

# **Bike Safety Sensor**

**ECE 445 Design Document**

Jerry Pitts and Edward Wang

Group 65

TA: Kexin Hui

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# **1 Introduction**

## **1.1 Objective**

The streets are a busy place, and it is impossible to be looking all around you at once. There could be a car approaching on your left while you are distracted by a flying newspaper. You could be so confident in your turns that you don't notice the trash bin right beside you. There are many dangers that exist on the open road, some coming at you directly and some unable to be moved by the impact of your bike.

Our solution to this problem is a belt with haptic feedback that will detect objects behind and to the side of you to give you a better idea of where the dangers are. This belt will vibrate when a car pulls up beside you or if you've stopped by a garbage can without noticing. The vibrations get stronger the closer the object is to give you a better idea of how imminent the dangers are. You no longer have to look around aimlessly trying to find every roadblock as this belt will tell you where they are.

## **1.2 Background**

There has always been research into ways for cars and trucks to detect objects in their blind spots. While a biker has a wider field of view than a car, they still cannot be looking around them all the time for incoming obstacles. There are some systems available to detect objects around a bike but most require you to take your eyes off the road to look at a display. They are also upwards of \$300 and not commercially available. Our device uses haptic feedback to tell you where an object is approaching and how close it is to you. It uses an extra sense that is not normally used when riding a bike to notify you of what is around you.

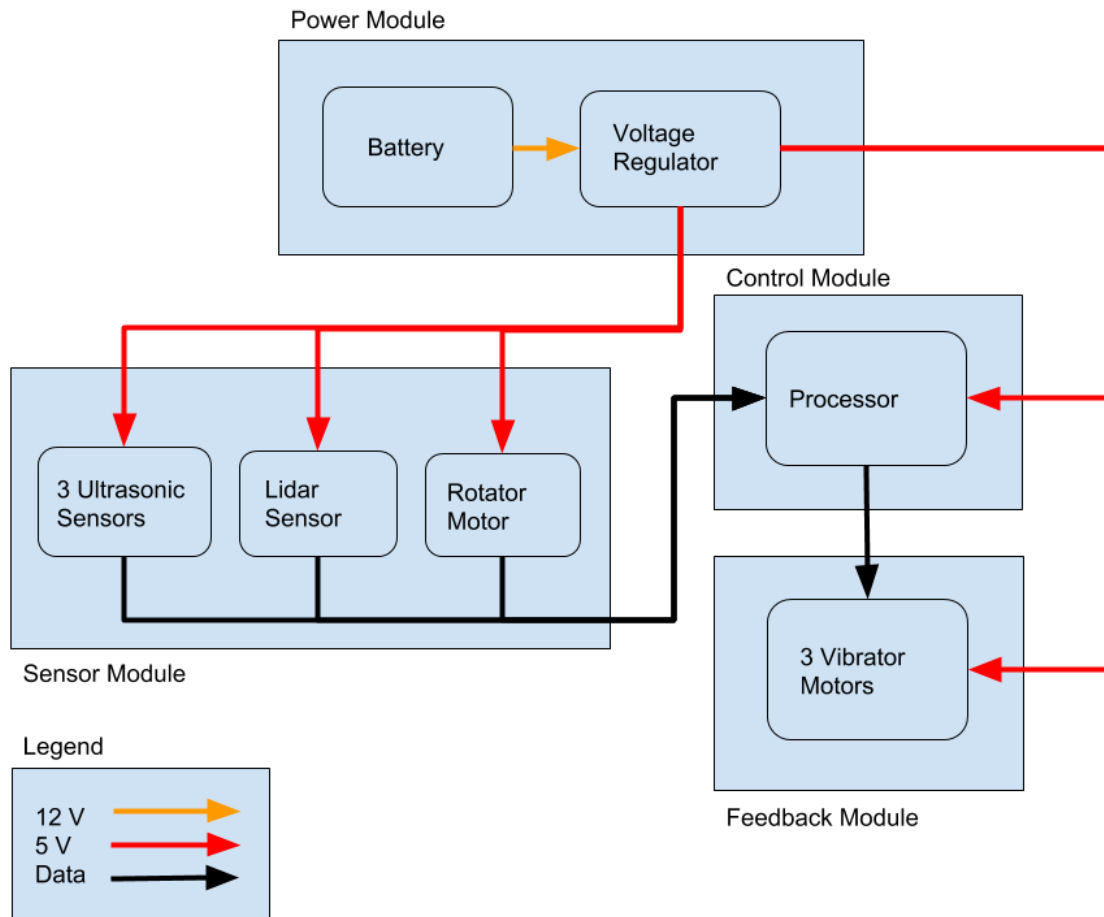
Most of these devices use radar or ultrasonic sensors to detect the objects that are approaching [2]. Our device will use a combination of lidar and ultrasonic sensors to detect incoming obstacles. Ultrasonic is mostly useful at close range, so we added a lidar sensor to be able to detect things farther than the ultrasonic can. The ultrasonic sensor will mostly be used to alert the wearer to objects in their immediate vicinity.

## **1.3 High-level requirements**

- Detect objects from 1~12 m away and alert user based on distance
- Have range of 60 degrees in 1d when measuring objects within 1 m around the wearer and detect 3 lanes of traffic (3.7 m each) up to 12 m behind the wearer
- Cost less than current commercially available radar sensor (\$300)
- Run for at least 4 hours on a single charge

## 2 Design

### 2.1 Block Diagram



**Fig. 1. Block Diagram**

### 2.2 Power Module

The power module is tasked with supplying power to all components in the device. There are three ultrasonic sensors, one lidar sensor, one rotating motor, three vibrating motors, and one microprocessor that need power. The module consists of the battery and a voltage regulator. The battery holds the charge to be used later and needs to last more than four hours on a single charge. The voltage regulator needs to be able to modulate the voltage to the level the parts need, within their operating requirements, once the components are all picked.

### 2.2.1 Battery

Since we need a power source that is both easily accessible and rechargeable, we settled on using a lithium ion battery. The battery of the device will be a TalentCell Rechargeable 12V 6000mAh battery. The battery needs to hold enough power to supply it to all the other components of the device. The parts needing power are the ultrasonic sensor, lidar sensor, rotating motor, microprocessor, and vibrating motor.

The battery will be connected through a wire to the voltage regulator and exist as a free hanging object. The device can be stored in the wearer's pocket or secured to the belt in a pocket or attachment.

Requirement	Verification
1. Able to supply power for a minimum of 4 hours.	1. Voltage regulator supplies a max of 1 A at 5 V. The battery has 6000 mah at full charge operating at 12 V. This leads to a 6 hour operation time.

### 2.2.2 Voltage Regulator

The voltage regulator needs to take the voltage from the battery and modulate it so that it can be used by the ultrasonic sensor, lidar sensor, rotating motor, microprocessor, and vibrating motor. The input voltage should be able to handle the operating ranges of the battery we choose and output a voltage that is within 5% of the required voltage of the other components.

The voltage regulator chosen for this is the L7806CV. This regulator operates between 7 to 35 V and produces an output voltage between 4.8 V to 5.2 V with an average of 5 V for its worst case scenario.

Requirement	Verification
1. Supplies 5 V $\pm$ 5%.	1. Battery will apply unregulated 12 V while the regulator will convert that to 5 V with a min of 4.9 V and max of 5.1 V and have a max operating current of 1 A.

## 2.3 Sensor Module

The sensor module will be used to take information from the environment and feed it into the microcontroller. It will use lidar sensors and ultrasonic sensors. It should be able to reasonably sense if there is an object within 12 meters and become very accurate within 4.5 meters.

### 2.3.1 Lidar Sensor

The sensor that we will use is the Benewake TFMINI Micro LIDAR Module [6]. This sensor is affordable and works under regular sunlight conditions of 70 klux up to 7 m and up to a max range of 12 m. This sensor will be on a motor so that it can turn 60 degrees to detect things behind the wearer. We will first test the lidar sensor using an arduino, then convert it to work with a microchip.

