SMART STAIR GATE

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1 Introduction

1.1 Problem

In today's society, parents have more things than ever to worry about especially parents of crawling children. Children are unpredictable at times especially when unsupervised, and the last thing parents want is their child to be doing something dangerous. One of the most dangerous activities a baby can do unsupervised is crawl down a flight of stairs. According to researchers, "Every six minutes, a child falls down stairs somewhere in the U.S., experts say. Over 90,000 kids under the age of 5 end up in emergency rooms because of stair-related falls every year" **[1]**. Although manual gates exist to solve this issue, parents may still forget to close the gate behind them leaving children susceptible to potentially life-threatening accidents.

1.2 Solution

Our solution provides peace of mind for parents of crawling children. We propose to create a smart gate enclosed at the top of a flight of stairs. The smart gate will be initially closed, and open if an adult or an animal approaches the gate.

This solution contains two main sub-systems: detecting when a baby approaches the gate and preventing the baby from crawling down a flight of stairs. Our detection system will be integrated into the gate containing a PIR sensor, a proximity sensor, and RF sensors to determine whether or not a crawling baby is approaching the gate. Our prevention subsystem will contain a motorized gate that will prohibit a crawling baby from crawling down a flight of stairs. We also plan to include a wireless system that enables parents to remotely monitor and control the gate's status, allowing them to open and close the gate.

