­­­­Production Model Design Report

F2019 – ECE 298

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| --- | --- | --- | --- |
| Lab Section: | 6 | Group: | 2 |

# Team Members

|  |  |  |
| --- | --- | --- |
| # | Name | Role |
| 1 | Muhammad Shah | Hardware Designer |
| 2 | Waleed Ahmed | *Software Developer* |

# Design Overview

## Problem Statement

Bicyclists often have difficulty navigating roads, as roads are dominated by automotive vehicles and is a dangerous environment for a slow-moving vehicle like a bicycle. Bicyclists don’t take up much space on the road and can be hard to spot in low visibility conditions such as fog or low light. Due to the lack of light intensity on a bicycle, bicyclists themselves also may have a hard time spotting obstacles in certain conditions. Design a system that involves two ultrasonic sensors, one for the forward, and one for the rear direction, that can alert the bicyclist and others on the road to oncoming danger.

## Design Scope

This project solves the problem by attaching a small device to the bicycle that has 2 ultrasonic sensors for detecting the proximity of objects in front of and behind the cyclist. The indicator for the rear direction is level sensitive coloured LEDs that turn on as each proximity threshold is passed. The indicator for the forward direction is a buzzer that beeps at different frequencies to indicate the proximity of objects.

It was assumed that the sensors could be mounted onto the front and back of the bicycle at locations where they would be able to safely detect nearby objects without obstructing the bicycle itself and that the sensors would only need to sense objects in the forward and backwards direction. It was also assumed that the cyclist could look at the ultrasonic sensor readings on a small LCD screen at a safe location that wouldn’t cause any distractions for the cyclist.

## Project Design Requirements

1. The device must display the output of the one of the ultrasonic sensor readings on a small LCD screen, converting the sensor digital readings to a distance value in cm, and be able to easily switch between the two directions
2. The device must turn on a certain coloured LED depending on where the distance from the rear ultrasonic sensor lies between 3 configurable thresholds
3. The project must create two unique buzzer frequency patterns depending on where the distance from the forward ultrasonic lies between 2 configurable thresholds
4. The project must allow the user to change the rear and forward proximity thresholds, done through interrupt-enabled push buttons

