Computer Engineering Technology
DEPARTMENT OF ENGINEERING TECHNOLOGY
COLLEGE OF TECHNOLOGY
UNIVERSITY OF HOUSTON

VEHICLE BLACK BOX
ELET 4208

Team Members (alphabetical order):

Name: Kenia Benitez	**E-mail:** keniab459@gmail.com	**Phone No.** 8327823741
Name: Eduardo Mendoza	**E-mail:** emendoza4lalo@gmail.com	**Phone No.** 8329081250
Name: Henry Nguyen	**E-mail:** nguyenhenry682@gmail.com	**Phone No.** 6827162726
Name: Alex Vo	**E-mail:** vmvo4@cougarnet.uh.edu	**Phone No.** 7133717354

Team Number: 6

Project Advisor: Dr. Mequanint Moges

Project Sponsor: N/A

Date Submitted: May 10, 2023

TABLE OF CONTENTS

I. Executive Summary

With almost 36,000 fatal car crashes in the United States resulting in almost 39,000 deaths as of 2020, the team wanted to tackle this issue [1]. During the 1960's, airliners were government mandated to carry flight recorders, or a black box, on their airplanes. They proved to be a valuable tool as they recorded important information of a flight in the case of a crash or unusual occurrence to investigators. Black boxes are also used in conjunction with a cockpit voice recorder, or CVR, to record not just the chatter in the cockpit but also sounds that can determine engine rpm, system failures, speed and when events occur [2,3].

The goal of this project is to build an airplane black box but for a car or truck. Like the black box in an airplane, it will collect important information during the duration of a car ride that can then be used by investigators in the case of an accident. The team's version of a car black box will include many components and sensors to collect the important information. One of the main differences between the car and airplane black box will be the lack of a microphone for audio recording. The car black box will be able to detect if there has been a crash, fire, or the presence of alcohol. It will also be able to determine the speed the vehicle was going and notify authorities and/or authorized users all while saving the data for later reference.

The market the team is trying to enter with the black box is commercial. This includes, but is not limited to, trucking companies, car rental agencies, and industrial motor fleets. Because of understandable privacy concerns, the consumer market is not viable. The team believes that there will be less pushback by drivers due to the simple fact that they do not own the vehicle. It would fall under the ownership of their employer and/or the car rental agency. Moreover, the black box does not actively track the user. Like an airplane black box, it just captures important data to be reviewed later if there were an accident or unusual event. Overall, it would be no different than how an employee would treat any other company issued device like a computer or work phone. Another potential avenue could be apps like Life360 or Apple's Find My. Close friends and/or families are already using apps like that for their loved ones for safety reasons.

Project implementation will differ from what the team envisions for the real-world application for the sake of demonstration. All components will be soldered on a PCB and encased by a plastic enclosure to be designed and 3D printed. It will then be directly connected to the DC motors of an RC car for simulation purposes. For the real-world application, the black box would be a compact device that will be placed somewhere within the cabin of the vehicle and difficult to tamper with. It would also be much more durable in order to withstand the force of a car crash and heat resistant in the case of a fire.

The components and sensors to be utilized include: a vibration sensor, temperature sensor, alcohol sensor, gyroscope, a GPS/GSM module, SD card module, and an LCD. The purpose of the vibration sensor is to detect if there has been a sudden force. The temperature sensor will detect a sudden change in temperature, specifically if the temperature gets very high. The alcohol sensor will detect alcohol in the air. The gyroscope will determine if the vehicle rolled over. The GPS/GSM module will provide coordinates of the vehicle and be able to notify first responders and/or authorized users. The SD card module will capture important information, such as speed, that can be examined later. The LCD will display messages, such as “alcohol detected”, to the user for the sake of demonstration.

Upon reaching the deadline, the project was incomplete. While all components were soldered onto the PCB, there were some setbacks. Some components on the PCB did not work as intended. As a matter of fact, when the SD card module was connected, it would cause some other components to fail. However, when it was disconnected, almost all would operate as intended except for the LCD. The setbacks also prevented the team from encasing the board and proper implementation with an RC car.

II. Project Report

A. Introduction

The team’s objective with this project is to develop and test a black box similar to one found in an airplane but for a car or truck. The black box is planned to be enclosed, include multiple sensors to capture data to be reviewed later, and will be integrated with an RC car. Overall success of the project will be predicated on accurate sensor readings, capture of data onto a SD card, successful notification for authorized users and/or authorities.

The project is not officially sponsored. However, there has been some assistance from Eduardo’s place of employment which includes providing some components and PCB design. While each member of the group contributes to any area when necessary and possible, their roles are as follows:

- Kenia Benitez - programming
- Eduardo Mendoza - hardware
- Henry Nguyen - programming
- Alex Vo - hardware/programming

The end product will mostly be a proof of concept. Many design choices were made to simplify things in order to make it easy to demonstrate. Successful results in the project will be used to prove the functionality of a car black box that can be applied to a car or truck. It will also be a small device that can be discreetly installed in the cabin and be durable and fire-resistant.

B. Background

Like any other good project, it needs to solve a problem being faced in today’s world. For Americans aged 1-54, car accidents are the leading cause of non-natural deaths [4]. This was the issue the team wanted to address. Driving is something people do everyday. No one really thinks about how dangerous it actually is. The team wants to make it safer. Even if it is just a little bit. And with technology improving each day, the team can create something to help.