1.2.1 Visual Aid

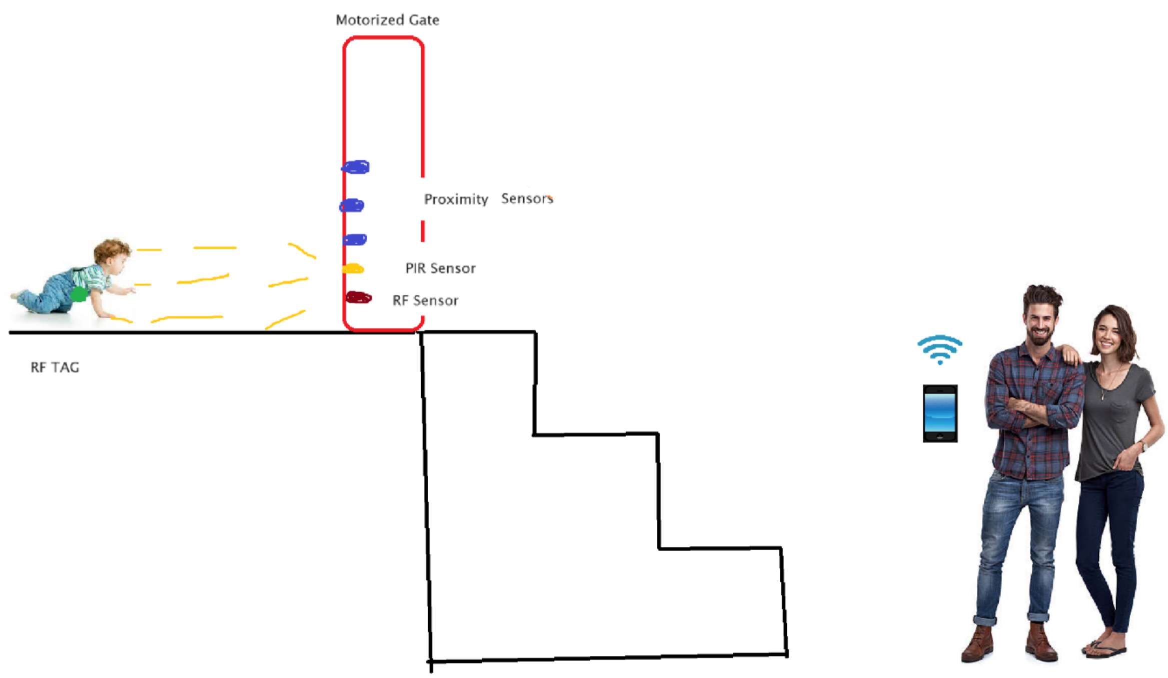


Figure 1: Simple Visual Aid of the Smart Stair Gate

1.3 High-level Requirements

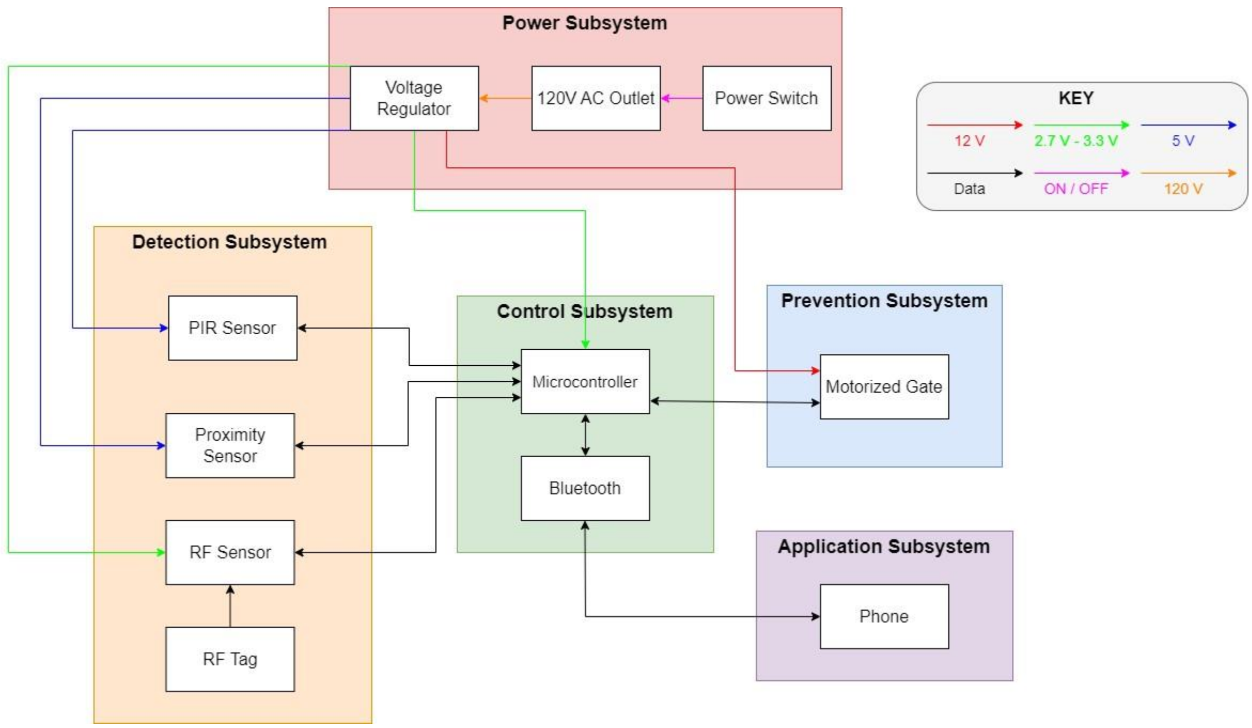
- Gate detection occurs when an object moves within a 3 ±. 5 foot proximity of the gate and sends a signal to the microcontroller.
    - The gate detection module will utilize information captured by a motion sensor. If the motion sensor is triggered, it will signal the microcontroller.

- Gate should be able to differentiate between a toddler, dog, and adult. The gate should automatically open if a dog or an adult wants to pass.
    - RFID tag should be detected within a 3 ± .5 foot radius. A toddler is assumed to have RFID on the body.
    - Gate should open when a dog or adult is within a 3 ± .25 radius. Should be able to tell if it is a human and not an object.

- Collision prevention should be active while the gate is in motion.
    - While the gate is in the process of opening/closing, there will be motion sensors active to detect if anything is near the gate. If any object is within 3 ± .5 inches of the gate door's front, it will stop until the object is no longer there.
    - After the object is gone, the gate will resume the former action

2 Design

2.1 Block Diagram



2.2 Subsystem Overview

Our product calls for five subsystems: power, control, detection, prevention, application.

2.2.1 Power Subsystem

The power system will connect to the power line and stepped down by a transformer. The AC signal will be fed into a rectifier turning it into a DC signal. With the use of filters, LDOs, and buck converters, we will get the voltages we need to safely power the microcontroller and the motors. The power line is used in the case that batteries run out of charge. An LED will be used to indicate the device's functionality.

2.2.2 Control Subsystem

The control system is where all the signals are sent to control the product. This subsystem consists of our main PCB equipped with a microcontroller that will send and receive electrical signals. The functionality will be provided by the power subsystem.

2.2.3 Detection Subsystem

The detection system will allow the gate to tell if it should remain open or closed. It consists of multiple sensors including PIR, proximity, and RF sensors. The PIR allows the gate to differentiate between objects and living things; proximity sensors for when the device should be on standby and if anything is nearby when opening/closing; and RF sensors/tags to distinguish between toddlers and dogs. The PIR sensor will be always on while all the other sensors will be on standby until PIR sensor is triggered.

2.2.4 Prevention Subsystem

The prevention system is everything that controls the mechanical parts of the products. This subsystem consists of a DC brushed gear motor w/encoder, the gate itself, and a solenoid lock.

