ECE 445 Senior Design Lab Project Proposal

Renter-Friendly Fob-Activated Door Lock

Project #29

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1. Introduction

Problem:

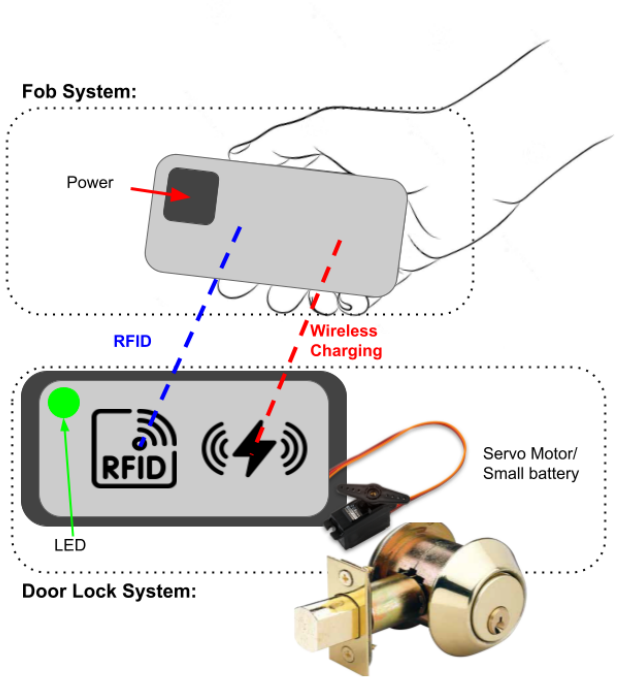
How many times have you been carrying ten bags of groceries and arrived at a locked front door, or been pressed for time and had to fumble through a set of keys? These frustrating and time-consuming issues could be solved by a commercial “smart lock” system, however this solution is not renter-friendly because it requires replacement of a deadbolt.

Solution:

Now imagine the same scenario at your rented apartment, except you arrive at a front door which automatically unlocks with a powered wireless transmitter fob, instead of fumbling with a traditional key.

Our solution is an inductive charging RFID system that uses a battery powered receiver to open the door lock automatically instead of a traditional key. When the correct fob transmitter is detected, a motor would immediately spin to open the deadbolt with a button to re-engage the deadbolt and close the door. This would build off of Project 40 from Spring 2023 by incorporating a separate inductive charging coil from the transmitter on top of the RFID identification that was previously done. In this solution, an RFID reader alone wouldn’t unlock the door because in order to power the servo motor remotely it needs more power then the RFID tag could receive and transfer. This will be accomplished by our fob system that includes two pairs of coils: one pair for RF Identification and one pair for wireless charging.

Visual Aid:

