# ECE 445
## Spring 2020
## Senior Design

# Three Piece Automatic Bike Lock

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# 1 Introduction

## 1.1 Objective

The hassle of fumbling with current bike lock designs takes time and efficiency out of people's day when utilizing a bike as a mode of transportation. For bike commuters the time it takes to take out a bike lock, secure the bike lock and ensure the bike is properly attached can add time to the daily commute. For example, many commuters in Chicago ride to the metra train station; it is often the case that people miss their train by a couple minutes or even seconds. The extra time added by fumbling with the currency bike lock designs can cause a missed train or bus.

Our goal is to reduce the time necessary to lock/unlock one's bicycle. We aim to solve this problem by using a fingerprint sensor to authenticate the owner of the bicycle and trigger a locking circuit which will automate the process of locking/unlocking the owner's bicycle.

## 1.2 Background

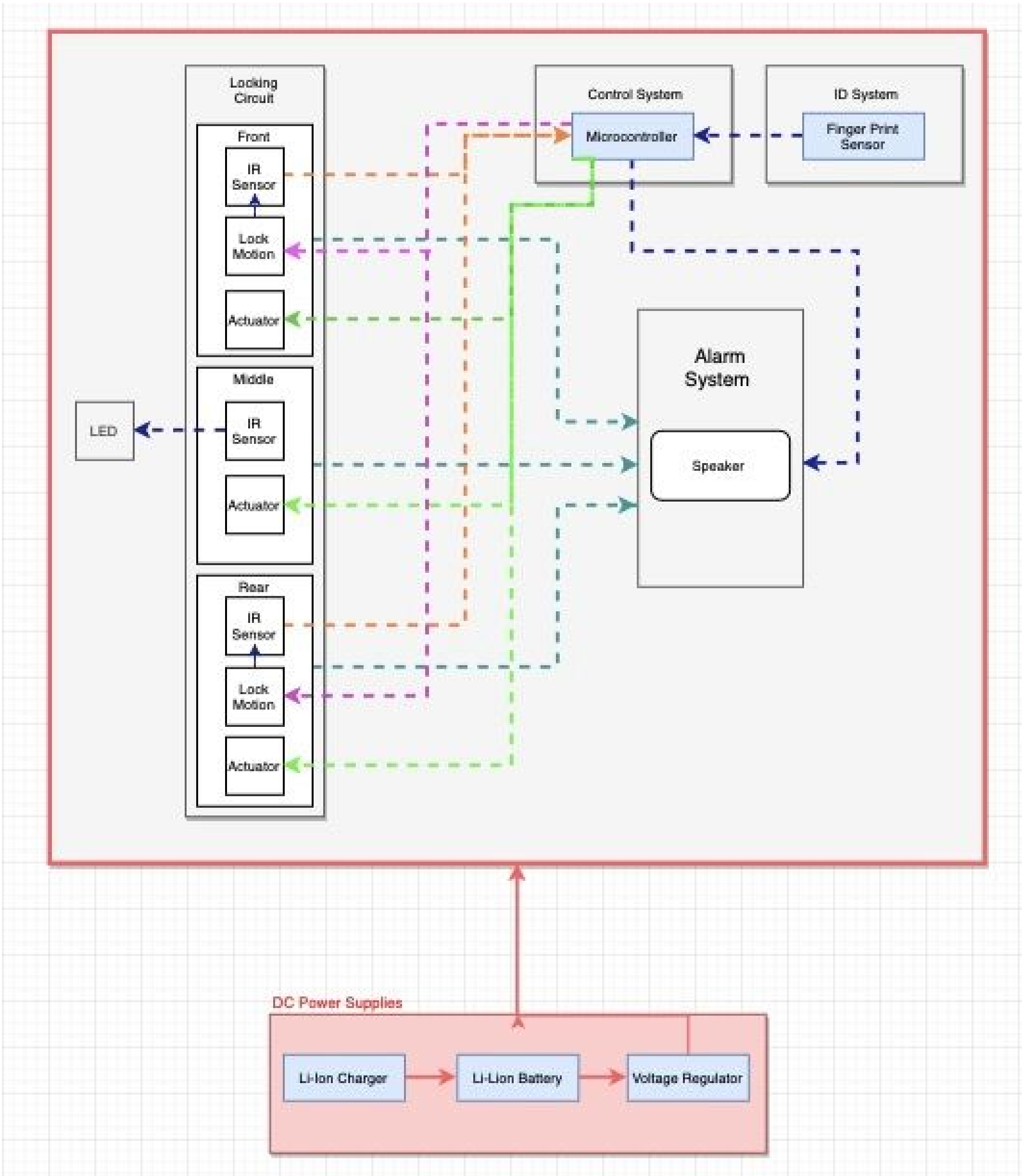
There have been automatic bike locks in the past such as products by Livalock, but these products do not secure every part of the bike. Often these products only lock the back wheel of a bike or they lock the bike to a rack leaving the user to purchase additional locking devices to get better security. Our system will automatically lock the user's bike and will prevent theft of any major part of the bike.