C. Global and Societal Impact

The biggest impact the team wants to have is to make roads safer. While the car black box may not directly make all drivers operate safely, it can be an effective deterrent. The idea of the final product is to sway drivers into operating safer because there is a monitoring device on board. And because of this, the area the team wants to make an impact is commercial vehicles, company motor fleets, car rental agencies, and insurance companies. While the black box may impact only a percentage of vehicles on the road, there were just over 12 million commercial cars sold for 2021 [5]. And that does not include the other aforementioned vehicle segments. With these market choices, the team believes it should not be a problem making a positive impact. These vehicles are company property and although the black box is a monitoring device, it is not actively tracking users. Just like an airplane black box, the data will only be extracted in accidents or unusual events. Furthermore, it shows that companies are ensuring their employees are operating vehicles safely. And there are already some trucks which have their speeds monitored by GPS.

D. Product Requirements

Requirements for the team's product include:

- The following sensors and components soldered onto a PCB:
    - Temperature sensor
        - Detect high temperatures
    - Vibration sensor
        - Detect collisions
    - Gyroscope
        - Detect rollovers
    - GPS/GSM module
        - Grab coordinates
        - Send SMS messages
    - Alcohol sensor
        - Detect presence of alcohol
    - SD card module
        - Record data for later examination
    - LCD
        - Display messages
- An enclosure designed to cover and protect the PCB and components whilst ensuring sensors and other components operate as intended
    - Durable enough to withstand some light collisions whilst keeping PCB and components from moving and remain operational
- Be integrated with an RC car for simulation

E. Design Alternatives

The Design Alternative that we have in mind for our solution would be by implementing (swapping) our vibration sensors for an inductive proximity sensor as this detects any metal target and can be used to identify an accident. The reason why we decided that this would be a design alternative and not our original solutions is because they have a very narrow field-of-view. This means that we would have to implement several sensors throughout the entire vehicle, driving up the overall power consumption. While we would be powering directly via an adapter and not batteries, hence meaning that power consumption should be a terrible problem it is important to note that the arduino mega that we are using, can only receive so much information and inputs all at once. However, we are aware that proximity sensors are very reliable and have a long functional life since they have very little mechanical parts and they will not be touched very much after installation. If in the event we are not able to get appropriate results utilizing the vibration sensor, we will connect the proximity sensor in its place and have it work together with the gyroscope. As a team we are familiar with working the proximity sensors, however, the deadline is coming up and costs incurred via these sensors are a route that we do not wish to exercise unless we have no other choice.

F. Design Specifications

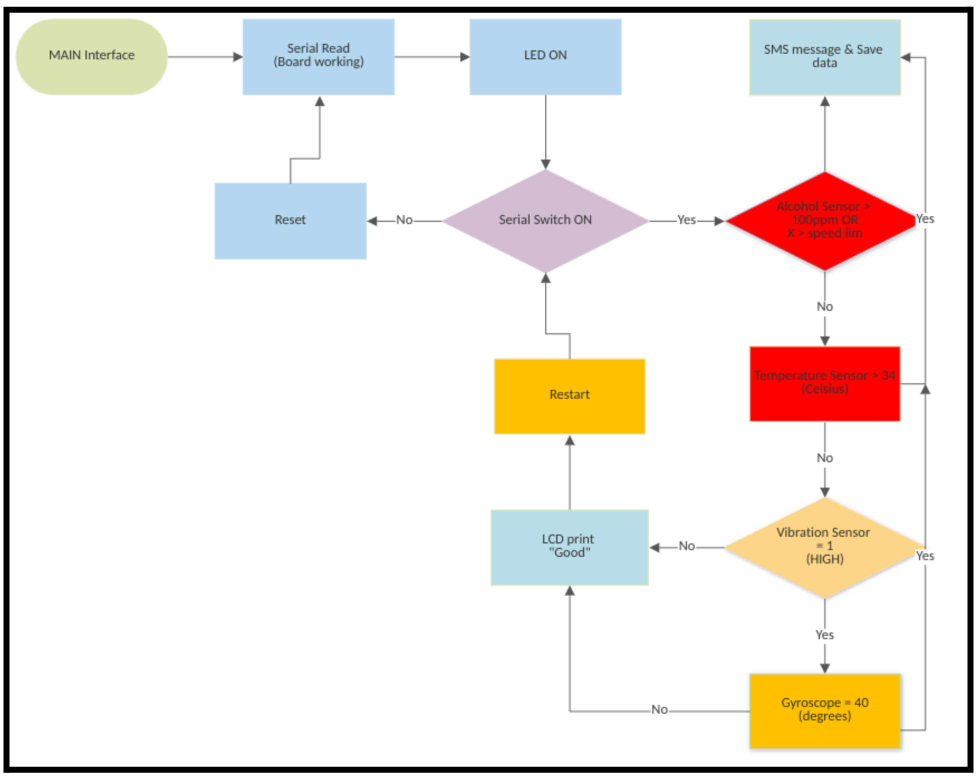


Figure 1. Programming Flow Chart

G. Design Description

- Microcontroller:
  We need high performance with a fast start-up time, a seriable programmable USART, SPI serial port, low power consumption, affordability, easy to use and

install, components that are readily available in the market. A 6-channel 10-bit ADC (analog input) 6 output PWM channels(analog output).

