Team 7

RetractaBLE-Lock

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Team Members: Simon Grevengoed, Kevin Simonson, Phil Schroeder, Conner Reinholt, Jacob Buehler, Harrison Field, & Matt Dupre

Mentor/Customers: David Merrick, Dipak Narula, & Matt Halladay

Customer Background

The Purdue Research Foundation is a private, nonprofit foundation created to advance the mission of Purdue University. Established in 1930, the foundation accepts gifts; administers trusts; funds scholarships and grants; acquires property; protects Purdue's intellectual property; and promotes entrepreneurial activities on behalf of Purdue. Matt Halladay and Dipak Narula work in PRF's Office of Technology Commercialization. They work to protect and commercialize Purdue Intellectual Property. Matt and Dipak are seeking to find a commercial partner to bring this electronic bike lock to market.

Problem Statement / Scope of Work

Large cities and college campuses are experiencing an upward trend in the need for last-mile transportation. PRF desires a commercially viable solution for bike sharing. This device allows the owner of a bicycle to keep it secured while also allowing the ability to grant shared access with others.

Requirements

REQUIREMENT NUMBER	DESIGN REQUIREMENTS	DESIGN TARGETS	Validation
	RATIONALE		
1	Must allow for a wireless connection with an external device	Pass	Physical device test
	Requested by client in Claim 1 of the Provisional Patent [1]		
2	Must allow an external, wirelessly connected device to control the locking mechanism(s)	Pass	Physical device test
	Requested by client in Claim 1 of the Provisional Patent [1]		
3	A manual unlock mechanism must be present as a failsafe	Pass	Physical device test
	Requested by client in Claim 7 of the Provisional Patent [1]		
4	The device must be able to be secured to a bicycle using a locking U-shaped strap	Pass	Physical device test
	Requested by client in Claim 1 of the Provisional Patent [1]		
5	The device must enable the user to lock a bicycle to an external structure	Pass	Physical device test
	Requested by client in Claim 1 of the Provisional Patent [1]		
6	A sping-coiled retractable cable must be contained within the device's housing	Pass	Visual Inspection
	Requested by client in Claim 1 of the Provisional Patent [1]		
7	The spring-coiled retractable cable must have one end protruding through the lock body	Pass	Visual Inspection
	Requested by client in Claim 1 of the Provisional Patent [1]		
8	The lock body must have a recess that allows the protruding cable end to be inserted	Pass	Visual Inspection
	Requested by client in Claim 1 of the Provisional Patent [1]		
9	The recepticle to accept the cable end must have a mechanism to secure the cable end	Pass	Visual Inspection
	Requested by client in Claim 1 of the Provisional Patent [1]		
10	The lock body's receiving slots for the U-shaped strap must allow for the cable to be inserted while the device is locked, but must be unlocked to allow the strap to be removed.	Pass	Physical device test
	Requested by client in Claim 4 of the Provisional Patent [1]		
12	The lock must be powered by a battery with a port for charging using an external source	Pass	System power analysis
	Requested by the client in Claim 9 of the Provisional Patent [1]		
13	An alarm must be equipped and set to notify audibly in the presence of tampering	Pass	Auditory test
	Requested by the client in Claim 8 of the Provisional Patent [1]		
14	The device must have an indicator to display the status of the lock	Pass	Visual Analysis
	Requested by the client in Claim 10 of the Provisional Patent [1]		
15	The device must be able to sustain conditions at or above an IP54 rating	Pass	FMEA Testing
	The device must be operable in inclement weather, including rain, freezing temperatures, and above average high temperatures.		

Experimentation and Concepts

Experimentation:

Initially the electrical team began comparing potential microcontrollers and developmental boards.
Additionally, the team ordered some commercially available retractable bikes locks to get familiar with some of the mechanisms used.
Different materials were ordered and tested for the strap and cable.

Concepts:

Initial concept design was provided from Purdue Research Foundation. (Image 1)
The team began exploring concepts about adding solar panels for charging the bike in outdoor conditions. (Image 2)
In Image 3, the team began building upon the design provided by our clients and mapping out some of the mechanisms required.
In Images 4 and 5, the team conceptualized methods of retaining a bulleted end of a potential retractable cable.

