Wheelie Smart

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Abstract — **This paper describes a bike safety precaution system that aims at increasing the safety of bicyclists by using a combination of high performance microcontrollers, different sensors, a display, a speaker, and LED lights to alert the rider about hazards, as well as to enhance the quality of the ride. The Main module will communicate with the Helmet module to ensure the use of the helmet before the ride starts. In addition, Wheelie Smart will provide useful data, such as instantaneous speed of the bike and heart rate of the user, by displaying them on a screen, which is mounted on the handlebar.**

I. INTRODUCTION

Teaching your children to ride a bicycle is a part of family tradition. Parents all over the world put their children on bicycle seats with a helmet, pads, and training wheels to go for a ride. Most Americans know how to ride a bicycle whether they learned in their early years or taught themselves further down the road. The amount of bicycles on the road is on the rise as more and more people use them to commute, exercise, or as a hobby. Although there has been a decrease in bicycle accidents, the toll of fatal accidents is mounting. Since 2010, cyclist death statistics appear to be on the rise. According to the Federal Highway and Administration (FHWA), there were a total of 8,908 cyclist deaths between 2007 and 2018; an average of 742 cyclists each year. In 2018, 857 cyclists were killed in traffic accidents. Whether they are commuting to work, exercising for a healthy lifestyle, or riding as a hobby, Wheelie Smart will enhance cyclist safety.

The Wheelie Smart is a product which includes a smart bicycle and a smart helmet. The product will aid cyclists during their ride whether it be for commuting to work, exercising, or just biking for fun. It will include a display for an easy-to-use experience while at the same time using features to aid the cyclist to complete a safe ride. The ultimate goal of Wheelie Smart is to ensure cyclist safety by implementing various features which will add precaution before a ride, prevention during a ride, and helpful tips after a ride. Ultimately, the features will avoid both minor and major accidents. Wheelie Smart is the future technology which will change cyclist safety for the better.

A. Goals and Objectives

The main objective of Wheelie Smart is to aid in cyclist safety through the means of prevention. Wheelie Smart also aims to assist cyclists in the case of an accident where the cyclist falls or collides with an object, pedestrian and/or another vehicle. To solve the problem of cyclist safety our group will apply engineering to technologically advance the modern day bicycle and helmet. To achieve our objective, Wheelie Smart will incorporate sensors, lights, and speakers.

As a group, we wish not only to satisfy our objective but to also apply what we have learned during our college careers and our interests. We aim to continue to gain knowledge as we work to complete the product and bring Wheelie Smart to life.

The following is a list of goals which will be pursued through hardware, software, and team collaboration:

- Research, design, test, and model a smart bicycle efficiently
- Detect objects, vehicles, and pedestrians
- Alert cyclist if obstacle is detected
- Use microcontroller to control the system
- Detect cyclist is wearing a helmet
- Sense and display the cyclist speed
- Sense and display the cyclist heart rate
- Minimize power consumption
- Minimize cost
- Adhere to all safety and road standards

B. Specifications

Below are the core specifications of Wheelie Smart design:

- **Speaker:** Resonance frequency of 1005 Hz to alert when an object is detected
- **Lights:** Light adjust within 5 Seconds of low visibility
- **Helmet detection range:** Detection within 5 feet of bicycle
- **Bike alarm:** Operates at 5V
- **Power supply output voltage:** Power supply of 12VDC
- **Power consumption:** Less than 75% of total power to protect components
- **Object detection:** Object detection detect obstacles within 10 ft
- **Wireless communication range:** must be able to transmit data within 2.0 meters
- **Wireless communication frequency:** Frequency of 315 MHz
- **Bicycle weight:** 7 lbs or less extra weight on bicycle
- **Helmet weight:** Less than 1 lb of extra weight on helmet
- **Battery life:** Maximum of 5 hours
- **Cost:** Low cost between $525-$700
- **LCD display - Speed:** Display 100% while bicycle is active
- **LCD display - Heart rate:** Detect heart rate sensor and display within 5 seconds

II. HARDWARE DESIGN

Our Project, Wheelie smart consists of three major subsystems that are Bike subsystem, Helmet subsystem, and Power subsystem. On our Bike Module we have all our sensors, speaker, LCD, RF receiver that are connected to our double layer PCB which uses an Atmega2560 microcontroller on our system. Our PCB will be powered up using the second subsystem that is our Power Module which is our 12V 10W Monocrystalline solar panel as the main source of power supply and 14.8V LiPo battery which is also connected for the backup power which can be used during night or bad weather conditions. The Helmet subsystem will be powered up with two cell batteries in series to operate the force sensor and RF transmitter which uses Atmega328 MCU attached on the Helmet PCB. Below is an overview of each subsystem, and the part selection in the next section will cover more in depth about the reasons we chose to implement each component in our Wheelie Smart.

