EE313 Analog Electronics Laboratory Term Project Final Report

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***Abstract* – This report includes information about EE313 Analog Electronics Laboratory term project of Electrical and Electronics Department of Middle East Technical University. This project is a lane adjuster circuit for smart car applications.**

***Index Terms* – Sine Wave Generator, Power Amplifier, Active Filter, Logic Gates**

I. Introduction

In this project, we are expected to design a lane adjuster circuit for smart car applications. It is supposed to show the lane on which our smart car should be moving in different scenarios. For this purpose, LEDs, operational amplifiers, resistors, capacitors, diodes, microphone and speaker is used.

The project consists of three main sub-blocks, which are audio signal generator, siren detector and lane decider.

In audio signal generator block, we firstly created three sine waves with different frequencies which represent the cars. Also, their amplitudes could be adjusted by using a potentiometer to show the lane on which they are moving. After that, we used a speaker to convert these signals to sound waves.

In siren detector block, we firstly used a microphone to collect the created sound waves by the speaker. After that, we used active filters to separate the collected signals. Then, we used LEDs which show the cars' corresponding positions on the road.

Lastly, in lane decider block, we first used logic gates whose inputs were the rectified signals of the siren detector block and the comparators which were used to determine their lanes. Finally, two LEDs will show the lane on which our car should be moving, considering the presence of the ambulance, police and regular car on the road.

II. Theoretical background and literature research

The project consists of three main parts, which are audio signal generator, siren detector and lane decider.

A. Audio Signal Generator

In this block, we were supposed to create three sine waves differing in frequencies and also their amplitudes should be adjustable. For this purpose, we have found that one of the best options is Wien Bridge Oscillator circuit. It is due to the fact that it does not contain any integrated circuit, and it can have a very low distortion using diodes. Also, it can be implemented easily. In order to change the frequencies, we planned using different resistor and capacitor values. Also, to adjust the amplitudes, we planned using potentiometers.

After creating these waves, we have noticed that a summing amplifier is needed for combining them in order not to change their magnitudes and frequencies.

Finally, to drive the speaker with the given condition on power, which is 1 Watt, and to obtain an audible sound, we noticed that a power amplifier circuit is needed. For this purpose, we observed that the class AB power amplifier is suitable.

Also, we have chosen our speaker to be 8 ohms in order to satisfy the supplied power condition easily.

B. Siren Detector

In this block, we needed a microphone to collect the signals generated from the speaker and, afterward, active band-pass filters with three different bandwidths to separate the signals. Finally, we were supposed to use LEDs to show the cars' corresponding lanes.

Firstly, we observed that a pre-amplifier circuit is needed to drive the microphone since the microphone output is quite small in magnitude.

After that, to separate signals, we needed filters which were supposed to attenuate the other two signals and pass only one of the signals. For this purpose, we have noticed that the best option is the active narrow band-pass filters since the frequency difference of the signals is very small, which should be less than 300 Hz. Therefore, an active band-pass filter with high-quality factor and small bandwidth is required for each of the signals.

Finally, having separated the signals, we were supposed to rectify the signals and convert them to DC values to decide on which lane the cars are moving. It can be done with a simple half-wave rectifier circuit. Having converted the signals to DC, we can finally use comparators to determine the lane and use LEDs to show the cars' corresponding lanes.

C. Lane Decider

In this block, we were supposed to take inputs from the siren detector block and show on which lane the smart car should be traveling. For this purpose, we noticed that a number of logic gates are required. We have decided that we should use two consecutive logic AND gates and one logic NOR gate using BJT transistors. We have decided the inputs of these gates should be from the comparators which were used to determine the cars' lanes in siren detector block. Finally, one of the two LEDs should be on that is showing the lane on which the smart car should be traveling.

III. Design Methodology and Mathematical Analysis of the Subsystems

A. Audio Signal Generator

Firstly, we have designed a sine wave signal generator using a Wien Bridge Oscillator. In this circuit, we used LM741 as the operational amplifier. The circuit we used can be seen in Figure 1. At the outputs of each signal, we used a switch since at a given time, there will be only two signals.

