System Design for SmartLock 4TB6 - Mechatronics Capstone

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Table 1: Revision History

Date	**Developer(s)**	**Change**
16-01-23	Steffi	All Sections
04-04-23	Steffi	Final Updates

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1 Reference Material

This section records information for easy reference.

1.1 Abbreviations and Acronyms

symbol	description
SRS	Software Requirements Specification
FR	Functional Requirements
NFR	Nonfunctional Requirements
LC	Likely Changes
ULC	Unlikely Changes
SC	System Contraints
A	Assumptions
MV	Monitored Variables

2 Introduction

The purpose of the SmartLock project is to design and build a product that will provide bicycle users with a safer, easier, and more accessible way to secure their bike(s) through their smartphone. Additionally, it will provide users with a GPS feature to locate the lock in case of bike theft or misplacement. It will consist of a physical lock that mounts to a bike and a smartphone application that will function as the user interface through which the lock can be disengaged wirelessly, as well as be located and informed of the lock's battery percentage. The project will provide an engineering solution using wireless communication, mechanical design, and smartphone application development. More broadly, it seeks to encourage members of society to pursue biking, in both a transportation and recreational capacity, improving the health of society's citizens and its environment. For more information on the project breakdown, planning or delivery refer to the following documentation: Problem Statement and Goals, Development Plan, SRS, HA, MG, MIS.

3 Purpose

The purpose of this documentation is to break down all of the components that will come together to create the final product, as well as how they interact and why they are used. This document will show everything that the SmartLock is made from and when it will be assembled in order to provide transparency throughout the entire design project.

4 Scope

This lock and application are designed for the use of the average bike rider. It is simple and easy to use and locks the primary components of the bike so that the user can be confident in its security.

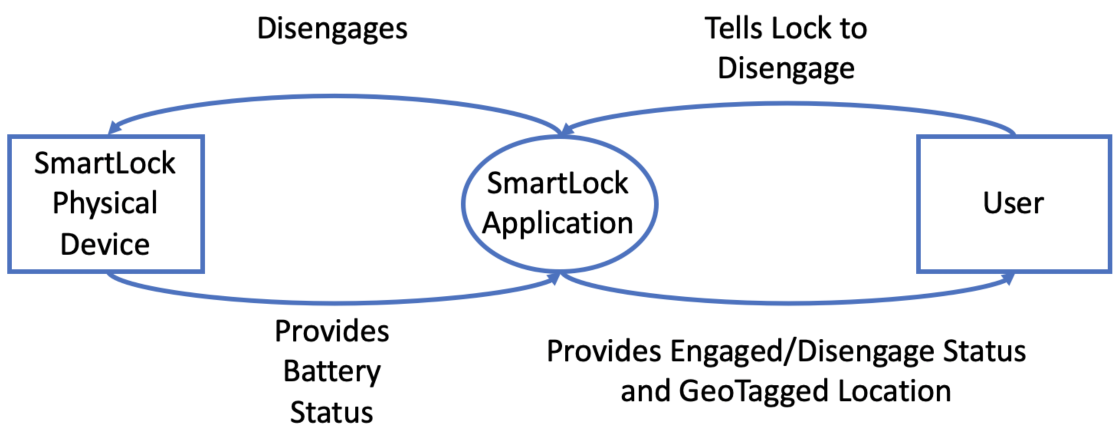

Figure 1: System Context

5 Project Overview

5.1 Normal Behaviour

The normal behaviour that is expected with the SmartLock is multistep:

1. After the first purchase of the SmartLock the user will have to attach the lock to the bike, and download the application from the AppStore or Google Play and pair the application with the physical device (this only happens once)

2. The user will put the cable around the wheel and external frame and then push the pin into the locking hole

3. The user will be able to geotag the location of the locked bike on the application

4. The user will be able to disengage the lock on the application so that they can remove the pin from the hole and release the bike

5. The application will warn the user when there is low battery so that the lock can be recharged

5.2 Undesired Event Handling

In the case of an undesired or unexpected event, the lock will stay in the locked position and the application will block the unlocking process. While this does inhibit the user's ability to be able to use their bike, it does prevent the bike from being stolen which is more important in an uncertain situation. The user will be able to reset the lock to eliminate the stimulus that caused the event and be able to use their app as normal after.

