Design Document

Alice in Robotland

Team C10: Sarah Copenhaver, Addison Elliott, Devaughn Menezes, Jordan Sanchez

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Contents

Revision Record

Date	**Author**	**Comments**
Sep 08, 2022	Team	Document Created (preliminary design review content)
Sep 25, 2022	Team	Document updated with PDR materials
Oct 11, 2022	Devaughn	Added Electrical CAD illustrations to subsystems
Oct 19, 2022	Devaughn	Added Test Plan Modified Project Overview
Oct 23, 2022	Devaughn	Added Electrical Design Section
Dec 5, 2022	Devaughn	Updated sections to reflect the new performance mode

Project Description

Our team designed a robot thespian ("AliceBot") which represents Alice (from Alice in Wonderland) performing a curtsy while reading lines which are prompted by the "Director". This robot is part of a production of Alice in Wonderland. The movement is accompanied by a synchronized lights and sound show. A light strip acts as a path for Alice, while the speaker outputs a quote from Alice in Wonderland.

The demands of the project orchestrated our design considerations for the dimensions of the stage and the selection of the electrical components. Because our robot was nearing the height constraint, we decided to depress the stage where the robot would be standing. This introduced a unique challenge to reshape the 'box stage' into a u-shaped platform. Another constraint was the two-layer PCB which would make delivering power a challenge. To mitigate this struggle, we decided to only use components which required 5V DC power.

All our software is written in Python, using the RPi.GPIO, neopixel, and gpiozero libraries.

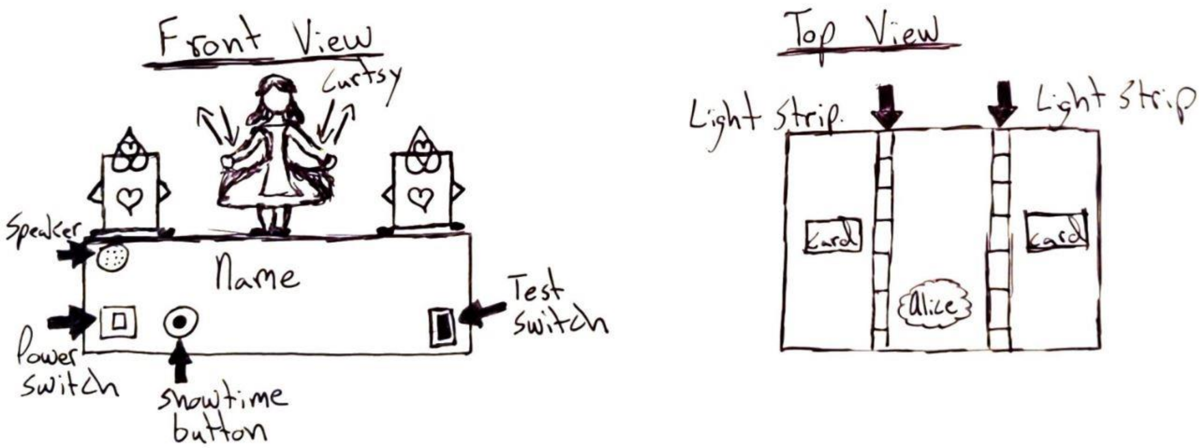


Figure 1: Our initial rendering of the AliceBot

System Design

The system inputs include 120V AC power, a toggle switch to switch between test and performance mode, a potentiometer for controlling sound volume, and pushbuttons for subsystem testing. The outputs of the system include sound from a speaker, light from LEDs, and the motion of the Alice doll. The system consists of six subsystems: power, lights, sound, motion, user interface, and the processor.

The power subsystem consists of a transformer to convert 120V AC to 5V DC and distributes it to the other subsystems. The processor subsystem consists of a Raspberry Pi Zero W V1 and the code that runs on it. The sound subsystem includes a speaker, a potentiometer that controls the gain of the sound output, and an amplifier module that reads the signal from the processor. The lights subsystem consists of a strip of Neopixel LEDs. The motion subsystem consists of two servo motors, the Alice doll, and the skeleton which is added inside the doll to allow rigid movement. The user interface consists of a test switch as well as lights, sound, and motion test buttons. The document details each subsystem in greater depth.