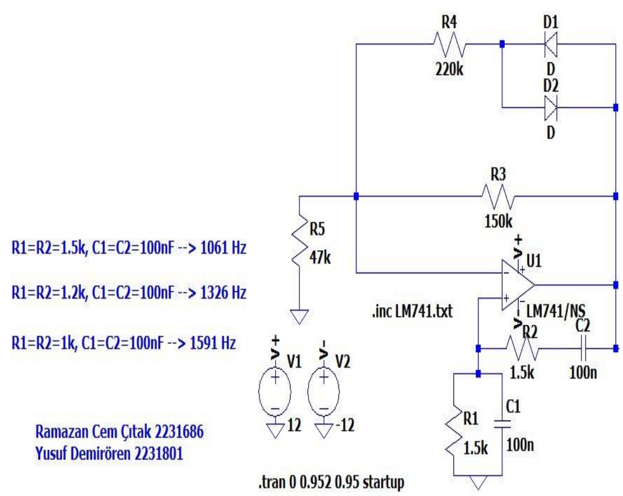

Figure 1. Sine Wave Generator Circuit

After that, we used a summing amplifier in order to combine the signals. The circuit schematic of the summing amplifier can be seen in Figure 2.

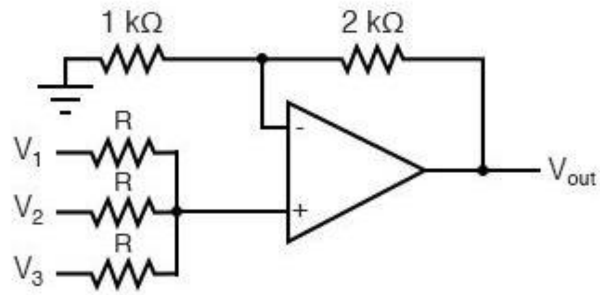

Figure 2. Summing Amplifier Circuit

In this block, finally, we used a power amplifier circuit to drive the speaker at the required power condition. We have designed the circuit given in Figure 3 for the power amplifier. We used a class AB type power amplifier since its efficiency is high and the crossover distortion can be made small. Also, we used a 2.2k resistor since the speaker was draining too much current otherwise.

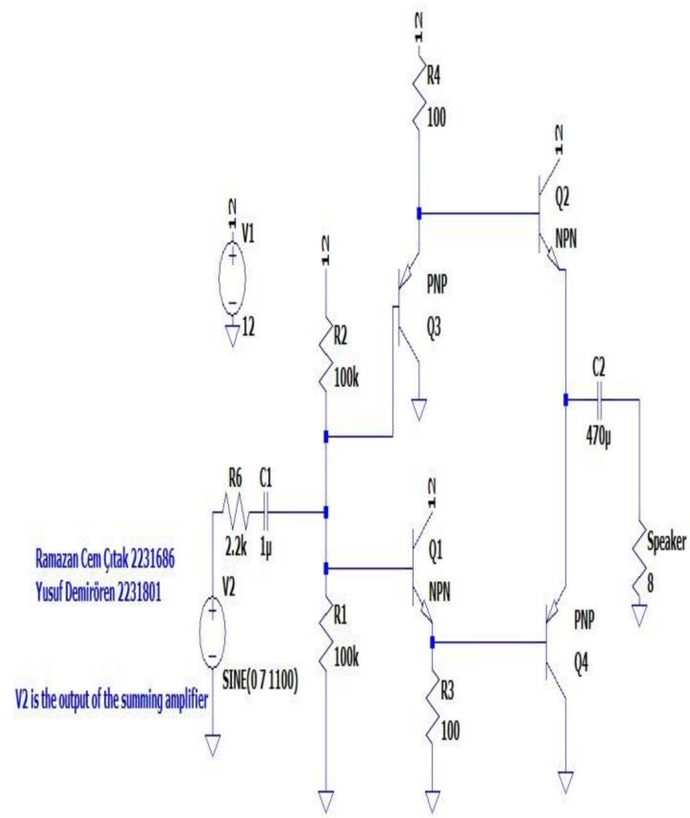

Figure 3. Class AB Power Amplifier Circuit

B. Siren Detector

We have used a pre-amplifier circuit to drive the microphone since its output had quite small amplitude. The pre-amplifier circuit can be seen in Figure 4.

