system

As it can be easily understood from Figure 3, we compare the output of microphone unit with the predetermined voltage values (which implies the noise of outside actually) to classify the microphone input voltages (environmental sounds). Then the output of comparator unit will be transmitted to LED unit as well as the output of triangular wave creator unit to be compared to create a duty cycle which determines the how many seconds LED will lighten.

2.1 Overall Diagram

Here is overall diagram which shows every units and subunits. The outputs and inputs of the unit are named instead of connecting with cable. Also since we cannot simulate the circuit with a real microphone we used a sine wave generator instead.

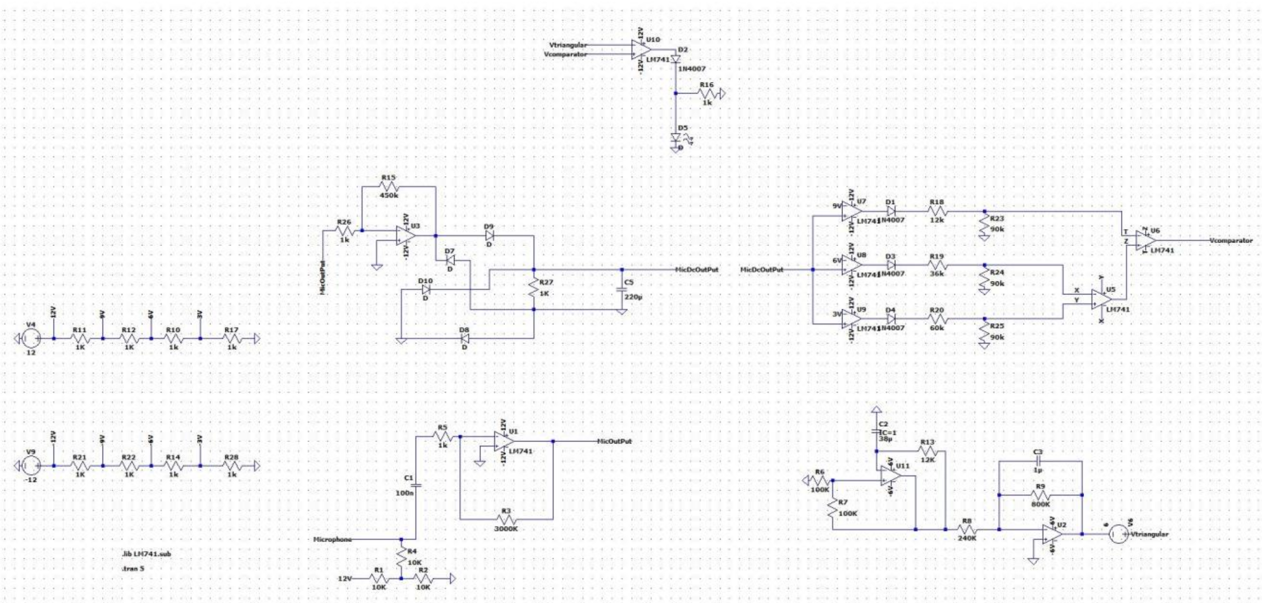

Figure 4: Overall diagram for the desired system

2.2 Microphone Unit

Microphone unit contains two subunits;

- ❖ Microphone Corrector Unit
- ❖ Microphone Amplifier and Transformer Unit

We will analyze these two subunits respectively.

2.2.1 Microphone Corrector Unit

In corrector unit, microphone acts like a AC voltage source; that is, microphone changes the sounds into AC waves. One of the pins of the microphone is connected to ground while the other one gives the AC wave. With the 12V DC source we support the microphone, without this DC voltage we cannot observe output from microphone. Also with the help of capacitor, DC offset is prevented. Furthermore, this capacitor leads to prevent low frequencies and noises up to some extend.

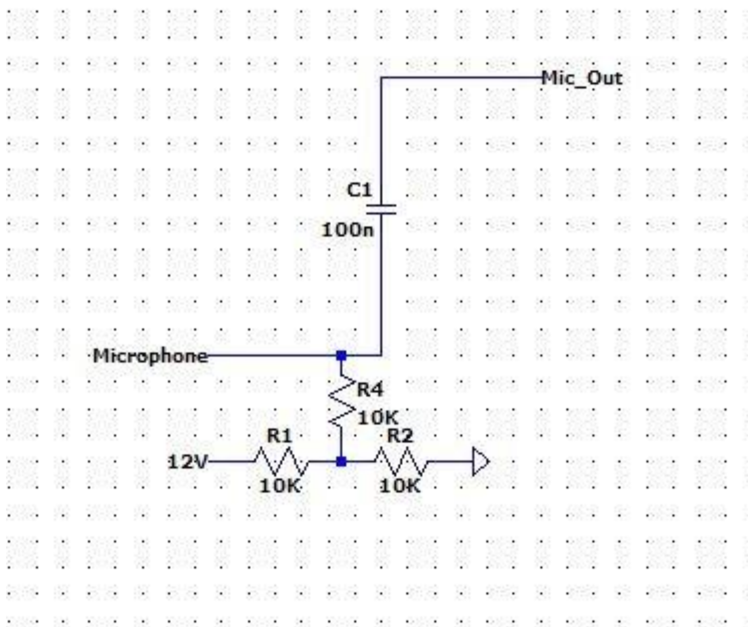

Figure 5: Diagram for the Microphone Corrector Sub-Unit

2.2.2 Microphone Amplifier and Transformer Unit

This subunit aims to increase the voltage coming from corrector unit. Because microphone corrector unit gives AC waves between 0 to 100mV nearly. It needs to be increased to range of 0 to 12V with the help of inverting amplifier(which will be discussed). So that we can compare the AC wave with some kind of voltages at the other parts of circuit.