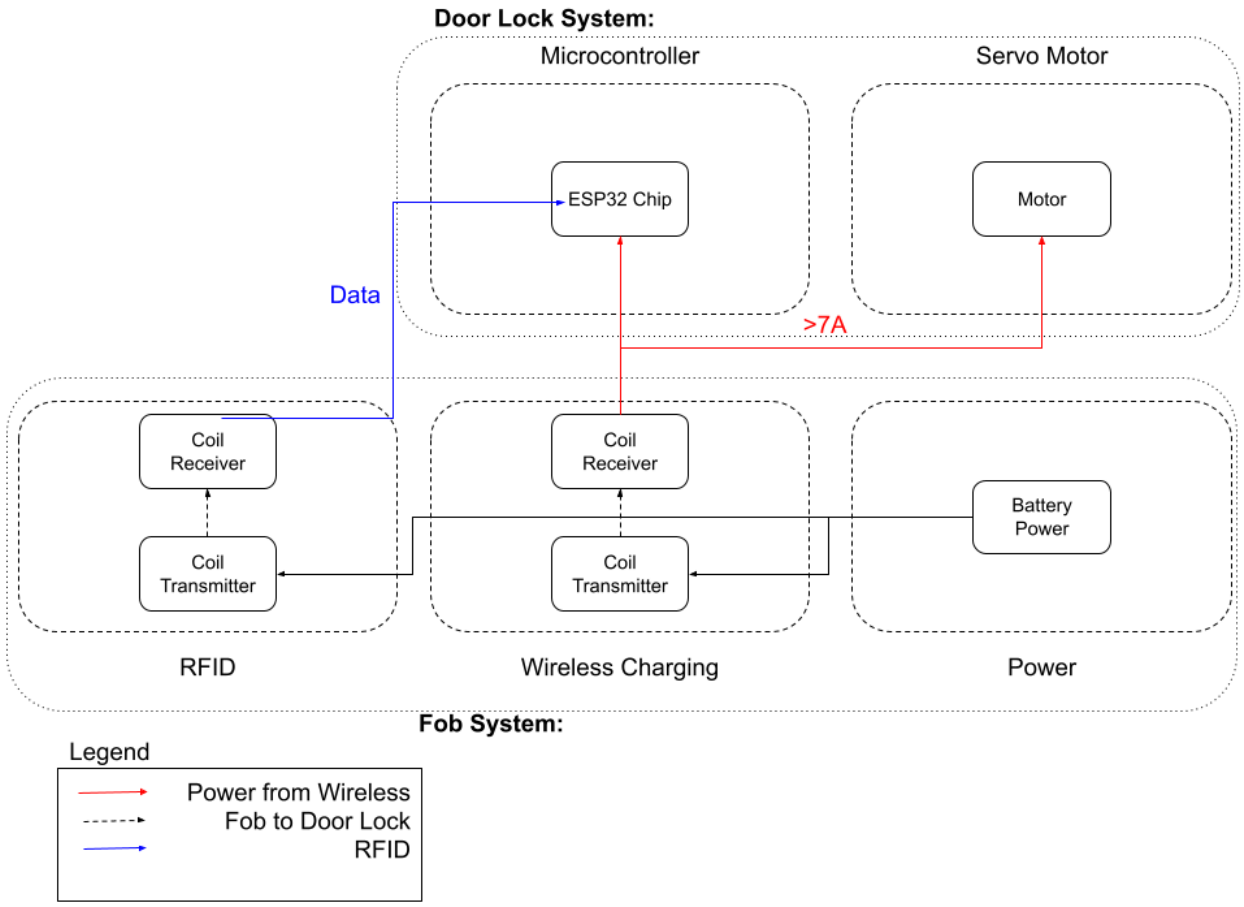


Three High-Level Requirements List:

- The RFID must match properly between the fob and lock. This success will be indicated by a green LED visible to the user.
- The Fob must transfer power to turn the deadbolt within 5 seconds
- The deadbolt must continue through its full range of motion even when the fob is removed prematurely

2. Design

Block Diagram:



Subsystem Overview:

The Door Lock System and The Fob System will contain each half of the Wireless Power and RFID subsystems. Our solution functions by utilizing these subsystems' wireless capabilities, which requires the necessary chip and transmitters to work. The Door Lock System will not be connected to any external power source such as a wall outlet in the home. The Fob system will

have a power subsystem to ensure it can transmit the required charge, RFID signal and power any additional indicator LEDs. The Door Lock system will also require its own power subsystem that could be simply powered by low voltage Lithium ion batteries to ensure proper operation.

Subsystem Requirements:

RFID/Indicator LED

We will implement an RFID system using an ESP32 chip in the door lock system. The RFID transmitter in the fob will be powered by the fob's battery, and it will require about 5 V to function. There will be another RFID chip in the door which will be powered by the coil in the door (which receives an induced current from the fob). This means we must induce a voltage of at least 5 V in the door's circuit when we hold the fob near the door lock so that the RFID chip in the door receives the power it needs to function. When there is a successful reading of data, a green LED indicator in the door will flash green. This LED will be powered by the door's coil as well, and it will only require about 10 mA of current.