A. Bike Module

The Bike Module is the main subsystem of Wheelie Smart, which is responsible for receiving data signals and processing them accordingly, from which it then provides useful information to the bicyclist through an LCD display. Here is the list of sensors and other components that are implemented in this module:

- Object-detection sensor
- Heart rate sensor
- Light sensor
- Vibration sensor
- Reed sensor
- LED light
- LCD display
- Speaker
- RF receiver

B. Helmet Module

In this subsystem, we use a simple microcontroller to send signals to the main circuit using an RF transmitter, indicating the use of a helmet. Since this system is implemented on the helmet, ideally we would like to keep the extra weight to be less than 1lb. In order to fulfill this, two coin cells batteries are used as their total weight is about 0.013lb. The design for this system is also kept simple to reduce the weight mounted onto the helmet.

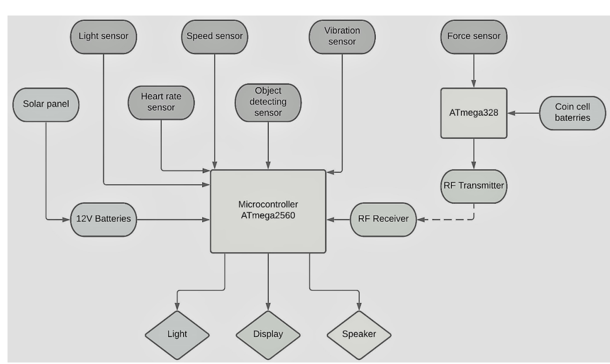

Fig-1: Hardware block diagram

C. Power System

Solar Panel: In our project Wheelie Smart we are using a 10W, 12V of Monocrystalline solar panel to generate energy and supply power to our whole system. Our panel outputs 17V to 21V during the daytime and it is very efficient, light weight and has reverse polarity protection. To provide a proper input power to our system and charge our battery we designed our charge controller using an LM317 adjustable regulator which can supply more than 1.5A over an output range of 1.25V to 37V and has additional features of current limiting, overload protection, and safe operating area protection. We designed this Solar Charge Controller circuit in EAGLE, which outputs 12V of power supply from our PCB. The one end of the terminal is connected to our battery to keep our battery fully charged when not in use. We connected a diode between the output of the charge controller and the battery to stop the current flow back into the charge controller.

Voltage Regulators: The terminal coming out from the charge controller is going into the PCB, which is stepped down from 12V DC to 5V DC using a switching regulator on our PCB. All the sensors that are Ultrasonic, Vibration, Reed switch, and the Heart rate need 5V of input voltage. Also, the LCD which is connected to our main PCB requires 5V. We used switching voltage regulators in our system because it dissipates no power and has very low risk of a meltdown as it reduces temperature. A switching regulator with PWM, constant frequency and varying duty cycle is very efficient and easy to filter out noise. It worked well on our system and is more efficient than the linear voltage regulator. We also used a 1.8 V regulator for the Heart rate sensor.

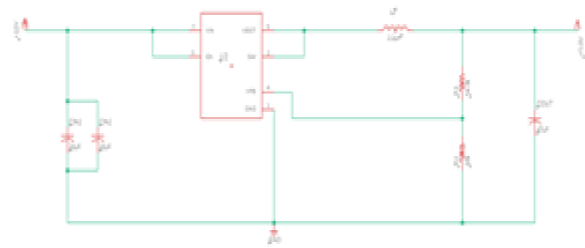

Fig-2: 5V Switching voltage regulator used in both the PCBs

Battery: The whole system of the Wheelie smart runs with the solar panel during direct sunlight and the battery is used during night and bad weather conditions. We are using a 14.8V LiPo rechargeable battery which is connected to the PCB to supply power when needed. This battery has a capacity of 1800 mAh and the consumption of our system is around 0.7Amps when all the sensors and LCD are connected to our PCB. The table below shows all the results.

	LiPO Battery
Battery Capacity	1.8A
Discharge	10%
Consumption	0.7A

So, from the Table above we can see that the battery will not last longer than 2-3 hrs. Therefore, after testing the battery life, we decided to connect another battery in parallel to get higher amperage to meet our specification requirement of 5hrs of battery life.

