21.11.2019

# MIDDLE EAST TECHNICAL UNIVERSITY

## ELECTRICAL & ELECTRONICS ENGINEERING

## EE 313 – ANALOG ELECTRONICS LABORATORY

## FALL 2019 TERM PROJECT

**PROJECT TITLE**: A LANE ADJUSTER CIRCUIT FOR SMART CAR APPLICATIONS

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# 1. PROJECT DESCRIPTION

Over the past few decades, the automotive sector has adapted itself in accordance with the needs of the customers. Among others, one important aspect of such an adaption is to provide a simple drive for the drivers and comfortable trip for the passengers. Consequently, modern cars have been equipped with lots of additional accessories and functionalities including air conditioners, automatic transmission, and cruise control systems, etc. With the rapid developments in technology, the engineers and designers have gathered their focus on eliminating the necessity of drivers, paving the way for autonomous and smart car applications. For that purpose, a variety of mechanisms have been proposed such as LiDAR sensors, accelerometers, gyroscopes, and lane tracking mechanisms for navigation and autonomous driving.

In autonomous driving schemes, one duty of the controller is to decide on which lane the vehicle must go under different circumstances. In this project, you are asked to animate a certain part of an autonomous driving controller from a particular perspective. As you might know, drivers of regular cars have to give the way to some special vehicles coming from behind (ambulance, police car, fire truck etc.), when their sirens are on. Although, it might be quite hard to teach that to the drivers, fortunately, autonomous cars will not share the problem, thanks to the controllers you will design. In short, you will design a circuit, determining the lane on which a vehicle is supposed to go by checking the cars coming behind them.

Basically, your controller will be controlling an autonomous car travelling on a double-lane road. There are always two types of cars coming behind you. In other words, in all cases, both of the lanes will be occupied. There are three types of cars, which might be coming from behind your car: Ambulance, police car, and regular car. Only two of them can come at a time, and two cars of same type cannot be present on the roads at the same time. Your car must understand which car is coming from which lane, and give the way to the one with the highest priority in a given situation. The priorities of the vehicles are as follows: Ambulance > Police Car > Regular Car. You can understand the design requirements by observing the scenarios described below.