Wireless Charging

This is the subsystem which is responsible for powering the majority of the circuit in the door lock system. This includes the servo motor, the small battery and capacitor, the RFID chip and indicator LED, and the battery indicator LED. In the moment that the fob is brought into close proximity to the door lock, the coil must induce a current in the coil in its sister coil in the door lock mechanism. The sister coil is what will then provide current to the rest of the door circuit. The coils we are considering are rated for a peak of 7 A, so the circuit must require less than 7 amps to operate. The servo motors we are considering for the deadbolt have a maximum current rating of 1.4 A, the LEDs require about 10 mA (this is an estimate), and (assuming these systems will be wired in parallel) whatever current remains can go toward charging the capacitor and small rechargeable battery, which are used to power the servo motor in the case that the power from the fob is interrupted before the deadbolt is achieves its full range of motion. The internal resistance of our considered coil is 72 mOh, so a 9V battery powering the coil should be able to supply the coil with enough current to guarantee the circuit in the door has enough power.

$$I = \frac{V}{R} = \frac{9V}{72m\Omega}$$

The 9V battery's output can be manipulated to find the most efficient voltage that will power the wireless charging system to be operational.

Microcontroller

The ESP32 is a Wi-Fi and Bluetooth combo chip that has applications useful to the RFID side of our design. It has a minimum current supply of 0.5A which is well covered by our wireless power coil. It will also be able to logically control the motor to the specifications of our design.

Servo Motor

This motor turns within the supplied 7A that is given by the wireless charging receiver as well as the backup battery in the door, which is only used when the fob (and thus the induced current) is

removed prematurely. This motor is part of the door's circuit and is responsible for moving the deadbolt through its full range of motion. It only engages upon the success of the RFID system.

Door Battery
We are planning to have a small battery pack in the door lock system to power a decoupling capacitor. This is to account for the case where the wireless charging subsystem gets powered partially by the fob but not enough to power the chip and motor system.

Tolerance Analysis:

One aspect of our design which poses a risk to our success is the wireless charging subsystem. If we are unable to induce enough current in the door's circuit, the RFID will not work, the motor will not turn, and the battery in the door will not get recharged. Based on the numbers from the previous section, the door's circuit would need a maximum of about 9 A to operate, maybe slightly more depending on how quickly we want to charge the door's backup battery during fob contact. We know our coils have a 7 A peak current rating, and an internal resistance of 72 Ohms, allowing for a current of over 9 A. So, with the proper power supply in the fob, we should be able to provide enough current to the door's circuit with our wireless charging subsystem for the system to function properly.

3. Ethics and Safety

In terms of ethics and safety, we believe that our project is sound in both aspects. In terms of the ethical standpoint we do not believe that there are any outright violations in the context of the IEEE or ACM code of ethics, however there are some precautions we will take due to the risk of a security issue. We as a team will be sure to uphold ACM 1.6, in regards to privacy and our design for construction and augmentation of a front door lock. Our team will never use our technology for any malicious intent to unlawfully enter a residence or monitor any data including personal information. Our design is only equipped to respond to short-distance authorized fobs that could unlock a door and can never be accessed remotely. There will not be any technology that could collect any information of the status of the door lock or location of a user.

This project will adhere to IEEE 7.8.II.9 in regards to the safety of the moving parts of an electric motor that could cause harm or property damage. We are responsible for the accurate testing and measurement of the torque that the motor will produce when induced with a current from our wireless charging design. This must be designed with caution from an electronic standpoint in order to ensure that our device will not damage an existing deadbolt, or a person with misuse of the device. A potential misuse of our device that could cause harm is locking and unlocking the door with any obstructions. As a team we also are responsible for testing and safety of the excess heat from the wireless charging subsystem. The power transferred wirelessly must be less than the amount to heat up the coil to an unsafe temperature that could lead to user harm.

Overall, we believe that our project is something that mainly achieves an easier lifestyle for the general population and has the same intent as a traditional key and lock system. We will abide

by all the IEEE and ACM Code of Ethics by responsibly testing and honestly reporting all information about our design

References:

72mOhm coil - https://www.digikey.com/en/products/detail/wurth-electronics-inc/760308104113/732-5717-ND/4988096
Microcontroller chip - https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf .