Project Competition Group 28
Project Document

Kelton Bruslind
Salman Alhuraiji
Meshari Alqahs
Daniel Maestas

April 28, 2023,

Table of Contents

1. Overview

1.1 Executive Summary

For the Product Competition, our group has decided to design an infinity cube. Throughout the first term, we researched different products that customers might be interested in and we deemed the infinity cube to be the best fit. The cube works by having one-way mirrors that have the reflective side face inside the cube along with LEDs that run across the edges of the cube. The idea is to have the cube small enough to be like a desk toy. Other functions implemented in the cube are Wifi/Bluetooth connectivity that can be used to manipulate the colors of the LEDs by outside sources such as weather, temperature, alarms, or music. Our group will have finalized the schematic by the end of week 12 after finalizing our research. From there we will start working on the prototype starting week 13 and getting the required parts. Once we assemble the product by week 18 we will do some testing and also finish our documentation as well.

1.2 Team Contact Information and Protocols

Table I

Team Member	Project Role	Expected Contributions
Kelton Bruslind: bruslink@oregonstate.edu	Mechanical Design	• CAD design of the enclosure • 3D print of the enclosure pieces • Manufacture of the one-way mirror panels
Salman Alhuraiji: Alhurais@oregonstate.edu	Schematic Designer	• Responsible for Sensors • LED • Schematic Design
Meshari Alqahs: Alqahsm@oregonstate.edu	Power Supply Designer	• Power Supply management • Schematic design • 3D printed enclosures
Daniel Maestas: maestasd@oregonstate.edu	Coder	• Microcontroller Code • Bluetooth/Wifi Connection

Team Protocols:

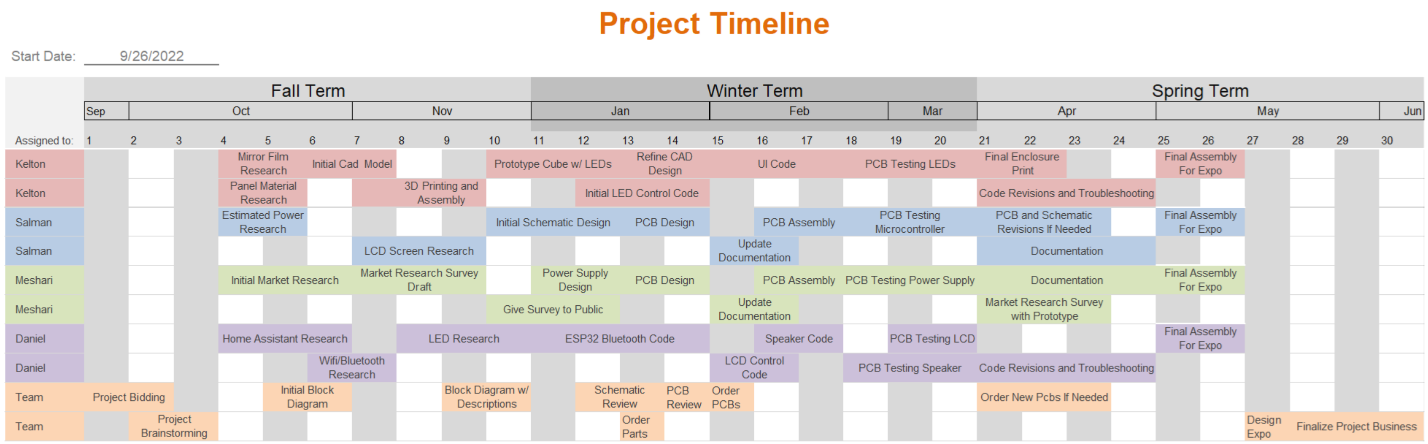
Table II

Protocol	Quality Metric	Plans for if not met
Attend meetings on time every week.	Group members will show up to team meetings within 10 minutes	If a member is regularly missing meetings the group will schedule a meeting with the instructors to discuss potential action
Give advanced notice about missing meetings.	Group members will give at least an hour's notice if they are unable to attend a meeting	If a member isn't attending team meetings the group will schedule a meeting with the instructors to discuss potential actions
Contact the team twice a week.	Group members will message the group through either the team discord or email twice a week	If a member isn't responding to any attempts at contact the group will schedule a meeting with the instructors to discuss potential actions
Collaborate with one another	Each group member will work with one or more members at least once a week	If a member refuses to help others the group will schedule a meeting with the instructors to discuss potential actions
Achieve tasks by team-specified deadlines.	Group members will complete all tasks by specified deadlines unless a valid reason is supplied	If a member is regularly missing deadlines the group will speak with them about ways to improve performance

1.3 Gap Analysis

The purpose of our project is to create a unique piece of art that users could keep in an area to add color and life. Our key assumption about this project is that users will want a piece of desk art that can provide an interesting light display and be connected to the internet to perform various functions. Looking at the tesseract cube found on either Etsy or Trancentral for example, their product costs up to $480 [1] [2]. We believe that our project will be more beneficial to customers than comparable art pieces by providing a similar experience in a smaller form factor at a cheaper cost. Our expected end user is someone who wants a light-based desk toy that they can control using a phone app.

1.4 Timeline/Proposed Timeline



1.5 References and File Links

- **Similar Products:**

“Infinity led hypercube with Music Sync Tesseract Cube by exoy,” *Etsy*. [Online]. Available: https://www.etsy.com/listing/849468090/infinity-led-hypercube-with-music-sync. [Accessed: 13-Oct-2022].

“Tesseract - infinite led hypercube with music,” *Trancentral Shop*. [Online]. Available: https://trancentralshop.com/products/tesseract-infinite-led-hypercube-with-music-sync. [Accessed: 13-Oct-2022].

1.6 Revision Table

Date	Action
10/13/2022	Meshari Alqahs: Reformatted draft font size on each section. Daniel Maestas: Rewrote the executive summary.
11/04/2022	Meshari Alqahs: Updated timeline table
11/04/2022	Kelton Bruslind: Updated several sections based on feedback from initial submission

11/18/2022	Kelton Bruslind: Updated timeline and added title page

2. Impacts and Risks

2.1 Design Impact Statement

One way that the Infinity Cube could affect public health, safety, and welfare is through security risks that come from its connection to Wi-Fi. The device can connect to outside sources like the weather or music through Wi-Fi, and it can be controlled by the mobile app, which leaves it potentially vulnerable to cyberattacks. Hackers might be able to get into the device to get private information about the users. The frequency of malware spread is a rising issue in the new digital world, as researchers have confirmed the occurrence of malware in the U.S. networks. According to this quote,“We uncover a major weakness of WiFi networks in that most of the simulated scenarios show tens of thousands of routers infected in as little as 2 weeks, with the majority of the infections occurring in the first 24–48 h.” [1] they have found serious flaws in today’s modern networks. To make sure the security features of a gadget are up-to-date, it must also get regular software updates and security patches. Users should also be informed about the risks of using devices that connect to Wi-Fi and given instructions on how to keep their devices safe.

Ethical concerns about where the Infinity Cube's parts come from are linked to the product's cultural and social effects. Using parts made by companies with poor working conditions can hurt people and communities. This is why it is important to find and choose component providers that put fair labor practices and ethical sourcing at the top of their priorities [2]. Choosing manufacturers that are open about their working practices prevents the perpetuation of poor working conditions through continued support.

The use of plastic filament in the 3D printing process to make the enclosure of the Infinity Cube has a potentially negative effect on the environment. Plastic trash is becoming a major threat to the earth and wildlife as it is consistent, disposed of improperly. A study found that about 79% of plastic garbage is ultimately thrown away and ends up in landfills or the natural environment [3]. These risks can be lessened by using PLA filament made from plant starch, which can break down in as little as 12 weeks in professional composting [4]. It is also important to inform users on how to safely throw away the product and to encourage them to do so responsibly.

The economic effects of the Infinity Cube product on customers can be both good and bad. On the one hand, if you own an Infinity Cube, you might not need to buy other devices that only do one thing, like a weather station, a speaker, or a room lamp, which could save you money [5]. On the other hand, the price of the product and the fact that it needs other smart IoT devices to work properly may make it too expensive for some users [6].

In conclusion, it is important to be mindful of the potential impact that our project may have on the world. We must be aware of how the materials used in the Infinity Cube affect the environment and what effect the use of our product could have on a consumer. This is why it is critical to carefully plan our project and continually discuss all potential sources of harm.

2.2 Risks

Table I

RISK ID	Risk Description	Risk category	Risk probability	Risk impact	Performance-indicator	Action Plan
R1	Complicated user guide	Design	M	M	…	Improve
R2	Latency	Technical	L	H	Latency time ms	Retain
R3	LEDs frequently burning out	Technical	M	H	LEDs flickering or not light	…
R4	Power supply provides insufficient power	Technical	M	H	System not powering on or randomly shutting down	Improve
R5	Enclosure design isn’t strong enough to hold panels	Design	L	M	3D prints keep breaking and structure won’t hold	Improve

2.3 References and File Links

[1] “WIFI networks and malware epidemiology | PNAS.” [Online]. Available: https://www.pnas.org/doi/10.1073/pnas.0811973106. [Accessed: 29-Apr-2023].

[2] Watson, S. (2019). Ethical Issues in Global Supply Chains. Business Ethics: An Interactive Introduction. Oxford University Press.

[3] Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. Science Advances, 3(7), e1700782. doi: 10.1126/sciadv.1700782

[4] Huang, H. (2020). The Application of Biodegradable Polymers in 3D Printing Filaments. Polymers, 12(3), 531. doi: 10.3390/polym12030531

[5] Riemer, M., Gollan, B., & Su, Q. (2021). The Internet of Things and Our Smart Home Future. Communications of the ACM, 64(2), 72-81. doi: 10.1145/3422706.

[6] Forrester Research. (2019). The Smart Home Consumer. Retrieved from https://go.forrester.com/blogs/the-smart-home-consumer/.

2.4 Revision Table

11/04/2022	Meshari Alqahs: Updated risk table
4/28/2023	Meshari Alqahs: Summarized the design impact assessment.