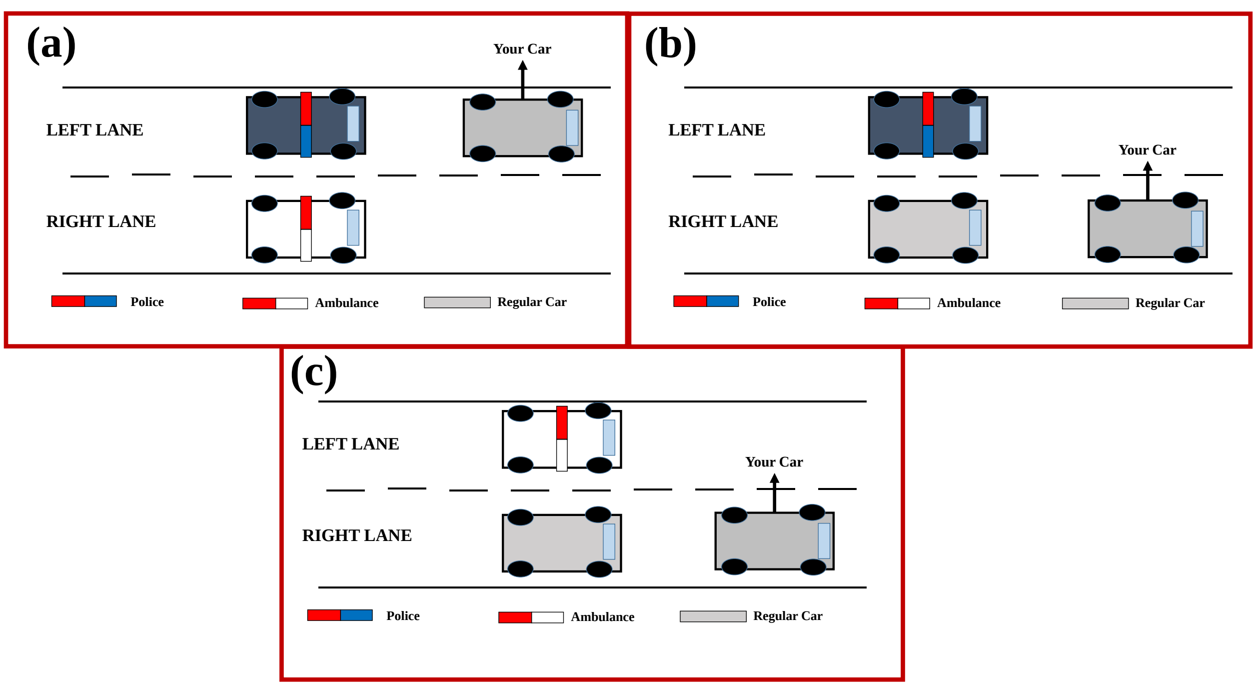


*Figure 1. Desired configurations for different scenarios*

In Figure 1, several different scenarios and their desired car distributions are provided. As you can see in the figure, ambulance has the highest priority, and your car is not on the same lane as of the ambulance, under no circumstances. On the other hand, if no ambulance is travelling, the police car has the highest priority, meaning that your car cannot be on the same lane with the police car.

## 2. DESIGN OVERVIEW

The animation of the above situation will be realized as follows. A unique frequency will be assigned to each car. These frequencies will represent the unique sirens of the cars. For this purpose, you need to generate three different sinusoidal signals. The frequency of these signals indicates the type of the car; while the amplitude will carry the information about the lane the vehicle is moving on. After generating and combining these signals, you will convert them to sound waves through a speaker.

In the second part of your project, you will design the circuit, detecting these sound signals and determining the lane on which your car must travel. For this purpose, you should use microphones in order to collect the sound signal. Afterwards, you will separate the signals coming from different vehicles. Then, you need to obtain a DC signal for each siren, whose level is proportional with that of sinusoids'. Finally, you need to implement a logic-circuit, deciding the lane on which your ca must go in order to give the way to the car with the highest priority in all scenarios.

### 2.1. Description of Sub-Blocks

In this part, the sub-blocks of the overall design are briefly described.

#### 2.1.1. Audio Signal Generator

In this part, you will generate the sound signals, imitating the sirens of the cars, present on the road. For this purpose, you are obliged to implement three sinus wave generators, differing in frequency. The choices of the sirens' frequencies are left to your liking, however, there are two restrictions: First, the frequency of each sirens must be different from each other. Second, the spectral distance between two consecutive frequencies cannot be higher than 300 Hz. In other words, let's assume you have picked three different frequencies for ambulance, police car, and a regular car, as $f_1$, $f_2$, and, $f_3$, respectively; such that $f_1 < f_2 < f_3$. In such a scenario, $f_2 - f_1$ and $f_3 - f_2$ must be smaller than 300 Hz. It is strongly recommended for you to consider the frequency response of your speaker, before choosing operation frequencies, as you will later convert them into sound waves. In addition to the frequency of the signals, their amplitudes require special attention. The information about the car's lane will be transmitted to your lane adjuster circuit via the amplitude of the signals. You are supposed to choose a threshold voltage, indicating whether corresponding vehicle is on the left lane or right lane, i.e. if the amplitude of a sinusoid is lower than $V_{REF,}$ it means that corresponding car is travelling on right lane, while it is moving on the left lane, if the amplitude is higher than $V_{REF}$. You can choose any value, as long as your circuit operates consistently. Moreover, chosen $V_{REF}$ must be same for all sirens. It is strongly advised that you should implement your audio signal generator block with tunable signal amplitudes so that we can easily observe every scenario in the project demonstration session.

Having generating the sinusoids, you need to combine them and convert them into sound signals via a speaker. For this part, after combining the signals, you need to drive the speaker, which requires the utilization of power amplifiers. At the output, you should be able to obtain a clearly-audible sound signal for each siren. At the end, your audio signal generator block should be as in Figure 2.