## System-Level Design (High-Level)

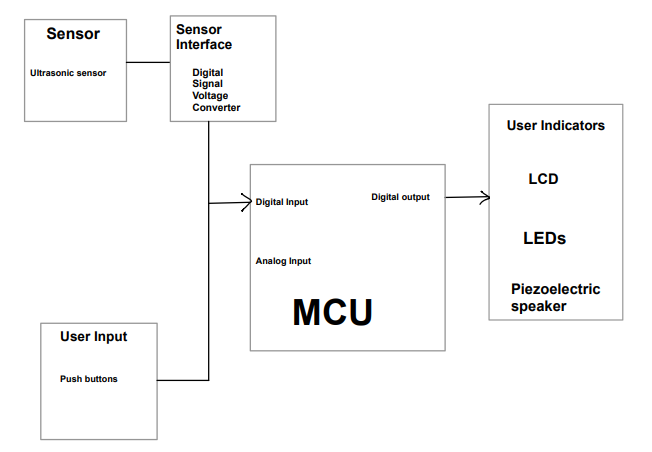


Figure 1: System-Level Design shown with a high -level block diagram

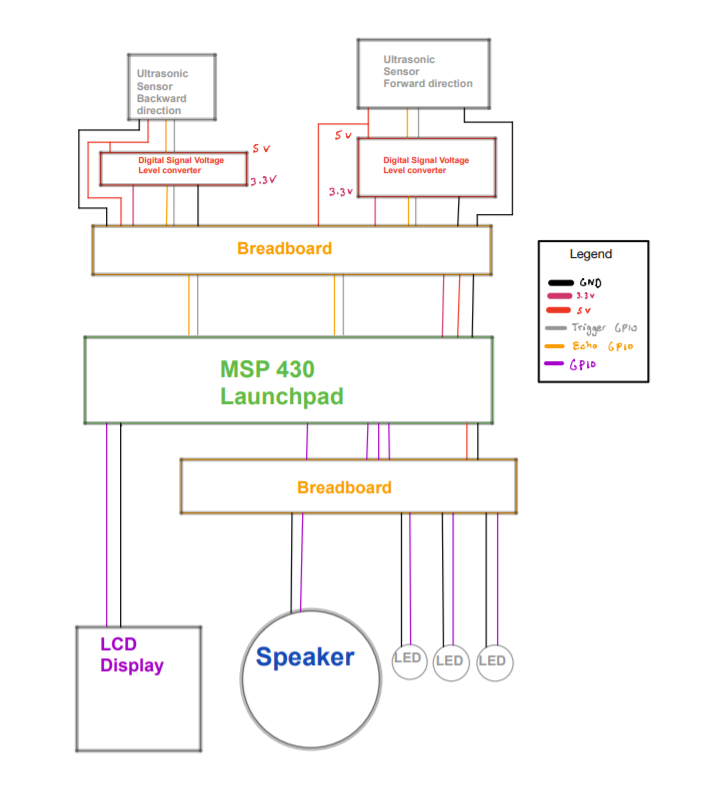


Figure 2: Feasibility Model Diagram

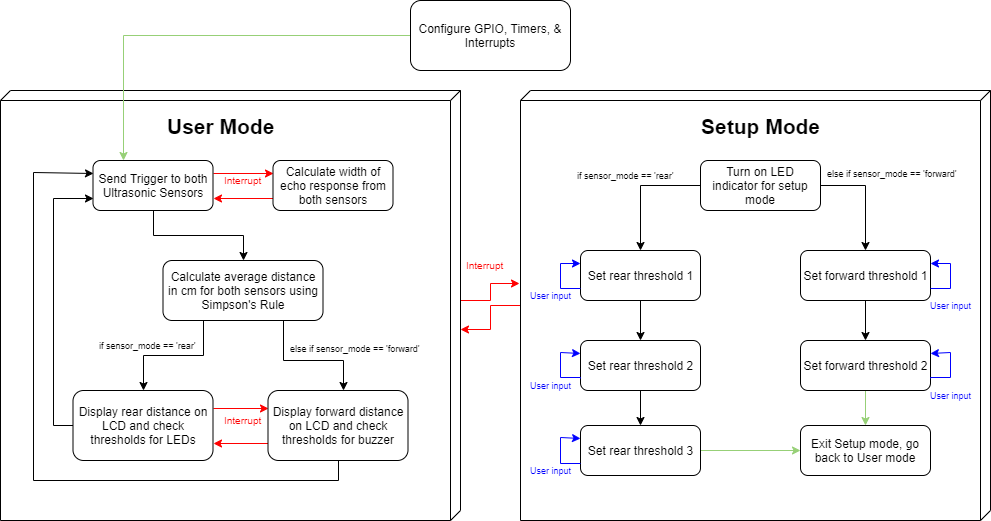


Figure 3: High-Level Software Flowchart

## Completed Prototype

|  |  |  |
| --- | --- | --- |
| Figure 4: Completed prototype with PCB on top of MCU |  | Figure 5: Rear proximity sensor reading (cm) below the lowest threshold value, indicated by a red LED |
| Figure 6: Rear proximity sensor reading (cm) past the highest threshold value, indicated by a green LED |  | Figure 7: Buzzer used for indication that object is near in the forward direction |