3. Top Level Architecture

3.1 Block Diagram

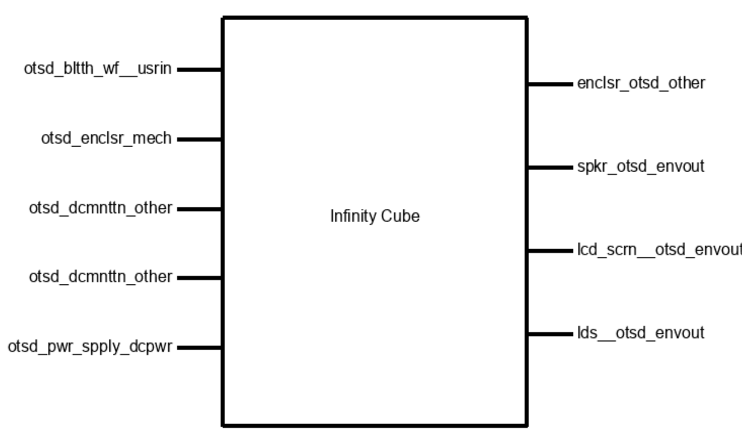


Figure 1: Black Box

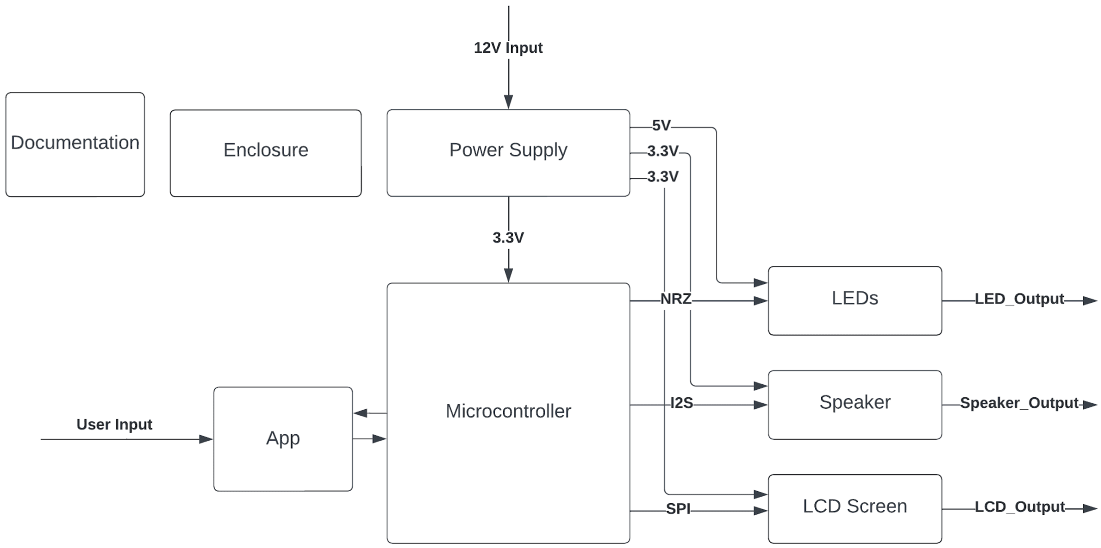


Figure 2: Block Diagram

3.2 Block Descriptions

Table I

Name	Description
Speaker Champion: Daniel Maestas	The speaker will be able to output the user's music through Bluetooth and will have an amplifier implemented into it. The speaker will receive its input from an amplifier which controlled using I2S from the ESP32. The speaker used is an 8 ohm .5W speaker.
Bluetooth/ Wifi UI Champion: Daniel Maestas	The esp32 will be able to communicate to phones using Wifi and Bluetooth. It will also be able to get data on the internet for time, weather, and date. The Wi-Fi connection will be made using the Blynk Arduino library, which will allow the ESP to get weather information and change the settings of the cube with the app. The Bluetooth connection will be made using the ESP A2DP library, which will allow for a device to be connected over Bluetooth and then stream audio.

ESP32 Microcontroller Champion: Kelton Bruslind	For our project, we plan to use the ESP32 as our microcontroller to control the LEDs, LCD screen, speaker, and Wi-Fi/Bluetooth connection. The ESP32 block will be connecting to both the hardware of the system and the code controlling other blocks. The ESP32 operates on 3.3V logic and is powered off the output of the power supply. The ESP32 is used to complete the affordable price and app controlled system requirements. The ESP32 has built in Wifi/Bluetooth, so it is possible for the user to control the system using either connection with the app. The ESP32 is also a very cheap microcontroller for its performance, making it possible to control all the system hardware at a low price.
Enclosure Champion: Kelton Bruslind	The enclosure handles the 3D prints that will house the main PCB and the structure that will hold the one-way mirrors in place. Individual pieces will be printed that slot together to create the full enclosure. The enclosure needs to be lightweight and durable, so the pieces will all be printed using PETG filament to increase strength.
LCD Screen Champion: Salman Alhuraiji	For this block, we will use the ILI9341 TFT LCD screen. The ILI9341 TFT LCD is a high-resolution color display that is widely used in embedded systems and mobile devices. It has a 2.8-inch diagonal display with a 320x240 pixel resolution, so images and graphics are clear and vivid. The operating voltage range for the ILI9341 TFT LCD screen is between 3.3V to 5V, with an estimated current draw of 55mA to 60mA, which is dependent on several factors such as the display size and the brightness of the backlight. However, it is recommended to consult the manufacturer's datasheet or specifications for more accurate information on the current draw of the specific ILI9341 TFT LCD screen being used.
LED’s Champion: Salman Alhuraiji	For this block, I will use the WS2812B LED, which is an RGB color that can be used for color-changing effects. When connected to an ESP-WROOM-32 microcontroller, the LED can be controlled using a digital signal. Also, the LED has four pins, including VCC, GND, DOUT, and DIN, and can be connected to the ESP-WROOM-32.
Documentation Champion: Meshari Alqahs	This block encompasses the work required to create the Market research and the User-Guide. The market research will be a mixture of surveys conducted on the general public to determine features that they would want from this product and research into comparable products. The user guide is a compilation of instructions and information about the cube to allow for easy use of the cube.
Power Supply Champion: Meshari Alqahs	The power supply block will be able to supply 12V at 3 amp of input, and it will get its power from a US standard wall outlet. The block will include a step-down converter that will convert the 12V to 3.3V which will be connected to the microcontroller, and speaker, and 5V to the LEDs, and LCD screen.

3.3 Interface Descriptions

Table II

Name	Properties
otsd_bltth_wf__usrin	• **Timing:** Can switch between input in under a second • **Type:** Will have clearly labeled buttons on phone for user inputs • **Usability:** Clear UI that can control LEDs
otsd_enclsr_mech	• **Fasteners:** Magnets will be used to join the panels together and attach them to the base. Three will be used per edge • **Other:** Must have a length less than 7" • **Other:** Must have a width less than 7" • **Other:** Must have a height less than 7"
otsd_dcmnttn_other	• **Other:** Includes Sketches (User-Guide) • **Other:** Understandable (User-Guide) • **Other:** Readable
otsd_dcmnttn_other	• **Other:** 2 Page min. • **Other:** Readable (Market Research) • **Other:** Understandable (Market Research)
otsd_pwr_spply_dcpwr	• **Inominal:** 50mA • **Ipeak:** 5A • **Vnominal:** 12V

esp32_mcrcntrllr_bltth_wf__rf	● **Other:** Must download information from a web address over Wifi ● **Other:** Must be able to configure a Wifi connection from esp32 ● **Other:** Must stream audio over a Bluetooth connection from phone to esp32
esp32_mcrcntrllr_spkr_dsig	● **Logic-Level:** 3.3V ● **Max Frequency:** 1.5Mhz ● **Other:** I2S connection ● **Rise Time:** Max 60ns
esp32_mcrcntrllr_lcd_scrn__dsig	● **Logic-Level:** 3.3V ● **Other:** Commands including: Color SET and Display ON ● **Other:** Must successfully make a connection using SPI with another device
esp32_mcrcntrllr_lds__dsig	● **Logic-Level:** 3.3V ● **Max Frequency:** 800 kHz ● **Other:** Can control 72 LEDs
enclsr_otsd_other	● **Other:** Mounting for LCD ● **Other:** Mounting for acrylic panels ● **Other:** Mounting for speaker ● **Other:** Mounting for barrel jack ● **Other:** Mounting for PCB
pwr_spply_esp32_mcrcntrllr_dcpwr	● **Inominal:** 50mA ● **Ipeak:** 240mA ● **Vmax:** 3.6V ● **Vmin:** 3V
pwr_spply_spkr_dcpwr	● **Inominal:** 10mA ● **Ipeak:** 100mA ● **Vmax:** 3.6V ● **Vmin:** 3V

pwr_spply_lcd_scrn__dcpwr	● **Inominal:** 60mA ● **Ipeak:** 70mA ● **Vmax:** 5V ● **Vmin:** 3.3V
pwr_spply_lds__dcpwr	● **Inominal:** 600mA ● **Ipeak:** 2.5A ● **Vmax:** 5.3V ● **Vmin:** 3.3V
spkr_otsd_envout	● **Other:** audio - 45dB ● **Other:** Can be heard at 45\dB from a foot away
lcd_scrn__otsd_envout	● **Light:** RGB Light ● **Other:** 9 out 10 users can distinguish the colors illuminated from the screen ● **Other:** Be able to display character (text)
lds__otsd_envout	● **Light:** Showing the RGB colors changing. ● **Other:** 9 out of 10 users can see from at least 8 feet away ● **Other:** 9 out of 10 users can distinguish the RGB colors.

3.4 References and File Links

3.4.1 References

3.4.2 File Links

3.5 Revision Table

3/15/2023	Kelton: Added content to sections 3.1-3.3
5/14/2023	Kelton: Updated descriptions based on feedback from previous

	submission

4. Block Validations

4.1 LCD Screen

4.1.1 Description

For this block, we will use the ILI9341 TFT LCD screen. The ILI9341 TFT LCD is a high-resolution color display that is widely used in embedded systems and mobile devices. It has a 2.8-inch diagonal display with a 320x240 pixel resolution, so images and graphics are clear and vivid. The operating voltage range for the ILI9341 TFT LCD screen is between 3.3V to 5V, with an estimated current draw of 55mA to 60mA, which is dependent on several factors such as the display size and the brightness of the backlight. However, it is recommended to consult the

4.1.2 Design

The principal interface for the user to interact with and gain access to information is provided by the Hiletgo full-color TFT touch display module, which is an essential component of the system. Graphics, text, and video information can all be displayed in a clear and detailed manner on its 2.8-inch screen because of the 320x240 pixel resolution it possesses. This display is outfitted with an ILI9341 a Si TFT LCD single chip driver, which allows for a high-quality visual display with full-color capabilities that range from 16-bit RGB 65K. The functionality of the touch screen provides an additional layer of involvement for the user, resulting in an experience that is both more straightforward and user-friendly. The ESP-WROOM-32 microcontroller and the display module are able to communicate with one another thanks to the 4-pin SPI protocol, which allows for a speedy and effective flow of data. The addition of a slot for SD memory cards increases the system's capacity for storing data and gives it the ability to both save and retrieve information as required. The display module was developed with power efficiency in mind; it has a low current consumption, which ensures that it will continue to function effectively for a long time. The module is powered by a power source with a nominal voltage of 3.3 volts and a maximum current demand of 70mA. The pwr_spply_lcd_scrn_dcpwr is responsible for supplying this power supply, and the lcd_scrn_otsd_envout is the component that allows the display's output signal to be sent to the primary system. Because of its high-resolution display, touch screen capability, efficient communication, and power efficiency, the Hiletgo full-color TFT touch display module is an excellent choice for the system. It offers the user a display that is both clear and responsive, allowing them to easily access information and take control of the system.