III. PARTS SELECTION

1. *Microcontrollers:*

For the main microprocessor of the whole system, we decided to use ATMega2560. The microcontroller has a 256KB ISP flash memory, in combination with an 8KB SRAM and a 4KB EEPROM. Since we are implementing a multiple-sensor system, a high-performance, low-power chip is necessary. The ATMega2560 offers up to 86 general purpose I/O pins, including 54 digital I/O pins, of which 14 provide PWM outputs, and 16 analog input pins. The operating voltage is 1.8V to 5.5V, which is powered up through a 5V voltage regulator.

For the helmet module, a simple microcontroller can handle the job easily. We decided to use the ATMega328 as it has 32 pins, in which 23 are general purpose I/O lines. This microcontroller has a flash memory of 32KB, an EEPROM of 1024B, and a SRAM of 2KB, which is enough to ensure the data will be collected, processed, and sent through the RF transmitter properly.

Selection: ATMega2560 (Bike module) and ATMega328 (Helmet module).

2. *Ultrasonic Sensor*

The distance between the sensor and the object can be calculated using the time it takes for the sound wave to travel from the transmitter, reflect when encountering the object, and back to the receiver. The equation is as follows:

$$D = \frac{1}{2} \times T \times a$$

where D = the distance in meters, T = the time in seconds, a = the speed of sound, which is about 343 meters per second.

There are various models of ultrasonic sensors that are available in the market. By taking into consideration the specifications that we need to fulfill, we chose the MB1000. From the datasheet [1], we can see that its range capability is over 20 ft, which is more than enough to satisfy our specification of 10 ft detection range. As we are designing a multiple-sensor, battery-based system, an operating current of 2mA is a good choice for the design. Even though this sensor is higher in cost, it has a wider detection range, a lower power consumption, and a larger covered angle.

Selection: MB 1000-000

3. *Heart Rate Sensor*

The basic heartbeat sensor consists of two parts: a light-emitting diode (LED) and a detector, which is basically a light sensor (can be either a photodiode or a light-detecting resistor). The LED acts as a light source emitting light, which illuminates tissues on the area that touches the sensor. Some of the light will be absorbed by the blood flow while the rest of it will get reflected back and received by the light detector. The output of the light detector will be electrical signals, and the relationship between the output and the heartbeat rate is directly proportional. The MAX30101 from Maxim Integrated was selected as it is a low cost sensor while it only draws 0.6mA of current, which means the power dissipation of this heart rate sensor is low.

Selection: MAX30101 Model

4. *Light Sensor*

The most common light sensor is photoresistor, which is sometimes referred as Light-Dependent Resistor (LDR). As its name suggests, a photoresistor is a passive component that does not produce any electrical energy. It is basically a resistor that has a resistance changing with the change in the light intensity, either natural light or artificial light. The relationship between the light intensity illumination and the sensor resistor is inversely proportional, which means the higher the amount of light received on the sensitive surface of the sensor, the lower the sensor resistance will be. When it is dark, the resistance can be in the Mega ohms range, while in daytime, we can receive a resistance of a few hundred ohms. We chose to use LDRs as they are easy to be implemented into the system. In addition, the price of this sensor is very affordable, and it is also small in size and lightweight.

Selection: Photoresistor 02-LDR2

5. *Vibration Sensor*

To detect the movement of the bicycle before the ride, we use an analog ceramic piezo vibration sensor module. The operating voltage of this module is 3.3V or 5V, which means we can easily supply the power without the need of another regulator for a different voltage level. The working current is about 1mA, meaning it has a low power dissipation and is exactly what we need for a battery-based system like Wheelie Smart. We can utilize analog input pins of the ATMega2560 to collect the electrical signals from this module.

Selection: MakerHawk Analog Ceramic Piezo Vibration Sensor Module

6. *Speed sensor*

Most of the speedometers available in the market are using reed sensors, which are electrical switches operated by applied magnetic fields. A reed switch consists of two ferromagnetic contacts separated by only a few microns. For most of the time, a reed switch is a normally-open (NO) switch, which can be closed by applying a magnetic field. When the magnetic field is removed, the switch is back to its normally-open position. By applying the same principle, instead of buying a speedometer, we decided to design our own speedometer using a reed switch. The main advantage of this method is low in cost and lightweight. No additional complicated components are needed for the build.

Selection: 54-637 Reed Switch

7. *Force sensor*

The use of a force sensor in the design is simply to indicate the use of a helmet by the cyclist, thus we will choose to use a Force Sensing Resistor because it is thin, lightweight, and low in cost compared to the two other types of force sensors: Load Cells and Strain Gauges. Its durability is high as it can be used in different environments (indoor, outdoor). Low power consumption is also one of the advantages that this sensor has. We have decided to use the FSR06 sensor from Ohmite Manufacturing Co. as it provides an active area of ø14.7mm, and a sensitivity range of up to 49N.

