Senior Design 1: Go Baby Go! Project

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1. Executive Summary

One of the most fundamental events of a toddler's development is the ability of movement. Learning how to walk, fall down, and move from one destination to another is essential for their growth and give them an underlying sense of freedom. However, children with limited mobility are not able to experience that and can make them feel socially excluded. UCF's Go Baby Go! the project aims to provide these children with opportunities for mobility, participation, and play so that they can have a higher quality of life. It is our objective to help our client design and create a system that can further improve the lives of individuals with mobility impairments. The goal behind this project is to develop a prototype of an autonomous car that is affordable, durable, safe, and easy for children to use and explore the freedom of movement.

Our client requires that the Go baby Go! Cars will have built-in safety features to prevent the child from crashing and hurting themselves or others around them. There will be sensors placed on the car that will be able to detect if the driver is about to collide and the car will come to a stop on it's own. This ensures that the caregiver does not need to be moving along with the car at all times. Sometimes a caregiver might have many children to watch after, so these collision-detection sensors can help them keep everyone safe. To further improve safety, there must also be a way for the caregiver to track the system and be able to intervene at a moment's notice. Through our companion web application, the caregiver will be notified if the child is about to collide with an object and give them the option to turn off the car remotely through a Bluetooth connection. This application will be easy and intuitive for anyone to uses

The Go Baby Go! cars are used by children with a wide-range of mobility impairments, so to improve the functionality of the system our customer has requested that we implement an alternative steering mechanism. The car will be outfitted with a joystick, so that more children will be able to drive the car. It is expected that the device will be used throughout various environments and some of these environments could be narrow or cluttered with others. To improve maneuverability, a zero-radius turn feature will be implemented so that the vehicle's turning circle radius is greatly reduced and will increase the precision of turns. Furthermore, since the drivers will be young children, their spatial awareness is still developing so they might not be accustomed to the turning radius of a normal vehicle. With a zero radius turn, they will be able to turn the car in any direction much faster than with a normal steering car. This feature would also help improve the battery life and efficiency of the motorized car, because less time is now needed to make a turn.

Since the Go Baby Go! is a national, community-based research program, it is important for them to continually investigate different ways to help children with limited mobility. Because of this, another key feature to our project is to incorporate data tracking. A location-tracking feature will be placed on the car and will transmit data through a connection that our client can observe and analyze.

This project will be a collaborative effort between mechanical and computer engineers. There are four different children that will be a part of this project. There is one mechanical engineering team per child, meaning that they will specifically modify the mechanical structure of the car to the child's specific needs. These modifications can include a higher seat, more support, and a smaller car. The mechanical engineering teams will also modify the axles of the wheels in order to ensure that the cars will be capable of zero-radius turns. The computer engineering team will be responsible for implementing the electrical and application system for the car. The team will design, develop, and implement a universal electrical system for these cars that can be further integrated into future Go Baby Go cars.

This goal of this collaboration with Go Baby Go! is to build a prototype device that will have the ability to modify readily available cars for use in the community and for research. Our team will focus on customizing and implementing affordable technology for our intended use, creating a user-friendly interface platform, and advancing common sense solutions for kids with limited mobility. We hope that this project will help restore physical independence for children with disabilities.

2. Project Description

This section serves to provide the motivation for developing the Go Baby Go car as well as portray the goals and objectives of this project.

2.1 Motivation

Recent trends of increasing childhood sedentary behavior and obesity are recognized as significant public health issues. These behaviors are more common among children with disabilities. Thus, childhood interventions are needed to address the low levels of physical activity and rise of obesity. One of most common causes of motor impairment in childhood is cerebral palsy. This disease has an overall prevalence of approximately 2 per 1000 children or live births across the globe. Along with motor impairment, cerebral palsy can be related to other disorders. For sintace, the prevalence rate of cognitive, vistual, and hearing comorbidities of children with palsy were vastly large. Due to these issues, Go Baby Go founder Professor Cole Galloway decided to develop the Go Baby Go program. In this program, modified toy cars can give children with mobility disabilities a chance to play and socialize with their peers more easily. Past research has shown that independent mobility is linked to cognitive, socia,, motor, language and other developmental benefits in young children.

Currently there are no commercially available devices for children with mobility issues to get around on their own, and the power wheelchairs cost around thousands of collars and are not an option for children. While UCF’s Go Baby Go program had a multitude of power wheel cars for children to use, these cars lacked a lot of essential features. Our goal is to design a Go Baby Go car with software features that can be implemented in future cars and help more children have active control over their own exploration.

2.2 List of Requirements

The list of requirements for the electrical system of the Go Baby Go! Car was decided upon using feedback from the clients, the parents of the children, the project advisor, and four mechanical engineering teams working on this project with the computer engineering team. The following requirements were given to us from the client. The client had informed us which requirements were more important than others.

The following is a bulleted list of the requirements given to us by the client

- The Go Baby Go car will have an alternative steering mechanism
- The Go baby Go car will have augmentative communication
- The Go Baby Go car will have remote control for the parents
- The Go Baby Go car will have distance detection sensors
- The Go Baby Go car will have the capability of making a zero radius turns.

- The Go Baby Go car will record data so that the Go Baby Go research team will be able to conduct further research on the benefits of the car.
- The Go Baby Go electrical system will be well documented for future integration.

Since, there are technically four different children, who have various disabilities, the requirements that were specified were features that would benefit all of them. Some of the children's parents had specific features that they wanted implemented in the car, which will be taken into consideration based on time, resources, and difficulty. Therefore, the following list is the list of requirement specifications for this project:

- The Go Baby Go car will have a bluetooth module that shall connect to a web application.
- The web application will allow the parent to turn the car off and on.
- The web application will allow the parent to steer, accelerate, and brake the car before a collision
- The web application will allow parents to add flashcards with pictures and sort them into different categories to help their child communicate.
- The Go Baby Go car will have a joystick to allow the child to steer, accelerate, and brake the car.
- The Go Baby Go car will incorporate ultrasonic sensors that prevent the car from colliding into objects that are 25 cm away.
- The web application will have a simple user interface.
- The Go Baby Go car will have the capability of making a zero radius turns.
- The Go Baby Go car will be able to recognize when it enters a new room in the house and pull up the correct flashcards for the children to communicate with.
- The Go Baby Go car will come to an automatic stop if the web application loses control with the car.
- The battery of the Go Baby Go car will be easily accessible by the parents to charge.
- The Go Baby Go car will record data so that the Go Baby Go research team will be able to conduct further research on the benefits of the car.
- The Go Baby Go electrical system will be well documented for future integration.

The list below is of the following key specifications of the project that will be demonstrable:

- The Go Baby Go will detect obstacles within a 200cm range
- The Go Baby Go car will automatically stop when an object is 25 cm away.
- The Go Baby Go car will come to a step within 2 seconds if the car loses connection with the application
- The Go Baby Go car will have a bluetooth module that can connect to a web application 100 m away.
- The Go Baby Go car will be controlled by a web application with less than a 30 ms delay.

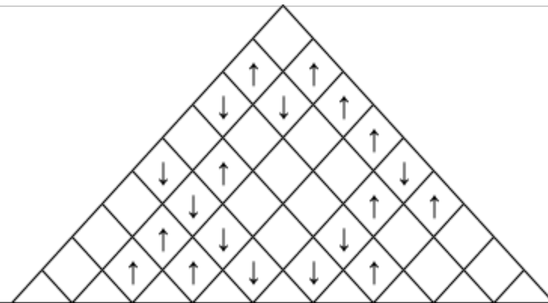
- The Go Baby Go car will have an installation time of under an hour.
- The Go Baby Go car will make 0 degree radius turns.
- The Go Baby Go will record data of the start and stop time.
- The Go Baby Go car will be able to read a QR code and pull up the correct category of flashcards with less than a 1 second delay.

2.3 House of Quality Diagram

The diagram shown in Figure 1 shows the tradeoff matrix for the Go Baby Go! project. This matrix shows the tradeoff between various aspects of the design specifications and requirements.

Customer requirements are a set of needs and wants from the perspective of the customers, in this case the parents of the children and Go Baby Go! Project lead Dr. Tucker. This includes things such as cost, which the customer wants as low as possible, since the overall goal of the project is to implement this system in multiple future cars. Another major customer requirement is the ease of use for the toddler. The toddlers will be using this car in order to maintain mobility independence, so it is essential that they are able to easily drive the car. Another customer requirement is that the parents would like to have control over the car in case the toddler loses control of their driving or might end up having difficulty driving. Having a simple web app interface for the parents, would make remote steering a lot more user friendly for them. The battery life of the car is a requirement that was requested by the customers. In the previous iteration of Go Baby Go cars, the batteries were very short-lived. Parents noted that they had to charge the battery after only an hour of use. Having an increased battery life would assist the parents and children in better utilizing their cars. The Go Baby Go cars will be used in various environments, so it is important the system is durable. Furthermore, since these are young children driving a car they might not have the correct motor reflexes and spatial awareness in order to avoid collisions. Therefore, this system needs to have the ability to detect obstacles in the driver's path to keep them safe from harm. Since Go Baby Go is a research project with many physical therapists investigators, another requirement is that they have the ability to track specific data from the car in order to improve the child's functionality.

The engineering requirements list the needs of the system from the perspective of the engineering team. The set up time for the new electrical system of the car should be as quick as possible, due to the fact that this system will be implemented in future cars. Having an accurate sensor would ensure that the children would be kept from hard, but could negatively affect the cost and battery life. This same logic also applies to the range of the sensors as well. A fast response time for the sensors is also important, so that they do not accidentally collide with an upcoming obstacle, but this could consume more power and negatively affect the battery life as well.



Column #		1	2	3	4	5	6	7	8	9	
Customer Requirements \ Engineering Requirements		Set Up Time	Power Output	Sensory Accuracy	Sensory Range	Cost	Signal Strength	Compatibility	Dimensions	Response Time	Row #
	Polarity	−	+	+	+	−	+	+	−	−	1
Cost	-	◇	↓↓	↓↓	↓↓	↑↑	↓↓	↓↓	↑	↓↓	2
Ease of Use for Toddler	+	↑	◇	◇	◇	↓	◇	◇	↑	◇	3
Web Application to control the car	+	↓	◇	◇	◇	↓	↑↑	↑↑	◇	↑↑	4
Battery Life	+	◇	↑↑	◇	◇	↓↓	◇	◇	↓	◇	5
Simple User Interface for Parents	+	◇	◇	◇	◇	◇	◇	↑↑	◇	◇	6
Durable	+	↓	◇	↓	↓	↓	◇	◇	↓	◇	7
Collisions	-	◇	◇	↑↑	↑↑	↓	◇	◇	◇	↑	8
Data Tracking Capabilities	+	↓	↓	◇	◇	◇	↑↑	↑↑	◇	◇	9
Target		< 2 hours to integrate into a car	> 5-watt hours	<2 mm distance accuracy	Detect obstacles up to 2 m away	$550	Bluetooth signal up to 20 ft away	Wifi + Bluetooth, Any android or IOS device can run the apps	The entire system should be compact and <2 ft wide	2 sec	

Polarity	
Positive	+
Negative	−

Relationships	
Strong Positive Correlation	↑↑
Positive Correlation	↑
Strong Negative Correlation	↓↓
Negative Correlation	↓
No Correlation	◇

Figure 1. House of Quality Diagram for Go Baby Go! Project

2.4 Block Diagrams:

The block diagram in Figure 2, provides information about the different components of the Go Baby Go! Project and how they interact with each other. This diagram also identifies who is responsible for each block by color and where the block is in the design process. Explanation of each block can be found below. This block diagram is a summation of the hardware and software features of the car.

- 1. Steering system
  - 1.1. Hardware
  - 1.2. Software
    - 1.2.1. Left and Right turns
    - 1.2.2. Zero degree turns
- 2. Control System
  - 2.1. Design
    - 2.1.1. Joystick option
    - 2.1.2. Wheel and paddle/pedal option
  - 2.2. Software
  - 2.3. Coding
    - 2.3.1. Interaction with steering system
- 3. Geolocation
  - 3.1. Hardware
  - 3.2. Configuring
  - 3.3. Software
    - 3.3.1. Location polling
    - 3.3.2. Storage, Possibly utilize bluetooth and app
- 4. Sensor system
  - 4.1. Design
    - 4.1.1. Location of sensors
    - 4.1.2. Number of sensors
    - 4.1.3. Detection limits
  - 4.2. Hardware
  - 4.3. Software
    - 4.3.1. Collision detection
- 5. Motor system
  - 5.1. Hardware

5.1.1. Power
5.2. Software
5.2.1. Control speed
6. Bluetooth connection
6.1. Hardware
6.2. Configuring
6.2.1. Baud rate
6.2.2. Sampling
6.3. Software
6.3.1. Data handling
7. Web Application
7.1. Software
7.1.1. Geolocation
7.1.2. Bluetooth communication
7.1.3. Remote on and off
7.1.4.
8. Main board design
8.1. Hardware
8.1.1. Module layout
8.1.2. Pin and pin out

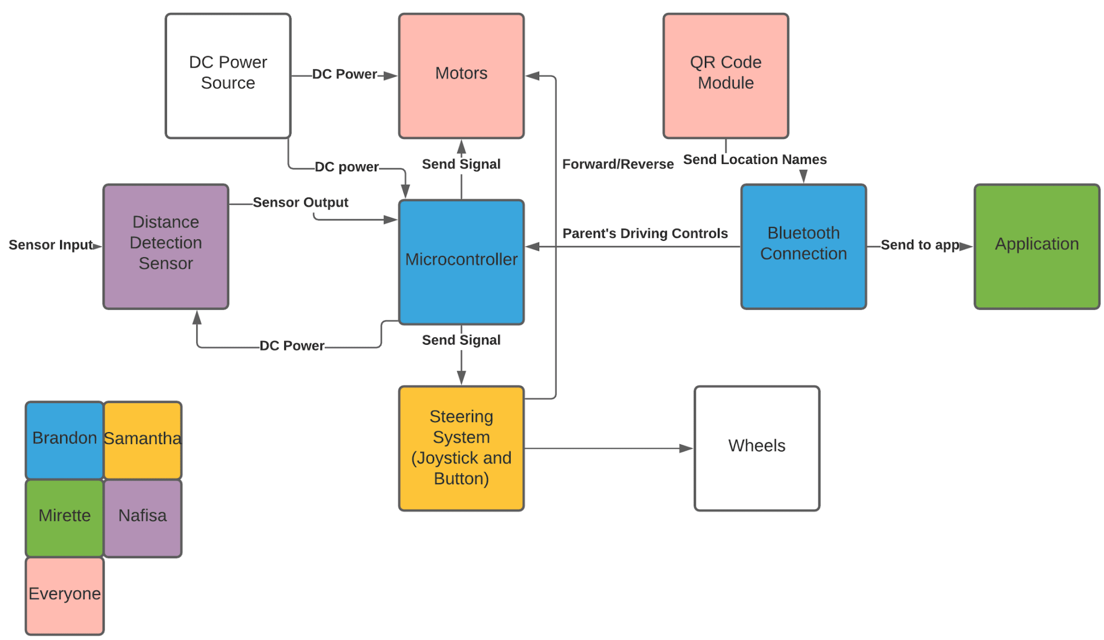


Figure 2: Hardware Block Diagram

As shown in Figure 2, the system's hardware includes the microcontroller, bluetooth connection, QR code camera, steering system, distance detection sensors, DC power source, and a printed circuit board that consists of all these

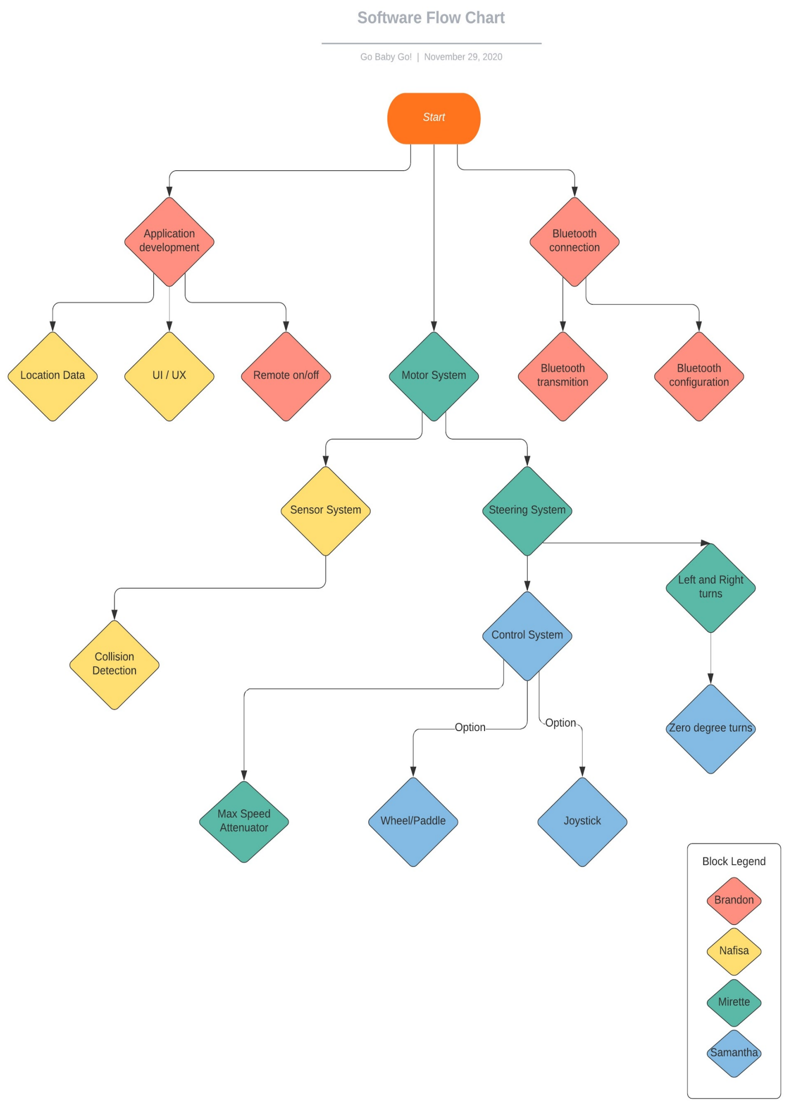


Figure 3. Software Development Flow Chart

parts. This block diagram describes the relationship between the various parts. The bluetooth connection will receive instructions from the parent's application and send those instructions to the microcontroller. The microcontroller will then send those signals to the motors and steering system which will remotely drive the car. If the child is driving the car then the steering system will send signals to the motors to move forward, which will all be powered through the DC power source and controlled by the microcontroller. The ultrasonic sensors, which are powered by the DC battery source, will receive inputs from various obstacles and then send those signals to the microcontrollers. Depending on how far away the object is the car will either keep moving forward or stop. The QR code module is its own entity which will locate QR codes and read them. Once it reads them, the QR code module will send the location names to the Bluetooth module, which will send that information to the app.

The hardware block diagram is color coded with each team member’s name, which indicates it is their responsibility to research and help implement that particular feature into the final product. This is the initial design of the system.

Figure 3 describes the overall software development flow chart of the project. Each team member has a certain module that they will research and help implement with the help of others. Some of these modules will also require the assistance of the mechanical engineering teams of this project. The software development and hardware development will be integrated processes that the whole team will work on together with further input from the mechanical engineering team. Further explanation of this design will be explored in Section 5.

3. Research

In this section we will be discussing our research related to the Go Baby Go project as it currently stands. This will include our assessments of the needs and requirements of the project. It will also contain our research related to the technologies that we will need to apply in order to meet each of our requirements. Our research is mainly from what is commonly available on the market for these technologies and the datasheets for these pieces.

Since our product will be immediately used by an end user we were also able to meet with the families that would be using our product and discuss concerns and needs of several families. From these meetings we were able to make additional changes to our design to meet their needs and wants as needed.

3.1 Existing product

There are two relevant products that we are working with. The existing Go Baby Go Project and what currently exist as Battery Operated Vehicles.

3.2.1 Go Baby Go Project

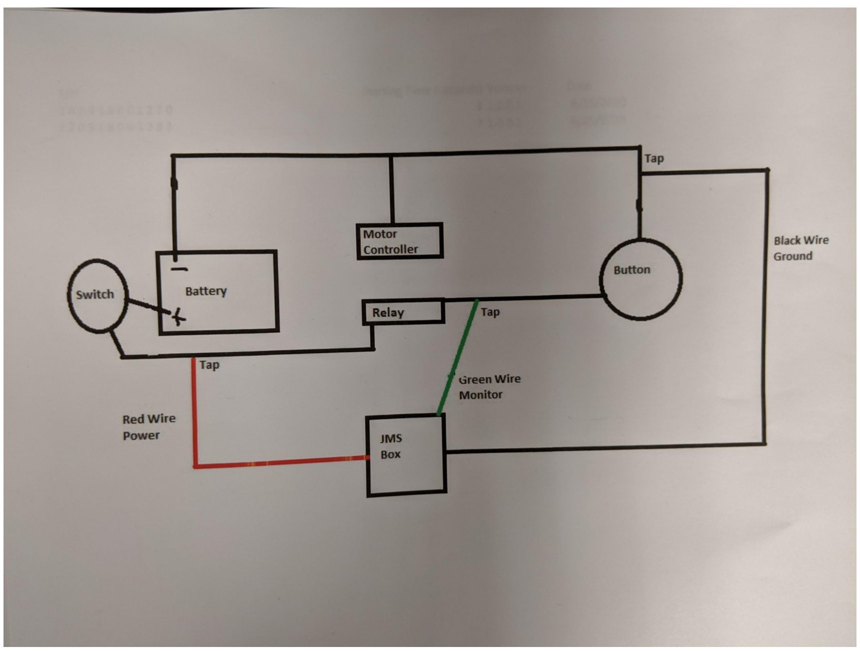


Figure 4. Current design of UCF Go Baby Go Car

Currently UCF Go Baby Go project is using modified Power Wheel cars for their design. The internal electronics of these cars are very stripped down. They have an internal battery that is charged externally and is normally wired directly to a motor controller that receives inputs from a pedal. They are modifying these instead of receiving input from a single button that is mounted on the steering wheel. A Switch is also added to the high side of the battery as a way to turn the vehicle on and off when not in use. The vehicle also has a single internal motor.

Figure 4. shows Go Baby Go's current circuit layout and approach, but they have retrofitted several other power wheels and other battery operated vehicles in the past with a similar design at robotic events that they host. Some of the other cars feature multiple motors controlled by a single button, normally hooked into where the gas pedal would be on the device. They also will feature larger batteries ranging from 12V to 48V.

3.2.2 Battery Operated Vehicles

From the information that we have most of the current vehicles that they are using are power wheels. Power wheels tend to have one or two motors located at the rear wheels and support either a 12V, 24V, or 48V battery, varying between the models.

We were also provided two sample vehicles from our sponsor to test with. The base model that they tend to use, the red "Lightning McQueen" car, features a single 12V battery and a single DC brushless motor and uses a single button to interact with the car's speed. The car's circuit is displayed in Figure 3. When the button is pressed the car moves forward and has to be manually steered. This is one of the challenges that they are having as some of their users do not have the ability to steer the wheel while also pressing the button and normally needs to be done manually by a second person.

The second vehicle that they provided has two motors for controlling the rear wheels and a single motor for controlling the steering that can be accessed from a Radio based remote controller. This is more appealing is our interest since this is a possible avenue that we could pursue. Using a Radio frequency transmitter to control the vehicle through remote operations. Most likely sending a set of binary data over a set frequency that both the controller and the car's receiver have been set to.

We will instead be using bluetooth to remotely control the car as it is a well known standard and opens up the possibility of multiple devices controlling the cars instead of a single controller frequency that has to be used.

Figure 5. The vehicles that we were provided by the Go Baby Go project.

3.2 Relevant Technologies

3.2.1 Microcontroller

The Go Baby Go car will be using one microcontroller to control the whole system. A microcontroller is a small computer on a metal-oxide-semiconductor integrated circuit chip which can be used to control other aspects of an electronic system. It usually consists of a CPU (central processing unit), RAM (Random Access Memory), function registers, programmable ROM (Read Only Memory), data ROM, several input/output (I/O) ports, and many other peripherals (Figure 5). Essentially a microcontroller can receive input, process this information, and output certain action based on what was received. These are usually embedded inside various electronic consumer products such as vehicles, medical devices, microwaves, and many others.

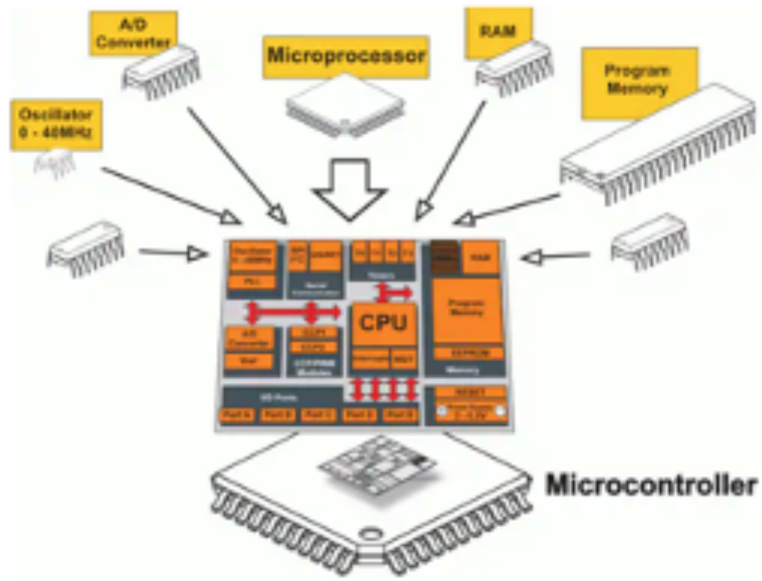


Figure 6. Microcontroller Diagram

The CPU is the “brains” of the microcontroller and controls all of the information that the microcontroller receives. It will process all the data and execute the correct and required instructions. The RAM is where the unit temporarily stores its data and can retrieve it quickly. The flash memory is the non-volatile memory within the microcontroller, where it can retain its data for extended periods of time. This will be very important for the Go Baby Go! car because our program can be saved and uploaded to the microcontroller. The I/O ports are what the microcontroller will use to connect to the various sensors, steering mechanisms, servos motors, and cameras. Using these ports, the microcontroller will send a signal to those peripherals and receive the instructions from them.

Since, the electrical design of the Go Baby Go! car will be implemented in four different cars, using a single microcontroller would be the most advantageous. Having one microcontroller to control the whole system makes maintaining and creating the system much easier for every car. From a financial standpoint, this would lower the cost of building the system, which will make it economically reasonable because this system will need to be implemented four times over. This microcontroller needs to have the ability to receive inputs from mobile applications through Bluetooth and remotely control the car along with detecting nearby obstacles.

3.2.1.1 Microcontroller Options

There are a wide range of microcontrollers to use for various applications made by several companies such as NXP, Texas Instruments, Cypress, Silicon Labs, and

Atmel Corporation. The Go Baby Go! team was able to narrow down their microcontroller choices to the following five choices.

MSP430FR6989

The MSP430x series is a family of 16-bit microcontrollers developed by Texas Instruments. The address bus, data bus, and registers in the CPU are all 16 bits wide, while the CPU has a modern design with many registers used for data or addressing. The MSP430FR6989 is a microcontroller that the Go Baby Go! team is considering it because UCF's Embedded Systems class requires computer engineers to use it in the lab component of that class. Every member of the Go Baby Go! team has knowledge of this microcontroller and has programmed it for a series of operations.

This microcontroller unit is $3.30, so it is very affordable. This unit has 83 GPIO pins to connect to peripherals and is used for advancing sensing. This module also minimizes power consumption of the system. It runs at 24 megahertz and has 5 16-bit timers and has direct memory access. With direct memory access, the peripherals can access the random-access memory of the system bypassing the CPU.

MSP430FG4618

The MSP430FG4618 is another microcontroller in the MSP430x family from Texas Instruments. The price of a single MSP430FG5618 unit is $15.29.

This microcontroller's greatest advantage is that it has an ultra-low power consumption. On Active mode, it only runs 1 megahertz and 2.2 volts, using only 400 microamperes. Another great advantage of this unit is that it can wake up from standby mode in less than 6 microseconds. This feature would be extremely vital for the car, that way the user can power on the car and not wait too long in order for it to be used. This unit also has 5 power-saving modes and various universal serial communication interfaces. It also consists of 80 I/O pins which would be extremely useful with the various peripherals that need to be connected and processed.

MSP432P401R

This microcontroller is a high performance unit that needs low power. This unit is an optimized wireless host with an integrated 16-bit precision ADC, which is able to deliver that low-power. An advantage of this unit is that the MSP432P401x series is part of the SimpleLink microcontroller platform, which allows the use of Wi-Fi and Bluetooth. This shares a common, easy-to-use development environment with a single core software development kit (SDK), which allows the reusability of code. This feature would be very advantageous for this project due to the wireless communication aspect. This unit is priced at $6.30.

Raspberry Pi and Broadcom 2837

The Raspberry Pi is a low cost, compact sized mini-computer. It is a very powerful device with the latest model having a 1.5 gigahertz 64-bit quad core processor, onboard Wi-Fi, Bluetooth, and various usb-ports. This device is used by many in order to do high-power processing and automation such as using TensorFlow's framework for image processing and recognition. The Raspberry Pi also has several GPIO pins that could be used to connect with peripherals and has extensive resources online that can be used to assist the team with any coding or connection problem. While one of the Go Baby Go! Car's team member has extensive experience with using a Raspberry Pi, the senior design requirements are to design and build a printed circuit board. Since the Pi is a mini-computer with a board already available, this will not satisfy those requirements. Another option would have been to look into the Raspberry Pi Zero, which is advertised as the "5 dollar computer." This Raspberry Pi Zero has the same capabilities as the general Raspberry Pis, without most of the serial connection. While this version of the Raspberry Pi is not as extensive as the other models in that family, it is still considered a mini-computer with a printed circuit board already attached.

Since the Raspberry Pi has so many functionalities and power, further research was conducted on the actual microprocessor used in this system. The processor used on the Raspberry Pi is actually a hybrid between a microprocessor and microcontroller. A microprocessor only consists of a central processing unit and is used primarily in personal computers. This hybrid is actually a SoC (system on chip), which consists of multiple dies stacked on top of each other, with a Broadcom BCM 2837 ARM CPU, a Broadcom VideoCore graphics processing unit, and RAM. The Broadcom 2837 has a quad core cluster with a quad-core ARM Cortex A53 cluster. However, the minimum order quantity for this microcontroller is several hundred thousand, so it is not in consideration anymore.

ATmega328P

The ATmega328P is a high performance, low-power microcontroller that is developed by Atmel. This unit is specifically very favorable, because it is used in Arduino boards. Since this microcontroller is so widely used there are various resources and tutorials that will be able to assist in using this unit. One of the Go Baby Go! team members use an Arduino board exclusively at their internship, so they are familiar with this microcontroller and its abilities.

This unit has a programmable memory of 32 Kbytes and various power saving modes which can work on mobile embedded systems. It utilizes an advanced RISC architecture and has 23 programmable I/O pins, which can be useful for the various peripherals. Of these 23 pins, there are 15 digital and 8 analog, where the analog pins can be used. These pins will be able to connect to the sensors and servos motors. One interesting feature of this unit is that it has six sleeping modes: idle, ADC noise reduction, power-save, power-down, standby, and extended standby.

Another benefit of the ATmega328P is that it can be purchased with the pre-loaded Arduino bootloader. This Arduino bootloader is what is used in the Arduino Uno. This will allow the Go Baby Go! team to prototype their electrical system using the Arduino Uno. If the program that is used with the Arduino Uno works correctly, then it can be transferred over to the ATmega328P on the printed circuit board.

Table 1 - Microcontroller Comparison

	Core Clock	Internal Memory	Pins	Built Wireless	price
MSP430FR6989	100 MHz	128 KB	83 GPIO	None	3.30
MSP430FG4618	8 Mhz	116 KB	80 GPIO	None	18.99
MSP432P401R	48 Mhz	256 KB	48 GPIO	None	34.59
Raspberry Pi and Broadcom 2837	1.5 Ghz	1 GB	10 GPIO	Wi-Fi & Bluetooth	34.99
ATmega328P	20 Mhz	32 KB	23 GPIO	None	2.50

3.2.2 Voltage Regulators

The voltage regulator is the most widely used electronic component. It provides the circuit with a predictable and fixed output voltage at all times, regardless of the input voltage. This ensures that if the supply voltage fluctuates or has some sort of variations, the circuit will still receive the correct amount of voltage. There are mainly two types of voltage regulators that most individuals work with – Linear Voltage Regulators or Switching Voltage Regulators.

Linear voltage regulators act as a voltage divider in a circuit and are commonly used when designing low power and low-cost applications. These voltage regulators use power transistors, such as BJT or MOSFETS. They usually play the role of a variable resistor, raising and lowering the output voltage of the circuit as the input voltage changes. Advantages of the linear voltage regulator is that it has few external parts and low noise.

The disadvantages of the linear voltage regulator is that it will waste energy as it converts resisted current to heat, which is why it is ideal for low power requirements. With a lower initial input power, the more efficient the voltage regulator will be able to be.

Switching voltage regulators are more prominently used when there is a large difference between input and output voltages. These regulators store and deliver the charge in smaller portions to the output voltage based on feedback. When feeding an output voltage back into the switch, the regulator can constantly check to see if it needs to increase or decrease the timing of the voltage outputs. This regulator sustains its charge by using a transistor which turns on when the storage needs more energy, and off when the storage is at its desired output voltage. The advantage of this method is that it is more energy-efficient.

The disadvantages of the switching voltage regulator, is that it takes more time to switch from a conductive to nonconductive state, which results in a reduction in efficiency. There is also more noise in the circuit through these regulators.

The team has decided to use a low dropout regulator (LDO) for this project. Since the Go Baby Go car's voltage inputs will only be 12-24V DC battery, the recommended regulator for this system would be the LDO.This is a linear regulator which is simple and cost-effective. The most interesting feature of the LDO is that it has a very low voltage drop across it when it is providing the correct voltage. This allows the LDO to be used in critical battery systems. The LDO can take a fluctuating input voltage and provide a controlled, steady, noiseless DC output voltage. It also has no switching noise and is smaller in size than most other linear voltage regulators.