Requirement	Verification
1. Detects up to 3 lanes of traffic behind wearer.	1. Mounted on a motor that will rotate back and forth between -30 and 30 degrees. Standard US interstate highway width is 3.7 m, motor will only sweep halfway into adjacent lanes (because cars are wide). Calculations done assuming 7 m range for average sunlight conditions as stated by datasheet. (refer to calculations)

### 2.3.2 Ultrasonic Sensor

The ultrasonic sensors that we will use are the HC-SR04 Ultrasonic Distance Sensor Modules [9]. These sensors are cheap and accurate up to 4.5 meters. There will be three of these sensors that will be on the left, right, and center of the back of the wearer. The purpose of these sensors is to give more accurate feedback at shorter ranges.

Requirement	Verification
1. Detect objects within 1 meter of the sensor.	1. Sensor is able to detect objects up to 4 meters away at max range, however there is a 2 cm blind spot in-front of the sensor.

### 2.3.3 Sweeping Motor

The sweeping motor will be attached to the lidar sensor and must rotate back and forth across a 140 degree range behind the belt. The motor needs to be able to send data containing the current angle the lidar is facing. The motor we will be using is the Parallax Standard Servo #900-00005. This motor will be constantly running and operates with an average current draw of  $140 \pm 50$  mA.

Requirement	Verification
1. Have a range of motion between -30 to 30 degrees.	1. Motor holds any position between 0 and 180 degrees.

### 2.4 Control Module

The control module will need to take inputs from the both the lidar sensor and the ultrasonic sensors. It will also take an input from the lidar motor to sense what direction the lidar is facing. The output will tell which of the vibrating motors to start vibrating, and how intensely.

### 2.4.1 Microcontroller

For our microcontroller, we will be using an Atmega328p. This chip is useful because it can be programmed in a similar way to an arduino, and it is inexpensive. We can start off using an arduino device to test many of our parts and get data from them. Then, we can change to the Atmega328p and program it to work in the same way. It will be important to handle the inputs and outputs to the sensors and motors. A schematic for this microchip is included in figure 4. The schematic available in eagle is the Atmega168, which is the same as the Atmega328 but slightly older.

Requirement	Verification
Must be able to run at a voltage of 5.0V $\pm$ 5%.	Make a simple test program to light an LED using one of the input output pins, and test with the microchip powered from 4.75 to 5.25 Volts.
Must be able to turn vibration motors on and off.	Test the output of the microchip to make sure that it can control up to 5 Volts for the motor and measure using a voltmeter in the lab.
Must be able to take input values from the lidar sensor, ultrasonic sensors, and the servo motor.	Make a program to light up LEDs when signals are received from the sensors. Different LEDs will light up based on which sensors are detecting and what angle the servo motor is facing.

### 2.5 Feedback Module

The feedback module consists of a collection of three vibrating motors. The motors will be located at the left, right, and back side of the belt. The motors need to be able to vibrate at different intensities to signal how close an object is to the wearer. The motors will be supplied power from the battery and voltage regulator, and the control module should dictate when and how strong each of the motors will vibrate.

Requirement	Verification
1. Be able to buzz strong enough to alert the person wearing it.	1. Motor operates at 11000 rpm with a 5 V input.

## 2.6 Functional overview

The device needs to take the data from the sensors and rotating motor and give it to the microprocessor. The microprocessor will tell the vibrating motor when to vibrate and how strong to. Motors should increase in strength when the sensors detect that an object gets closer.