- Software compatibility with C or C++
- Alcohol Sensor must be sensitive to alcohol not just any liquid, hence it must be able to measure a minimum of 100ppm.
- Vibration sensor must be embedded, but catered to longevity. Here we do not necessarily want sensitivity as there are a number of variables that can cause the vibration sensor to be continuously triggered hence providing no purpose.
- A sensor that can both collect acceleration and changes in axis, this will be what allows us to identify the severity of a car accident along if there is an incident of a roll over. Here we will be utilizing physics to be able to get an estimate of the force that a car is impacted with. Force is equal to the change in momentum over the change in time (referred to as impulse) and the change in momentum is equal to the impulse. Knowing this we will be able to differentiate a severe accident from a minor fender bender. If for whatever reason cannot get this to work we can also utilize the change in kinetic energy to determine the severity of the situation.

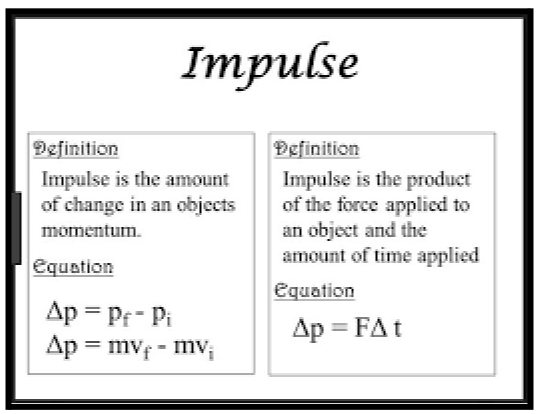


Figure 2. Impulse formula

$$W = \Delta KE$$

$$KE = \frac{1}{2}mv^2$$

$$W = F\Delta r\cos\theta$$

Figure 3. Work formula

- Temperature sensor is very important, as we want to notify the authorities in the event of a fire. Although the circumstance is rare, its severity would be the only event where we warrant reaching out to the authorities instead of family first. Although this will be something for us to test there are a lot of implications that come with the territory and or working with emergency services. If we were to continue with this, we would have this be the only condition that can contact the authorities as we obtain data and figure out what conditions would warrant immediate action.

- GPS location, live time location of where the vehicle is located when the sensors/conditions have been triggered.
- LED to signify whether or not the board is operating

Procedure Summary: (already soldered and built the board)

1. Each sensor will be continuously collecting data of which will be logged on to the sd card in the event of an accident.
2. Upon powering the board we will check the voltage along a couple of key capacitors throughout each component that we got from their data sheets in order to identify that each component is working as it should.

   Developing the code:
3. Only the alcohol and temperature sensors will independently notify family members if detected, the gyroscope and vibration will have to trigger in unison (and statement will connect them together) in order for there to be a SMS notification to the other users.
4. We will be connecting the GPS antenna onto a GPS-2 peripheral from where I [Eduardo] work and using Micro IDE I will be able to determine if the board works and the antenna works as it prints real-time coordinates of the device.
5. We will program the board using Arduino IDE from the web browser via a connection through a type B USB cable to the arduino mega.

H. Construction Details

To begin the construction of our PCB, we first designed the circuit with all of our components and tested them using a breadboard. Once we finalized the necessary voltages, resistances, and capacitances needed for each component, provided by the figures in the Appendices, we began the process of designing our PCB using Eagle, an Autodesk software. The next step in the process is to program the Arduino to take in the sensors' inputs and outputs. All of the components will be initialized and configured using C++ and then tested to match the scale of our project. Lastly, the design of our enclosure will be built using AutoCAD and Inventor Pro., which will be built using a 3D printer or through manual construction.