4.1.3 General Validation

The layout of the Hiletgo ILI9341 LCD screen and the ESP-WROOM-32 microcontroller was selected because it satisfies the requirements of the system in terms of the function that the block is intended to perform. The fact that the display of the ILI9341 has a high resolution and a depth of color makes it appropriate for showing text, graphics, and video, all of which are essential for the block to fulfill the requirements that are imposed by its functional specifications. It is vital for the block to fulfill its performance criteria in order for it to have the capacity to get information from the internet and display it on the screen. The ESP-WROOM-32 microcontroller, which is equipped with WiFi capabilities, provides this capability. The ILI9341 display and the ESP-WROOM-32 microcontroller are both appropriate for use in this application due to their low prices and extensive availability. Additionally, the ILI9341 display and the ESP-WROOM-32 microcontroller both have a reasonably low overall production cost.

The components are excellent for use in this project due to their user-friendliness and the ease with which they can be understood. Additionally, they are frequently used in electronic projects and have datasheets and libraries that are thoroughly documented. The amount of time that must be spent on engineering in order to construct the block is quite low due to the fact that the components are both well-established and frequently utilized, and there are numerous resources accessible for the development and integration of these components. The size of the components is also appropriate for the block, as they are small and can be easily incorporated into a wide variety of projects thanks to their adaptability. Utilizing an OLED display and a different microcontroller, such as a Raspberry Pi, is one alternative method that might be used to solve the problem presented by this block. OLED screens give a high resolution and quick response times, and the Raspberry Pi provides a high degree of computing power and the capacity to run a full operating system. However, it is possible that this solution will not be as cost-effective as the ILI9341 display with the ESP-WROOM-32 microcontroller. Additionally, it is possible that this alternative will have a higher power consumption, which may be an issue for applications that are powered by batteries.

In conclusion, the design of the Hiletgo ILI9341 LCD screen and the ESP- WROOM-32 microcontroller is suitable for the requirements of the system in terms of the function that the block is intended to perform. This is because it offers a high resolution, a high color depth, and quick response times, as well as WiFi capabilities and compatibility with a wide variety of other components and systems. This design offers a solution that is suitable for a wide range of projects that is not only cost-effective but also reliable and has a strong support network.

4.1.4 Interface Validation

There are three primary interfaces present on the Hiletgo ILI9341 LCD screen, which is connected to the ESP-WROOM-32 microcontroller. This is done to guarantee that the function is carried out without any interruptions.

The power supply interface, which is also known as the "pwr_spply_lcd_scrn_dcpwr" label, is the first component. This interface describes how the LCD screen is powered by the ESP-WROOM-32 microcontroller and comprises four characteristics: Inominal, Ipeak, Vmax, and Vmin. These properties are given in the datasheet. Because of these characteristics, the power needs of the LCD panel are always satisfied.

The second component is the communication interface, which has the name "esp32 mcrcntrllr_lcd_scrn_disg" written on its label. This interface shows the connection between the ESP-WROOM-32 microcontroller and the Hiletgo ILI9341 LCD screen. It has three properties, including a logic level of 3.3V, communication between the screen and the microcontroller using the SPI protocol, and the capability to adjust the brightness and characters through command codes programmed in the Arduino IDE using the relevant libraries for both the microcontroller and the LCD screen.

Last but not least is the output interface, also known as "lcd_scrn_otsd_envout" This interface is responsible for displaying the output of the ILLI9341 LCD screen. This interface has three qualities, the first of which is the capacity to show RGB colors, the second of which is the ability to display text characters, and the third of which is the ability to offer clear and identifiable lighting from a distance to nine out of ten users. This interface is essential since it is the one that the consumers will interact with in the end. It should be easily legible and aesthetically appealing to attract their attention. The compatibility of the Hiletgo ILI9341 LCD screen with the system requirements are ensured by these interfaces and their qualities, which also contribute to the screen's smooth operation as an interface.

pwr_spply_lcd_scrn_dcpwr

Inominal: 55mA	The nominal current was chosen based on the current that is needs in the overall system	In the LCD screen the nominal current draw as it shown in the datasheet as it is depending on several factors including the display's operating mode, the brightness of the backlight, and the power supply voltage.
Ipeak: 70mA	The maximum current draw that the LCD screen might take up to 70mA was chosen based on the current that is needs in the overall system.	In the LCD screen the maximum current draw is 70mA as the LCD screen can take as it shown in the datasheet the current draw is depending on several factors including the display's operating mode, the brightness of the backlight, and the power supply voltage.
Vmax: 5V	This maximum voltage was chosen based on the expected maximum voltage that is needs in the LCD screen 5V.	In the LCD screen the that needs as it shown in the datasheet which is 5V at maximum.
Vmin: 3.3V	This minimum voltage 3.3V was chosen based on the minimum voltage that will supply from ESP WROOM_32 that is needs in the overall system.	In the LCD screen the that needs as it shown in the datasheet which is 3.3V at minimum.

esp32_mcrcntrllr_lcd_scrn_disg

Logic-Level: 3.3V	This value was chosen the which is 3.3V that the microcontroller uses to communicate with the LCD screen and control its functions.	In the LCD screen as it shown in the datasheet that the microcontroller needs 3.3V to communicate with the LCD screen.
Other: Must successfully make a connection using SPI with another device.	This allows the microcontroller to communicate with the LCD screen and can transfer the data as it needed to the overall system.	In the LCD screen as it shown in the datasheet that is using a SPI communication to allow the users to see the data that has been coded.
Other: Command code	This command code will show how the microcontroller will send the commands to display the data in the LCD screen by the command code.	In the LCD screen by using a commands code by programming the LCD screen by using Arduino IDE.

lcd_scrn_otsd_envout

Light: RGB color light	This was chosen based on the programing that we will code to display the RGB colors light in the LCD screen.	In the LCD screen as it shown in the datasheet that the LCD screen is able to display RGB colors light if we write code properly.
Other: Be able to display character (text)	This was chosen based on the programing that we will code to display the RGB colors light in the LCD screen.	In the LCD screen as it shown in the datasheet that the LCD screen is able to display character (text) if we write code properly.
Other: 9 out 10 users can distinguish the colors illuminated from the screen	This was chosen based on the needed of the users to have the overall system be checked	In the LCD screen as it shown in the datasheet that the users can see the colors and characters such as text from 8 feet.

4.1.5 Verification

A. User Testing

- This test will verify that the viewer/users can identify the data from the block.

1. Supplying power to the ESP-WROOM-32 microcontroller and the Hiletgo ILI9341 LCD screen is as follows: Make sure that the ESP-WROOM-32 is working at the appropriate voltage once you have connected the power supply to it (3.3V nominal). Connect the LCD screen for the Hiletgo ILI9341 to the ESP-WROOM 32 by utilizing the SPI protocol for 4-pin connections. Connect the ESP32 to the esp32_mcrcntrllr_lcd_scm_dsig.

2. To verify the compatibility of the Hiletgo ILI9341 LCD screen with the ESP WROOM-32 microcontroller, a test program should be loaded onto the microcontroller using the Arduino IDE. The necessary libraries for both the ESP WROOM-32 and the ILI9341 LCD screen should be downloaded and included in the coding process. Upon completion, the program should display the intended data, including text and RGB colors, on the LCD screen.

3. Upload the code to the ESP-WROOM-32 microcontroller the is using a SPI communication to be connecting to the ILI9341 LCD screen and test it by sending data. For instance, text, graphics, or RGB colors light.

4. Verify the that the data is displayed such as RGB colors are illuminating properly and the characters as well.

5. Have 9 out of 10 users match the requirement and report it as it shown.

B. Power Testing

- the communication interface esp32_mcrcntrllr_lcd_scm_disg to verify the testing to see if the data is shown.

1. Connect the LCD screen block to the pwr_spply_lcd_scrn_dcpwr at the interface at 3.3V using the DMM and the current 55mA.

2. Connect the ESP32 to the esp32_mcrcntrllr_lcd_scrn_disg.

3. Load a test program when finishing the coding part for the LCD to the ESP32 to show the data that should appear as it is meant to in the lcd_scrn_otsd_envout to see the data displays in the LCD screen.

4.1.6 References

[1] educ8s. “Arduino TFT LCD Touch Screen Tutorial (2.8’ ILI9341 Driver) Also for ESP32.” YouTube, YouTube, 7 Apr. 2018, https://www.youtube.com/watch?v=beyDkTBhpgs.

[2] “2.8inch SPI Module ILI9341 SKU:MSP2807.” 2.8inch SPI Module ILI9341 SKU:MSP2807 - LCD Wiki,
www.lcdwiki.com/2.8inch_SPI_Module_ILI9341_SKU:MSP2807

[3] “MSP2807 Full Color TFT Touch Display Module [2.8 Inch] [320x240 Pixel]. Siqma Robotics, store.siqma.com/msp2807-tft-touch.html.

[4] “TFT LCD 2.8’ 240X320 RGB SPI Display with Touchscreen.” ProtoSupplies, 3 Feb. 2023, https://protosupplies.com/product/tft-lcd-2-8-240x320-rgb-spi-display with-touchscreen/.

[5] Alldatasheet.com. “Ili9341 PDF, Ili9341 Description, Ili9341 Datasheet, ili9341 View ::: Alldatasheet :::” ALLDATASHEET, https://pdf1.alldatasheet.com/datasheet-pdf/view/1131760/ETC2/ILI9341.html.

[6] OpenAI, “CHATGPT: Optimizing language models for dialogue,” OpenAI, 02- Feb-2023. [Online]. Available: https://openai.com/blog/chatgpt/. [Accessed: 12- Feb-2023].

4.1.7 Revision Table

01/21/2023	Salman: Revised the interfaces.
02/11/2023	Salman: Edited the document sections. Edited the References. Edited the schematic for the block. Edited the verification plan section.

4.2 LEDs

4.2.1 Description

For this block, the WS2812B LED will be used, which is an RGB color that can be used for color-changing effects. When connected to an ESP-WROOM-32 microcontroller, the LED can be controlled using a digital signal. Also, the LED has four pins, including VCC, GND, DOUT, and DIN, and can be connected to the ESP-WROOM-32.

4.2.2 Design

This block covers the RGB LEDs and their connection to the ESP32. The LEDs are connected to the 5V power supplies, which are used to power four separate strips of LEDs. The LEDs are controlled by the ESP32 using a NZR control signal. The LEDs have an environmental output, which is the light that they emit.