The LDO regulator functions as a linear voltage regulator. There are three main components of this regulator: pass element, error amplifier, and reference voltage source (Figure 7). The pass element is either a N or P-channel MOSFET or transistor. The input voltage is applied to the pass element. This pass channel, which is technically a field-effect transistor, operates linearly to reduce the input voltage to the correct voltage. The error amplifier is a sort of a checkpoint that can compare the output voltage to the input voltage.

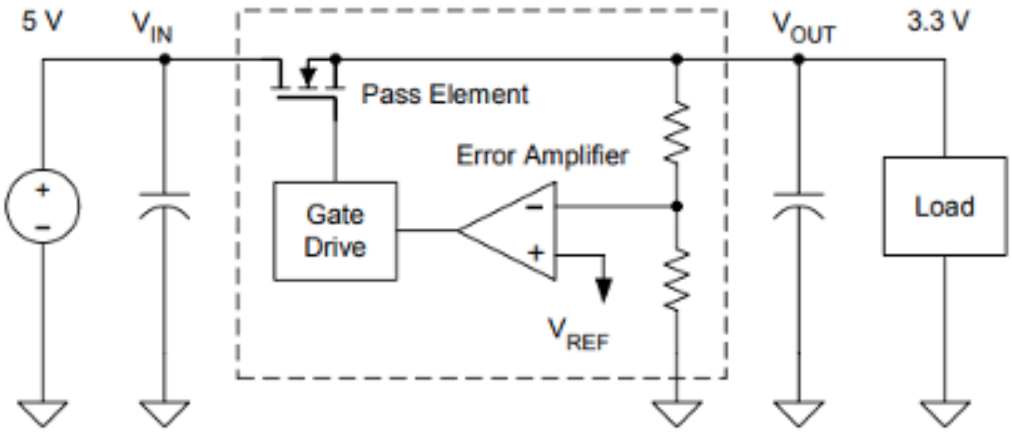


Figure 7. LDO Regulator (reprinted with Permission from Texas Instruments)

3.2.3 PWM

To control multiple parts of our product we will be making use of Pulse width modulation waves. Pulse width modulation waves contain two components. Their duty cycle, how often they are high or low, and their periodic frequency, how often each duty cycle is repeated comes out. These square waves produce an average power level over a given period that gives the appearance of different power levels on devices that do not have variable settings.

We are using Pulse Width modulation to control the various motors that we are using since they have only two states, powered on or powered off. By quickly switching between these two states an average power level is produced that follows the form of The voltage applied multiplied by the percent of the duty cycle. Figure 8. Shows an outline of these types of waves. Using a Pulse Width Modulation lets us rapidly switch between these states to give a weaker average signal.

Having a weaker Voltage being applied to the motor will result in the motor having less total Power, in turn it will perform less work and not turn as fast. This lets us control the speed of the motor and, in turn, the speed of the vehicle.

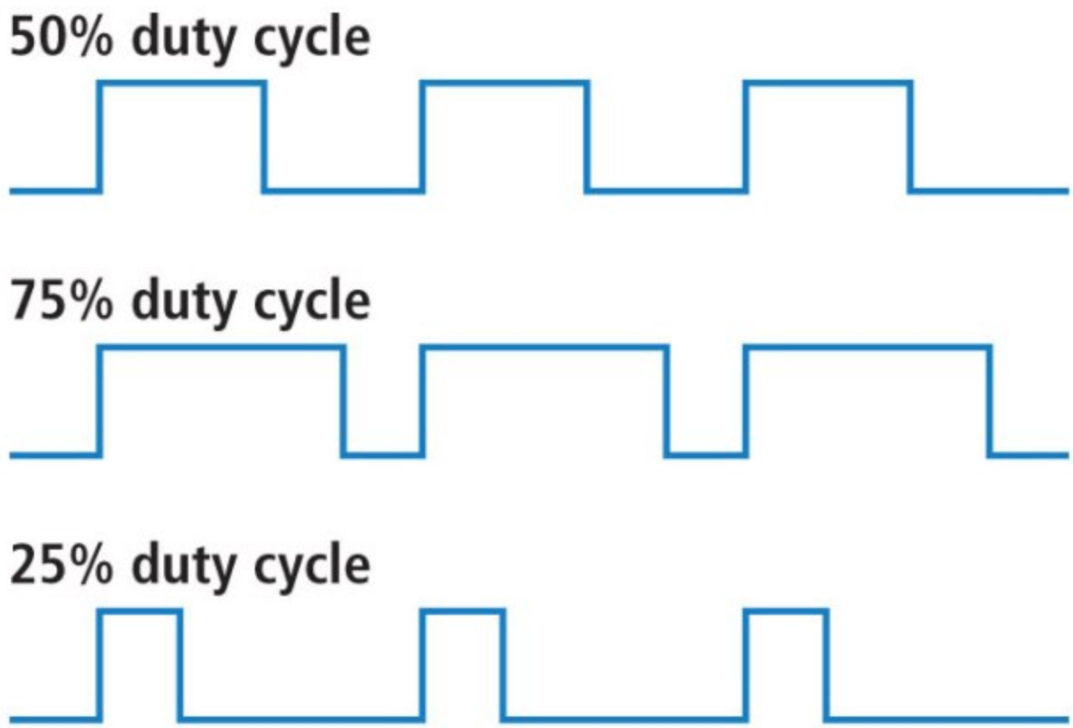


Figure 8. Various Duty Cycles during a Pulse Width Modulation

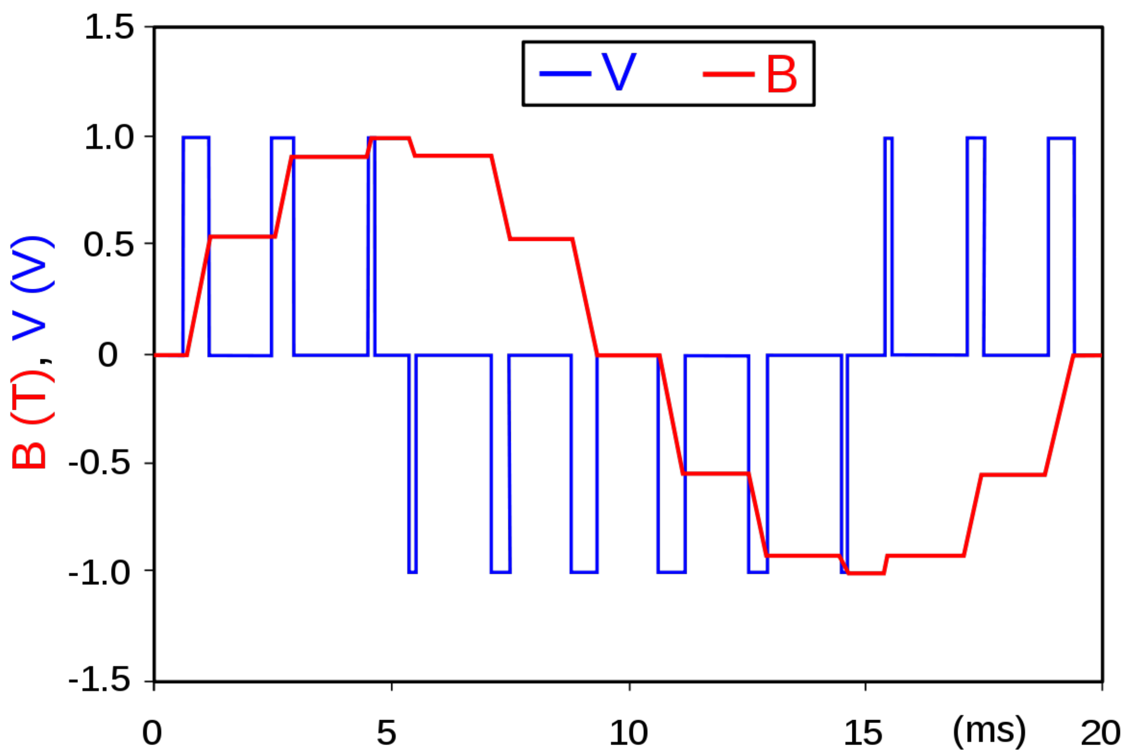


Figure 9. Example of Pulse Width modulation over Time

3.2.4 Motors

Our project requires making a pre-existing product into an accessible and safe means of transportation through the use of a joystick and a remote controlled Application. To do this we would have to control a set of motors on the vehicle through a microcontroller that will interpret inputs from the joystick and remote application into vehicle functions. Our approach will have to utilize two different sets of motors. Stepper motors and DC Brushless motors.

DC Brushless Motor

We are assisting the mechanical engineering teams in modifying an existing product. The product that they are using is a range of battery operated motor vehicles, from various manufacturers. Each of these vehicles already have a set of built in DC motors and power supplies that we will be using in the final product. We will not be adding any additional DC Brushless motors for forward or reverse control. Instead we are adding circuits to control when and how the motors will be getting power. Since we will not be adding any additional DC Brushless Motors we will have to design our approach to be able to turn the wheels both clockwise and counterclockwise to produce both forward and reverse motion.

We do not have to worry about the weights or force of these motors since they are already designed for the cars that they are being used in. The additions being made by the Mechanical engineering team may add additional weight to the vehicle, but this is negligible as top speed is not a factor that we are concerned with and actually may want to be limiting to ensure that the vehicle will be safe. We only need to account for our device being able to work with the Voltage and Current that are already being produced by these devices.

Stepper Motor

Part of our requirements is to have the car controllable with a Joystick and from a remote controller. This will require the front wheels of the cart to be turnable both left and right. We believe that this will be achievable with a motor attached to the steering column of the vehicle to control turning the steering column left and right. The challenge with this is that the wheels need to return to a straight forward position each time. So the motor would need to have an initial position that it could return to, It's starting state, whenever the joystick is released to the center. Since the amount of rotations has to be repeatable and precise this will best be done by

The motor will also have to return to this state when the remote control is not being pressed left or right. This will not be controlled mechanically. Instead we add this functionality though code that maps each of the positions of the joystick and remote controller to a set state for the motor and maintains the state that the motor is currently in.

A trade off of this design is if the wheels are moved outside of the controllers then the car will move slightly off. To correct this additional controls will have to be added to the car to set the alignment of the wheels. Our stepper motor will also have to be a bi-pollar configuration as we will want to control both clockwise and counterclockwise turns.

The stepper motor will have to be powered by the battery onboard the car since it will be drawing a high amount of current. In the ranges of 1A to 3A depending on the motor choice. The voltage of stepper motors can be ignored since they are mostly a by-product of high current draw and the resistance of the coils. A diagram of a stepper motor is shown in Figure 10.

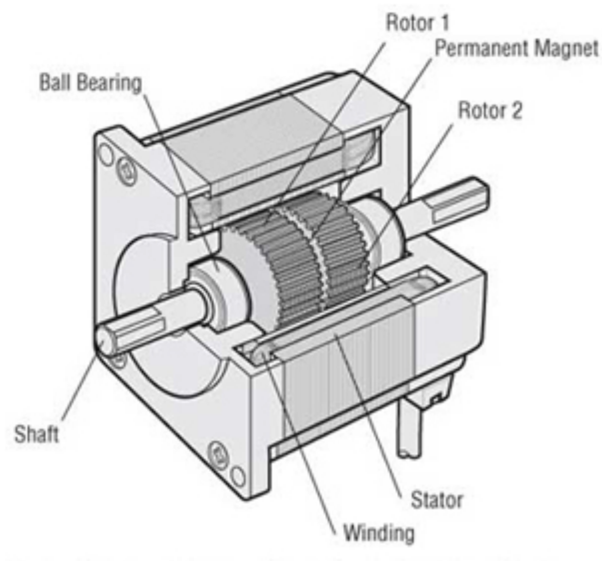


Figure 10. Diagram of Stepper Motor

H-Bridge

The car should be able to move both forward, and backwards based on the inputs from the joystick or the remote controlled application. DC motors have two poles for connecting wires, one has to be high and one has to be low. This gives us two possible states.

- **State 1:** If pole 1 is given a high signal and pole 2 is connected to ground the The current that will flow through the motor's stator and cause the rotor, the shaft that will connect to the wheels, to turn clockwise. This will give the car forward motion.
- **State 2:** If pole 1 is connected to ground and pole 2 is given a high signal the inverse will happen. The motor's rotor will turn counter clockwise and cause the car to move in reverse.

To achieve both forward and reverse motion the final device will need a way to swap the connections to the motors terminals, if a forward value is sent from the joystick the motors should turn clockwise, if a reverse value is sent the motors should spin counter clockwise. This is where an H-Bridge comes in. Using a set of four transistors or relays we can swap the states of the motor to provide both forward and reverse controls.

Something that has to be considered is inside each of the Battery operated vehicles the batteries will have a variety of voltages, ranging from 12V for smaller cars to 48V for larger cars. Our H-bridge will need to be able to support up to 48V power supplied then.

For initial testing we will be using an IBT_2 motor driver. From the schematics that we were able to find this used a BTN7970 half-driver for connecting the Powersource (P2 header) with the Motor connectors (P1). This is a part of the Arduino project and it’s design is open source.

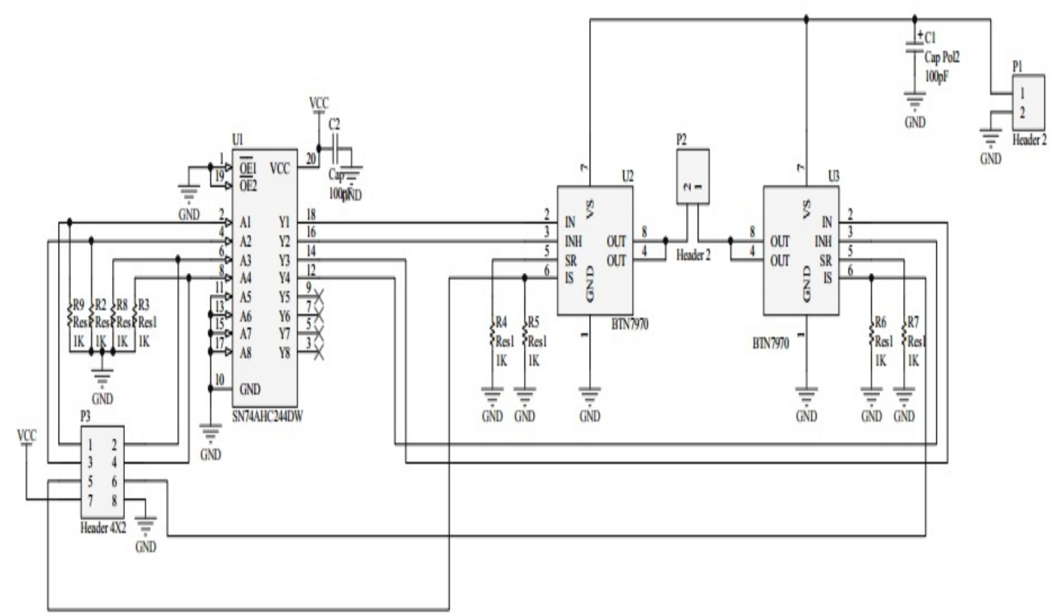


Figure 11. Schematic for the IBT_2 Motor Driver (reprinted with permission from Texas Instruments)

According to the BTN7970 data sheet the max power that their pins are rated for ranges from -0.3V to 45V. So this would be suitable for our final prototype board as well. We will be integrating A similar H bridge design in our final product

3.2.5 Joysticks

Joysticks will be used on our project as per some of the parents request. Using a joystick will facilitate the manipulation of the car. For our project the parents have expressed concerns about their children not being able to manipulate a steering wheel due to their limited mobility capabilities. To safely maneuver a steering wheel, the child will need to use both hands on the wheel and rotate it in the desired direction to move the car. This is an action that not every kid can perform. Having a joystick will allow them to safely maneuver the car with only one hand. Also, since the car is being modified the joystick can be positioned closer to the child so that he could comfortably manipulate the car.
For this project the joystick will not be built from scratch. However, it is imperative to know the components and the technical aspects to correctly adapt it to the car by making the proper electrical connections.

The joystick has four basic components: stick, circuit board, contact terminals and buttons. This can be seen on Figure 12. A joystick is essentially a specialized electrical switch.

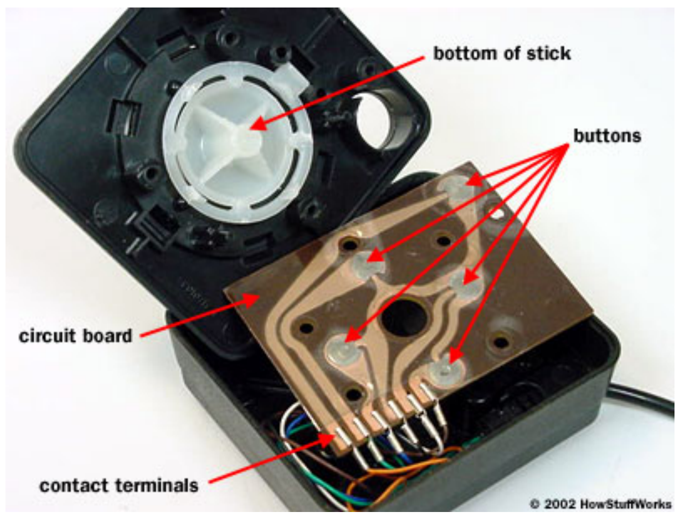


Figure 12. Basic Joystick components

The joystick mechanism consists in translating the movement made by the stick, into electronic information that the computer can understand. The contact terminals emmit the electrical data to the computer.This terminals are directly connected to the circuit board. Which will act as a mediant between the buttons, stick and the contact terminals. The circuit board has 4 buttons which represent the four directions in which the joystick is capable to move: right, left, up and down. These buttons will be pressed when moving the stick on either one of the four previously mentioned directions. When the circuit board picks up a charge on a particular wire. The computer knows that the joystick is in the right position to complete that particular direction circuit.

3.2.6 Sensors

The Go Baby Go project wants to be able to keep the children safe as they are driving their car. These children are fairly young and have not been able to practice their mobility due to their separate disabilities. As a result, they might not be able to drive the car safely around various obstacles and hazards.

In order to ensure the children's safety while driving and to allow them more freedom while driving, collision detection sensors will be installed on the car. These sensors will be able to detect if an obstacle is approaching and warn the parents that their child could be in potential danger.

Proximity Detection Sensors

Proximity sensors detect the presence of any object without physical contact and relay that information captured into an electrical signal. The major features of these sensors are that they are contactless, unaffected by surface colors of objects, usable in a wide range of environmental conditions, longer life cycle, and high speed response rate.

Inductive Proximity Sensors

There are two types of proximity sensors, inductive and capacitive. Inductive proximity sensors are used to only detect metal objects and use induction, by driving a coil with an oscillator once a metal object approaches it, as shown in Figure 13.

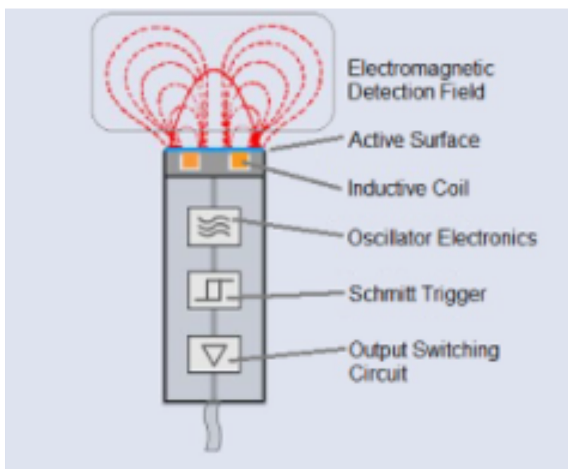


Figure 13. Diagram of Inductive Sensor

In the inductive proximity sensor, the oscillator consists of an inductive coil made of turns of copper wire, a capacitor, and an energy source. The size of the coil and capacitor are carefully matched to produce a self-sustaining sine wave oscillation at a fixed frequency. The way this sensor operates is that an alternating current is supplied to the coil in order to generate an electromagnetic detection field. Then the metal object comes closer to the electromagnetic field, eddy currents will build up, and the inductance of the coil will change. When this changes, the circuit will trigger the sensor's output switch. This switch is only triggered if an object is present. There are two types of inductive sensors, unshielded and shielded. The unshielded version is used to sense greater distances because the field generated by the coil is unrestrained. The shielded version has the field generated towards the front of the sensor. These sensors are commonly used in industrial and security environments such as banks and armories.

Capacitive Proximity Sensor

The second type of proximity sensor is the capacitive proximity, which are contactless sensors that can detect metallic and non-metallic objects and operate through capacitance. A diagram of a capacitive proximity sensor is shown in Figure 14.

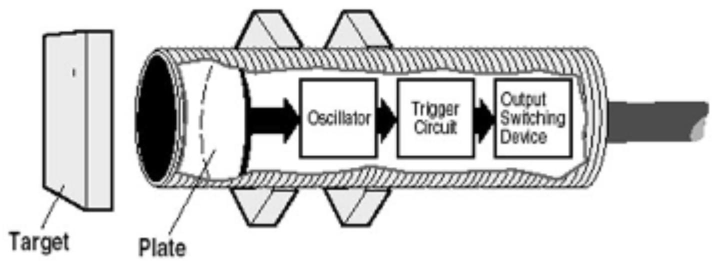


Figure 14. Capacitive Proximity Sensor

Capacitive proximity sensors act similarly to a simple capacitor. A metal plate in the face of the sensor is connected to an internal oscillator circuit and the object that needs to be detected acts as the second plate of the capacitor. Instead of producing an electromagnetic field, it produces an electrostatic field.

The external capacitance between the target and the sensor plate form the feedback capacitance. So as the target approaches the sensors, the oscillation increases until they reach a threshold and that will activate the output signal. The way these sensors function is that the proximity sensor produces an electrostatic field. Then, the object approaches the sensing area and the capacitance of both the internal and external plates increase. This results in an oscillator amplitude gain. The final amplitude gain triggers that sensor output switch. Common uses for the capacitive proximity sensors are for industrial functions such as fluid level, pipelines, and fluid pressure. Other uses would be in touch application and moisture control.

Advantages and Disadvantages of Inductive and Capacitive Sensors

The advantages of inductive proximity sensors are that they can be used in contactless detection, adaptable to any environment, specifically dust and dirt, ability to detect metals, cheap pricing, and no moving parts. The advantages of the capacitive proximity sensors are that they have contactless detection, detect a wide-range of obstacles, detect objects through non-metallic walls, suited for various environments, allows users to adjust the sensor sensitivity so that only certain objects will be detected, and no moving parts.

The disadvantages of inductive proximity sensors are that they can only detect up to 80mm away, only detect metal objects, and can be affected by extreme external conditions such as extreme temperatures. The disadvantages of the capacitive proximity sensors are that they have a relative low range and are much higher priced.

These two sensors are primarily used in industrial settings, which makes them overloaded with features that are not necessary for the Go Baby Go! car. Also, these sensors are more suited for detecting metal objects, which is not encompassing for the usage of this care. Therefore, these two sensors will not be considered for this project.

Ultrasonic

Ultrasonic sensors are sensors that use sound waves to detect obstacles. These sensors use a sound frequency that humans cannot hear in order to determine how far away an obstacle is located. This range of sound can only be heard by animals as depicted in Figure 15.

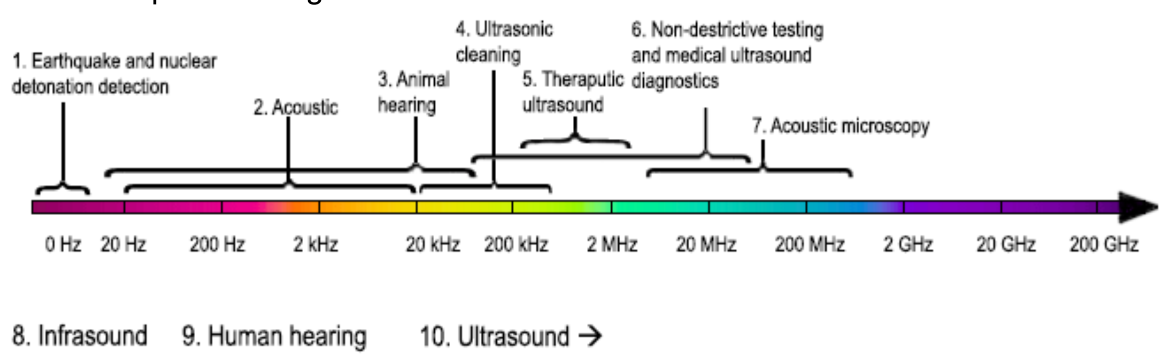


Figure 15. Sound Wave Spectrum

Ultrasonic sensors transmit a high frequency sound wave, which is where the term "sonic" emerges from. Once the sound wave is triggered and transmitted, it moves outward until it reaches an object (see Figure 16). Once the wave reaches the object it will be reflected back to the sensor in order to determine how far away the object is. These sensors are based on the principles of time of flight, Doppler effect, and the attenuation of sound waves. If there are no objects present, the wave would be moving forward and then the sensor would essentially time out indicating that there is not an obstacle in its current vicinity. This ensures that the sensor does not end up detecting obstacles that are very far away and do not currently pose a threat to the user. Depending on the ultrasonic sensor used, the range that the sensor can send a wave and receive a reflected wave back differs. An advantage of these sensors is that they are contactless, so they do not require physical contact with their target.

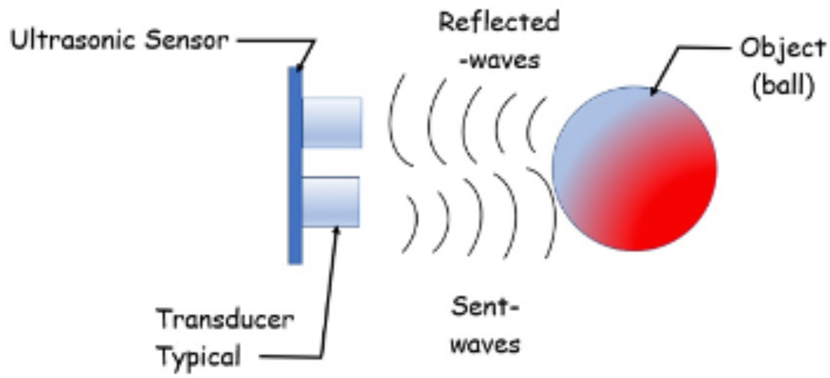


Figure 16. Diagram of Ultrasonic Sensors

After the sensor receives that high-frequency sound wave. It measures how long it took for the then times how long it takes for the echo of the sound to reflect back. Once it measures the duration of the sound wave it uses that to calculate the distance using the formula:

$$\boldsymbol{Distance = (Speed * Time) / 2}$$

Equation 1 – Distance Measurement Equation for Ultrasonic Sensors

The time is obviously the duration of the sound wave, but the speed is the speed of sound. Since, the wave that is being transmitted by the sensor is a sound wave, the speed of sound needs to be used in this calculation. The speed of sound is approximately 341 m/s in air. After, the speed and time are multiplied together, the result is divided by 2. This is due to the fact that the duration of the sound wave is the time it takes for the sound wave to reach the object and bounce back.

The history behind using ultrasonic sound to measure distance comes from the way animals use echolocation. For example, bats are nocturnal and use echolocation order to navigate their surroundings. Echolocation is the use of sound waves and echoes to determine how far away objects are. When the bats send out sound waves, those waves hit an object, and create echoes. These echoes return to the bats similarly to how the sound waves return to the sensor. An additional ability of bats is that they can tell how big an object is based on the echo's intensity. A smaller object will reflect less of the sound wave and produce a less intense echo. They can also use the pitch of the echo to determine what direction an obstacle is coming. If echo has a lower pitch than the original sound, the object is moving away from the bat, while a higher pitch indicates that the object is moving towards it.

Common applications of ultrasonic sensors are anemometers for wind speed, fluid detection, UAVs, and robotics.

Infrared

Infrared proximity sensors are sensors that detect the presence of an object by emitting a beam of infrared light. Infrared light or waves are part of the electromagnetic spectrum. People encounter these waves, but the human eye cannot see it because it is above the range of visible light as shown in Figure 16. Common uses of infrared light waves are when a remote control uses them to change channels on a television set.

Infrared proximity sensors consist of an infrared LED that emits and a light detector that detects the reflection. There is also an in-built signal processing circuit that can determine an optic spot. The way an infrared proximity works is that infrared light is emitted from the LED emitter. This beam of light hits and object and is reflected back at an angle. This reflected light will then reach the light detector. The sensor in the light detector then determines the distance of the object relative to its reflection. This process is depicted in Figure 18.

There are various different types of infrared proximity sensors. One is a photo interrupter which is a photo sensor that integrates an optical receiver and emitter in a single package. This is typically useful in rotating machines. These sensors are mainly available in two types of outputs: transistor and logic outputs. The transistor outputs consists of NPN and Darling, while logic includes NPN, PNP, open collector, and pull-up resistors.

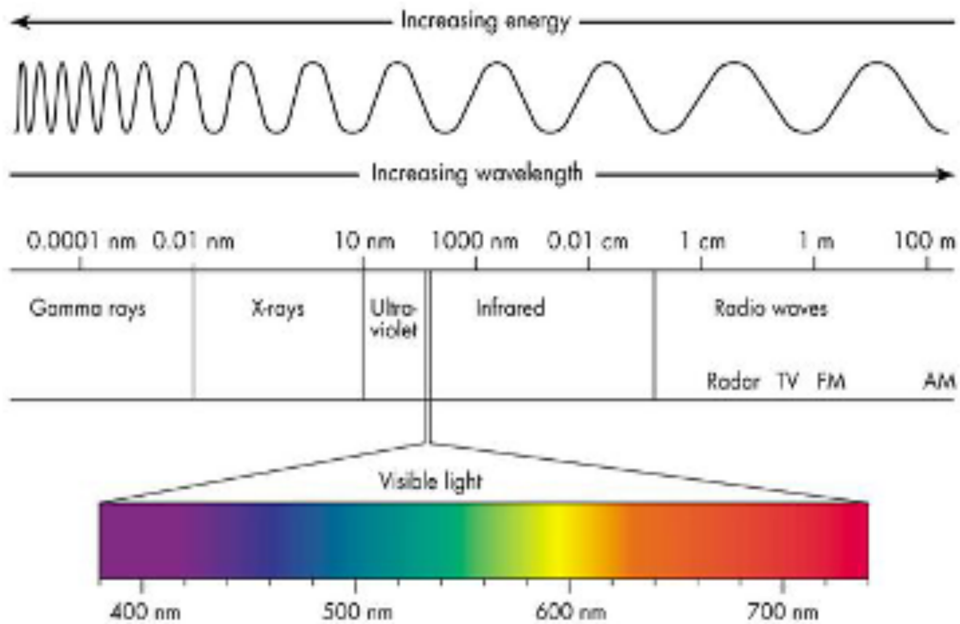


Figure 17. Electromagnetic Spectrum

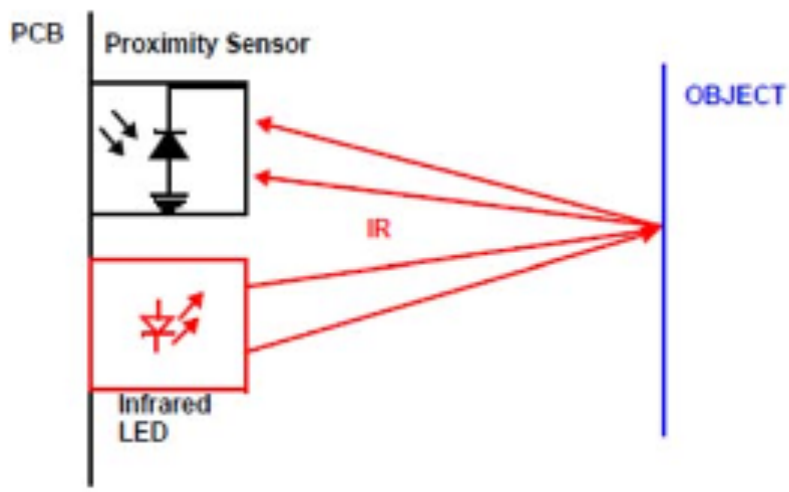


Figure 18. Infrared Proximity Sensor Diagram

Another type of infrared sensor are photo-reflective type of sensors, which are side-by-side emitter-sensor devices that can detect reflected beams from a surface. The size and reflective properties of the times in proximity can determine if the trigger is activated, which results in less precision. An interesting aspect of this specific sensor is that the sensitivity can be controlled through the use of modulations.

Laser Distance Sensors

Light Detection and Ranging (LIDAR) are a form of laser distance sensors. It measures the distance from targets using light waves from a laser instead of radio or sound waves. This technology is used heavily in robots for environmental perception and object classification. LIDAR can provide 2D elevation maps of terrain, high precision distance to the ground, and the velocity for safe landing of aerial vehicles.

The way LIDAR works is that it has a transmitter which can illuminate a target with a laser and a receiver that can detect the component of light which is the coaxial with the transmitted beam. The receiver sensors calculate the distance, based on the time needed for the light to reach the target and return, similar to the mechanism of ultrasonic sensors. This distance is calculated by using the relationship between the speed of light and the duration of the signal. The mechanism of how LIDAR sensors are able to detect distances is shown in Figure 19.