## 1.3 High-Level Requirements

- Upon entering a fingerprint the locking system will activate the actuator in the middle lock, and the two motor circuits and the actuators of the front and rear locks.
- If the system is locked, the correct fingerprint will unlock each locking system.
- A damaged locking system or an incorrect fingerprint will trigger the alarm system.

## 2 Design

Our overall design contains five modules: the ID System, Control System, Locking Circuit, Alarm System, and the DC Power Supply.



## 2.1 Identification System

The identification system outputs the appropriate signal determined by the user's fingerprint to the microcontroller.

### 2.1.1 Fingerprint Sensor

We will utilize a TTL fingerprint scanner that has a thin optical sensor, the scanner will keep track of the owner's fingerprint and will be powerful and dynamic enough that even in moist or dry conditions the scanner will be able to pick up on a fingerprint. The scanner will also be scratch resistant.

## 2.2 Control Unit

The control system is responsible for authenticating the owner of a bicycle, triggering the locking circuit that physically locks/unlocks the bicycle and triggering an alarm when an unauthenticated user repeatedly tries to unlock the bicycle.

### 2.2.1 Microcontroller

We will utilize a stm-32 as a microcontroller which will be responsible for handling the authentication and communication between the TTL fingerprint scanner. The stm-32 will also be responsible for triggering the locking circuit to activate when a user wishes to unlock / lock their bicycle. The stm-32 will trigger an alarm if a user fails authentication multiple times as well.

*Requirement* : The stm-32 must trigger the locking circuit if and only if authentication is passed. The stm-32 must also be able to trigger the alarm system.

## 2.3 Locking Circuit

This system is responsible for locking the front wheel, rear wheel, and the bike to a rack. This system is controlled by the control system and this system can control the alarm system.

### 2.3.1 Front and Rear Lock

The front and rear locks are designed to prevent any theft of the front or rear wheels. These locks will operate once an authorized user has been correctly identified by the identification system. These locks are also used to control the alarm system if they are damaged. These locks will utilize a metal wire, that has two loops on its ends, which will move around the wheels and be secured by the actuator.

#### 2.3.1.1 Lock Motion

This block is responsible for the motion of the locking wire. Once the user uses their fingerprint this block will activate, leading to the rotation of a motor and then having the locking wire move from one end of the wheel to the other.

*Requirement:* The circuit must control the motor in a way so that the locking wire will fully move to the other side of the wheel.

#### 2.3.1.2 IR Sensor

The infrared sensor will indicate when the lock motion block has moved the locking wire at an appropriate distance for the wire to be fully secured. This sensor will feed into the microcontroller and will indicate when the actuator needs to be activated. We plan on using the Osoyoo IR sensor which can take between 3-5 volts.

*Requirement:* Needs to be properly calibrated so that when the locking wire is at an appropriate location the actuator will be able to secure the other side of the wire.

#### 2.3.1.3 Actuator

This block is controlled by the microcontroller. As stated above, once the proximity sensor indicates that the locking wire has moved to an appropriate location the microcontroller will power the actuator, which will then fully secure the locking wire by having the actuator move through the other loop of the wire..

*Requirement:* When the actuator is active the locking wire will be very difficult to move.