## Preliminary Production Design Changes

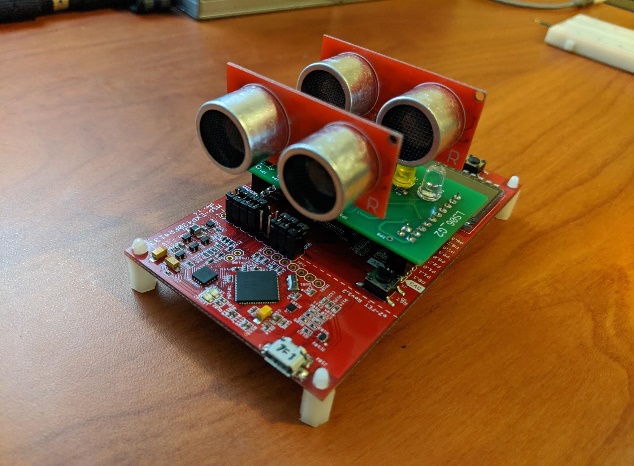
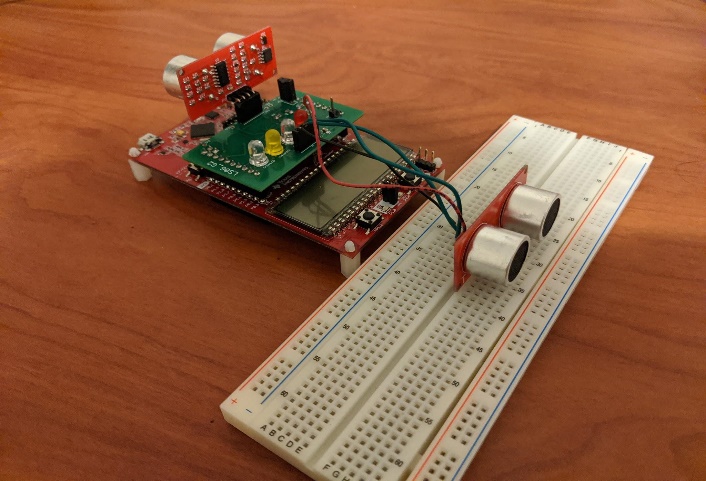
One major issue that needs to be tended to in a future revision of the product is correct pin arrangement for the ultrasonic sensors on the PCB. Currently, the forward ultrasonic sensor is wired to be facing the same direction as the rear sensor, as seen in Figure 8. This can be fixed by correcting the pin arrangement on the PCB design and fabricating a new board.

Figure 9: Requires jumper wires to a breadboard to fix sensor arrangement

Figure 8: Ultrasonic sensors facing the same direction

Another possible improvement is to use more powerful ultrasonic sensors, as the ones currently used are not as accurate at farther distances. For the production model, the ultrasonic sensors should be attached through long jumper wires to the PCB, so the sensors can be mounted at the front and back of the bicycle. Finally, it would be ideal to manufacture the board so that it is smaller, so it can be easier to install and less prone to falling off.

# Member 1 Production Details

[Muhammad Shah] – ID# [20725801]

## Design for Reliability

To design the current bicycle sensor project, we would need to make sure that we design the system for reliability. Reliability engineering design describes the system to have the ability to function under a certain condition for a specific period of time for a successful period of time. [2]The reliability of a system and the quality of a system are closely tied. As checking for the quality of a system focuses on minimizing and preventing defects of a product during the warranty phase while on the other hand testing for the reliability of a design is looking to prevent failures during the useful lifetime of the product. The reliability of a system ties closely together with system safety.

Designing for reliability ties very closely into the functionality of our project. As an unreliable bicycle collision detection system is useless, it would be completely unreliable for the user and would cause great harm if it were not reliable as it could result in potential harm to the user if the system cannot detect a nearby object that could cause danger to the user. For example if the user of the project was in a situation where they were in low visibility conditions and they were riding their bicycle fast they would need the help of the sensors to detect objects that are far in front of them so they do not end up going too fast and hitting the object. If the ultrasonic sensors were unreliable in their detection of nearby objects because of an incorrectly designed detection algorithm, software bug, or hardware failure, the buzzer indicator for the forward direction could end up not making a sound for an incoming object and the user might end up hitting an object they did not see. To make sure a scenario like this does not happen to a user of our product we would need to further design our initial prototype to make sure it can perform in a variety of conditions and make sure that it consistently gives correct data.

