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UNIVERSITY OF NEVADA LAS VEGAS
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

EE498 Senior Design
Fall 2016

Smart Home Speaker System

Senior Design Final Project Report

Class instructor: Dr. Grzegorz Chmaj

Faculty advisor: Dr. R. Jacob Baker

Group Members:

Ulises Diaz	EE
Name (Print)	CPE/EE/ME
Dane Gentry	EE
Name (Print)	CPE/EE/ME
Brandon Thomas	EE
Name (Print)	CPE/EE/ME

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UNLV UNIVERSITY OF NEVADA LAS VEGAS

Class:	EE498 Senior Design II	Semester:	Fall 2016

Group members:	Project topic:	*Smart Home Speaker System*
Ulises Diaz *Dane Gentry* *Brandon Thomas*	Document:	Final Report

Abstract

The Smart Home Speaker System consists of wirelessly-connected speakers which "follow" a user from room to room. The user wirelessly streams music from an app on their phone to each room's designated speaker which only outputs the streamed music if the user is in that room. As the user enters a room, a RFID (radio-frequency identification) reader in the room's doorway detects the user's RFID tag which prompts the room's designated speaker to stream the music. The speaker then stops streaming the music when the user exits the room.

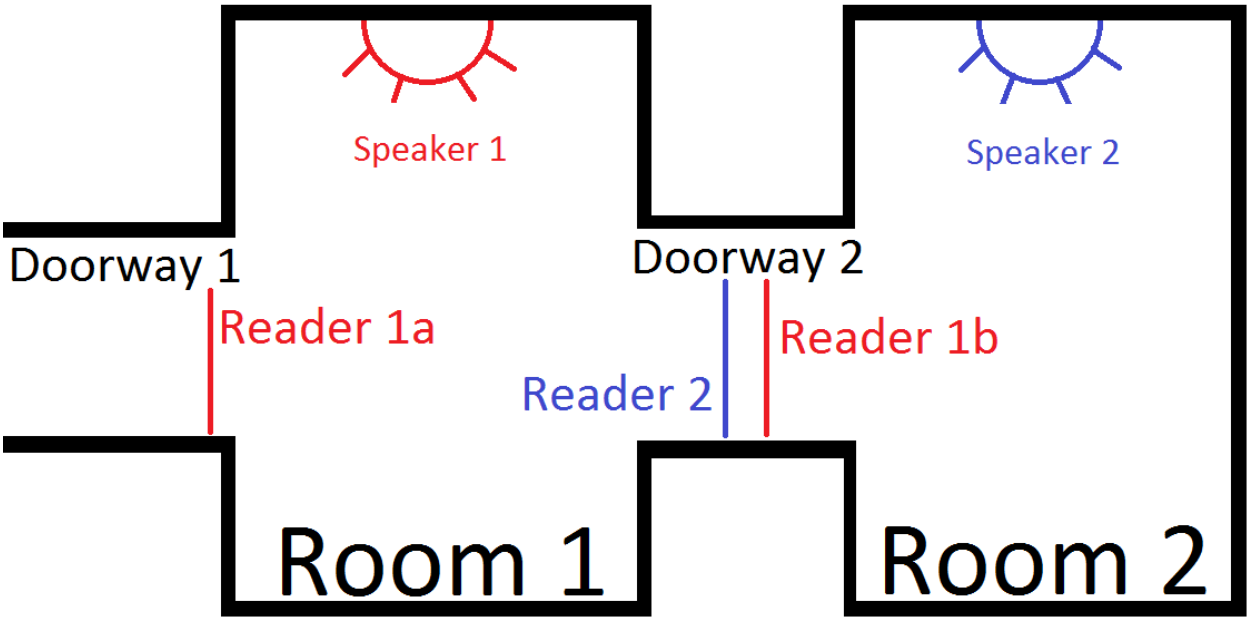
Common RFID tags include key fobs and proximity cards, but our project utilizes an RFID sticker which can be attached to any of the user's belongings, namely their phone from which they are streaming their music. The system has been designed to work for rooms with one or two doorways (with a RFID reader located in each doorway) and has the capability of being extended to rooms with numerous doorways. Thus, a room's speaker turns on/off based off detecting the user entering/exiting the room through either doorway. The system also allows for guest users each with a unique RFID tag. The user(s) can also manually turn the speakers on/off as well as control the volume of each speaker using the app. The system ensures none of the speakers will undesirably output to anyone without a RFID tag.

The Google Chromecast Audio, which utilizes Wi-Fi technology, was implemented in our system as the most effective means of wirelessly streaming music from the user's phone to multiple wirelessly-connected speakers. Before implementing the Chromecast, we researched and experimented with other various possibilities for wirelessly streaming music from the user's phone to multiple wirelessly-connected speakers such as Bluetooth technology/speakers as well as FM radio speakers using an FM transmitter. Bluetooth, however, doesn't allow for a convenient, cost-effective method of wirelessly streaming to more than two speakers and often uses confusing interfaces while FM results in issues due to compliance with FCC regulations.

Our system also implements the use of the Qunqi MFRC-522 RFID sensor for tracking the user(s) as they move between rooms. Though RFID sensors rely on NFC (near field communication) which requires the RFID tag to come within a few inches of the RFID reader in order to be detected, research and experimentation with various other sensors such as PIR (passive infrared) motion sensors, ultrasonic sensors, and thermal sensors proved to be less favorable. Though these sensors are all efficient presence detectors, they simply detect any human presence as opposed to detecting a specified user(s) and differentiating from others.

In addition, we built our own speakers for the Chromecast to be plugged into by using the Dayton Audio DTA-2 amplifier module as well as the Fountek FE87 speaker driver.

Full Project Presentation Room Diagram



Room 1 = Two Doorway Case

Room 2 = Single Doorway Case + Two Doorway Case

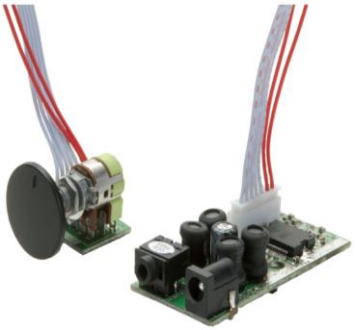
Single Doorway Case:

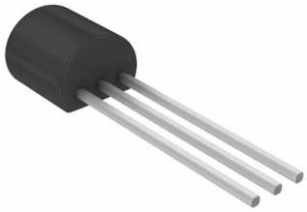
- Room has one designated speaker
- Room has one doorway (one RFID reader in this one doorway)
- Speaker turns on/off when user walks in/out of room (through the one doorway)
    - RFID reader in doorway detects user's RFID tag as they walk in/out the room through the one doorway

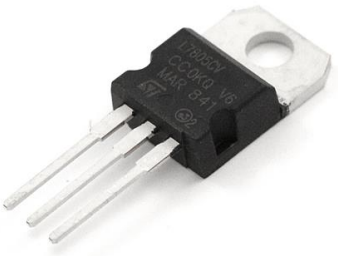
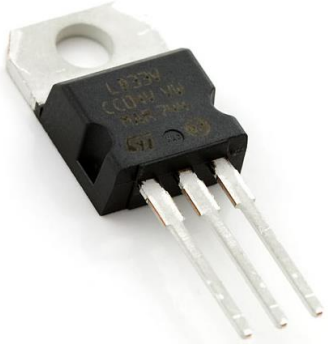
Two Doorway Case:

- Room has one designated speaker
- Room has two doorways (one RFID reader in each doorway – total of two RFID readers)
    - Both RFID readers are connected to the room's one designated speaker
- Speaker turns on/off when user walks in/out of room (through EITHER doorway)
    - RFID reader 1 in doorway 1 detects user's RFID tag as they walk in/out the room through doorway 1
    - RFID reader 2 in doorway 2 detects user's RFID tag as they walk in/out the room through doorway 2
        - Can be extended to multiple ays such that…
            - RFID reader "X" in doorway "X" detects user's RFID tag as they walk in/out the room through doorway "X"
            - "X" RFID readers are connected to the room's one designated speaker

Components List

Part type	Vendor	Model	Parameters
Google Chromecast Audio	Best Buy		- Includes: Chromecast, 3.5mm aux cable, wall adapter w/ USB ➔ microUSB cable - Audio device (phone) connects via Wi-Fi - Can connect 1 phone to multiple Chromecasts - Can connect multiple phones to Chromecast via guest mode - Connects to speaker via 3.5mm aux cable - Connects to power via wall adapter w/ USB ➔ microUSB cable - Utilizes Google Cast app - Price: $37
Audio Amp Module	Parts Express	Dayton Audio DTA-2 	- Digital Class T Audio Amp Module - Features Tripath TA-2024 IC - 15W/ch continuous power - Measures 2-11/16" x 1-5/16" - Price: $19.90
Speaker Driver	Parts Express	Fountek FE87 	- 3’’ Full Range Driver - 8 ohm - Power Handling: 12W (RMS), 24W (max) - Frequency Response: 100Hz – 25kHz - Price: $7.90
Speaker Cabinet	Parts Express	Denovo Audio 	- Comes in pairs - Requires assembly - 0.04 cu. ft. (70 cu. in.) - Weight: 3.85 lbs. - Price: $24.90