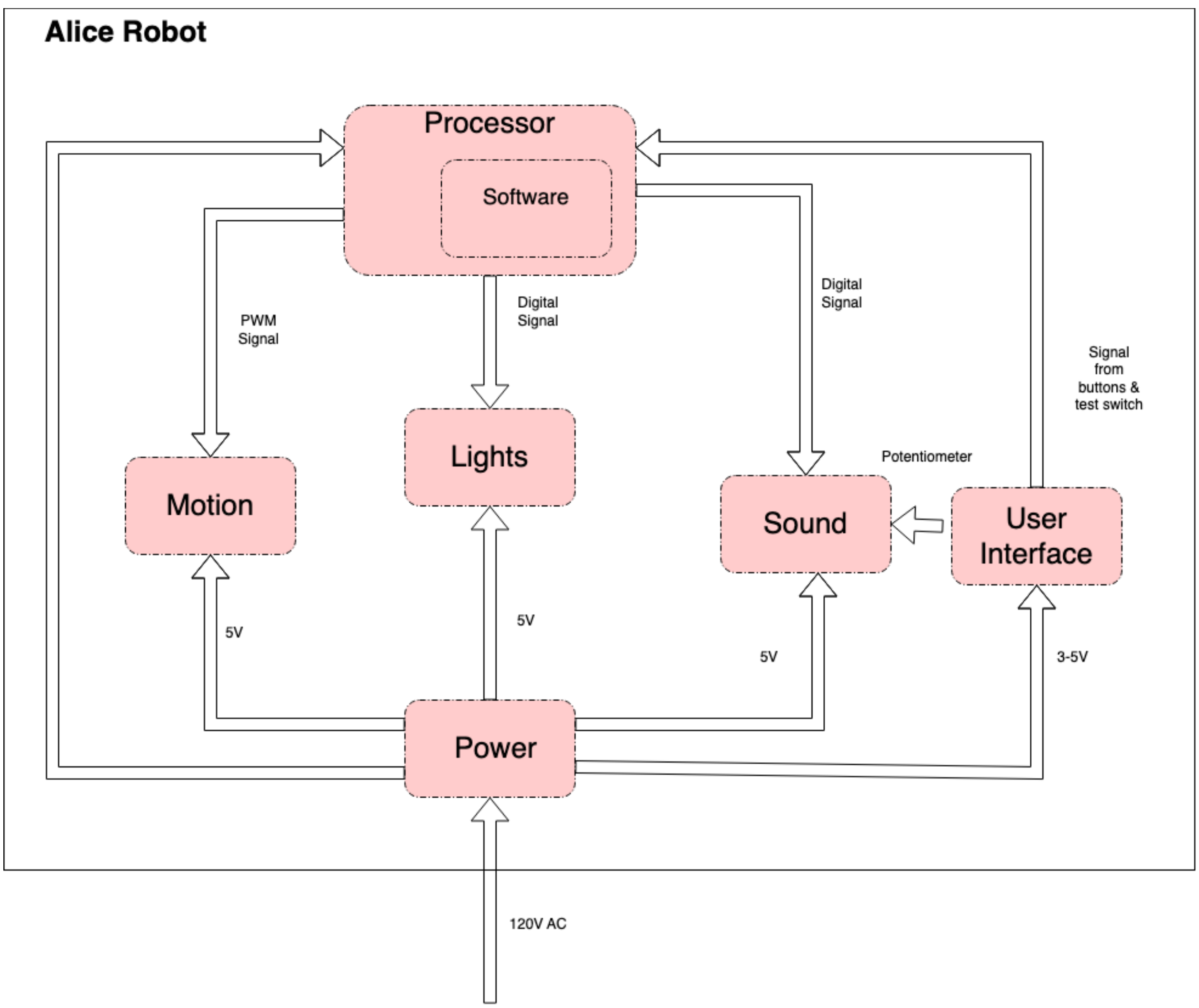


Figure 2: System Diagram

Interface	Source	Destination	Description
PWM Signal	Processor	Motion	Controls the motors
Digital Out	Processor	Lights	Bitstream to control LEDS
PWM Signal	Processor	Sound	Out of GPIO pin
120V AC	System Input	Power	Input power from outlet
5V DC	Power	Processor, Audio, Motion, Sound, UI	Power the components
Digital Signal	User Interface	Processor	Indicates if buttons/switches are activated
Potentiometer (resistance)	User Interface	Sound	Controls the volume

Table 1: Sub-system inputs and outputs

Sub-System Designs

Our system is divided into six subsystems: Power, Lights, Sound, Motion, Processing, and Testing. The power subsystem converts the power coming into the system and divert it to whichever subsystems need it. Lights subsystem controls the data and power of the LEDs. Sound subsystem outputs the desired sound(s) through the speaker. Motion subsystem encompasses the physical doll, the motion of the doll, and the base which the doll stands on. The processing subsystem contains the Raspberry Pi controls all the output signals that control the other subsystems, as well as taking in power from the Power subsystem and data from the Director itself. The Testing subsystem contains the physical switch that enables “test mode” and the buttons that activate each subsystem’s tests.

Power Subsystem

To minimize the components required for the power subsystem, we planned to use 5V DC to power all our components. This is achieved by using a 120V AC to 5V DC power adapter which is be plugged into a standard power outlet. The flow of current into the system is controlled by an SPST rocker switch (for user input). The maximum current provided by the subsystem is two amps, however, the entire system is designed to run under this limit.

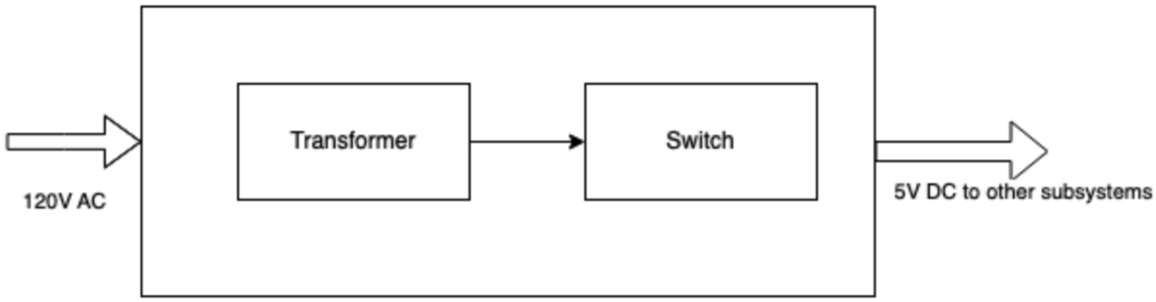


Figure 3: Block Diagram of Power Subsystem

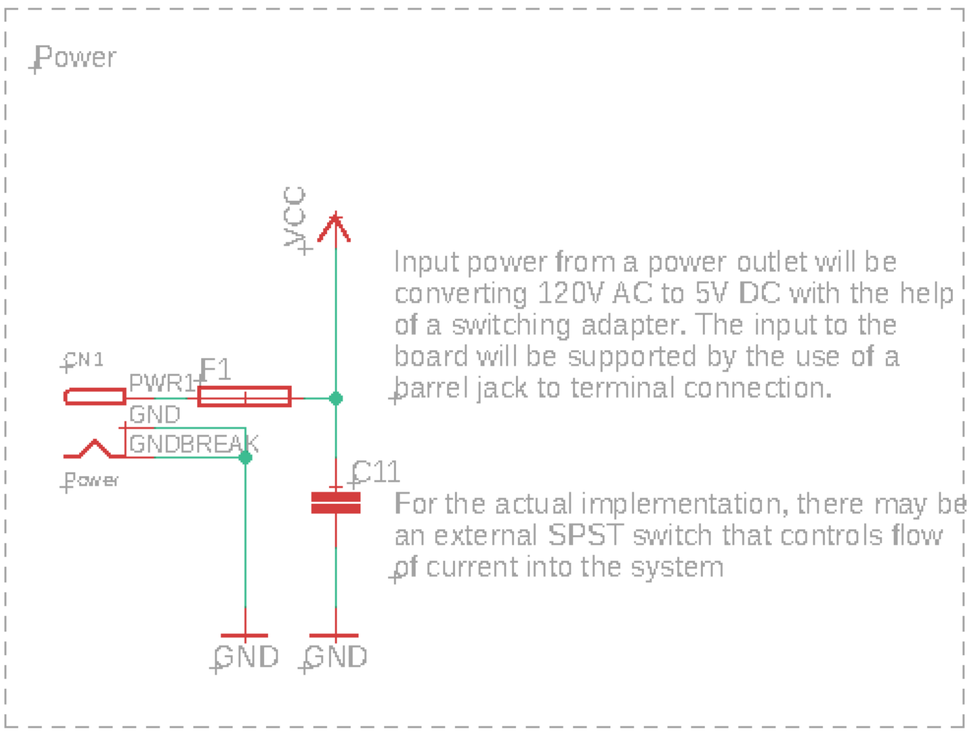


Figure 4: Schematic view of Power Subsystem

Lights Subsystem

A strip of 60 Adafruit NeoPixels RGB LEDs is laid out parallel to each other to represent a path for Alice. The LED strips flash and glow in sync with the speaker output and the doll motion. The digital signal line is output from the Raspberry Pi to control the color, brightness, and sequence.