### 2.3.2 Middle Lock

The middle lock is different from the other two locks in the sense that the user is responsible for moving a chain around a rack and to the other side of the lock in order to secure the bike. The actuator of this system is controlled by the microcontroller whenever the user uses their fingerprint. This system also can control the alarm system, if tampered with.

#### 2.3.2.1 IR Sensor

This sensor is used so that the user knows if they inserted the chain at an appropriate depth within the lock housing. This sensor controls the LED block. We will be using the Osoyoo IR sensor.

*Requirement:* This sensor needs to be calibrated so that it can properly interact with the LED block to tell the user that they are able to properly lock the chain in place.

#### 2.3.2.2 Actuator

This device is controlled by the microcontroller. When the user enters their fingerprint the actuator will be activated regardless of the value of the proximity sensor.

*Requirement:* When activated the actuator will be very rigid and prevent the chain from being removed when locked.

## 2.4 Alarm System

This system takes in input from the locking circuit. If any of the locks are tampered with then this system will sound. The microcontroller can also activate this system if an unauthorized user attempts to use the fingerprint sensor. This system will consist of a circuit which utilizes a speaker.

### 2.4.1 Speaker System

This system will take in input from the three locking circuits along with the identification system. If any of these systems has been compromised then the speaker will activate. If activated the speaker will stop if an authorized user uses their fingerprint.

*Requirement:* This system must activate if either lock is damaged or if an incorrect fingerprint is used. It must also stop making sound if the correct fingerprint is used.

## 2.5 LED System

This system is fairly basic and is only controlled by the proximity sensor of the middle lock. There will be a single LED that will glow red if the middle chain is not placed at the correct location for the actuator. If this is not the case then the LED will glow green. The standby color for the LED is red.

*Requirement:* The LED for this system can only glow green if the chain is at an appropriate location for the actuator to secure it.

## 2.6 Power System

This system provides power for the Identification system, the locking circuits, the alarm system, and the LED system.

### 2.6.1 Li-ion charger

This block is used to charge the Lithium ion batteries that are used for the project. The user will be able to use this charger to charge the locks using a wall adapter.

*Requirement:* This charger will be able to charge each of the batteries in the device and allow the user to manually charge their locks.

### 2.6.2 Li-ion Batteries

The batteries are used to power each component of the three piece lock. This will be a fairly simple DC battery that gets fed into a voltage regulator.

*Requirement:* Each of the batteries will be able to fully power their respective circuit.

### 2.6.3 Voltage Regulator

The voltage regulator will be used to prevent any motor or actuator from getting too much voltage which would lead to a dead device. The front and rear locks will have the same regulator.

*Requirement:* The regulators will prevent any dead devices.

## 2.7 Risk Analysis

The front and rear locks are a significant risk to the successful completion of the project. These locks need to be fully automated and need to move the locking wire all the way around the wheel back into the housing for locking. These locks also need to be able to be run in reverse so that the bike can be unlocked. We will need to design a motor drive circuit that will power a motor enough for the locking wire to fully move around the wheel, and this circuit must be able to reverse the direction of the motor for unlocking purposes. The housing for this system must also be somewhat compact and thus we need a smaller actuator which we will design ourselves to cut costs. This can also be a difficult process since we need another DC motor to make this. By far this is the most complicated system of the project.