RFID Reader & Tag(s)	Amazon	Qunqi MFRC-522 	- Includes: RFID Reader Module, White Card Tag, Blue Key Ring Tag, Headers - Power Voltage: 3.3VDC - Operating Frequency: 13.56 MHz - Read Range: 60mm (2.36 in.) - Price: $7.99
RFID Sticker Tag	Amazon	Adafruit RFID/NFC Sticker 	- Will stick to phone (Phone = RFID tag) - Dimensions: 41 mm x 24 mm x 0.2 mm - Frequency: 13.56 MHz - Price: $0.86
Microcontroller	Amazon	Atmel ATMEGA328-PU AVR 	- Core Size: 8-bit - Speed: 20MHz - Program Memory Size: 32KB - Supply Voltage: 1.8~5.5V - 28-DIP - See Datasheet for Specifications - Price: $4.50
Relay	Digikey	Omron G5V-1 	- Used in switching circuit - Pin 5, Pin 6, and Pin 10 are internally connected - Pin 5 = Pin 6 will be connected to + I/P of speaker driver - Pin 1 will be connected to + O/P of audio amp - Pin 10 connects to Pin 1 (connecting + O/P of audio amp to + I/P of speaker driver) if switch closes (due to digital O/P high “1” being sent to base of transistor) - Coil Current: 12.5mA - Coil Voltage: 12VDC - Price: $1.99
Transistor	Digikey	Fairchild Semiconductor FJN3302RTA 	- Used in switching circuit - Digital O/P high “1” being sent to base of transistor results in closing switch - Pre-Biased Bipolar Transistor (BJT) NPN - See Datasheet for Specifications - Price: $0.21
Diode	UNLV	1N4005 	- Used in switching circuit - See Datasheet for Specifications - Price: N/A

DC Barrel Power Jack	Amazon	PJ-202A 	- Compatible w/ DC wall power supplies - 16VDC @ 2.5A - 5.5mm jack - 2.2mm center pole diameter - Price: $0.50
DC Power Supply	Parts Express		- 12 VDC 2000mA Switching Power Supply - Delivers up to 24W - 60 Hz, 110/120 VAC - 6 ft. connection cable w/ 2.1 mm x 5.5 mm plug - All power in our circuit will be derived from this power supply - Price: $15.85
Capacitor	UNLV	Xicon 10uF Capacitor 	- Capacitance: 10uF - See Datasheet for Specifications - Price: N/A
5V Voltage Regulator	Amazon	L7805 	- Output Voltage: 5V - Output Current: 1.5A (max) - Thermal Overload, Short Circuit, and Output Transition SOA Protection - TO-220 Package - See Datasheet for Specifications - Price: $2.25
3.3V Voltage Regulator	Amazon	LD1117V33 	- Output Voltage: 3.3V - Output Current: 800mA (max) - Low Dropout Voltage (1V Typ.) - Internal Current and Thermal Limit - TO-220 Package - See Datasheet for Specifications - Price: $2.25

Description of Components

- **Google Chromecast:**
  - Connecting a Google Chromecast to each speaker via aux cable allows the capability of wirelessly streaming (via Wi-Fi) from a smart phone (or similar device) to each speaker simultaneously using the Google Cast app. The app also allows the user (as well as guest users with the pin to each respective Chromecast/speaker without having to be connected to Wi-Fi if guest mode is enabled) to manually cast to individual speakers as well as control the volume of each speaker.
- **Dayton Audio DTA-2 Class T Digital Audio Amplifier Module:**
  - The Chromecast inputs the streamed audio via aux jack input to the amp module in order to amplify the audio in a quality manner to the speaker driver. This amp module requires power from a 12 VDC 2A switching power supply.
- **Fountek FE87 3'' 8 Ohm Speaker Driver:**
  - The amp module outputs to this 3'' 8 ohm speaker driver in order to provide quality audio.
- **Speaker Cabinet:**
  - The speaker cabinet is constructed, and the speaker driver is installed in the cabinet in order to improve audio quality. In addition, all major components and hardware are stored and hidden within the cabinet.
- **Sensor - MCFR222 RFID Reader & Tag:**
  - The RFID reader and RFID tag communicate using a 13.56 MHz electromagnetic field. If the tag is brought within detection range (roughly 2.35 inches) of the reader, the reader sends the detection information to the MCU which performs and executes actions based off the code programmed to it.
- **Analog Switch – G5V-1 Relay, FJN3302 Pre-Biased Transistor, and 1N4005 Diode:**
  - The analog switch, consisting of a G5V-1 relay, a FJN3302 pre-biased transistor, and a 1N4005 diode connects the positive terminal of the output of the amp module to the positive terminal of the speaker driver (outputting the streamed audio) ONLY IF the MCU sends a digital high signal (Binary "1" or 5V). Otherwise, the audio is not outputted due to the switch being sent a digital low signal (Binary "0" or 0V=GND).
- **Microcontroller Unit (MCU) – Arduino Uno ➔ Atmega328P:**
  - Based off the code programmed to the MCU (Single Doorway Case or Two Doorway Case) and based off the information received from the sensor (Binary "1" if detect; Binary "0" else), the MCU makes the decision to send either a digital high signal (Binary "1" or 5V), resulting in outputted audio, or a digital low signal (Binary "0" or 0V=GND) to the analog switch. For the Single Doorway Case, the room's designated speaker turns on/off based off the RFID reader (which is located in the room's single doorway and wired to the room's speaker's MCU) detecting the RFID tag as the user walks in/out of the room. The Two Doorway Case is the same as the Single Doorway Case except that the room (which still only has one designated speaker) has two doorways and, therefore, two RFID readers (one in each doorway) such that the room's speaker turns on/off based off the user walking in/out of EITHER doorway. Simply put, a

room's speaker turns on when the user walks in the room and turns off when the user walks out of the room.

- Working code for the Single Doorway Case and Two Doorway Case are shown below.

Code for Single Doorway Case

```
#include <SPI.h>
#include <RFID.h>

#define SS_PIN 10
#define RST_PIN 9

RFID rfid(SS_PIN,RST_PIN);

int led = 6;
int power = 8;
int state = 0;
int serNum[5];
int cards[][5] = {
  {254,93,124,178,109}

};

bool access = false;

void setup(){

   Serial.begin(9600);
   SPI.begin();
   rfid.init();

   pinMode(led, OUTPUT);
   digitalWrite(led, LOW);

}

void loop(){

   if(rfid.isCard()){

      if(rfid.readCardSerial()){
         Serial.print(rfid.serNum[0]);
         Serial.print(" ");
         Serial.print(rfid.serNum[1]);
         Serial.print(" ");
         Serial.print(rfid.serNum[2]);
```

```
      Serial.print(" ");
      Serial.print(rfid.serNum[3]);
      Serial.print(" ");
      Serial.print(rfid.serNum[4]);
      Serial.println("");

      for(int x = 0; x < sizeof(cards); x++){
        for(int i = 0; i < sizeof(rfid.serNum); i++ ){
           if(rfid.serNum[i] != cards[x][i]) {
              access = false;
              break;
           } else {
              access = true;
           }
        }
        if(access) break;
      }

  }

 if(access)
 {
    Serial.println("Welcome!");
    if (state==0)
    {
      digitalWrite(led, HIGH);
      state=1;
      delay(1000);
    }
    else
    {
      digitalWrite(led,LOW);
      state=0;
      delay(1000);
    }
}

else
{
     Serial.println("Not allowed!");
     digitalWrite(led, HIGH);
     delay(500);
     digitalWrite(led, LOW);
     delay(500);
     digitalWrite(led, HIGH);
     delay(500);
```

```
        digitalWrite(led, LOW);
      }
    }
    rfid.halt();
}
```

Code for Two Doorway Case

```
#include <SPI.h>
#include <RFID.h>

#define SS_PIN 10
#define RST_PIN 9
#define SS_PIN2 8
#define RST_PIN2 7

RFID rfid(SS_PIN,RST_PIN);
RFID rfid_2(SS_PIN2,RST_PIN2);


int led = 6;
// int power = 8;
int state = 0;
int serNum[5];
int cards[][5] = {
  {254,93,124,178,109}

};

bool access = false;

void setup(){

    Serial.begin(9600);
    SPI.begin();
    rfid.init();
    rfid_2.init();

    pinMode(led, OUTPUT);

    digitalWrite(led, LOW);

}

void loop(){
```

```
if(rfid.isCard()){

    if(rfid.readCardSerial()){
        Serial.print(rfid.serNum[0]);
        Serial.print(" ");
        Serial.print(rfid.serNum[1]);
        Serial.print(" ");
        Serial.print(rfid.serNum[2]);
        Serial.print(" ");
        Serial.print(rfid.serNum[3]);
        Serial.print(" ");
        Serial.print(rfid.serNum[4]);
        Serial.println("");

        for(int x = 0; x < sizeof(cards); x++){
          for(int i = 0; i < sizeof(rfid.serNum); i++ ){
              if(rfid.serNum[i] != cards[x][i]) {
                  access = false;
                  break;
              } else {
                  access = true;
              }
          }
          if(access) break;
        }

    }

   if(access)
   {
     Serial.println("Welcome!");
     if (state==0)
     {
       digitalWrite(led, HIGH);
       state=1;
       delay(1000);
     }
     else
     {
       digitalWrite(led,LOW);
       state=0;
       delay(1000);
     }

  }
```