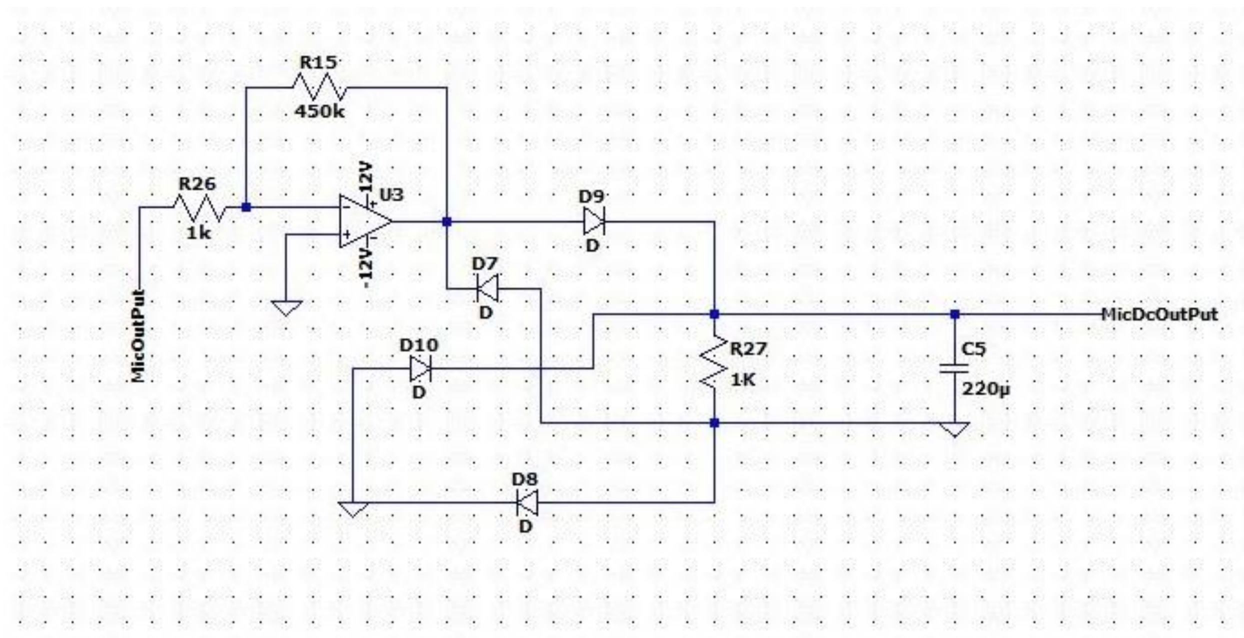

Figure 6: Diagram for the Microphone Amplifier and Transformer Unit

Beside this, with the full-wave rectifier, we convert AC voltage to DC voltage. As can be seen from the figure, the capacitor helps to convert AC to ripple voltage.

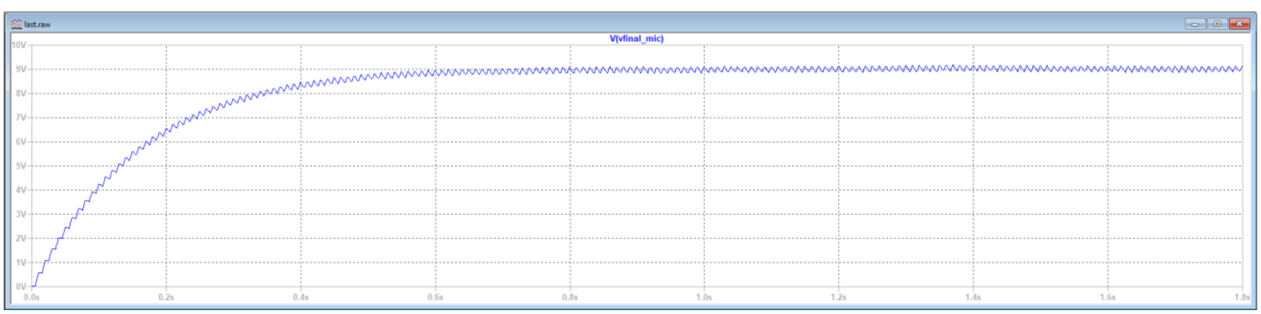

Figure 7: Simulation result of Microphone Amplifier and Transformer Sub-Unit (Ripple Voltage)

Inverting Amplifier

Since current cannot flow into the amplifier, it has to pass trough R_f . Also since, ideally inverting input and non-inverting input of amplifier needs to have same voltage values (in this example, $V^+ = V^-=0$), there will be a gain in V_{out} value proportional to resistors. The gain ratio is given below.

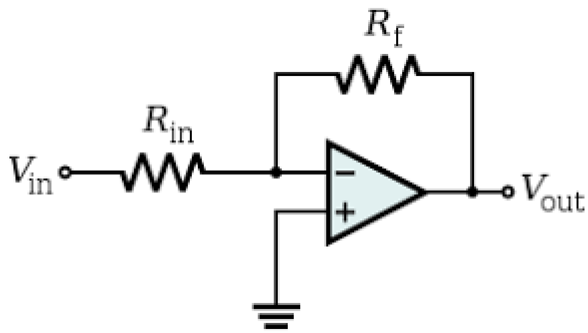

Figure 8: “Frequency dependency of an inverting amplifier” [Accessed: 27-Dec-2019]

$$\boxed{\text{Gain (Av)} = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}}$$

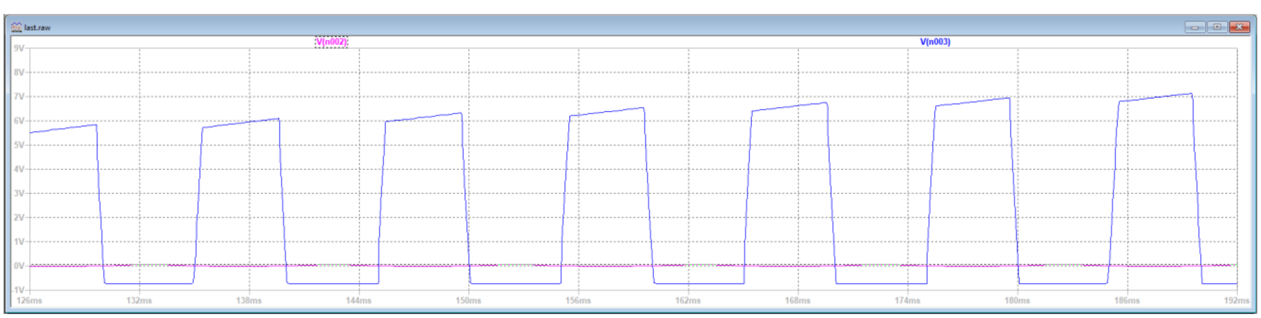

Figure 9: Simulation result of Microphone Amplifier and Transformer Unit-Inverting Amplifier Part (Boosted Voltage)

Full-Wave Rectifier

With the help of this part of circuit, we can change AC voltage that comes from microphone output to DC voltage. As it can be seen from Figure 7 it creates ripple voltage which is very similar to DC voltage.