There are several issues that should remain top-of-mind for the production engineer who will take the prototype design through to a production-ready product. Firstly, the production engineer should take notice of the current ultrasonic sensor we are using. These are the HC-SR04 Ultrasonic Range Finder [1] This is a relatively cheap ultrasonic sensor that has a detection range of 3-400cm but based on testing we found that the max distance to fluctuate at a lower distance of around 50cm to 100cm. This not ideal and it is a suggestion that the production engineer should investigate a more reliable ultrasonic sensor module or perhaps there needs to be further development with the software so that the trigger and echo responses are more accurate. Another issue that the production engineer should regard is that of the PCB layout. Looking at Figure 11 of the PCB layout design the 1x4 J6 connection has a mistake that could be quite an issue for a user. The issue is question is that the pin arrangement is incorrect for the cables, the production engineer team would have to rearrange the pin arrangement for the J4 connector so that they are correct. This can cause an issue in reliability because if the final production model design were to use a 1x4 jumper cable that goes from the J4 connector to the ultrasonic sensor they might end up with incorrect signals going into their ultrasonic sensor and damaging the components. Another issue in reliability that production engineer could tackle is that regarding the method of changing how the ultrasonic sensors are triggered. Looking at Figure 10 one can notice that both the forward and backwards facing ultrasonic sensors are triggered using the same trigger pin and there is no redundancy built in. This could become unreliable in a real-world scenario where the board might receive damage and not trigger correctly anymore. In this case the production team would need to design built in redundancies for triggering if the triggering component fails, and they also might need to investigate creating a design that has 2 sets of triggering mechanisms, 1 for each ultrasonic sensor.

## Ethical Consideration

Engineering ethics is the field of study that focuses on the actions and decisions of a team and group of engineers and the ethics of their actions. [3] Based upon the code of ethics by the PEO. [4] It states “it is the duty of a practitioner to the public, to the practitioner's employer, to the practitioner's clients, to other licensed engineers of the practitioner's profession, and to the practitioner to act at all times with, … 4. devotion to high ideals of personal honour and professional integrity;” as well as several other components. The IEEE also has a code of ethics that its members should follow. [5] The code of ethics is like that of the PEO code of ethics, but some subtle difference and a few more codes involved. These codes of ethics should be key in the decision making for an engineer and their team when working on a project, and the engineer should make sure that they are committing themselves to the highest ethical and professional conduct.

In this project the ethical decisions that we will investigate are regarding the manufacturing of our PCB board, making sure that the project will uphold to being safe to be used by the public by making sure it does not cause injury to those using the product. As stated by the IEEE and PEO code of ethics, engineers should commit themselves to the highest ethical and professional conduct on their work. In the case of our project we must make sure we are not manufacturing our product in a location that violates the code of ethics defined above. We must also perform rigorous testing on our product and make sure it has a reliable design. By testing for reliability, we are ensuring we create an ethical product that works properly, and it does not malfunction and end up injuring the users of our product.

A major ethical issue that we have in regards is in regard to the production of our PCB, we had currently produced our initial PCB prototypes in China, and manufacturing and doing any business in China is known to be a major ethical issue due to their oppressive government, labour rights, stealing of IP and various other issues. [6] [7] I suggest that the team work to try and manufacture the PCB boards either in-house or with a company based in a different location. Another suggestion I make is for the team to provide rigorous testing with the production level design for the project. It is critical that we do as much testing and design changes as we can for this product to make sure it works due to its nature as a safety system. It is in our ethical duty as engineers to make sure that this product does not end up malfunctioning because it could end up disastrous for the user of our product.

# Member 2 Production Details

[Waleed Ahmed] – ID# [20659541]

## Design for Test

Design for testing is a design methodology that consists of integrated circuit (IC) design techniques that add testability features to a hardware product design. [8] The motivation for this methodology is to enable easier testing, manage complexity, minimize development time, and reduce manufacturing costs. [10] While this methodology does add more development time and increased cost, it is crucial for very large-scale integration (VLSI) chips that involve millions of transistors. A defective design at this scale is very costly and can potentially sink a company. A past example of this is Indel’s Pentium FDIV recall [9], which cost Intel nearly $500 million in losses. Design for testing techniques can vary from as little overhead as test points to something with larger overhead such as scan chains for registers and flip flops. This concept is not exclusive to hardware design, software development also has design techniques to facilitate efficient testing and verification of software systems through unit tests and continuous integration pipelines.

Design for testing relates to our project as the bicycle sensor involves hardware development of a custom PCB as well as embedded software development on the TI MSP430 platform. The prototype PCB for the bicycle sensor features test points for all the important aspects of the design, which includes the echo and trigger lines for both ultrasonic sensors, the buzzer, LEDs, and a ground test point for reference. These test points are conveniently all located on the edges of the PCB, far from the components of the PCB to minimize testing errors. These test points played an important role in debugging the PCB when the components were being soldered on, as they exposed which components where not soldered properly or where a connection was missing. For the software development, each individual component of the logic was abstracted out into functions, to allow for readable and modular software design. This approach to software development reduces the lines of code and makes it easier to test individual logic through unit tests. One example of this is the buzzer. In our codebase, the buzzer code is in a separate file, and the primary buzzer function call takes the frequency and duration of the sound required. This allowed us to call that function multiple times to test the buzzer at different frequencies and durations.