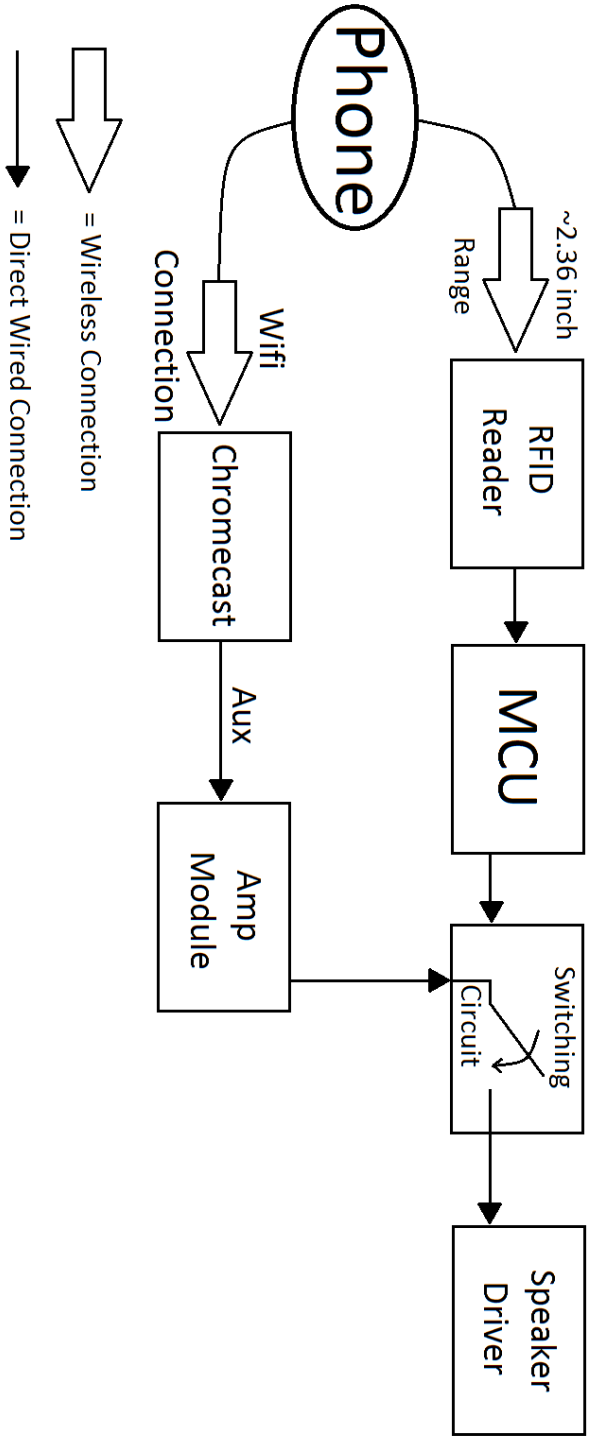
```
  else
  {
      Serial.println("Not allowed!");
      digitalWrite(led, HIGH);
      delay(500);
      digitalWrite(led, LOW);
      delay(500);
      digitalWrite(led, HIGH);
      delay(500);
      digitalWrite(led, LOW);
   }
}

rfid.halt();

if(rfid_2.isCard()){

    if(rfid_2.readCardSerial()){
        Serial.print(rfid_2.serNum[0]);
        Serial.print(" ");
        Serial.print(rfid_2.serNum[1]);
        Serial.print(" ");
        Serial.print(rfid_2.serNum[2]);
        Serial.print(" ");
        Serial.print(rfid_2.serNum[3]);
        Serial.print(" ");
        Serial.print(rfid_2.serNum[4]);
        Serial.println("");

        for(int x = 0; x < sizeof(cards); x++){
          for(int i = 0; i < sizeof(rfid_2.serNum); i++ ){
              if(rfid_2.serNum[i] != cards[x][i]) {
                  access = false;
                  break;
              } else {
                  access = true;
              }
          }
          if(access) break;
        }

    }

   if(access)
   {
      Serial.println("Welcome!");
```

```
        if (state==0)
        {
          digitalWrite(led, HIGH);
          state=1;
          delay(1000);
        }
        else
        {
          digitalWrite(led,LOW);
          state=0;
          delay(1000);
        }
      }
      else
      {
          Serial.println("Not allowed!");
          digitalWrite(led, HIGH);
          delay(500);
          digitalWrite(led, LOW);
          delay(500);
          digitalWrite(led, HIGH);
          delay(500);
          digitalWrite(led, LOW);
       }
    }
    rfid_2.halt();
}
```

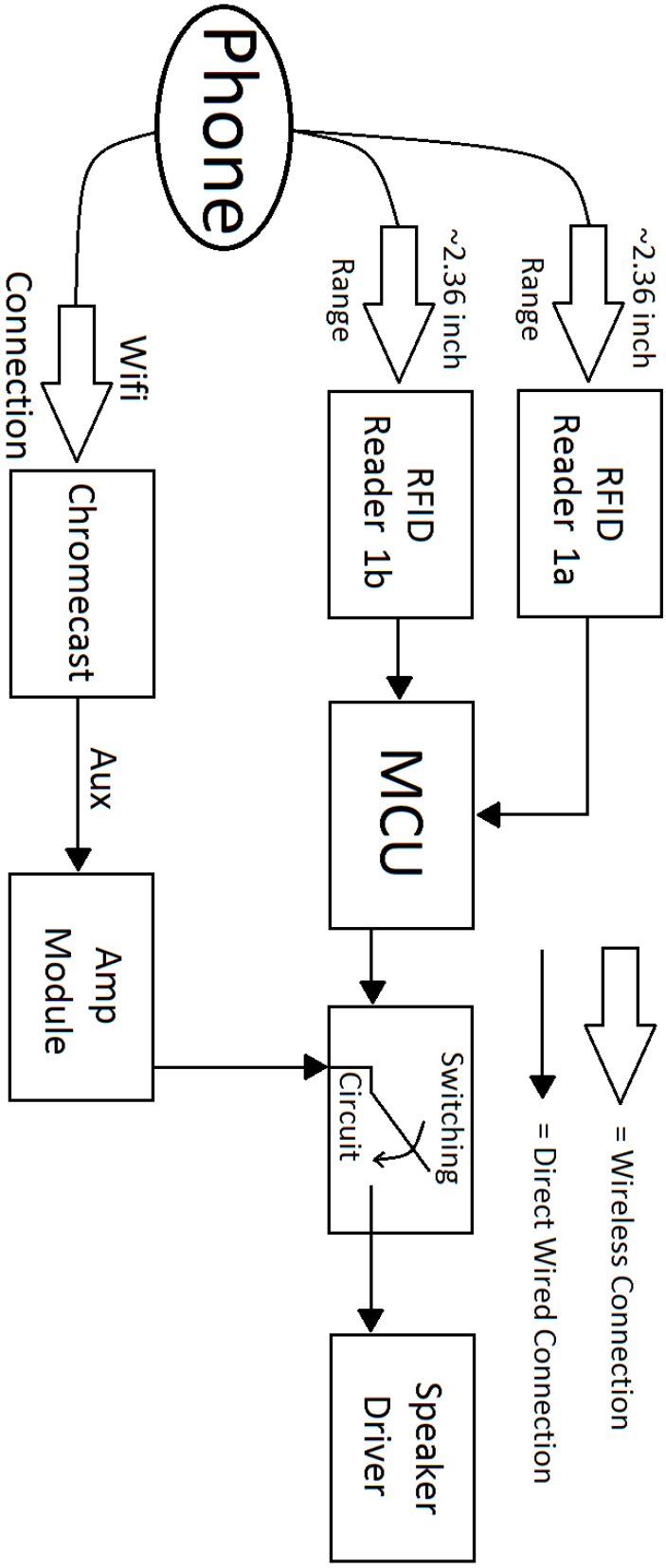
- **Project Block Diagram:** The below block diagrams show the basic configurations of how each element/component in our project are connected to one another for the Single Doorway Case, the Two Doorway Case, and the full project presentation.