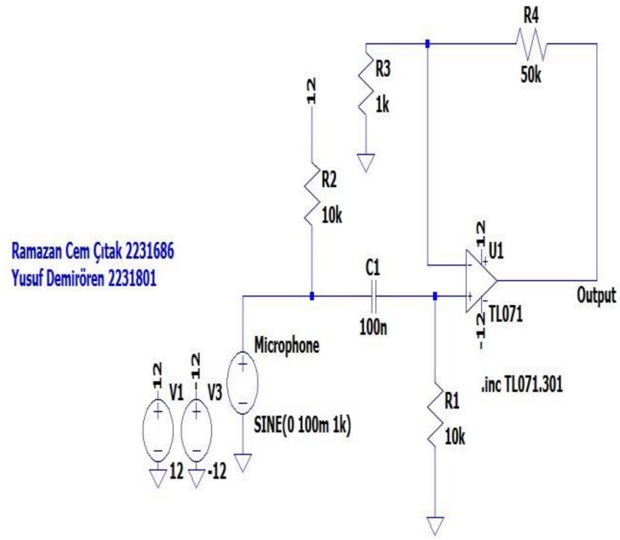

Figure 4. Microphone Pre-amplifier Circuit

We assumed that the microphone output has the amplitude of 100 mV.

After that, we designed active narrow band-pass filters to separate the signals. The circuit schematic of an active narrow band-pass filter can be seen in Figure 5.

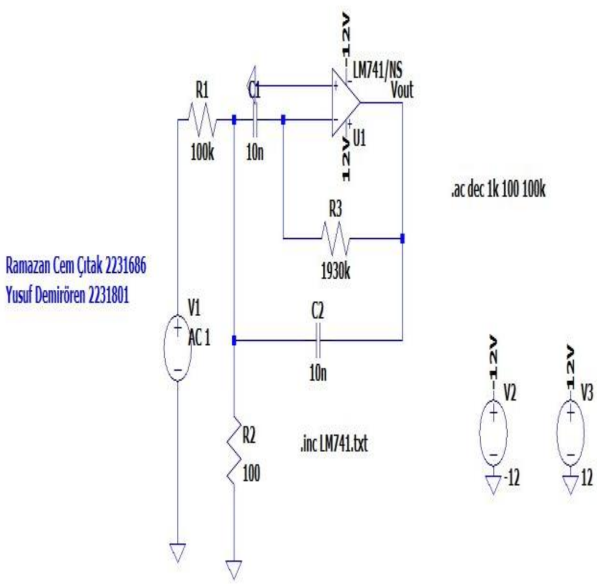

Figure 5. Active Band-Pass Filter Circuit

After active band-pass filters, we used half-wave rectifier circuits which are consisting of a diode and a capacitor. The diode is in series with the output of the filter, and the capacitor is in parallel to the rest of the circuit in order to avoid the voltage dropping to zero.

Hence, using this, we will have obtained DC levels proportional to the amplitudes of the signals.

Finally, we will compare these DC levels with firstly 1 Volt to check if the car is present on the road and then with the reference voltage, which we have chosen to be 4 Volts, to check if the car is on the left lane. The circuit schematic for the comparators can be seen in Figure 6.

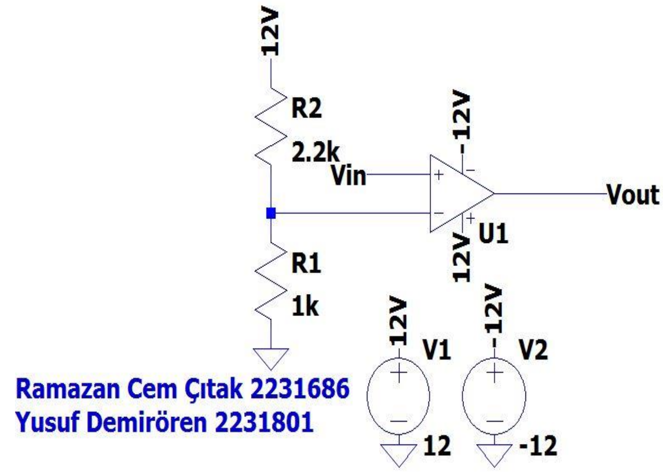

Figure 6. Comparator Circuit

Related to the output of the two comparators, using LEDs at the outputs of the comparators, we can show their lanes. We can connect LEDs at the output in series with a resistance and diode in order not to allow a large voltage presence on the LEDs alone.

C. Lane Decider

In this block, we first used an AND logic gate where Vin1 is the police car's DC output after comparing with 1V, and Vin2 is the regular car's DC output after comparing with 1V, using comparator circuits. This gate enables us to check if both police car and regular car are present on the road at the same time. After that, we used another AND logic gate with Vin1 corresponding to the Vout of the first AND gate, and Vin2 corresponding to the police car's DC output after comparing with reference voltage. The circuit schematic for the AND logic gate can be seen in Figure 7.