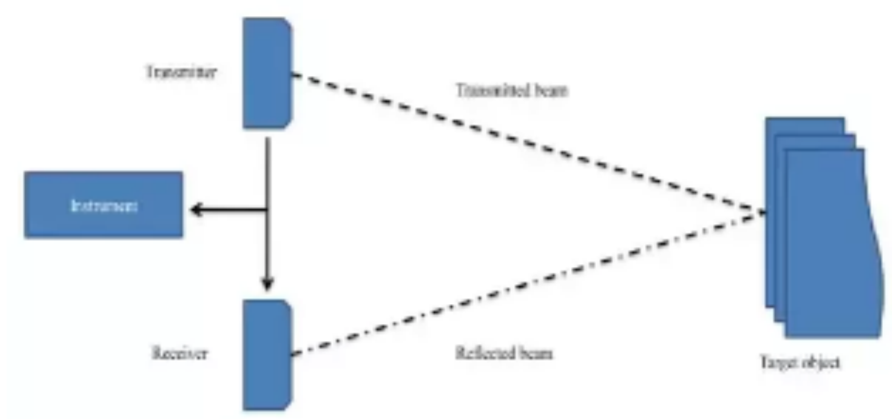


Figure 19. Diagram of LIDAR Sensor

LED Time-Of-Flight Distance Sensors

LED time-of-flight sensors are sensors that are part of the LIDAR spectrum, but use time-of-flight technology to measure distances. Time-of-Flight sensors measure the duration it takes for a wave to reflect off an object back to the sensor. It has the ability to produce 3D imaging with a single picture, in which it can measure the duration it takes for light to travel from the emitter to the receiver.

These sensors work similarly to LIDAR sensors. They will have a transmitter that can emit infrared-LED light at the obstacle. The pulse of the LED will then hit the obstacle and reflect back to the sensor. The duration of time it takes to send and receive the signal is used to calculate the distance of the obstacle.

The benefits of this particular distance sensor is that it can cover a wider range, read and process data a lot faster, and have great accuracy. Time-of-Flight sensors are primarily used in machine learning devices. However, in the case of our project that is a disadvantage. These sensors are very expensive and are overloaded with features that are not necessary for the car. These powerful sensors will consume more power from the car’s battery and deplete it’s life a lot faster. Due to these circumstances, this particular sensor is no longer being considered for the Go Baby Go project.

3.2.7 Wireless Communication

The Go Baby Go project wants to be able to remotely disable the car in case the vehicle ever moves too far away from the parents, or if the car becomes unsafe for any reason. This means that we would have to incorporate some type of wireless communication technology that can interact with the controls for the car.

Wireless communication is technology that can be used to establish communication between two products. Wireless Communication is the fastest growing and most vibrant technological areas in the communication field. It is a method of transmitting information from one point to another, without using any connection like wires, cables or any physical medium. The way communication systems operate is that the information is transmitted from the transmitter to the receiver that are placed over a limited distance. Wireless communication, the transmitter and receiver can be placed anywhere.

There are numerous advantages of Wireless Communication Technology, Wireless Networking and Wireless Systems over Wired Communication like Cost, Mobility, Ease of Installation, and Reliability etc.

Cost

The cost of installing wires, cables and other infrastructure is eliminated in wireless communication and hence lowering the overall cost of the system compared to wired communication systems. Installing wired networks in building, digging up the Earth to lay the cables and running those wires across the streets is an extremely difficult, costly and time consuming job.

In historical buildings, drilling holes for cables is not a best idea as it destroys the integrity and importance of the building. Also, in older buildings with no dedicated lines for communication, wireless communication like Wi-Fi or Wireless LAN is the only option.

Advantages of Wireless Communications

Mobility

As mentioned earlier, mobility is the main advantage of wireless communication systems. It offers the freedom to move around while still connected to the network.

Ease of Installation

The setup and installation of wireless communication network's equipment and infrastructure is very easy as we need not worry about the hassle of cables. Also, the time required to setup a wireless system like a Wi-Fi network for example, is very less when compared to setting up a full cabled network.

Reliability

Since there are no cables and wires involved in wireless communication, there is no chance of communication failure due to damage of these cables which may be caused by environmental conditions, cable splice and natural diminution of metallic conductors.

Disaster Recovery

In case of accidents due to fire, floods or other disasters, the loss of communication infrastructure in wireless communication systems can be minimal.

Disadvantages of Wireless Communication

Even though wireless communication has a number of advantages over wired communication, there are a few disadvantages as well. The most concerning disadvantages are Interference, Security and Health.

Interference

Wireless Communication systems use open space as the medium for transmitting signals. As a result, there is a huge chance that radio signals from one wireless communication system or network might interfere with other signals.

The best example is Bluetooth and Wi-Fi (WLAN). Both these technologies use the 2.4GHz frequency for communication and when both of these devices are active at the same time, there is a chance of interference.

Security

One of the main concerns of wireless communication is Security of the data. Since the signals are transmitted in open space, it is possible that an intruder can intercept the signals and copy sensitive information.

Health Concerns

Continuous exposure to any type of radiation can be hazardous. Even though the levels of RF energy that can cause the damage are not accurately established, it is advised to avoid RF radiation to the maximum.

Basic Elements of a Wireless Communication System

A typical Wireless Communication System can be divided into three elements: the Transmitter, the Channel and the Receiver.

A typical transmission path of a Wireless Communication System consists of Encoder, Encryption, Modulation and Multiplexing. The signal from the source is passed through a Source Encoder, which converts the signal in to a suitable form for applying signal processing techniques.

The redundant information from signal is removed in this process in order to maximize the utilization of resources. This signal is then encrypted using an Encryption Standard so that the signal and the information is secured and doesn't allow any unauthorized access.

Channel Encoding is a technique that is applied to the signal to reduce the impairments like noise, interference, etc. During this process, a small amount of redundancy is introduced to the signal so that it becomes robust against noise. Then the signal is modulated using a suitable Modulation Technique, so that the signal can be easily transmitted using an antenna.

The modulated signal is then multiplexed with other signals using different Multiplexing Techniques like Time Division Multiplexing (TDM) or Frequency Division Multiplexing (FDM) to share the valuable bandwidth.

The channel in Wireless Communication indicates the medium of transmission of the signal i.e. open space. A wireless channel is unpredictable and also highly variable and random in nature. A channel may be subject to interference, distortion, noise, scattering etc. and the result is that the received signal may be filled with errors.

The job of the Receiver is to collect the signal from the channel and reproduce it as the source signal. The reception path of a Wireless Communication System comprises Demultiplexing , Demodulation, Channel Decoding, Decryption and Source Decoding. From the components of the reception path it is clear that the task of the receiver is just the inverse to that of the transmitter.

The signal from the channel is received by the Demultiplexer and is separated from other signals. The individual signals are demodulated using appropriate Demodulation Techniques and the original message signal is recovered. The redundant bits from the message are removed using the Channel Decoder.

Since the message is encrypted, Decryption of the signal removes the security and turns it into a simple sequence of bits. Finally, this signal is given to the Source Decoder to get back the original transmitted message or signal.There are many types of wireless communication, but the ones that we will consider are Wi-Fi and Bluetooth.

Wi-Fi

Wi-Fi wireless connectivity is an established part of everyday life. All smartphones have Wi-Fi technology incorporated as one of the basic elements of the phone enabling low cost connectivity to be provided. In addition to this, computers, laptops, tablets, cameras and very many other devices use Wi-Fi. Wi-Fi access is available in many places via Wi-Fi access points or small DSL / Ethernet routers. Homes, offices, shopping centres, airports, coffee shops and many more places offer Wi-Fi access.

Wi-Fi is now one of the major forms of communication for many devices and with home automation increasing, even more devices are using it. Home Wi-Fi is a big area of usage of the technology with most homes that use broadband connections to the Internet using Wi-Fi access as a key means of communication. Local area networks of all forms use Wi-Fi as one of the main forms of communication along with Ethernet. For the home, office and many other areas, Wi-Fi is a major carrier of data.

To enable different items incorporating wireless technology like this to communicate with each other, common standards are needed. The standard for Wi-Fi is IEEE 802.11. The different variants like 802.11n or 802.11ac are different standards within the overall series and they define different variants. By releasing updated variants, the overall technology has been able to keep pace with the ever growing requirements for more data and higher speeds, etc. Technologies including gigabit Wi-Fi are now widely used.

The term Wi-Fi was coined as a brand name by the Wi-Fi Alliance when they were formed and took on board the promotion of the standard.The technology uses license free allocations so that it is free for all to use without the need for a wireless transmitting licence. Typically Wi-Fi uses the 2.4 and 5 GHz ISM, Industrial, Scientific and Medical, ISM bands as these do not require a licence, but it also means they are open to other users as well and this can mean that interference exists. Power levels are also low. Typically they are around 100 or 200 mW, although the maximum levels depend upon the country in which the equipment is located. Some allow maximum powers of a watt or more on some channels.

The core of any Wi-Fi system is known as the Access Point, AP. The Wi-Fi access point is essentially the base station that communicates with the Wi-Fi enabled devices - data can then be routed onto a local area network, normally via Ethernet and typically links onto the Internet.

In Wi-Fi, the protocol architecture consists of the Open Systems Interconnection (OSI) reference model (Figure 20). This model was developed by the International Organization for Standardization. This layered model consists of the Medium Access Control (MAC) or Data Link Layer and the physical layer (PHY). The MAC layer provides the functional and procedural means to transfer data between network entities and to detect and possibly correct errors that could occur in the physical layer. In the MAC layer, the responsibilities are divided further into the MAC sub-layer and the MAC management sub-layer. The MAC sub-layer defines access mechanisms and packet formats. The MAC management sub-layer defines power management, security, and roaming services.

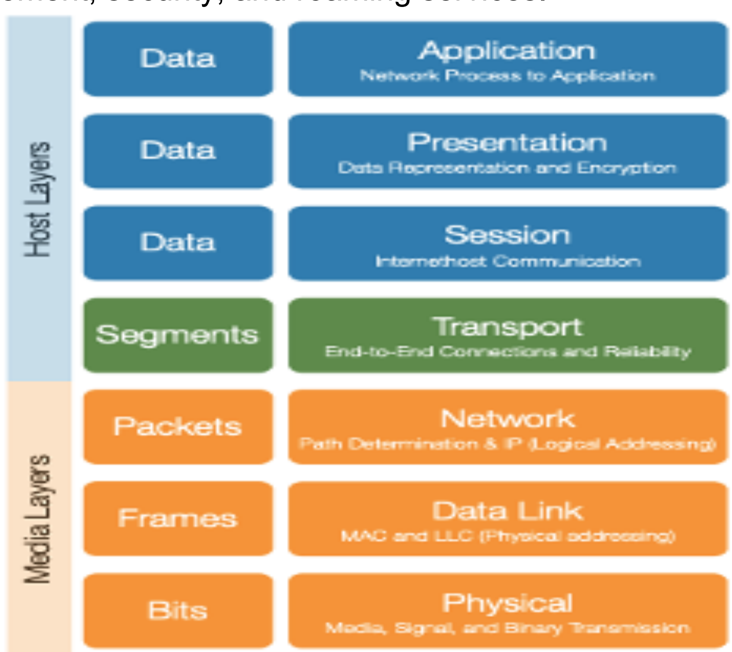


Figure 20. OSI Model

The Physical Layer defines the electrical and physical specifications for devices. In particular, it defines the relationship between a device and a transmission medium. The major functions and services performed by the physical layer are the establishment and termination of a connection to a communications medium, participation in the process where the communication resources are effectively shared among multiple users, and modulation or conversion between the representation of digital data in user equipment and the corresponding signals transmitted over a communications channel. These are signals operating over the physical cabling (such as copper and optical fiber) or over a radio link.
Public Wi-Fi access points are typically used to provide local Internet access often on items like smartphones or other devices without the need for having to use more costly mobile phone data. They are also often located within buildings where the mobile phone signals are not sufficiently strong.

Home Wi-Fi systems often use an Ethernet router: this provides the Wi-Fi access point as well as Ethernet communications for computers, printers and the like as well as the all important link to the Internet via a firewall. Being an Ethernet router it transcribes the IP addresses to provide a firewall capability.

Although Wi-Fi links are established on either of the two main bands, 2.4 GHz and 5GHz, many Ethernet routers and Wi-Fi access points provide dual band Wi-Fi connectivity and they will provide 2.4 GHz and 5 GHz Wi-Fi. This enables the best Wi-Fi links to be made regardless of usage levels and interference on the bands.

There will typically be a variety of different Wi-Fi channels that can be used. The Wi-Fi access point or Wi-Fi router will generally select the optimum channel to be used. If the access point or router provides dual band Wi-Fi capability, a selection of the band will also be made. These days, this selection is normally undertaken by the Wi-Fi access point or router, without user intervention so there is no need to select 2.4 GHz or 5 GHz Wi-Fi as on older systems.

In order to ensure the local area network to which the Wi-Fi access point is connected remains secure, a password is normally required to be able to log on to the access point. Even home Wi-Fi networks use a password to ensure that unwanted users do not access the network.

Many types of device can connect to Wi-Fi networks. Today devices like smartphones, laptops and the like expect to use Wi-Fi and therefore it is incorporated as part of the product - no need to do anything apart from connect. A lot of other devices also have Wi-Fi embedded in them: smart TVs, cameras and many more. Their set up is also very easy.

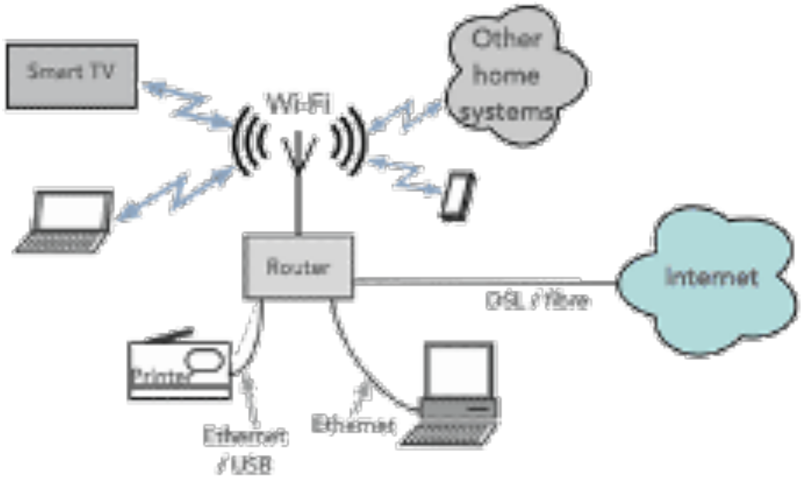


Figure 21. Home Wi-Fi System

Occasionally some devices may need a little more attention. These days, most desktop PCs will come ready to use with Ethernet, and often they have Wi-Fi capability included. Some may not have Wi-Fi incorporated and therefore that may need additional hardware if they are required to use Wi-Fi links. An additional card in the PC, or an external dongle should suffice for this.

In general, most devices that need to communicate data electronically will have a Wi-Fi capability.

Bluetooth

Bluetooth is another wireless communication technology that allows devices to communicate with each other. Using bluetooth offers us several advantages over using standard wireless technologies such as IEEE 802.11. The main one is generability, Bluetooth is a wide spread technology that is one of the main driving forces of the Internet of Things. It was designed for adding wireless technologies into embedded or microsystems such as our design. It also offers us the ability to seamless communicate with a device that most of the families already have and use, a smart phone. We don't need to bring in a new controller that they would have to maintain and keep track of, the families will be able to use already existing technologies and hardware that they are familiar with.
Bluetooth can be differentiated from Wi-Fi in such that it can operate on much lower distances and is not primarily focusing on communication to devices, instead emphasizing direct communication.

After speaking with several of the families it appears that there was also some want to be able to control the car without having to. Not steering the car entirely, as the child should be using this car to have some type of independence and freedom of movement, but course correcting and fine movement controls.

The Bluetooth standard has two or more devices setup in a wireless communication array called a “piconet”. In the piconet one device is designated as a master and the other devices are set as slaves. The slaves and masters both can communicate back and forth without issues, but the master controls the connection. Connected Bluetooth devices can also swap roles. In our design the Bluetooth module in the car will be the slave device and the family phone will be the master controller.

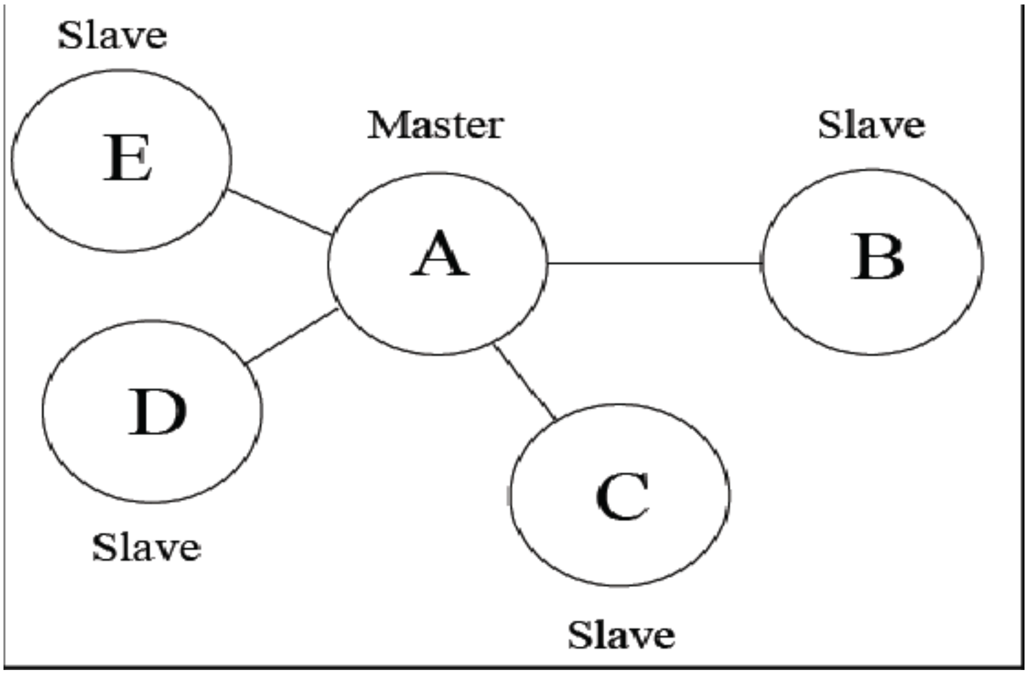


Figure 22. Piconet

Table 2 - Wireless Technology Comparison

	Wi-Fi	**Bluetooth**
Frequency	2.4 GHz/5 GHz	**2.4 GHz**
Maximum Range	70m	**100m**
Maximum Data	54-600 Mbps	**3 Mbps**
Power Consumption	50-110 mA	**5-15 mA**

As seen in the above table, Bluetooth has a much larger range compared to Wi-Fi. Also, the data rate characteristics of a Bluetooth module fit the needs of our project better than Wi-Fi. Also, a main concern of the car is the reduce power consumption and Bluetooth has a much lower power consumption than Wi-Fi.

Based on these factors our chosen wireless technology is the Bluetooth standard IEEE 802.15.1.

3.2.8 Web Applications

One of the essential parts of our project is to implement an application with features that would aid the children in terms of communication. After discussing the different options with the children's families of the types of smart devices that they might use, as a team we decided that implementing a web application over a mobile application would be more suitable. Since families use different smart devices, implementing a web application would be our best option because families will be able to use any type of smart device to use the web application.

Using web applications has many benefits over the usage of mobile applications. Not only because it can be used from any smart device but also it is better and easier from the development side. One of the main restraints with developing a mobile application is that it is way more expensive due to the fact that it requires a developer license to be able to publish the mobile application in the app store or google play store. Implementing a web application would be more convenient in terms of expenses which will lead us to save a lot of money on our given budget.

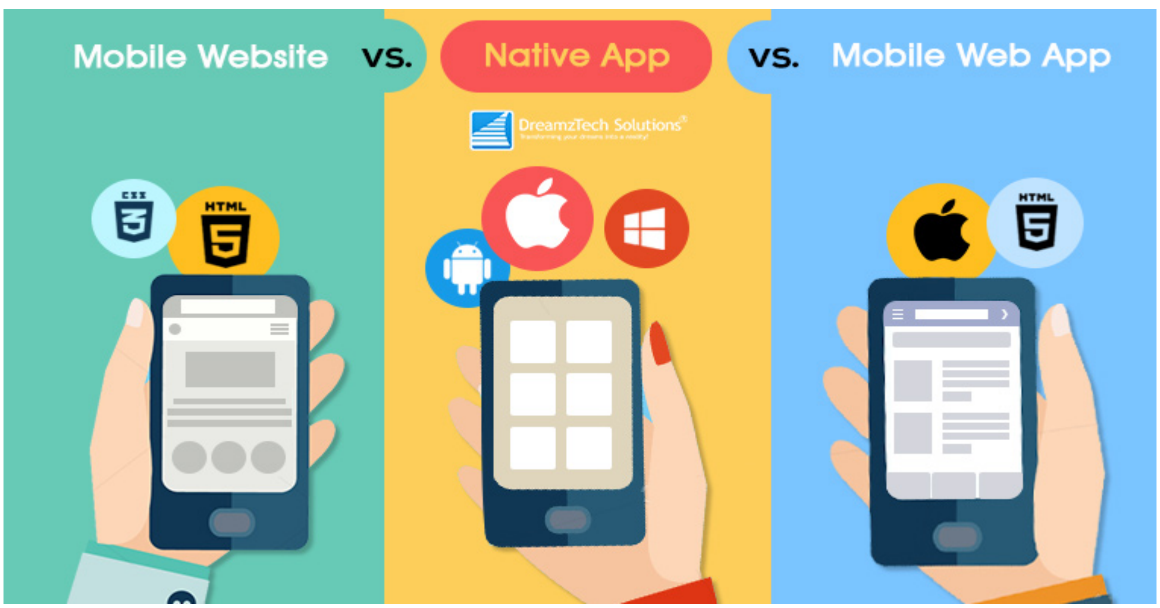


Figure 23. Mobile Website vs Native App vs Mobile Web App

Our web application will have one of the highest priorities as part of our project because through it we will develop a design to satisfy most of the requirements that we were given as part of this project. Although there is an existing version of the web application that we are trying to implement but this option is accessible to most of the families due to the price of it and also it doesn't have enough features that satisfy the families' needs.

Some of the requirements include a way for the parents to be able to turn the car on and off from distance as well as taking control over the steering capability of the car in terms of accelerating, slowing down and brake in case of any emergency situation like collision or any road hazards. Our web application will have this feature where it will allow parents to take over the control of the car and be able to turn it off and on and to steer it.

Another requirement was to allow the parents to easily communicate with their child due to the fact that most of the children lack the ability to speak and communicate their needs. Our web application will have a feature that will allow parents to add flashcards with pictures of anything that the child may want or need and they will have the capability to sort them into different categories to help their child communicate. This feature is known as augmentative communication. Augmentative and alternative communication is used by people who cannot rely on their speech. It incorporates the individual's full communication abilities and may include any existing speech or vocalization. We will be creating an aided mode of communication, which will require the form of external support such as symbols and pictures for the children to use to communicate with the parents. This is a great way to make the child be in control and help them make choices of what they need.

Our web application will have a simple user interface for both parents and children and will be easy and intuitive for anyone to use. As a team we decided that we will design two different versions of the web application. One for the parents and the other for the child. That will allow the parents to create their own account where they can upload necessary information and manage their child's account and manage the different widgets that they would like their child to interact with according to their child's needs.

Parent Account

Parents will have to sign up in the web application choosing their role as parents. This version of our web application will allow parents to manage their child account. Through their account they will be able to upload flashcards with pictures of the stuff that the child uses or interact with and they will have the ability to arrange those flashcards into categories. For example, there might be three different categories, food, clothing, and games. The pictures can be of real objects or it can be a simple image that represents something they have.

Through the parents account, parents will have a widget that will allow them to control the car. They will have the ability to turn it on and off as well as accelerate, slow down or brake the car. After speaking with parents, this feature was one that most families agreed on since it will act as a safety mechanism.

One family has two children that will receive a modified car, so the app will also have each child's car as a separate page so that the parents can easily switch between the two.

Child Account

Children will have to be signed in into their corresponding version of the web application with their role as child. This version of the web application will be simple and intuitive for the child to use. The child will have the access to the categories of flashcards that the parents added through their account.

The Attainment Company has created the app GoVisual, which is an augmentative communication program that can convert photos and videos into literacy and communication opportunities. This app can allow users to draw hot spots with their finger, incorporate speech to text, offer options for multiple images, send scenes wirelessly to nearby devices, provide the Transition to Literacy feature. However, this app is 50 dollars and can be quite expensive for parents to purchase. We are suggesting a free flash card application for the children to use for their basic communication needs.

This version of the web application will be linked with the car capability of determining where the child is at the moment and this will help the application to only show the child the category with the items related to the place that the child will be at. The child then will only see the category of flashcards related to the place they are at with the car and this will help in narrowing down the choices of flashcards they can choose from. For instance, if a child enters the kitchen, the web app will determine their location and will display the category with flashcards of food options. Then the child will have to choose one of the options displayed through the flashcards and the application will then read the option that the child chose. This will help in making the child feel that they made a choice and act as their voice.

Technologies that will be used in the web application

One option that was discussed to be used is LAMP stack as the web service for our application. It is a very common example of a web service stack, named as an acronym of the names of its original four open-source components: the Linux operating system, the Apache HTTP Server, the MySQL relational database management system (RDBMS), and the PHP programming language. The LAMP components are largely interchangeable and not limited to the original selection. As a solution stack, LAMP is suitable for building dynamic web sites and web applications.

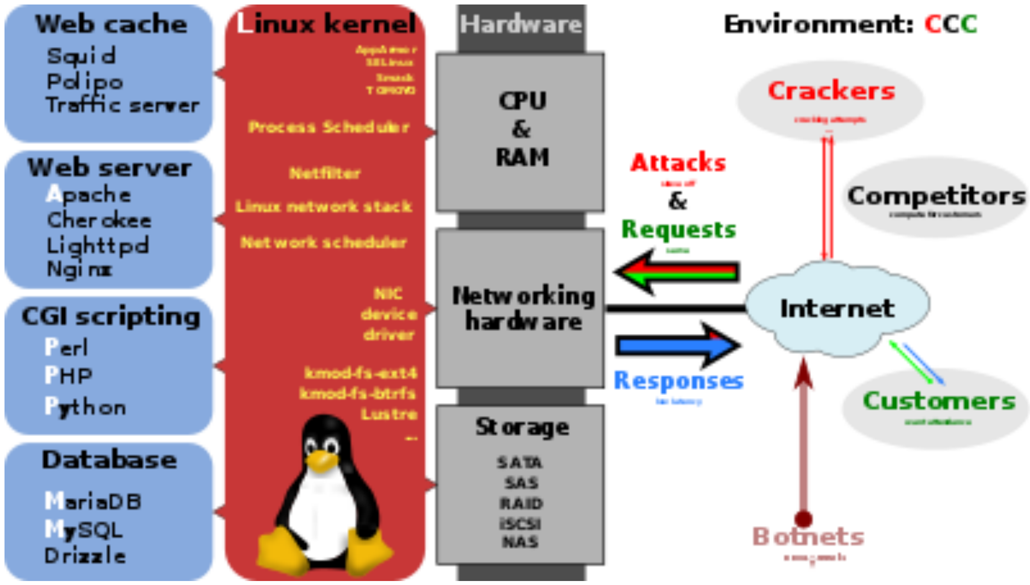


Figure 24. High level overview of LAMP's building blocks

Table 3 - LAMP Stack Components Comparison

	Pros	Cons
Linux	• Used by almost everyone. If you are not using C# or some microsoft variant, you are most likely using linux. • Very Stable. • Lots of freedom and control. • Better security. • So many distros and so much free, open source software. • Large Community.	• Does not run many windows programs. • There is a learning curve to learning how to use it.
Apache	• Most popular web server currently. Reliable. • Feature-rich. • Multi-threaded. • Works great alongside PHP.	• Can have performance problems when under heavy stress. • Multi-threaded.
MySQL	• Many major websites use MySQL. • Reliable.	• Not as mature and less feature-rich

	• Scalable. • Open Source and designed with focus on the web.	than other applications. • Not as open source as it used to be.
PHP	• Speed up custom web application development. • Simplify web application maintenance. • No need to write additional code. • Work with databases more efficiently. • Automate common web development tasks.	• Programmers need to learn PHP frameworks instead of PHP. • Affect Speed and performance of websites. • Lack of options to modify core behavior.

Another option is to use MERN stack. MERN Stack is a Javascript Stack that is used for easier and faster deployment of full-stack web applications. MERN Stack comprises 4 technologies namely: MongoDB, Express, React and Node.js. It is designed to make the development process smoother and easier. Each of these 4 powerful technologies provides an end-to-end framework for the developers to work in and each of these technologies play a big part in the development of web applications.

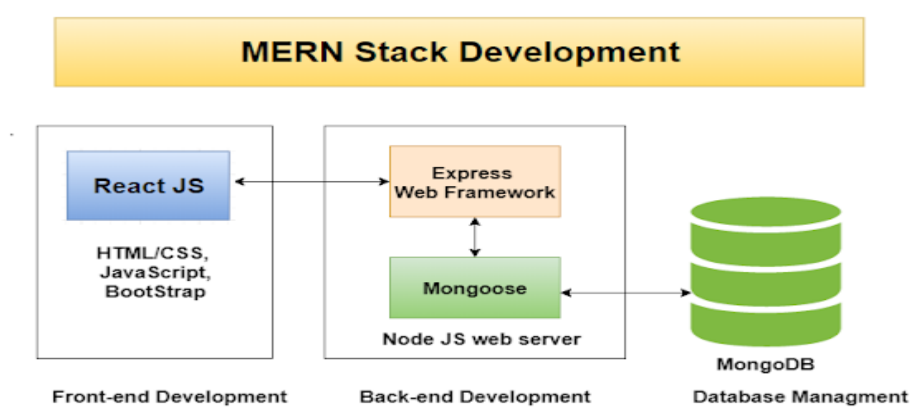


Figure 25. An overview of MERN's building blocks

Table 4 - MERN Stack Components Comparison

	Pros	Cons
MongoDB	● MongoDB scales elastically in terms of data volume and throughput. ● The flexible data model with dynamic schema, and with powerful GUI and command line tools, makes it fast for developers to build and evolve applications. ● MongoDB stores data in flexible JSON-like documents, which makes data persistence and combining easy.	● MongoDB doesn't support joins like a relational database. Yet one can use joins functionality by adding by coding it manually. But it may slow execution and affect performance. ● MongoDB stores key names for each value pair. Also, due to no functionality of joins, there is data redundancy. ● To achieve the performance and scalability, MongoDB ditches the transaction support.
Express	● Asynchronous and Single-threaded. ● It is fast and scalable. ● It helps with code reusability using a built-in router. ● Robust API.	● More challenging to learn compared to other languages.
React	● Virtual DOM makes the user experience better and developer's work faster. ● It relies on a virtual-DOM and re-render only what has really changed, hence better performance-wise ● Helps tight binding of values or handling of local variables vs global variables ● One-direction data flow provides a stable code	● Integrating with some of the MVC frameworks would require one to be aware of what configuration changes to go through. ● The learning curve for the developers is quite high, ReactJS should not be the first one to start with for any new WEB developers.
Node.js	● It is open-source, friendly, and easy to use. ● Node.js can help you use the web app and the	● Node.js's API or the application programming interface keeps changing continuously. It isn't

	server easily. This is because you have the same code which runs in the server-side end and as well as the same code which runs in the client-side. ● Powerful server-side applications can be built with Node.js.	consistent at all. ● Node.js makes you write everything from scratch. It might result in a decrease in productivity, slowing your work down. ● Node.js doesn't support multi-threaded programming yet. It is able to serve way more complicated applications than Ruby, but it's not suitable for performing long-running calculations.

A comparison was made for both stack options. LAMP is a traditional web stack, but it is as useful as other stacks are. It has many other advantages that make it the right stack to use. For example: LAMP is scalable and easily customizable. In the case of LAMP, developers use PHP as a standard APACHE module and upload PHP files through a MySQL Database to an APACHE server. A key advantage of MERN is that developers can use JavaScript code on a server as well as client side. But it also eliminates security when both the server and the client codes are the same. On the other hand, working with JavaScript also makes it a lot easier for developers to work.

Table 5 - LAMP vs MERN Stacks Comparison

	LAMP Stack	MERN Stack
Pros	**Scalability:** The web stack is scalable. A web solution made using LAMP grows or shrinks with the increase in demand. **Fast development:** There are built-in open source libraries and frameworks that make it easy to quickly develop a web app.	**Javascript:** Using MERN stack, every single life of code is written in Javascript, which is used on both server and client side. **Easy development:** As only one programming language is used, it becomes easy for

	Security: LAMP is securer than many other web stacks in the market right now, thanks to the latest updates and the security architecture it provides to developers.	developers to quickly develop a web app.
Cons	LAMP is not the latest web stack and might get outdated after some time in future due to the adoption of MERN.	The support community is no way comparable to LAMP.

As a result of the comparison made between the two different stack options, LAMP stack and MERN stack, We decided to use LAMP stack in our web application development because of its many advantages over the MERN stack as well as the amount of the available free resources that could be used to help us through the development process of our LAMP stack web application. LAMP stack appears to be the more secure option and as one of the main concerns about security issues that developers face when it comes to web application development, LAMP will help in our process of creating a secure web application that parents and children can use without having concerns regarding the security of their data.

GoDaddy will be used as our domain registrar and web host. A domain registrar is a company or entity that is responsible for handling the sale, registration and management of domain names, a domain registrar must be an ICANN Accredited Registrar to be allowed access to the domain registry that they will interface with.

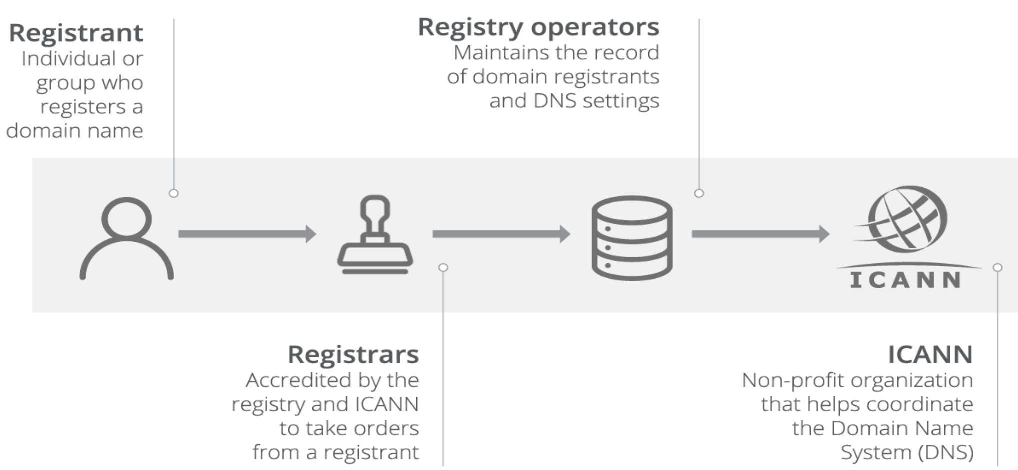


Figure 26. Domain registry process

A Web Host is someone who sets up, manages and sells space on web servers, this is a program that accepts requests from web browsers and delivers web pages. Once the hosting company hosts your website, users can access it by typing in your web address (domain name) in their web browser. When they do this, their computer connects to the server your website is hosted on. The server in turn serves (sends the files you have stored on the storage to display) the website to your web visitor in their web browser. There are a lot of web hosting options available including shared hosting, WordPress hosting, reseller hosting, dedicated hosting and VPS hosting. Our web application will be hosted through the dedicated hosting option. Dedicated hosting will give us complete, administrative control over our server with full root access.