5.3 Component Diagram

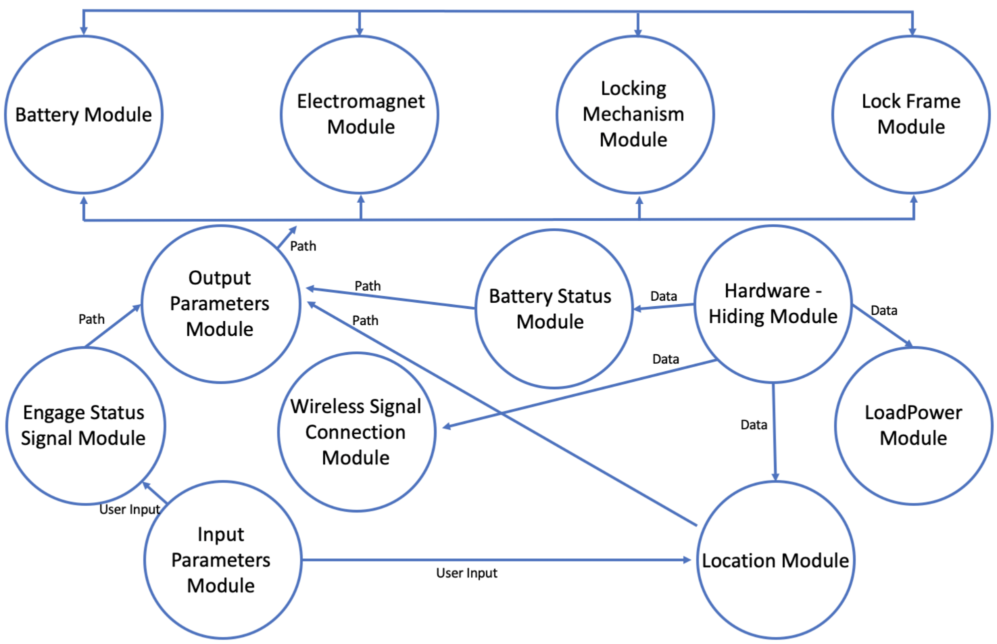

Figure 2: Component Diagram

5.4 Connection Between Requirements and Design

Table 2: Connection between requirements and design choices

Requirement/Constraint	Design Description
SC2: The materials and resources used to design and build the project must be accessible to students	Rev 0 will be primarily made from 3D printed materials, with an option to move to machining for Rev 1
SC4: The project must be mounted on existing bike designs	Current market bike lock mount is being used to ensure compatibility
SC5: The project must be locked on existing external locking frames or racks	Current market bike lock cable is being used to ensure compatibility
FR2: LockDisengage input must disengage the lock on the bike	Using a solenoid t for locking allows for a easier connection to a microcontroller that can communicate with a phone app
FR3,4,7: The application has to show the status of the solenoid and battery as well as display the location	The UI was designed so that this information is easy to see, these are requirements to make the lock secure but they relate to the user experience
FR8: Effective Bike Lock: The lock is sturdy and cannot be manually opened by the average human once engaged	Using simple pieces without a lot of components that can break off makes it more sturdy, and using a market bike cable makes sure it is strong enough not to be broken
FR9: Lock must only be engaged/disengaged by the intended user(s)	The application is password protected
NFR1: Can be used by people of any language	Language choice can be selected on the app
NFR2, 12: Can reasonably be used without instructions or extra force	Uses similar mechanics of inserting a pin that traditional bike locks use
NFR5: The design must not impede normal bike functions	Attaches to the bike using current market mounts so that it is small and out of the way
NFR6,7: The lock must be waterproofed to withstand normal rainfall	All circuitry is encased and the materials are waterproof
NFR11: iPhone app locking must be quicker to use than a typical keyed/combo bike lock	The phone will accept face or touch id as a password form and then one button click will unlock the bike
NFR14: Batteries must be accessible to replace or chargeable	A chargeable battery was used for user ease and less waste
NFR22: The app should run on iOS and Android.	Designed on Flutter for cross-platform development

6 System Variables

6.1 Monitored Variables

Table 3: Monitored Variables

Variable Name	Description	Type	Units
m_SignalEngaged	Monitors whether or not the locking mechanism is engaged	Digital	Boolean
m_SignalDisengaged	Monitors whether or not the locking mechanism is disengaged	Digital	Boolean
m_SignalClosed	Monitors whether or not the physical mechanism is closed	Digital	Boolean
m_Location	Monitors the location of the bike when it is locked	Analog	Coordinates
m_BatteryPower	Monitors the current battery percentage	Analog	Percentage

6.2 Controlled Variables

Table 4: Controlled Variables

Variable Name	Description	Type	Units
c_LockEngaged	Engages the lock	Digital	Boolean
c_LocklDisengaged	Disengages the lock	Digital	Boolean
c_LockClosed	Indicates to the user that the latch is closed	Digital	Boolean
c_BikePosition	Marks the location of the bike when it is locked	Analog	Coordinates
c_BatteryPercentStatus	Indicates what the percentage of the battery is	Analog	Percentage

6.3 Constants Variables - NA

7 User Interfaces

There are two user interfaces related to our product. The first is through an application (SmartLock) and the second is the lock itself where the user will be required to manually open/close the chain to secure the bike.