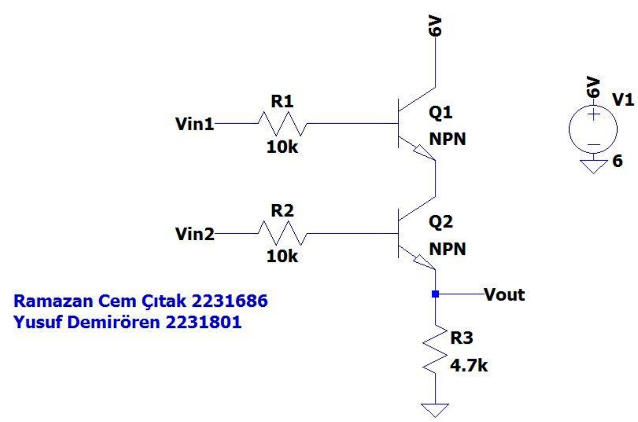

Figure 7. Logic AND Gate Circuit

After these two AND logic gate, we will be able to check if police and regular car are both present and if police car is on the right or left lane. If the output from these gates is non-zero, it means regular car and police are present and police is on the left lane.

Finally, we used a NOR logic gate where Vin1 is the output of the previous AND logic gate and Vin2 is the ambulance's DC output after comparing with reference voltage. Output of the NOR gate is non-zero if both inputs are zero, which means ambulance is not present or on the right lane and the output of the second AND gate is zero. In this case, the car should be moving on the left lane and, otherwise, on the right lane. The circuit schematic of the NOR logic gate can be seen in Figure 8.

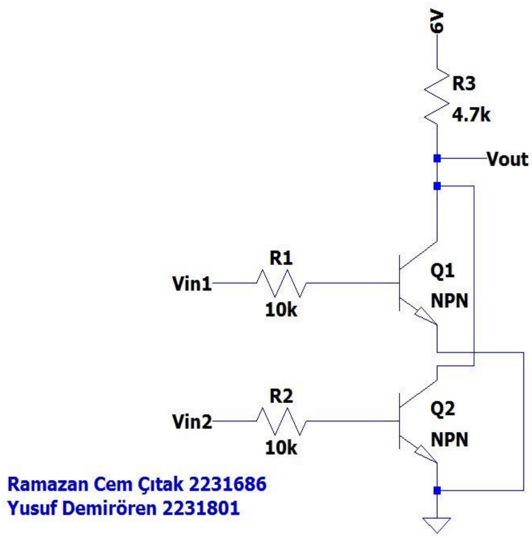

Figure 8. Logic NOR Gate Circuit

After NOR logic gate, we used LED in the output with diode and resistors. If the output is non-zero, LED will be on and this means the smart car should be on left lane. Also, we used an inverting comparator in the output and if the voltage is zero, then the output of the inverting comparator will be non-zero. Hence, LED connected to the output of the comparator will be on and this means the smart car should be on the right lane.

IV. SIMULATION RESULTS

We used LTspice to simulate the circuits that we have designed.

A. Audio Signal Generator

Simulation result of the sine wave generator circuit with 1061 Hz can be seen in Figure 9. Similarly, when we changed the resistors, we observed sine waves with 1326 Hz and 1591 Hz.