## 3 Physical Design

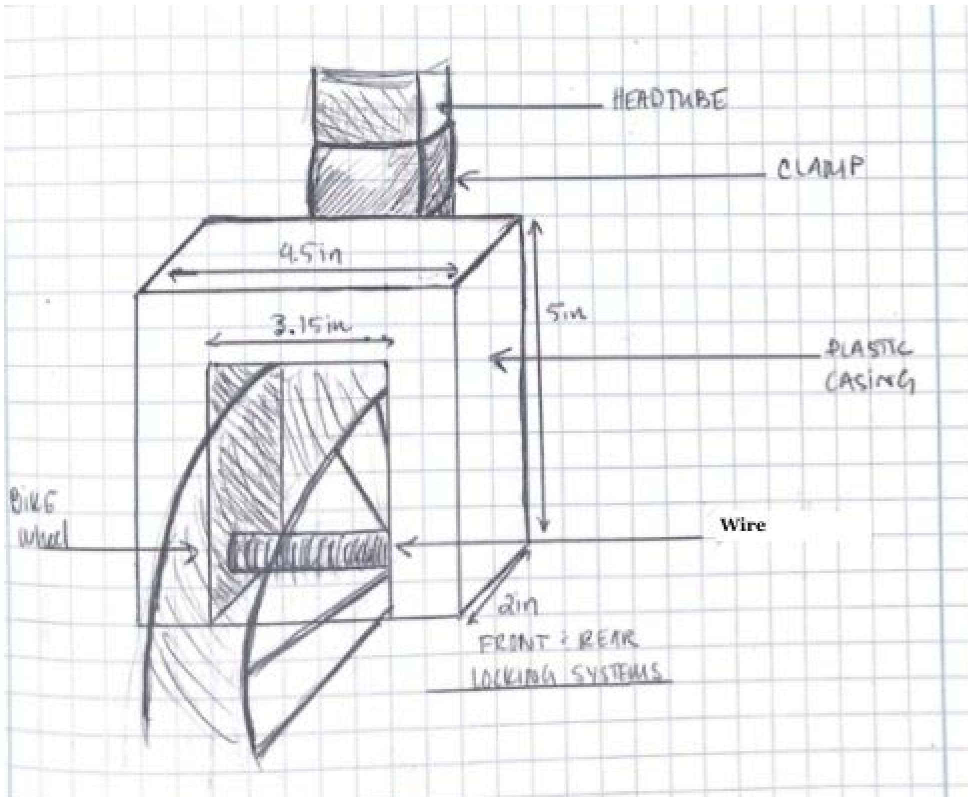



Fig 3.1 Front and Rear Locking System

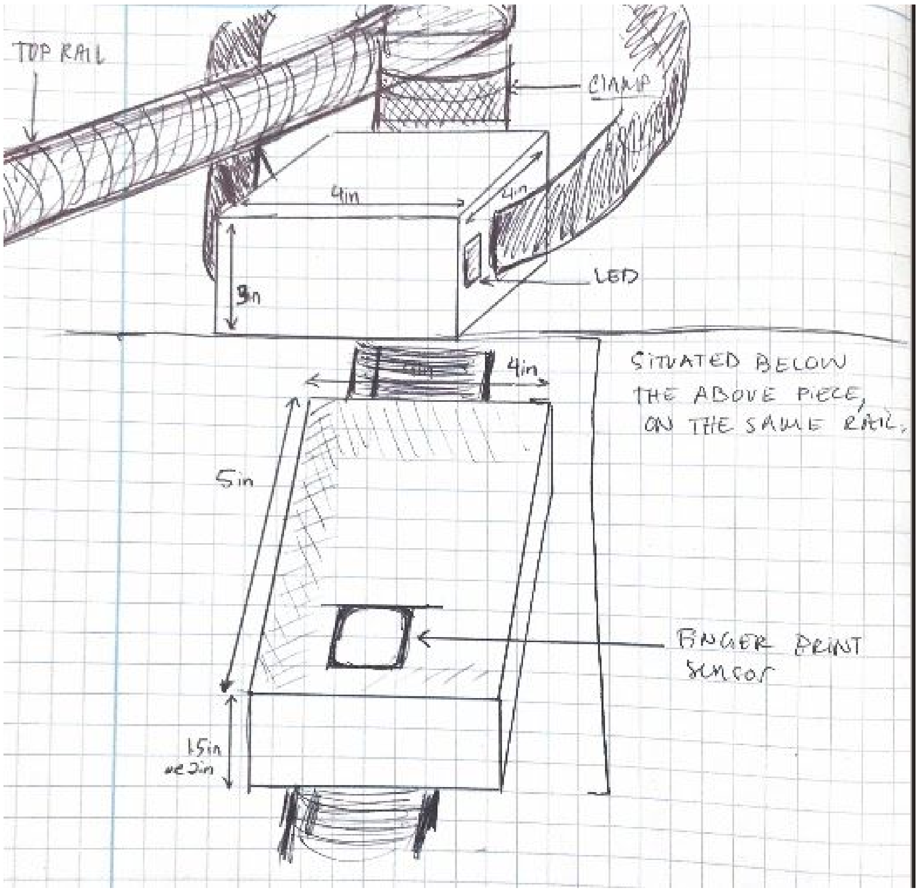



Fig 3.2 Middle Locking System

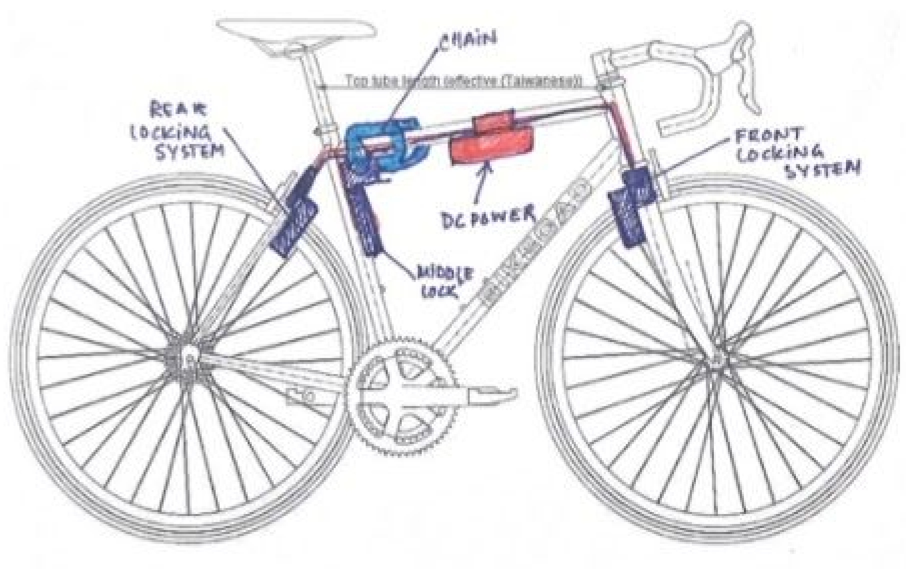



Fig 3.3 Overall Design

## 4 Safety and Ethics (can mention the potential danger if system locks when moving)-done

There are several potential safety issues for our project.

Damage done to the electrical and/or mechanical components can cause our design to break or short, causing a safety hazard.The outer casing of our design must be waterproof as well as able to withstand harsh weather conditions. The electrical circuitry must be protected appropriately to prevent the product from breaking or shorting. The outer casing must be durable enough to withstand weighted stress if the bike falls while it’s parked or if a minor impact occurs. Additionally, our design must be structurally secure so that all parts maintain their integrity when the bike is in motion.

The dangers of lithium batteries pose another safety hazard for our design. If the battery is punctured, overcharged, overheated, or short circuited it can set fire or explode. To manage this hazard we will use preventative measures such as consistently monitoring the battery's condition before and after use.

There is also a risk in the locking system activating when the user is riding their bike. If this occurs then the user can be injured, as the front/rear locks can stop the motion of the front and rear wheels, or the locking system can be completely damaged. For this reason we will place the fingerprint sensor on the underside of the central lock so that a user cannot easily lock their bike when in motion.

We believe that our design is  in compliance with the IEEE Code of Ethics [1] and the ACM Code of Ethics and Professional Conduct [2]. To prevent any harm done to the user and the environment, as stated in ACM, code 1.2, and similarly in IEEE Code of Ethics, code 1, we will make our design process and the final product as safe as we can. Additionally, as stated in the ACM Code of Ethics code 2.9, “Design and implement systems that are robustly and usably secure”, our fingerprint sensor will be intuitive and easy to use. This will make sure that our bike lock achieves its intended purpose, making the biker’s life easier.

## References

[1] “IEEE Code of Ethics,” *IEEE*, Jun-2019. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 03-Feb-2020].

[2] “The Code affirms an obligation of computing professionals to use their skills for the benefit of society.,” *Code of Ethics*, 22-Jun-2018. [Online]. Available: https://www.acm.org/code-of-ethics. [Accessed: 03-Feb-2020].