The application is where the user will be able to disengage their lock and locate where it was left with the Geotagging feature.

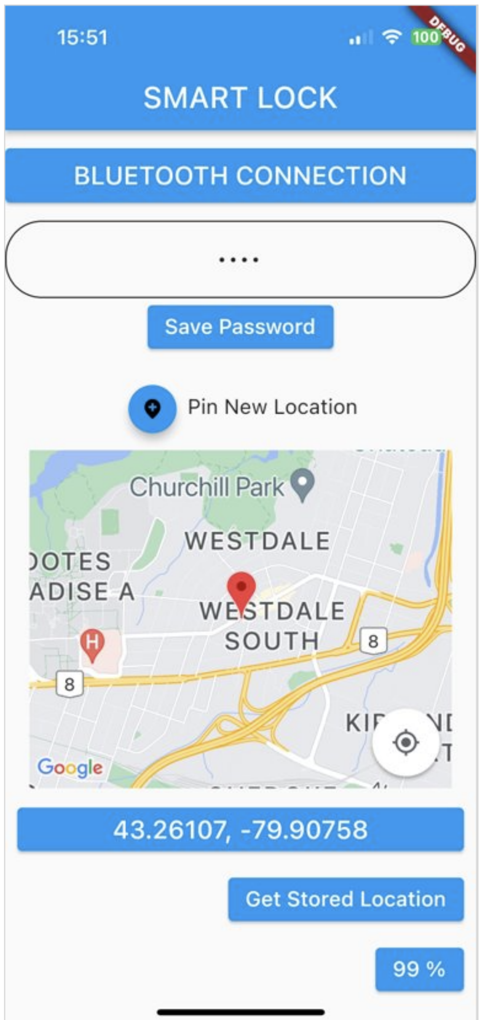

Figure 3: Application User Interface

The hardware will be mounted to the bike, which will require user interaction upon the purchase of the SmartLock. Additionally, the user must push the locking pin into the hole to engage the lock, and disengage the lock with their phone to be able to remove the pin.