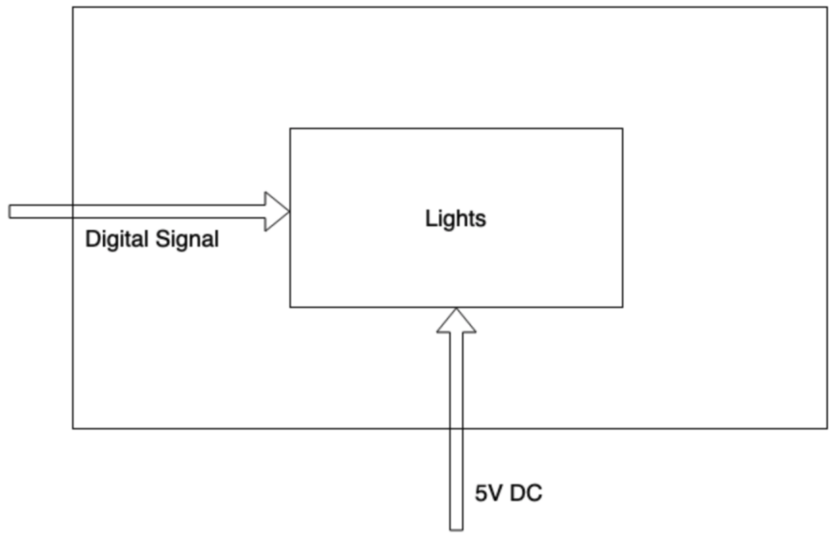


Figure 5: Lights Subsystem

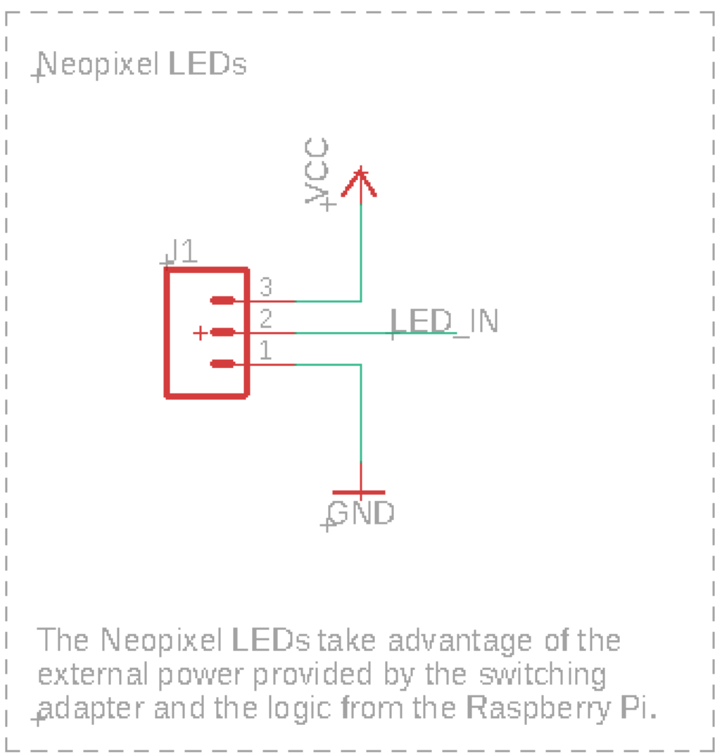


Figure 6: Schematic view of Lights Subsystem

Sound Subsystem

The sound subsystem consists of a single speaker which is controlled by the Raspberry Pi in the processor subsystem. There is an amplifier module between the PWM signal from the processor and the speaker, and this is integrated on the PCB. The amplifier module is a MAX98357A Class D Amplifier. A potentiometer is connected to the GAIN and Vin pins on the amplifier module to control volume. The speaker is an 8 Ohm 0.5W magnetic plastic shell Speaker.