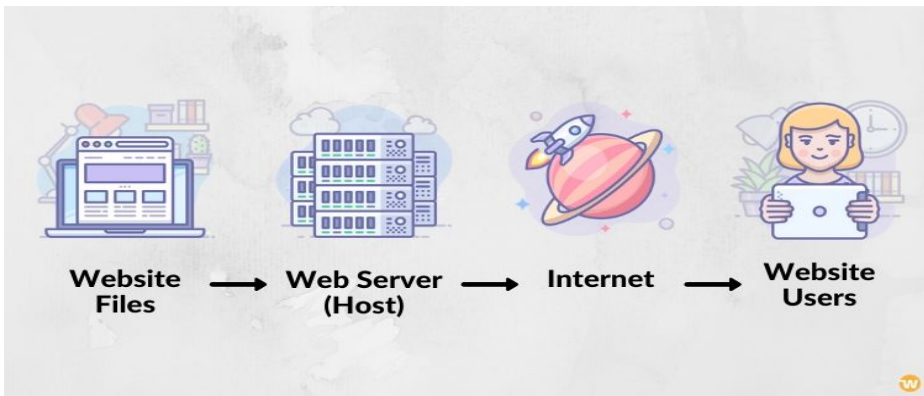


Figure 27. Web Hosting Process

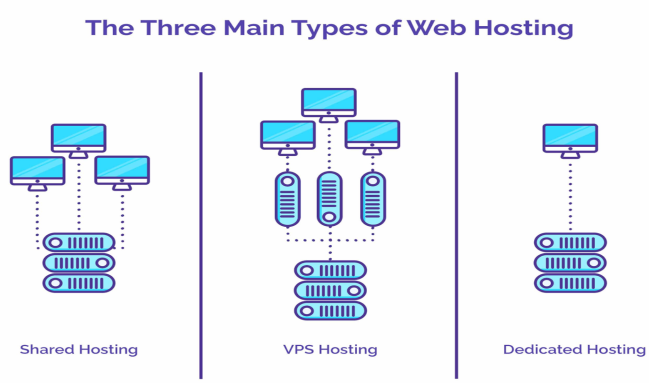


Figure 28. Web Hosting Options

GoDaddy deals with every type of service to start a website. The company offers fast and reliable hosting service at a very affordable range. GoDaddy hosting provides one of the cheapest platforms to host websites. There are a lot of features and tools that GoDaddy provides including free website building, online file manager, many resources and great security and protection.

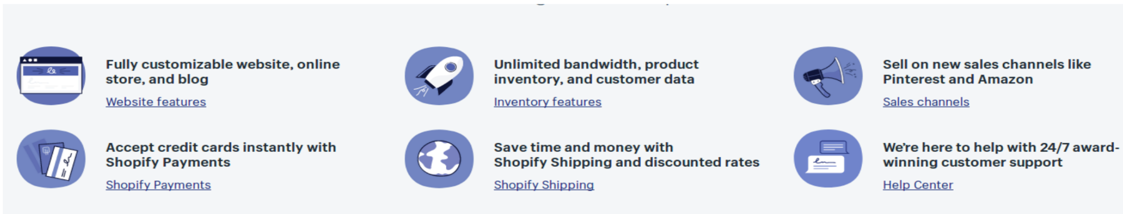


Figure 29. GoDaddy tools and features

GoDaddy is providing free website builder in their hosting plans. GoDaddy website builder gives professional looks to the website. It provides thousands of free templates by which we can create our website attractively. This will help us to modify our website design without any extra cost.

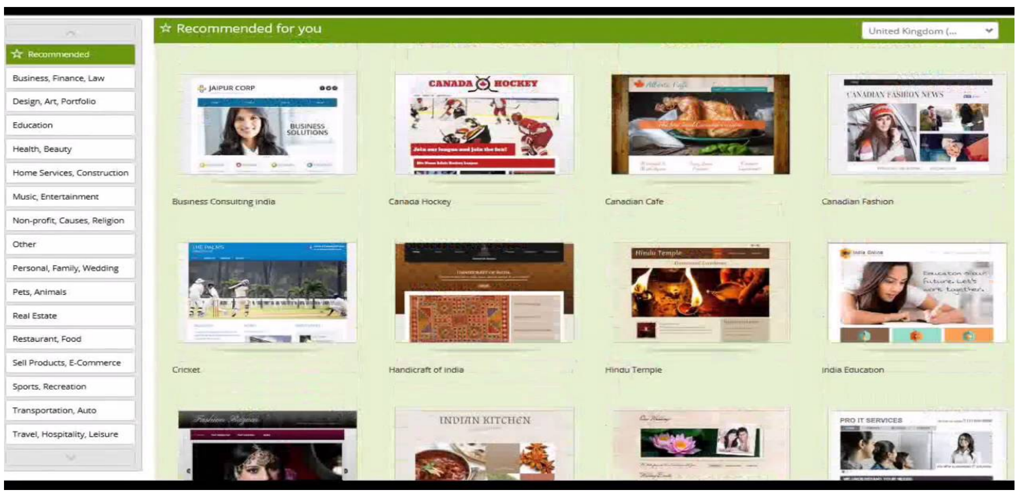


Figure 30. GoDaddy Website Builder Tool

GoDaddy provides the Online File Manager which allows us to make changes anytime. No matter where we are, if we notice something we can just make the changes. If we want to make changes in any of the GoDaddy websites then we can easily change by using the online File Manager.

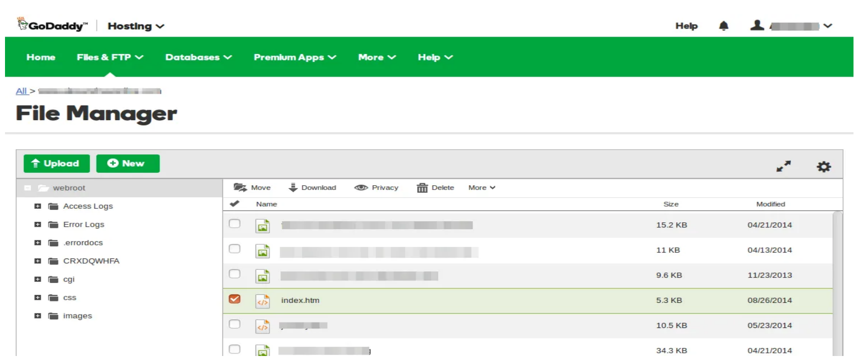


Figure 31. GoDaddy File Manager tool

3.2.9 Location-Based Technology

The children that will be driving this car have difficulty with verbal communications. Therefore, parents need to use flashcards to communicate with their children. We are developing an application that will hold all these flashcards for the children to use to communicate with their parents. However, it was requested for there to be an easier and faster way to have a certain category of flashcards appear based on location. For example, if the toddler is in the kitchen with the car, then kitchen-based flashcards will appear for them to use to communicate with their parents.

Global Positioning System Module

When thinking about location-based features, the most common and popular device is a Global Positioning System or (GPS). GPS is a satellite-based navigation system made up of at least 24 satellites. GPS works in any weather conditions, anywhere in the world, 24 hours a day.

GPS satellites will circle the Earth twice a day and each one will transmit a unique signal and orbital parameters that allow GPS devices to decode and compute the precision location of the satellite. These receivers use the information and trilateration to calculate the exact location. The receiver can measure the distance to each satellite by the amount of time it takes to receive a transmitted signal. A picture of this procedure is shown in Figure 32.

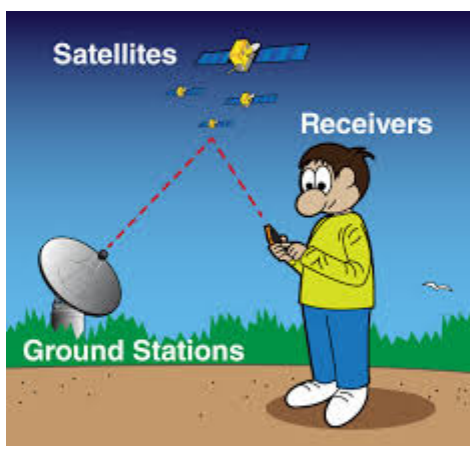


Figure 32. Global Positioning System

The signals that are transmitted by GPS satellites are low-power radio signals. These signals will travel by line of sight and can pass through clouds, glass, and plastic. However, they will not be able to go through solid objects, such as buildings. A disadvantage of the GPS is that it is difficult to use indoors, specifically within a small range. Two of the four families will be using their car primarily indoors, so the GPS will not be able to detect if the car is in the kitchen or the living room because of such an enclosed space. Simply put, it will not be accurate enough. Another potential issue is that for the families who want to use the car outside, they would have to input the exact latitude and longitude coordinates that they want certain flashcards to appear at. After inputting these coordinates, they would have to ensure that they drive the car over that exact location anytime they want the flashcards to appear automatically. If the parents want to take the car to the neighborhood park, they would have to enter the park at the exact location every single time, which might not be possible. It would also be complicated for the parents to input these coordinates, and an important feature of this project is a simple user-interface. Due to these concerns, the GPS will not be in consideration for this project.

QR Code Reader

A quick response (QR) code is a code that is easily read. These are essentially machine-readable 2D barcodes that give people information. Unlike regular barcodes, QR codes can deliver a lot of information. For example, if a smartphone is used to scan a QR code, it can open up a website or an application, as shown in Figure 33.

Figure 33. Smartphone scanning a QR Code

The modern-day QR code consists of seven parts. Each part creates a pixel pattern that has a specific purpose of conveying certain information through the code. Each part is known as a module. They are the black and white blocks that can make up the data that is encoded in a QR code as seen in Figure 34. The QR code scanner is able to translate and identify the information inside a QR code using Finder Patterns.

QR codes are widely used and popular for various companies in order to advertise their businesses. There are also various types of QR codes, depending on the size, which can be used for different applications. There are also plenty of QR code APIs available that will be able to assist us in generating the correct QR codes for the family.

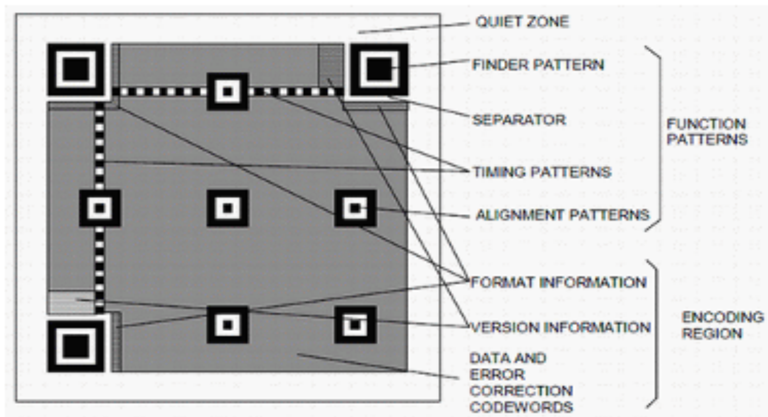


Figure 34. QR Code Modules

Selection of Location-Based Technologies

As seen from the table, the GPS module does not work well indoors, which is a huge disadvantage because some parents want to use their car outside. Also, inputting the coordinates for every new location can be troublesome for the parents to do as they are taking care of their child.

By utilizing QR codes, the parents of these children can place them in different rooms and as the children drive into that room, the scanner on the car will be able to scan those codes and retrieve the correct flashcards categories. For the families that will primarily use this car outdoors, we will implement a feature where they will be able to pull up the flashcard categories on their child's tablet using the web app interface that we are creating.

Table 6 - Advantages and Disadvantages of Location-Based Technologies

	Advantages	Disadvantages
GPS	• Low Cost • Accurate outdoors • Available anywhere • Always updated and maintained	• Difficult to use indoors • Input coordinates for every location • Child needs to drive through that same location for

		the location feature to work • Cannot go through solid objects
QR Code	• **Free and inexpensive** • **Versatile** • **Can be used for anything** • **Works well indoors and outdoors**	• **Requires a specific camera to read the QR codes** • **Child has to ensure that they drive in front of the QR code** • **Could not be read properly**

Due to these considerations, our team will be implementing a QR code scanner in the Go Baby Go cars.

3.2.10 Switches

One of the children that we are designing the electrical system for has difficulty with their motor control. Specifically, they will clench their hands into a fist and not release that pressure. According to the parents, a joystick would not be a suitable controller for the child to use. The parent has requested a device that allows the child to physically touch in order to move the car forward with a manual handle to steer the car.

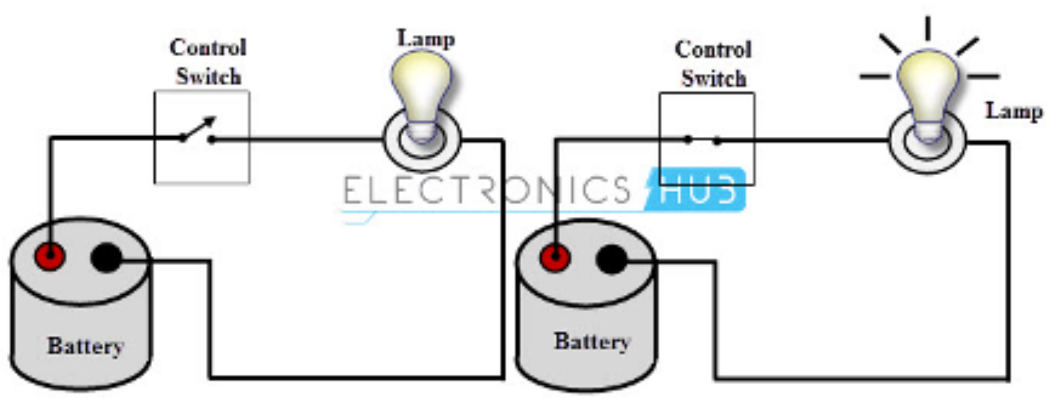


Figure 35. Switch Diagram from Electronics Hub (reprinted with Permission from Electronics Hub)

A switch is a device that is used to interrupt the flow in a circuit, so that it can make or break the circuit. They are essentially binary functions, which can perform two functions, fully ON (closed) or fully OFF (off). As seen in Figure 35, when the switch is closed, the switch can create a closed path for the flow of the circuit. When the switch is flipped to open, no power will be consumed.

There are two main types of switches: mechanical and electronic. Mechanical switch requires the user to perform a physical action in order for it to activate. Electronic switches do not require any pressure for activation. They are usually activated by a semiconductor. Due to the nature of this project, mechanical switches will be considered because the child needs to be able to physically control the car.

Mechanical switches can be classified into different types based on different features, such as method of actuation, number of contacts, number of poles, operation, and states.

Single Pole Single Throw Switch (SPST)

A SPST switch consists of a single pole and a single throw (Figure 36). A pole represents the number of individual power circuits that can be attached and the number of throws represents the number of states that the current can pass through. A SPST switch is a basic ON and OFF switch, which consists of one input contact and one output contact. It’s functionality consists of switching the single circuit which can make or break the load.

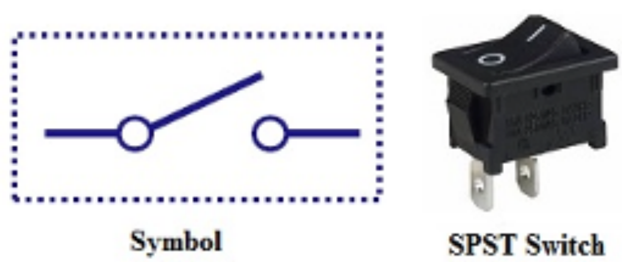


Figure 36. SPST Switch

Single Pole Double Throw Switch (SPDT)

This switch has a single pole but double throws. It has three terminals, one for input contact and the other two for output contacts. Therefore, this switch consists of two ON positions and one OFF position. As seen in Figure 37, these types of switches are primarily used when there are two devices in a circuit that need to be turned on or off.

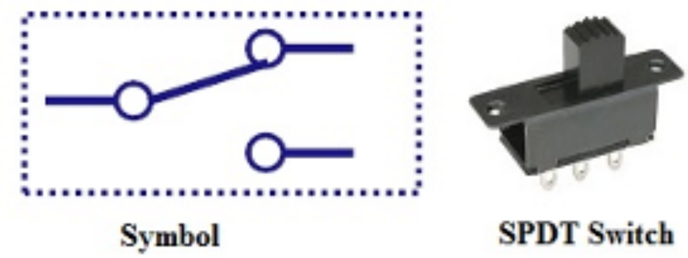


Figure 37. SPDT Switch

Double Pole Single Throw Switch (DPST)

The DPST switch consists of four terminals, with two input contacts and two output contacts. It’s behavior is similar to two separate SPST switches that are operating at the same time. While it only has one on position, it can simulate the two contacts at the same time, so that each input will be connected to the correct corresponding output.

While the switch is in the off position, both switches are at an open state. This particular switch (Figure 38) is usually used to control two different circuits at a time.

Figure 38. DPST Switch

Toggle Switch

A toggle switch is manually activated by a mechanical handle, level or rocking mechanism. They are commonly used as light control switches. These switches come with two or more lever positions which are in version of SDPT, SPST, DPST, and DPDT switches. Some other toggle switches will have an internal spring mechanism returning the lever to a certain normal position, which allows for momentary operation.

Figure 39. Toggle Switches

Push Button Switch

Push button switches are two-position devices actuated with a button that is pressed and released. Most push button switches have an internal spring mechanism returning the button its “out,” or “unpressed,” position, for momentary operation.

Some pushbutton switches will latch alternatively on or off with every push of the button. Other push button switches will stay in their “in,” or “pressed,” position until the button is pulled back out.

Generally, this pressure is supplied by a button pressed by someone’s finger. This button returns its normal position, once the pressure is removed. The internal spring mechanism operates these two states (pressed and released) of a push button. It consists of stationary and movable contacts, of which stationary contacts are connected in series with the circuit to be switched while movable contacts are attached with a push button. Push buttons are majorly classified into normal open, normally closed, and double acting push buttons.

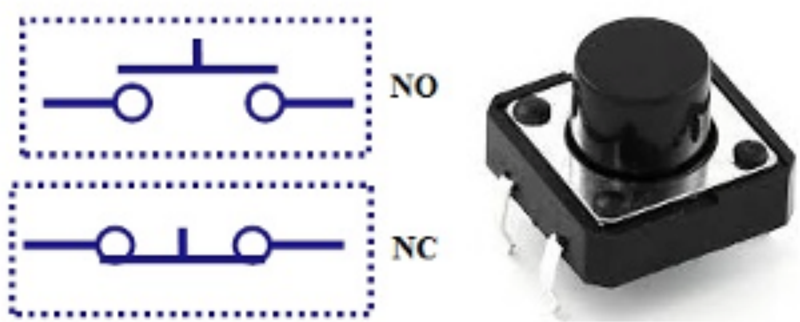


Figure 40. Push Buttons

Due to the parent's request for the child to be able to push a button in order for the car to go forward, the senior design team is selecting Push Buttons for one of the child's car. The intended child is very young and the parents only want him to have the ability to go forward, so a push button will be able to provide that functionality. When the child pushes the button, the connection to the motors would be made and the car would move forward. When the child releases the button, the connection would break.

3.2.11 Zero Turn Radius

When every car makes a turn, there is a certain turning radius. The turning radius is the smallest circular turn that the vehicle is capable of making. Due to the fact a lot of young children will be using the car, they might not be able to properly judge the distance it takes to turn a car. Cars with a zero radius turn are vehicles that can take a sharp turn about a vertical axis passing through its center of gravity. The vehicle will be able to rotate in the circle having a diameter equal to its length, eliminating the requirement for the additional space. This type of turning system is seen lawn mowers and Jeeps.

Specifically with the Jeep Hurricane, there is a four-wheel independent steering. This entail that each wheel can turn independently from one another. The vehicle has two modes of four wheel steering. In the first mode, front tires and rear tires will turn in opposite direction and reduce the turning circle. In the second mode, front and rear wheels will turn in the same direction, which helps park at narrow spaces without changing direction. Therefore, to implement these turns the front two wheel and back two wheel need to move in the opposite direction in order to create this skid turn.

For cars with only a two-wheel steering capability, the use of caster wheels would be an alternative. A caster wheel is an undriven, single compound wheel that allows the object to be moved in any direction. These are mainly used in shopping carts and hospital beds. These wheel are on a rotating mount and allow a free range of movement, which would be beneficial in this situation. With the use of castor wheels, the front two wheels would be able to freely move in any direction the back wheels are turning.

A disadvantage of caster wheels are that they are difficult to use in large vehicles. A few of the power wheel vehicles need to support larger children so the weight would not be supported correctly. In the cases when there is only a two wheel steering option and no caster wheel support, we will attach two extra motors to the front wheels of the car in order to create zero turn radius capabilities.

3.3 Part Selection

3.3.1 Microcontroller

3.3.1.1 Comparisons of Microcontrollers

After researching and investigating the microcontrollers mentioned above, the team was able to narrow down their choices to 4 units. The factors that are taken into consideration with selecting a microcontroller are power consumption, cost, memory, I/O pins, and clock frequency. Table 7 compares all the following features throughout the different microcontrollers.

Table 7 - Microcontroller Features Comparison

	MSP430FR6989	MSP430FG4618	MSP432P401R	**ATmega328P**
Lowest Operating Voltage	1.80V	1.80V	1.80V	**1.80V**
Power Consumption	0.180 mW	0.720 mW	0.129 mW	**0.360 mW**
Cost per Unit	$3.30	$12.20	$14.29	**$2.08**
Flash Memory	128KB	116KB	256 KB	**32 KB**
RAM	2 KB	8 KB	64 KB	**2KB**
GPIO Pin Count	83	80	48	**23**
Output Current per Pin	20 mA	12 mA	100 mA	**100 mA**

Clock Frequency	16 MHz	10 MHz	48 MHz	**20 MHz**

Power

When speaking with the parents of the four children, a major concern that was brought up was that the Go Baby Go! cars would lose power after only an hour of use. The battery life of the cars is a major concern because the children want to be able to use their cars for extended periods of time to practice their motor controls and gain mobility independence. The microcontroller will be powered through the 24V DC battery that are included in every car, so it is essential that it does not use too much power to function. All four microcontrollers have the same operating voltage. The MSP430FG4618 has the highest power consumption compared to the other microcontrollers. Therefore, this unit would draw in the most power when it is performing and could possible result in a lower battery life. On the other hand, the MSP432P401R and MSP430FR6989 have extremely low power consumptions, which would be advantageous to the design of the system. However, it is stated in the ATMega328P user guide that by disabling many of the internal peripherals of the unit, such as SPI, UART, ADC, and timers, the power consumption could potentially be lower.

Cost

Another important aspect of this project is the cost. Since there will be five different cars (four that go to the children and one that the senior design team uses to prototype) that will need to be integrated and implemented with the printed circuit board, it is essential to keep production cost low. Potentially this system will be integrated into future Go Baby Go! cars, so it would be economically sound to be conscious of the price per unit.

As shown in Table 1, the MSP430FG4618 is the most expensive while the ATmega328p is the least. All of these prices are the cost per unit, so the actual cost would at least 5 times that is given. The argument can be made that the MSP430FG4618 has more features and capabilities, such as a higher flash memory size, which could justify the price. However, with a limited budget, the ATmega328P is the most economically favorable decision.

Memory

Microcontrollers normally have 3 types of memory. The RAM, Flash, and EEPROM (Figure 41). The RAM (random access memory) is the type of memory where data must be read and written to repeatedly. This is the dataspace that is used to temporarily store data and variable values that are used by the microcontroller during execution. It is volatile in the sense that it cannot retain data in the absence of power, so it is lost after the power is turned off. Specifically in microcontrollers, there is SRAM, static RAM which is fact and be accessed in the range of a few nanoseconds. The more RAM a system has, the more it can process data, therefore allowing more complicated functionality.

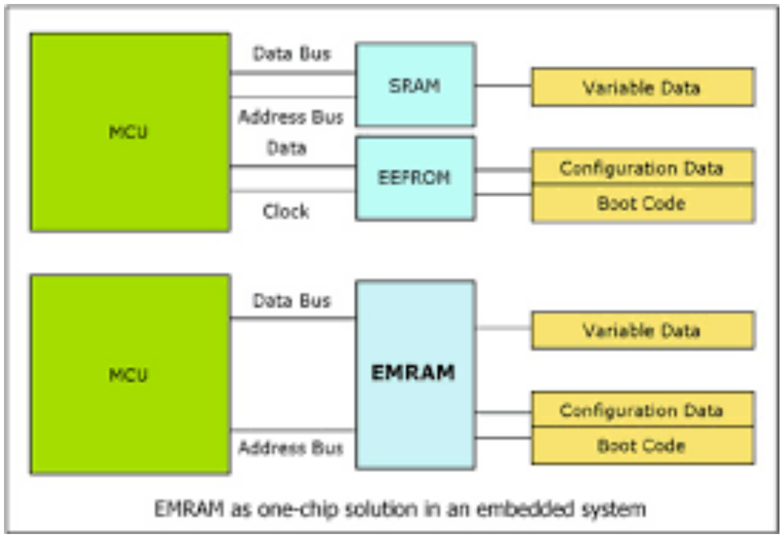


Figure 41. Diagram of Memory Allocation in Microcontrollers

The MSP432P401R has the most amount of physical ram size compared to the others. With 64KB it will be able to efficiently execute complicated programs, which would be advantageous for the Go Baby Go! team due to the various sensors, motors, cameras, and web app that need to be connected and used by this unit. This incredible ram size could also factor into the high pricing of this unit. The ATmega328P and the MSP430FR6989 have the lowest physical ram size, so it would not be able to run as complicated programs as the MSP432P401R.

Flash memory is non-volatile. This means that it is memory that normally stores data that does not change. This is essentially the program memory, in which it stores the part of the microcontroller program that is fixed and will always stay permanent. The advantageous feature of flash memory is that it does not require a power source to retain its data, so once the microcontroller is disconnected from the battery it will still retain its contents. The majority of the code for the microcontroller will be stored within the flash memory. Similarly to the RAM size, the MSP432P401R has the most amount of flash memory, while the ATMega328P has the lowest amount. This further exemplifies the memory capabilities of the MSP432P401R and the potential functional uses of this device.

EEPROM, which stands for electrically erasable programmable read-only memory, is the third type of memory in a microcontroller. It is a type of non-volatile memory that is used to store relatively small amounts of data but allowing individual bytes to be erased and reprogrammed. This type of memory will not be utilized by the Go Baby Go! system, so it will not be used as a comparison metric.

General Purpose Input/Output Pins

With the Go Baby Go! system, there are many peripherals that will be used and need to function properly, so it is essential that the microcontroller chosen will be able to receive input from these devices, output instructions to these devices, and process this data. Specifically, the collision detection sensors and servos motors will need to be attached through GPIO pins to the microcontroller and have a high enough output current to power all of them. These pins act as switches that output 3.3 volts when set to high and no voltage when set to low. In the metric of GPIO pin count, the MSP430FR6989 has the highest number of 83 I/O pins, while the ATmega328P has the lowest at 23 I/O pins. However, the ATmega328P and the MSP432P401R have the greatest power capability with each pin. Each pin for those two microcontrollers can output a current of 100 mA, whereas the MSP430FR6989 can only output 20 mA per pin. This aspect needs to be considered while choosing a microcontroller because each sensor and motor need to be powered.

Clock Frequency

The clock frequency is often referred to as the speed of the microcontroller, specifically the rate at which it takes to execute instructions. The CPU requires a fixed number of clock cycles to execute an instruction. The faster the clock, the more instruction the CPU can execute per second. Toddlers and children will be utilizing the Go Baby Go! cars in order to practice motor skills and while using the car they will be making sharp turns and driving close to other objects. It is important the collision detection sensors are able to process the distance of obstacles from the car in order to keep the driver safe and out of harm’s way. The MSP430P401R microcontroller has the fastest clock frequency at 48 MHz compared to the other, which means that the time it takes to complete 48,000,000 clock cycles on this microcontroller will be faster than the others.

Microcontroller Choice: ATmega328P

After comparing the different metrics of the four chosen microcontrollers, the Go Baby Go! car senior design team will be using the ATmega328P unit. Throughout all the comparisons of the different units, the MSP432P401R had the highest performance in the majority of metrics. Such as having a three times faster clock frequency, eight times more RAM size, and double flash memory storage. The MSP432P401R also has a simple SDK that would assist with connecting the unit through Bluetooth. It would seem like this microcontroller would be the obvious choice; however, it is the most expensive unit out of the four. With a limited budget, we would not be able to afford at least five of these microcontrollers while also buying other parts. Another consideration is that this high performing microcontroller would essentially be over complicated for the Go Baby Go! Car's system. With so many GPIO pins and memory, a lot of it would be unutilized due to the nature of the system and the amount of peripherals. With this microcontroller, no one in the group has any experience with using it. While there are various resources and Texas Instruments has a support desk, there could be the potential problem of spending a lot of time on programming this unit. None of the team members have any experience with designing a PCB board and adding another system that no one has any experience in could lead to detrimental results. Due to these reasons, the MSP432P401R will not be used in the PCB.

The MSP430FR6989 and the ATmega328P are extremely similar in terms of cost, with only a dollar differentiating between the two. The MSP430FR6989 has a lower power consumption compared to the ATmega, so it would not consume too much power from the battery. While it has the same physical RAM size, the MSP430FR6989 has four times larger flash memory, which would be advantageous with the coding of the system. However, it has a lower clock frequency compared to the ATmega328P, so it would execute less instructions in the same amount of time as the ATmega328P. Ultimately, the biggest drawback of the MSP430FR6989 is the output current per pin. It is only 20 mA and with various sensors, motors, cameras, and Bluetooth module, this unit would not have enough current to sustain powering and processing the data from those peripherals. Therefore, due to the low output current per GPIO pin, the MSP430FR6989 and the MSP430FG4618 will not be considered for this project.

The ATmega328P is not the most powerful microcontroller of the ones that were compared. However, it is the microcontroller that best suits this team's needs. With such a limited number of peripherals that will be connected to the microcontroller, there is no need for an extensive number of pins. The ATmega328P's 23 pins will be more than enough to connect every peripheral. Most importantly each pin has an output current of 100 mA, so it will be more than enough current to power everything. Another benefit of this microcontroller is that it has a clock frequency of 20 MHz, which will allow more instructions to be executed and allow the parents and children to enjoy the car without too much delay. While the RAM size is on the lower end, many of this team's group members have used an Arduino board to power and control the same sensors and motors that will be used in the project and have not recorded any issues of delay. Therefore, the 2 KB of RAM should be sufficient enough for this system. An essential factor of the ATmega328P is its low cost of $2.08 per unit. With such a low cost, the Go Baby Go! team will be able to order many PCBs with this microcontroller for debugging, prototyping, and implementation purposes without financial strain.

As stated before many members of this team are familiar with the Arduino system having used it in internships and class. In general the team feels most comfortable with programming and utilizing an ATmega328P, because it is the same microcontroller used with Arduino. Another benefit is that the Go Baby Go! team is planning to develop a prototype of their system using an Arduino board. Since the ATmega328P can be pre-loaded with an Arduino bootloader, any code that is used in the prototype can be transferred onto the microcontroller with no modification. Also, since this microcontroller is prevalent in Arduino systems, there are a plethora of resources and guides that can be used if the team needs any assistance.

Due to the economic, sustainability, efficiency, power, and usability reasons explained before, the senior design team will use the ATmega328P as the microcontroller for the Go Baby Go! Car.

3.3.2 Joystick

The specifications provided by the parents require the cars to be modified to fit the needs of the different children. Most of the children are unable to operate a steering wheel, and it was decided to replace that element with a joystick. The biggest advantage to using a joystick over a steering wheel is that it is much easier to operate for the children and will allow them to select the direction in which the car will be moving.

Digital Joysticks

These types of joysticks are the most popular. They can perform four different commands which include: Right, Left, Up, Down. Digital joysticks have been largely manufactured by the gaming industry since Atari games came out. We considered using digital joysticks for our project since there is a large set of documentation and are easy to program using Arduino.

A digital joystick module for Arduino has a market price around $20.00 to $120.00 dollars depending on the size and functionalities. Most models will include other programmable features such as buttons and lights. The main digital joystick model we have considered for our project is Newark JS5208. This model is displayed on Figure 42. This joystick model has a contact voltage of 15V and a maximum contact current of 20mA.

Figure 42. Newark JS5208

Paddle Joysticks

These types of Joysticks also most commonly used in the gaming industry, consist of a knob and one or more buttons. A paddle controls the absolute position and gives direction. If we look at the car that we are currently working on, we can see the similarities with this type of joystick. The knob will be the steering will give the car direction, and the buttons will move the car forward and stop the car.

Since the specifications of the project do not match this joystick type, we will not be using it on our project. The knob is one of the components that we are planning to replace since some of the children have difficulties controlling the car with a steering wheel. For reference, we can look at Figure 43. We will find paddle joysticks that are used for Atari video games.

Figure 43. Atari 2600 Paddle Joystick

Analog Joysticks

These types of joysticks combine both Digital and Paddle joysticks. The joystick uses internal digital electrical contacts for right, left up and down commands. The position on this joystick is the center by default and can move in any of the four directions mentioned above. Commonly, analog joysticks have dual sticks. This joystick model became popular as 3D environment gaming started to develop.