Smart Home Speaker System Block Diagrams

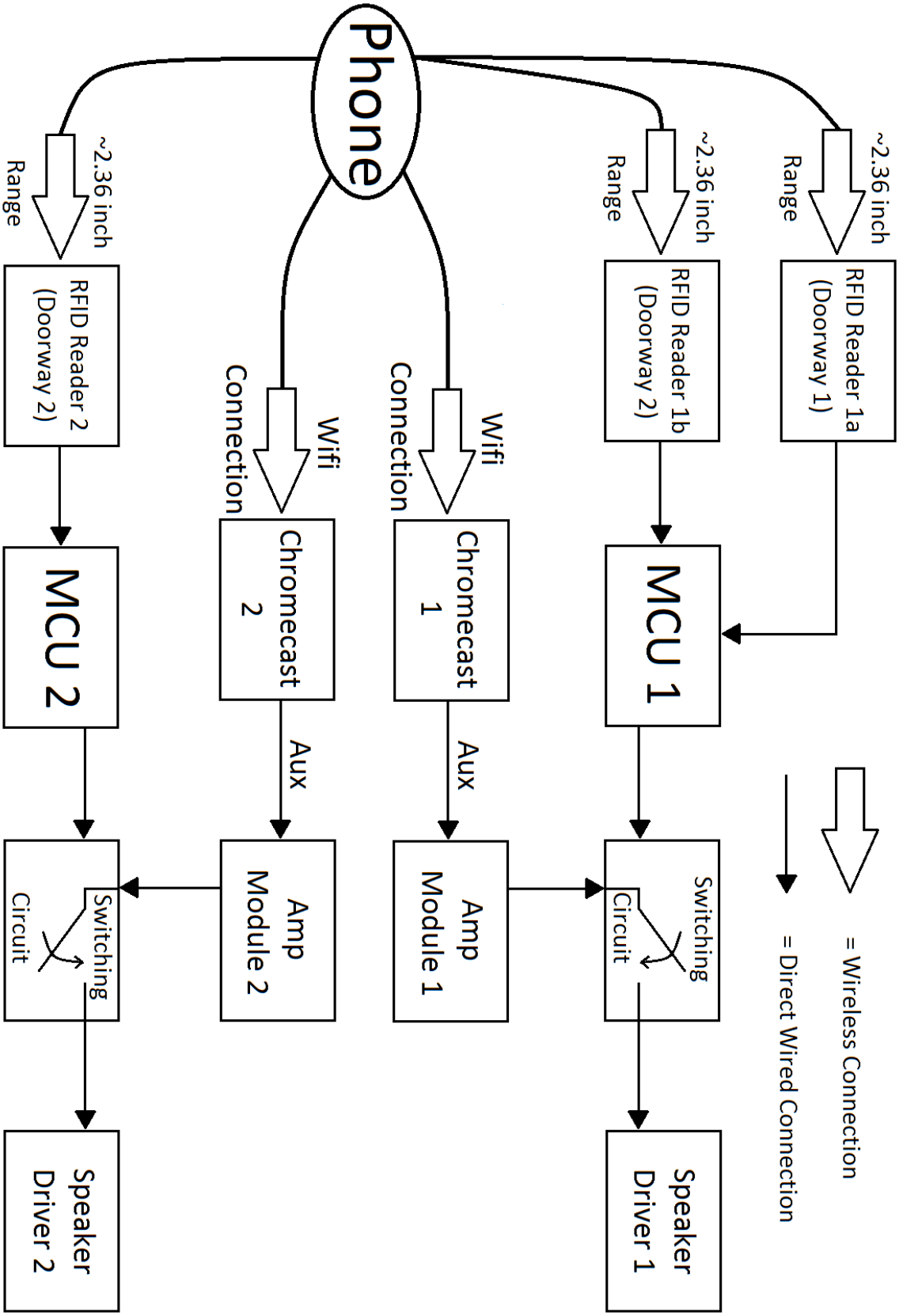
Single Doorway Case Block Diagram



Two Doorway Case Block Diagram



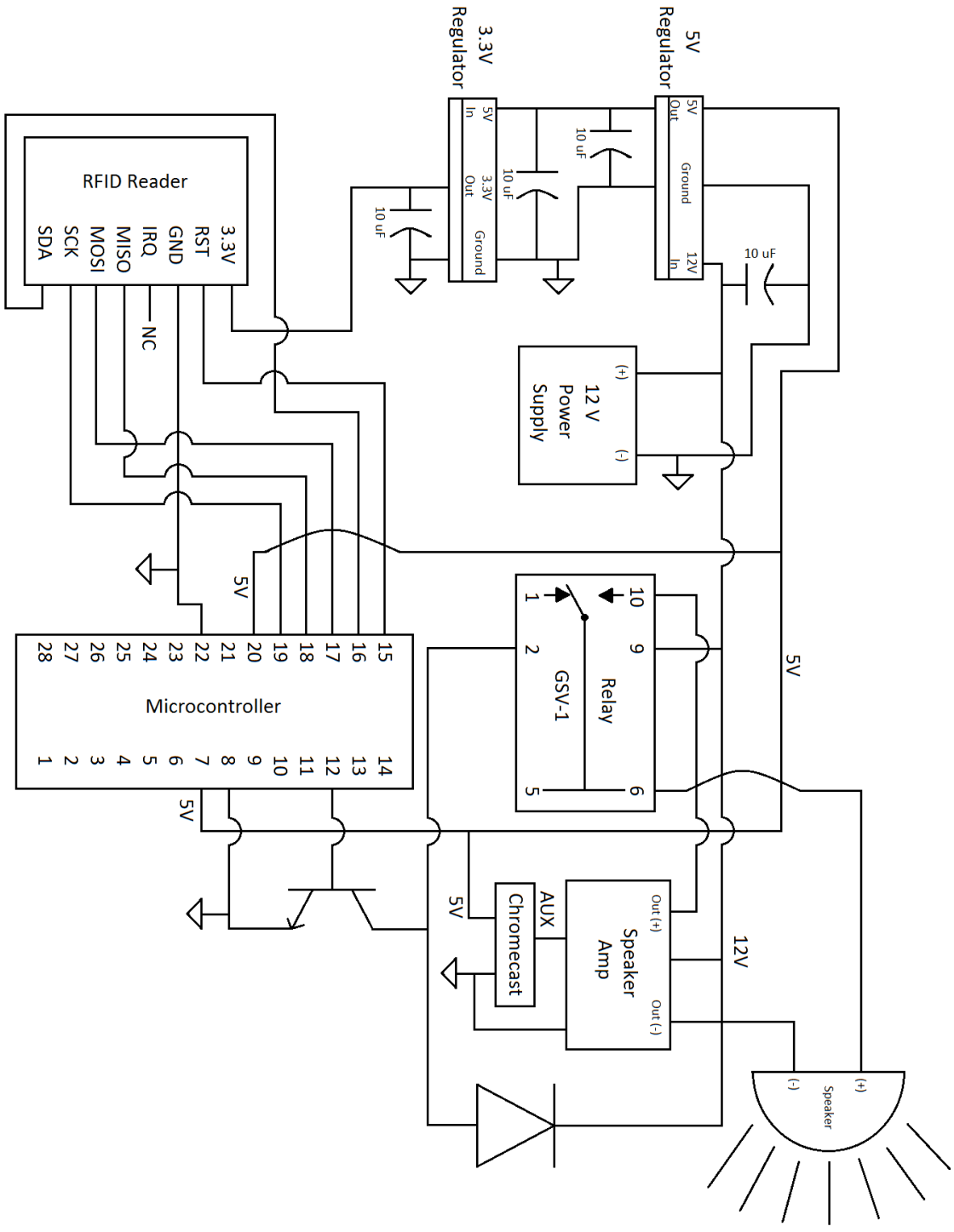
Full Project Presentation Block Diagram



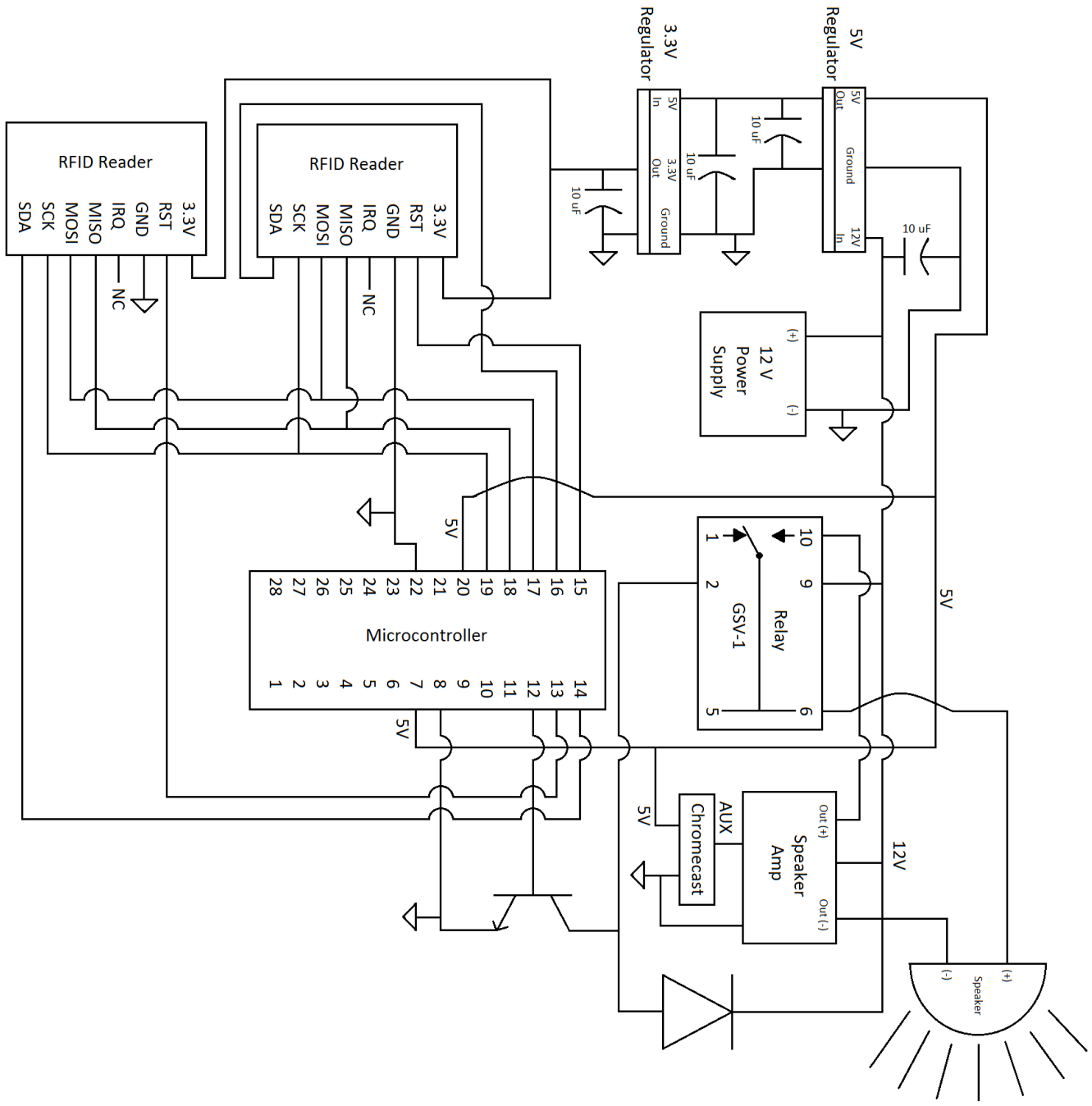
- **Project Schematic:** The below schematics show ALL necessary electrical circuit connections for our project as well as schematics specifically to be implemented in our PCB layout for both the Single Doorway Case as well as the Two Doorway Case.