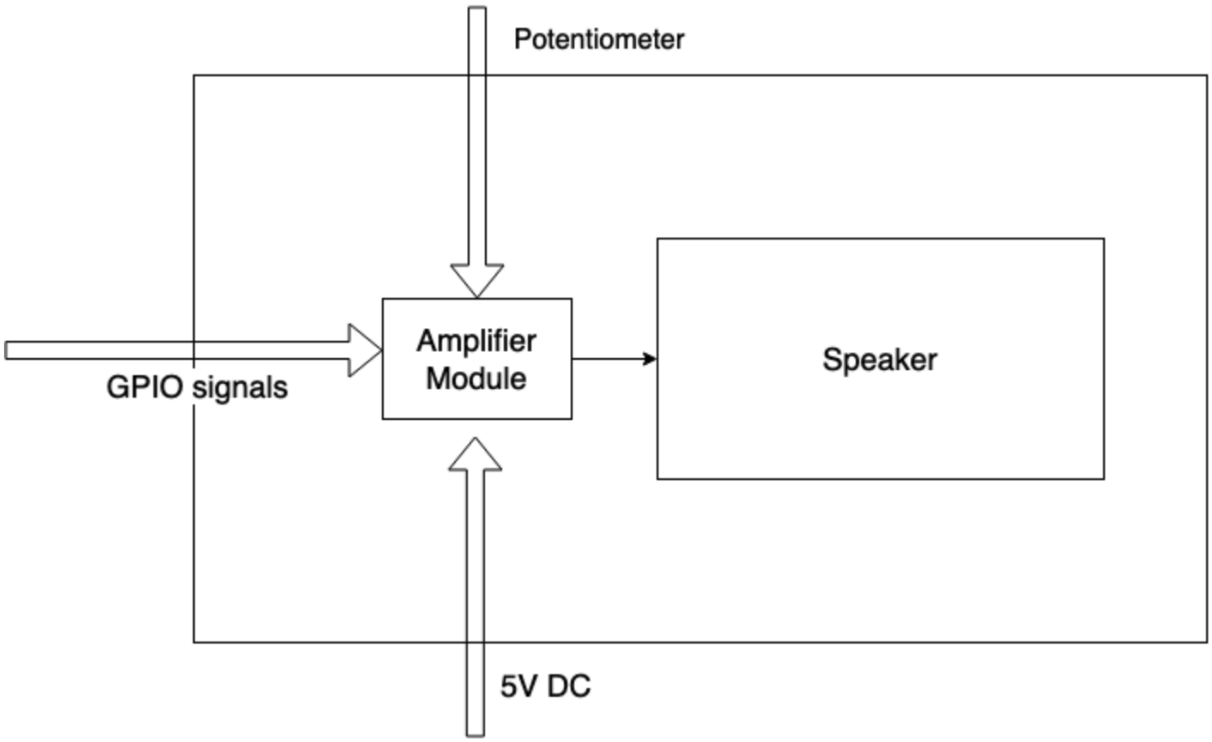


Figure 7: Sound Subsystem

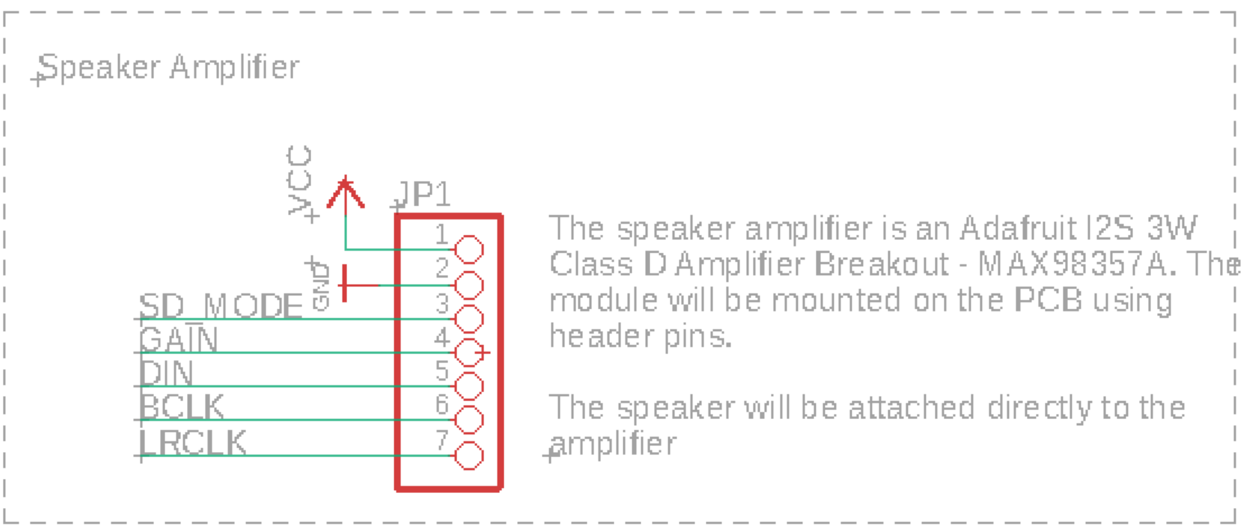


Figure 8: Schematic view of Sound Subsystem

Motion Subsystem

The motion subsystem consists of two DC powered servos that takes in 5V DC (from the power subsystem) and a PWM signal (from the processor subsystem). The PWM signal determines the motors' movements, and both motors use the same PWM channel on the Raspberry Pi, since they both have the same motion. The motors are Standard Servo-TowerPro SG-5010's with 180° Rotation.

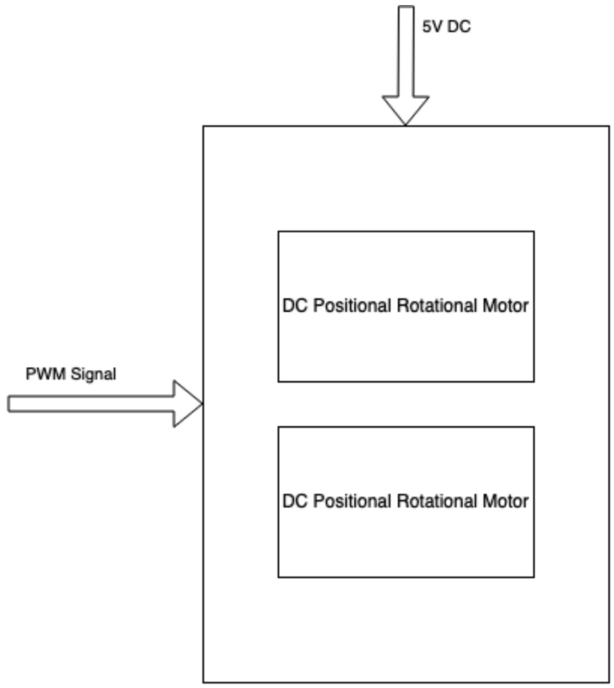


Figure 9: Motion Subsystem

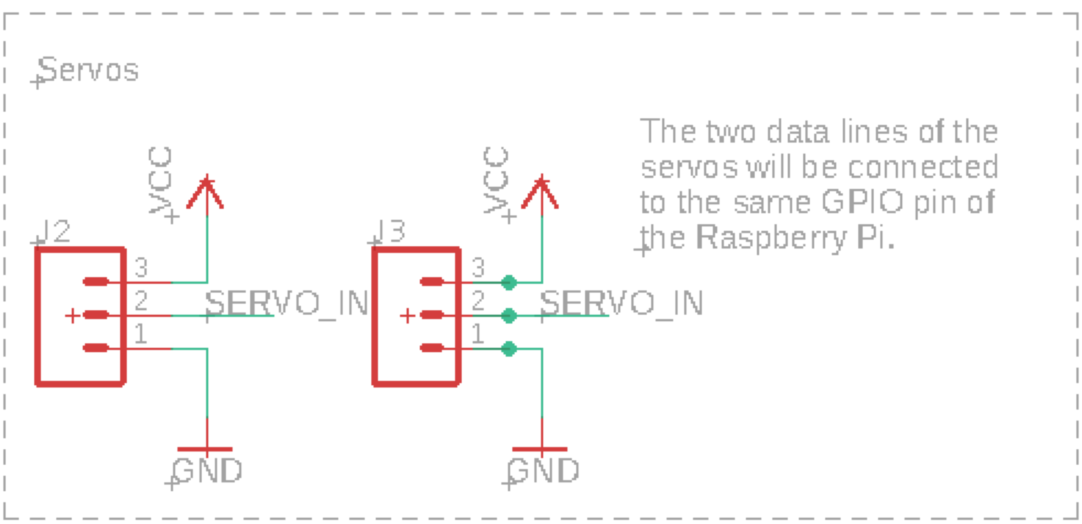


Figure 10: Schematic view of Motion Subsystem

Processor Subsystem

The inputs to the processor subsystem are 5V DC power from the power subsystem as well as the signals from the buttons and switches. The software runs on the processor and outputs signals which control the motors, lights, and sound. The processor is a Raspberry Pi Zero W V1 running Raspbian OS Lite.