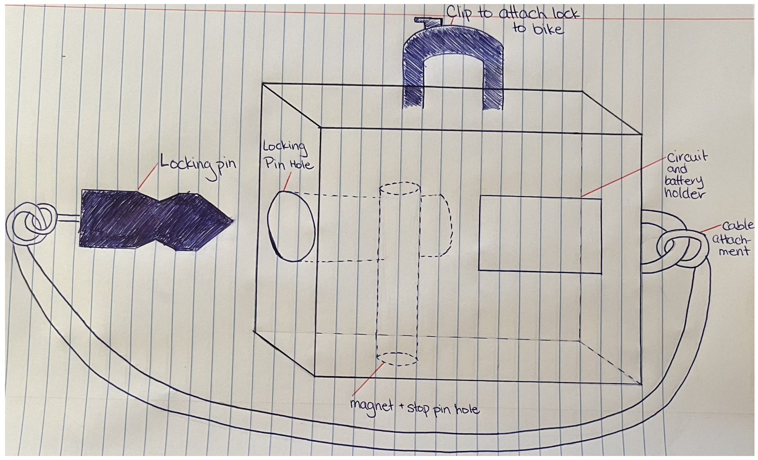

Figure 4: Hardware User Interface

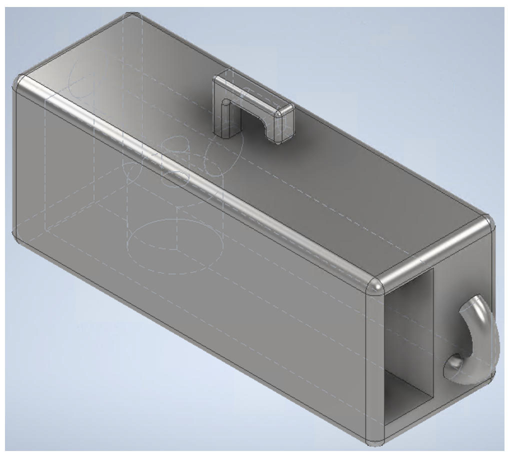

Figure 5: CAD of the Housing

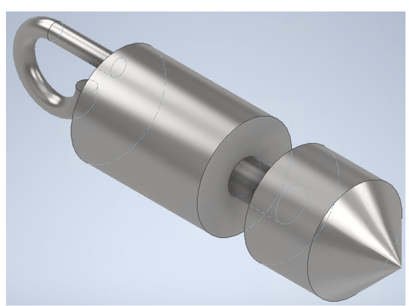

Figure 6: CAD of the Pin

8 Design of Hardware

The following is a list of the hardware components that will be acquired to build the SmartLock:

- Arduino
- Locking Cable
- Bike Attachment

The following is a list of the hardware components that will be built for the SmartLock:

- Circuit (discussed below)
- Lock Housing (CAD)
- Locking Mechanism (CAD)

See Appendix for hardware components both purchased and 3D printed

9 Design of Electrical Components

The following is a list of the electrical components that will be used in combination with the aforementioned Arduino to make up the circuitry used to control the SmartLock:

- Battery
  - Needs to be acquired
- Transistor
  - Previously owned
- Wiring
  - Previously owned
- Breadboard
  - Previously owned
- Solenoid
  - Needs to be acquired
- Resistors
  - Previously owned
- Diode
  - Previously owned

See the Appendix for visualizations of the components and circuit diagrams

10 Design of Communication Protocols

In order for the SmartLock to work there are signals that have to be used to communicate between the application and the physical lock. The features of our lock include:

- Locking the bike from the application

  - A Bluetooth microcontroller is utilized so that the application is able to communicate with the physical device

  - The microcontroller is wired directly to a solenoid that controls the disengagement of the lock

- Geotagging the location of the bike

  - Integration with Google Maps will be used to save the coordinates of the locked bike

11 Timeline

Table 5: Product Development Timeline

Date	Description	Group Member Assigned
January 16	Housing Design	Abi, Elsa & Steffi
January 18	Design Documentation	MG - Elsa MIS - Abi & Anthony SystDes - Steffi
January 22	CAD of Housing Design (Module 7, 11)	Steffi
January 22	Circuit	Stephen
January 22	App (Module 1, 5, 6)	Anthony
January 22	Arduino Coded (Module 3)	Abi
January 25	Arduino and Circuit Testing (Module 2)	Abi & Stephen
January 29	Housing 3D Printed	Abdul
January 29	App (Module 4, 8, 9)	Anthony
February 1	Assemble Housing and Circuit	Steffi & Stephen
February 1	All Documentation has been updated to reflect the current project including Git issues & battery calculations	Elsa
February 4	Rev 0 Testing (Module 10)	Everyone
February 6	Rev 0 Demonstration	App & Arduino - Anthony & Abi Circuit - Stephen Housing - Steffi & Elsa Documentation Elsa & Steffi
March 8	V & V Report Rev 0	Everyone (Reqs divided by area of expertise on Rev 0 Demonstration)
March 20	Final Demonstration	Everyone (Divided by areas of work)
April 5	Final Documentation	Everyone (Divided by areas of work)
TBD	EXPO	Everyone (Divided by areas of work)