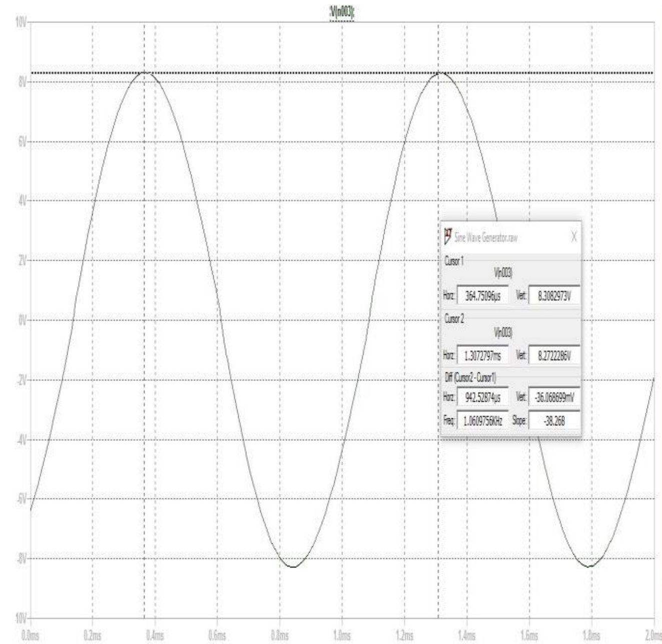

Figure 9. Simulation Result of the Sine Wave Generator

In the simulation result of the power amplifier, we observed a sine wave with 3 Vrms amplitude when we applied a sine wave with 7 Volts amplitude. Hence, the power on the speaker is around 1.1 W, which satisfies the supplied power condition. The voltage on the speaker can be seen in Figure 10.

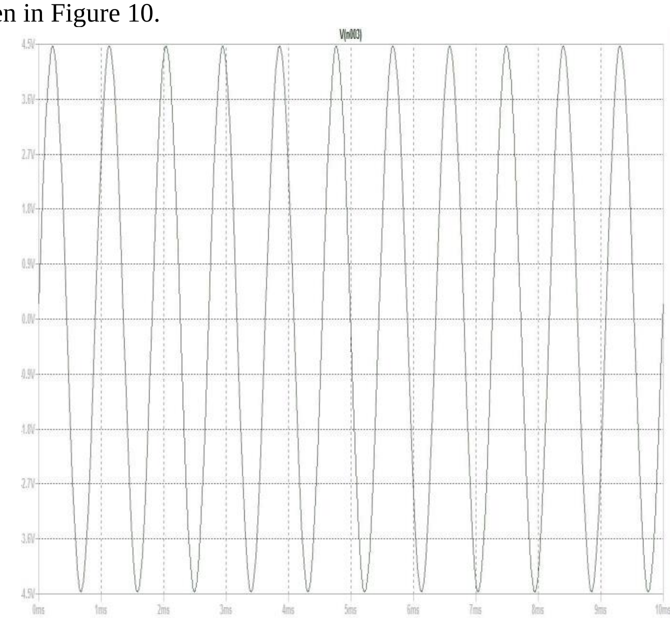

Figure 10. Simulation Result of the Power Amplifier

B. Siren Detector

In the simulation result of the microphone preamplifier, we observed a 5V sine wave at the output, as expected since we have amplified the microphone output by 51. The output of the microphone preamplifier circuit can be seen in Figure 11.

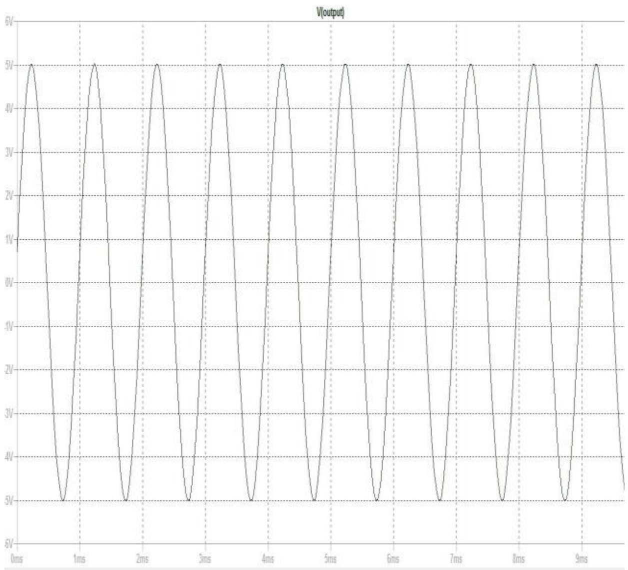

Figure 11. Output of the Microphone Preamplifier

The frequency response of the active filter can be seen in Figure 12. It is the active band-pass filter used for 1060 Hz sine wave. The other active band-pass filters are obtained changing the resistance values. Therefore, they have similar results.