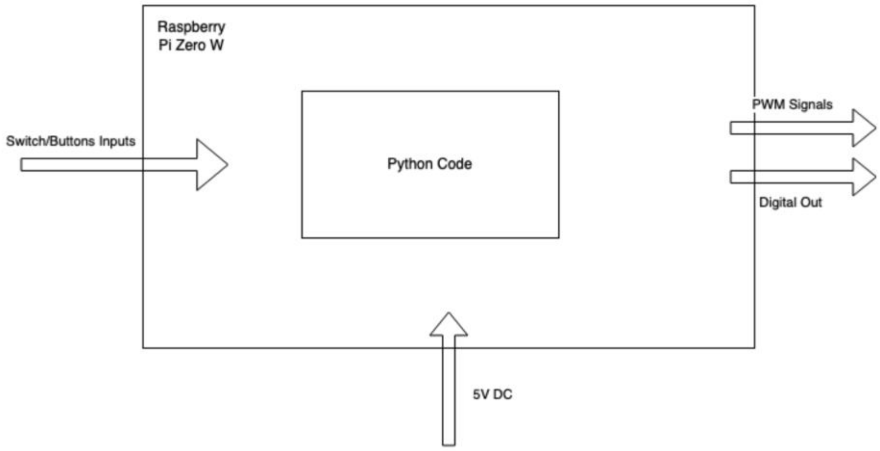


Figure 11: Processor Subsystem

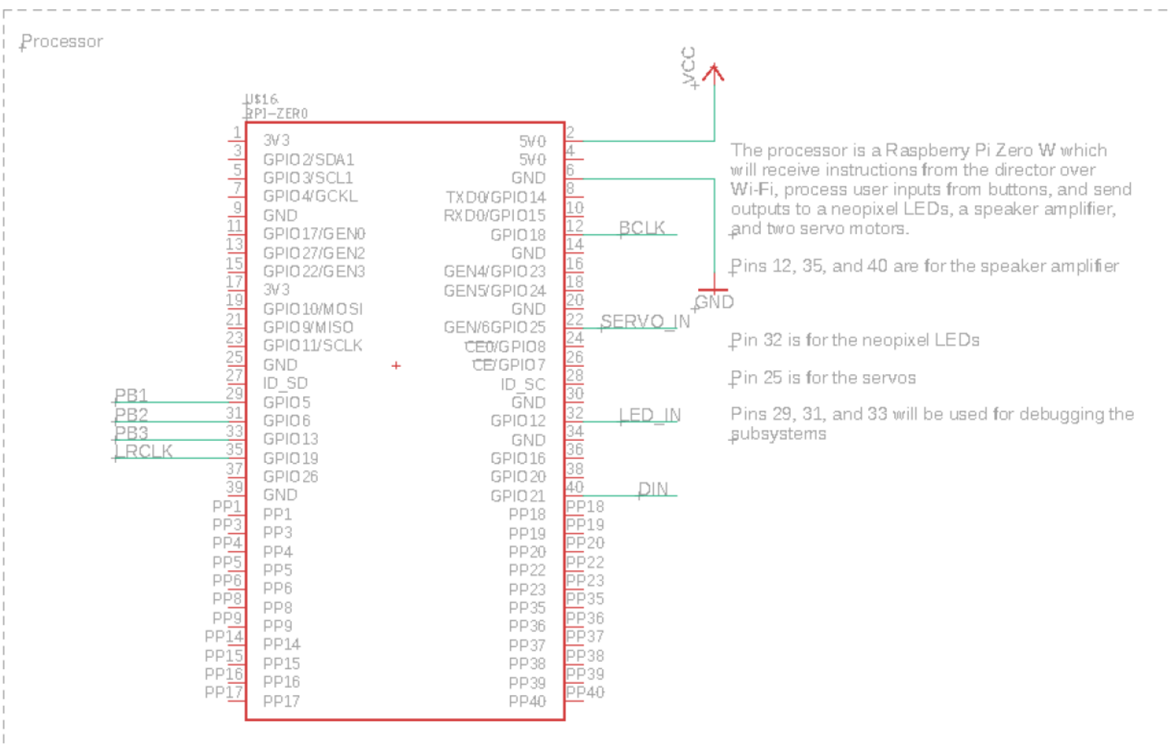


Figure 12: Schematic view of Processor Subsystem

User-Interface Subsystem

The user-interface subsystem consists of three distinct SPDT pushbutton inputs which interrupt the main program to run three different tasks: lights, sounds, and motion. It also includes an SPDT switch to engage the system's "Test Mode". Once in test mode, the three buttons can be used to individually run each of the three tasks.

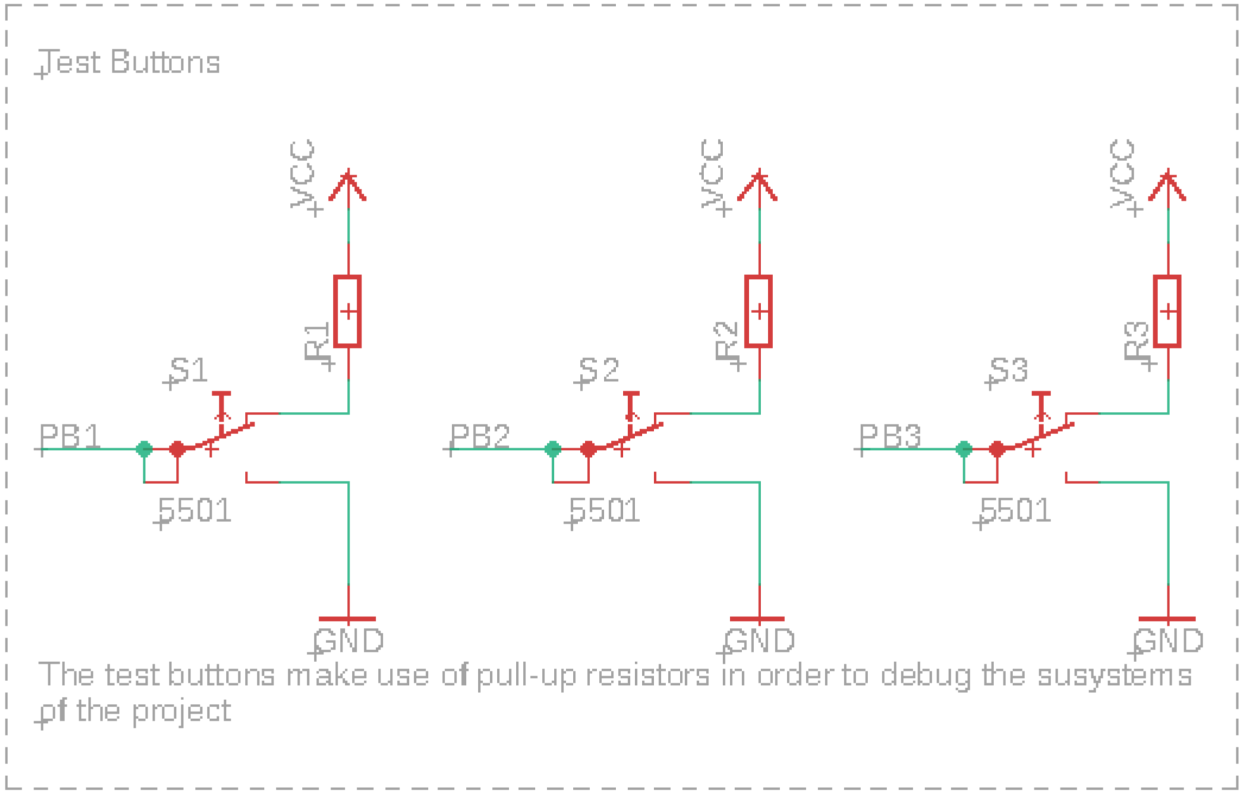


Figure 13: Schematic view of Test Subsystem

Software Design

This is the state diagram for the software that runs on the Raspberry Pi. For the software subsystem, we created a robot class with two modes: the showtime mode and the test mode. If the robot is in test mode, then interrupts are used to enact one of our three functions of the robot class: speak() move() or light_up(). If the robot is in showtime mode, it performs all three functions simultaneously.