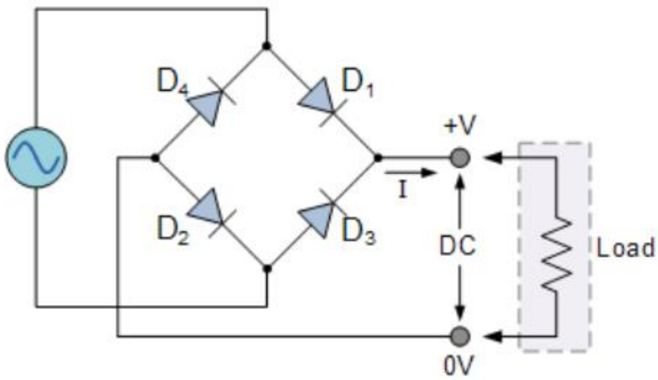

Figure 10: Ediz.(1970 January 1) Tam Dalga Doğrultmaç Devresi (Full Wave Rectifier)

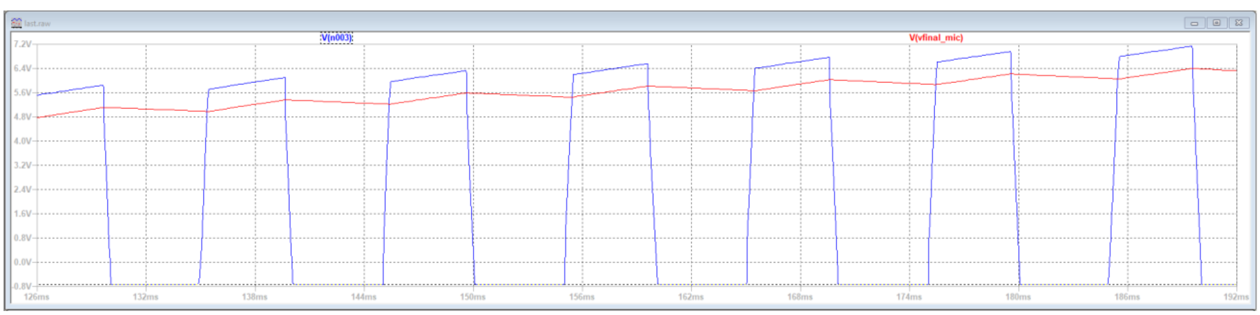

Figure 11: Simulation result of Microphone Amplifier and Transformer Unit- Full-Wave Rectifier Part (Ripple Voltage

2.3 Comparator Unit

In this unit our aim is to classify voltage values that came from microphone amplifier and transformer unit according to their amplitudes. Input voltage will be compared with the voltage values where we produced in voltage source unit that will be discussed later. After the comparison, the bigger value leads to; for example when noninverting side of the amplifier is bigger then V_{out} has the value of positive saturation +12V and so on so forth. Also the diodes prevents the negative voltages. So that when microphone output is less than the inverting input value of amplifier, the V_{out} after diode will be 0V.

For example **if the input voltage value is 7V the wave will pass through** last two amplifiers which have lower inverting inputs 3V and 6V. Then the outputs of these two amplifiers will have positive saturation values which is 12V. On the other hand, the output of first amplifier will have negative saturation value -12V which could not pass through diode. Then these two waves which passed through last two amplifiers will enter the U5 amplifier to be compared. In this amplifier, X will dominate because although the saturations are same, the following voltage values will be determined by the resistors. And if the AC voltage will cause U8 amplifier to have positive saturation 12V, it will certainly pass through the U5 amplifier because as mentioned before the voltage of node X will be bigger than voltage of node Y. Also since there will be no output from upper amplifier, the resultant voltage will same with the voltage of X node.

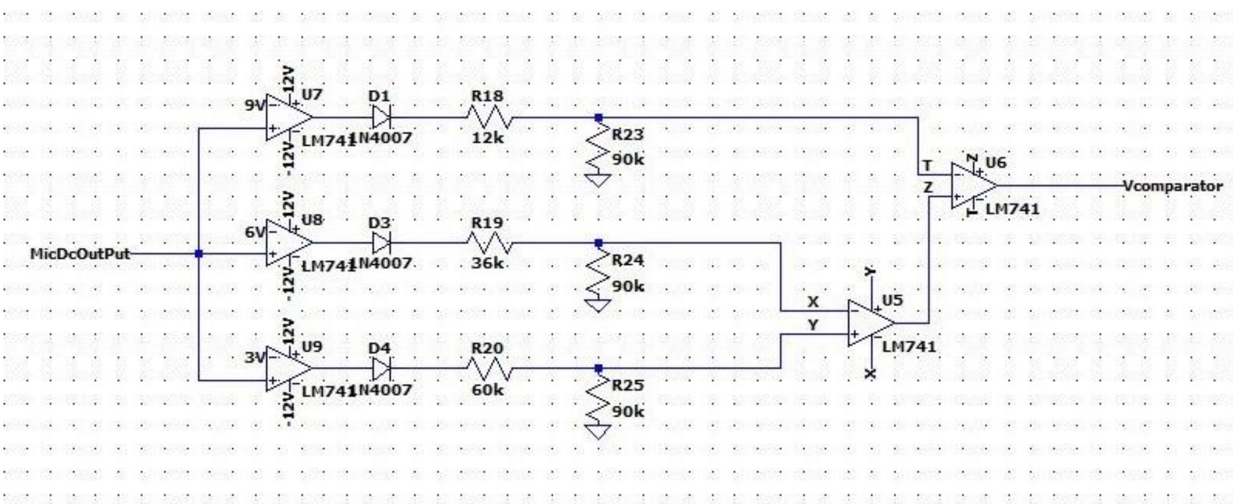

Figure 12: Diagram of Comparator Unit

Basic Comparator

One can simply use the basic comparator configuration given in Figure 8 to compare two voltages V_A, V_B (respectively) with each other to see which one is bigger by checking whether $V_{OUT} = V_{S+}$ or $V_{OUT} = V_{S-}$. If we have the positive DC voltage we feed to the op- amp as the output that means V_A is bigger than V_B, and for the negative DC voltage vice versa.