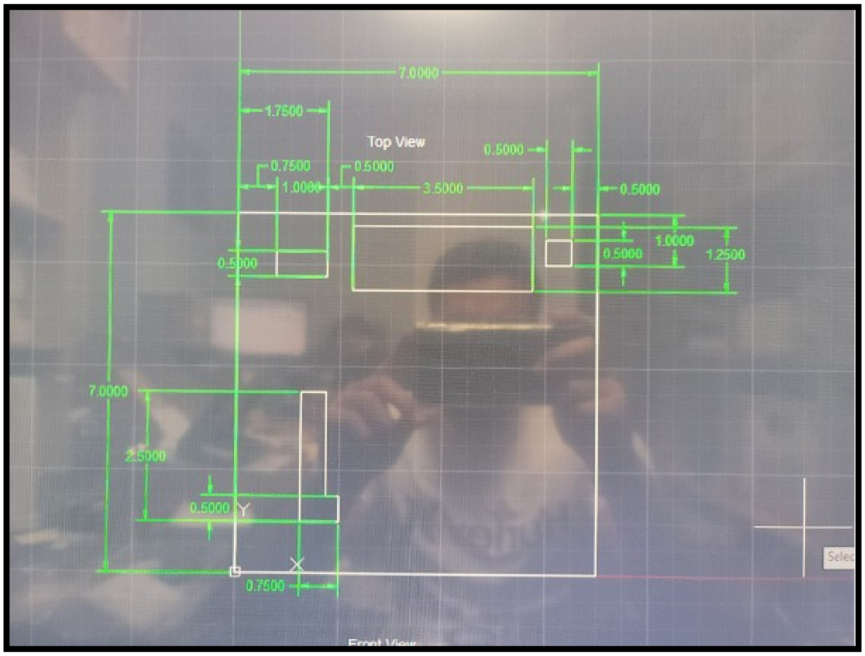


Figure 4. Prototype Enclosure

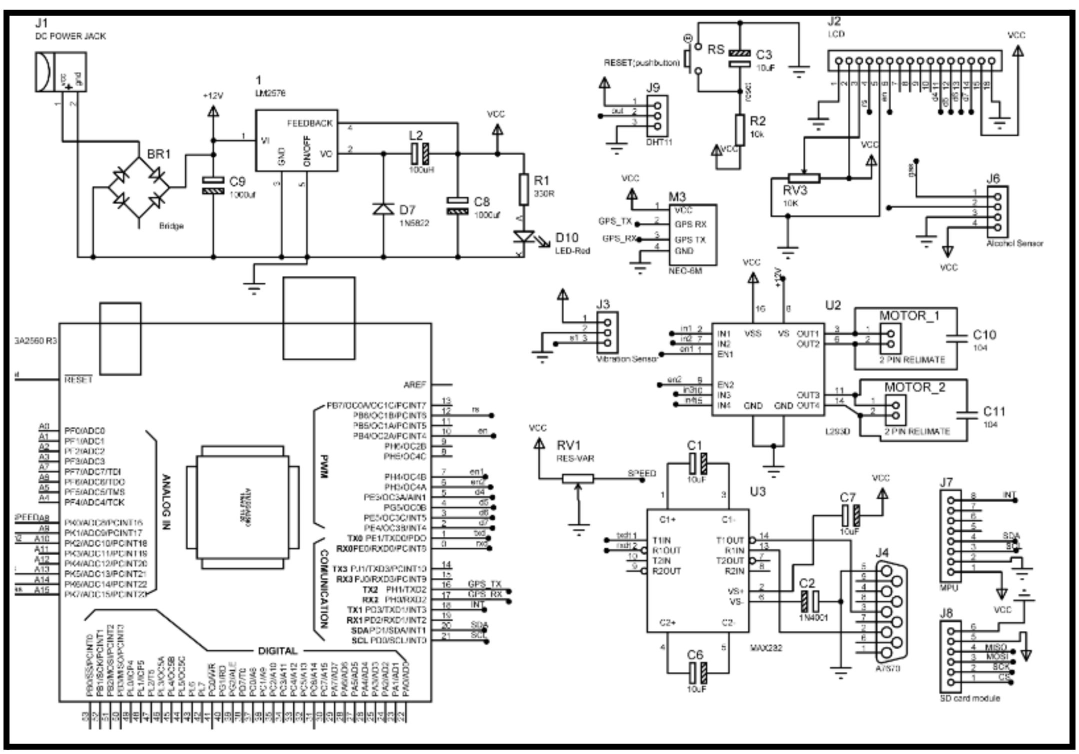


Figure 5. Circuit Schematic

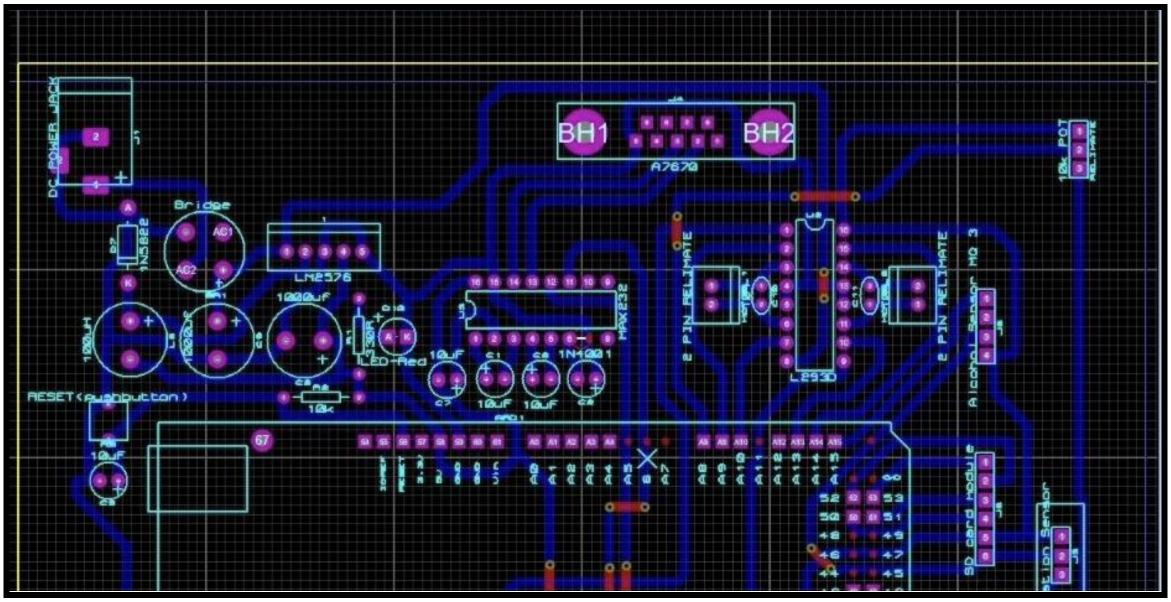


Figure 6. PCB

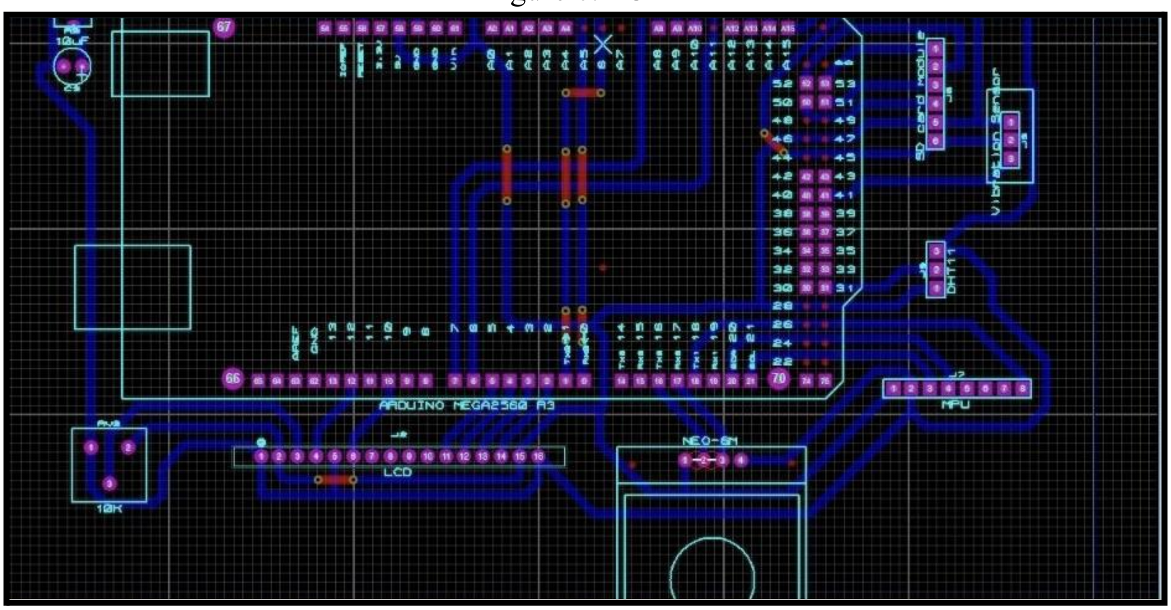


Figure 7. PCB

I. Costs

Item	Price
Arduino Mega	$49
PCB	$41
LCD	$16
Trim Potentiometer	$1

Temperature Sensor	$2
Vibration Sensor	$6
Alcohol Sensor	$6
Gyroscope Sensor	$10
GPS/GSM Module	$23
SD Card Module	$6
DC Motors	$9
Resistor Kit	$10
Capacitor Kit	$9
Transistor Kit	$9
Jumper Wires	$7
RC Car	$25
	Total: $229

Table 1. Cost Analysis

J. Conclusions

Ultimately, the project fell a little short of the team's expectation. While there were great strides such as the PCB and soldering of components, there was no enclosure or integration with the RC car. In addition, Eduardo soldered all the components onto the PCB, however not all of them worked as intended. The LCD powered on but did not display anything even when programmed to do so. The SD card module, considered the one of the key components due to its shared similar purpose of an airplane black box, did not work and would cause other components to fail when connected to the PCB. However, not all was lost as stuff like the alcohol sensor, gyroscope, vibration sensor, temperature and humidity sensor, and gsm/gps module worked. The team attributes the setbacks to human error with regards to soldering. All in all, the team still feels the project turned out okay, but wanted to do more.