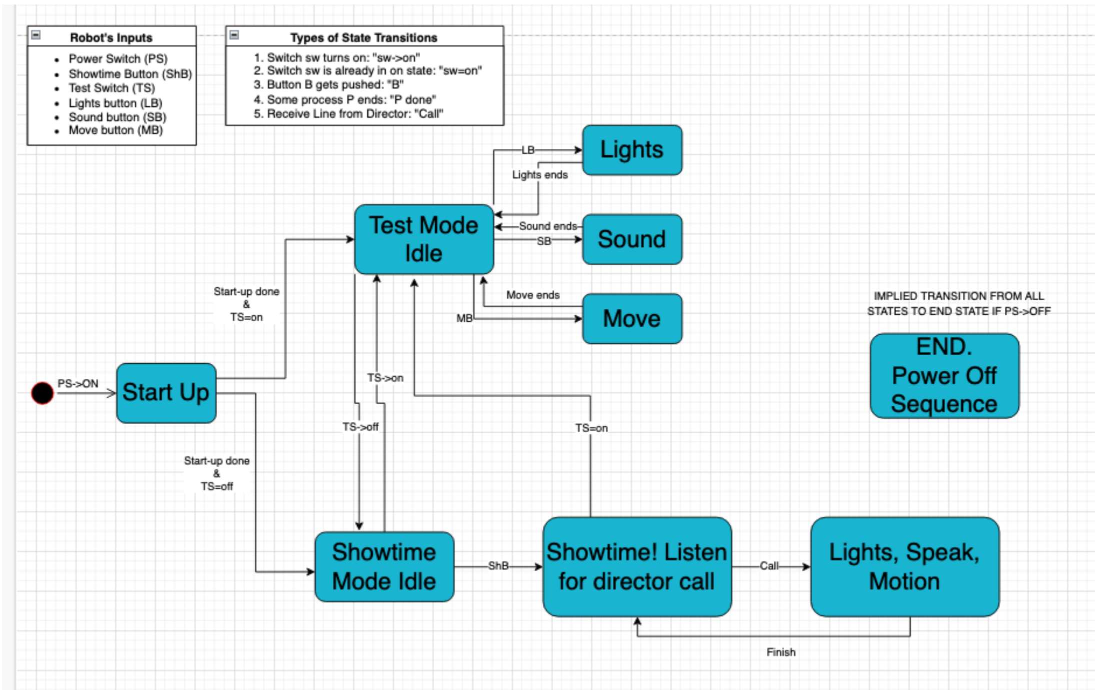


Figure 14: Software State Diagram

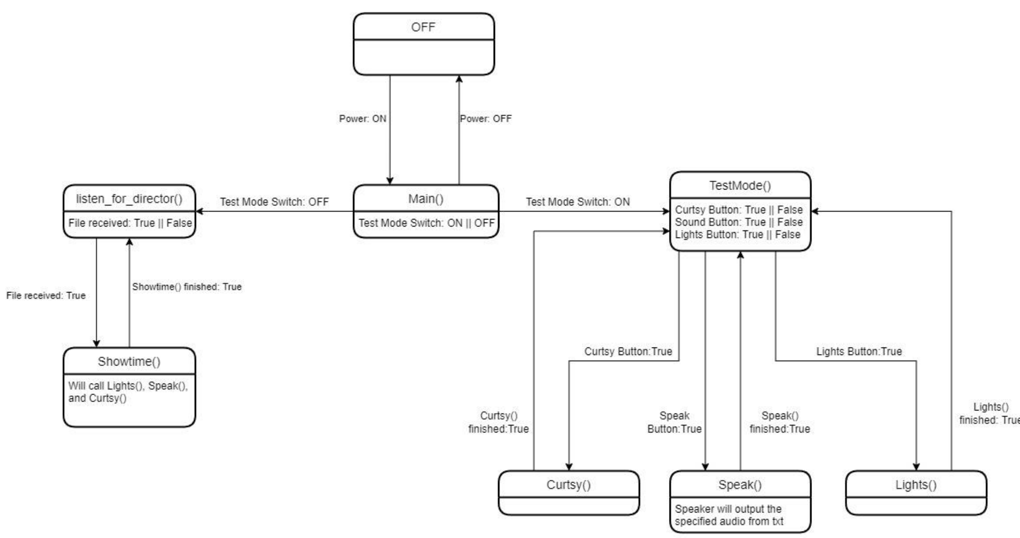


Figure 15: Software Architecture Diagram

Electrical Design

The PCB takes advantage of a two-layer design that allows for more complex connections between the components. Most of the components connect to the Raspberry Pi. The interconnects on the top of the board have header pins soldered onto them to easily connect the external components. From left to right, these external components are the speaker amplifier, two servos, and the LED strip. The bottom three boxes represent the pushbutton pins. The top right component is the DC barrel jack for power intake.

Not pictured in the PCB design is the potentiometer for volume control, the external toggle switch for toggling modes, and the rocker switch for master power control. These components are mounted on the housing and have separate connections to the PCB.