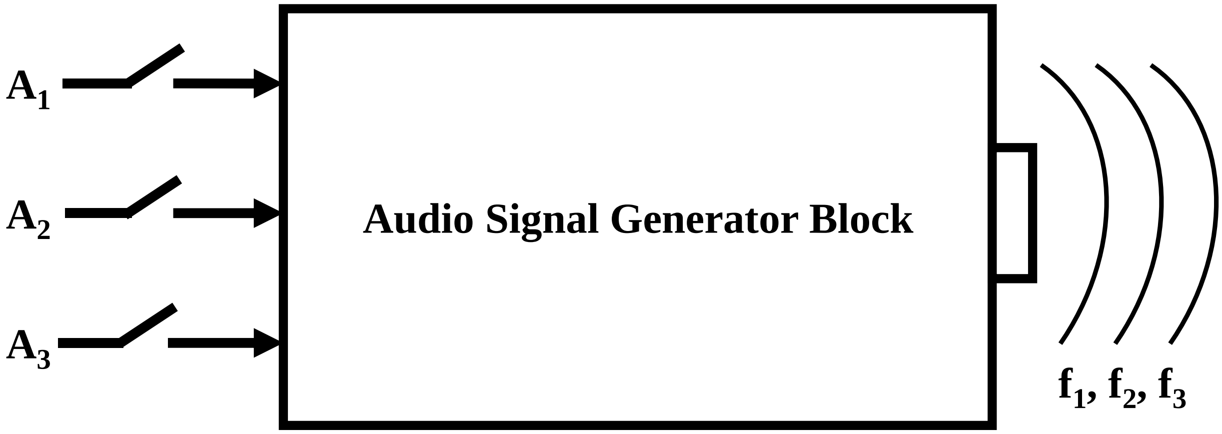


*Figure 2. Block diagram of audio signal generator*

In Figure 2, the block diagram of the audio signal generator part is given. As you can see, this part will have three inputs, which are the amplitudes of the sirens. Please note that, there should also be switches enabling the generation of these signals, as only two of them will be at a time.

2.1.2. Siren Detector

In this part, your aim is to collect the sound signals and detect which type of cars are behind you. In order to collect the sound signals, you should use microphones. You need to drive the microphone and amplify the signal coming from the microphone. Afterwards, you have to separate the signals coming from different cars Then, you need to generate DC levels, proportional to the amplitude of these signals. Additionally, there must be two LED indicators, for each type of cars, indicating the presence or the lane of the cars. In other words, if the car is not present on the road, both of the LEDs should be at OFF state. If it is on the right lane, then the other one must be ON. This configuration must be implemented for all types of cars. The block diagram is given in Figure 3.