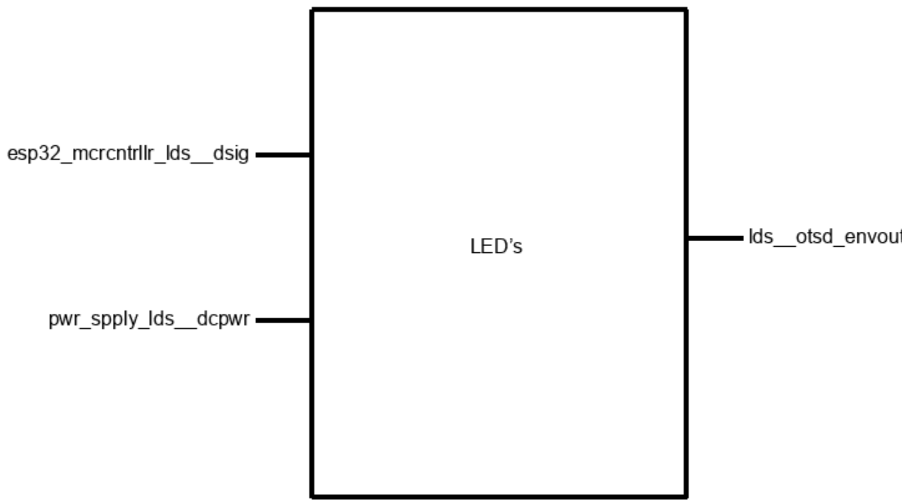


Figure 1: Black Box of LEDs

4.2.3 General Validation

A major factor in choosing the WS2812B LED strips to use for the system is their brightness. The mirror film that is used to create the one way mirror effect requires that the interior brightness of the cube is greater than the exterior brightness, or the mirror effect is diminished. This means that very bright LEDs are needed, so the mirror effect will still be present even during bright conditions. The WS2812B LEDs were chosen because they have the greatest brightness compared to similar individually addressable LEDs such as the SK6812 LEDs.

Another major factor in choosing the WS2812B LEDs is the fact that their control signal allows for individual LEDs to be selected and can change the qualities of the light they are outputting. This makes the different LED modes possible and greatly increases the potential options for user control.

Another style of LEDs considered was the SK6812 LEDs. These LEDs have a similar control scheme which allows individual LEDs to be controlled. They also have a similar brightness level to the WS2812B, but are slightly less bright under most operating conditions. Ultimately, the SK6812 LEDs weren’t chosen because they are more difficult to source at a price that would allow for the cube to be manufactured under its budget.

4.2.4 Interface Validation

Interface Property	Why is this interface this value?	Why do you know that your design details <u>for this block</u> above meet or exceed each property?
esp32_mcrcntrllr_lds__dsig : Input		

Logic-Level: 3.3V	The esp32 operates off of a voltage range of 2.3V to 3.6V with a nominal voltage of 3.3V.	ESP32 Datasheet, pg 21: The operating voltage of ESP32 ranges from 2.3 V to 3.6 V. When using a single-power supply, the recommended voltage of the power supply is 3.3 V
Max Frequency: 800 kHz	The typical frequency of the LEDs that we plan to use is 800 KHz so that is the max value we expect to see.	SK6812 Datasheet, dynamic parameters: typ 800 KHz
Other: Can control 72 LEDs	There are 12 edges of the cube and each edge can hold 6 LEDs	Information only

pwr_spply_lds__dcpwr : Input

Inominal: 600mA	Each LED draws 8mA normally	Information only
Ipeak: 2.5A	Each LED can draw a max of 34mA	Information only
Vmax: 5.3V	The LEDs can handle a max of 5.3V	WS2812 Datasheet
Vmin: 3.3V	The LEDs can handle a min of 3.3V	WS2812 Datasheet

lds__otsd_envout : Output

Light: Showing the RGB colors changing.	The LEDs must change colors to create effects	Information only
Other: 9 out of 10 users can distinguish the RGB colors.	User must be able to see the different colors	Information only
Other: 9 out of 10 users can see from at least 8 feet away	User must be able to see the leds	Information only

4.2.5 Verification

1. Connect a 6 LED strip to a power supply

2. Change the voltage to 3.3V
3. Change the voltage to 5.3V
4. Set the voltage to 5V and set the LEDs to rainbow mode
5. Ask a user to stand 8 feet away and confirm if the LEDs are on
6. Ask the user to return and say if the LEDs are changing color

4.2.6 References

[1] "ESP32 Overview | Espressif Systems," Accessed: Feb 11, 2023. [Online]. Available: www.espressif.com. https://www.espressif.com/en/products/socs/esp32

4.2.7 Revision Table

01/21/2023	Salman: Add initial draft
02/11/2023	Salman: Made revision based on team feedback

4.3 Documentation

4.3.1 Description

This block encompasses the work required to create the Market research and the User-Guide. The market research will be a mixture of surveys conducted on the general public to determine features that they would want from this product and research into comparable products. The user guide is a compilation of instructions and information about the cube to allow for easy use of the cube.

4.3.2 Design

This block is for the Market research and the User-Guide. The market research will be composed of surveys give to potential customers to gauge interest and determine what features they wish to see. The user guide is a collection of instructions and information about the cube to allow for easy use of the cube.

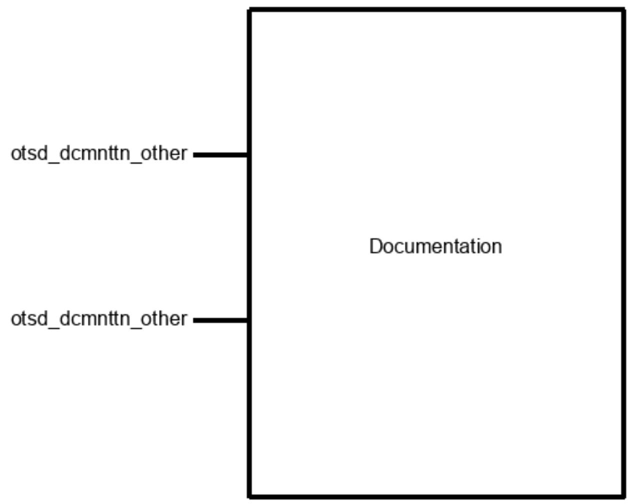


Figure 1: Black box of Documentation

4.3.3 General Validation

We chose to do our user guide in this manner because it allows us to give users a condensed packet of information to teach them about the infinity cube. By creating a short document, we can educate the user about the product easily. The PDF format of the document allows it to be shared easily online or printed out and shared physically.

We chose to do the market research in this way because it allows us to get direct feedback from potential customers about the product. We can ask targeted questions and use the information to make revisions to our product.

4.3.4 Interface Validation

Interface Property	**Why is this interface this value?**	**Why do you know that your design details for this block above meet or exceed each property?**
otsd_dcmnttn_other : Input		
Other: 2 Page min.	**The document should be comprehensive in its information**	**Information only**
Other: Readable (Market Research)	**The market research needs to be readable and understandable**	**Information only**

Other: Understandable (Market Research)	**The market research needs to be readable and understandable**	**Information only**

otsd_dcmnttn_other : Input

Other: Includes Sketches (User-Guide)	**The user guide should provide visual imagery**	**Information only**
Other: Understandable (User-Guide)	**The user guide needs to be understandable**	**Information only**
Other: Readable	**The user guide needs to be readable**	**Information only**

4.3.5 Verification

1. The user guide will be read to determine if it is understandable and readable
2. The market research pages will be counted to she if there is a min of 2
3. The market research will be read to determine if it is understandable and readable

4.3.6 References

4.3.7 Revision Table

1/21/2023	First rough draft written
2/1/2023	Updated the interfaces
2/2/2023	Updated the general Validation
2/3/2023	Added all the missing data

4.4 Power Supply

4.4.1 Description

The power supply block will be able to supply 12V at 3 amp of input and it will get its power from a US standard wall outlet. The block will include a step-down converter that will convert the 12V to 3.3V which will be connected to the microcontroller, and speaker, and 5V to the LEDs, and LCD screen.

4.4.2 Design

The power supply block will be divided into three parts. The first part is a US standard wall wart [2] that is going to take 120VAC of input, and outputs 12V at 4A. The second part is an LM317 voltage regulation circuit (Fig,2) that will take 12V of input and output 3.3V at 1A. The third part is an LD1085V50 voltage regulation (Fig,3) circuit that will take 12V of input and output 5V at 2A.

The 3.3Vout will be connected to the microcontroller, speaker, and LCD screen. Meanwhile, the 5Vout will connect to the LEDs. The black box diagram is illustrated as shown below in Fig. 2.

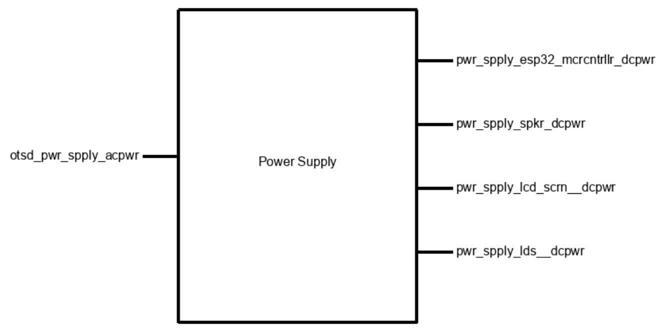


Fig. 1
Black Box Diagram of Power Supply Block

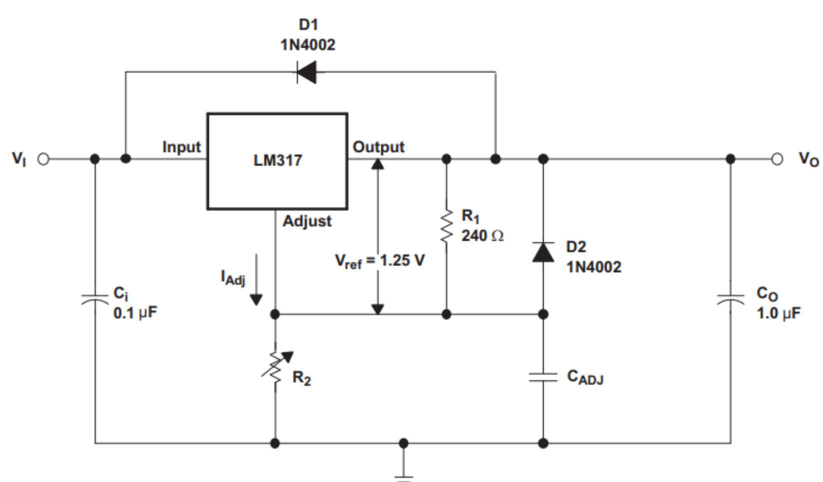


Fig. 2

LM317 Circuit Diagram [4]

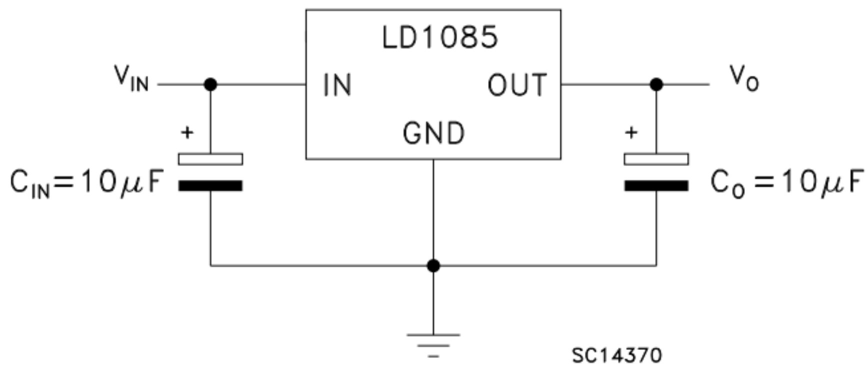


Fig. 3
LD1085V50 Circuit Diagram [1]

4.4.3 General Validation

LD1085V50 [1]**:**

The LD1085V50 is a commonly used voltage regulator that provides a consistent and controlled output voltage in several electronic circuits. The device is intended to give a regulated voltage output range from 5V to 12V, making it an excellent choice for our application in which the input voltage must be controlled to a steady level. When determining if the LD1085V50 is the optimal solution, it is crucial to examine a number of essential variables. These variables include cost, availability of parts, time to comprehend and engineer, technical performance, interaction with other blocks, and size.