III. User Instructions

Appendices

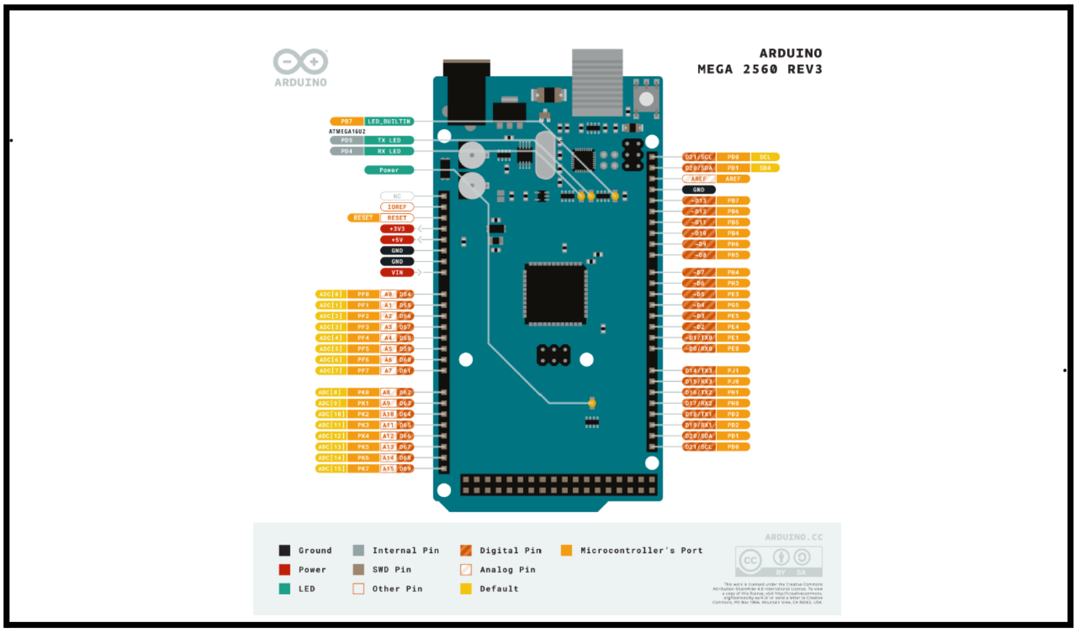


Figure 8. Arduino Pin-out

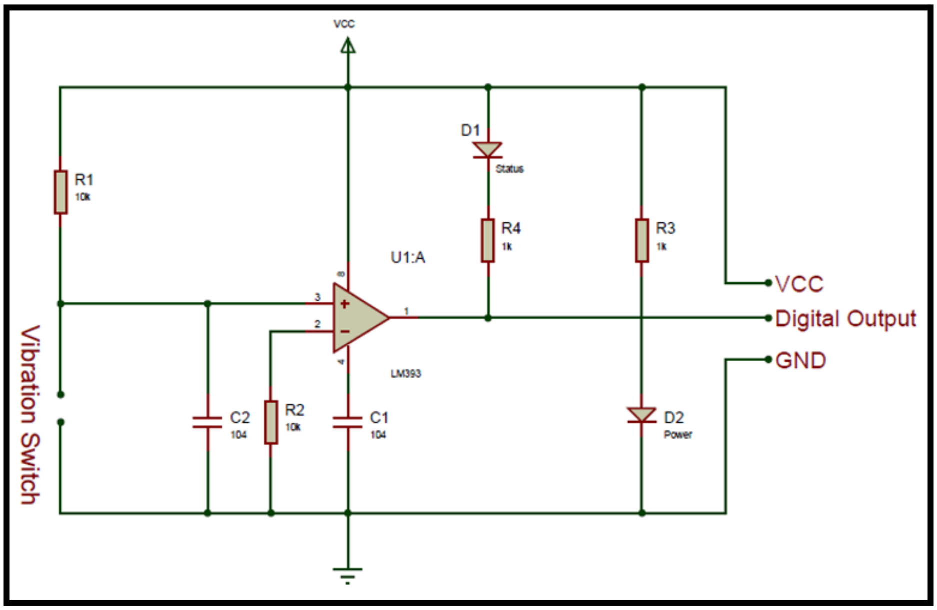


Figure 9. Vibration sensor Pin-out

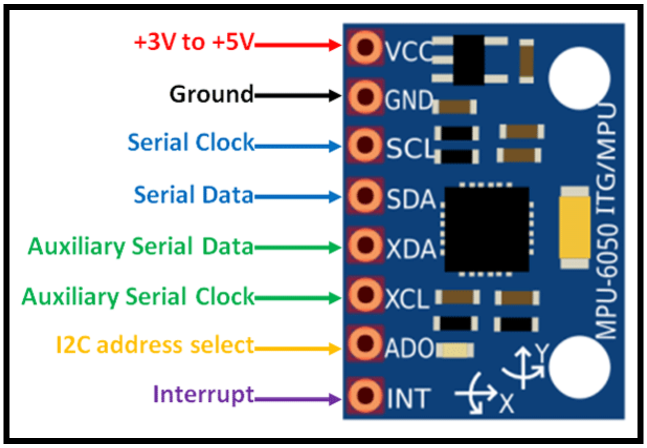


Figure 10. Gyroscope Pin-out

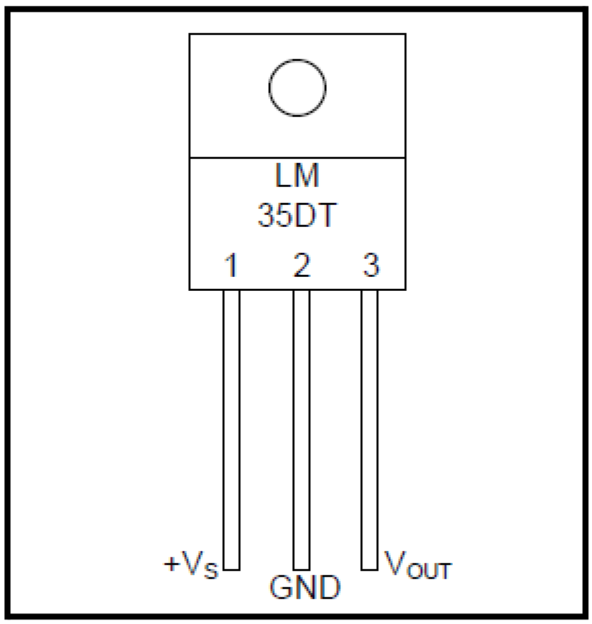


Figure 11. Temperature sensor Pin-out

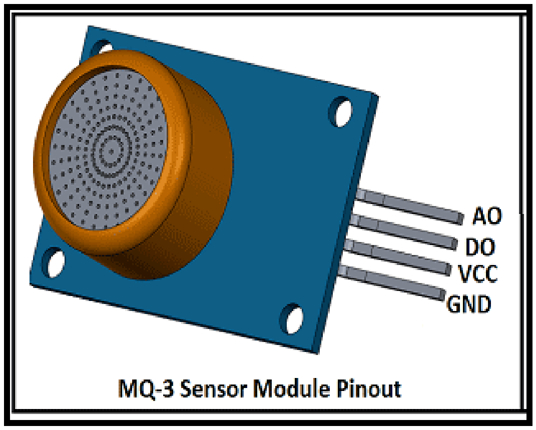


Figure 12. Alcohol sensor Pin-out

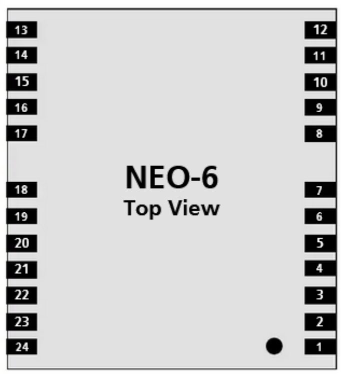


Figure 2 Pin Assignment

No	Module	Name	I/O	Description
1	All	Reserved	I	Reserved
2	All	SS_N	I	SPI Slave Select
3	All	TIMEPULSE	O	Timepulse (1PPS)
4	All	EXTINT0	I	External Interrupt Pin
5	All	USB_DM	I/O	USB Data
6	All	USB_DP	I/O	USB Data
7	All	VDDUSB	I	USB Supply
8	All	Reserved		See Hardware Integration Manual Pin 8 and 9 must be connected together.
9	All	VCC_RF	O	Output Voltage RF section Pin 8 and 9 must be connected together.
10	All	GND	I	Ground
11	All	RF_IN	I	GPS signal input
12	All	GND	I	Ground
13	All	GND	I	Ground
14	All	MOSI/CFG_COM0	O/I	SPI MOSI / Configuration Pin. Leave open if not used.
15	All	MISO/CFG_COM1	I	SPI MISO / Configuration Pin. Leave open if not used.
16	All	CFG_GPS0/SCK	I	Power Mode Configuration Pin / SPI Clock. Leave open if not used.
17	All	Reserved	I	Reserved
18	All	SDA2	I/O	DDC Data
19	All	SCL2	I/O	DDC Clock
20	All	TxD1	O	Serial Port 1
21	All	RxD1	I	Serial Port 1