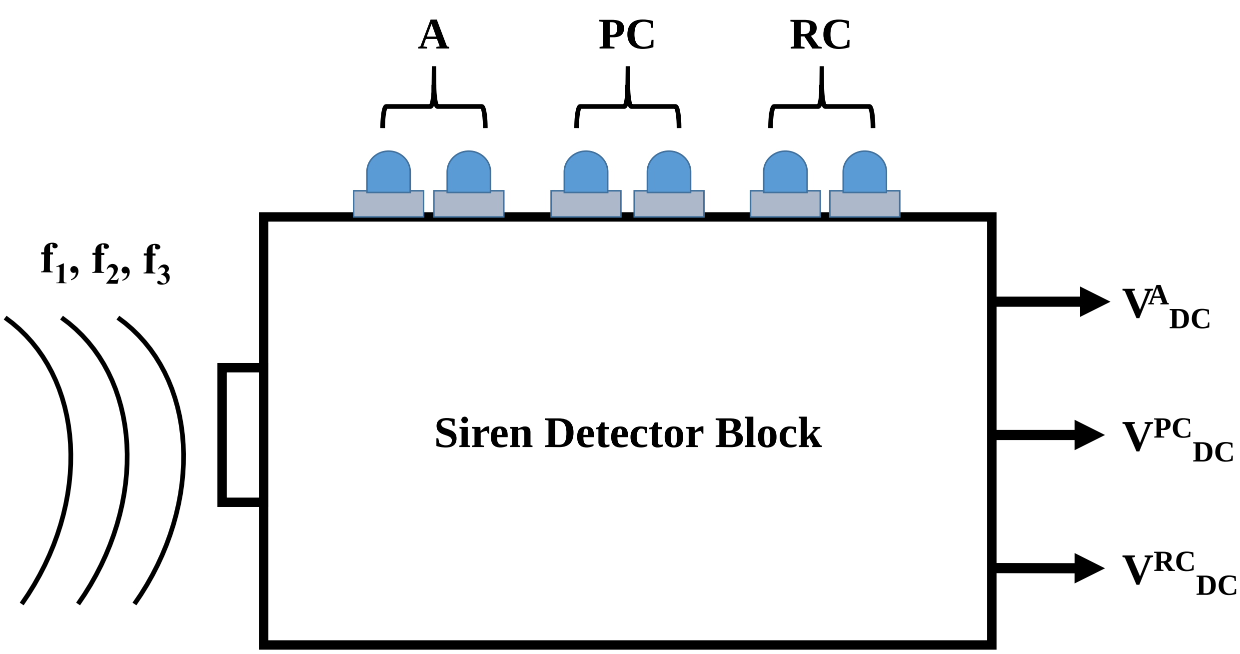


*Figure 3. Block diagram of siren detector part*

As it can be seen in Figure 3, the input of this block is the sound signals coming from the audio signal generator part. This block must be able to collect the signals and operate properly, when located at least 10 cm away from the speaker. Finally, it must output the DC levels, proportional to the amplitude of the collected sinusoids and must indicate which car is on which lane via LEDs.

### 2.1.3. Lane Decider

The last block of your design will be the lane decider block. In this part, you will design a circuit, deciding which lane your car must travel under different scenarios. For that purpose, you need to implement a logic circuit. There are various ways of implementing logic circuits. It would be beneficial for you to do some literature search on basic logic gates and their operations. You can implement these gates by using diodes, transistors or operational amplifiers. The inputs of this part is up to you. You can utilize any signal you have previously generated unless it is wired to the audio signal generator block. As you might notice, the audio signal generator block represents the cars coming from behind you, therefore any wired connection violates the idea behind the design. At the output of this block, you'll have two LEDs indicating the lane on which your car must travel. Each LED should indicate a lane and there should be one active LED, at a time. In Figure 4, you can observe the block diagram of the lane decider part.

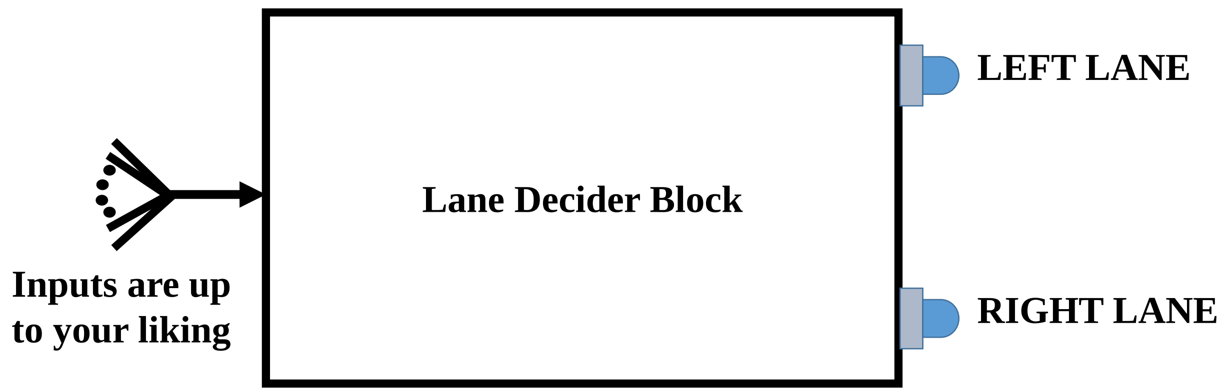


*Figure 4. Block diagram of lane decider circuit*

## 2.2. Design Specifications

- The frequency of the sirens will be decided by you. However, the spacing between consecutive frequencies cannot be larger than 300 Hz.
- The amplitudes of the generated sirens must be tunable, as it incorporates the lane information of the car.
- The power on the speaker must be larger than 1W.
- The siren detector block should be able to operate properly 10 cm distance away from the audio signal generator block.
- When you separate the collected signals, each car's channel must attenuate the other cars' signals at least by 20 dB.
- The siren detector part must be able to distinguish all states (Absent, Left Lane, Right Lane) for all cars (Ambulance, Police Car, Regular Car).
- At the output of the lane decider block, LEDs must indicate the correct lane for all configurations in accordance with the priority of the cars (Ambulance > Police Car > Regular Car).

## 2.3. Available Components

You can use any resistors, capacitors, inductors, diodes, LEDs, LDRs, transistors, and general purpose operational amplifiers.

Regarding microphones, you can utilize the electret microphones, such as the one in Figure 5. They are easy to find and quite inexpensive.