Smart Home Speaker System Schematic

Single Doorway Case Schematic

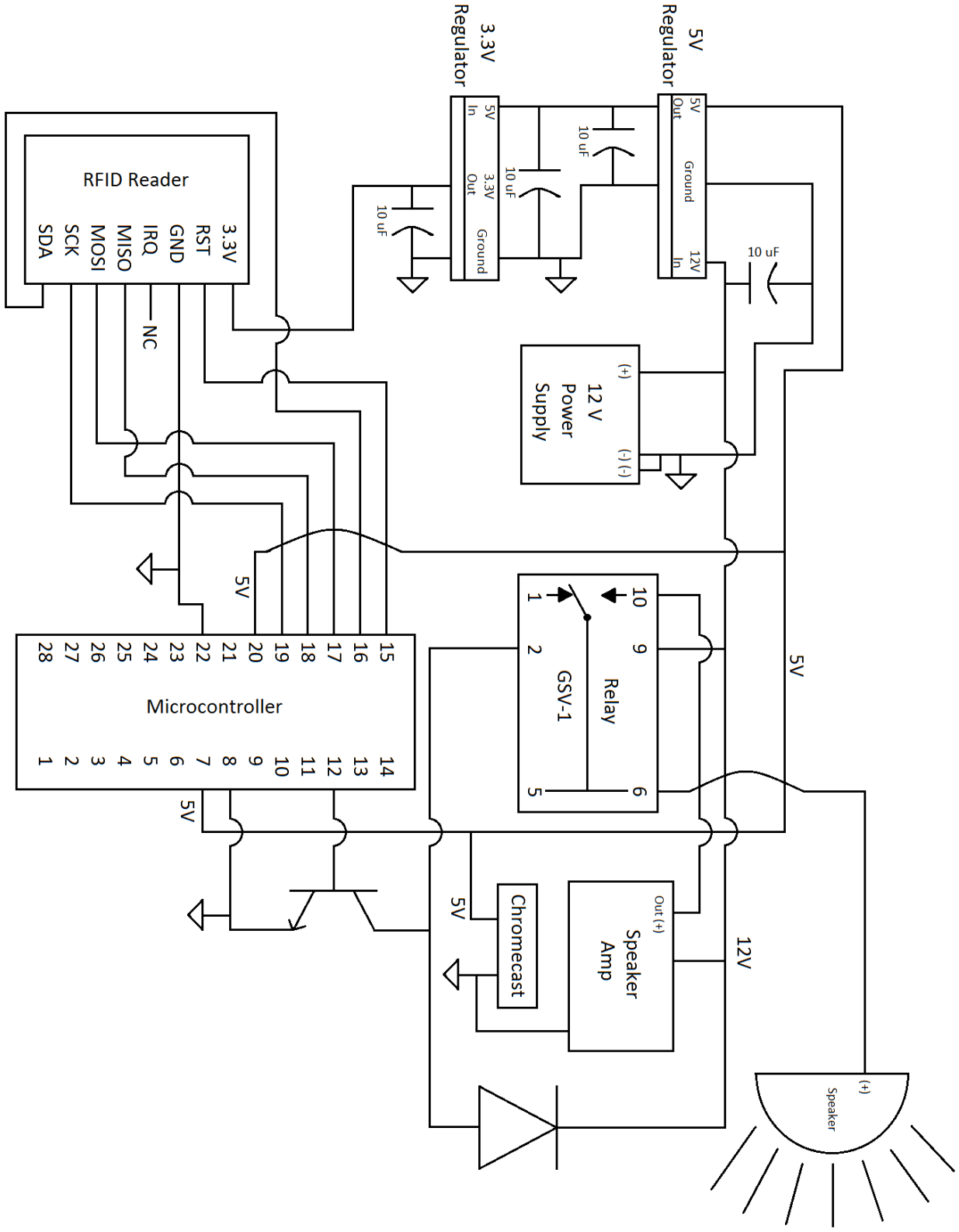


Two Doorway Case Schematic

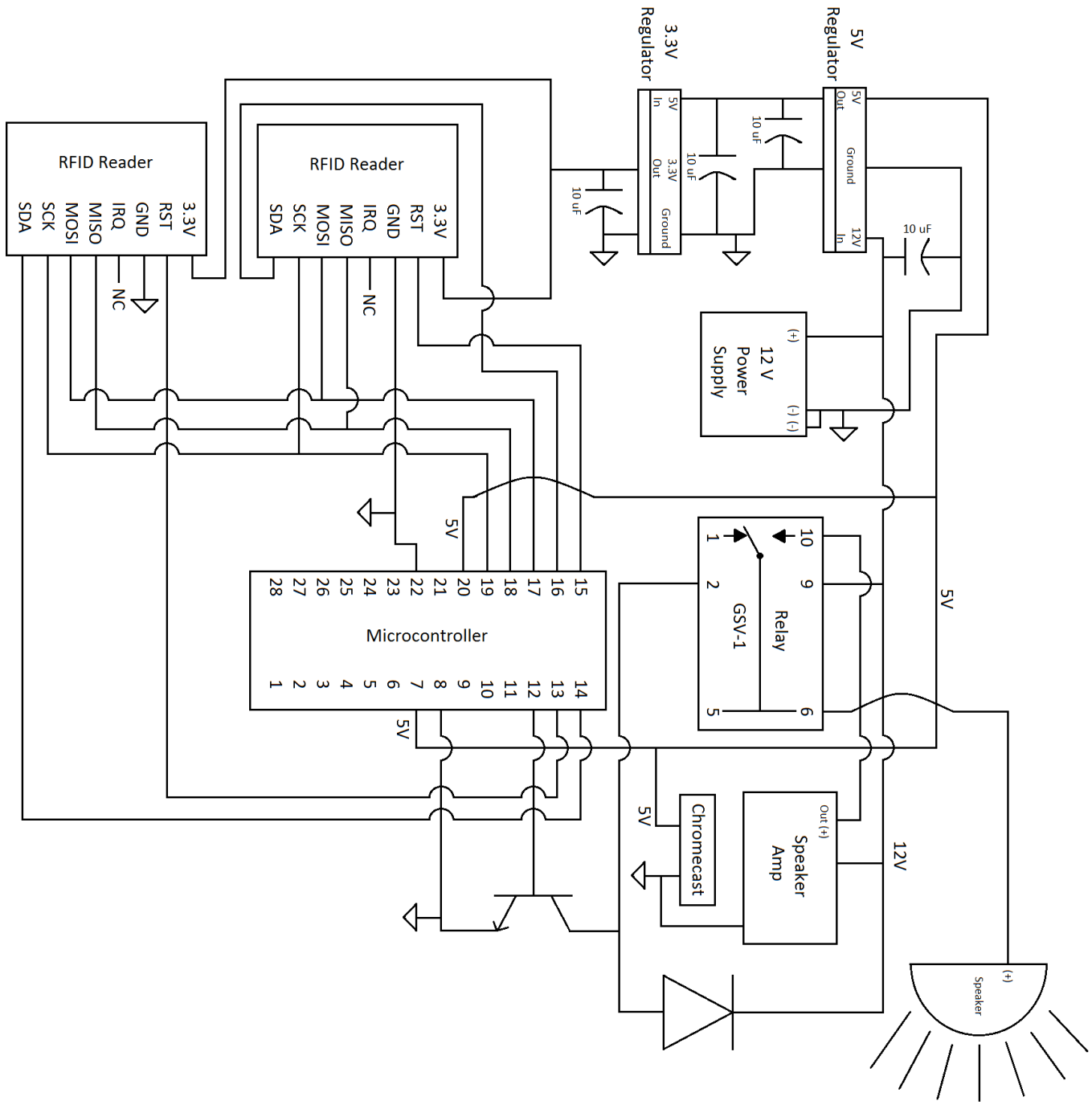


Smart Home Speaker System PCB Schematic