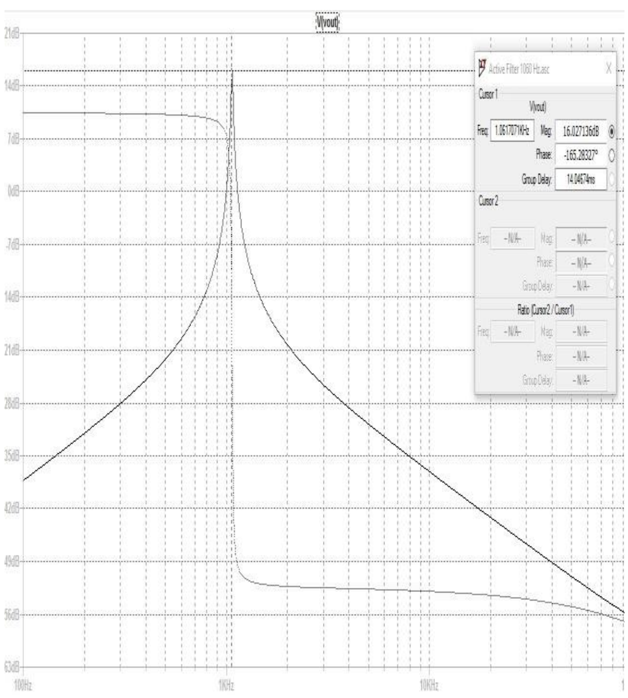

Figure 12. Frequency Response of the Active Band-pass Filter Circuit

V. EXPERIMENTAL RESULTS

We have constructed the sine wave generator circuits as we had designed. We observed that the amplitude of the sine waves were not the same as the simulation results. We obtained 5 Volts peak-to-peak sine waves when the cars are on the left and 3 Volts peak-to-peak sine waves when the cars are on the right. Also, we observed that the frequencies of the sine waves were a little bit different than the simulation results since the resistors that we used in the circuit had tolerance values but in simulations we assumed they had exactly the same resistance value. We used different resistors in order to satisfy the condition on the frequency difference of the sine waves.

When we constructed the power amplifier circuit, we observed that less than 1 Watt was supplied to the speaker since the input signal had smaller amplitude than the input we used in the simulation. To satisfy the supplied power condition, we amplified the input signal using another operational amplifier.

We obtained an audible sound using the speaker, and we were able to collect the signals using the microphone. In the output of the preamplifier microphone circuit, we observed a sinusoidal signal which had the same frequencies as the generated sine waves in the audio block. However, we observed some distortions in the shape of the sine wave.

When we constructed the active band-pass filter circuit, we observed that the circuit had a different center frequency than the simulation results. Also, the bandwidth was larger and did not have a quality factor as large as the filter in the simulation results. Therefore, the change in the resistance values was required and more than one band-pass filter circuit in series should have been used in the circuit to satisfy the attenuation condition.

We have constructed rectifier circuits but after the rectification, we observed different values than we expected. Also, we observed DC off-set values even if there was no input provided to the rectifier circuit. Hence, a change in the resistance values that we used in comparator circuits was required.

Finally, we have constructed the logic gates but some LEDs were on all the time even if there was no input supplied to the gates and some LEDs were off all the time. Therefore, we observed different results than we expected.

VI. COMPARISON OF THE EXPERIMENTAL RESULTS WITH THE SIMULATION RESULTS AND MATHEMATICAL CALCULATIONS

We have simulated all of the circuits in LTspice and they were working properly. However, we observed that the active band-pass filter that we have designed did not work as it worked in the simulation. This can be due to the fact that a large quality factor cannot be obtained easily using the circuit we used in real life. Hence, a small bandwidth and a large attenuation of the signals that are not in the bandwidth could not be achieved.

Therefore, our project did not work as desired although it was functioning properly in the simulation.

VII. Conclusion

In this project, we were expected to design a lane adjuster circuit for smart car applications and implement the designed circuit. Firstly, we created sine waves using Wien Bridge Oscillators, and then used a speaker to convert these signals to sound waves. After that, we used microphone to capture these sound waves and convert them into signals. Then, three different active narrow band-pass filter circuits were used to separate the signals, and we converted these AC signals to DC outputs, using rectifier circuits. After that, comparators and LEDs were used to show on which lane the cars were present and, finally, after logic gates, the lane on which the smart car should be traveling was shown using, again, LEDs.

We have mainly used what we had learned in EE201, EE202, and EE311 courses. Therefore, it was an opportunity to practice our knowledge. We observed that some discrepancies exist between the simulation results, theoretical knowledge and the experimental results. In this project, we have tried to eliminate these undesired results as much as possible. Therefore, even if our design was working properly in the simulation results, we could not make our project work as desired in real life.

We have spent around 40 hours for the whole project.

Reference

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