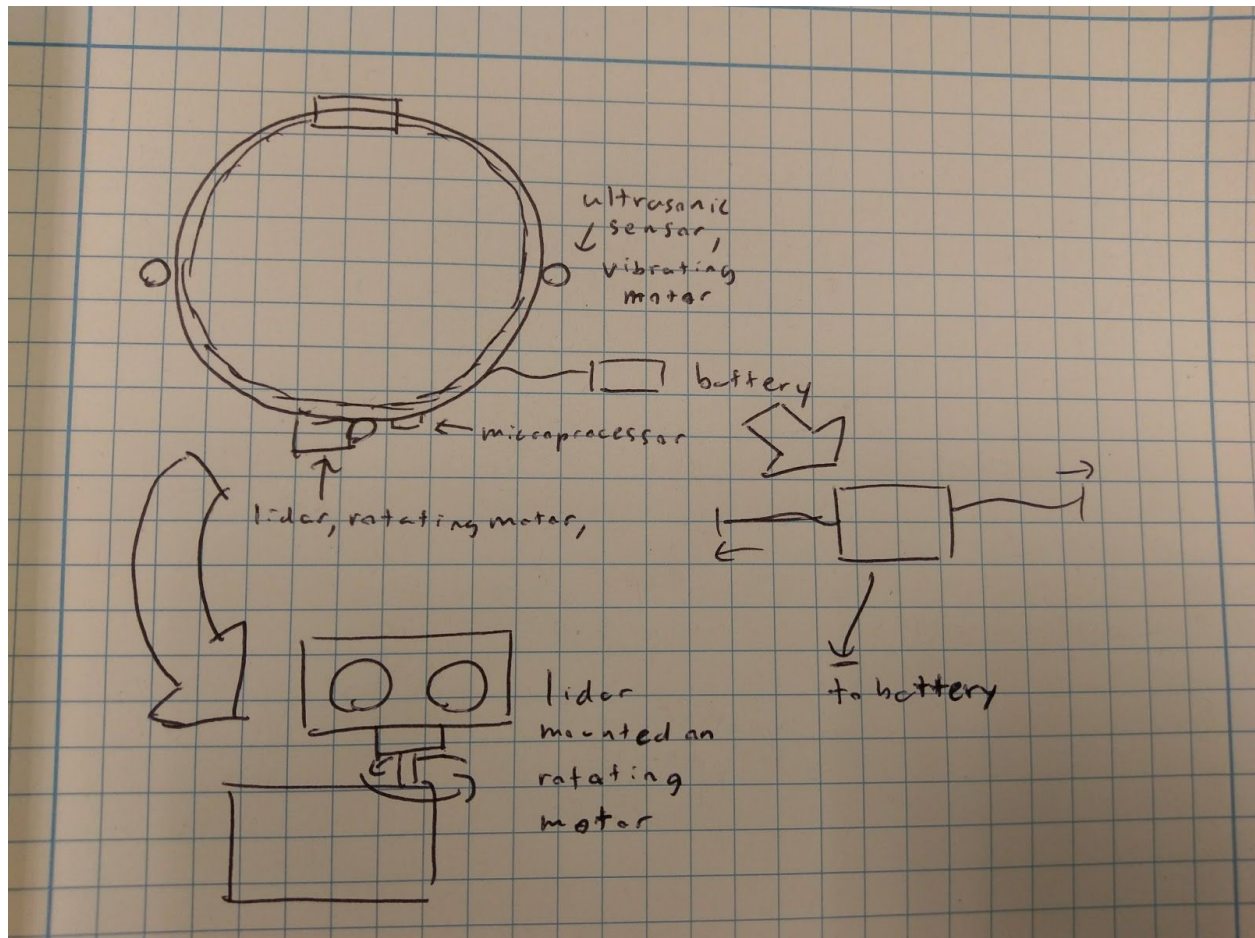
## 2.7 Cost

Part Name:	Cost
Lidar	\$39.99
Ultrasonic x3	\$3.95 ea
Battery (tentative)	\$33.99
Regulator	\$0.45
Sweeping motor	\$13.95
Vibrating motor x3	\$1.95 ea
Microcontroller	\$2.28
16 MHz crystal	\$1.25
Misc passive circuit elements	\$10
Total (electronics)	\$119.61

This cost only accounts for all the electrical components we need. Additional costs will come from the belt and the mounting tools we need to secure the items to the belt.