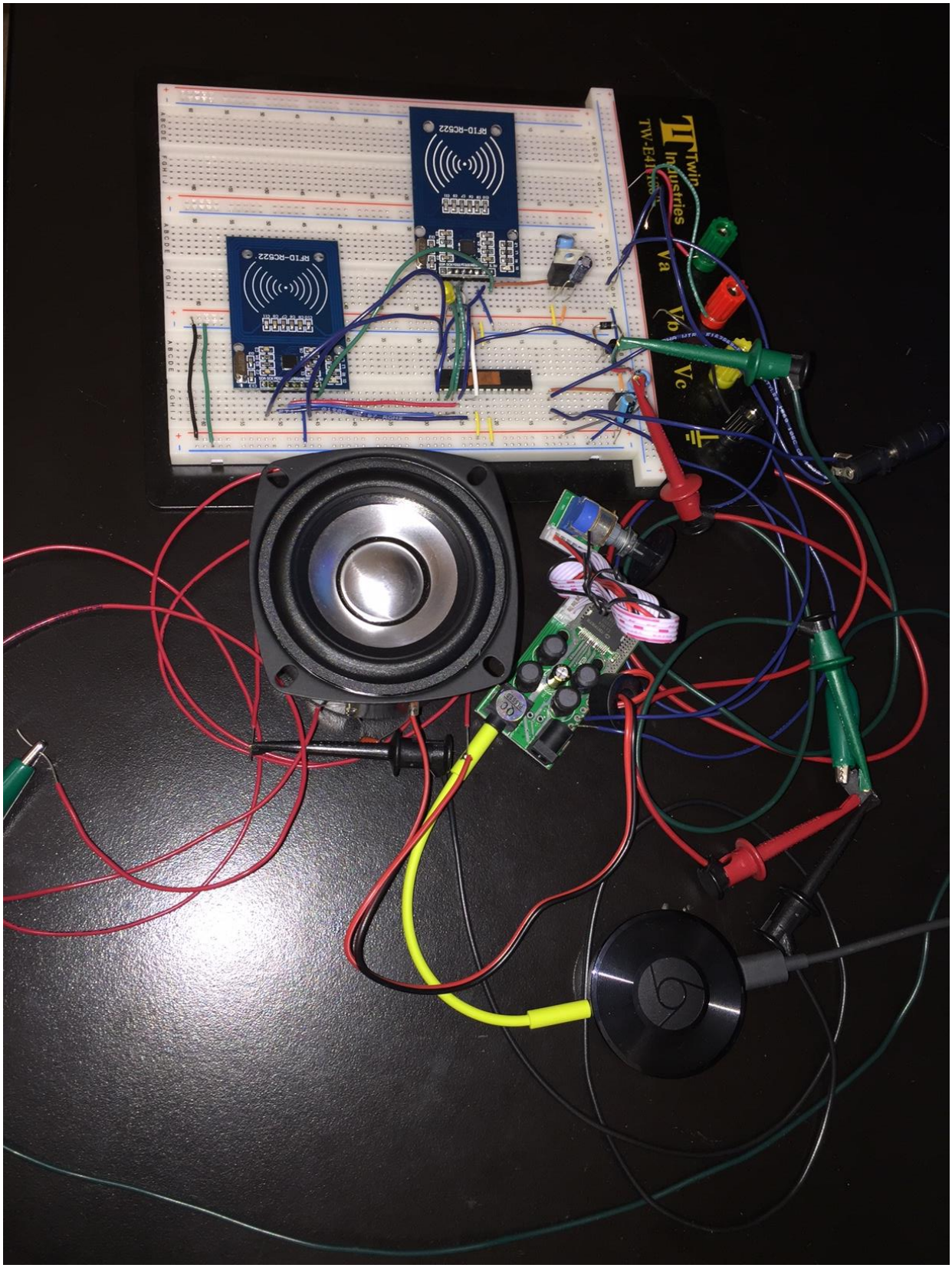
Single Doorway Case PCB Schematic



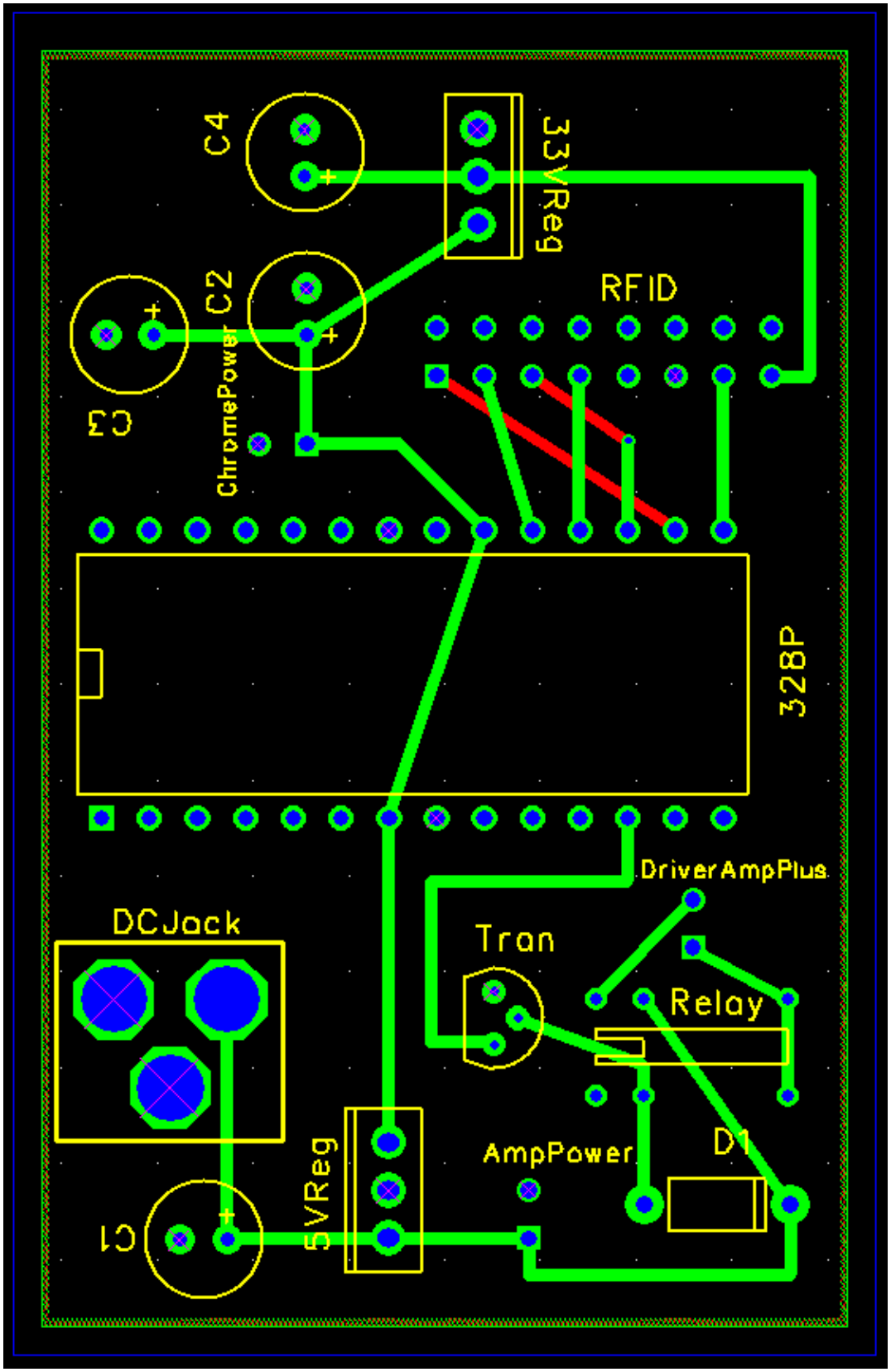
Two Doorway Case PCB Schematic



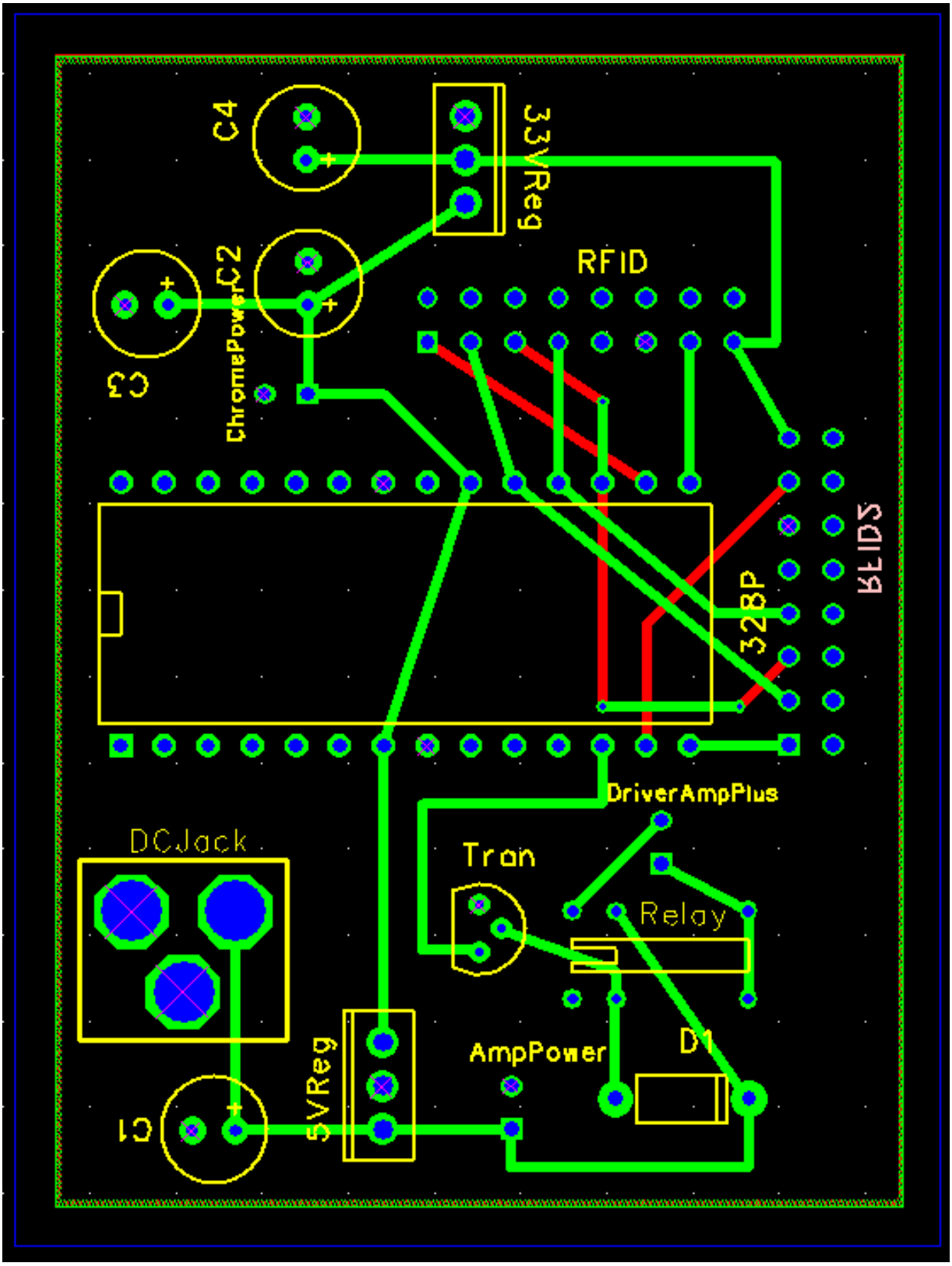
Breadboard Prototype: Double Doorway Case