The biggest drawback to analog joysticks are the analog to digital conversion and the processing power. For some conventional analog joysticks there will be an analog to digital conversion. This process is often not very accurate and could possibly cause difficulties when reading the inputs. The second disadvantage is the processing of power. The position of the stick needs to be known at all times. This takes up a lot of power that could have been used for other operations. This model can be visualized on Figure 44.

Figure 44. PDM502 Analog Joystick

Joystick choice: Analog 2-axis Joystick

After extensive research and careful consideration, our choice for our joystick will be a 2 axis analog joystick model. This model can be visualized on Figure 45. The main reason why this model was decided to be used on our project is because of the compatibility with the already existing motor vehicle and the programming process. This joystick is a powerful module and once connected to the car will allow the driver to choose the speed and direction at which the car will be moving.

Figure 45. Analog 2-axis joystick

- **Technical Details :**

  Usable with any voltage up to 6V.
  Two Analog outputs.
  1miliamp draw when exceeding 6V
  1.5" wide x 1.5" long x 1.25" tall

- **Software implementation**

  These joystick modules can be programmed with Arduino. This will be a major advantage since our team members are familiar with the Arduino interface. This module in particular has the simple functionalities that we are looking for. The two analog outputs to be programmed are X and Y. They will determine the direction at which the joystick will be moved.

- **Electrical compatibility**

  The joystick has three hardware components that need to be assembled. The first one is the joystick itself. Next, a rubber cover for the stick and an electrical breakout board.

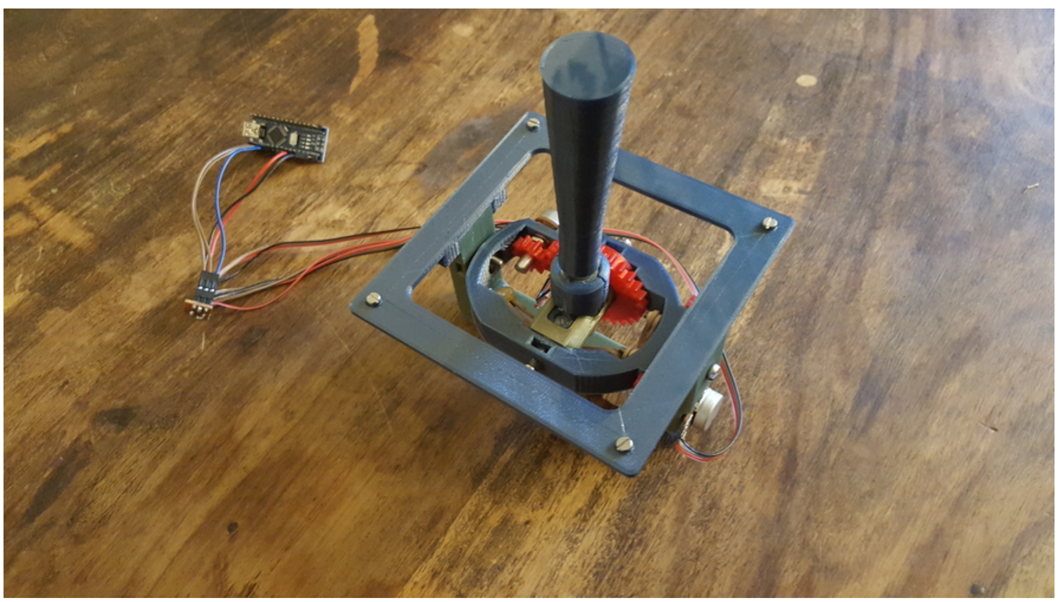


Figure 46. Joystick with 3D printed component.

- **3D printed component:**

  To provide better accessibility and movement, a 3D printed joystick handle has been considered. This will essentially be an extension attached to the module that will help the child manipulate the vehicle more comfortably. The joystick module we have chosen is significantly small for the car that we will be working on. Therefore, making a 3D design will allow us to create a personalized model for the child. Once adapted, the 3D printed piece should be as functional and responsive as the module itself. A sample of a 3D printed stick attached to a joystick is shown in Figure 46. and Figure 47.

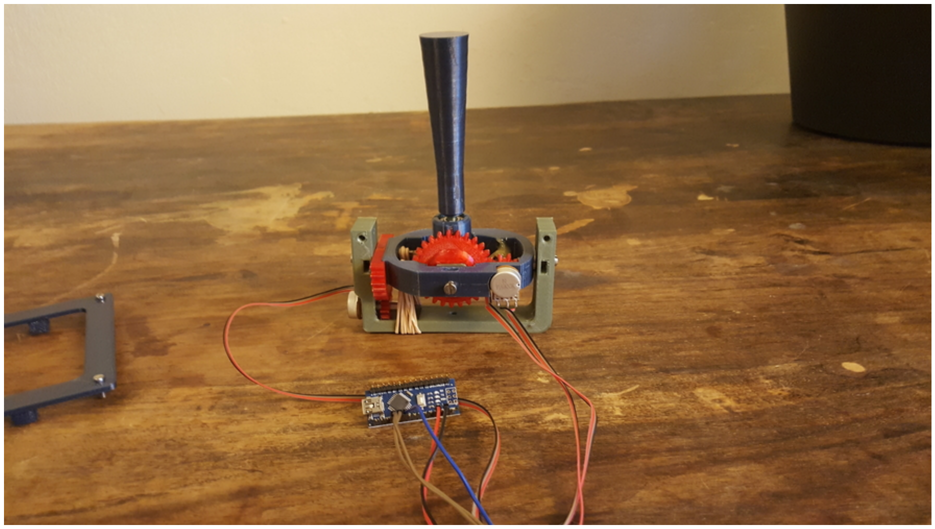


Figure 47. Joystick with 3D printed component.

The major advantages to this model are pricing, easy software implementation and the use of the Arduino interface. Analog 2-axis joysticks are very accessible. Their market price is around $5.00 to $10.00 dollars. It is a very common module and there are multiple manufacturers that produce it. Selecting this module fits our budget and will allow us to spend more budget in other components that we still need to purchase and design to modify the joystick implementation. Second biggest advantage is the software implementation for the module. In previous classes at UCF, we have learned about software implementation for joysticks. This applied knowledge will help our team be successful on this part of the project. These joystick modules are compatible with Arduino which makes the programming clear and straightforward. Since the joystick will be programmed for its regular functionalities there are plenty of resources we can use to program the module.

The functionalities that the joystick will have are up, down, left and right. These movements will translate to our car as forward, backward, left and right. When the joystick is in the origin position the car will come to a complete stop. The speed will also be controlled by the joystick. When the joystick is moved forward it will slowly ramp up to full speed the longer the joystick is held. Similarly, once the joystick is released and back to origin position it will decelerate at double rate to ensure the driver is able to stop the car completely with more efficiency. Left and right will give direction to the car.

The major drawback on this module is the size. This joystick design is 1.5" wide x 1.5" long x 1.25" tall. A conventional joystick with capabilities to control a moving vehicle come in bigger sizes for better grip and more precision. Our approach to resolving this problem is to add the 3D modification that was previously discussed. This will increase the price of the total budget planned for our joystick, but it will still be less than $250.00 in total.

3.3.3 Sensors

Collision detection sensors are sensors that will be able to detect an upcoming obstacle in the Go Baby Go! Car's pathway. Once these sensors detect an obstacle within a certain distance, it will automatically stop the car until the driver moves further away. The overall method to how these sensors measure distance is that they output a signal and measure a certain delta when the signal returns. The sensors that will be considered and compared for this project are ultrasonic, infrared, and LIDAR.

Ultrasonic vs. Infrared vs. LIDAR

It is essential that the sensor chosen for this project fits all the requirements and needs of the car. These cars will be driven by toddlers and if these sensors fail to detect obstacles, then it could potentially put them in harm. Another added benefit of the sensor is that it will allow parents to keep their distance from the car, instead of standing right next to it and helping their child steer. The following tables list the advantages and disadvantages of each sensor type.

Table 8 – Advantages and Disadvantages of Ultrasonic Sensors

Advantages	Disadvantages
Not affected by object color and transparency	Limited detection range
Works in various environments (indoors and outdoors)	Low resolution and slow refresh rate
Works in dim lighting	Not suitable for detection of fast-moving targets
Consumes low current and power	Unable to measure the distance of objects with extreme textures.

Multiple interfacing options	

Table 9 – Advantages and Disadvantages of Infrared Sensors

Advantages	Disadvantages
Small size	Limited measurement range
Use in daytime and nighttime	Low usability with hard object
Secure communication	Affected by environmental conditions
Measure distance of objects with extreme textures	

Table 10 – Advantages and Disadvantages of LIDAR Sensors

Advantages	Disadvantages
High range of measurements	Expensive
High range of accuracy	Harmful to the naked human eye
Suitable for faster objects due to the faster refresh rate	Large Power Consumption
Functional in day and nighttime	

After investigating the advantages and disadvantages of three different types of sensors (see Table 8 through Table 10), we have decided that the LIDAR sensors will not be selected for this project. The largest drawback of these sensors is its price. Since this sensor is so powerful, accurate, and can detect distances up to a large range, it becomes much more expensive. The cheapest LIDAR sensor that could be found is the SparkFun Range Finder Sensor for $25.95. Since, it is expected that a single car will have at least six sensors and the fact that there will be at least four different cars that are implementing these sensors, the cost of this sensor exceeds our budget. Also, the LIDAR sensor has a lot of high-functioning features that are not needed for the Go Baby Go cars, so a lot of these features would not be utilized. Another factor to consider is that these sensors consume a lot of power from the battery, which we have mentioned before is a concern of the parents. Due to these circumstances, the LIDAR sensor is out of consideration.

The team then considered the advantages and disadvantages of the ultrasonic and infrared sensors and compared them below in Table 11.

Table 11 – Ultrasonic vs Infrared Sensors

Ultrasonic	**Infrared**
Works in different environments (light and dark)	Small size
Color and transparency do not affect the accuracy	Use in daytime and nighttime
Longer range of distance measurements compared to the infrared	Secure communication
Can detect hard objects: walls and doors	Measure distance of objects with extreme textures
Lower Power Consumption	Faster refresh rate and response time (able to detect fast-moving objects)
Better Accuracy	Low Supply Current

The infrared sensors are smaller, faster, and overall cheaper than the ultrasonic sensors. They would be very easy to attach to the exterior of each car without wasting too much space and would not cause a financial strain. These sensors could also be beneficial due to the fact that it can detect fast-moving objects, which would be helpful when the toddler is driving the car.
However, the major drawback of the infrared sensors are that they cannot be used outside due to the sunlight interfering with infrared waves. Two out of the four children plan to use their car exclusively outside, so these sensors would not be able to function. Another disadvantage is that these sensors cannot detect hard objects such as walls. The other two children plan to use their car inside, so these sensors would not be able to detect any incoming walls or doors. Overall, using these sensors would not prevent the drivers from crashing and hurting themselves.

Due to these factors, the infrared sensors will no longer be considered for this project.

The senior design team has ultimately decided to use ultrasonic sensors based on these factors.

HC-SR04 Ultrasonic Sensors

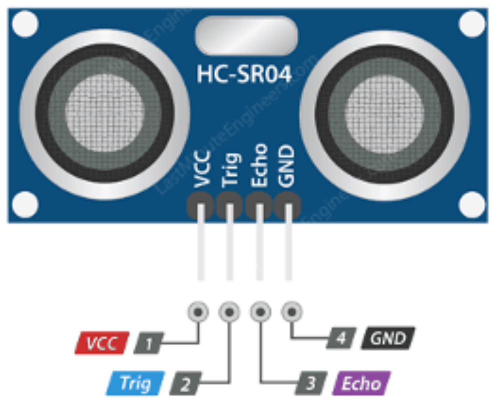


Figure 48. HC-SR04 Ultrasonic Sensor

The HC-SR04 ultrasonic sensor is the most common and popular type of ultrasonic sensor. The sensor is compatible with Arduino and Raspberry Pi, so this sensor would be able to interface with our chosen microcontroller. This sensor consists of two ultrasonic transducers. One of these transducers acts as a transmitter, which can convert electrical signals into a 40 KHz ultrasonic sound pulse. The other transducer, otherwise known as the receiver will listen for those pulses. As seen in Figure 49, the Trig pin is used to trigger the ultrasonic waves, while the echo pin produces the pulse when the reflected wave is received. This pulse is what is used to determine the duration of the transmitted wave.

The pulse of this particular sensor is 10 microseconds long and applied to the trigger pin. Then, the sensor will transmit a sonic wave of eight pulses at 40 KHz. This pulse pattern is unique to this device and it is what is received by the transducer. This way the sensor can differentiate between the actual sonic wave transmitted and ambient noise. Once the pulses travel away from the transmitter, the echo pin switches to HIGH in order to start the echo signal. If the waves are not reflected back, the echo will timeout after 38 milliseconds and switches to low, as shown in Figure 49. This indicates that there is no object blocking the sensor's path. However, if the sound wave is reflected back, then the echo pin switches to low as soon as it is received.

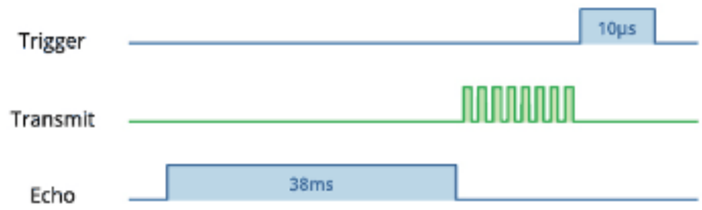


Figure 49. Diagram of the HC-SR04 Signals if No Obstacle is Present

MB1030 LV-MaxSonar-EZ3

The MB1030, LV-MAxSonar-EZ3 is a compact sonar range finder developed by Matbotix. A benefit of this sensor is that it has no “dead zone” and detects small objects very close to the sensor. This sensor works in the same manner as the HC-SR04 sensor, in which a sound wave is emitted, reflected back, and the duration used to calculate distance. This sensor is very popular with indoor use and has consistent reading in a compact size. A picture of this sonar range finger is shown in Figure 50.

Figure 50. Picture of MB1030 LV-MaxSonar-EZ3

Parallax 28015 Sensor

The Parallax 28015 ultrasonic sensor provides an easy method of distance measurement. This sensor is able to perform measurements of stationary and moving objects. A great advantage of this sensor is that it is very easy to interface with a microcontroller. As seen in Figure 51, this sensor only has three pins, specifically a single I/O pin. This I/O pin is used to trigger and transmit a sound wave and listen for the reflected wave or echo. Another interesting feature of this sensor is that it has a burst indicator LED that will indicate if a measurement is taking place. This sensor uses the same procedure as the HC-SR04 and MaxSonar sensors to detect obstacles.

Figure 51. Picture of Parallax PING Sensor

Ultrasonic Sensor Comparisons

Our team has narrowed down our ultrasonic sensor choices to the three described above. It is important for us to ensure that we select the right sensor for this project. In Table 12, all three sensors' metrics were compared to one another.

Table 12 – Sensor Metrics Comparison

	HC-SR04	MB1030 LV-MaxSonar-EZ3	Parallax PING
Range	**2-400 cm**	15-645 cm	2-300 cm
Angle of Measurement	**15 degrees**	15-45 degrees	15 degrees
Operating Current	**15 mA**	2 mA	30 mA
Cost Per Unit	**$3.95**	$21.95	$27.07

According to Table 12, the Parallax PING sensor is the worst performing compared to the others. It has the smallest distance range and the largest operating current. While there would only be one I/O pin being used for this particular sensor, the pricing of it makes it infeasible. With at least 6 sensors being purchased per car, the cost per sensor is not economically favorable. Due to these considerations, the Parallax PING sensor will note be used in this project.

Comparing the MaxSonar with HC-SR04 sensor, it is obvious that the MaxSonar out performs the HC-SR04 in almost every metric. It has 1.5 times more the range, meaning that this sensor can detect objects from a larger distance away. It has a greater angle of measurement, meaning that it would be able to detect more obstacles in its peripheral view. This could be beneficial because it would reduce the amount of sensors needed for each side of each car. Finally, this sensor has a very low operating current, so it would not consume too much power from the microcontroller.

A disadvantage of this sensor is that the minimum distance an obstacle needs to be in order for the sensor to detect it is 15 cm. This would not be feasible for driving the car indoors, where every obstacle will be much closer than that range. Another drawback is that the pricing of the MaxSonar makes it unfeasible for this project for the same reasons as the PING sensor. Purchasing this sensor would cause us to spend over budget; therefore, the MB1030 LV-MaxSonar-EZ3 sensor is no longer in consideration.

The HC-SR04 sensor has a distance detection range from 2 to 400 cm. This is particularly desirable for our project because the minimum detection range is so low, which would ensure that the car could be driven indoors and still be able to detect various obstacles. Another feature of this sensor that is desirable is the cost per unit. It is such an inexpensive sensor that we will be able to purchase the right number for every car and not exceed our limited budget. As a side note, two members of this team have these particular sensors in their inventory due to previous classes and side projects, which would considerably lower the overall cost of these sensors.

There are a few disadvantages with the HC-SR04 ultrasonic sensors. The sensors need to transmit a sound wave to a surface that is hard and flat to receive an echo. If the surface is not flat, such as gravel, the sensor will retrieve an echo, therefore believing there to be an obstacle. The greatest disadvantage is that these sensors will require time for the transducer to stop after each transmission burst before they are ready to receive the echo. This can result in slower sensor response times than other technologies at about 0.1 seconds. Changes in the environment such as temperature, pressure, and air turbulence could affect the response as well. Despite these disadvantages, the practical for obstacle detection.

As stated before, the HC-SR04 sensor is the most popular and compatible sensor used in the industry. There are many guides and tutorials for this sensor and it is widely used with an Arduino board, which is what we are using to prototype our Go Baby Go car. One of our team members has used these particular sensors extensively with their research and as a group we feel most comfortable using this. Due to the factors discussed above, the Go Baby Go senior design team will select the HC-SR04 sensors as the collision detection sensors for this project.

3.3.4 Bluetooth Modules

Our design is supposed to be repeatable by the UCF Go Baby Go project for all of the vehicles that they will be producing in the future. The parts that they will want to use need to be readily available on the market and have drop in replacements in case they are ever unavailable. Because of this our main concerns with selecting parts is availability and simplicity in case they ever need to be replaced. Another concern is ensuring that the module will be able to communicate with our web based application through a cell phone. Reviewing what is generally available for Bluetooth modules we were able to narrow down our options to the two following modules.

HC-05

A general purpose Bluetooth module chip. It follows the IEEE 802.15.1 standard protocol and lets us transmit data back and forth with a USART interface. We are also able to set the baud rate, but we most likely will use the default of 9600. The password and discovery are both configurable through a microcontroller, so it can be easily set up once it has been programmed. It supports ranges up to 100m, more than enough distance. As well as it can communicate with a phone or computer device. The price varies between $5.00 on some component stores and $8.00 depending on manufacturer through Amazon. The downside is the modules require a current of 30 mA and a 5V power source. This is doable with our design, but it is a high power consumption.

HM-10

A different type of Bluetooth chip. This one still follows the IEEE 802.15.1 standard, but instead uses UART connections to communicate back and forth, this is a more well known serial communication and does not have to worry about synchronous transfer. It does also allow us to communicate up to 100 M in open spaces. And has a similar price point of $8.00 on most component stores and $10.00 on Amazon. The main advantage of this module is it was designed for low power applications as it is a BLE (Bluetooth Low Energy) module. It requires 235 uA and 3.6 V power source. A much more efficient power consumption.

Table 13 - Bluetooth Module Comparison

	HC-05	HM-10
Bluetooth Interface	Bluetooth V2	Bluetooth 4.0 BLE
Distance	Less than 100 meters	100 meters
Price	$5.00	$10.00

Amperage	30 mA	0.235 mA
Voltage	5V	3.3V
Serial Interface	USART	UART

The main deciding factor for us is power consumption and the interface that is used. Using lower power lets the vehicle run for a longer time and reduces the number of times that the end user has to charge the vehicle. A smaller power usage also gives our circuit a smaller power usage footprint. Using standard UART also lets us not have to worry about Synchronizing the data between modules. More modules, including phones, support standard UART over USART. So for our design we will move forward with the HM-10 bluetooth module.

Due to these considerations, we will be using the HM-10 Bluetooth Module for the Go Baby Go car.

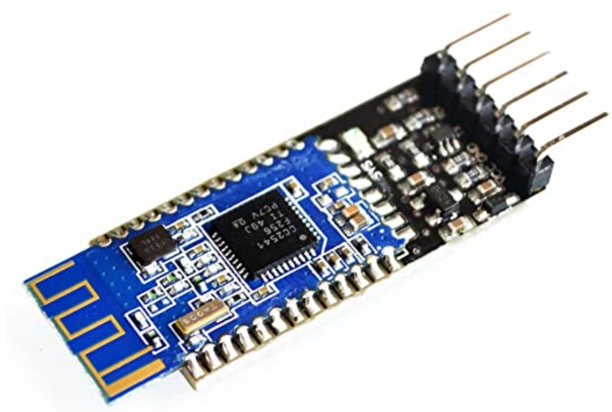


Figure 52. Bluetooth Hm-10 module connected to GPIO board

3.3.5 Stepper Motor

Our main concern with the stepper motor is it’s accuracy and repeatability. The cars and light weight devices, only supporting a max weight of 65lbs, and do not need a large amount of torque to turn the wheels because of this.

STEPPERONLINE Nema 17 1A Stepper Motor Bipolar 17HS08-1004S

Each step turns 1.8 Degrees of rotation which lets us have 200 unique positions on the steering column. However, one concern would be that this is a high torque stepper motor and we are using it to turn a plastic or aluminum steering column. It can easily damage the interior if for any reason the stepper motor tries to over turn the steering column. This stepper motor has a 1 A draw for it's power and provides 3.5 Ohms of resistance, meaning it has a power of 3.5 Watts and has 13N/cm of torque. This should not be enough to damage the steering column, but it may also not be enough to turn the wheels when the vehicle is not moving

STEPPERONLINE Nema 17 Stepper Motor Bipolar 2A 17HM19-2004S

Similar to their other offering this stepper motor also has 1.8 Degrees of rotation with 200 unique positions, but instead has 2A of current draw and has 1.4 Ohms of resistance. Meaning it has 5.6 Watts of power, but offers 59 N/cm of torque. This is closer to the kind of force that would be needed to turn a wheel when the vehicle is at rest with the cars that Go Baby Go is using.

Nema 23 CNC Stepper Motor 425oz-in Bipolar 1.8deg 4.2A Stepping Motor

A motor that offers a significantly higher torque holding point. It is able to hold 3N/m of torque at rest and draws 4.2A at its peak through 0.9 Ohms resistance. Using up up to 16 Watts of power instead. This is hopefully more on the extreme end of what we would need to. This would also have to run on the same power source that is already in the car and may end up using a large amount of battery power to turn the vehicle.

Table 14 - Stepper Motor Comparison

	STEPPERONLINE Nema 17 1A	**STEPPERONLINE Nema 17 Stepper Motor Bipolar 2A**	**Nema 23 CNC Stepper Motor 425oz-in Bipolar 1.8deg 4.2A**
Amperage	1A	2A	4.2A
Resistance	3.5 Ohms	1.4 Ohms	0.9 Ohms
Degrees per rotation	1.8 Degrees	1.8 Degrees	1.8 Degrees
Holding Torque	0.13 N/m	0.59 N/m	3 N/m

3.3.6 QR Code Scanner

Our team has decided to implement a QR code scanner in the Go Baby Go cars. By utilizing QR codes, the parents of these children can place them in different rooms and as the children drive into that room, the scanner on the car will be able to scan those codes and retrieve the correct flashcards categories. This will allow the parents to not constantly retrieve the correct flashcards for the children and help them gain independence.

ESP32-CAM

In order to scan and read a QR code, a lot of image processing needs to be done. Usually a smartphone or Raspberry Pi would be able to process these images due to their processing powers, whereas a singular Arduino board could not. Therefore, we would require a portable device that is able to process QR codes and send that information to the web application.

Our team has selected the ESP32-CAM (Figure 53) module to read QR codes. The ESP32-CAM is a full-featured microcontroller that also has an integrated video camera and a microSD card. It’s an inexpensive, compact-sized device that is compatible with various devices and is able to perform advanced functions such as image tracking, image recognition, and QR code processing.

This module has the ESP32s microcontroller which is an ultra-low power consuming device that is used in various wearable electronics. The ESP32-CAM however includes the OV2640 camera module which is a 2 megapixel sensor which has an image transfer rate of 15 to 60 frames per second. The most interesting feature of the ESP32-CAM is that it can perform as a complete standalone system and interface with other systems because it has Wi-Fi and Bluetooth functionality. This would be essential when connecting to the web application.

This system also has a small footprint of only 27 x 40.5 x 4.5 mm, which makes it much easier to attach to any region of the car. The ESP32-CAM is compatible with home smart devices, wireless identifications, and wireless monitoring. It has a DIP package and can be inserted into a packlane for rapid production as well. The ESPs’ microcontroller is a low power 32-bit CPU, so it will not consume too much power from the car’s limited battery source. It also supports image Wi-Fi upload and has multiple sleep modes as well. It also has a clock speed up to 160 MHz, 520 KB of RAM, and 9 GPIO ports. The ESP32-CAM is very low cost and would not put any strain on our financial budget.

Due to these considerations, the team is selecting the ESP32-CAM module as their QR code scanner.

Figure 53. ESP32-CAM Module

3.3.7 Buttons

Due to the parent's request of using a push button for their child's car, the senior design team will be implementing a push button for the car. With input from the mechanical engineering team designing for that same car, it was determined that the button would be situated in the middle of the original steering wheel. This is to ensure that the steering and driving capabilities are all placed in one single component. Since, this child will be using handles to steer the car from the wheel, the most ergonomically sound solution is with the button on the wheel as well. Figure 54 shows the specific wheel that will be situated with a button and the dimensions of that wheel.

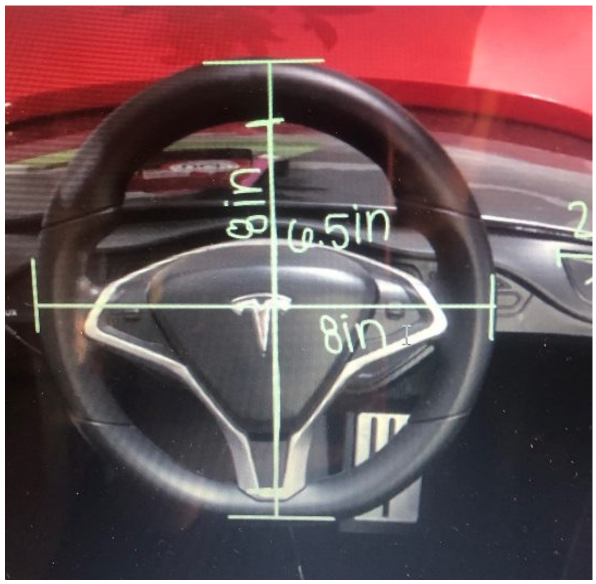


Figure 54. Dimensions of Steering Wheel

Tactile Switch Button

The most common type of push buttons that have been used by the senior design team are the medium-sized momentary switches shown in Figure 55. However, these switch buttons are only 12mm x 122mm x 6mm tall, which are too small for the child to use to drive the car.

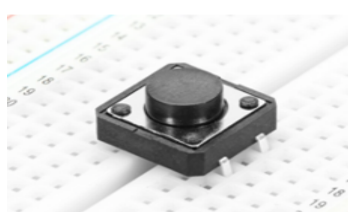


Figure 55. Tactile Switch Button

Arcade Button with LED

These specific push buttons are buttons that are usually seen in arcades. An advantage of these buttons is that they are easy to mount on nearly any kind of enclosure. These types of buttons have a flat plastic cover with a black retaining ring around it as seen in Figure 56. The LED has a built in resistor which can be run up to 12 V.

Figure 56. LED Arcade Button

There are various sizes of these types of buttons and we are selecting to choose the 100mm (3.94 inches) diameter arcade button, which will be easy to mount to the steering wheel (Figure 57). The microswitch terminals are 0.187” wide and the LED connection terminals are 0.25”, as seen in Figure 58.

Figure 57. LED Arcade Button inside Steering Wheel

The button will be wired through a relay in order to avoid sending high amperage to the button, as it should only be used to send signals and not current. The specific color of the wheel will be decided by the child.

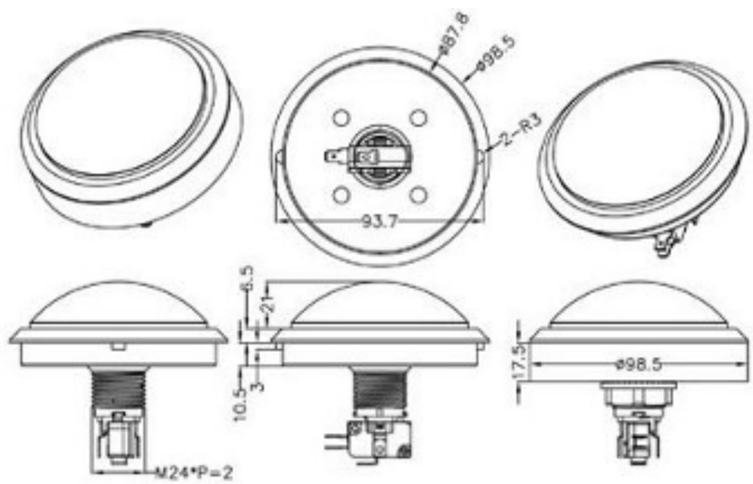


Figure 58. Technical Details of LED Arcade Button

4. Related Standards and Realistic Design Constraints

4.1 Bluetooth standards

Bluetooth standard was standardized by “Institute of Electrical and Electronics Engineers” (IEEE) as IEEE 802.15.1, but the standard is no longer maintained and the technologies related to bluetooth now goes beyond IEEE 802.15.1. The technology for bluetooth is now maintained by Bluetooth Special Interest Group and has a new update roughly every two years since 2006. Adding various features to improve the security and reliability of wireless technologies. Mainly with a focus on “Internet of Things”. The idea that embedded devices can communicate freely with each other over the internet.

4.1.1 Bluetooth low energy

Bluetooth low energy (BLE) is a branched version of Bluetooth that was developed by Nokia for cell phone usage and has now been adopted by the Bluetooth special interest group as a part of their standard. The technology uses the same frequency as Bluetooth to communicate, but instead uses frequency-shifting modulation to reduce the power draw on the Bluetooth’s device battery. When on the device only draws 15 mA of current and in a sleeping state it will pull 1uA to maintain a clock signal. The drawback is low Data throughput, capping out at roughly 1 Mbps. However, in the Go Baby Go application we will only be updating the main device about the state of a controller which will never use more than 1 Mb of data.

One issue that we will have to address is the handshake, or connection of devices. Once the car is on it will need to link up with the parent’s phone, advertising as a slave device, and the tablet for the car and then no longer broadcast once both connections are made. The Bluetooth specification has several “Channels” that devices can broadcast on so we will have to address scanning through each of the channels depending on the type of device that this will be connecting to.

Bluetooth devices mainly communicate through a serial connection that has to be established through a key exchange. One of the devices will broadcast that it is looking for a new device to join and any devices can respond to their request to pair. The process of pairing devices is shown in Figure 59.

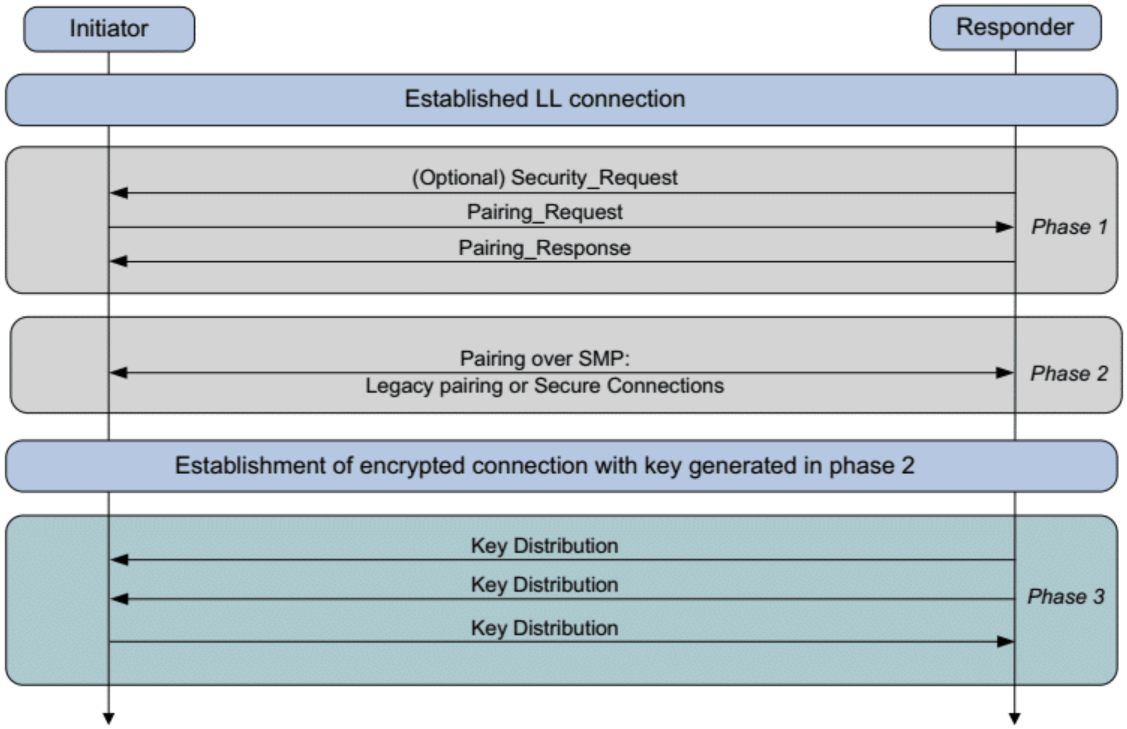


Figure 59. Bluetooth Pairing diagram

4.1.2 Web based Bluetooth Connection

We will also be passing the connection through the phone or tablet to a web host application. This means that the web application will need to be able to interact with the bluetooth devices, most likely needing permission to access the device as well. Mozilla provided an API that interacts specifically with the Bluetooth Low Energy standard devices. It allows for passing data between the browser and a bluetooth module, such as those included in phones. This is what will enable us to communicate over bluetooth through the web application.