## 2.8 Physical Diagram



## 3 Circuit Diagrams

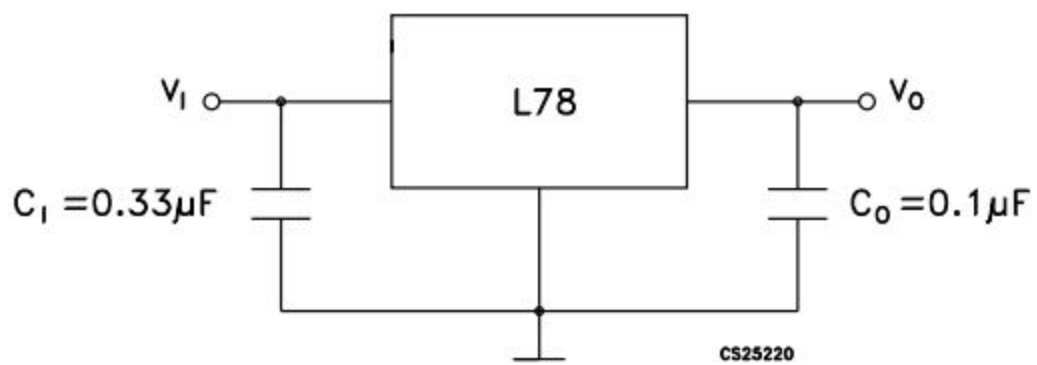
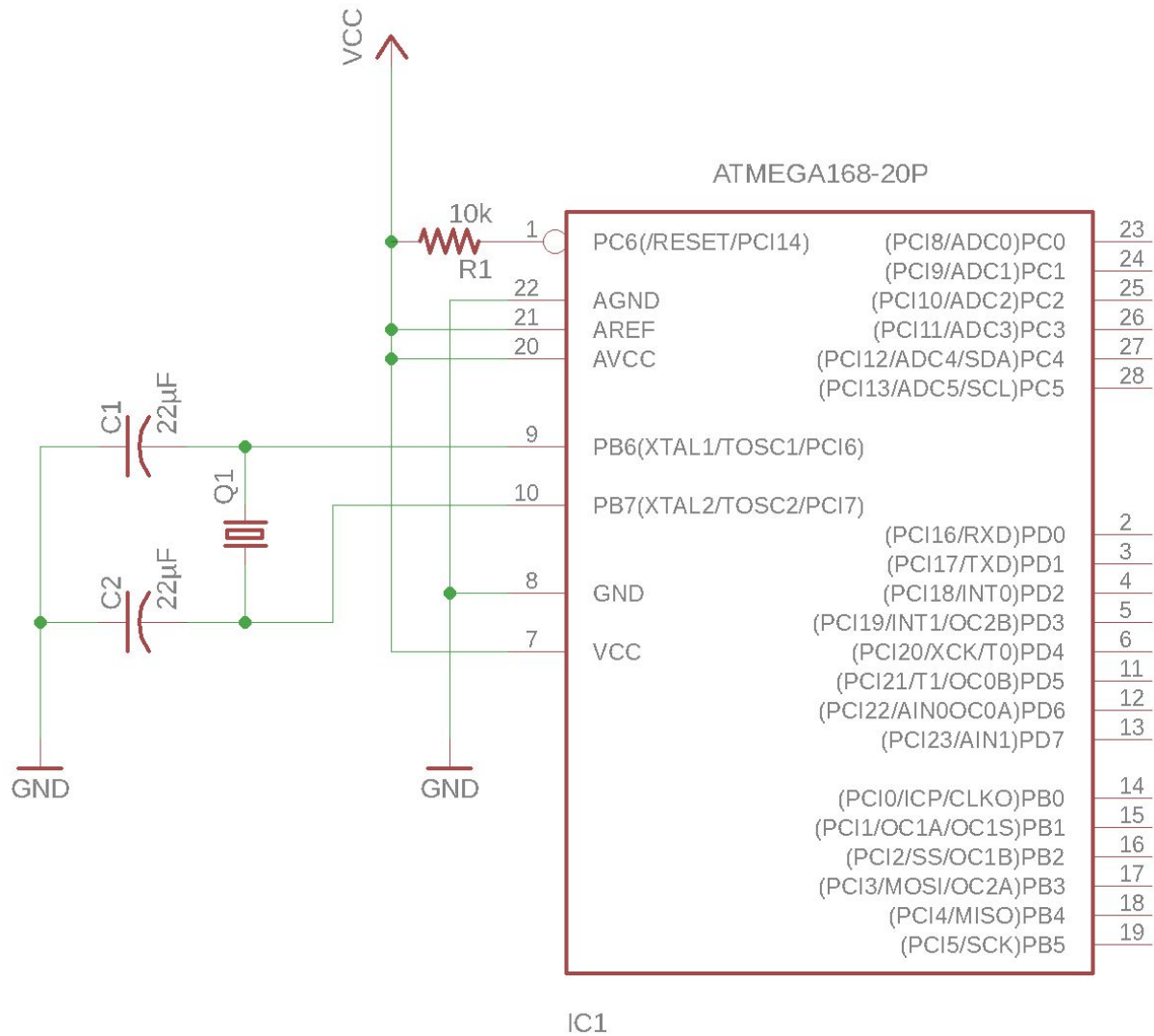