To limit the amount of heat produced by the LD1085V50, we would divide them into four independent regulators capable of handling up to 1.5 amps each.

In terms of cost, the LD1085V50 is often a more cheap alternative than many other voltage regulators available on the market. Additionally, the gadget is readily available from several vendors, making it simple to locate and acquire in volume. This combination of cheap cost and high availability makes the LD1085V50 an excellent option to cut expenditures while still obtaining high levels of technical performance.

Since the LD1085V50 is a frequently used voltage regulator, it is generally accessible from a variety of wholesalers. This guarantees that we can readily locate the components we want, even in bigger numbers, and have timely access to the parts we require to finish our design. Having a variety of alternatives to pick from when purchasing the LD1085V50 also allows us to compare costs and locate the best offer.

The LD1085V50 is a basic and well-documented device, making it simple for us to incorporate into our designs. The device's straightforward pin arrangement and constant output voltage save the time and effort necessary to develop and debug a circuit. In addition, the LD1085V50 is a well-established device, so engineers have access to a variety of knowledge on how to use it, as well as reference designs and samples to get started. This combination of usability and information availability makes the LD1085V50 an excellent option for our team seeking to save engineering time and minimize the work necessary to finish projects.

In terms of technical performance, the LD1085V50 is an excellent option for applications requiring a regulated output voltage between 5V and 12V. It is excellent for situations where power dissipation is a problem because of its high power efficiency and outstanding thermal performance. In addition, the LD1085V50 has a broad input voltage range, allowing it to be utilized with a variety of voltage sources. In addition, the device has a low dropout voltage, allowing it to regulate the output voltage even when the input voltage is near the output voltage. This makes the LD1085V50 an excellent choice for situations in which the input voltage is inconsistent and must be stabilized.

The LD1085V50 is compatible with a range of other electrical components, providing our team with a diverse alternative. It is easy to incorporate into a broad variety of circuits due to its straightforward pin design and consistent output voltage. In addition, the device is designed to have a low profile, making it suitable for small circuit designs with limited space. This combination of adaptability and small size makes the LD1085V50 an excellent option for designers seeking a readily integrated voltage regulator.

The LM2937ET-5.0 is an alternate voltage regulator to the LD1085V50. Similar to the LD1085V50, the LM2937ET-5.0 delivers a controlled output voltage and is suited for a variety of applications. The LM2937ET-5.0, on the other hand, is a low dropout voltage regulator intended primarily for low-voltage applications. With a maximum input voltage of 40V, it is appropriate for use in applications that demand a higher input voltage. In addition, the LM2937ET-5.0 has a low quiescent current, which makes it appropriate for battery-powered applications where power consumption is an issue. The device also has a low dropout voltage, enabling it to adjust the output voltage across a wide range of input voltages. Lastly, the LM2937ET-5.0 is available in a tiny SOT-223 package, which makes it suitable for compact circuit designs when space is constrained.

LM317 [4]**:**

The LM317 is a flexible voltage regulator that may be used to control the output voltage of a power supply. Due to its cost-effectiveness, user-friendliness, and technical excellence, it is utilized in a broad number of applications.

The LM317's ability to adjust output voltage across a wide range of input voltages is one of its primary benefits. This makes it an excellent option for applications requiring a constant output voltage independent of the input voltage.

The LM317 is a reasonably inexpensive voltage regulator, making it a common choice for applications with restricted budgets that require voltage control. In addition, it is widely available and manufactured by several companies, making it easy to locate and acquire.

The LM317 is an easy-to-understand and uses a linear voltage regulator for individuals with a basic understanding of electronics. Its datasheet contains comprehensive information on its specs and functioning, allowing us to easily incorporate it into our designs.

The LM317 is appropriate for applications that demand steady output voltages despite its basic design because it provides stable voltage regulation and effective load regulation. Its small size and compatibility with a wide variety of blocks and systems also make it an excellent option for our project which requires voltage management in confined spaces.

Overall, the LM317 is a flexible and cost-effective voltage regulator that is utilized in a broad range of applications due to its user-friendliness, technical performance, and compatibility with several systems.

Two prevalent alternatives to the LM317 voltage regulator are listed below:

- The LM7805 is a similar linear voltage regulator to the LM317. It is widely used due to its affordability and usability, as well as its stable voltage management and excellent load regulation. The LM7805 has a narrower input voltage range than the LM317, making it less flexible.
- LM2675 is a commonly used step-up voltage regulator. It is particularly useful for applications that demand a higher output voltage than the input voltage, as it can boost the voltage up to 40 volts. Additionally, the LM2675 is small and energy-efficient, making it an excellent choice for applications requiring voltage control in confined spaces.

4.4.4 Interface Validation

Interface Property	**Why is this interface this value?**	**Why do you know that your design details for this block above meet or exceed each property?**
otsd_pwr_spply_acpwr : Input		
Inominal: 2.3A	Based on the system requirements, and the components names supplied by the team members, the system would need at least this value as Inominal.	This is a pre-built wall wart with its values given.
Ipeak: 5A	The system would need 2.5 A at max but it is set to this value to be on the safe side.	This is a pre-built wall wart with its values given.
Vnominal: 12V	The power source will be from a wall wart, and the written output value will be 12V.	Based on the given value on the properties on the transformer.

pwr_spply_esp32_mcrcntrllr_dcpwr : Output

Inominal: 50mA	Based on the data given by team members.	My design would be able to operate at 3A, so it will allow system components to draw out the required current.
Ipeak: 240mA	Based on the data given by team members.	My design would be able to operate at 3A, so it will allow system components to draw out the required current.
Vmin: 3V	The ESP chip needs 3.3V to function.	My design has a step down voltage regulator that will allow the voltage to be at 3.3V.
Vmax: 3.6V		

pwr_spply_spkr_dcpwr : Output

Inominal: 100mA	Based on the data given by team members. The speaker would need 100mA nominal current.	My design would be able to operate at 3A, so it will allow system components to draw out the required current.
Ipeak: 300mA	Based on the data given by team members. The speaker can handle up to 300mA at max	My design would be able to operate at 3A, so it will allow system components to draw out the required current.
Vmin: 3V	Based on the given data by team members, The speaker would need 3Vmin to function properly.	My design has a step down voltage regulator that will allow the voltage to be at 3V.
Vmax: 3.4V	Based on the given data by team members, The speaker would need 3.4Vmax to function properly.	My design has a step down voltage regulator that will allow the voltage to be at 3.4V.

pwr_spply_lcd_scrn__dcpwr : Output

Inominal: 60mA	Based on the given data by team members, the LCD would draw	My design would be able to operate at 3A, so it will allow

	out 60mA at normal operating conditions.	system components to draw out the required current.
Ipeak: 70mA	Based on the given data by team members, the LCD would draw out 70mA at max.	My design would be able to operate at 3A, so it will allow system components to draw out the required current.
Vmin: 3.3V	Based on the given data by team members, the LCD screen needs 3.3V at minimum.	My design has a step down voltage regulator that will allow the voltage to be at 3.3V.
Vmax: 5V	Based on the given data by team members, 5V is the max required for the LCD to function properly.	My design has a step down voltage regulator that will allow the voltage to be at 5V.

pwr_spply_lds__dcpwr : Output

Inominal: 600mA	Based on given data by team members, the leds would operate at 2A in normal condition.	My design would be able to operate at 3A, so it will allow system components to draw out the required current.
Ipeak: 2.5A	Based on given data by team members, the leds would draw out 2.5A at max.	My design would be able to operate at 3A, so it will allow system components to draw out the required current.
Vmin: 4V	Based on the given data by team members, 4V is the min. required for the leds to function properly.	My design has a step down voltage regulator that will allow the voltage to be at 4V.
Vmax: 5V	Based on the given data by team members, 5V is the max. required for the leds to function properly.	My design has a step-down voltage regulator that will allow the voltage to be at 5V.

4.4.5 Verification

A verification process has to be conducted to ensure that the block is functioning as expected and that it is clear of any flaws. Showing the verification process also ensures that the block is ready to be integrated into the system.

- **Nominal Current Testing and Voltage - 3.3V**

Since the block must be capable of supplying the specified powers under all input conditions, this test will measure voltage output while supplying nominal current at all valid input powers.

1. Connect the Power Supply block to power via the **otsd_pwr_spply_acpwr** interface at 12V. Insert a current meter (DMM) inline OR use a power supply that displays the used current.
2. Using either a Dynamic load or a fixed resistance, load **pwr_spply_esp32_mcrcntrllr_dcpwr, pwr_spply_lcd_scrn__dcpwr**, and **pwr_spply_spkr_dcpwr** to draw 50mA, 60mA, and 100mA separately, assuming a 3.3V output level.
3. Energize the system for 30 seconds. At the end of the 30 seconds while still powering the system, ensure that the output voltage is still between 3.3V

PASS: This test passes if at both 12V, the current draw on **otsd_pwr_spply_acpwr** never exceeds 300mA and the voltage on **pwr_spply_esp32_mcrcntrllr_dcpwr**, **pwr_spply_lcd_scrn__dcpwr**, and**pwr_spply_spkr_dcpwr** stays in the range of 3.3V.

- **Nominal Current Testing and Voltage - 5V**

Since the block must be capable of supplying the specified powers under all input conditions, this test will measure voltage output while supplying nominal current at all valid input powers.

1. Connect the Power Supply block to power via the **otsd_pwr_spply_acpwr** interface at 12V. Insert a current meter (DMM) inline OR use a power supply that displays the used current.
2. Using either a Dynamic load or a fixed resistance, load **pwr_spply_lds__dcpwr** to draw 600mA, assuming a 5V output level.
3. Energize the system for 30 seconds. At the end of the 30 seconds while still powering the system, ensure that the output voltage is still 5V

PASS: This test passes if at 12V, the current draw on **otsd_pwr_spply_acpwr** never exceeds 600mA and the voltage on **pwr_spply_lds__dcpwr** stays in the range of 5V.

- **Peak Current Testing - 5V**

Since the block must be capable of supplying the specified powers under all input conditions, this test will measure voltage output while supplying peak current at all valid input powers.

1. Connect the Power Supply block to power via the **otsd_pwr_spply_acpwr** interface at 12V. Insert a current meter (DMM) inline OR use a power supply that displays the used current.
2. Using either a Dynamic load or a fixed resistance, load **pwr_spply_lds__dcpwr** 2.5mA and 300mA separately, assuming a 5V output level.
3. Energize the system for 3 seconds. At the end of the 3 seconds while still powering the system, ensure that the output voltage is still 5V

PASS: This test passes if at 12V, the current draw on **otsd_pwr_spply_acpwr** never exceeds 600mA.