12 Appendix

12.1 Interface - Included in Section 8

12.2 Mechanical Hardware

Figure 7: Solenoid

Figure 8: Bike Lock Cable and Mount Attachment

Figure 9: Arduino

12.3 Electrical Components

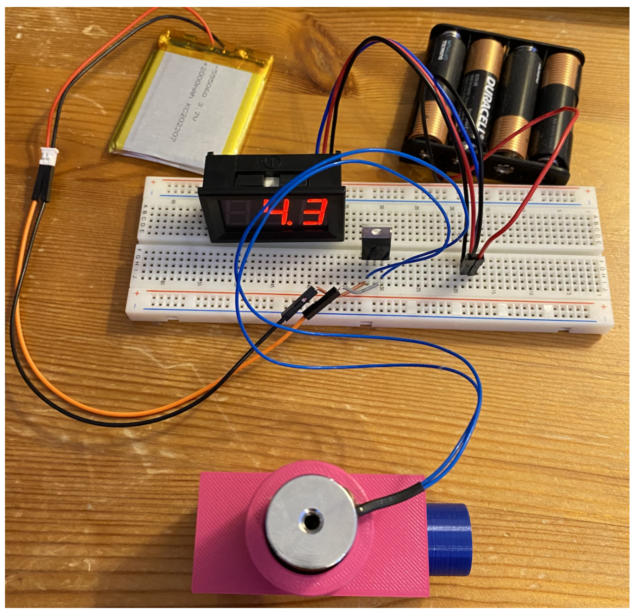

Figure 10: Circuit without the Arduino

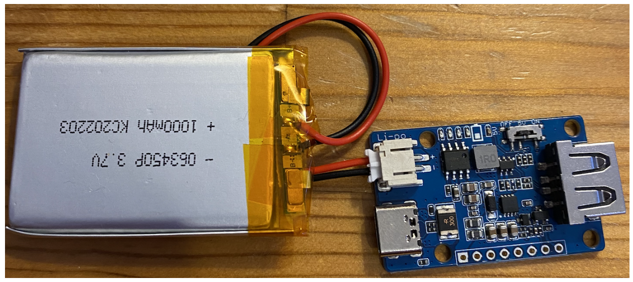

Figure 11: Rechargeable Battery

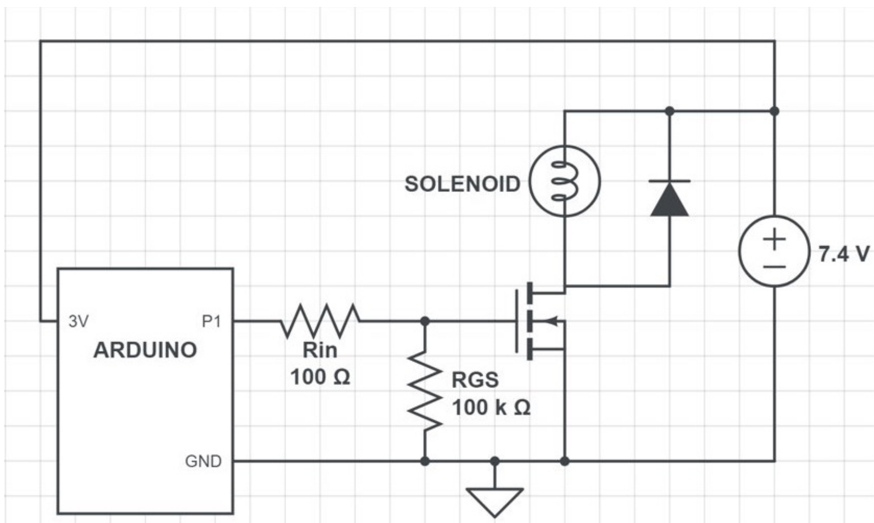

Figure 12: Circuit Diagram

12.4 Communication Protocols - Included in Section 11

12.5 Reflection

The information in this section will be used to evaluate the team members on the graduate attribute of Problem Analysis and Design. Please answer the following questions:

1. What are the limitations of your solution? Put another way, given unlimited resources, what could you do to make the project better? (LO_ProbSolutions)

   Given unlimited resources our bike lock would function without any human exertion, ie. mechanics, specifically, motors would work to open and close the lock eliminating the need for the user to touch the lock at all. They would simply have to touch a button on their phone. Additionally, there would be separate components to ensure the locking of the wheels to the frame and the frame to an external secure location. Finally, with unlimited resources, there would be a way to ensure the seat of the bike could not be removed either. However, when considering all the additional things that could be accomplished with unlimited resources, we also have to consider the downfalls of those solutions. The solution described above which increases the automation found in our design would require a lot more battery consumption and would also be bulkier and more expensive to accommodate the additional mechanics.

2. Give a brief overview of other design solutions you considered. What are the benefits and tradeoffs of those other designs compared with the chosen design? From all the potential options, why did you select documented design? (LO_Explores)

   All of our solutions were fairly similar given that there are only so many different ways to lock a bike. The main differences came from various housing alternatives and "chain" variations. Our original idea functioned more similarly to the ideal situation described above, but in scaling our project to be realistic we had to eliminate and restructure our ideas.

   Some of our other ideas were:

   - A foldable chain that could be folded up small and compressed to the bike while riding
   - A circular arm for locking
   - An extendable arm so that you could be multiple distances
   - Individual locking units for each component

   We landed on our final design because it uses components that are familiar to the average bike rider, it allows for the bike to be varying distances from a frame and it only involves one locking mechanism which is simpler, less bulky and easier to use. Additionally, we opted against the motor as a way to eliminate physical intervention because it would require much more battery and replacing or charging the battery that often would be more inconvenient than using your hands to insert the lock.