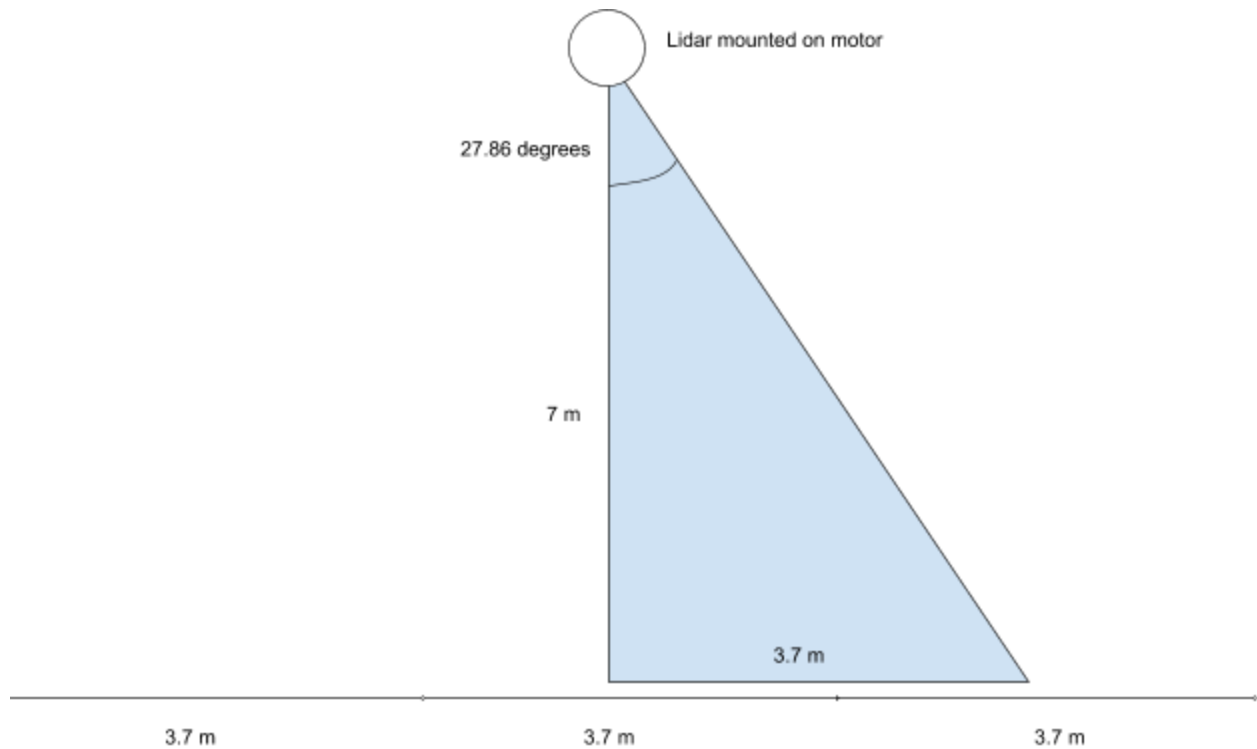
Fig. 3 Voltage Regulator



**Fig. 4 Atmega 328p**

#### 4 Calculations

In order to find the angle at which the lidar should sweep, we need the distance the lidar should detect and the width of a standard traffic lane. The lidar accurately detects objects in normal sunlight at 7 m, and a standard highway lane is 3.7 m across [5]. Figure 5 shows us the relation between the width of the lane and the distance we sense at. We only scan across half of a lane on each side because a car will be detectable if driving in a traffic lane.



**Fig. 5 Lidar Range**

#### **4.1 Tolerance Analysis**

When operating the L7805CV voltage regulator at between 7 to 18 V with an output current between 5 mA to 1 A, the output voltage is between 4.75 V to 5.25 V with an average at 5 V [10]. This is within 5% for our design requirement, and is in the acceptable range for our devices.

The Atmega328p chip has some tolerances that must be met to keep our device running properly. For this chip, the tolerances are easy to maintain, but are still important. The chip must be supplied with 1.8 to 5.5 volts to keep it running at 20 MHz. This should be easy to maintain through our power supply and our voltage regulator, which outputs 5 volts. The chip also needs to be kept at a temperature of -40 to 85 degrees celsius. The temperature outside will always be within this range when someone may be biking outside. [8]

The HC-SR04 Ultrasonic Sensor also has some tolerances. The speed of the bike should not make a difference for the distance calculation between the sensor and the obstacle because the sound pulse must travel to the obstacle and back. Some of the other tolerances to be considered are the range. This sensor is meant to sense objects that are close to the user. The datasheet states that the sensor can sense up to four meters. At this range, the obstacle

is very close to the user, so it is good for this purpose. The measuring angle of this sensor is 15 degrees.

$$\tan(7.5^\circ) * 4 \text{ meters} * 2 = 1.05 \text{ meters}$$

This equation shows that the range of one ultrasonic sensor is 1.05 meters wide from four meters away. This should give a good range for if an obstacle is coming close to the biker.  
[9]

## 5 Schedule

Week	Jerry	Edward
2/26	Test components as they come in (ultrasonic, lidar, microprocessor)	Order battery and test components as they come in (voltage regulator, motors)
3/5	Make programs for microchips	Design circuit for power module and figure out how to wire things together
3/12	Design PCB for sensor and control module	Design PCB for power and feedback module, also overall board
3/19	Out of town	Out of town
3/26	Finalize PCB designs	Finalize PCB designs
4/2	Connect sensor and control modules, write report sections corresponding to modules	Connect power and feedback modules, write report sections corresponding to modules
4/9	Assemble/Debug sensor modules and processor code	Assemble/Debug battery pack and physical belt
4/16	Prepare for mock presentation	Prepare for mock presentation
4/23	Final round of bug fixes/improvements	Final round of bug fixes/improvements
4/30	End of project	End of project

## **6 Risk analysis**

The lidar sensor is one of the most important parts of this project, and it could possibly have some problems. The website says that it works in all types of light environments [6], but it could work differently outside. Also, there comes some risk involved with the way we are using this sensor. We want it to sweep back and forth to cover an area behind the wearer, but that could make the laser pick up some unwanted detections.

Another risk to the project is the way that the belt works, a simple belt may not have enough support to carry the entire device with all of its sensors and batteries. The belt will also not always be facing exactly where we want during different activities such as running or biking. To counter this problem, we will make something that the lidar detector can hinge on with the bottom of the detector being more heavily weighted. This should cause the lidar sensor to face the way that we want, which is even with the surface of the earth.

## **7 Ethics and safety**

Lithium ion batteries are known to malfunction when overcharged or at high temperatures [1]. Most of these issues can be avoided as the batteries usually come with overcharging protection. We must also consider how the battery is stored. The battery needs to be held on the person's body either in a pocket or attached to the belt.

Since we are using vibrating motors to alert the wearer where the dangers are coming from, the motors must be strong enough to alert the person but not enough to shock the person. Shock meaning both electrical shock and scaring the person that is wearing the device. We also cannot have a super strong motor that is constantly running while a person is right next to an object.

Something else to consider is the device will be worn outside the person. The person will most likely be biking outside so the device needs to have some sort of weatherproofing. We are considering wrapping all exposed connections.

There come some ethical concerns with this project. One of the most important things that come to mind when thinking about this project is the safety of the user and those around the user. This goes along with the IEEE Code of Ethics, #1: "To hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment" [4]. By using this project in everyday life, a user could become too reliant on the device, making the user less reliant on his or her senses. There could be some situation where the belt would not work well, and the user would not notice something coming up

behind them. Ultimately, our goal is to enhance the safety of bicyclists, but it is important to consider the side effects.