Selection: FSR06 Model

8. *LCD Display*

One specification that we looked for in a display is to be able to place all the features onto the bicycle without it having to consume too much space. We want to leave enough space for the cyclist to be able to ride the bike comfortably and not run into any electrical components while riding the bicycle. The 1602 Serial LCD has a display size of 16x2 with the brightness of the display being adjustable using a potentiometer.

Selection: 1602 Serial LCD

9. *Speaker*

The requirements we have for our speaker are that the speaker must be programmable and be able to connect to our ATmega2560 microcontroller. It should be small in size so that it does not hold up valuable space on the bicycle, and the speaker must be loud enough to alert the bicyclist. Visaton 2816 offers an ideal size and the ability to produce a loud noise, which can be heard in a noisy environment, and it meets our budget requirement.

Selection: Visaton 2816 Mini Loud speaker

10. *RF Transmitter/ Receiver*

We decided to go with Radio Frequency (RF) technology for our Wheelie Smart Bike. RF transmitter and receiver will allow us to send specific data from the force sensor on the helmet back to the main microprocessor. The module used in Wheelie Smart is the 315MHz transmitter/ receiver. This has a communication range of up to 100m. One thing about this module is the need of being tuned to operate properly. We had to use wires as antennas and soldered them onto the modules. Other than that, the RF module is low in cost, lightweight, and the signal is reliable enough for our design.

Selection: HiLetGo 315MHz transmitter/ receiver

IV. SOFTWARE DESIGN

Software design is the process of defining software methods, functions, objects, and the overall structure interaction of your code with hardware so that the resulting functionality will satisfy the users requirements. Wheelie Smart has two main software systems. One is for the Helmet and another is for the Bicycle. We consider our Bicycle software system as our main system due to most of our sensors being utilized on the Bicycle. Our Helmet is considered a secondary system which utilizes the ATmega328 microcontroller and force sensor.

The way the Helmet software system works is that there is a Force sensor that is attached to the helmet. We are utilizing the FSR06 Model of the force sensor. The function of this force sensor is to convert an input mechanical load, weight, tension, compression or pressure into an electrical output signal. This signal is represented by a number. Through multiple tests done of different heads we realized that when a force sensor detects the proper tension onto it, it will output a number of 500 or greater. So everytime a force detects a number equal to or higher than 500 it would send a signal back to ATmega328 microcontroller. On the ATmega328 microcontroller we have connected the Transmitter that utilizes radio frequency waves to communicate messages to the receiver which is connected to ATmega2560 on the bicycle. Each time ATmega328 receives that specific signal from the force sensor, the ATmega328 triggers the Transmitter to send out a message “on” to the receiver, letting the receiver know the helmet is on. If the Atmega328 does not receive the signal from the force sensor this means the helmet is “off” the user’s head. The ATmega328 will trigger the Transmitter to send out an “off” message to the receiver continuously until the helmet is detected.

The main software system is started through a switch that is connected to the ATmega2560. If the switch is off, this means the user is away from the bicycle. We have attached a vibration sensor onto the bicycle that detects any movements onto the bicycle when the switch is off. If it does detect movement it will cause the speaker to go off.

If the switch is on, this means the user is ready to go on a ride. The first thing the main system makes sure to check to see what the receiver is receiving. As mentioned previously, the helmet has a force sensor attached to it. If the force detects force greater than or equal to 500, it will transmit the message “on” to let the receiver know the helmet is on. Else it will transmit the message “off” letting the receiver know that the helmet is currently not on the user. The receiver which is connected to the ATmega2560, if it is getting “off” it will cause the speaker to make loud noise continuously until the helmet is on. Once the helmet is on, the receiver will send out a signal to the ATmega2560 microcontroller. Then the ATmega2560 microcontroller will trigger the rest of the sensors to be activated. These sensors are Speed, Light, Heart Rate, Ultrasonic. The Ultrasonic sensor is connected on the back of the bicycle. Ultrasonic sensor will continuously be looking out for objects within its scope and if it does detect an object within 10 feets of the bicycle it will cause the speaker to make a distinct loud noise warning the user. The Light sensor is continuously sensing the brightness of the environment. Through testing the light sensor day and night, we determined that if the light sensor responds with a number lower than 100 the LED light on the bicycle must be turned on. The Heart Rate sensor will calculate the user’s heart rate when the user gently puts the finger onto it and will display the heart rate onto the LCD within less than 5 seconds. The Speed sensor is continuously counting the speed and displaying it onto the board. However, when the speed is “0”, the system loops back and checks if the helmet is still on. If the helmet is still then it will continue to display the speed, if not then it will trigger the speaker to make a loud noise reminding the user to put on the helmet. Lastly, when the user is done with the ride, they can simply turn off the main switch on the bike which will turn off the main system.