2.2.5 Application Subsystem

The application subsystem allows for phone interaction. It consists of a wifi signal and a phone app. This phone app will be able to open and close the door from any location and will tell the user the state of the door.

2.3 Subsystem Requirements

2.3.1 Power Subsystem Requirements

The power line must be single phase 120 Vrms and dropped to 12 Vrms by a voltage transformer. Due to the large amount of power when transmitting Wi-Fi, we need a transformer that can handle it (185D24). After the transformer, we need a Schottky full bridge rectifier CDBHD260-G to receive a DC voltage and feed it into a filter. To receive a more consistent DC voltage, we use a multi-output buck converter to drop the voltage down to 12V and 5V. The 12V is used to power the motors and solenoid while 5V is for some sensors. In the case of a power outage, our buck converter will need a UVLO to make sure the micro does not brown out. Also, to control an LED, the IC will need a power good pin. The 12V will be passed through an LDO to reach 3.3V to power the microcontroller and its peripherals. Because the LDO will be dissipating a lot of power, we employ a heat sink.

2.3.2 Control Subsystem Requirements

We plan to use a ESP32 microcontroller. The ESP32 allows for a high amount of RAM and has an inbuilt WI-FI module which we will use to connect with the phone. To support the transmission of Wi-Fi, we need a large amount of current 180mA to 240mA depending on the Wi-Fi settings. The ESP32 will communicate with the sensors using SPI as the distance between the PCB and sensors is far (> 1 meter). The input voltage for the ESP32 is 2.7V - 3.6V thus our LDO must output within tolerance.

2.3.3 Detection Subsystem Requirements

Because our design requires one custom PCB, we may use a 5V PIR breakout board for motion and human detection from Adafruit. This PIR can detect up to 20 feet depending on the configuration passing our requirements. This board will be connected to the main board via the use of GPIO on the ESP32. For the proximity sensors, we will use HC-SR04 Sparkfun breakout board and convert it to the SPI interface to account for the noise from I2C. The required voltage is 5V. Finally, to be able to read the RFID, we will use RC522 that can be controlled with SPI protocol. It takes in a 3.3V input. SPI interface allows us to use less GPIO (4) while accessing many different devices.

2.3.4 Prevention Subsystem Requirements

Due to the difficulty in creating a product of size, and consulting the Machine Shop, the product is downscaled to 20 in x 20 in. The motor is used to open and close the gate and will be controlled using an H-Bridge IC (controlled by a microcontroller). An encoder is necessary for the control subsystem to measure the gate's arm position (0-90 degrees). The solenoid lock is used to ensure that the gate is safe when closed and will require 12V (Digikey 1512). Since we cannot directly control 12V, a PWM will be used for the motor to ensure smooth operation, and a Mosfet for the solenoid lock.

2.3.5 Application Subsystem Requirements

The app should be easy to follow and use. It should give a notification when the door opens or closes.

2.4 Tolerance Analysis

Due to the devices above, the tolerances of the power lines will need to be 12V±.5%, 3.3V±5% and 5V±5%. We do not care about the tolerances of the sensors are stated in the high level and will be programmed according to the aforementioned.

3 Ethics & Safety

We intend to abide by the regulations established by both the IEEE and ACM code of ethics.

Throughout development of the project, we intend to create a product that relates to the safety of young children. As a result, necessary precautions will be taken to ensure compliance with the IEEE ethical code 7.8.1.1 stating “[to] hold paramount the safety, health, and welfare of the public” as well as AMC code 1.2 in which we promise to “Avoid Harm” **[2]**. Regulations of these codes will be followed by running multiple tests on the sensors and motors. We will ensure that the proximity sensors and motors don’t move the gate if there is a chance that anyone can be injured as a result of the movement.

In addition, since we plan on allowing the user of the gate to have an app that receives signals from the microcontroller, we will pay great attention to ensure we abide by AMC code 1.6 in which we will “Respect Privacy” **[2]**. The app will only be used to allow the user to interact with and give commands to the microcontroller. The app will not be able to access any unnecessary information on the user’s device.

4 References

[1] Iyamba, N. (2012, March 12). *Stairs Among Leading Causes of Injury, Death for Kids*. KSL.com. https://www.ksl.com/article/19560857/stairs-among-leading-causes-of-injury-death-for-kids#:~:text=Every%20six%20minutes%2C%20a%20child,stair%2Drelated%20falls%20every%20year

[2] IEEE. “”IEEE Code of Ethics”.” (2016), https://www.ieee.org/ about/corporate/governance/p7-8.html