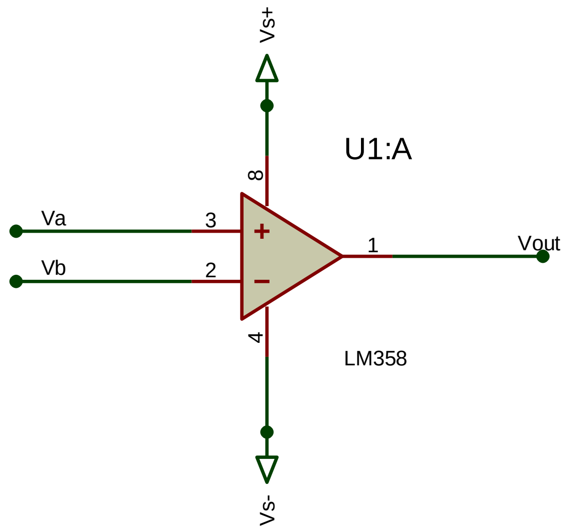

Figure 13: "Op-amp Comparator and the Op-amp Comparator Circuit," 14-Jul-2019

2.4 Triangular Wave Creator Unit

In this unit, our aim is to create triangular waves. In order to accomplish that we use a fully charged capacitor (If the capacitor has zero initial charge in the beginning, simulation will give no results because we've given the capacitor initial charge. But in real life we don't need to start with initial charge because the system is unstable.) The capacitor creates square wave by continuously charging and discharging due to the saturations of amplifier. Also R13 and C2 elements is the key point of frequency.

General equation of frequency: $f = \frac{1}{2*R*C}$

For our system: $f = \frac{1}{2*R13*C2} \approx 1Hz$

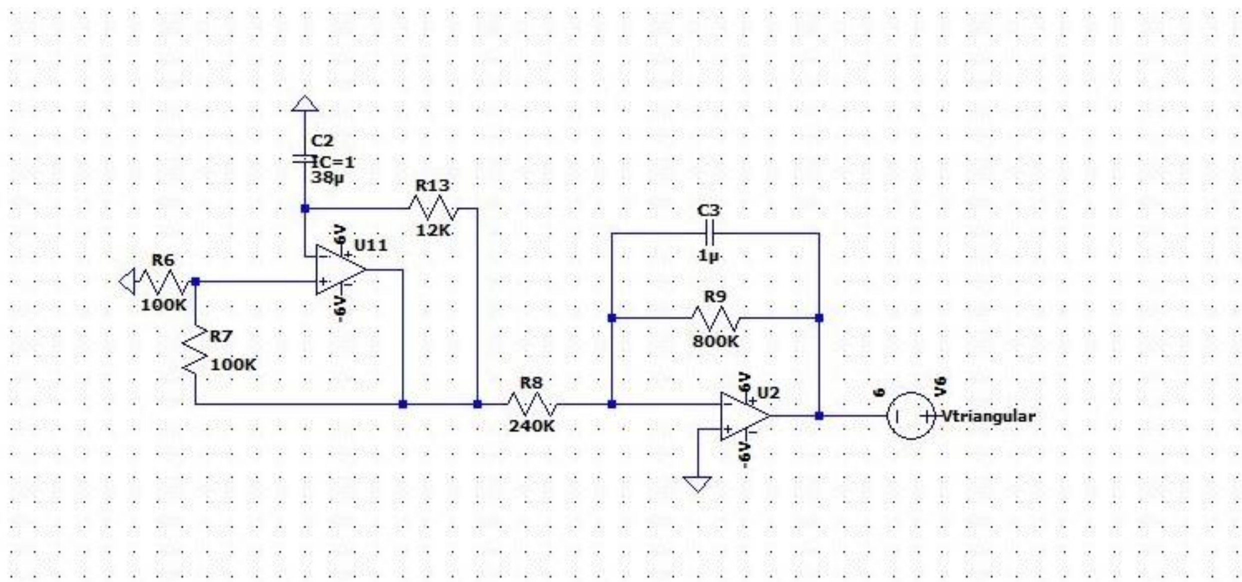

Figure 15: Diagram of Triangular Wave Creator Unit

The frequency is adjusted to 1Hz because we want to see how much time LED lighten easily and so that understand the environmental noise level with bare eyes.

Then with the help of integrator amplifier, the square wave is transformed to triangular wave. Integrator will be discussed below.

Moreover the last element of the unit 6V voltage source helps us to give offset value to triangular wave. Without this element, we will obtain a triangular wave whose frequency is 1Hz and max and min amplitudes are 6V and -6V respectively. DC supply boosts its amplitude 12V and 0V respectively.

Integrator Amplifier

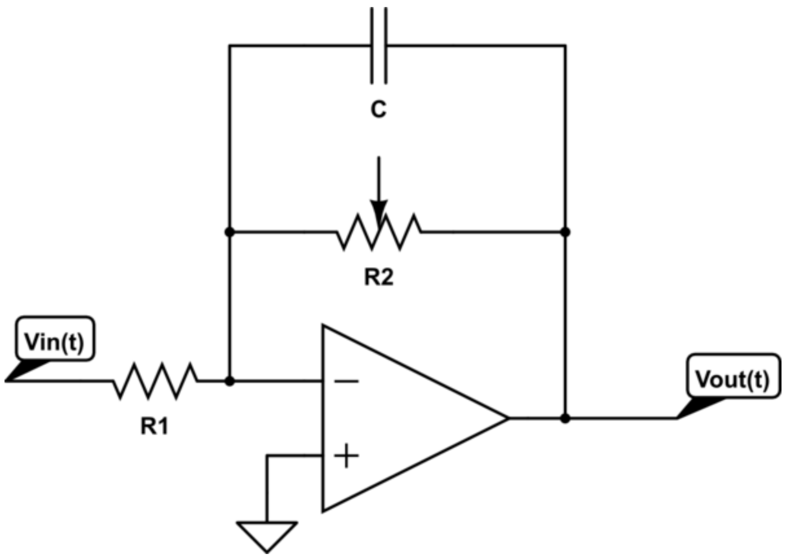

Figure 16: Electrical Engineering Stack Exchange, 01-Mar-1968.. [Accessed: 27-Dec-2019].

$$V_{out} = -\frac{1}{R_{in}C}\int_0^t V_{in}\,dt = -\int_0^t V_{in}\frac{dt}{R_{in}.C}$$

As its name implies, the integrator amplifier is an operational amplifier circuit that performs the mathematical operation of integration**;** that is, we can cause the output to respond to changes in the input voltage over time as the op-amp integrator produces an output voltage which is proportional to the integral of the input voltage. For example a square wave input will be converted to triangular wave in the output.

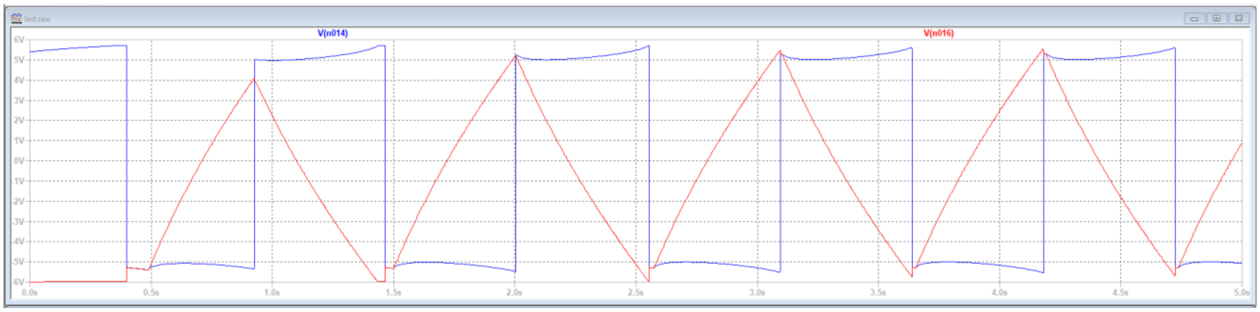

Figure 17: Simulation Result of Triangular Wave Creator Unit – Square Wave to Triangular Wave Part

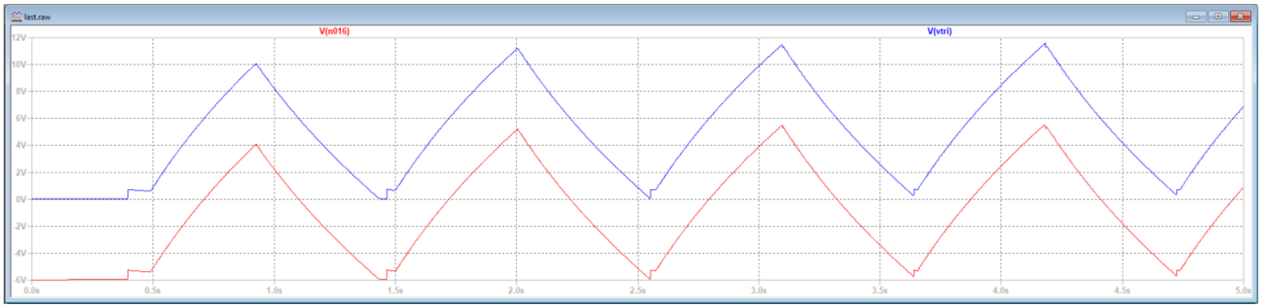

Figure 18: Simulation Result of Triangular Wave Creator Unit –Boosted Triangular Wave by DC Voltage

2.5 Voltage Source Unit

In this part, we've created the specific voltage values that we will be using in the desired circuit. To accomplished that we used resistors. All the needed voltage values are 3V, 6V, 9V, 12V. The specific values can be obtained by changing the resistor values.