Figure 13. GSM/GPS module Pin-out

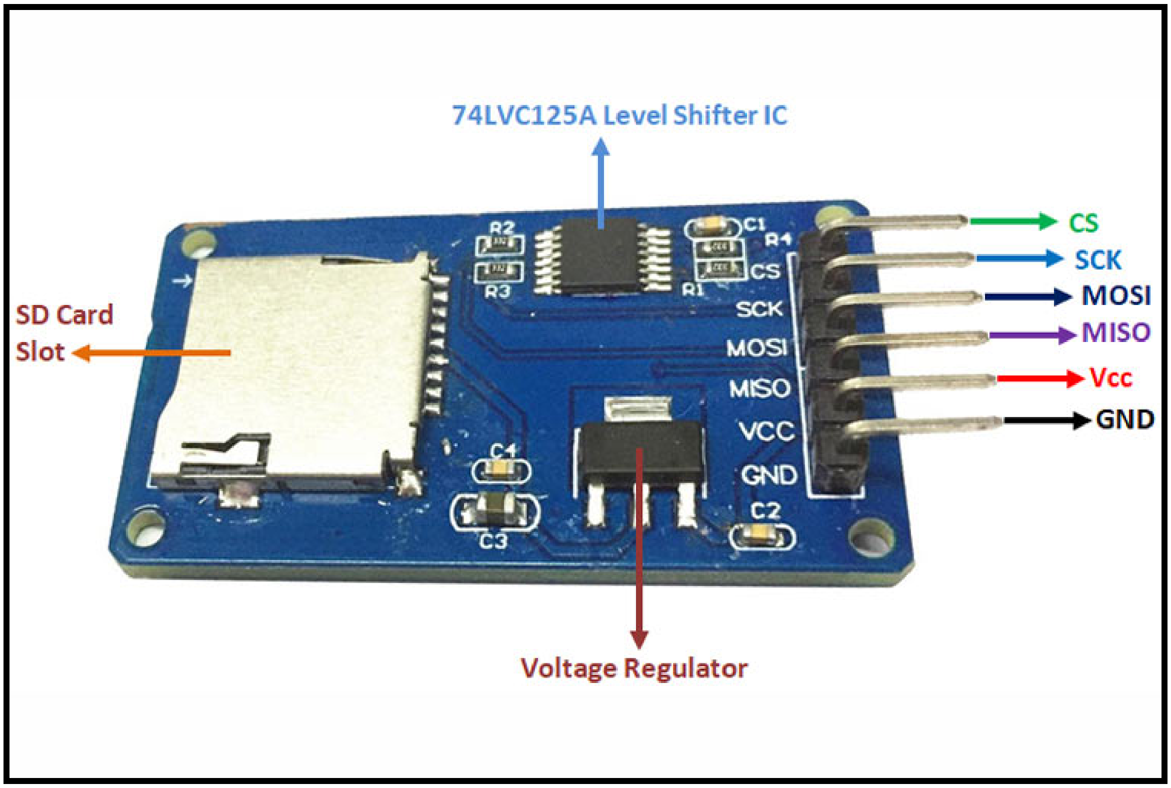
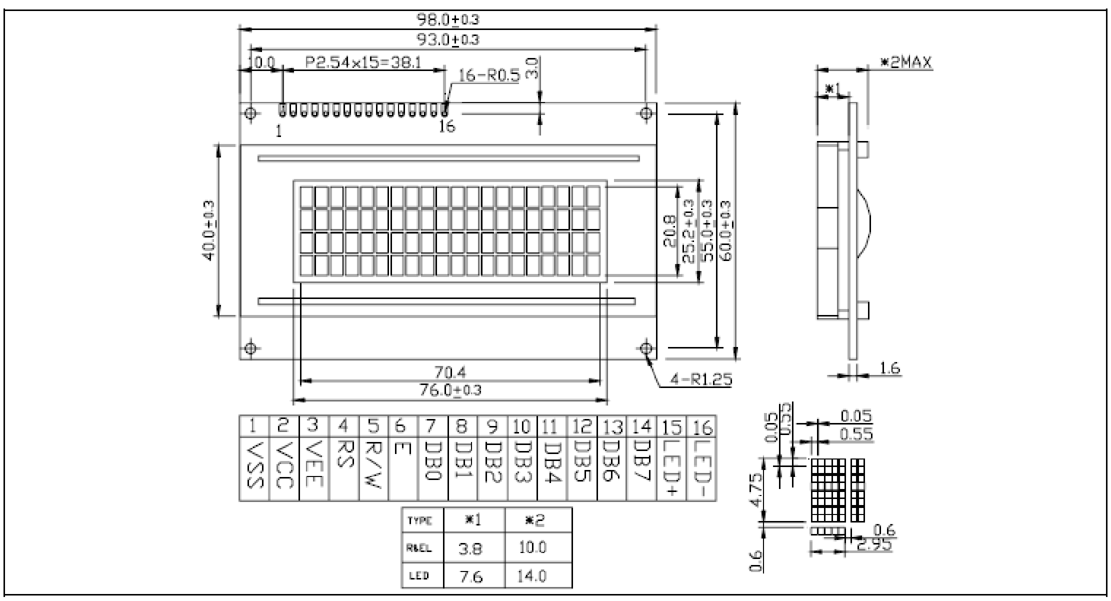