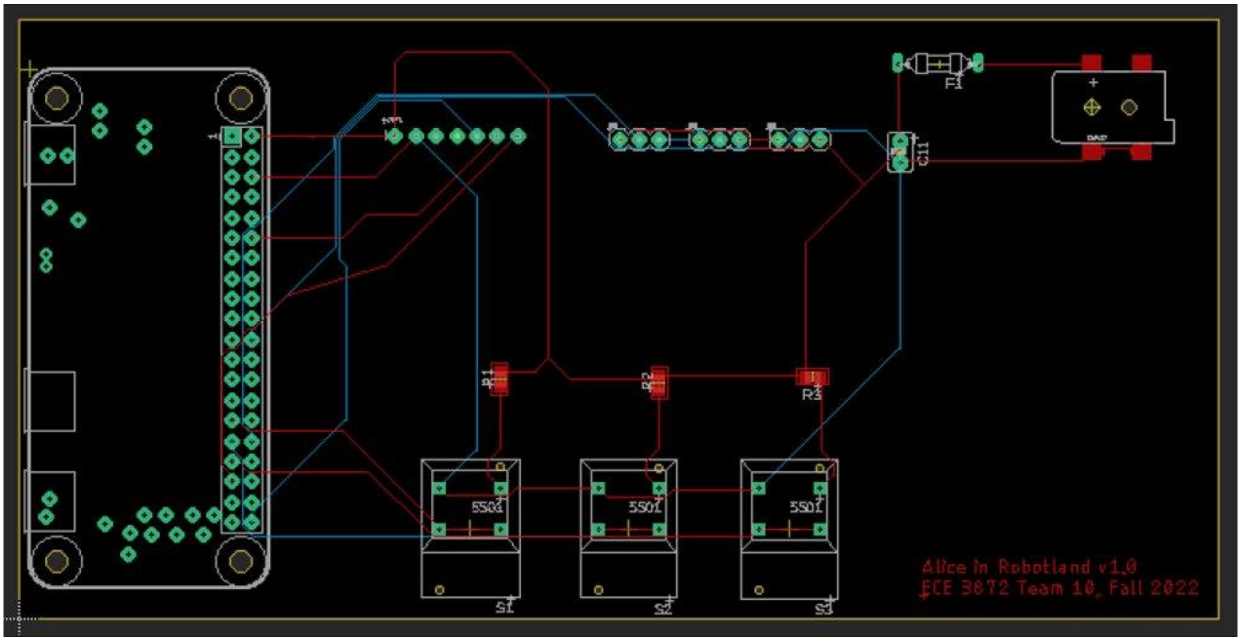


Figure 16: Finalized PCB Design

Mechanical Design

The only moving parts of the system include the two servos which lift Alice's arms with the help of rigid supports coming up from the box base. Alice's arms are supported by laser-cut elbow pieces cut from wood. The elbow pieces are cut to a size that fit comfortably inside the doll's arms, while also allowing them to be shaped in a bent manner. Because our model is a hand-puppet, we have the advantage of being able to hide all the moving parts.

There is also a small cardboard rod up from the base box of our design to the head to keep Alice standing straight. Alice's arms are sown to her dress so that the motion of her arms make it look like Alice is doing a curtsy.