- **Peak Current Testing - 3.3V**

Since the block must be capable of supplying the specified powers under all input conditions, this test will measure voltage output while supplying peak current at all valid input powers.

1. Connect the Power Supply block to power via the **otsd_pwr_spply_acpwr** interface at 12V. Insert a current meter (DMM) inline OR use a power supply that displays the used current.
2. Using either a Dynamic load or a fixed resistance, load **pwr_spply_esp32_mcrcntrllr_dcpwr,** **pwr_spply_lcd_scrn__dcpwr**, and **pwr_spply_spkr_dcpwr** 240mA, 70mA, and 300mA separately, assuming a 3.3V output level.
3. Energize the system for 3 seconds. At the end of the 3 seconds while still powering the system.

PASS: This test passes if, at 12V, the current draw on **otsd_pwr_spply_acpwr** never exceeds 240mA, 70mA, and 300mA.

4.4.6 References

[1] "3 a low drop positive voltage regulator: Adjustable and fixed." [Online]. Available: https://www.mouser.com/datasheet/2/389/ld1085-974046.pdf. [Accessed: 13-Feb-2023].

[2] A. R. T. H. U. R. D. E. K. K. E. R. SAVAGE, "12 V 5A AC/DC ADAPTER," *Amazon*, 2016. [Online]. Available: https://www.amazon.com/dp/B09BQBWKKT?ref_=cm_sw_r_apin_dp_G94AN6MXARFA7WTSTBRF&th=1. [Accessed: 24-Jan-2023]].

[3] "ESP32 series - espressif." [Online]. Available: https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf. [Accessed: 24-Jan-2023].

[4] "LM317 3-terminal adjustable regulator - texas instruments." [Online]. Available: https://www.ti.com/lit/ds/symlink/lm317.pdf. [Accessed: 13-Feb-2023].

4.4.7 Revision Table

1/21/2023	First rough draft written
2/1/2023	Updated the interfaces
2/2/2023	Updated the general Validation
2/3/2023	Added all the missing data

4.5 Enclosure

4.5.1 Description

The enclosure handles the 3D prints that will house the main PCB and the structure that will hold the one-way mirrors in place. Individual pieces will be printed that slot together to create the full enclosure. The enclosure needs to be lightweight and durable, so the pieces will all be printed using PETG filament to increase strength.

4.5.2 Design

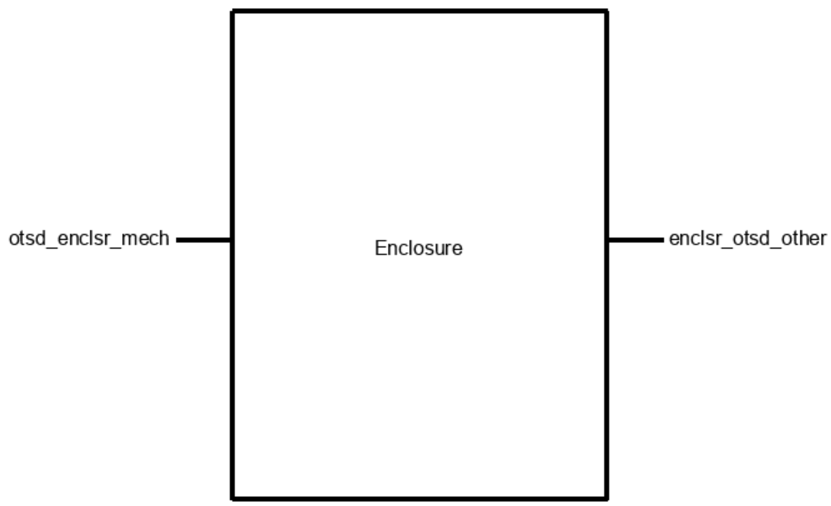


Figure 1: Black Box of Enclosure

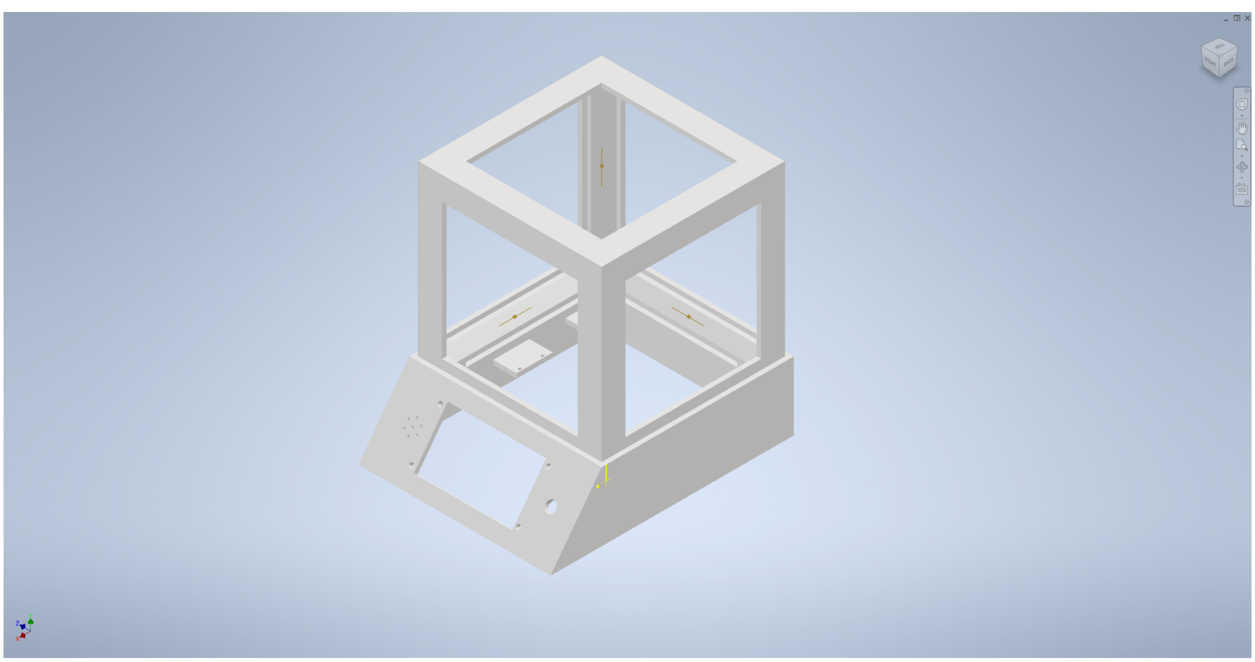


Figure 2: Full Enclosure Assembly

The enclosure for our system is composed of six separate pieces consisting of five panels that hold the acrylic panels and one base that holds the PCB, LCD, and speaker. The five panels and the base are held together using neodymium magnets equally spaced along the edges. This design allows for the panels to be snapped together easily and makes it simple to take the system apart.

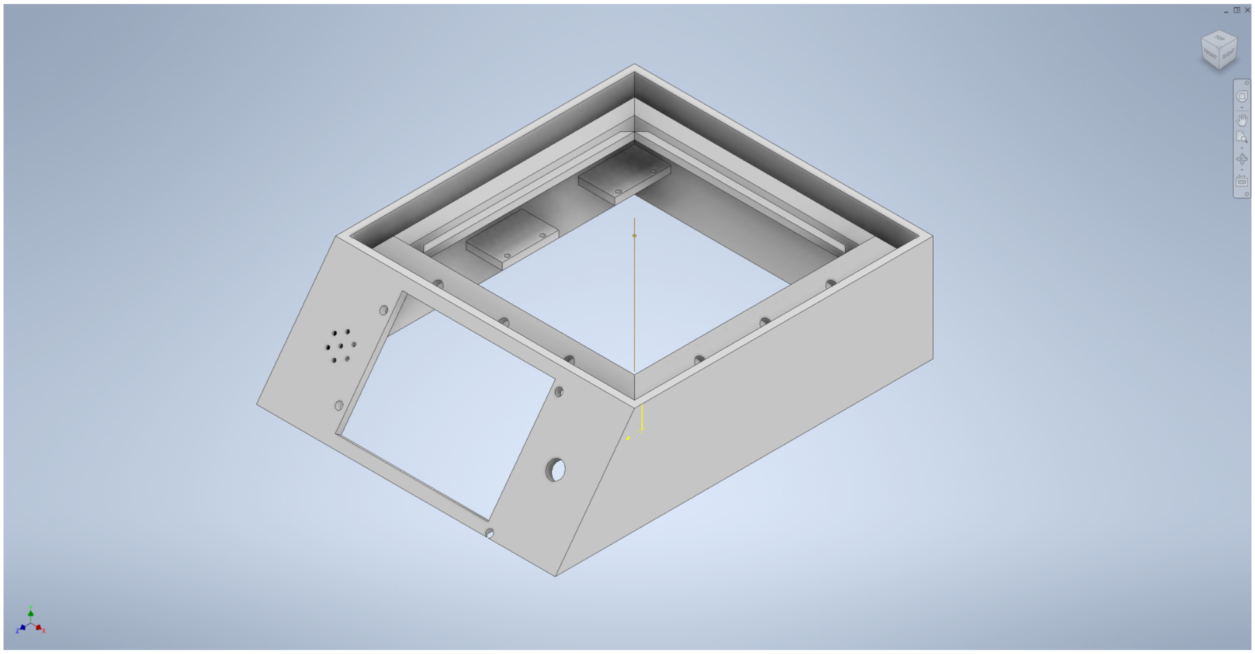


Figure 3: Enclosure Base

The base holds the majority of the electronics of the system. The PCB is mounted on the inside and is screwed into small ledges to hold it firmly in place. The LCD, speaker, and rotary encoder are mounted on the front of the base at a 45-degree angle. This angle makes it easier to view the LCD screen clearly from many angles and projects the sound from the speaker to the user.