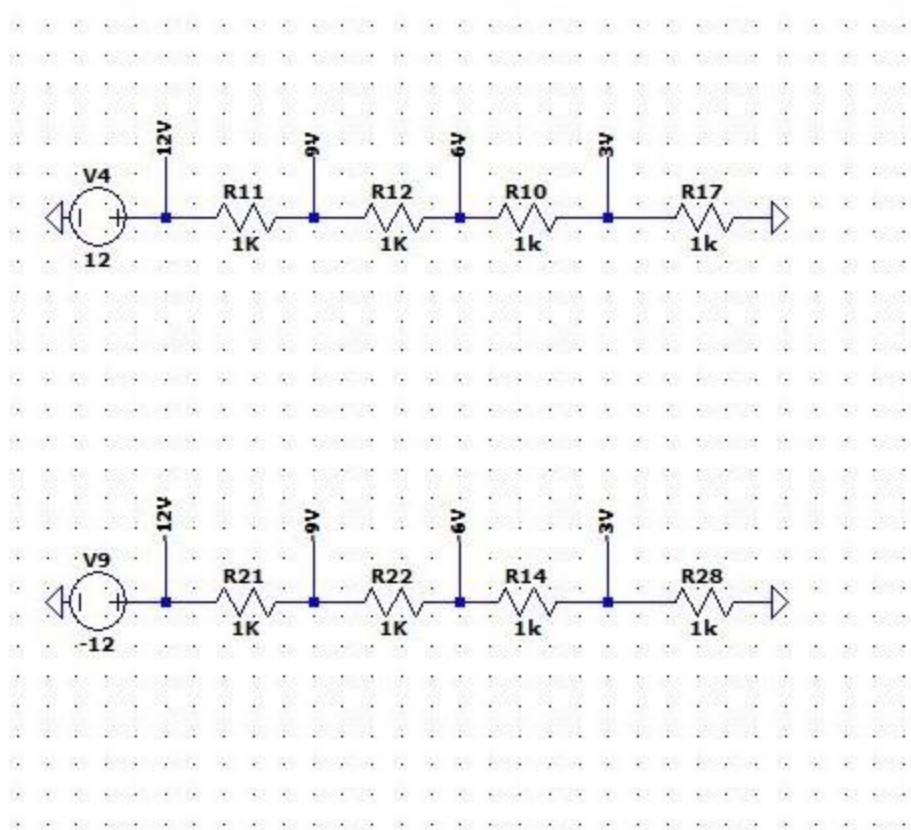

Figure 19: Diagram of Voltage Source Unit

2.6 LED Unit

Finally in this unit, we compare the waves which came from comparator unit and triangular wave creator unit. And at the points where $V_{comparator}>V_{triangular}$ duty cycle will occur. Then for the times duty cycle occurs, led starts to blink with respect to width of duty cycle. We can determine the noise by the lightning time of the LED. If the LED gives light for 0.75 seconds that means there are lots of noise outside. If the LED gives light for 0.50 seconds, there are an average noise outside. Finally, the LED gives light for 0.25 seconds, it means that environment is quite. Beside this, if the LED doesn’t give light, there is no such noise that can be measured by the circuit.

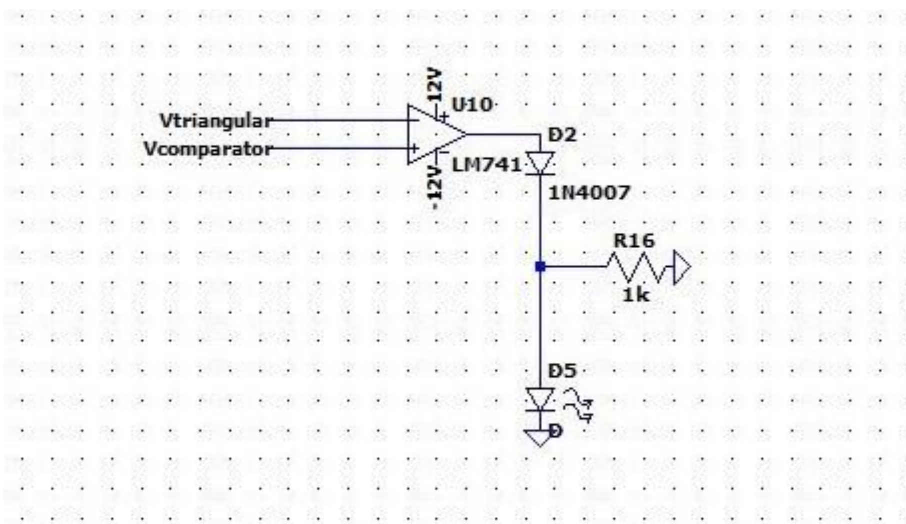

Figure 20: Diagram of LED Unit

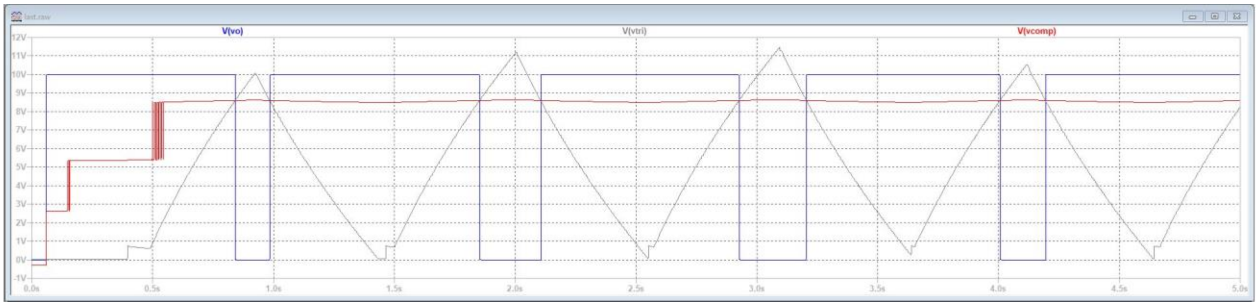

Figure 21: Simulation Result of LED Unit - %75 Duty Cycle (50mV Mic Input)

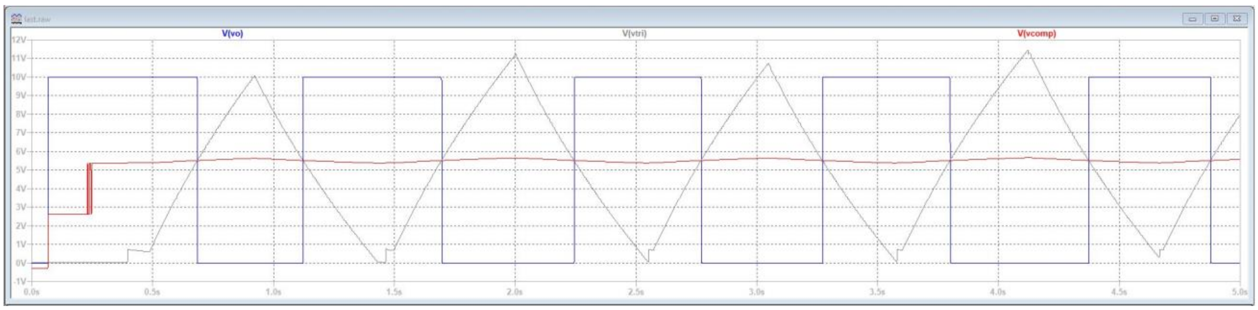

Figure 22: Simulation Result of LED Unit - %50 Duty Cycle (35mV Mic Input)