Another ethical consideration is the claims of our products. It is important to accurately report our devices limitations for the safety of the user. The Code of Ethics #3 states: “To be honest and realistic in stating claims or estimates based on available data” [4]. This rule is important to consider for our project because our project has to do with safety. Also, the sensors that we use could not be the most optimal for what our project is trying to accomplish. It is important to be realistic about what our project can do.

## References

- [1] "Lithium-ion Safety Concerns", Batteryuniversity.com, 2018. [Online]. Available: [http://batteryuniversity.com/learn/archive/lithium\\_ion\\_safety\\_concerns](http://batteryuniversity.com/learn/archive/lithium_ion_safety_concerns). [Accessed: 22- Feb- 2018].
- [2] D. Rainmaker, "Hands-On with Backtracker: Radar for your bike", DC Rainmaker, 2014. [Online]. Available: <https://www.dcrainmaker.com/2014/07/hands-on-backtracker-radar.html>. [Accessed: 22- Feb- 2018].
- [3] "Wavetronix - Bicycle Detection", Wavetronix.com, 2018. [Online]. Available: [https://www.wavetronix.com/en/case\\_studies/13-bicycle-detection](https://www.wavetronix.com/en/case_studies/13-bicycle-detection). [Accessed: 22- Feb- 2018].
- [4] "IEEE (Institute of Electrical and Electronics Engineers) Code of Ethics", ieee.org, 2018. [Online]. Available: <https://www.ieee.org/about/corporate/governance/p7-8.html> [Accessed: 18-Feb- 2018].
- [5] "Mitigation Strategies For Design Exceptions - Safety | Federal Highway Administration", Safety.fhwa.dot.gov, 2018. [Online]. Available: [https://safety.fhwa.dot.gov/geometric/pubs/mitigationstrategies/chapter3/3\\_lanewidth.cfm](https://safety.fhwa.dot.gov/geometric/pubs/mitigationstrategies/chapter3/3_lanewidth.cfm). [Accessed: 23- Feb- 2018].
- [6] "TFmini Infrared Module Specification", robotshop.com, 2018. [Online]. Available: [https://www.robotshop.com/en/benewake-tfmini-micro-lidar-module-12-m.html?gclid=EAIaIQobChMI1pz9spmV2QIVBodpCh0xIQizEAQYBSABEGKPOvD\\_BwE](https://www.robotshop.com/en/benewake-tfmini-micro-lidar-module-12-m.html?gclid=EAIaIQobChMI1pz9spmV2QIVBodpCh0xIQizEAQYBSABEGKPOvD_BwE) [Accessed: 22- Feb -2018].
- [7] "From Arduino to a Microcontroller on a Breadboard", arduino.cc, 2018. [Online]. Available: <https://www.arduino.cc/en/Tutorial/ArduinoToBreadboard> [Accessed: 22- Feb- 2018].
- [8] "ATMEL 8-BIT MICROCONTROLLER WITH 4/8/16/32KBYTES IN-SYSTEM PROGRAMMABLE FLASH", mouser.com, 2018. [Online]. Available: <https://www.mouser.com/ds/2/268/atmel-8271-8-bit-avr-microcontroller-atmega48a-48p-1065900.pdf> [Accessed: 22- Feb- 2018].
- [9] "Ultrasonic Ranging Module HC - SR04", cdn.sparkfun.com, 2018. [Online]. Available: [https://www.bananarobotics.com/shop/HC-SR04-Ultrasonic-Distance-Sensor?gclid=EAIaIQobChMI4eLL3J6V2QIVUJ7ACH0OUABFEAQYASABEgLNZvD\\_BwE](https://www.bananarobotics.com/shop/HC-SR04-Ultrasonic-Distance-Sensor?gclid=EAIaIQobChMI4eLL3J6V2QIVUJ7ACH0OUABFEAQYASABEgLNZvD_BwE) [Accessed: 22- Feb- 2018].
- [10] "L7805CV", mouser.com, 2018. [Online]. Available: <https://www.mouser.com/productdetail/?qs=9NrABl3fj%2FqplZAHiYUxWg%3D%3D> [Accessed: 22- Feb- 2018].