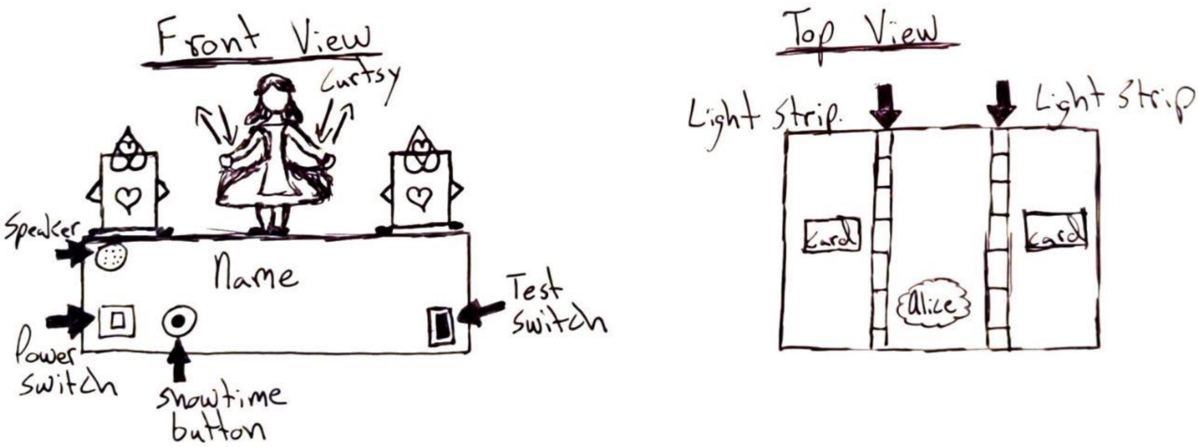


Figure 17: Overview of Robot Design, Including Placed Components

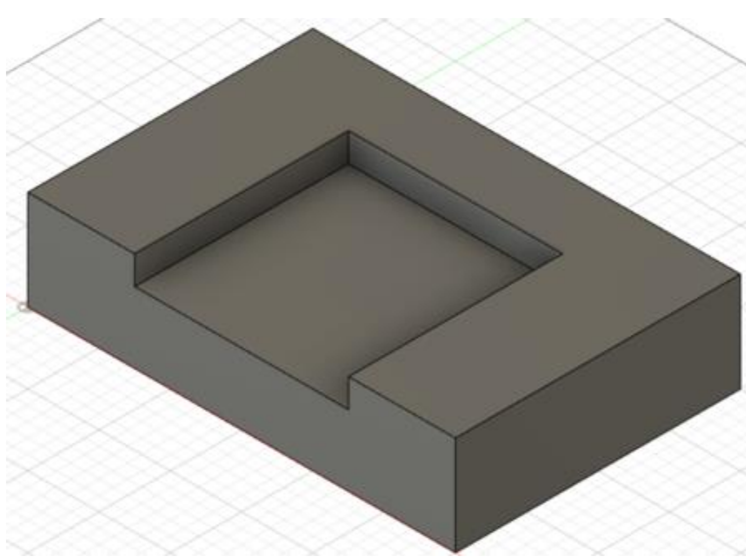


Figure 18: Box Isometric View

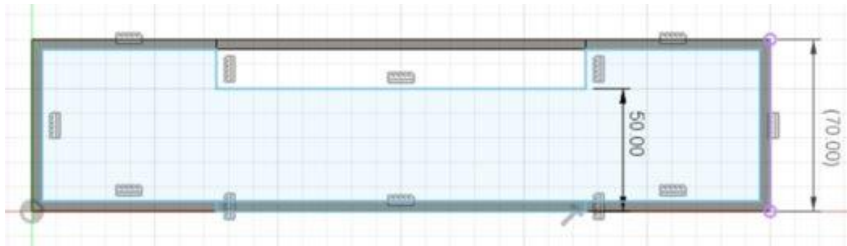


Figure 19: Box Front View

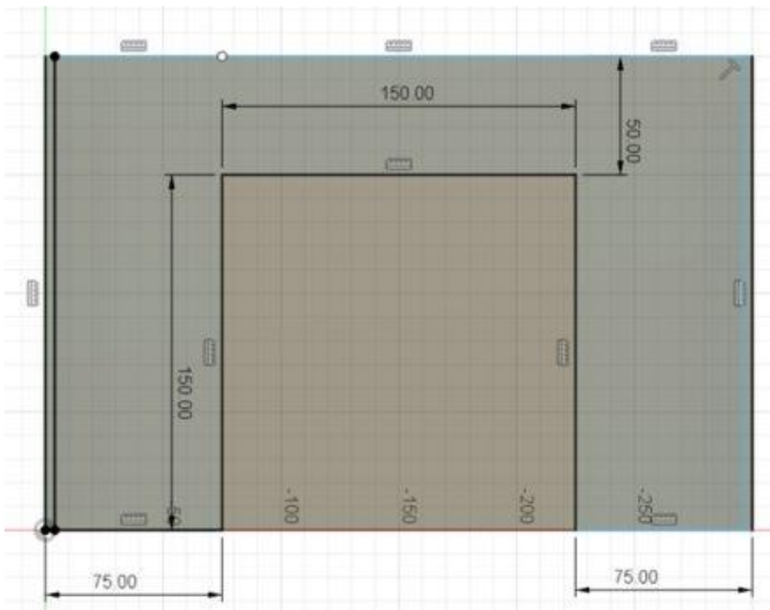


Figure 20: Box Top View

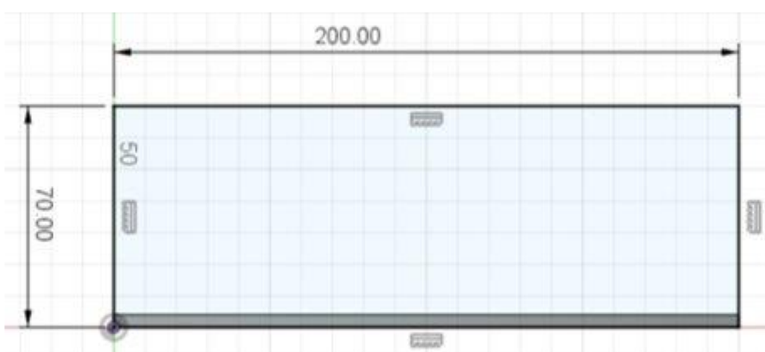
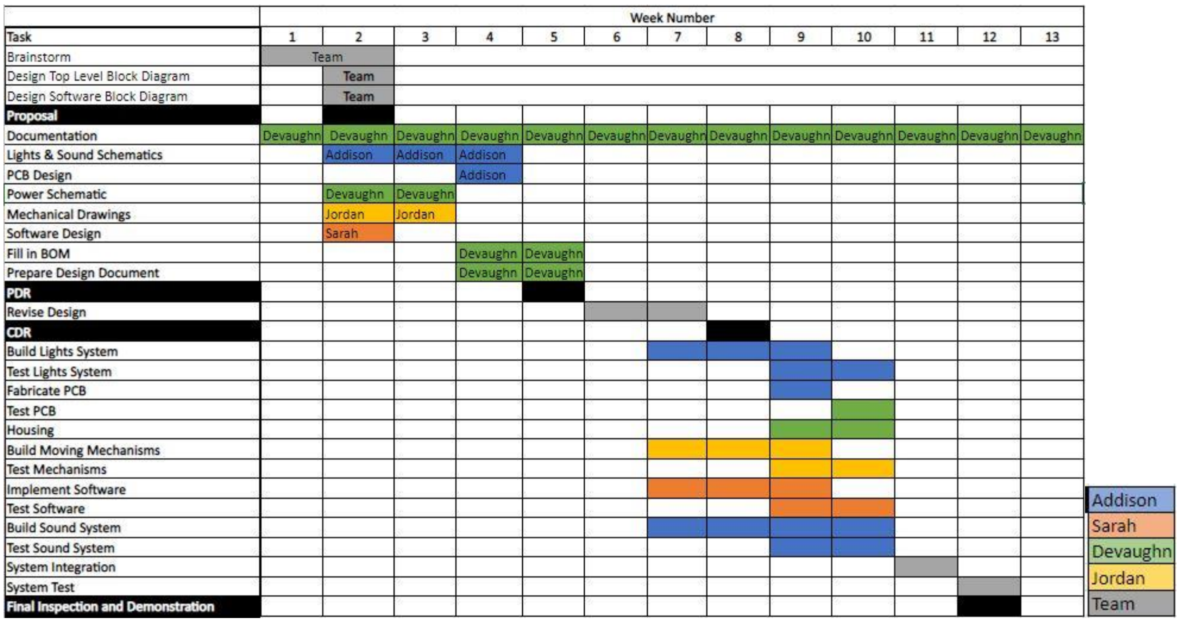


Figure 21: Box Side View

Figure 22: Photo of final product of mechanical system

Schedule



Task	1	2	3	4	5	6	7	8	9	10	11	12	13
Brainstorm	Team												
Design Top Level Block Diagram		Team											
Design Software Block Diagram		Team											
Proposal													
Documentation	Devaughn	Devaughn	Devaughn	Devaughn	Devaughn	Devaughn	Devaughn	Devaughn	Devaughn	Devaughn	Devaughn	Devaughn	Devaughn
Lights & Sound Schematics		Addison	Addison	Addison									
PCB Design				Addison									
Power Schematic		Devaughn	Devaughn										
Mechanical Drawings		Jordan	Jordan										
Software Design		Sarah											
Fill in BOM				Devaughn	Devaughn								
Prepare Design Document				Devaughn	Devaughn								
PDR													
Revise Design													
CDR													
Build Lights System													
Test Lights System													
Fabricate PCB													
Test PCB													
Housing													
Build Moving Mechanisms													
Test Mechanisms													
Implement Software													
Test Software													
Build Sound System													
Test Sound System													
System Integration													
System Test													
Final Inspection and Demonstration													

Week Number

Addison
Sarah
Devaughn
Jordan
Team

Table 2: Schedule to Complete the Alicebot

Test Plan

Number	Customer Needs	System Requirement Number	System Requirement	Test Type	Test Number
1	The robot must have some motion to increase/decrease in size while remaining within the given size/weight constraints	Sys 1.1	System has a doll (Alice) who performs a curtsy by lifting its arms and skirt up to a 45-degree angle	Demonstration	1
		Sys 1.2	System remains within 35x35x35 cm at the start	Inspection	2
		Sys 1.3	System remains within 75x75x75 cm when in motion	Inspection	2
		Sys 1.4	The system should weigh no more than 20 lbs.	Inspection	2
2	System should run all the subsystems at once on startup.	Sys 2.1	System should run all the subsystems at once on startup, and run all of them once again when the test switch is flipped to the not-test position	Test	3

3	System should have a synchronized lights and sound system.	Sys 3.1	Lights should sync up to the sound and run automatically from the code	Test	3
		Sys 3.2	Sound should match the motion in some way and run automatically from the code	Test	3
4	There should be at least one analog circuit.	Sys 4.1	Sound system should be communicated to through an analog circuit	Test	4
		Sys 4.2	Sound levels should be easily controllable by the user	Test	4
5	A test mode should be implemented which must operate the subsystems separately through the help of buttons and switches.	Sys 5.1	An external switch is used to enable or disable test mode. No automatic functions should be run in test mode	Demonstration	5
		Sys 5.2	External buttons are implemented to manually test the different systems	Demonstration	5
6	System must be powered from 120VAC power outlet and should not consume more than 60W. Electrical safety (fuses, insulation) should be used appropriately.	Sys 6.1	System should take in the power appropriately and convert it if necessary. Ensure safety precautions are met	Test	6

Table 3: Test Plan