The standard layouts a set of API calls that can be made by any browser to allow access to bluetooth devices through the browser app. Through this API we will be able to use JavaScript in the web browser to get access to the bluetooth modules that will be housed on the circuit board..

The standard is currently supported across all phones through at least one web browser. Thankfully most of our end users will be using an Android or Ipad which currently use Chrome and Safari as their default browsers, both of which support this standard and have been implemented in their current versions per the chart provided in Figure 59.

4.2 IPC PCB Standards

One of the most widely used industry standards in the manufacturing of printed circuit boards is IPC. The IPC (Association Connecting Electronics Industries), is an association which aims to standardize the production and assembly requirements of electronic equipment and assemblies. These standards are an important part of the process for a PCB contract manufacturer. Some of the IPC assembly standards include IPC-A-600, which aims at the standards for incoming inspection of bare boards from a PCB fabricator. This describes the ideal, admissible, and non-negotiable conditions that are observable on printed boards. The IPC/WHMA-A-620C, which is used for the manufacturing of cables used in conjunction with PCB assemblies. The IPC-6012 is used for quality and performance specification for rigid printed circuit boards, which are used for single side, multilayer, and active embedded circuitry printed boards.

These standards should be followed because they help the design be better and achieve the desired results. These standards help ensure quality products, reduce costs, streamline communication, and improve credibility with boards. Through the use of IPC standards, board designers are able to design robust PCBs that achieve the necessary, minimize their time to market, and have confidence in a reliable board when the end product is used in the field. One of the most important things to notice is that IPC standards as the minimum benchmark help save the designer and manufacturer time before the product is built, during the manufacturing process, and after the final product is assembled, which results in saving money.

Using these standards will ensure that our printed circuit board will be designed and created with the same standards as an industry professional, which should assist us in avoiding errors and common mistakes with building printed circuit boards.

4.3 Standard System C Language Reference Manual Standard

The IEEE Std 1666TM-2011 is the standard which defines SystemC. SystemC is an ANSI standard C++ class library for system and hardware design. This is used for problems that need to be addressed through complex systems that use both hardware and software components. This standard can provide a whole definition of the SystemC class library. As the electronics industry is building more systems with so many different components, it is important to have a language that can be implemented for this system. This project will utilize an Arduino board for prototyping and an ATmega microcontroller, which are both programmed through C/C++ programming languages. Therefore, this standard will be vital as it relates to the C++ class library that will be used.

4.4 Design Impact of Standard Systems C Language Reference Manual Standard

This particular standard allows for more advanced code to be written for complex hardware and software systems. This will allow us to expand our project and introduction new capabilities to the software and our design.

4.5 Software and Systems Engineering - Software Testing Standard

The standard, ISO/IEC/IEEE 29119, is a combination of software testing standards. This standard is in place in order to define an internationally-agreed set of standards for software testing that can be used by any organization when performing any form of software testing. It helps to ensure proper testing processes, techniques and documentation of software. This series of international standards can support testing in many different contexts. This will be used with our project due to the software element of the application and the software aspect of the hardware. There are five different parts in this standard that will be followed for this project and outlined below.

Part 1: Concepts and Definitions
This part facilitates the use of the other parts of the standard by including vocabulary on which the standard is build and provides examples of its application in practice. This part provides definitions, a description of the concepts of software testing, and a way to apply these definitions and concepts to the other parts of the standard.

One of the main concepts that will be used is software testing. Software testing is necessary because it provides information on the quality characteristics of the test items. The items being tested does not always do what it is expected to do. The test item being tested needs to be verified. The item also needs to be verified. This evaluation of the test item needs to be processed throughout the software and system development life cycle.

It is genetically impossible to create the perfect software. Therefore, it is necessary to test the software as much as possible before it is released to the user. This will allow the reduction of mistakes. This is extremely important for this project due to many young children using the software product.
The primary goals of testing are to: provide information about the quality of the test item and any residual risk in relation to how much the test item has been tested; to find defects in the test item prior to its release for use; and to mitigate the risks to the stakeholders of poor product quality. This information can be used for several purposes ; including: to improve the test item by having defects removed, improving management decisions about quality and risk, and improving process in

the organization. Following these testing definitions will allow us to build a more suitable project.

Part 2: Test Processes

This part defines the generic test process model for software testing that is intended for use by organization when performing software testing. This process is split into three groups: organizational test process, test management process, and dynamic test process.

The organizational test process has requirements and constraints on the test management process and the dynamic test process to be performed on all the projects. With reference to this project, this organizational test process will be with the four different group members doing different portions of the project.

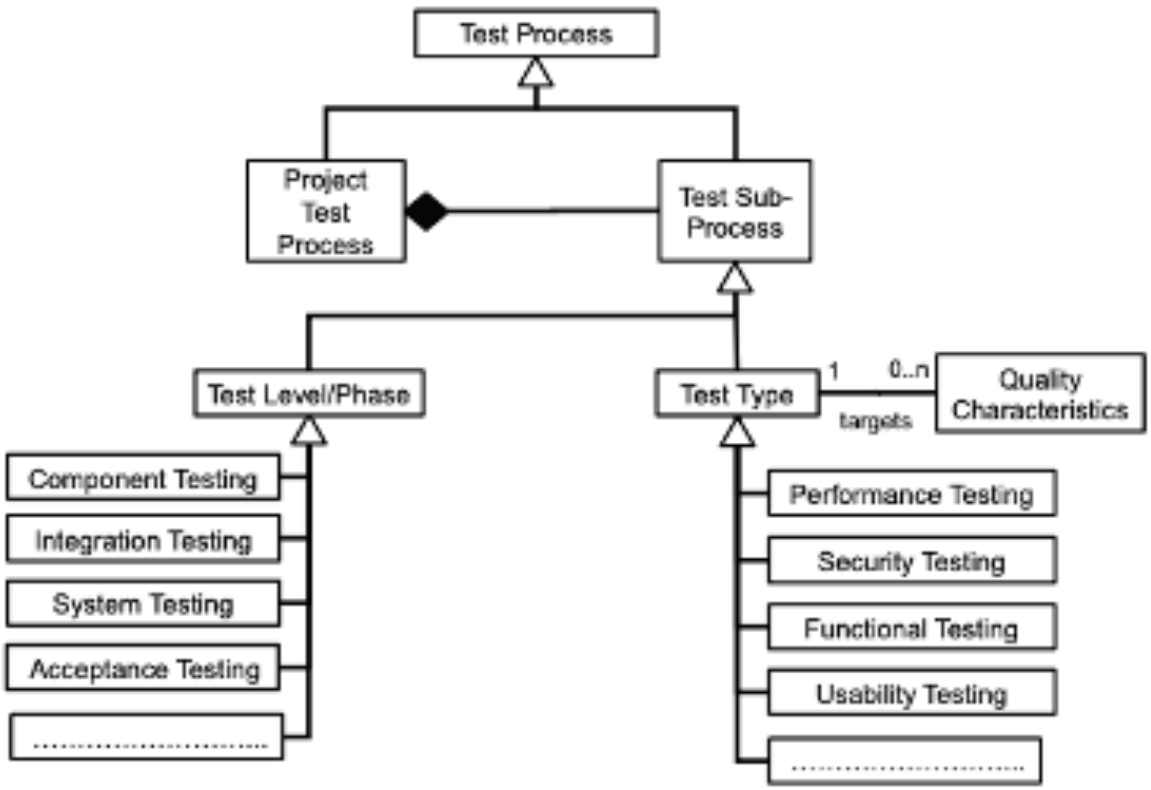


Figure 60: The relationship between test levels and test sub processes

The test management process describes the management of testing. Based on analysis of risks and project constraints, with respect to the Organizational Test Strategy, a project-related test strategy is developed. This strategy is in terms of defining the static and dynamic testing that need to be performed, overall staffing, balancing resources within the correct scope. During testing, activities will be performed and monitored so that testing is progressing on schedule and that the risks are being considered. This overall process will be documented in a Project

Test Plan and while monitoring the test, Test Status Reports will be used to inform the stakeholders (Go Baby Go) of test progress. Testing is further broken down into smaller sub-processes, such as component testing, system testing, usability testing, and performance testing (Figure 60). The team will divide the testing into further sub-processes in order to ensure safety and usability.

After accounting for the unplanned results in the test plan, the project can move on to the dynamic test process. Dynamic test process is in place in order to ensure that the testing process was performed correctly and that all team members are aware of the test results.

Part 3: Test Documentation

This portion of the standard deals with software test documentation and includes templates and test documentation examples that can be produced during this step. The templates support the three test process levels described in Part 2. The documents are organized as follows:

> **Organizational Test Process:** Test Policy, Organizational Test Strategy
>
> **Test Management Process Documentation:** Test Plan, Test Status, Test Completion
>
> **Dynamic Test Process Documentation:** Test Design Specification, Test Case Specification, Test Procedure Specification, Test Data Requirements, Test Data Readiness Report, Test Environment Requirements, Test Environment Readiness Report, Actual Results, Test Results, Test Execution Log, and Test Incident Report

The team will utilize the Organizational Test Strategy, Test Plan, Test Status, Test Design Specification, Test Environment Requirements, Actual Results, Test Results, and Test Incident Report for the project.

Part 4: Test Techniques

This part of the standards provides standard definition of software test design techniques and the coverage measures that can be used during the test design and implementation defined in Part 2. The purpose of these techniques is to assist the testers in finding defects as efficiently as possible. These techniques are categorized into three main categories: Specification, Structure, and Experience-Based.

Specification-based test design techniques are used to create test cases from a test basis that can describe the expected behavior of the test item. These test techniques allow both the test input part of the test case and the expected result to come from the test basis. These are also known as black-box testing techniques. Suggested test design techniques in this group are: equivalence partitioning, classification tree method, boundary value analysis, syntax testing, combinatorial test design techniques, decision table testing, cause-effect graphing, state transition testing, scenario testing, random testing.

The structure-based test design techniques are used to create test cases from a structural feature, such as the structure of the source code. If these techniques are applied to the source code, then the expected results should be derived from the test basis. Some examples of these techniques include: branch testing, condition testing, and data flow testing. This is also known as white-box testing

Experience-Based test is based on previous testing experience, knowledge of a particular system, and metric from previous project. This is described in the standards as Error Guessing. This uses previous experience to predict what may cause failures in the system, where each defect will be considered as a test condition.

Part 5: Keyword-Driven Testing

This standard is an approach to specify software tests using the software testing industry. This is intended for users who will create keyword-driven test specifications or build test automation based on keywords.

4.6 C Standard - ISO/IEC 9899

The ISO/IEC 9899 standard is the International Standard that specifies the form and establishes the interpretation of programs written in the C programming language. This can specify the representation of C programs, the syntax and constraints of the C language, the semantic rules for interpreting C programs, the presentation of input data to be processed by C programs, the representation of output data produced by C programs, the restrictions and limits imposed by a conforming implementation of C.

Specifically this standard is important for aspects of the software of this project due to the use of Arduino and the ATmega chip. Both systems use C++ programming, so it is important for our team to apply this standard for our project. This standard includes: representation of C programs, semantic rules of interpreting C programs, and representation of input/output data that is processed by C programs. The standard as whole applies to this project, but we will cover the specific portions of the standard that are important to the Go Baby Go project.

One specific portion of the standard is the syntax notation. The notation is used in order to ensure that code is written in the correct syntax for readability and reproducibility purposes. This usually is described within the notation and include in the italic type, which can represent the nonterminal and the bold type which represents the terminals. A colon is followed by a nonterminal, which introduces its definition. On the other hand, syntactic categories are not italicized and spaces are used instead of hyphens.

Another important portion of the standard are identifiers. An identifier can denote an object; a function; a tag; a typedef name; a label name; a macro name; or a macro parameter. These identifiers can be used to denote different objects at different parts in the program, even with the same name. However, the identifier can only be used within the scope of the program. For every different entity that is in a program, the identifier needs to be visible only within its cope. The four different types of scopes are function, file, block, and function prototype. Whilst a label name is the only kind of identifier that has a function, the other have a scope that is determined by the placement of its declaration. This means a label name can appear anywhere in the function and is implicitly declared. Whereas other identifiers depends on the placement of declaration. For example, if the declarator declares the identifier outside of a block, the identifier has a file scope, which will end at the end of the unit. However, if the type specifier that declares the identifier appears inside a block, then it is a block scope which ends at the end of the block. If the identifier is a function prototype scope, it will end at the end of the function declarator.

Another aspect of the C standard is the storage duration of objects. An object must have a storage duration that can determine its lifetime. The lifetime of an object is the portion of the program that can be executed during which the storage is guaranteed to be reserved for it. The three storage durations are static, automatic, and allocated. In order to make our project more efficient, it is essential to follow these storage duration standards.

Since this code will be used by Go Baby Go's research and development team it is important to comment every single portion of the code for readability and reproducibility purposes. The contents of a comment need to be within the multibyte characters of */.

Using these standards will ensure a seamless process in writing our software code.

4.7 Realistic Design Constraints

4.7.1 Economic Constraints

The economic constraints are constraints that were placed on the design of the car due to budget. This is a sponsored project with a budget of $400-500. These constraints played a significant role in our design due to the fact that our system would be reproduced and integrated into future Go Baby Go cars. With this restriction in mind, it was important to not select the best technology for each requirement, but rather focus on selecting the component that completes the task but within a reasonable cost. Not included in this budget is the budget of the Go Baby Go car. Go Baby Go has kindly supplied our team with various cars to use in order to build our system. Therefore, the entirety of our budget will be used on components and tools.

4.7.2 Time Constraints

Another constraint that was imminent throughout this project was the time restriction. Time constraints will allow us to create a progress chart of when each part of the design should be completed. Since this is a two semester project, the project was separated into two major components. The research and testing of the design should be complete by December 8th 2020. The printed circuit board should be ordered by January 29, 2020. The completed Go Baby Go electrical system will be ready to present at the end of Spring 2021 semester. With these timelines in mind, our team will be able to realistically plan our schedule and the work that will need to be done. If we realize that a certain method is taking too much time, we will then decide to alter it in order to fit out constraints.

4.7.3 Environmental, Social, and Political Constraints

Go Baby Go is an organization with various communities nationally and internationally. This organization creates modified toy cars for children with mobility disabilities. It is important to consider the social constraint and develop the project so that it can meet these children's specific needs. In regards to environmental constraints, these cars will be using a lot of power in order to sustain them, so we need to keep that in mind when developing our systems and the power that they will draw from the battery. The differences in our design compared to other Go Baby Go cars will satisfy the social and political constraints to give each child a customized car.

4.7.4 Ethical, Health, and Safety Constraints

This device will be used by children ranging from 2-7 years old. These children will be driving this car, so it can be quite dangerous. The car also has a motor with quite a considerable amount of speed, so it could possibly be unsafe. For that reason, we will be advising children to wear a helmet if they are under the age of 3 years old. We will also give the option to lower the speed of the car depending on the children's ability and age. All the electrical wiring will be hidden, so that none of the children will be hurt from them. There will also be an easy access point to the battery for parents to charge the system without causing any harm. Another important factor to consider is that all the electrical components are properly grounded. The application that the parents and children will use will not cause any ethical concerns, due to the fact that no data from the user will be saved.

4.7.5 Manufacturability and Sustainability Constraints

This system that we are developing will be reproduced by UCF's Go Baby Go chapter for future cars. It is essential that we are considerate of designing a product in such a way that our client is able to manufacture the car themselves effectively and quickly. With this constraint in mind, we will be leaving extensive documentation of our process of developing this car along with a manual that describes how to integrate the system with any power wheels car.

Many of the children that will be using this car will use it for many years to come. With this constraint in mind, we are designing and developing a product that is able to be used in the future. We are selecting components that are reliable and making sure that they are durable as well.

5. Project Hardware and Software Design Details

The following section depicts the hardware and software design of the project. Each portion will show the design process of each component and the various subsystems.

Note: Overall Schematics are found in Section 6

5.1 Overall Hardware Design Architecture

Using the diagram in Figure 61, we were able to create an initial hardware design flow diagram in order to layout the known aspects of the design. This allowed us to visualize the different components of the hardware and how they will all interact.

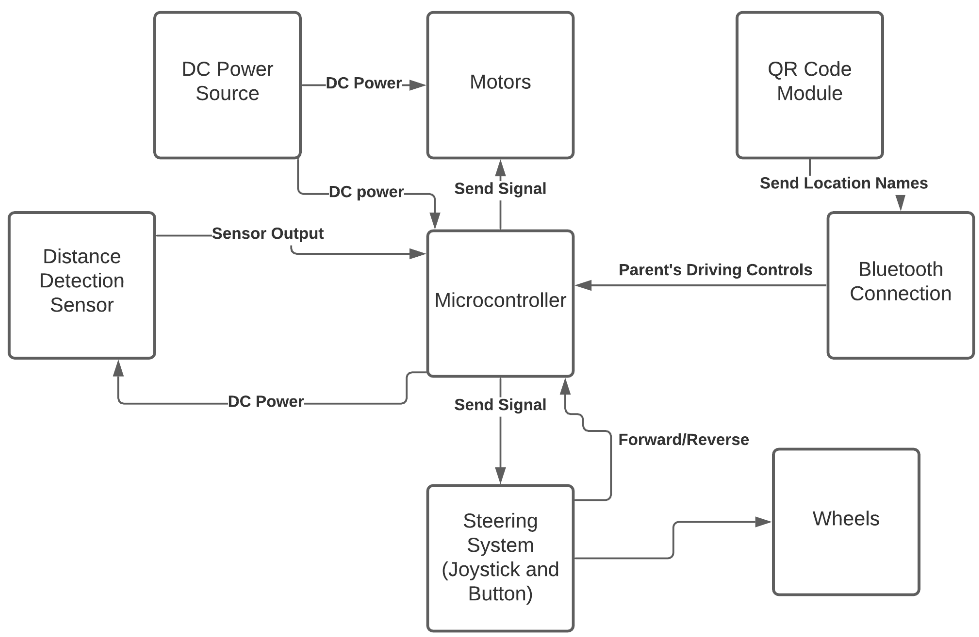


Figure 61: Hardware Design Diagram

The following subsection will describe each subsystem in this project.

5.1.1 First Subsystem – Microcontroller Design

One of the most important subsystems in this design is the microcontroller (Figure 62). The microcontroller would control every aspect of this project and power a lot of the other systems. Within the microcontroller design, there will be headers and GPIO pins that will be used for programming and connecting to the other subsystems. Another aspect of this subsystem is the voltage regulator, which the chip requires in order to power regulate the correct voltage to the other systems. In order to power the whole system, the DC power source will also be required, which is provided by the specific car.

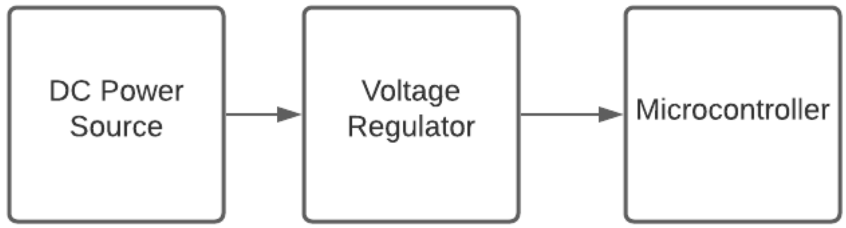


Figure 62: Microcontroller Subsystem

5.1.2 Second Subsystem – Sensors

The sensor subsystem consists of the ultrasonic sensor system (Figure 63). These sensors will be controlled by the microcontroller. There will be various sensors placed around the vehicle and each one will be able to detect obstacles. Once an obstacle is detected, a signal will be sent to the microcontroller and applied to the braking system of the car.

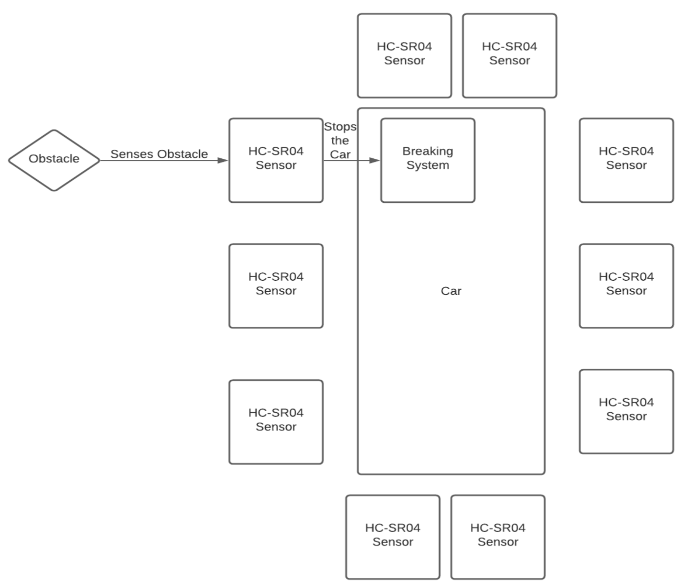


Figure 63: Sensor Subsystem

5.1.3 Third Subsystem – Steering and Motor System

The steering and motor subsystem consists of a joystick, button, stepper motor, and H-Bridge (Figure 64). When the joystick or button is used to steer, input signals will be sent to the motor system. The H-Bridge motor will be able to move the car forward and backwards based on the inputs from the joystick or the remote controlled application. In order to turn the car left and right, a stepper motor will be used to turn the wheels. The stepper motor will allow for remote control from the web application.

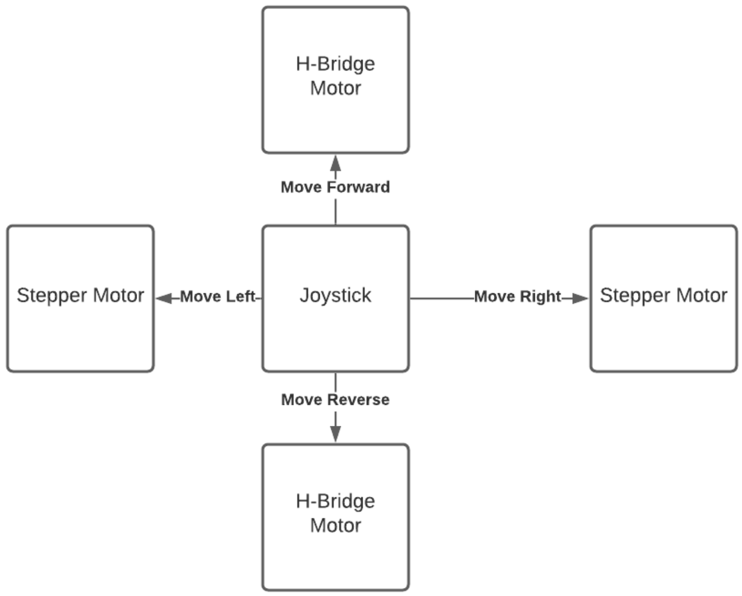


Figure 64: Steering and Motor Subsystem

5.1.4 Fourth Subsystem – Bluetooth System

The bluetooth subsystem is the bridge between the hardware and software implementation. In this subsystem, the bluetooth is connecting the inputs form the remote control application to the microcontroller. This allows the parents to control the car. Further testing of this system is included in the Prototyping Section.

5.2 Overall Software Design Architecture

The overall software design of the system consists of multiple algorithms that will be used to control the sensors, motors, and joystick of the car. The sensors will be able to have the flexibility of detecting obstacles from 2-400 cm. Depending on the client's request, the car will be able to stop when it can detect an obstacle within that range.

There will be two applications created for this project, the parent's and child's application. The parent's application allows the parent to remotely control the car. This application will have a four keypad arrow with a stop button. The parent can select any of these buttons to control the car. Once a direction is selected, a signal will be sent from the application to the bluetooth module. That module will then send a controls signal to the microcontroller, which will then instruct the correct hardware subsystem.

Another application that will be created for this project is the child's application. This application is an augmentative communication tool that will allow the children to communicate with others. This will be a flashcard-based application where children and their parents can create a flashcard with a word and place it in a certain category. Then the children will be able to use those cards to communicate their wants and needs with others.

An overall schematic and schematics of the various subsystems is found in Sections 6 and 7.

6. Prototyping

6.1 Basic inputs

Breadboard testing started with using a basic Arduino joystick to send Analog inputs to an AT-Mega 2560. The joystick is two potentiometers that vary the voltage depending on the position of the joystick. The AT-Mega is able to interrupt this as values as analog inputs and stores the results as an integer ranging from 0 to 1023. During our testing we found that the Joystick seems to “drift” between 450 and 510 when at idle. This is expected and provided us with an idea of a threshold value for the joysticks.

After determining the joystick inputs the board needs to send out a set of Pulse Width Modulated waves. This requires a system to generate PWM based on the joystick values. We do not want the car hard braking and hard accelerating so we cannot simply map each position on the joystick to a PWM duty cycle. Instead using the threshold values that were previously found we created a system to steadily accelerate the car to its maximum velocity.

If the joystick is moved beyond its “idle” threshold the motors will start to accelerate in a direction based on the joystick input, from our test it appears that increasing at a rate of 4 per loop worked well. Once the joystick is returned to an idle position the car will decelerate at twice the acceleration rate until it reaches a 0 duty cycle. This also helps prevent the values from overflowing.

A second catch had to be added. The user may end up switching directions rapidly. This would result in the previous direction needing to be slowed down while a new direction is increased. This was dealt with by having both directions dropped at double the acceleration rate whenever that direction is not being engaged.

Using the methods above we were able to see a smooth transition between rest, forward motion, and reverse motion observed through LEDs. Our final project will be leaving a set of LEDs on the board so that we can observe the input that is being sent by the X and Y inputs of the joystick.

The Joystick will also be read to provide input for the stepper motor that will control the steering wheel. For this we will have to do almost a one to one mapping of the wheels to the joystick position. When the joystick is in it's idle position.

If the car has two motors it will be possible to do a “Zero Turn radius” turn by pressing the joystick in. This will cause the wheels to spin in opposite directions based on if the joystick is pushed to one of the sides. When the joystick is pressed in only the “Left” and “Right” values will be read. The forward and backward values will be ignored.

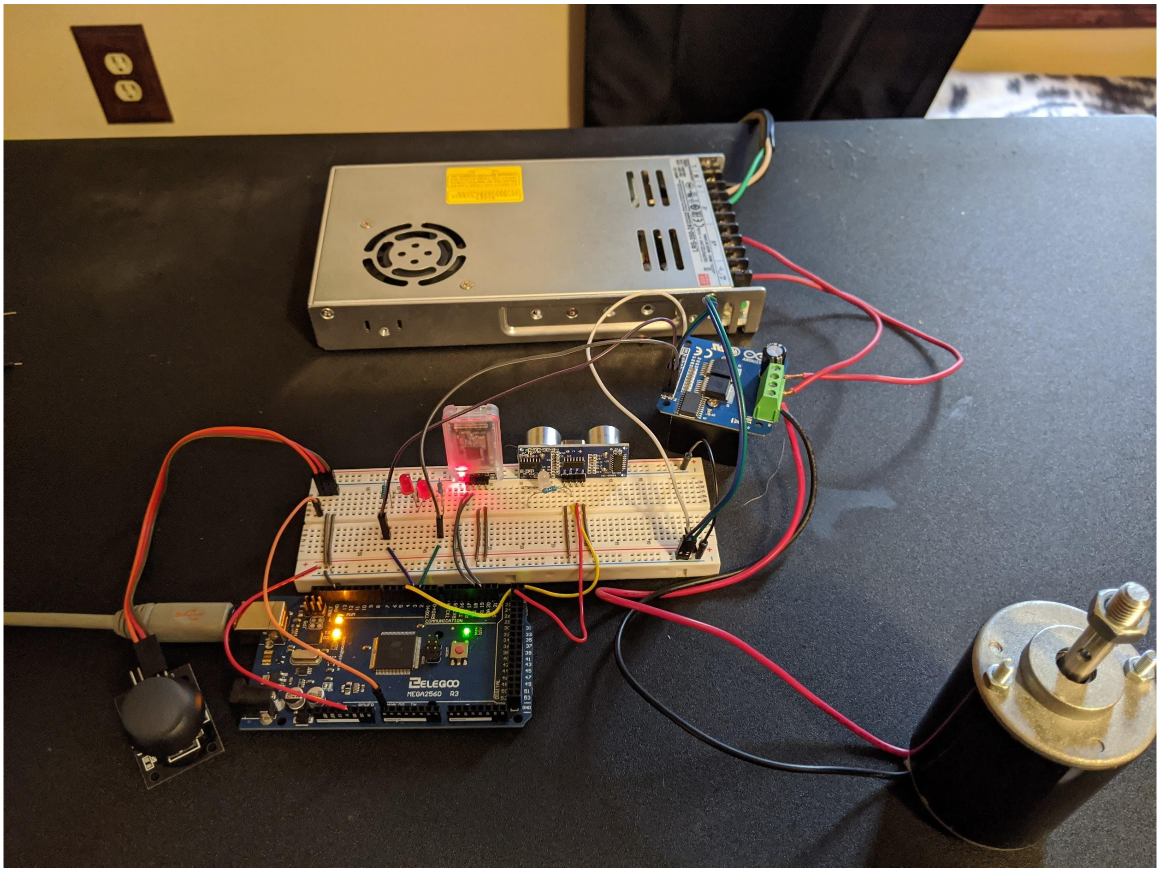


Figure 65. Basic Bread with inputs setup.

In our testing it was possible to spin the motors in opposite directions but the results varied based on the amount of weight in the vehicle. The amount the vehicle would turn is also questionable and may cause additional damage to the wheels of the vehicle or surface that the vehicle is operating on.

6.2 Motor Driver

For testing we used a set of IBT_2 H bridge motor drivers. These are breakout board H bridge drives that use a set of MOSFETs to allow a motor to be rotated both forward and backwards.

We connected both of the inputs for forward and reverse to a set of PWM pins on the AT-Mega and were able to drive the motor both forward and backwards depending on the input. The driver was able to operate with voltages varying between 12V and 48V. They performed well under load for our testing and did not show signs of overheating even under full load from 48V for 10 minutes.

Unfortunately the parts that are included on the IBT_2 are not available as individual components. So to make things easier we found a similar H bridge driver. For our final schematic we used a Texas instrument DRV_8841 as it has similar voltage and current ratings to the IBT_2. It also operates on a similar logic level so not many changes are needed. Figure 66 shows the schematic layout for the H Bridge that will be used on our final board.

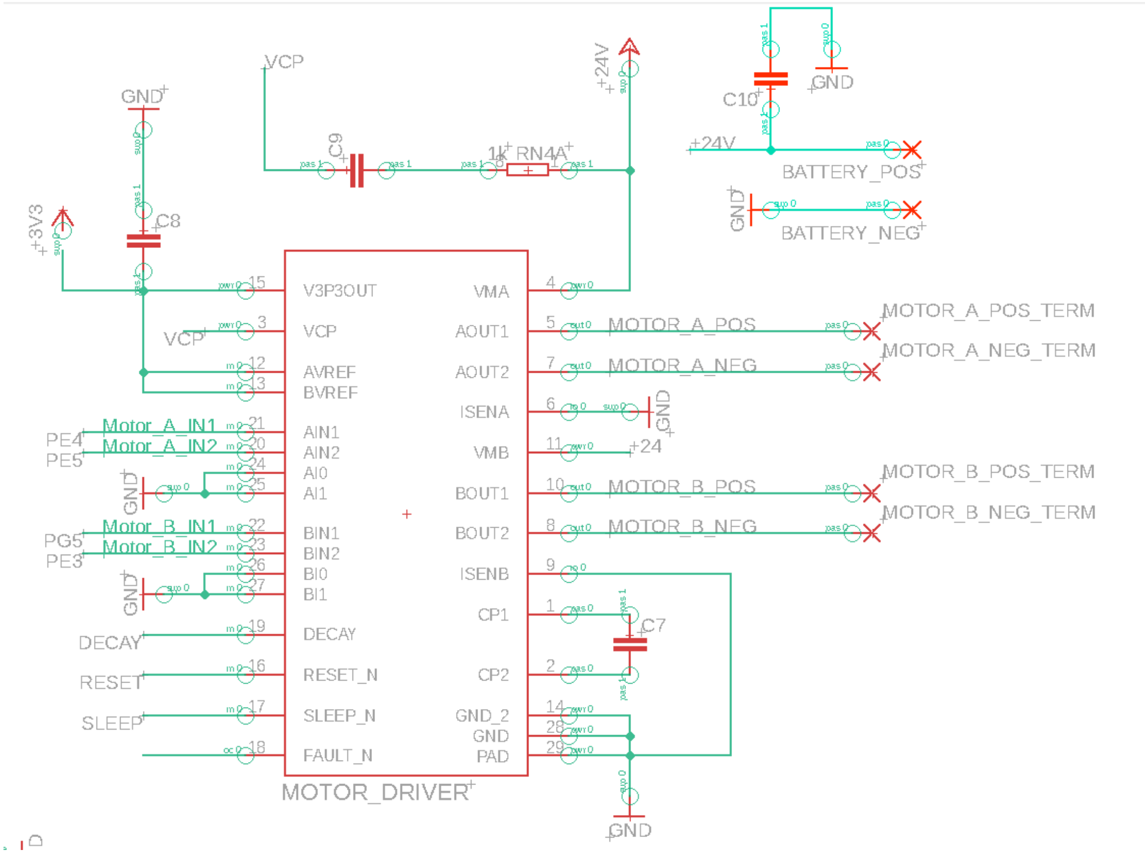


Figure 66. Schematic for DRV 8841 Driver (reprinted with Permission from Texas Instruments)

This integrated circuit board is also able to control stepper motors according to the Datasheet. Because of this we are also using this as the driver for our Stepper motors as well so that we can control the steering wheel of the vehicle.

Based on the Datasheet for this board we have to set various settings for the board through the pins on the Integrated Circuit. The AIN and BIN pins control the amount of current that flows through the Motor. By pulling both down to ground we allow full current to flow through the device.