Figure 14. SD card module Pin-out



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
VSS	VCC	VEE	RS	R/W	E	DB0	DB1	DB2	DB3	DB4	DB5	DB6	DB7	LED+	LED-

AC Characteristics Read Mode Timing Diagram

Figure 15. LCD Pin-out

Project Schedule

Senior Project
Dec 14, 2022 - Apr 14, 2023

Grid Board Timeline Charts People

	Name	Lead	Start	Finish
1	Research materials	Alex Vo	12/14/2022	12/23/2022
2	Gather materials	Alex Vo	12/23/2022	1/6/2023
3	PCB assembly	Eduardo Mendoza	1/9/2023	1/20/2023
4	Develop source code	Henry Nguyen	1/23/2023	2/3/2023
5	Test sensors	Kenia Benitez	2/3/2023	2/17/2023
6	Test GSM/GPS module	Kenia Benitez	2/3/2023	2/17/2023
7	Verify SD Card data	Kenia Benitez	2/3/2023	2/17/2023
8	Refine sensor thresholds	Henry Nguyen	2/3/2023	2/17/2023
9	Develop device enclosure	Eduardo Mendoza	2/20/2023	3/3/2023
10	Prototype testing	Alex Vo	3/6/2023	3/17/2023
11	Integrate prototype into vehicle system	Eduardo Mendoza	3/20/2023	3/31/2023
12	Test integrated system	Kenia Benitez	3/31/2023	4/7/2023
13	Work on overall product design (cosmetics)	Henry Nguyen	4/7/2023	4/14/2023

Figure 16. Project Distribution Table

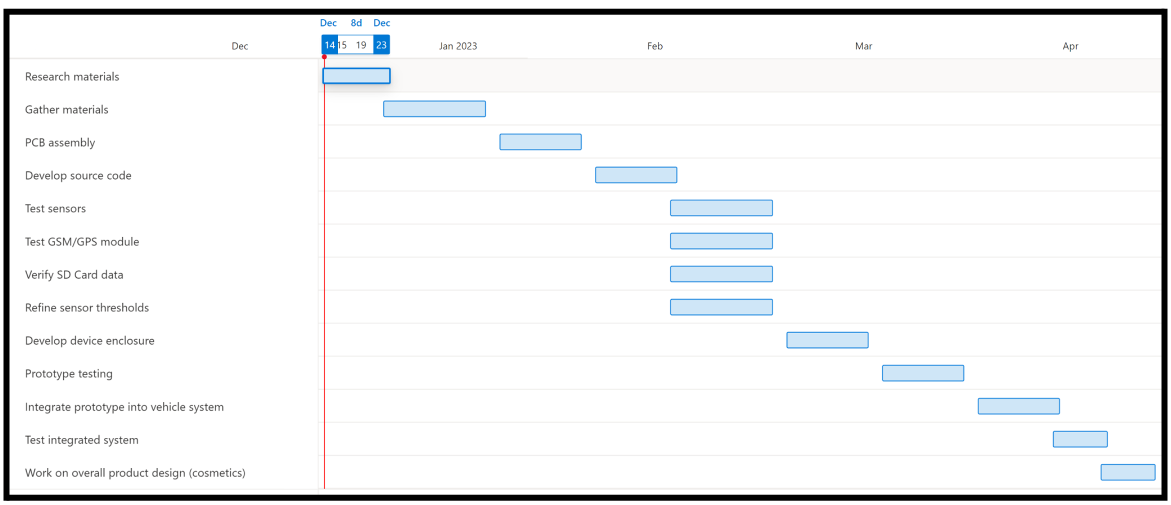


Figure 17. Project Visual Timeline

References

[1] "Fatality facts 2020: State by State," *IIHS*. [Online]. Available: https://www.iihs.org/topics/fatality-statistics/detail/state-by-state#alcohol-involvement. [Accessed: 07-Mar-2023].

[2] E. Gregersen, Ed., "Flight recorder," *Encyclopædia Britannica*. [Online]. Available: https://www.britannica.com/technology/flight-recorder. [Accessed: 07-Mar-2022].

[3] "Cockpit Voice Recorders (CVR) and Flight Data Recorders (FDR) ," *Cockpit Voice Recorders (CVR) and Flight Data Recorders (FDR)*. [Online]. Available: https://www.ntsb.gov/news/Pages/cvr_fdr.aspx. [Accessed: 07-Mar-2023].

[4] "Global Road Safety," *Centers for Disease Control and Prevention*, 10-Jan-2023. [Online]. Available: https://www.cdc.gov/injury/features/global-road-safety/index.html. [Accessed: 08-Mar-2023].

[5] "United States Motor Vehicle Sales: Commercial cars," *US Motor Vehicle Sales: Commercial Cars, 2005 – 2023 | CEIC Data*. [Online]. Available: https://www.ceicdata.com/en/indicator/united-states/motor-vehicle-sales-commercial-cars. [Accessed: 08-Mar-2023].