1

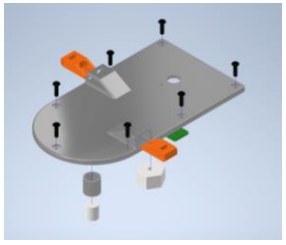
2

3

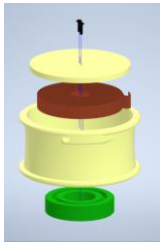
4

5

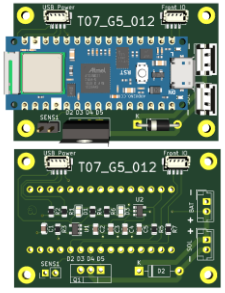
Final Design



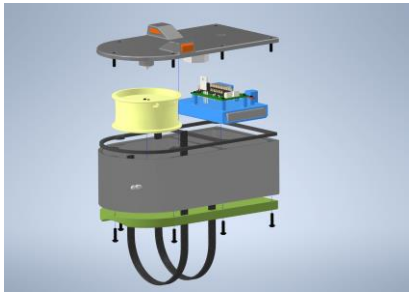
Exploded view of the Lid assembly



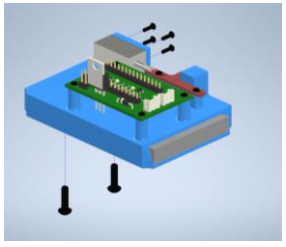
Exploded view of the Spool assembly



Detailed render of PCB



Exploded view of the Main assembly



Exploded view of the Electronics assembly

FMEA

FMEA - Failure Mode and Effects Analysis

Requirements	Potential Failure Mode	Potential Failure Effects	Severity	Potential Causes(s) of Failure	Occurrence	Current Design Controls Prevention	Current Design Controls Detection	Detection	RPN	Actions Taken
Arduino Nano 33 BLE Sense Microcontroller										
Code Continuous Preformance	Code does not execute as expected	Solenoid may activate unreliably, causing the device to remain locked or become unlocked when not intended	7	Compiler error	2	Utilization of proper coding techniques	Comprehensive test plan that covers all functions over an	2	28	Performed full test of operation after each code revision
			7	corrupted file during firmware upload	2	standardized firmware flashing procedure	Comprehensive test plan that covers all functions over an extended timeframe	2	28	Performed full test of operation after each code revision
			7	mistakes in code	1	Utilization of proper coding techniques	Comprehensive test plan that covers all functions over an extended timeframe	2	14	Each code revision was evaluated by two parties and fully tested to ensure no errors were present
			7	improper data type causes overflow	1	Utilization of proper coding techniques	Comprehensive test plan that covers all functions over an extended timeframe	2	14	All data types were correctly sized and checked for possibility of overflow.
Component Tolerance	Onboard Component Fails	Microcontroller does not operate as expected, causing the solenoid to not activate reliably	6	Defect in device manufacturing	3	Ensure the selected microcontroller manufacturer has strict quality control	Perform a multi-cycle test to ensure all components are performing as expected before fully embedding it	3	54	Selected microcontroller is manufactured by reliable company with strict quality control.
Battery Charge Controller Subsystem										
Component Tolerance	Onboard Component Fails	Battery is unable to be charged at all or at specified charging rate	6	Defect in device manufacturing	3	Select quality components from established manufacturers	Perform multiple full-cycle tests to ensure that there are no failures	3	54	Reliable and time-tested components were selected for the design.
Battery Management	Device fails to properly manage battery charge	Battery may not provide the needed current to unlock the solenoid, or at worst case, may allow high current draw, causing the battery to combust or lower overall lifetime	7	Defect in device manufacturing , onboard component failure	2	Ensure the circuit is designed in a way that follows manufacturer's suggestions	Perform multiple full-cycle tests to ensure that the battery operates as expected	6	84	Battery charging circuit built to manufacturer's specs. Battery performs as expected after continuous use

Testing

Test ID	Test Name	Test Description	Test Stage	Test Requirement	Test Date Complete	Actual Results
1	External Connectivity	Test the Bluetooth connectivity to the device	DV	Bluetooth connection is established between the lock and an external device	11-Mar-22	Pass
2	Wireless unlocking	Unlock the device by using bluetooth connectivity	DV	Unlock bike lock with other device	11-Mar-22	Pass
3	Manual Straps Unlock	Unlock the Straps by using a key	DV	The key unlocks the straps of the bike lock	24-Mar-22	Pass
4	U-strap Securement	Test if the Straps stays secure after strap has been "locked"	DV	The strap stays secure after being locked	24-Mar-22	Pass
5	Lockable to Structure	Test if the bike lock stays in place on the bike	DV	The bike lock does not slide on the bike	12-Apr-22	Pass
6	Spring Retractable Cable	Test that the power spring retracts the cable	DV	The power spring retracts the cable	11-Mar-22	Pass
7	Cable Securement	test that the cable will be caught by the solenoid	DV	The cable is caught by the solenoid	11-Mar-22	Pass
8	Cable Recess	Test that the cable will retract when the cable is released	DV	The cable retracts all the way	11-Mar-22	Pass
9	Cable Locking	Test that the cable locks once connected to the solenoid	DV	Cable is locked after being connected to the solenoid	12-Apr-22	Pass
10	Battery Capabilities	Test that the battery powers the bike lock's functions	DV	The battery powers the bike lock's functions	11-Mar-22	Pass
11	Alarm Security	Test that the alarm will go off once tampered with	DV	Alarm sounds	12-Apr-22	Pass
12	LED Display	Ensure LED displays status of lock when powered on	DV	LED lights up	12-Apr-22	Pass
13	Weatherproofing	Ensure the lock body resists splashes of water at all angles	DV	Body of bike lock does not allow water inside	12-Apr-22	Pass

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