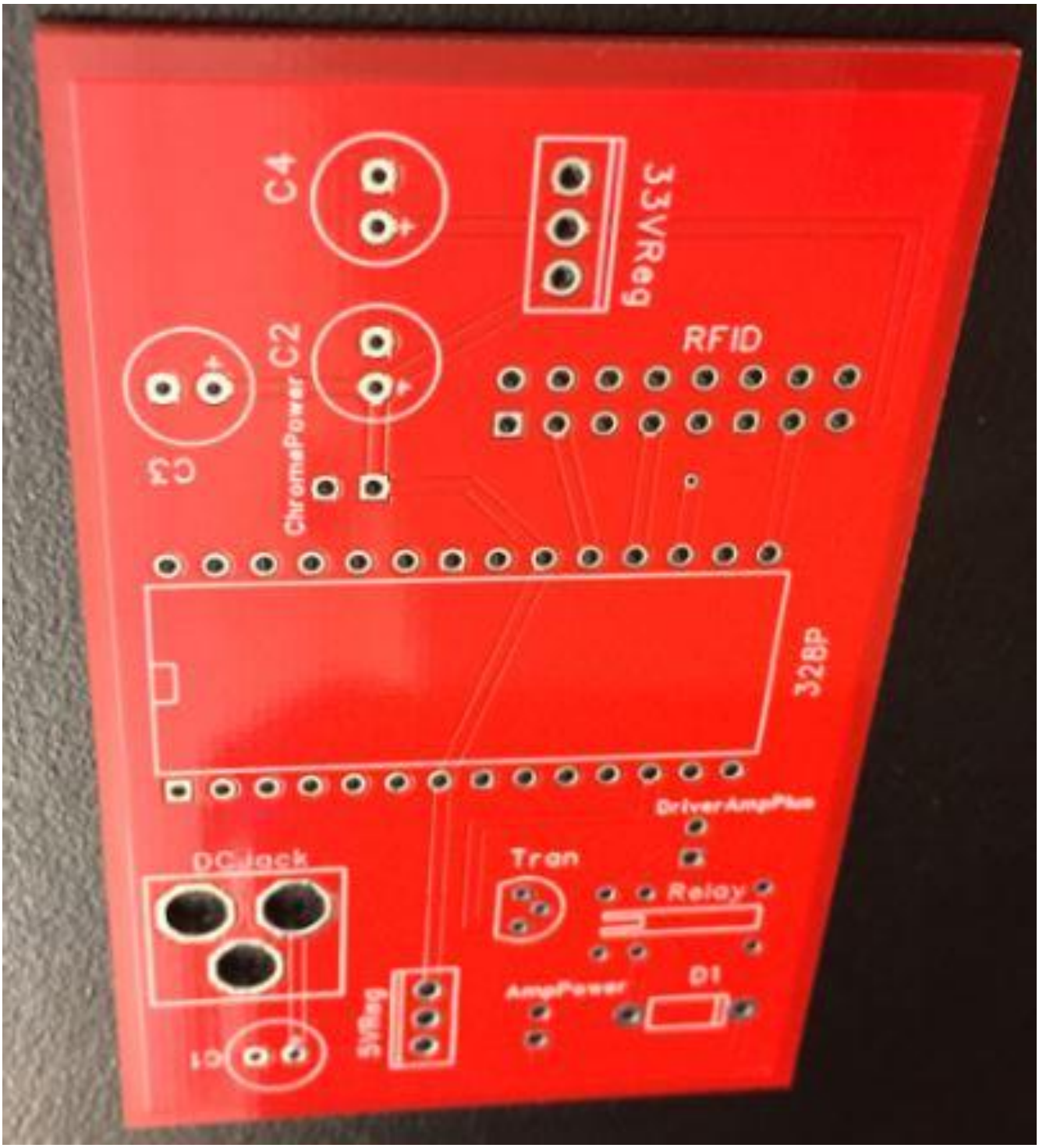
PCB Layout: Single Doorway Case



PCB Layout: Two Doorway Case

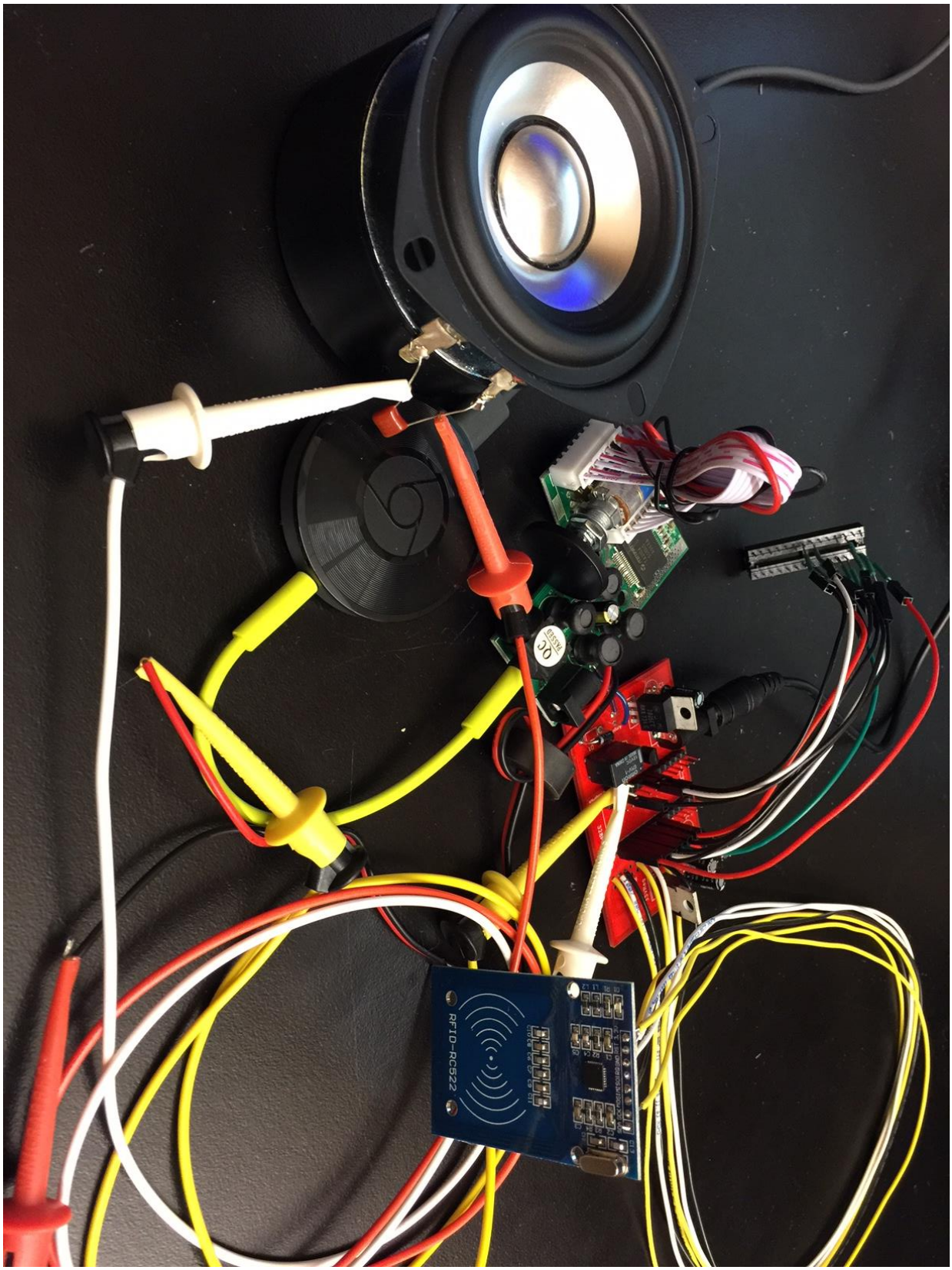


Fabricated PCB: Single Doorway Case

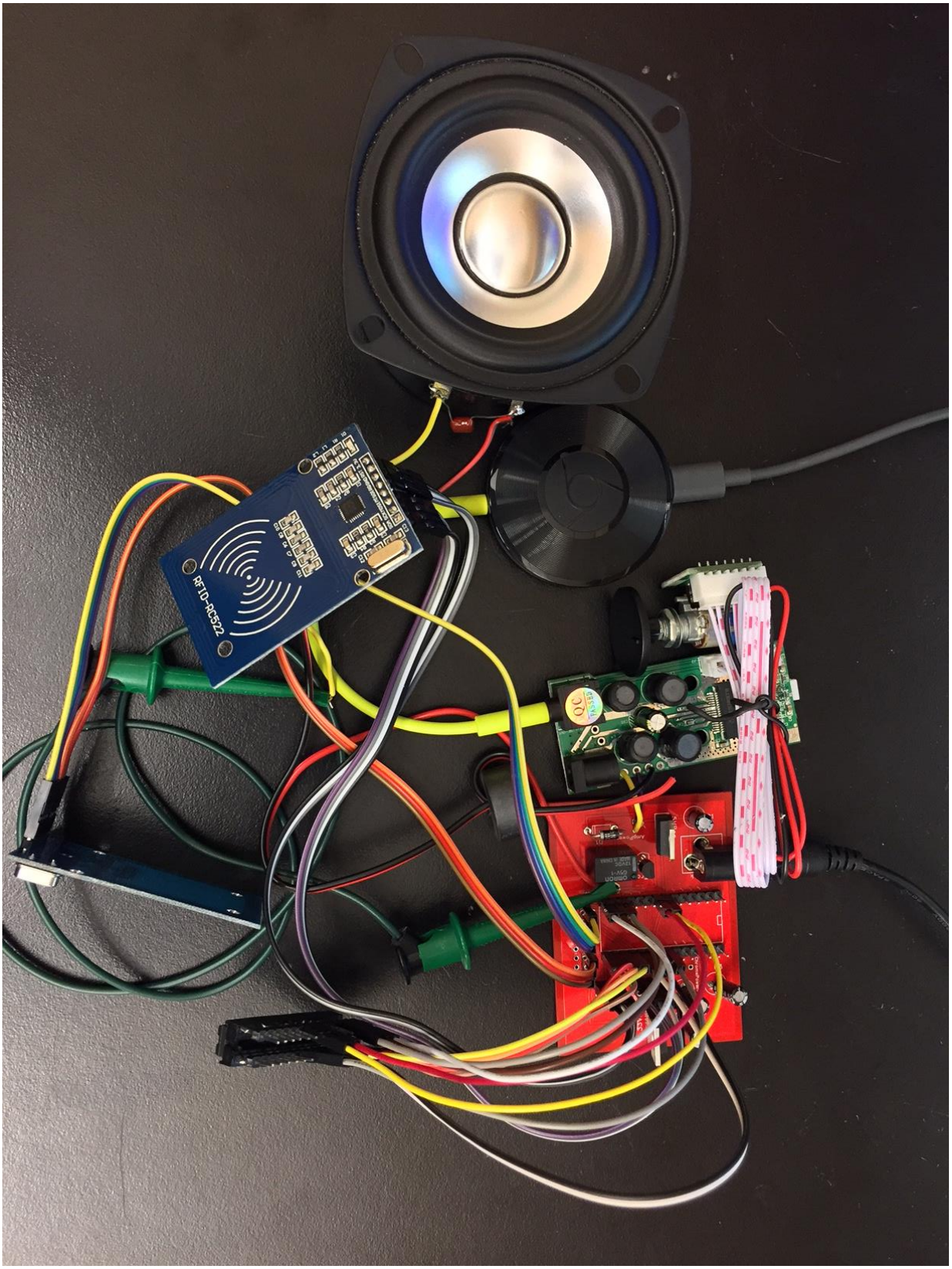


Fabricated PCB: Two Doorway Case

Soldered PCB: Single Doorway Case



Soldered PCB: Two Doorway Case



Presentation Poster

UNLV Howard R. Hughes College of ENGINEERING
Department of Electrical and Computer Engineering