6.3 Bluetooth

With our breadboard testing we were able to connect the bluetooth module to the serial lines of an AT-Mega 2560 and were able to create a serial communication over bluetooth with the testing board.

The bluetooth module sends in the data that it receives over a Serial UART connection that has to be connected to the main chip. These have to be connected so that TX on the bluetooth chip is connected to RX on the microcontroller and RX on the bluetooth chip is connected to TX on the microcontroller.

Setting up the bluetooth module requires sending a set of AT commands over the serial line to the device to tell it specific settings to enable or disable. Such as the broadcasting name, the pin for the device if it wants to be locked, and set broadcasting modes. These commands were obtained from the data sheet for the bluetooth module.

One issue that was discovered with BLE devices is that they cannot always connect to conventional phones, of the four phones and two computers that we used in testing only Windows based phones and Computers could maintain the connection properly. The bluetooth device is able to be found and connected to, but it does not maintain the connection like a conventional bluetooth device. The connection is opened, data is read or written, and then the connection is closed. The Bluetooth Web API is able to talk with the device, but it will not work as a conventional device.

A second issue that was discovered is the Bluetooth Web API is currently a development only feature. Special settings have to be enabled through the Chrome and Safari browser in order to use this feature. This may prompt issues later on as a non-technical person will be enabling this feature on their phone and may not know how to do it. This means that we will need to create a user guide that will instruct the users on how to enable and use this feature. Or consider switching to a basic bluetooth device. For the time being we are moving forward with the BLE device and using the Bluetooth Web API.

The datasheet says that the range of the device is up to 100ft in direct line of sight. Testing this in a home environment we found that around corners and through walls the connection was reliable up to 50 ft. Beyond that some inputs were dropped or not properly communicated. There were also issues that when the device moved outside of the range the connection was not immediately re-established. This could lead to issues in the future if the parents move too far away from the vehicle and should be addressed in our code.

The bluetooth does not stay online at all times, it only wakes up and receives data when data is sent directly to it. To handle this in the code we assume that if the bluetooth device is sending inputs it should override anything that the joystick is doing. This requires that in order for the bluetooth device to override the joystick it would have to send data at the rate of the main loop of the program, which is almost impossible.

Instead of keeping the bluetooth in control once the bluetooth sends a command it keeps control of the vehicle for a set number of cycles, in our test it appears that 64 cycles is fine.

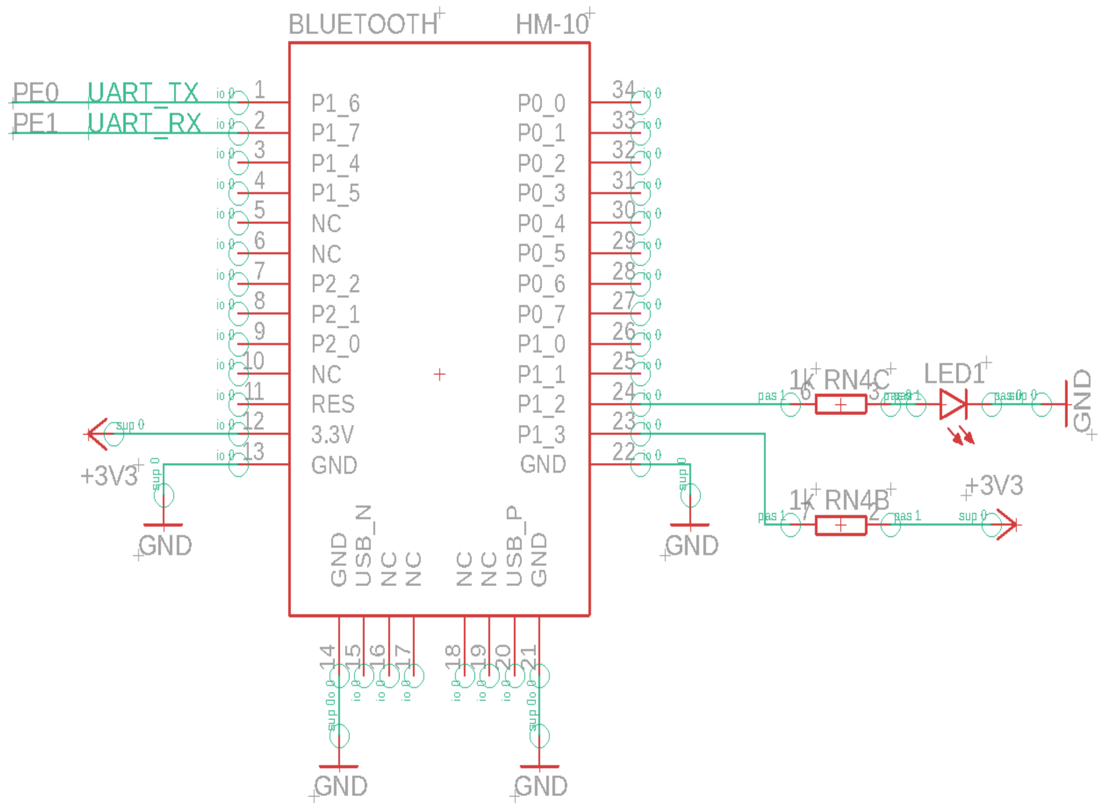


Figure 67. Schematic for HM-10 Bluetooth Module

6.4 AT-Mega Chip

For our final product we will be using an AT-Mega chip. Most of our testing was done on an AT-Mega 2560, but this has a large number of pins that will not be fully utilized on the final product. Instead we will be using an AT-Mega 328PB-MN chip. This has just enough pins for us to control two DC Brushless motors, a single Stepper Motor, receive inputs from a single joystick, and read inputs from up to 6 Sensors at a time.

Following the data sheet there are a few setups that have to be done for the chip to work on any circuit board. One is that the board will need to have a set of MIOS and MOSI pins in order to program the board. In all of our prototyping we have not programmed the boards directly with an AVR programmer, AVR does not stand for anything according to Atmel, over MISO and MOSI, instead we have done most of the programming over

Serial communication that would then feed the code into the MISO and MOSI receivers.

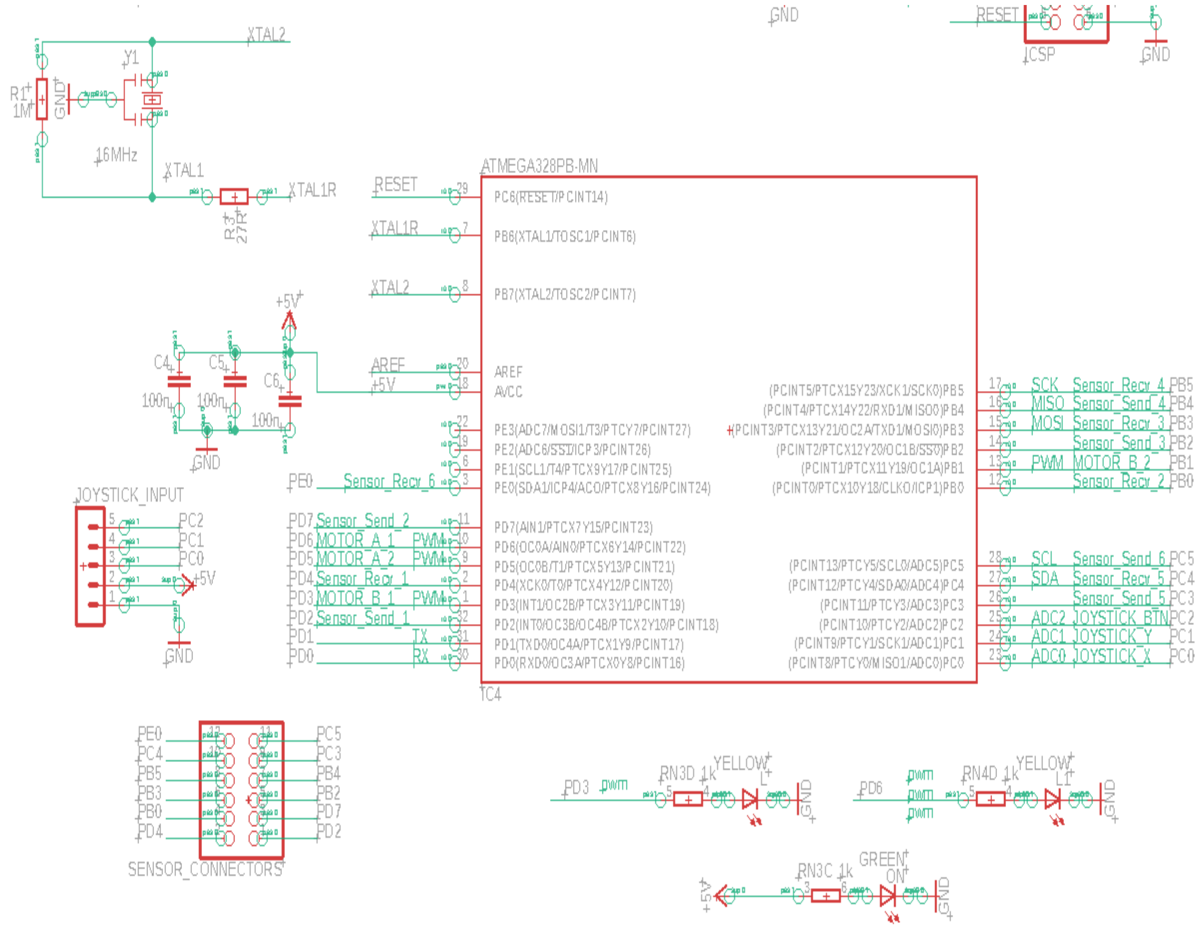


Figure 68. Schematic for AT-Mega 328PB-MN (reprinted with Permission from Atmel)

Each vehicle will vary and will incorporate up to 6 possible sensors. Because of this variance and possible damage to these components, as they will be located on the edge of the car and will possibly be knocked off or smashed into the wall we are connecting the sensors to the breadboard through a Pin Header instead of soldering the wires on for easy replacement.

Similarly the joystick will be connected into the board through a set of Jumper pins to allow the end users the option to replace the joystick if it ever breaks, or the option to upgrade the joystick in the future.

6.5 Voltage Regulator

The chip requires both a Vcc voltage and a Reference Voltage for calculating the changes in logic. The Datasheet recommends that the reference voltage is pulled to ground through a capacitor to ensure that no sudden changes occur; this will ensure that the reference voltage is always seen as ground and avoid errors in the middle of operations. The same is done for the +5V that is used at the VCC voltage to ensure that a constant steady +5V is supplied as the capacitor cannot suddenly change it's voltage usage.

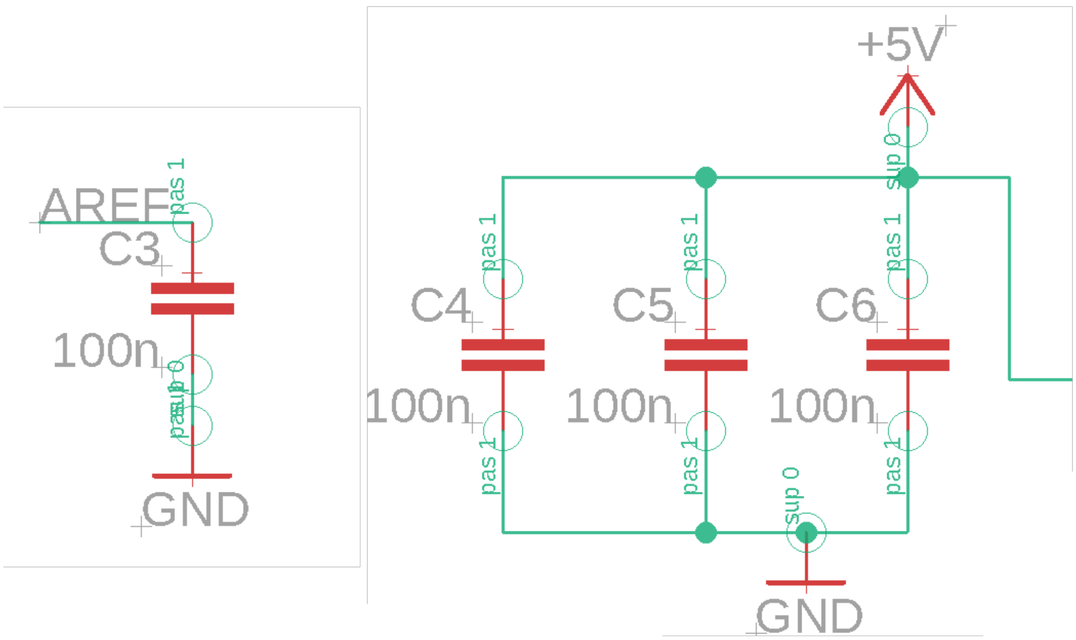


Figure 69. Reference Voltage and VCC voltage

The HM-10 chip required only 3.3V according to it's Datasheet, in our breadboard testing we used a breakout board version of the HM-10 with 5V for power, but this board had a voltage regulator on it to prevent damage to the circuit. While the Motor Driver DRV 8841 required 5.0V for power. To meet this our final circuit board will have to be able to regulate the voltage that it takes in. Currently we are only planning on powering the board off of the car's internal battery, which can vary from 12V to 24 V depending on the model of vehicle.

This means that we will first have to regulate the Voltage down to 5V for most of our operations. Then we will use a voltage divider circuit to step the continuous 5V down to 3.3 V. At the same time we also want to pass on all 24V to the motors for the car to continue work so we will branch off the voltage being passed into a +24V system so that the driver is able to fully power the motors. Our entire voltage regulation circuit can be found in Figure 70.

All of this testing could not be done with actual parts as we want to ensure that they perform the operations that we want before they are ordered with the board. Because of this our simulations were done through the EAGLE software and online with Multi-sim Online.

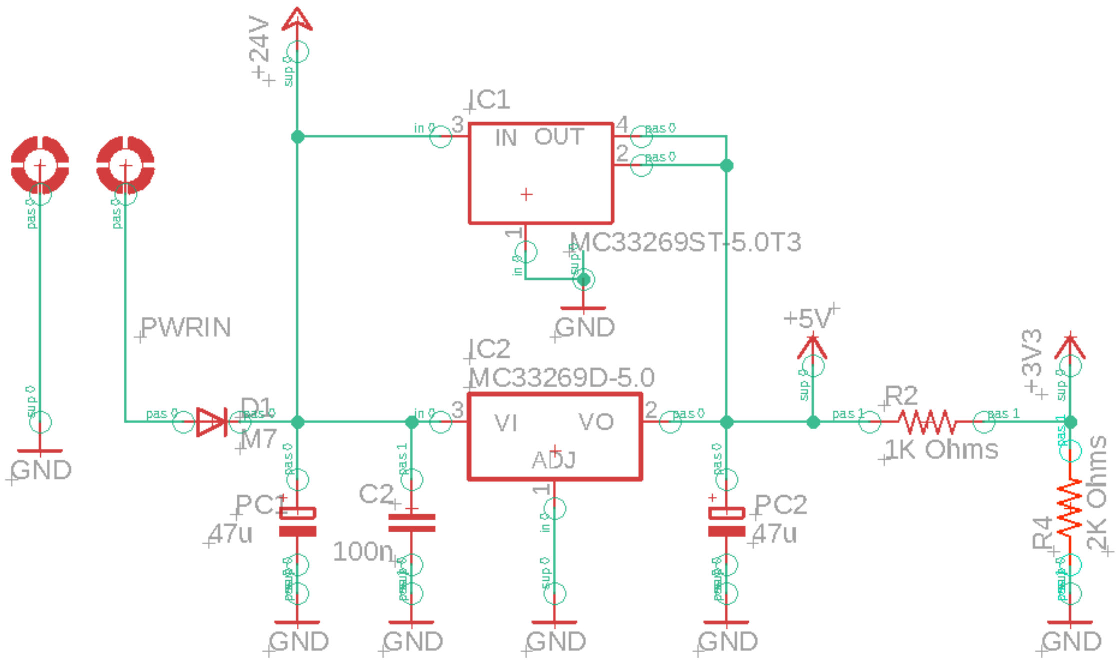


Figure 70. Voltage Regulating circuit.

6.6 Sensors (HC-SR04)

Due to the COVID-19 pandemic, the senior design team members are not able to meet in person in order to test out different ideas and concepts. Since one team member has an Arduino and another team member has a Raspberry Pi, it was decided that the ultrasonic sensors would be tested out with the Raspberry Pi. This is because the team member that has a Raspberry Pi has the most experience with HC-SR04 sensors.

The HC-SR04 Ultrasonic sensor has four pins: ground (GND), Echo Pulse Output (ECHO), Trigger Pulse Input (TRIG), and 5V Supply (Vcc). We power the module using Vcc, ground it using GND, and use our Raspberry Pi to send an input signal to TRIG, which triggers the sensor to send an ultrasonic pulse. The pulse waves bounce off any nearby objects and some are reflected back to the sensor. The sensor detects these return waves and measures the time between the trigger and returned pulse, and then sends a 5V signal on the ECHO pin.

ECHO will be “low” (0V) until the sensor is triggered when it receives the echo pulse. Once a return pulse has been located ECHO is set “high” (5V) for the duration of that pulse. Pulse duration is the full time between the sensor outputting an ultrasonic pulse, and the return pulse being detected by the sensor receiver. The python script that was written therefore measures the pulse duration and then calculates distance from this.

As shown in Figure 72, the wiring of the ultrasonic sensor required two resistors. These two resistors were connected in series in order to create a voltage divider, which was needed to reduce the output voltage. The Vin needs to be decreased from 5V to 3.3V. While doing the calculations below, we were able to calculate the resistor values that we needed:

$$\frac{3.3}{5} = \frac{R2}{1000 + R2}$$

$$0.66 = \frac{R2}{1000 + R2}$$

$$0.66(1000 + R2) = R2$$

$$660 + 0.66R2 = R2$$

$$660 = 0.34R2$$

$$1941 = R2$$

Figure 71. Resistors needs 3.3V voltage divider

Therefore, a 1k and 2k ohms resistors were used in this circuit (Figure73).

Since, there will be multiple ultrasonic sensors attached to the cars, we prototypes with multiple sensors as shown in Figure 74 with a Raspberry Pi. We have also developed the wiring schematic for the Arduino and ultrasonic sensor, in order to give us an idea of how to wire the sensors with the microcontroller (Figure 75).

For the basic model of the car, two ultrasonic sensors will be attached to the left and right side, while one sensor will be attached to the front of the car and one attached to the back of the car. While testing out our sensors, we realized that if the sensors are too close to each other, the sound pulses and echoes can interfere with each other. With this complication in mind, we intend to place the sensors strategically around the car so that none of the viewing angles overlap.

Another complication we ran into is that since each ultrasonic sensor has their own GPIO pin, it is difficult to simultaneously take distance measurements from all the sensors. There are two possible solutions to this complication. One is that each sensor will record a distance measurement after another. Therefore, once a sensor sends a trigger wave, receives the echo, and then calculates the distance measurement, then the next sensor will be able to repeat that process. It takes around 10 microseconds for a sensor to receive and process a sound wave, so the delay would not be noticeable to the human eye.

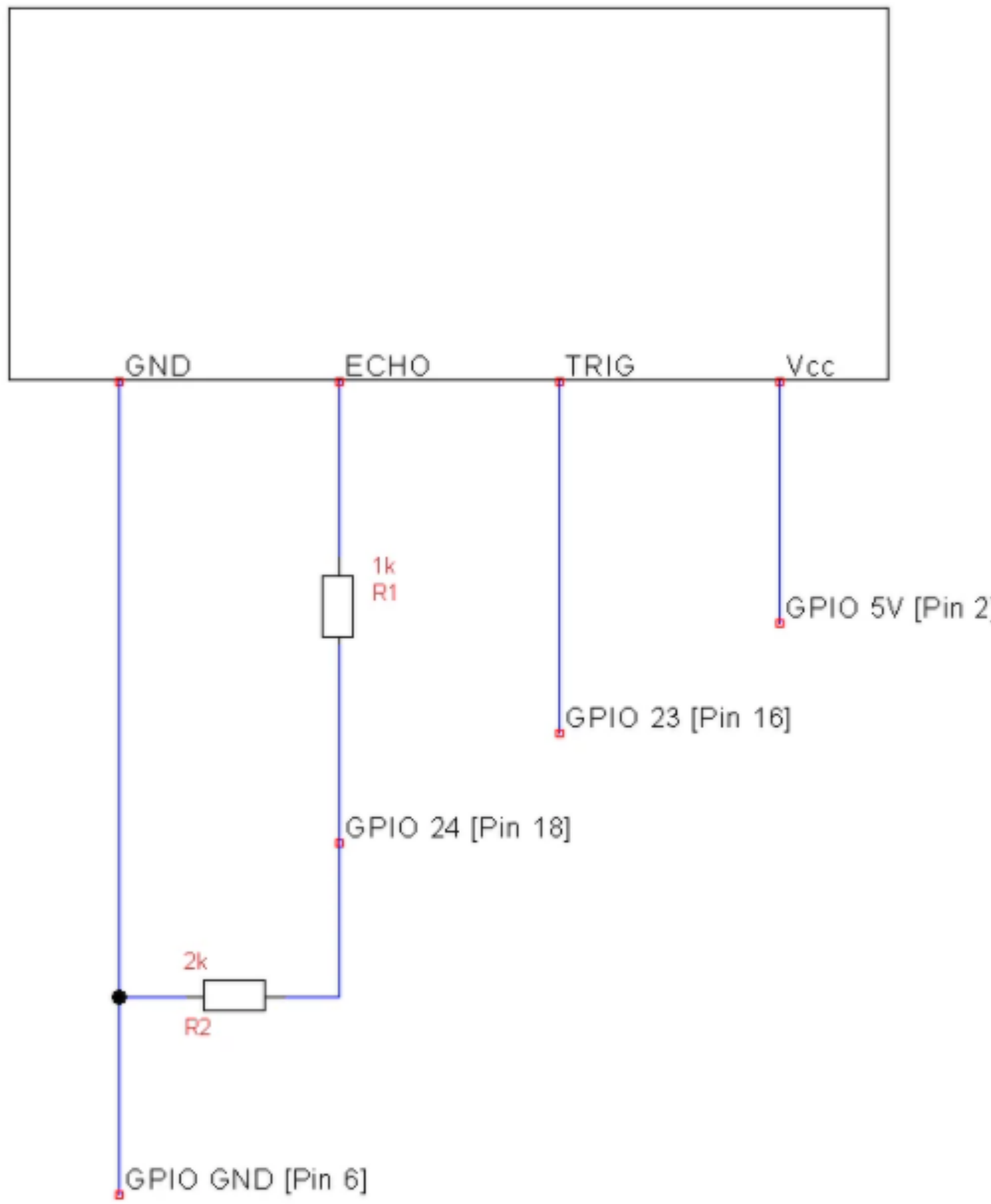


Figure 72. Ultrasonic Sensor Wiring Schematic

Another possible solution is to have all the triggers of the ultrasonic sensors be connected to the same GPIO pins. When testing this solution out, it was noted that the single trigger GPIO for the ultrasonic sensors sent out the sound wave at the same time (Figure 75). When there are separate GPIO pins, the signals are sent out at different times and are never overlapping, but when they are all under one GPIO pin then the signals overlap (Figure 76). Further testing on the cars will be required in order to determine which method to utilize.

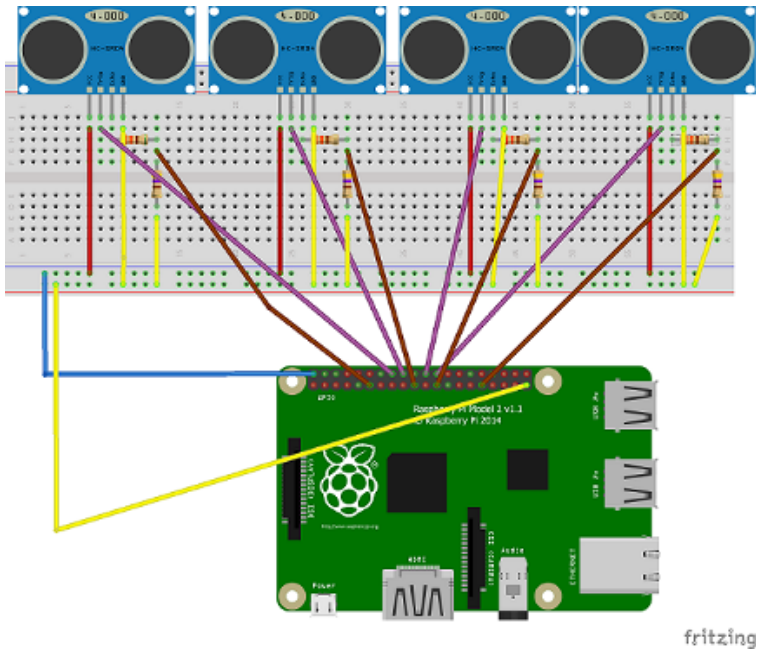


Figure 73. Raspberry Pi Wiring Schematic to Ultrasonic Sensors

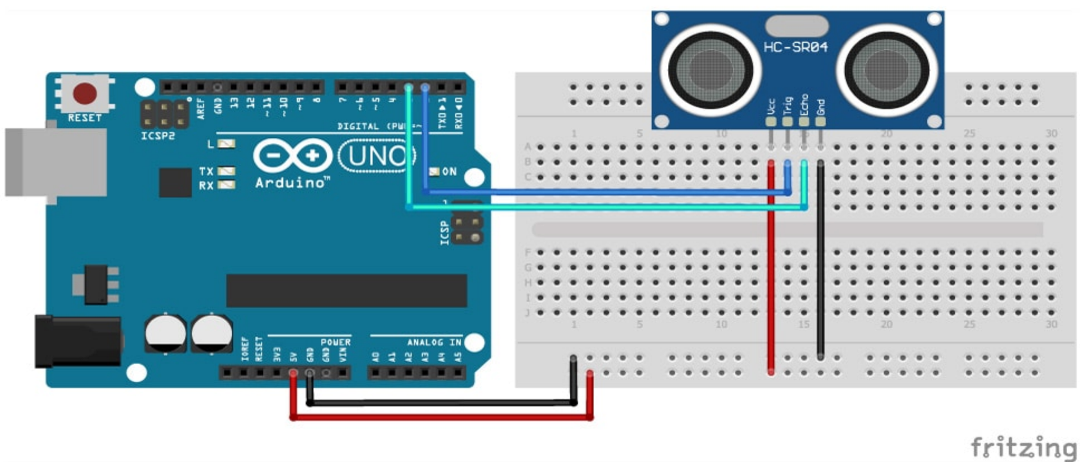


Figure 74. Arduino with Ultrasonic Sensor

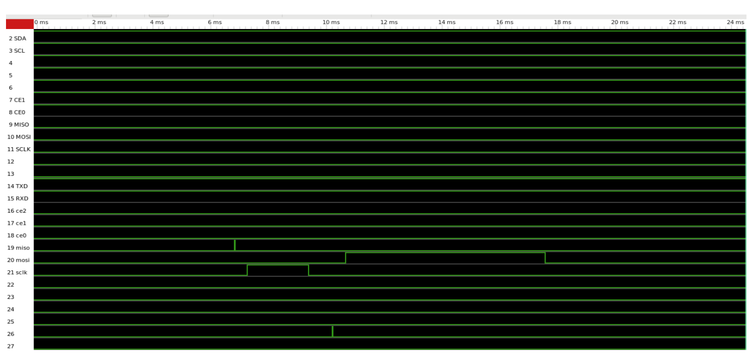


Figure 75. Separate GPIO Pins for Sensor Reading

As seen in Figure 77, multiple ultrasonic sensors were prototyped with a breadboard and a Raspberry Pi. These sensors were placed right next to each other in order to observe the effects of various trigger and echo signals and how they might interfere with one another.

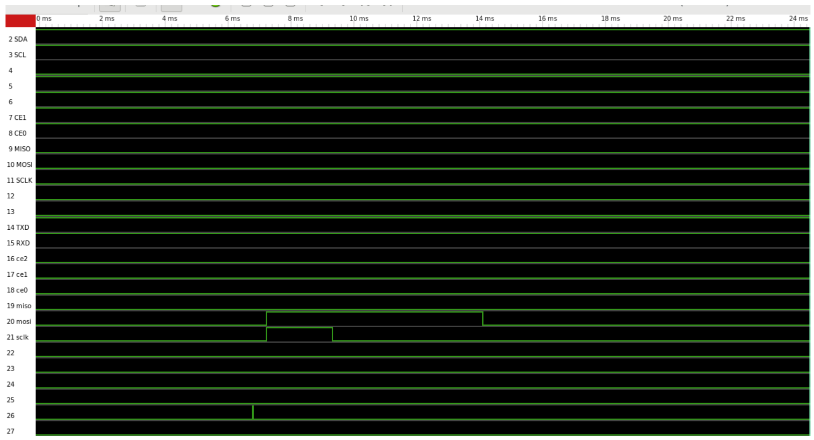


Figure 76. Same GPIO Pin for Sensor Readings

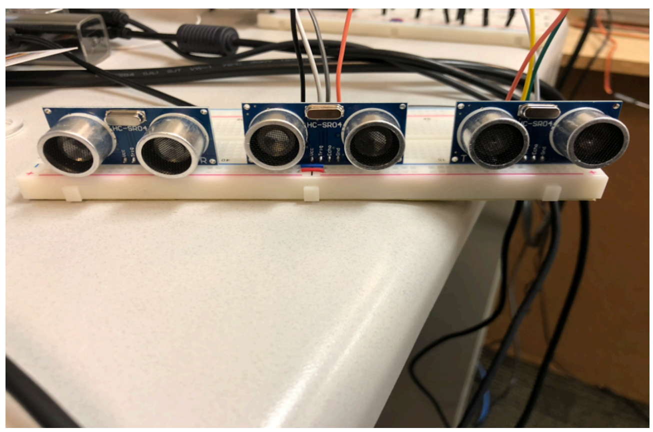


Figure 77. Ultrasonic Sensors Testing

7. Overall Schematic and Prototype Construction

This section is talking about our final prototype as a whole. Joining each of the previous parts together into a cohesive final product.

7.1 Hardware prototype

For our final prototype schematic we combined as many elements as possible in EAGLE and began selecting the component that would be used on our board.

Being more familiar with Through hole pin resistors and limited experience on soldering we opted to use larger through hole pin resistors instead of array resistors as these will be easier to attach to the board and are more readily available. Most of the onboard resistors that we are using are negligible, there is no specific resistance required for the parts, they are only being used to apply current to a set of LEDs. Two are being used to connect Crystal oscillators to the main Microcontroller per the recommended information in the datasheet.

Our joystick will be connected externally to the through a set of wires. These wires are being fed into a pin header, lower left side of Figure 78. with 5 inputs that will be soldered onto the board. Three of these pins are connected to Analog inputs on the Microcontroller, one pin is +5V as the joystick is a set of attenuators that will be performing voltage division to give us our inputs, and the other is ground.

The Bluetooth connectors are mostly being utilized. The main connections that we believe that we will need are the RX and TX lines that will be used to communicate with the controller. We are also using the Pin_1 and Pin_2 to use an LED to signal when the board is connected over bluetooth. This will help us with troubleshooting the final product. The bluetooth model is located at the bottom right of Figure 78.

One consideration that had to be made was to add MISO/MOSI connectors to the board so that we could program the Microcontroller once it is attached to the board. This will be a set of 6 pin headers that have to be left on the board for programming. These are shown in the top right of Figure 78.

Two Motors drivers are being used, they are featured in figure 79. One is being used entirely to control the DC motors that will power the wheels of the vehicle. The other set is being used to control the Stepper motor that will control the steering column of the vehicle. Both of the drivers will be connected to mounting holes that the motor’s leads will have to be connected to.