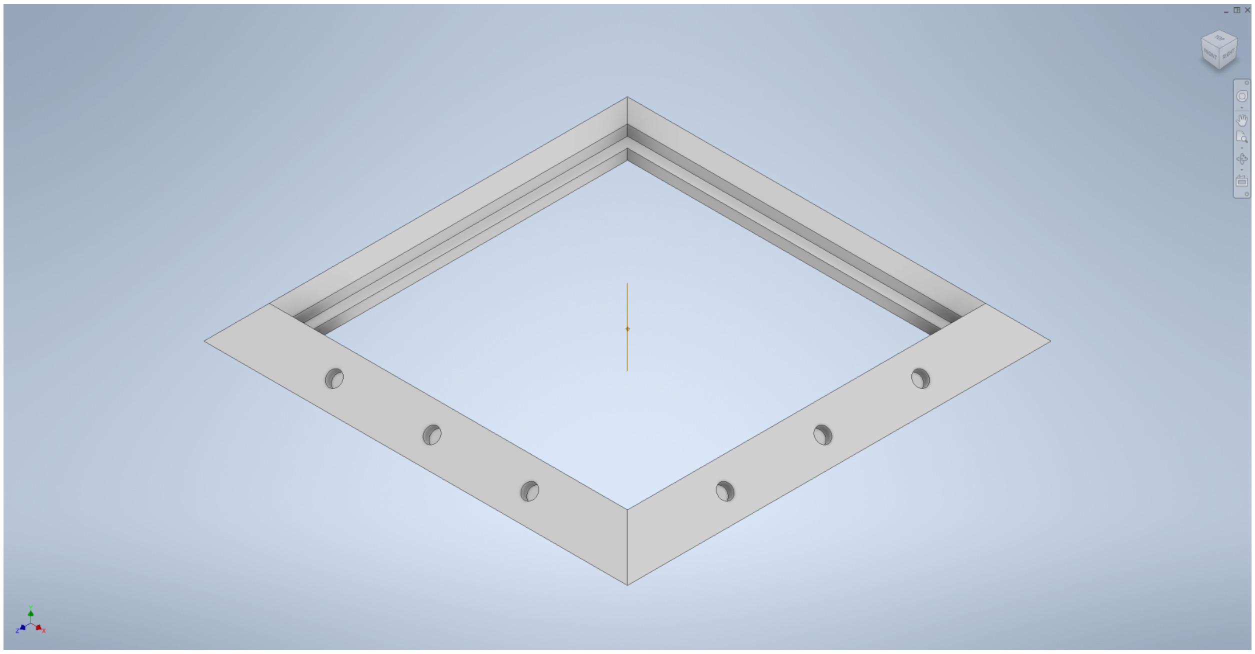


Figure 4: Enclosure Side Panels

The side panels are designed to snap together with each other to allow for easy assembly/disassembly and to ease the requirements of the 3D printing process. The inside of the panel is a 4”x4” square with a small lip to hold the acrylic panels in place. There is also a small strip at a 45-degree angle that is half the size of the LED strips that we use. This strip allows us to mount the LED strips inside the cuber easily and improves the viewing experience due to the angle.

4.5.3 General Validation

The primary goal of this enclosure design is to have a design that is easy to manufacture and assemble. This is achieved by separating portions of the enclosure into individual pieces that can be printed in a shorter time than if the pieces were printed as a single object. This can be seen in the side panels. Making the side panels individual pieces that snap together lets us 3D print several short prints rather than one long print. It also allows us to replace side panels that become damaged.

The side panels are designed to hold the acrylic panels and the LEDs in place to create the infinity effect. They achieve this goal by holding the acrylic panels at right angles of each other. This right angle means that all panels are always opposite of another mirrored panel and repeatedly reflect. To create the right angle, the panels are printed with a 45-degree angle on all sides so when two panel edges are placed against each other at 90-degree angle is created. Joining the panels also has the effect of creating a .4” strip that the LEDs can be mounted to. This strip is also at a 45-degree angle to improve the reflections that are made.

The base is designed to hold the side panels, PCB, LCD, speaker, and rotary encoder. The side panels are held in place by a combination of magnets set at a 45-degree angle and a small side wall. The magnets make sure that the panels slide into the correct positions, and the side walls add extra support. The PCB is held in place on the inside by screwing it into small ledges printed into the base. The LCD screen is held on the front of the enclosure and screwed onto a

45-degree slope. The speaker is held in place with a small amount of glue on the inside of the enclosure in a circular hole. The rotary encoder has a hole that it protrudes through and is held in place with a nut that screws onto its built in threading.

A different design that was considered was to print individual edges of the cube that would either slot into corner pieces or magnetize to each other. This design has the advantage of greater modularity because individual edges could be replaced or swapped around. It was decided against because the separate edges meant that there was a decrease in structural strength. The design also required more pieces to be printed, and this increased the time it took to prepare a 3D print for actual use.

4.5.4 Interface Validation

otsd_enclsr_mech : Input

Interface Property	**Why is this interface this value?**	**Why do you know that your design details <u>for this block</u> above meet or exceed each property?**
Fasteners: Magnets will be used to join the panels together and attach them to the base. Three will be used per edge	To allow for easy assembly and disassembly, magnets are used to secure the panels to each other and the base	Information only
Other: Must have a length less than 7"	One of our engineering requirements is that the system should be compact enough to fit on a desk and should have all of its dimensions be smaller than 7”	Information only
Other: Must have a width less than 7"	One of our engineering requirements is that the system should be compact enough to fit on a desk and should have all of its dimensions be smaller than 7”	Information only
Other: Must have a height less than 7"	One of our engineering requirements is that the system should be compact enough to fit on a desk and should have all of its dimensions be smaller than 7”	Information only

enclsr_otsd_other : Output

Other: Mounting for LCD	We need an LCD to display information to the user, so the enclosure must hold it in place for the user to view.	Information only
Other: Mounting for acrylic panels	The infinity effect requires acrylic panels to be held facing each other in a cube shape.	Information only
Other: Mounting for speaker	The enclosure needs to hold a speaker in place to play audio for the user.	Information only
Other: Mounting for barrel jack	We are using a barrel jack as the input for our 12V supply.	Information only
Other: Mounting for PCB	The PCB must be held in place by the enclosure to prevent wires from being disconnected.	Information only

4.5.5 Verification

1. Fully assemble the enclosure
2. Measure the length of the enclosure
3. Measure the width of the enclosure
4. Measure the height of the enclosure
5. Confirm LCD is mounted within the enclosure
6. Confirm acrylic panels are mounted within the enclosure
7. Confirm speaker is mounted within the enclosure
8. Confirm barrel jack is mounted within the enclosure
9. Confirm PCB is mounted within the enclosure

4.5.6 References

4.5.7 Revision Table

3/11/2023	Kelton: Created initial document
3/15/2023	Kelton: Added information to Design and General Validation

4.6 ESP32 Microcontroller

4.6.1 Description

For our project, we plan to use the ESP32 as our microcontroller to control the LEDs, LCD screen, speaker, and Wi-Fi/Bluetooth connection. The ESP32 block will be connecting to both the hardware of the system and the code controlling other blocks. The ESP32 operates on 3.3V logic and is powered off the output of the power supply. The ESP32 is used to complete the affordable price and app controlled system requirements. The ESP32 has built in Wi-Fi/Bluetooth, so it is possible for the user to control the system using either connection with the app. The ESP32 is also a very cheap microcontroller for its performance, making it possible to control all the system hardware at a low price.

4.6.2 Design

This block covers the ESP32 itself and its connections to physical devices of the system and the code of the system. The physical devices it communicates with are the LCD, LEDs, and the speaker. The code blocks that it communicates with are the LED code, the LCD code, the speaker code, and the Bluetooth/Wi-Fi code. The ESP32 is also connected to the power supply of the system and is powered by a 3.3V connection.

Here is the black box image of the connections to the ESP32. The ESP32 takes in a 3.3V input from the power supply. The ESP32 outputs to three pieces of hardware, the LCD, the LEDs, and the speaker. The ESP32 must also be able to make a connection over Bluetooth to the app that is used to control various parts of the system.

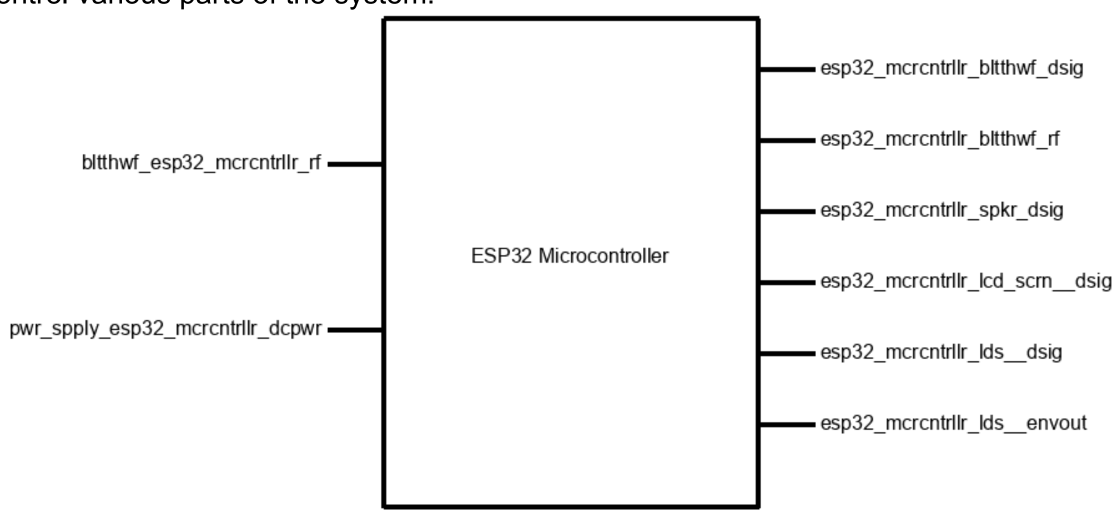


Figure 1: Black Box of ESP32

Here is a more detailed view of how the ESP32 connects with the other parts of the system. Here we can see the protocols that the ESP32 is using to control the pieces of hardware in the system. The LEDs are controlled using a protocol called NRZ, which is a proprietary protocol similar to PWM. The speaker is controlled by an I2S signal which receives audio data from the Bluetooth connection. The LCD screen is controlled using a SPI connection.

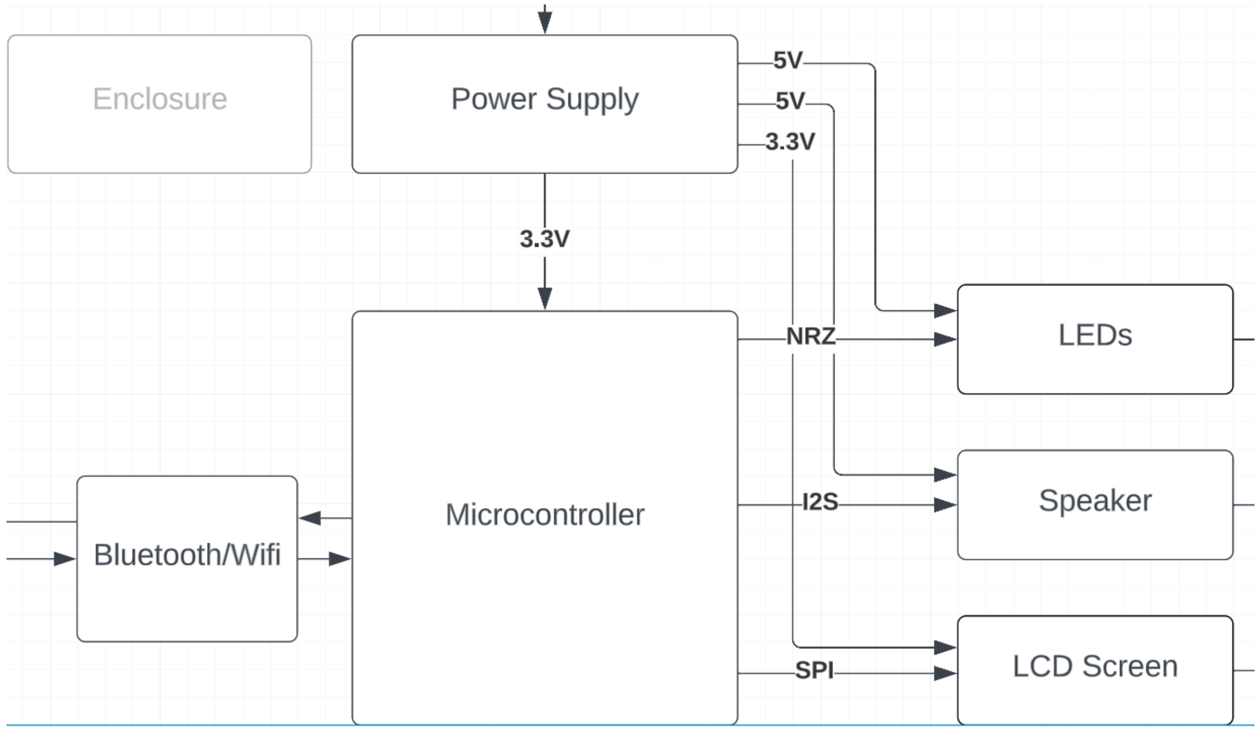


Figure 2: Block Diagram with connections to other blocks

4.6.3 General Validation

One major factor in deciding to use the ESP32 was the availability of coding libraries. The ESP32 is compatible with most major Arduino libraries and has many libraries written specifically for it. There is also a library that was created for controlling the LEDs that we planned to use. Having all of those libraries available meant that we would be able to some very powerful functions to improve the efficiency of our code, rather than having to write every function ourselves.