V. SCHEMATICS/PCB

A. Schematic

The final schematic of our main circuit includes the solar panel charger, voltage regulator, LCD display, switches (reed and two push buttons), RF receiver, light sensor, heart rate sensor, ultrasonic sensor, servo motor, USB micro type B port, and a RF receiver module. Each module is grouped up with a label on top so it is easier to keep track and identify its functionality. It is important to check the connections between the solar panel charger and the voltage regulator to ensure there is current flowing through the circuit and supplying a sufficient amount of power so that each module can operate correctly. Depending on the breadboard testing, we modified the schematic accordingly so that each module guarantees a proper performance before moving on to finalizing the printed board layouts and sending them to a PCB vendor.

B. PCB

The Printed Circuit Board (PCB) design is the final step in the hardware designing process as this board layout design gives the electrical circuits its physical form. After we completed creating the schematics of all our hardware circuits used in our Wheelie smart project we designed our PCBs for the Bike module and the Helmet subsystem in EAGLE.

Both the PCBs are double layer boards, the main PCB of the Wheelie smart is attached on the front of the bike and the smaller PCB is on the back of the Helmet. The smaller PCB runs on the separate power which is on two cell batteries. The Helmet PCB has a force sensor and the transmitter which will send a signal to the main PCB with the help of Atmega 328 MCU.

The main PCB will be on the Bike and is powered with the 12V solar panel and the 14.8V back up battery. It has all the sensors attached to the board and the LCD in the center. The Atmega 2560 is placed on this board to operate all the code for all the sensors and the LCD screen. The signals from the Helmet PCB are received by the receiver on the Atmega 2560 and the system begins to function in a loop. We soldered the surface mount and through hole components on both our PCBs. Below is the final board layout of our PCB that was sent to the JLPCB vendor for manufacturing.

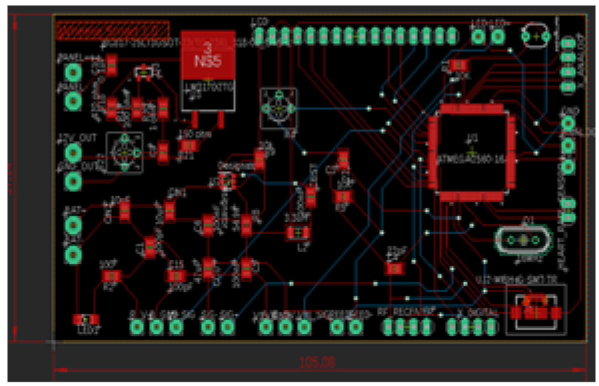

Fig-3: Final PCB of the Bike Module Wheelie Smart

We tested out our PCB by soldering all the components on the board. All the tests are performed using a Multimeter to check the voltage, current and continuity of our component to make sure our design is accurate, and our system works perfectly well.

VI. CONCLUSION

In conclusion, Wheelie Smart has met all the core specifications that Group 12 would like to achieve. After seven months of working on the project, we believe that Wheelie Smart is an affordable safety precaution system that everyone, if interested, can learn and implement on their bicycles. We tried to keep everything as low cost while maintaining the reliability of the system.

This project allowed us to accomplish our values and hopes that we discussed at the beginning of the Senior Design 1 course while satisfying the requirements given by the University of Central

Florida. Throughout the project, we have used and put into practice our knowledge in engineering; learned how to work collaboratively and efficiently. We have also improved our research skills as well as presentation skills, which are an important part in engineering.

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[1] MaxBotix, “LV-MaxSonar-EZ Series High Performance Sonar Range Finder MB1000, MB1010, MB1020, MB1030, MB1040”. [Online]. Available: https://www.maxbotix.com/documents/LV-MaxSonar-EZ_Datasheet.pdf [Accessed 26 July 2021]

ENGINEERS BIOGRAPHY

Hemil Patel is a graduating Electrical Engineering student at the University of Central Florida. He is presently an intern at TRC, Power Distribution Department. After graduation he will be working for FPL, Power Delivery Department.

Jainav Patel is a graduating Computer Engineering student at the University of Central Florida. He interned at Lockheed Martin as a performance Engineer and last summer interned at L3Harris as a Software Engineer. After graduation he plans to work as a Software Engineer at Raytheon Technologies.

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Tam Tran is a graduating Electrical Engineering student at the University of Central Florida. She is currently working as a manufacturing engineer in Orlando. After graduation, she will continue to work at her current position and be pursuing a Master’s Degree in Electrical Engineering.