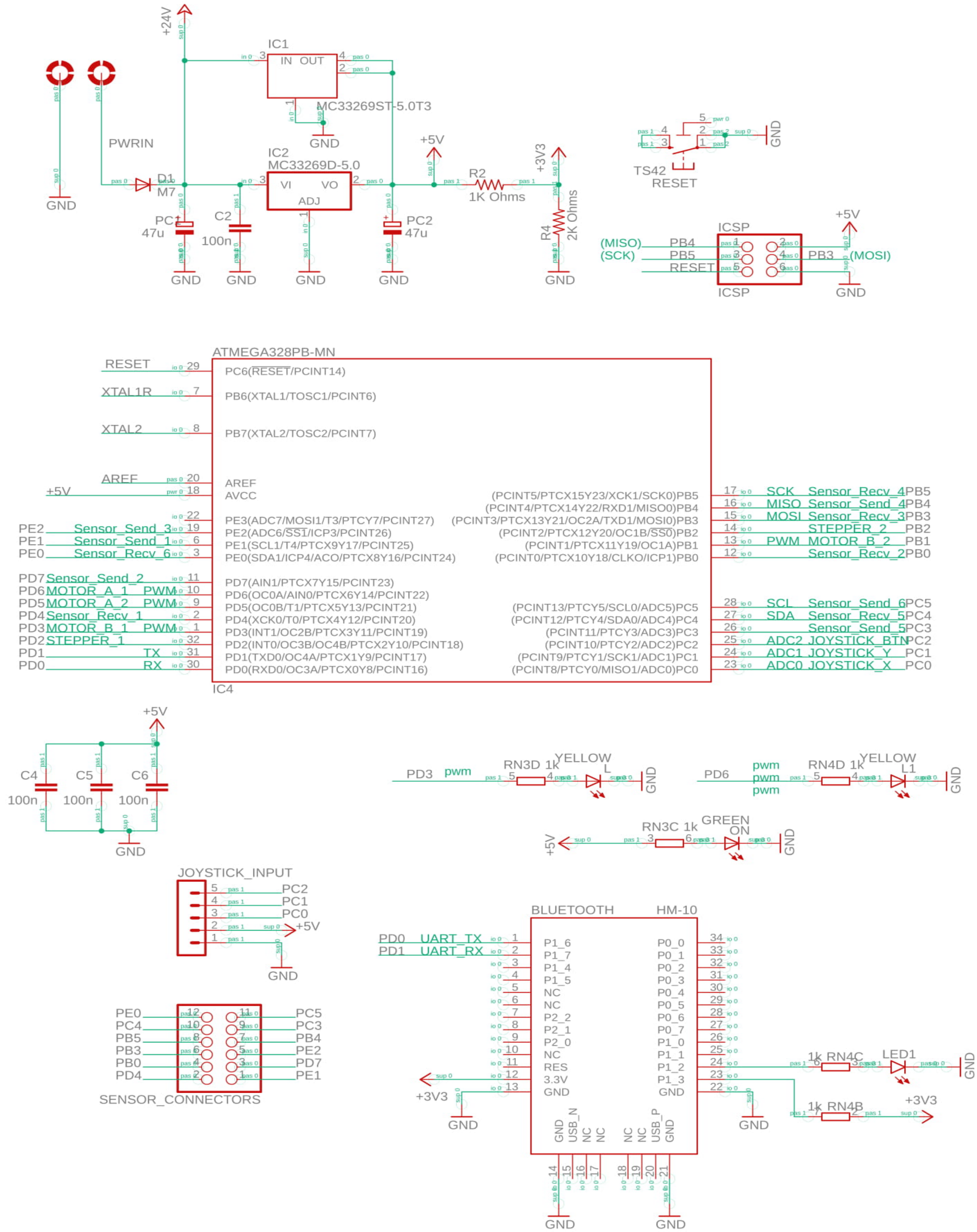


Figure 78. Final Microcontroller and Bluetooth Schematic

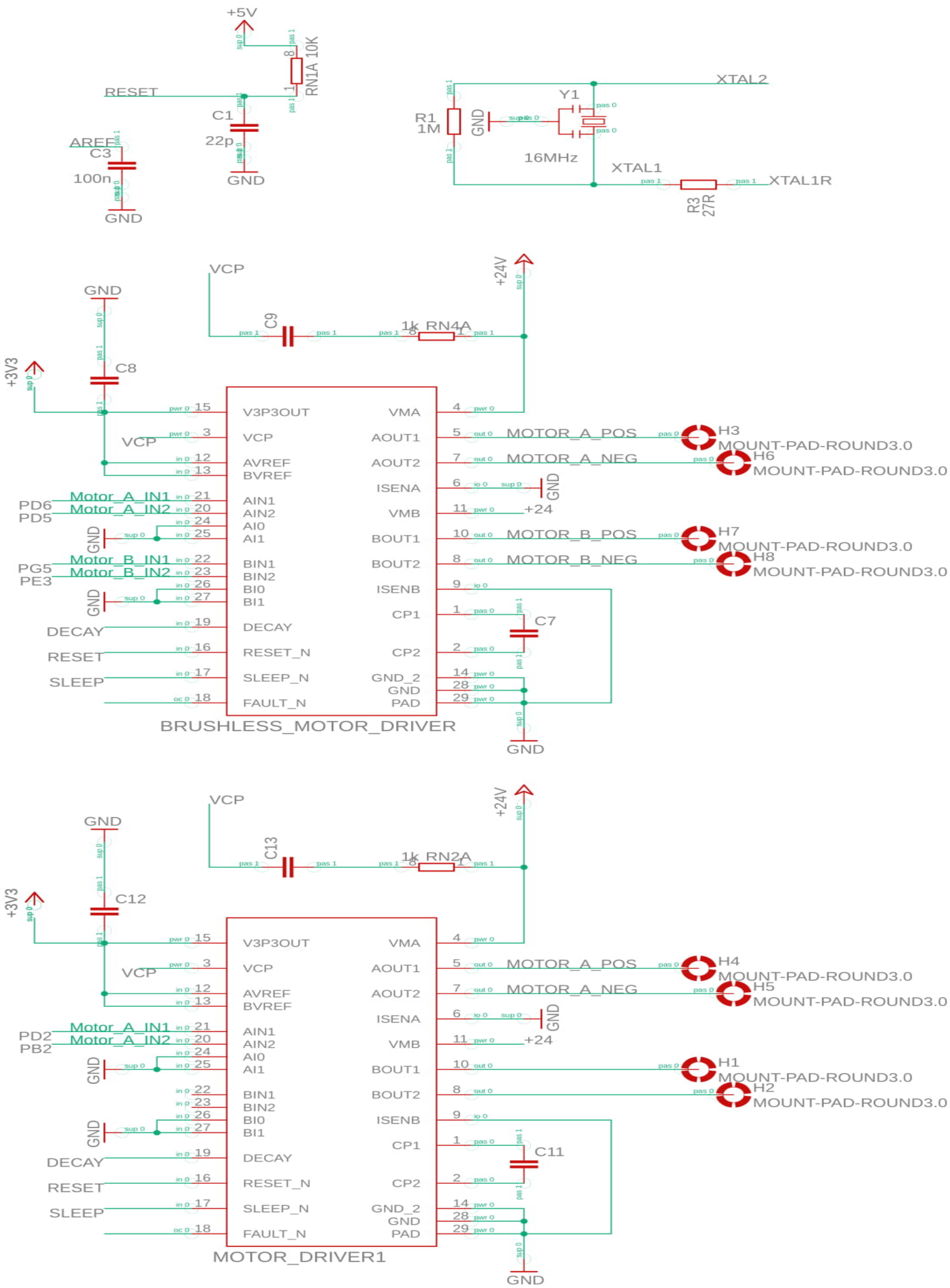


Figure 79. Final Motor Driver Schematic

7.2 Software Prototype

For our final software will be a combination of our previous code, but we will have to have all of the code running on a single processor and a single thread. This means that we will have to have a single loop that will process each of the software parts related to Controlling the Motors, processing input from the sensors, handling input from the bluetooth connection, handling input from the joystick, and.

To achieve this we will have to structure the main software loop to iterate over a set of functions that will control each of these systems in order of priority.

The sensors are a safety feature and should take top priority for processing. When we receive any inputs from these sensors we should process those inputs first before moving on to the next components. If there is any input from the sensors we should ignore the input from the joystick and bluetooth controller for the time being. Once the vehicle is brought to a stop the users will be able to override the safety settings and advance the vehicle as it will be moving at a slow speed and will not be able to cause serious injury or impact. It may also be possible to have bluetooth enable or disabled this safety feature in the future at the parent's wishes.

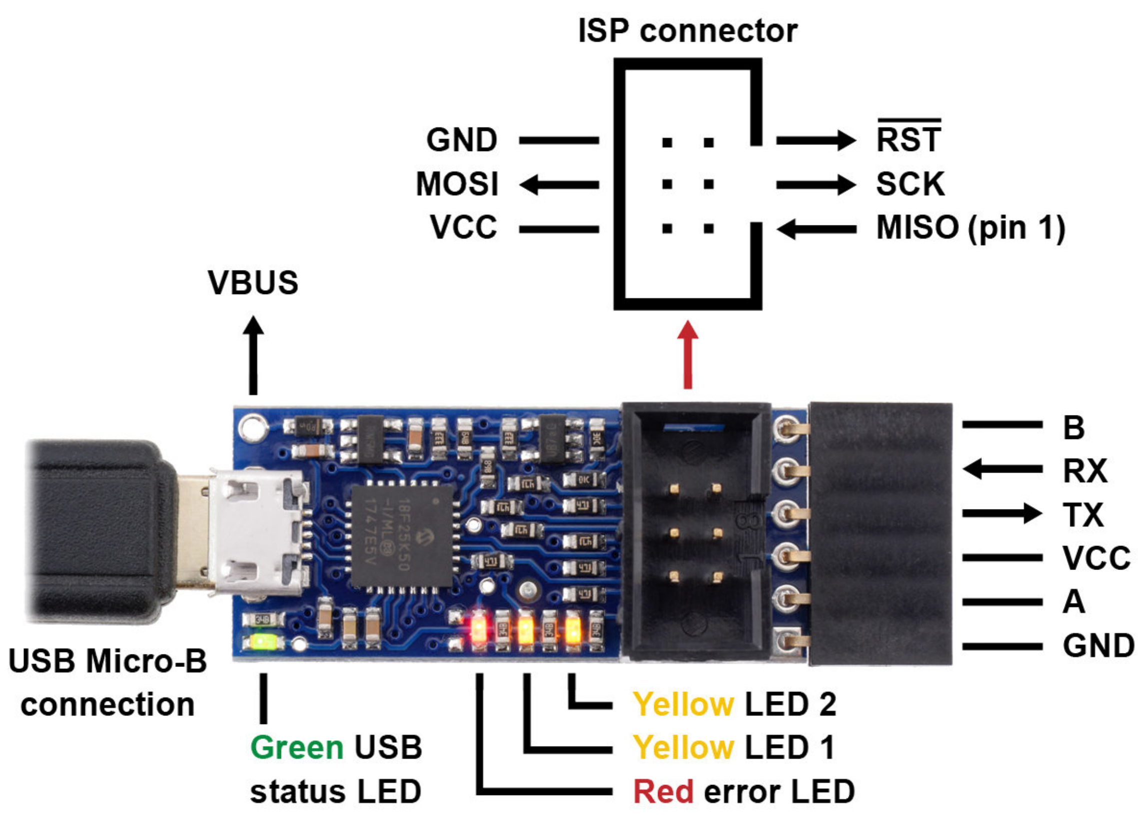


Figure 80. AVR Programmer

If some kind of Bluetooth connection is received it should override the input from the joystick as this is the parent controlling the vehicle. We will have to check if there is any input on the Serial line for the controller. If there is no input waiting we can process input from the joystick instead. Since we don't have to process both of these inputs on the same loop this also lets our program be more responsive.

Finally we will take the input from the sensors, Bluetooth, and joystick and modify the state of the motors based on the state of these inputs. If we are receiving a high input from the sensors we should quickly stop the motors from advancing. If we received input from the Bluetooth sensor or the joystick we should continue to increase the motor's speed to its max velocity. If we have received input we should be slowing the motors down for the vehicle to come to rest.

All this will be handled by C++ code on the ATMega controller. The code will have to be loaded onto the microcontroller through an AVR programmer that ATMega and Atmel offer. This is a programmer that is able to upload all of the code to the controller over MISO/MOSI pins to be saved in the onboard EEPROM memory for the controller. This programmer will also let us set the programmable fuses on the microcontroller that will let us access some of the features of certain pins, such as ACD or disabling JTag so that all of the pins can be used.

To help with some functionality we are also making use of the Arduino library, an open source application that was developed for ATMega controllers.

8. Project Testing Plan

This section details the testing environment that we will be using to confirm the functionality of our Project board as well as our project software.

8.1 Hardware Testing Environment

Once our board is assembled and soldered in place we will have to perform several tests to ensure that the proper signals are being sent. We will be testing several signals on the board to ensure that the proper voltage is being supplied to each device, some of our devices require 3.3 V or logic, but others will require 5.0 V of logic. We will also have to be sure that several reference voltages and ground voltages are indeed reading near 0 V.

We will need to perform several tests from the Pulse width modulation pins on the microcontroller to ensure that our pins are outputting proper Pulse width modulation waves that were discussed in section 3.2.3. To do this we will have to make use of an oscilloscope.

We will also have to be sure that the board is able to regulate it's input voltage properly from high voltage sources such as a 24V or 48 V power source. We have access to a 48V AC to DC power supply that will be used for this part of the testing.

Due to Covid-19 some of these tests will have to be performed separated from most of the team or in different sets until we can combine the board pieces. Thankfully we were provided an oscilloscope for testing by the senior design team. The Engineering companies that we work for have also offered the use of their labs and equipment to help meet our needs during Covid-19.

Figure 81. Tool kit provided

8.2 Software Testing Environment

Most of the code will be developed in the Atmel studio that is built on top of Microsoft Visual Studios. Depending on the type of AVR programmer that we acquire we may be able to use debugging modes to confirm the values of some variables on the boards, but this is unlikely meaning most of our coding will be trial and error with the use of a Serial line to see the outputs of some variables while we are constructing the logic for our microcontroller.

For our Application we will be making use of a free tier Amazon Web Services environment since this is free hosting for Linux based environments. This will be used to configure the communication between the front end of our Application and the web-server.

Our front end application will mostly be developed in a JavaScript editor environment and tested on both Chrome and Safari as these are two major browsers that support BLE Bluetooth communication. Both of these browsers also support a debugger and console windows that we can use to test and develop our front end application.

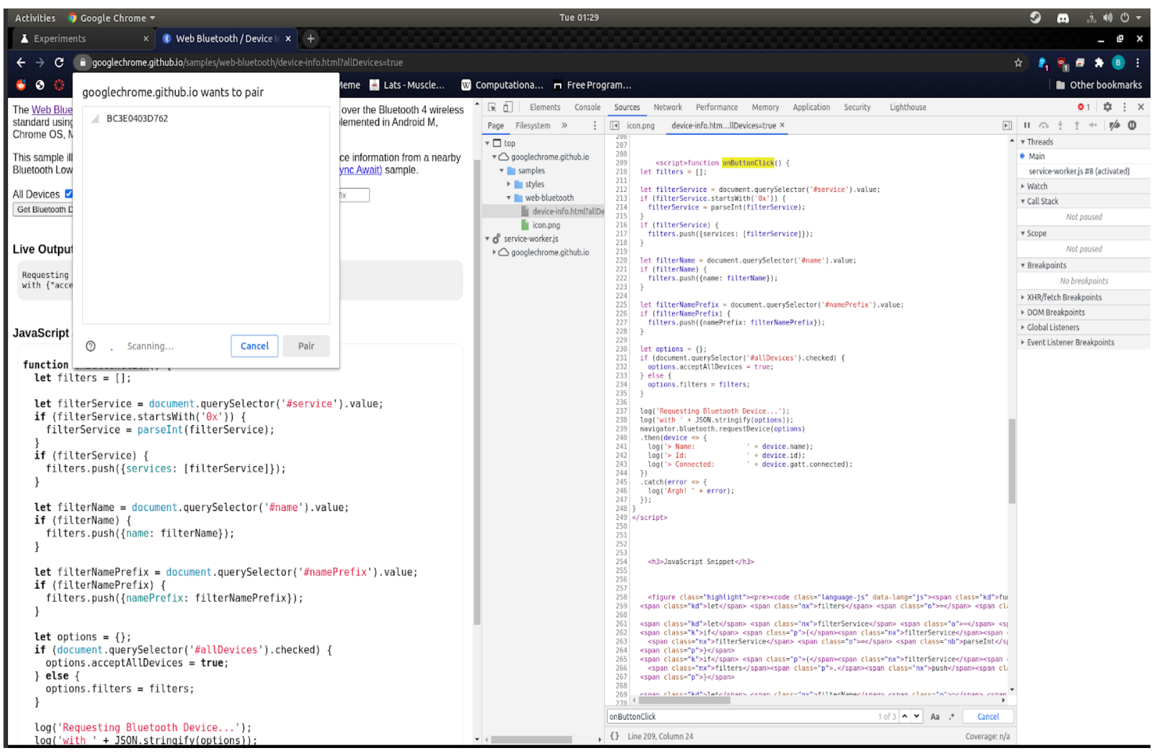


Figure 82. Google Chrome pairing with BLE device

8.3 Hardware Testing Plan

Our first test will be ensuring that each component on the board has a proper DC supply when connected to a high voltage supply (24V or 48V). Each of the Vcc and Vin pins for our various integrated circuit boards should have a +5V in or a +3.3V input. We will also need to be sure that no Grounds are accidentally being set high. All of our grounds should read roughly 0V. Our Vref on the main microcontroller should also be confirmed to. These voltages will all be tested with a DC voltage meter.

Our first hardware test will be can we send Pulse Width Modulation waves from Pins 1, 9, 10 13, 14, 32. This will be tested by having these pins output steady 25% duty cycle waves and measuring them each on an oscilloscope to confirm that they are steady waves and maintain a 25% duty cycle. We will then increase it to 50%, 75% and finally 100%. We should be able to at least maintain those 4 types of waveforms.

Next we will have to confirm that these waveforms are being sent to each of the Integrated Driver circuits and that they are outputting a steadily increasing average voltage to the DC motors that will be connected to them. This will have to be done by reading the output pins 5, 7, 8, and 10 on the Motor drivers. We will first read the outputs with an oscilloscope to confirm that they are pulse width modulating waves. We will then measure the DC voltage to confirm that it is slowly increasing as the duty cycle increases to be sure that this part is working as intended.

The input on the joystick header pins will have to measured as well to be sure that the correct values are reaching the Analog to digital converters on the microcontroller, and are being properly converted to a digital value based on the reference voltage and the voltage that is being divided by the joystick.

From our previous testing with these joysticks we know that the readings will be slightly off and have some “drift” to them based on their quality, but we will be adding code to handle some error in these readings.

To confirm that the sensors are working we will input up to 5V across each of the Pin headers with a power supply and ensure the correct values are being read by the microcontroller on the receiving end.

We will also have to attempt to read the input values on these pins and output the results to a serial line to ensure that each sensor pin header is being interpreted correctly inside of the Microcontroller.

During some of our meetings with the parents some of them expressed concerns about the consistency of Bluetooth as they have had some issues with signals being dropped in the past on other Bluetooth devices. Serial communication in general is susceptible to dropped bits or even flipped bits due to signal noise in the circuit lines. Adding in wireless communication where signals can be lost due to other wireless signals in the air that the signals pass through and this can be a valid concern.

We will be testing how long it takes for a signal to be dropped when sending a signal to the Bluetooth device once it is soldered in place or board. This test will have to be done several times to avoid single errors. This will give us the mean operations between failures to know on average how many signals will be lost. We will send 1024 characters back to back to see how much data is lost on average over a large sample set. This will let us know for sure how reliable the communication of the final Bluetooth implemented is.

8.4 Software Testing Plan

As part of our software testing plan, we will be performing some acceptance testing. Acceptance testing is a test conducted to determine if the requirements of a specification or contract are met. In our case, acceptance testing will test the functionality of each one of our features that we will be developing in our web application which will ensure that each feature is functioning correctly. Our acceptance testing will also aid in terms of discovering any bugs that might rise in the future.

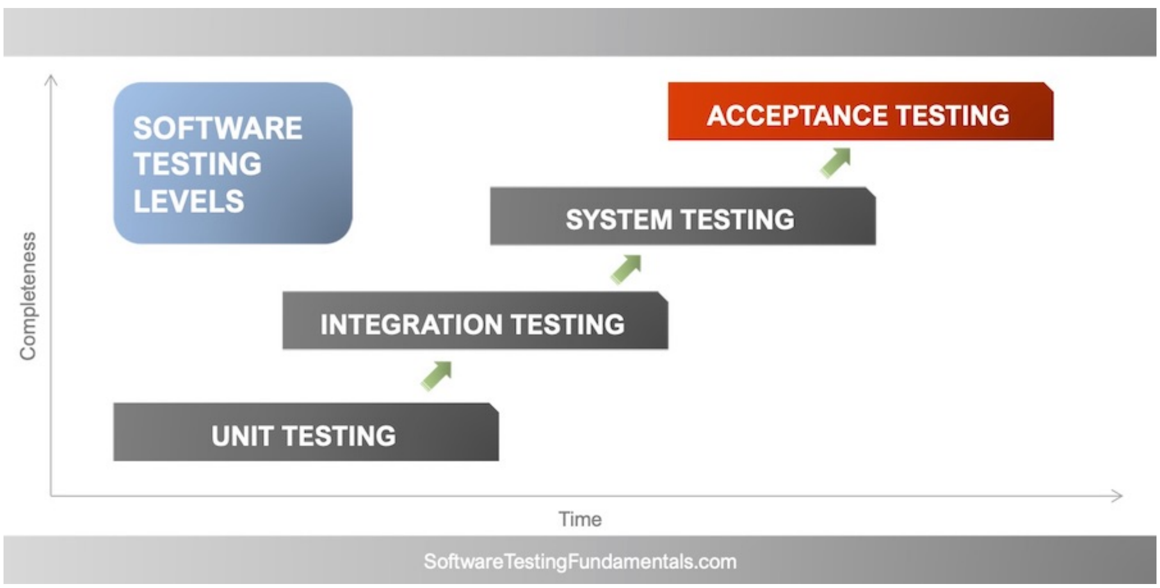


Figure 83. Software testing levels

Robot framework will be used to build our acceptance tests suite. Robot Framework is a generic open source automation framework. It has easy syntax, utilizing human-readable keywords. Its capabilities can be extended by libraries implemented with Python or Java which makes it an easy framework that we can easily use without the need of learning new programming languages. It is a free framework which also will help to bring down the cost of our project.

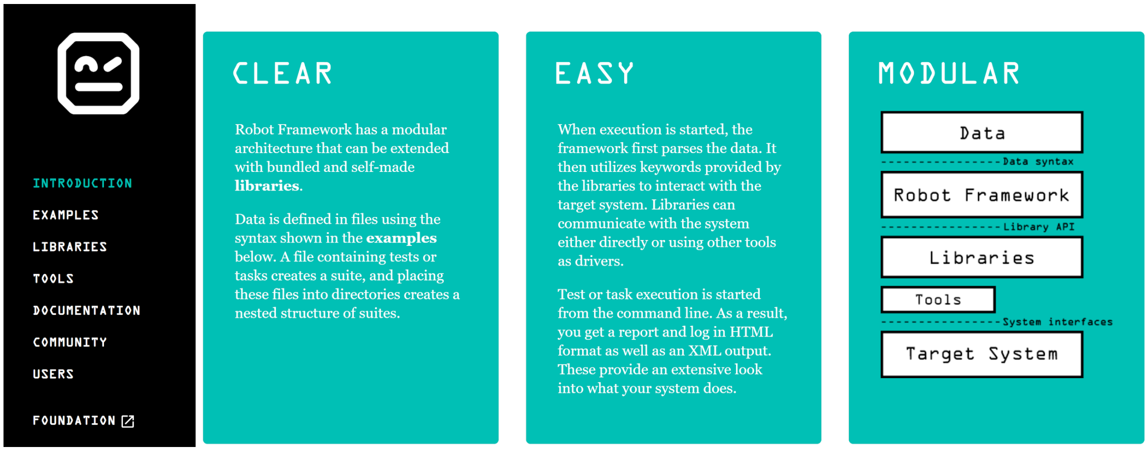


Figure 84. Robot Framework for automated acceptance testing

Robot Framework provides a very detailed test results report which helps in terms of debugging and maintaining our web application over time. Through the test results report we will be able to see trends of our acceptance testing suite for each of our web application features over the time which provides information of how the application is performing over time.

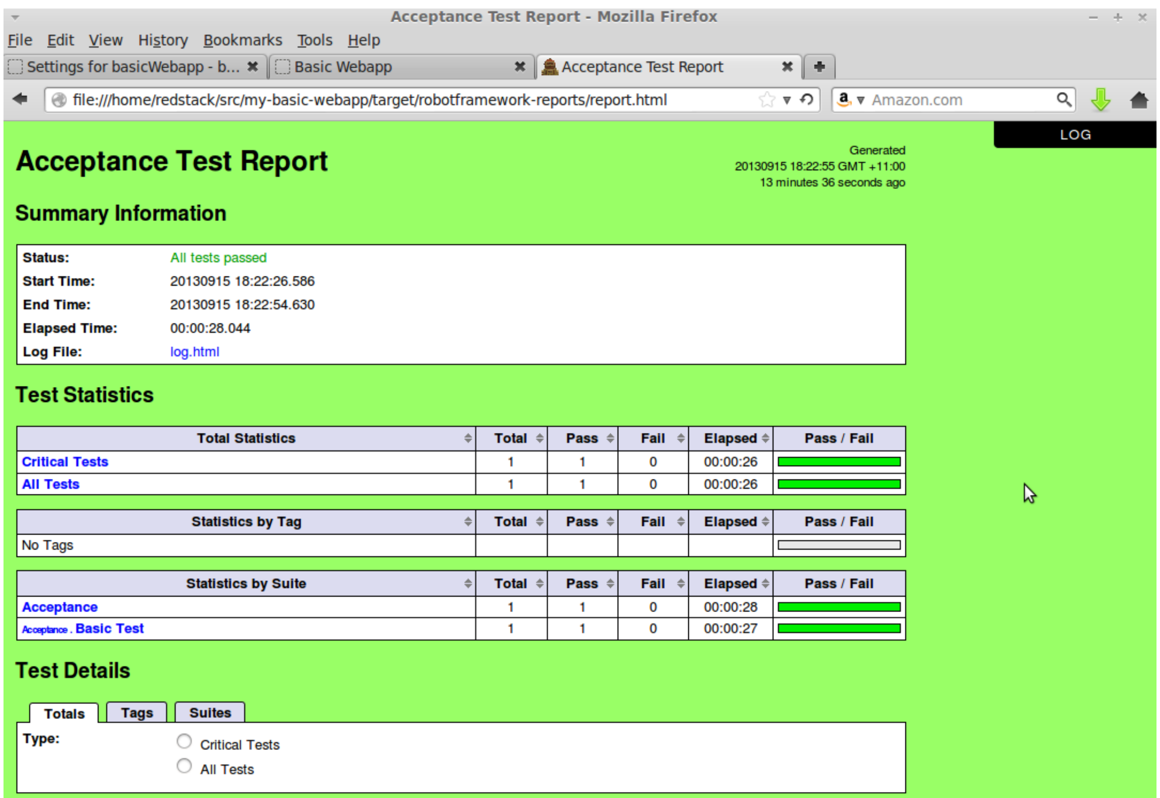


Figure 85. Robot Framework Acceptance Test Report

To confirm that our web application will work correctly we will have to perform several tests from our browsers of choice, both Chrome and Safari, ensuring that the browser is able to locate the Bluetooth device reliably when it is broadcasting mode and nearby a phone or another receiver.

Several tests similar to the hardware test will need to be performed from the web application as well. We will have to set a large number of characters over the Bluetooth communication line, roughly 1024 characters such as we did for the hardware test, to determine if there is any volatile nature to the information that is being transmitted over Bluetooth.

9. Administrative Content

This section explains and encapsulates all of our administrative content. Such as project planning, our estimated Budget, and our planned course of action.

9.1 Estimated budget

The Go Baby Go Car! Project is sponsored by UCF's Go Baby Go! Program. The parts listed in Table 15 give a basic idea of the components that will be needed for this project. The total price is only a rough estimate, as it is likely that other parts were overlooked and the design specifications will change as the semester progresses. It is important to note that the budget for this project is only for one car. In order to utilize this system for multiple cars, the overall budget needs to be multiplied by a factor of four.

Table 15 - Estimated Budget for Go Baby Go! Car Project

ITEM	PRICE ESTIMATE
Collision sensors	$10 – $40
Motors	$45 - $100
Joystick	$20 - $120
Power source	$30 - $100
Bluetooth Module	$3-$50
Web Application Module	$40-50
Motor Module	$100 - $250

Custom PCB	$30 - $150
Miscellaneous (Tools, Wires, etc)	$50 - $150
TOTAL (Estimated Range)	~$328 - $1010

9.2 Project Milestones

The project milestones for the Go Baby Go! Car project is shown in Table 16 and Table 17. These milestones are divided between the two semesters of senior design and name the person/group responsible for each task.

Table 16 - Project Milestones for Go Baby Go! Senior Design Project

Senior Design 1		Planned Completion
Familiarize ourselves with the project	Group 13	09/15
Role Assignments	Group 13	09/15
Identify parts	Group 13	09/25
Project Report		
Initial Document	Group 13	10/08
Updated initial document	Group 13	10/16
First draft	Group 13	11/13

Final draft	Group 13	11/29
Final document	Group 13	12/04
Research, Documentation, and Design		
Sensors Module	Nafisa	12/04
Bluetooth Module	Brandon	12/04
Joystick Module	Samantha	12/04
Motors Module	Mirette	12/04
Application	Brandon	12/04
Schematics	Group 13	12/04
PCB	Group 13	12/04

Table 17 - Senior Design 2 Schedule

Senior Design 2	Member	Date
Build Prototype	Group 13	01/11/21
Testing and Redesign	Group 13	02/25/21
Finalize Car	Group 13	03/25/21
Peer Presentation	Group 13	04/28/21
Final Report	Group 13	04/29/21

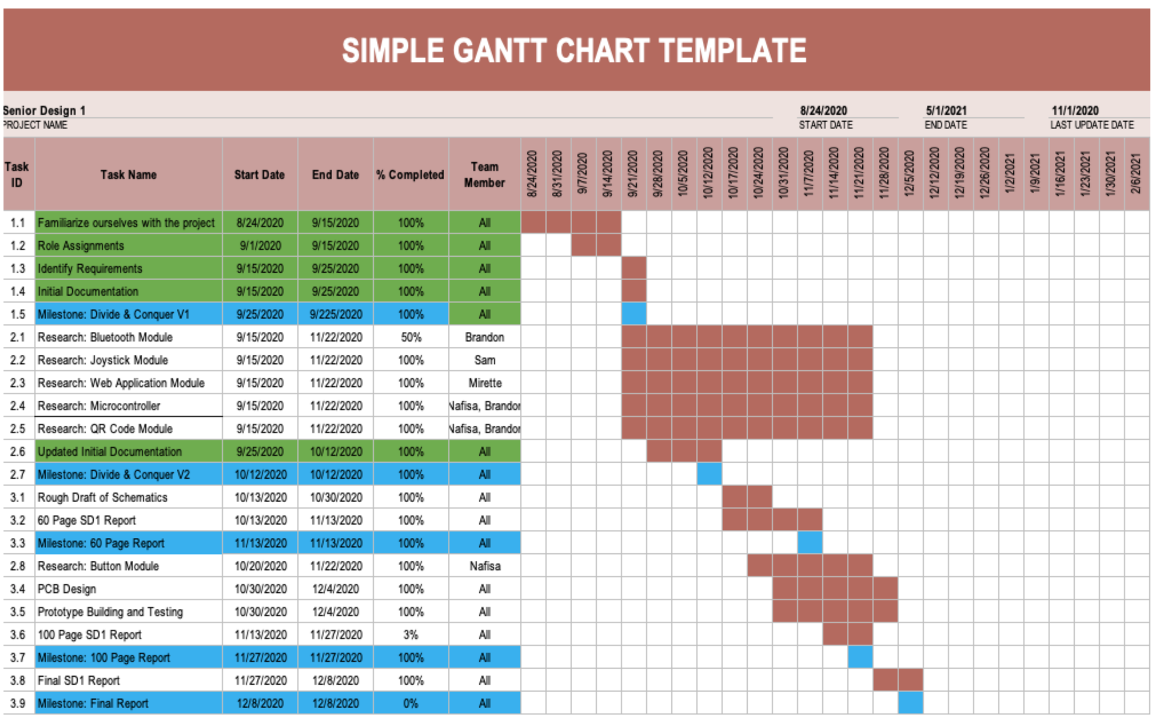
In the following Table, a bill of materials for the various parts of the project is represented.

Table 18 - Bill of Materials

Item	Quantity	Price per unit
HC-SR04 Sensors (Collision Sensors)	6	12.99 (10 pack from Amazon)
ATMega-328P (microcontroller that controls the whole system)	1	2.08
LDO Regulator (Mid-VIN) (makes sure that our voltage to the circuit board is constant)	1	1.60
ESP32-CAM (QR Code)	1	18.99 (2 pack from amazon)
Analog 2-Axis Joystick	1	5.95
HM-10 Bluetooth Module	1	9.99
Nema 17 Stepper Motor Bipolar 2A (allows us to have remote steering)	1	12.99

IBT-2 H-Bridge (controls the motors)	2	14.89 (2 pack from amazon)
Printed Circuit Board	1	~30
GPIO pins, serial ports for PCB		1-2

Part of our requirements for the client was to create a GANTT chart to track our progress during the project. The GANTT chart seen in Figure X depicts the various tasks our team had to complete during Senior Design 1, the date when they should be completed, and who was responsible for that task. This allowed our team to be on time and keep track of our progress throughout the project.



Task ID	Task Name	Start Date	End Date	% Completed	Team Member
1.1	Familiarize ourselves with the project	8/24/2020	9/15/2020	100%	All
1.2	Role Assignments	9/1/2020	9/15/2020	100%	All
1.3	Identify Requirements	9/15/2020	9/25/2020	100%	All
1.4	Initial Documentation	9/15/2020	9/25/2020	100%	All
1.5	Milestone: Divide & Conquer V1	9/25/2020	9/225/2020	100%	All
2.1	Research: Bluetooth Module	9/15/2020	11/22/2020	50%	Brandon
2.2	Research: Joystick Module	9/15/2020	11/22/2020	100%	Sam
2.3	Research: Web Application Module	9/15/2020	11/22/2020	100%	Mirette
2.4	Research: Microcontroller	9/15/2020	11/22/2020	100%	Nafisa, Brandon
2.5	Research: QR Code Module	9/15/2020	11/22/2020	100%	Nafisa, Brandon
2.6	Updated Initial Documentation	9/25/2020	10/12/2020	100%	All
2.7	Milestone: Divide & Conquer V2	10/12/2020	10/12/2020	100%	All
3.1	Rough Draft of Schematics	10/13/2020	10/30/2020	100%	All
3.2	60 Page SD1 Report	10/13/2020	11/13/2020	100%	All
3.3	Milestone: 60 Page Report	11/13/2020	11/13/2020	100%	All
2.8	Research: Button Module	10/20/2020	11/22/2020	100%	Nafisa
3.4	PCB Design	10/30/2020	12/4/2020	100%	All
3.5	Prototype Building and Testing	10/30/2020	12/4/2020	100%	All
3.6	100 Page SD1 Report	11/13/2020	11/27/2020	3%	All
3.7	Milestone: 100 Page Report	11/27/2020	11/27/2020	100%	All
3.8	Final SD1 Report	11/27/2020	12/8/2020	100%	All
3.9	Milestone: Final Report	12/8/2020	12/8/2020	0%	All

Figure 86: GANTT Chart

10 Conclusion

In conclusion, we have designed and prototyped an electrical and computer system for UCF's Go Baby Go program. Many engineering design challenges have been attempted and overcome with this project. The future goals of this project is to develop and integrate this system into the four prototype cars and further document the system. Using this system, Go Baby Go will be able to provide multiple cars for children with mobility impairments and hopefully improve their quality of life and movement.

Appendix A - References

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