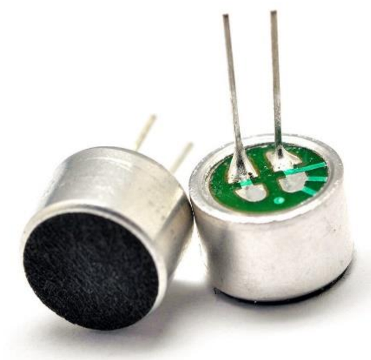

*Figure 5. Electret microphone*

In the audio signal generator part, you can use 8 Ω, 16 Ω, or 32 Ω speakers, easily found in electrical component stores. Please make sure you satisfy the power requirement, while designing your circuit.

In addition to the components mentioned above, if you think that you have found a component useful for your design, you can contact with the corresponding assisting in order to verify that the component does not violate any design criteria. Please do not come up with ICs directly bypassing all the steps of the project. The usage of such components will not be allowed, since it prevents you from gaining the design insight and experience as it is organized to be. Thus, please only get into touch, **<u>if you are sure</u>** that the component will not create such a problem.

## 3. REPORT FORMAT

**<u>Proposal Report:</u>** The aim of the proposal report is for you to start your research early on so that you can have a solid idea about the project. This report will contain preliminary work on your project. A good report should include your proposed way to solve the problem, the equipment required for the solution, some block diagrams of the overall system and any additional info (circuit schematics, mathematical calculations etc.) you see fit. Maximum page limit for the preliminary report is 3 pages (Times New Roman, 10-point font). Longer reports will be rejected. It is crucial that you determine your project partner, and do some brain storming to come out with solutions well before the preliminary report deadline. You have to upload your proposal report in pdf format to ODTUCLASS until **20th of December, 23:59**. Late submissions will not be accepted.

**<u>Final Report:</u>** The final report should be in the IEEE double column paper format (please check the IEEE paper format) and it should not exceed 10 pages in total, any more pages will decrease your grade. The formatting is one of the most important parts of the project. If the final report is not in the IEEE paper format, the project will not be graded, and you will get zero from the whole project. Any formatting mistake (such as no figure captions, not referral to the figure in your main text, etc.) will result in grade deduction. You have to upload your proposal report in pdf format to ODTUCLASS until **15th of January, 17:00**. Late submissions will not be accepted. Your report should include the following items:

- Theoretical background and literature research
- Design methodology and mathematical analysis of the subsystems
- Simulation results verifying that your subsystems and overall system is working properly.
- Experimental results
- Comparison of the experimental results with the simulation results and mathematical calculations and explanation of any discrepancies.

**<u>Project Video:</u>** Each group must submit a video about their project. This video must be in English. The evaluation of the video will be based on the oral skills not the technical situation of the project. You do not have to show a working project. The explanation of the overall project, the solution method, and the final situation of the project are the main criteria. The total time of the video should be around 5 minutes and each group member must talk in this duration.

**Grading**

- ✓ Proposal Report: 10 pts
- ✓ Project Demonstrations: 50 pts
- ✓ Final Report: 40 pts

## 4. IMPORTANT DEADLINES AND ADDITIONAL INFORMATION

- **20th December:** Proposal Report
- **13-14th January:** Project Demonstrations
- **15th January 17:00:** Final Report and Video Submissions

- ➢ This is NOT a weekend project. So, please start working on the project as soon as possible.
- ➢ It is highly unlikely that the projects implemented with a stressful rush on a day before the demonstrations will work properly on the demo-day. For that reason, try to extend your work into a period of time.
- ➢ The project groups will contain at **most 2 students**. Although it is not recommended, you may do your project alone. So, determine your project partner as soon as possible. It is not necessary that your lab partner and project partner is the same person.
- ➢ All assistants are responsible for the project. Primary contact mechanism with the assistants is via **e-mail**.
- ➢ If you have any questions, feel free to contact with the assistants.

## 5. REFERENCES

For information on power amplifiers;

https://www.electronics-tutorials.ws/amplifier/amplifier-classes.html

For information on microphone driving;

https://www.ece.ucsb.edu/Faculty/rodwell/Classes/ece2c/labs/Lab1b-2C2007.pdf

For information on filter design;

https://www.electronics-tutorials.ws/filter/filter_7.html

For information on fundamental logic gates;

https://en.wikibooks.org/wiki/Fundamental_Digital_Electronics/Fundamental_Logic_Gates