Smart Home Speaker System

Ulises Diaz, Dane Gentry, Brandon Thomas Senior Design Project Fall 2016

Goal

- User-detecting speaker system
  - User wirelessly streams audio from smart phone to system of wirelessly connected "smart" speakers
  - Audio "follows" user from room to room (without manual user control)
  - Each speaker automatically outputs ONLY when user is in its presence

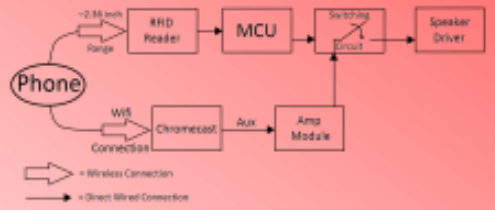
Problem

- Current speaker systems that use Bluetooth or Wi-Fi are complex, expensive, and inconvenient
  - Require long wires (commonly hidden in walls)
  - Audio doesn't "follow" user around home
    - Require manual user control through confusing interfaces
  - No convenient, cost-effective method for pairing phone to multiple Bluetooth speakers simultaneously

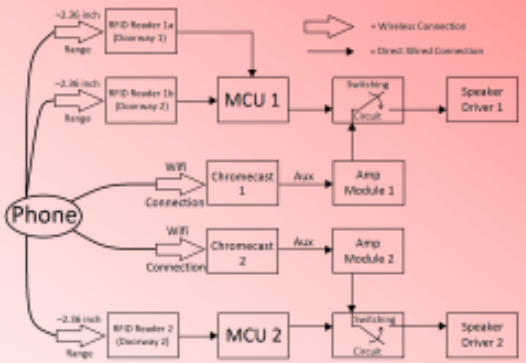
Considerations

- Speaker Systems
  - Bluetooth
  - FM
- Sensors
  - Each detect human presence as opposed to differentiating user from others
    - Thermal
    - PIR (Passive Infrared) Motion
    - Ultrasonic

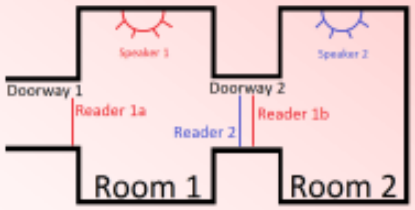
Single Doorway Block Diagram



Full Project Block Diagram



Full Project Room Diagram



Implementation

- Speaker System
  - Google Chromecast Audio
    - Connects to a speaker via AUX input
    - Uses Wi-Fi to stream audio from phone (using Google Cast app) to multiple speakers simultaneously
- Sensor
  - RFID (Radio-Frequency Identification)
    - RFID tag = RFID sticker on user's phone
- Allows for guest users, each with unique RFID tag
- User(s) can manually:
  - Turn speakers on/off
  - Control volume of each speaker

Cost Analysis

Item	Price
Chromecast	$35
Amp Module	$20
Speaker Driver	$8
Speaker Cabinet	$13
RFID Reader	$8
RFID Sticker	$1
Atmega328P MCU	$4
Electrical Components	$10
Power Supply	$16
Total	**$115**

Acknowledgments

Instructor: Dr. Grzegorz Chmaj
Mentor: Dr. R. Jacob Baker
Tech. Advisor: Angsuman Roy

Breakdown of Work (Who did What)

- Ulises Diaz (**Did 40% of work**):
  - Conducted extensive research and experimentation on:
    - How to wirelessly stream music from phone to multiple speakers
    - What sensors to be used in the project
    - What components to obtain and use in project (see Components List)
    - How to connect and use multiple Chromecast devices
    - How to connect RFID reader to MCU and program MCU with RFID code such that LED (connected to pin on MCU) will turn on/off when RFID reader detects presence of a unique, specified RFID tag (for both MCU on Arduino UNO and MCU on breadboard using Arduino UNO cases)
    - How to use smart phone as RFID tag (using RFID sticker)
    - How to connect and power audio amplifier module and speaker driver
    - How to turn speaker on/off using switching circuit (diode, relay, and transistor)
    - How to turn speaker on/off using switching circuit, based off information from RFID reader and MCU (instead of turning LED on/off)
    - How to effectively power all components of project on breadboard prototype, then on PCB
  - Assisted in creating hand-drawn schematics and block diagrams
  - Laid out PCB design using FreePCB software and sent in for fabrication
  - Extensive troubleshooting of assembled Two Doorway Case (Double RFID) PCB
  - Extensive troubleshooting with programming (and bootloading) MCU's
  - Woodwork in order to cut holes in cabinets
  - Assisted in writing documents including Project Topic Proposal, Full Project Proposal, Parts List, Progress Report I, Progress Report II, Final Report, and PowerPoint Presentation (from EE 497 - Senior Design I) as well as Parts List, Schematics and Block Diagrams, Abstract/Blurb, Short Progress Report, and Final Report (from EE 498 - Senior Design II)
  - Designed and printed poster
  - Directed and edited movie

- Dane Gentry (**Did 55% of work**):
  - Conducted extensive research and experimentation on:
    - How to wirelessly stream music from phone to multiple speakers
    - What sensors to be used in the project
    - What components to obtain and use in project (see Components List)
    - How to connect and use multiple Chromecast devices
    - How to use Arduino UNO with Arduino software
    - How to program MCU on Arduino UNO
    - How to connect and program (and bootload) MCU on breadboard using Arduino UNO
    - How to connect RFID reader to MCU and program MCU with RFID code such that LED (connected to pin on MCU) will turn on/off when RFID reader detects presence of a unique, specified RFID tag (for both MCU on Arduino UNO and MCU on breadboard using Arduino UNO cases)

        - How to extend the above goal to multiple (two) RFID readers connected to a single MCU (for Two Doorway Case)
        - How to use smart phone as RFID tag (using RFID sticker)
        - How to connect and power audio amplifier module and speaker driver
        - How to turn speaker on/off using switching circuit (diode, relay, and transistor)
        - How to turn speaker on/off using switching circuit, based off information from RFID reader and MCU (instead of turning LED on/off)
        - How to effectively power all components of project on breadboard prototype, then on PCB
    - Created hand-drawn schematics and block diagrams for Single Doorway Case, Two Doorway Case, Complete Project Presentation (Single Doorway + Two Doorway), and PCB connections
    - Made digital schematics and block diagrams from hand-drawn versions
    - Laid out PCB design using FreePCB software and sent in for fabrication
    - Obtained multiple components from the Engineering department stockroom
    - Performed ALL soldering in project
    - Extensive troubleshooting of assembled Two Doorway Case (Double RFID) PCB
    - Extensive troubleshooting with programming (and bootloading) MCU's
    - Connected to Chromecast using router
    - Woodwork in order to cut holes in cabinets
    - Wrote, compiled, and revised documents including Project Topic Proposal, Full Project Proposal, Parts List, Progress Report I, Progress Report II, Final Report, and PowerPoint Presentation (from EE 497 - Senior Design I) as well as Parts List, Schematics and Block Diagrams, Abstract/Blurb, Short Progress Report, and Final Report (from EE 498 - Senior Design II)
    - Designed and printed poster
    - Directed, performed in, and edited movie

- Brandon Thomas (**Did 5% of work**):
    - Conducted moderate research and experimentation on:
        - How to wirelessly stream music from phone to multiple speakers
        - What sensors to be used in the project
        - How to connect and use multiple Chromecast devices
    - Made digital schematics and block diagrams for Single Doorway Case, Two Doorway Case, and Complete Project Presentation (Single Doorway + Two Doorway) from hand-drawn versions
    - PCB troubleshooting (noted DC power supply jack should be rotated outwards)
    - Moderate assistance in programming MCU's (changed code to turn LED on/off instead of blink), building project prototype on breadboard, connecting multiple RFID readers to a single MCU, and assembling project on PCB
    - Assisted in troubleshooting assembled Two Doorway Case (Double RFID) PCB
    - Connected to Chromecast using router
    - Ordered/bought parts and created expenses spreadsheet
    - Assisted in writing documents including Project Topic Proposal, Progress Report I, Final Report, and PowerPoint Presentation (from EE 497 - Senior Design I) as well as Parts List (from EE 498 - Senior Design II)

Smart Home Speaker System User Manual

1. For each room you desire to contain a Smart Speaker:
    I. Place Smart Speaker in desired location of room (preferably near power)
    II. Install RFID reader (which is connected to Smart Speaker) in the room's doorway
        i. If room has multiple doorways, install a reader in each of the room's doorways (each reader connected to the room's Smart Speaker)
2. Stick RFID sticker to back of phone
3. Connect provided power supplies of each Smart Speaker to power (wall socket, extension cord, power strip, etc.)
4. Use Google Cast app to connect to speaker group containing each Google Chromecast Audio (Each Smart Speaker contains a Chromecast)
    I. See Google Chromecast Audio user manual for more information
5. Stream desired music from Google Chromecast compatible app (Spotify, Pandora, etc.) and cast to speaker group
6. Walk from room to room and enjoy continuous stream of music!
    I. Ensure phone comes within specified proximity of RFID reader

Final Remarks

Simply put, our project ensures that a room's speaker turns on when the user walks in the room and turns off when the user walks out of the room.

Further development of the project entails increasing the detection range of the RFID readers, wirelessly connecting RFID readers to their respective speakers, extending the project to include rooms with more than two doorways as well as rooms with no doorways, making each speaker capable of being powered by battery, and connecting a single RFID reader to multiple speakers (by connecting the RFID reader to multiple MCU's) so that there is only one RFID reader in each doorway.

Overall, our project has proved successful as we have accomplished building working prototypes for both the Single Doorway Case and Two Doorway Case. After assembling the final project on PCB's, we have working projects for both the Single Doorway Case and Two Doorway Case.

We feel we have certainly succeeded in accomplishing the goals we set out for our project. We plan to pursue improving our project for effective realization and implementation in future smart homes as well as various other similar systems. In all, we feel fortunate for being given the opportunity and motivation to apply our knowledge and skills in electrical engineering to accomplish a real-life application that is not only technical but also interesting, intriguing, and desired by many people, since virtually everybody listens to music.