There are several issues that should remain top-of-mind for the production engineer who will take the prototype design through to a production-ready product. From a hardware perspective, it would be a good idea to remove all the test points on the final production board. This would help decrease the size and complexity of the board, which is ideal for a production model. Also, for a large-scale production model, it would be a good idea to integrate some hardware testing methodologies described in the IEEE Std 1149.1 (JTAG) Testability Primer [10]. From a software perspective, if more features and developers are to be added in the future, it would be a good idea to write software unit tests using a unit testing framework that will verify all components of the software are working. This can be setup to run on every commit to a git repository through a continous integration pipeline, which will allert developers immediately if they have commited something that broke a test case. If the test cases are written well enough and cover all the important logic of the code, it guarantees the software shipped with the board will be bug-free.

## Safety Considerations

Any engineering product, especially one that is being used to a tackle a problem in which injury can occur, needs to take safety considerations into account. This is to ensure the safety of the public and that products that are sold to consumers are developed with safety in mind. To help facilitate this, there are many organizations and institutions that exist to define safety standards that engineers can look to. An example of this would be the International Organization for Standardization (ISO), which is an international standard-setting body composed of representatives from various national standards organizations. [11] National standards organizations such as the Standards Council of Canada (SCC) [12] and the American National Standards Institute (ANSI) [13] are members of the ISO and collaborate with the other members of the ISO to define international standards. These standards are for a wide variety of commercial products that cover both functional and safety standards.

Safety considerations should be considered for development of the bicycle sensor. This is because the bicycle sensor is going to be used in a scenario where the user of the product could potentially get injured. Cyclists are at risk of getting injured from hitting or being hit by obstacles on the road, including both static and dynamic obstacles. Some aspects of the design that should be considered is how the device is mounted on the bicycle. It needs to be mounted in a location that does not obstruct the operation of the bicycle in any way. For example, if the device is installed in a location where the chains are close by, the chains could get caught or obstructed by the device, and this could potentially cause an injury to the cyclist. Another safety concern is weather conditions. If the device is not waterproof, it could short circuit in rainy weather without the user noticing, and the user would continue going on expecting the device to beep when an object gets too close, when in fact the device has died and is no longer available to alert the user in time to prevent an injury.

There are several issues that should remain top-of-mind for the production engineer who will take the prototype design through to a production-ready product. I would advise the production engineer to take a thorough look through all the ISO safety standards regarding electronic systems, and ensure the product complies with all the relevant ones. Then, if the product is only being deployed in one country first, ensure it complies with any relevant safety standards proposed by the primary standards organization for that country, as it is possible there are some standards for a specific country that are not included in the ISO standards. As mentioned in the previous paragraph, waterproofing is a top priority for this product, as the weather conditions where this product is the most useful is foggy and rainy weather where visibility is low. Careful consideration should also be placed on how the device is going to be mounted on the device, and it should be ensured the mounting location and method does not obstruct the operation of the bicycle in any way.

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# Appendix – Detailed Design

**Table 1:** What changes had to be made to get your Feasibility Model working as expected?

Table 1: Necessary Design Changes

|  |  |  |
| --- | --- | --- |
| # | Change | Reason/Notes |
| 1 | Connected 4 LEDs to GPIO pins | To convey information about the proximity thresholds for the forward-facing sensor |
| 2 | Added Interrupt for PB 1 on board (1.2) | To switch between user and setup mode |
| 3 | Implemented software logic for setup mode | To effectively allow user to adjust proximity thresholds for the ultrasonic sensors |

**Table 2:** Lessons Learned – Is there anything you want to remember so that you don’t make the same mistake again? Or, not waste time on something you already figured out?

Table 2: Important Notes

|  |  |
| --- | --- |
| # | Note |
| 1 | MSP430FR4133 datasheet lists that only 7/8 of the available GPIO pins are interrupt capable. I assumed all GPIO pins were interrupt capable and this was causing problems when trying to configure the second ultrasonic sensor as I was using the 1 GPIO pin that was not interrupt capable. |

Table 3: Hardware Signal Test Plan

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Signal (TP\*) | Property | Required Software Mode | Min | Nominal | Max |
| Audio\_Out (TP 1\*) | Voltage | User mode | 0 V | 3.0 V | 20 V |
|  | Current | User mode |  |  | 3 mA (at nominal voltage) |
|  | Frequency | User mode |  | 4000 +- 50 Hz |  |
| ECHO  (TP 3, 4\*) | Voltage | User & Setup mode |  | 5 V |  |
|  | Current | User & Setup mode |  | 15 mA |  |
|  | Frequency | User & Setup mode |  | 40 kHz |  |
| TRIGGER  (TP 6\*) | Voltage | User & Setup mode |  | 5 V |  |
|  | Current | User & Setup mode |  | 15 mA |  |
|  | Pulse Width | User & Setup mode |  | 10 µS |  |

\*Indicates Test Point Required

Table 4: Hardware Signal Connectivity

|  |  |  |  |
| --- | --- | --- | --- |
| Signal | MSP430FR4133 Pin | LaunchPad J1/J2 Pin | Prototype Connection |
| Audio\_Out | P1.7 | J2 pin 2 | Audio\_Out |
| ECHO | P2.5, P1.5 | J1 pin 8, J2 pin 10 | Echo\_InGPIOFwd, Echo\_InGPIOBwd |
| TRIGGER | P2.7 | J1 pin 5 | Trigger\_Out |

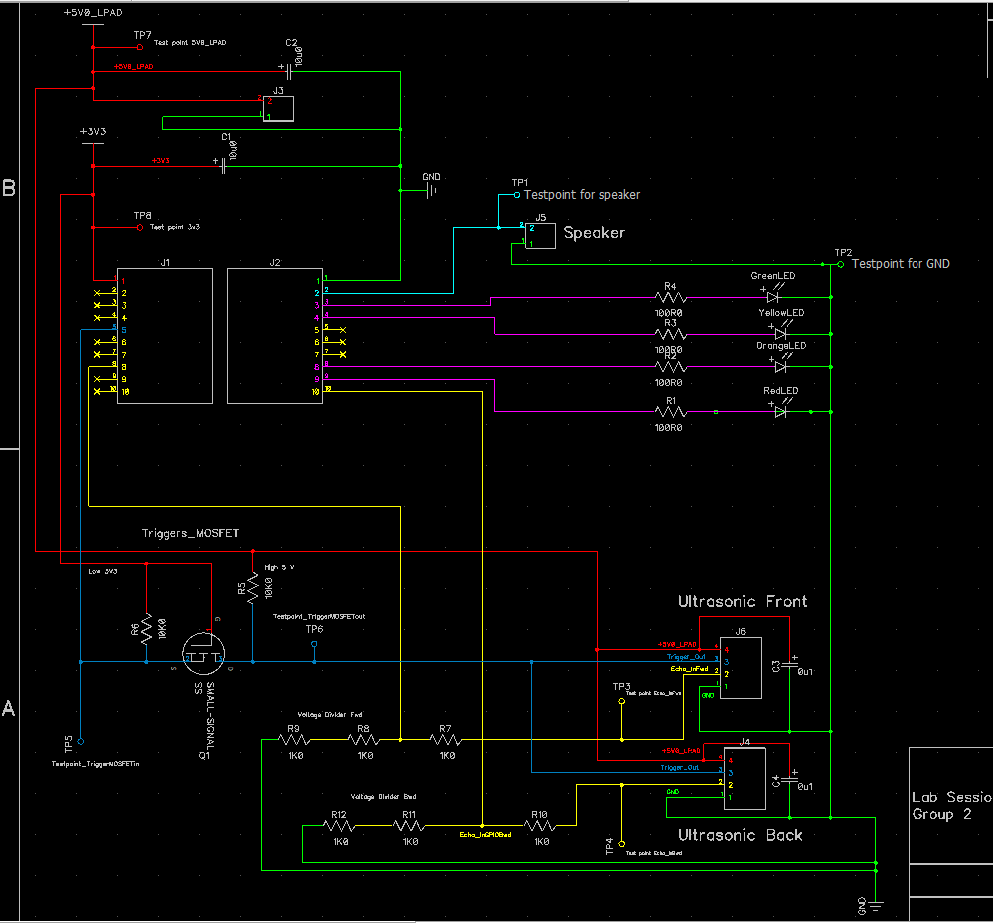


Figure 10: Schematic Diagram

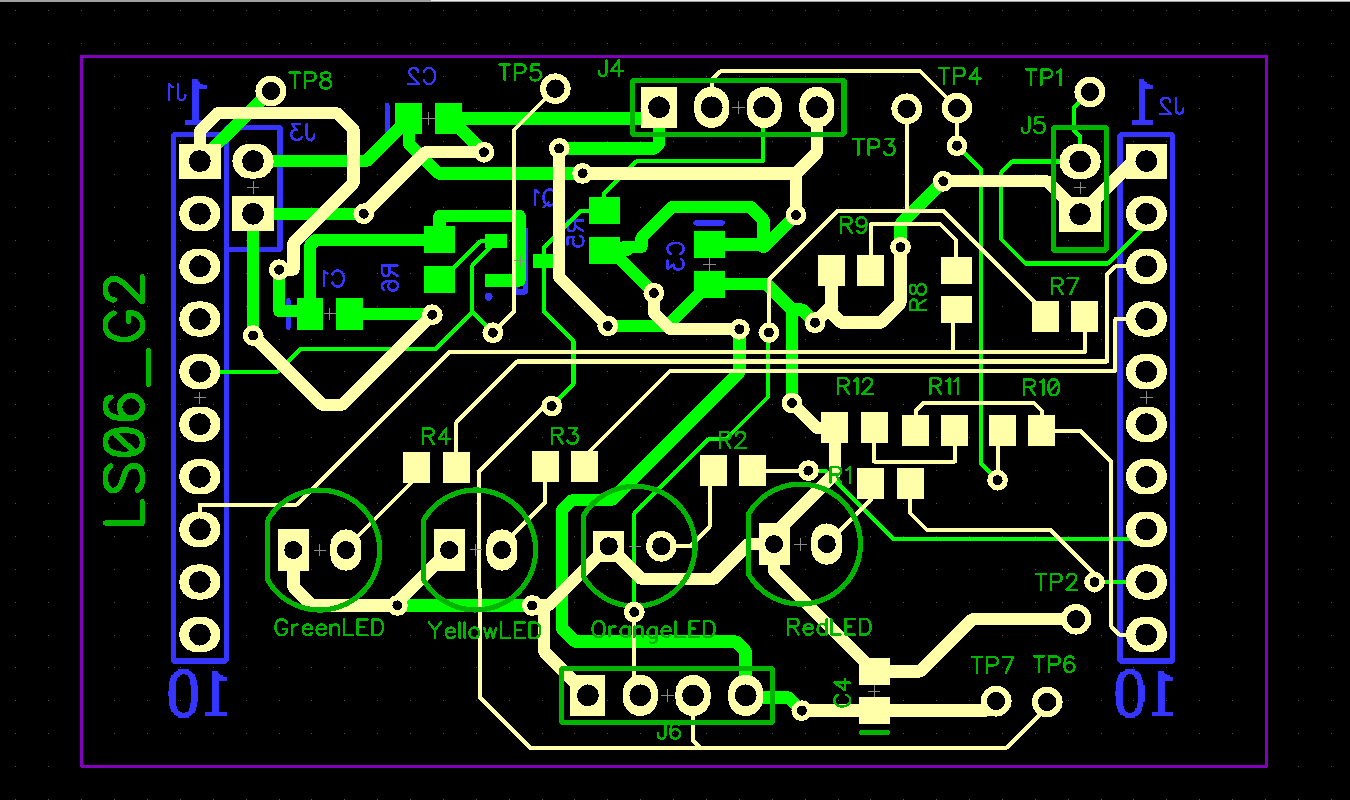


Figure 11: PCB Layout Design

Link to GitHub repository: <https://github.com/w29ahmed/ECE298-Sec6-Grp2-Proj1>