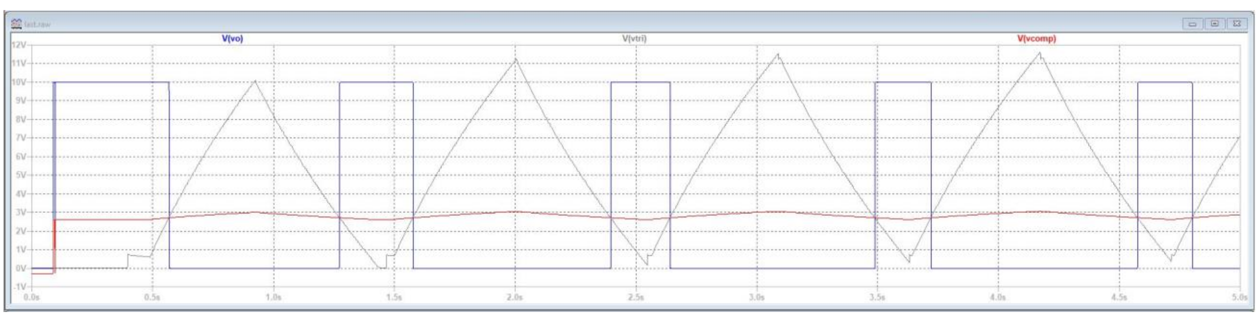

Figure 23: Simulation Result of LED Unit - %25 Duty Cycle (15mV Mic Input)

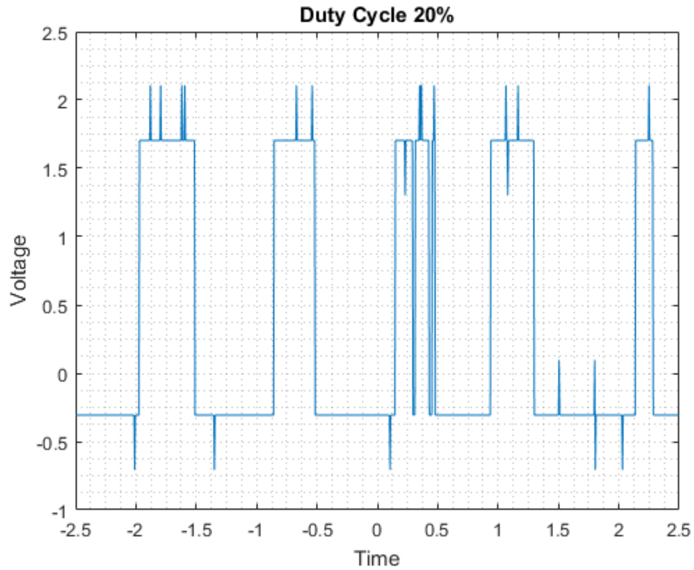

Figure 24: Matlab Result of LED Unit - %20 Duty Cycle

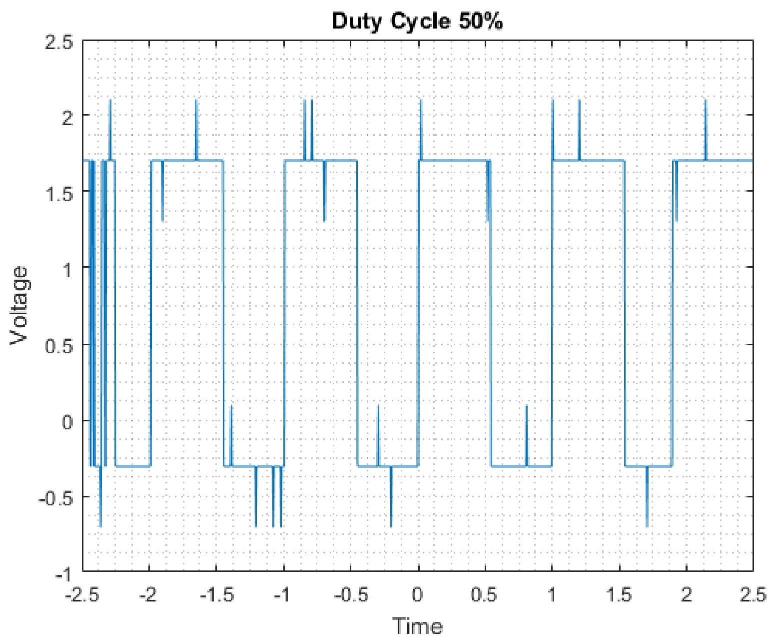

Figure 25: Matlab Result of LED Unit - %50 Duty Cycle

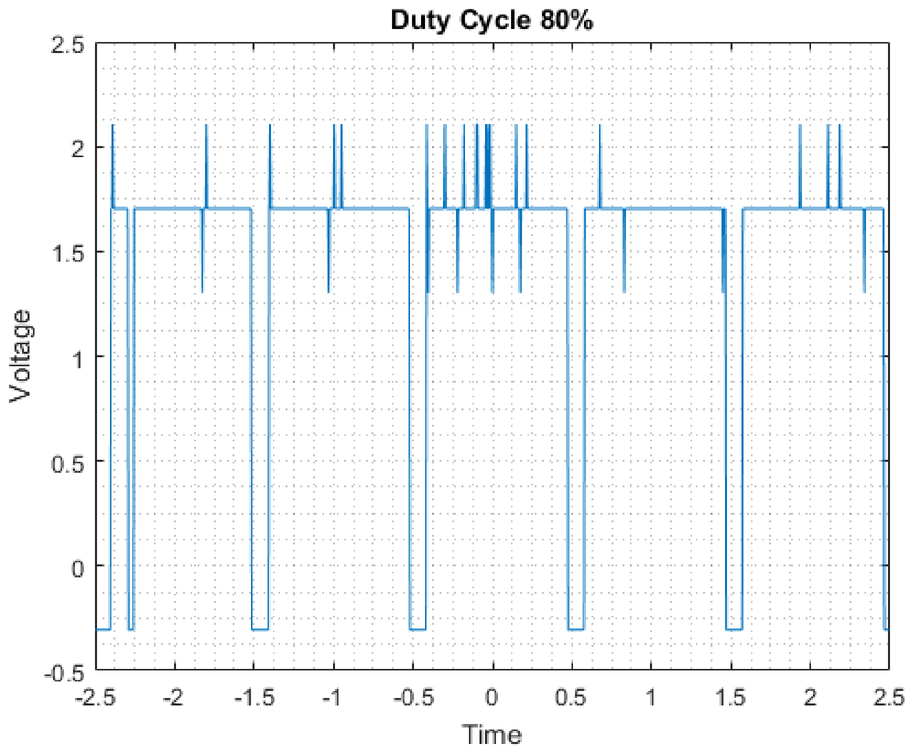

Figure 26: Matlab Result of LED Unit - %80 Duty Cycle

3. Conclusion

The aim of this report was to explain our last and unique design for the Displaying Sound Level System. The simulations had already showed us our design was applicable for the desired conditions but we also had to make a lot of analysis and make changes in our design according to these analyses. In addition to that, due to non-ideal conditions the most crucial change we made was removing the 6V DC offset in the triangular wave creator part. Instead we applied that offset by establishing full-wave rectifier at the end of the triangular wave creator part. However, by doing this we've doubled frequency. In order to compensate that we've divided frequency by two with the help of the capacitor and resistor in the beginning of this part. Furthermore, because of the reason we couldn't figure out, we weren't be able to create -6V by using some elements like resistors and operational amplifiers. Because of that we used 12V and -12V for the saturation values for all operational amplifiers, although we were planning to use 6V and -6V saturation values for some operational amplifiers. Moreover, since LM741 is not an ideal operational amplifier, we needed to changed many resistor and capacitor values. Also we had to use two inverting amplifiers in the microphone amplifier unit, because in reality the boosted voltage value was not enough to work on. Beside these, at the end of the microphone unit we were planning to use full-wave rectifier, however we needed to use half-wave rectifier. Moreover we had to use a non-inverting amplifier after half wave rectifier as it absorbs voltage value that we want to compare in the fallowing units. Because full-wave rectifier absorbs too much voltage that we couldn't predicted before. Finally, the last problem we faced was that we couldn't find the specific values for capacitors and resistors. In order to solve this problem, we used capacitors and resistors in parallel or in series whichever is appropriate for our circuit.

To sum up, we have accomplished our aim with some of the mistakes. For example, we couldn't create the exact duty cycle values with simulation results. Instead of 75% and 25% duty cycle we have obtained 80% and 20% duty cycle values respectively. Also we have observed some fluctuations in the duty cycles because of the real life obstacles.

Our overall system has the following schematic:

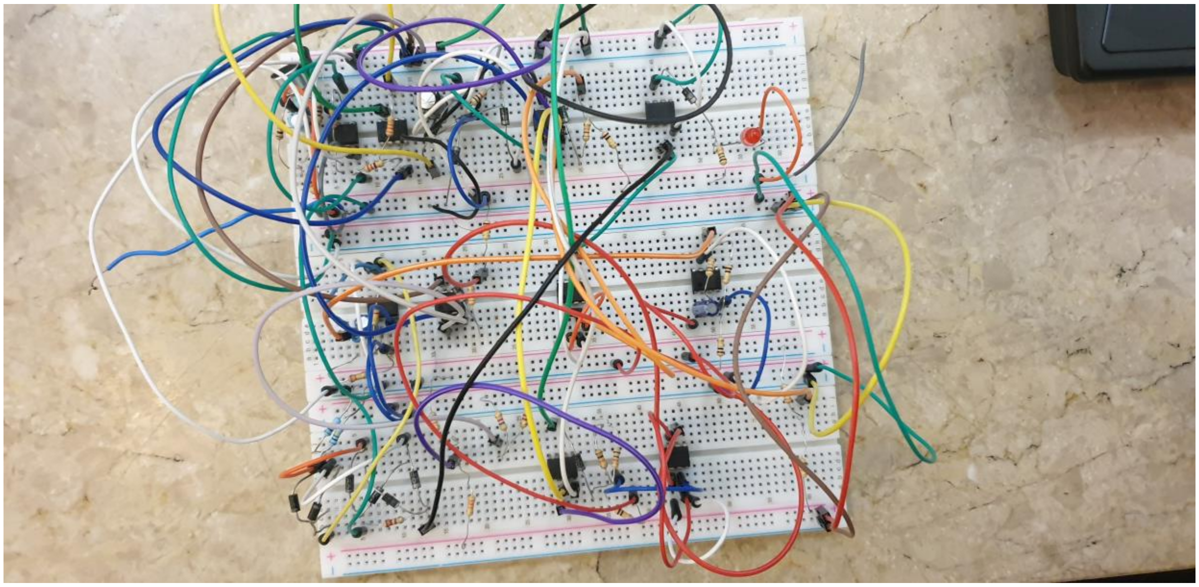

Figure 26: A picture of main system

4. Physical Analysis of The System

4.1 Cost Analysis

The components we have used and their prices in Turkish Liras are given in the table below:

Component	**Unit Price (₺)**	**Amount**	**All Price(₺)**
Resistor	0.08	100	8
Capacitor	0.3	25	7.5
LM741 Op-Amp	2.5	10	25
1N4007 Diode	0.03	8	0.24
Jumper	0.13	75	10
Breadboard	5	4	20
LED	0.1	5	0.5
Total			**71.77**

Table 1: Unit and Total Prices of Components and The Total Sum

Actually we haven't used all of the components we have bought, it was obvious that there will be differences in reality than simulation. We knew that we will be changing some of the elements of the circuit. Therefore we have bought more than our needs.

4.2 Power Analysis

The power supplied by two DC sources for the given duty cycle values of the system are given in the tables below:

Duty Cycles	**Current Drawn from 12V DC source (A)**	**Power Supplied from 12V DC Source (Watts)**
%0	0.016	384
%20	0.029	696
%50	0.035	840
%80	0.041	984

Table 2: Power Supplied by 12 Volts DC Source

5. Appendix

Total time spent on/during (items 3-5 are required in your final report)

- Pre-Design Report : 3 hours (average time spent on your initial research and report writing)
- Pre-Report : 15 hours (average time during the design and report writing)
- Project Implementation: 35 hours (average time spent building/debugging your design)
- Final Report: : 12 hours (average time spent for final report)
- Demo. Video: : 1 hours (average time spent for preparation of demonstration video)

6. References

[1]Ediz, "Tam Dalga Doğrultmaç Devresi (Full Wave Rectifier)," (01-Jan-1970)

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