Cost was a major factor in choosing the ESP32. One of our engineering requirements is that the system components must cost less than $40 combined. This requirement combined with our initial estimated budget limited our options down to only a couple of microcontrollers, including the Arduino Nano, Arduino Nano 33 BLE, and the Raspberry Pi Pico. From these options, we decided that the ESP32 was the best choice because it had a similar price to the Nano and Pico but significantly greater computing power [1][2].

Another major factor in deciding to use the ESP32 was the fact that it has a dual-core microprocessor [3]. The system has several systems that need to be able to run simultaneously without issue. While the LEDs are changing color, it is very possible that the LCD or the speaker would need to be running as well. By having a microcontroller with dual cores, it becomes possible to design the code so that different functions can be running on both cores at the same time. This allows greater flexibility in how the code is written and makes it easier to control multiple parts of the system at once.

One reason the ESP32 fits well into our system is because it has many communication protocols that it supports. It supports I2C, I2S, UART, SPI, and PWM with a built-in ADC and

DAC [3]. This support allowed us to easily control the devices that we wanted to use and made it simple to find other alternatives.

An alternative to using the ESP32 would be to use the Arduino Nano 33 BLE. The Nano 33 has many of the same features that made the ESP32 our chosen microcontroller. The Nano 33 has built Wi-Fi and Bluetooth, allowing us to design a system without a dedicated Wi-Fi/Bluetooth circuit [2]. It is also can make use of the many pre-written libraries that make coding the ESP32 significantly easier. One major difference though is the price of the Nano 33. The Nano 33 typically costs around $26 which would make it extremely difficult to meet our engineering requirements of costing less than $40 [2].

4.6.4 Interface Validation

Table 1: Esp32_mcrcntrllr_bltthwf_rf: Input

Interface Property	Why is this interface property this value?	Why do you know that your design details for this block above meet or exceed each property?
Other: Must be able to configure a wifi connection	The project must be able to display real-time information about the user’s area.	Information only
Other: Must download information from a smartphone over Bluetooth	The project be controllable by the user with a smartphone app	Information only
Other: Must be able to configure a Bluetooth connection with a smartphone	The project be controllable by the user with a smartphone app	Information only
Other: Must download information over wifi	The project must be able to display real-time information about the user’s area.	Information only

Table 2: Esp32_mcrcntrllr_spkr_dsig: Output

Logic-Level: 3.3V	The esp32 operates off of a voltage range of 2.3V to 3.6V with a nominal voltage of 3.3V.	ESP32 Datasheet, pg 21: The operating voltage of ESP32 ranges from 2.3 V to 3.6 V. When using a single-power supply, the recommended voltage of

		the power supply is 3.3 V
Max Frequency: 2.5Mhz	This is the listed typical communication frequency for an I2S connection, so it is the max frequency we expect to use for our speaker.	I2S bus specification pg 3: Typ: T = 400ns
Rise Time: 60ns	This is the expected clock rise time for an I2S connection	I2S bus specification pg 3: Max 60ns

Table 3: Esp32_mcrcntrllr_lcd_scrn__dsig: Output

Logic-Level: 3.3V	The esp32 operates off of a voltage range of 2.3V to 3.6V with a nominal voltage of 3.3V.	ESP32 Datasheet, pg 21: The operating voltage of ESP32 ranges from 2.3 V to 3.6 V. When using a single-power supply, the recommended voltage of the power supply is 3.3 V
Max Frequency: 40Mhz	We plan to communicate with our LCD screen at a frequency of 40Mhz	TFT_eSPI User_Setup.h ln 349: // With an ILI9341 display 40MHz works OK, 80MHz sometimes fails
Other: Must successfully make a connection using SPI with another device	The LCD screen we plan to use is controlled by an SPI connection	Information only

Table 4: Esp32_mcrcntrllr_lds__dsig: Output

Logic-Level: 3.3	The esp32 operates off of a voltage range of 2.3V to 3.6V with a nominal voltage of 3.3V.	ESP32 Datasheet, pg 21: The operating voltage of ESP32 ranges from 2.3 V to 3.6 V. When using a single-power supply, the recommended voltage of the power supply is 3.3 V
Max Frequency: 800 KHz	The typical frequency of the LEDs that we plan to use is 800 KHz so that is the max value we expect to see.	SK6812 Datasheet, dynamic parameters: typ 800 KHz
Other: DOUT Transmission Delay: 500 ns	The max transmission delay for the LEDs we plan	SK6812 Datasheet, dynamic parameters: Max

	to use is 500 ns.	DOUT transmission delay, 500ns

Table 5: Pwr_spply_esp32_mcrcntrllr_dcpwr: Input

Inominal: 50mA	We aren't powering any devices using the ESP, so we expect the nominal current to be around 50mA while the ESP is performing normal operations.	Insight Into ESP32 Sleep Modes & Their Power Consumption: Modem sleep, 20mA. We expect our nominal to be slightly higher than this from the times when Wi-Fi or Bluetooth are turned on.
Ipeak: 260mA	At its peak when both Wi-Fi and Bluetooth are being using we expect the current consumption to spike to around 260mA	Insight Into ESP32 Sleep Modes & Their Power Consumption: Active Mode 160-260mA
Vmax: 3.6	We are powering the ESP32 off of it's 3.3V pin, which has an absolute max input of 3.6V	ESP32 Datasheet, pg 46, Table 13: VDDA, VDD3P3, VDD3P3_RTC, VDD3P3_CPU, VDD_SDIO, Max: 3.6V
Vmin: 3.0	We are powering the ESP32 off of it's 3.3V pin, and it is recommended not to go below 3.0V when powering this way	ESP32 Datasheet, pg 46, Table 14: VDDA, VDD3P3_RTC,note 1 VDD3P3, VDD_SDIO (3.3 V mode), Min 3.0V

4.6.5 Verification

ESP32 Power Verification

1. Set up an ESP32 so it is being powered by a power supply set to 3.3V
    i. During the testing, the current draw will be monitored to verify the interface inominal
2. Set the power supply to 3.0V and confirm the ESP is still functioning
3. Set the power supply to 3.6V and confirm the ESP is still functioning.
4. Reset power supply to 3.3V for the rest of the testing

Speaker/I2S Verification

5. Attach the ESP to a computer and upload I2S testing script
    i. GPIO 32 will be set as SCK, GPIO 33 as SD
6. Attach an oscilloscope probe to GPIO 32

7. Using the oscilloscopes built in tools measure the frequency of the signal on the connection
    i. This connection is the Esp32_mcrcntrllr_spkr_dsig CLK signal and should measure at 2.5Mhz
8. Detach the oscilloscope probe and move it to GPIO 33
9. Measure the voltage on the connection
    i. This is the logic level of Esp32_mcrcntrllr_spkr_dsig should be 3.3V
10. Measure the rise time of the connection
    i. This is the rise of time Esp32_mcrcntrllr_spkr_dsig and should be ~60ns

LED/NZR Verification

11. Attach the ESP to a computer and upload NZR testing script
    i. GPIO 32 will be set as the output
12. Attach an LED strip to a power supply set to 5V and the DIN attached to GPIO 32
13. Attach an oscilloscope probe to GPIO 32
14. Measure the logic level of the connection
    i. This is the logic level of Esp32_mcrcntrllr_lds__dsig and should be 3.3V
15. Measure the frequency of the data transmission
    i. This is the frequency of Esp32_mcrcntrllr_lds__dsig and should be a max of 800 kHz
16. Attach a second probe to DOUT of the first LED
17. Compare the delay between the signals of DIN and DOUT. The difference between them will be the transmission delay
    i. This value is the delay of Esp32_mcrcntrllr_lds__dsig and should be less than 500ns

LCD/SPI Verification

18. Attach the ESP to a computer and upload SPI testing script
    i. GPIO 18 as SCK, 19 as MISO, and 23 as MOSI.
19. Set up second ESP32 to act as a slave for the SPI connection and receive the communication
20. Using an oscilloscope attached to GPIO 18, 19, and 23 the voltage levels and frequency will be measured to determine if they meet the interface requirements. The second ESP will output a message on its serial monitor to display if the connection is made successfully.
21. Attach an oscilloscope probe to GPIO 18
22. Measure the frequency of the connection
    i. This is the CLK line for Esp32_mcrcntrllr_lcd_scrn__dsig and should measure at a max of 40Mhz

Bluetooth/Wifi Verification

23. Attach the ESP to a computer and upload Bluetooth testing script
24. A smartphone will connect to the ESP to determine if it can make a Bluetooth connection
25. Attach the ESP to a computer and upload Wifi testing script
26. The ESP will output information about the wifi network to confirm its connection

4.6.6 References

[1] “ESP32 Overview | Espressif Systems,” Accessed: Feb 11, 2023. [Online]. Available: www.espressif.com. https://www.espressif.com/en/products/socs/esp32

[2] “Arduino Nano 33 BLE Sense,” Accessed: Feb 11, 2023. [Online]. Available: *Arduino Online Shop*. https://store-usa.arduino.cc/products/arduino-nano-33-ble-sense

[3] “ESP32 Series Datasheet” Accessed: Feb 11, 2023. [Online]. Available: https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf#66

4.6.7 Revision Table

1/20/23	Kelton: Created initial document
2/10/23	Kelton: Added sections to verification sections Added title and block champion information
2/11/23	Kelton: Removed code interfaces Added revision statement Change interface properties for Updated block diagram and black box Added more detail to description Added descriptions of images to design section

4.7 Bluetooth/Wifi UI

4.7.1 Description

The esp32 will be able to communicate to phones using Wifi and Bluetooth. It will also be able to get data on the internet for time, weather, and date. The Wi-Fi connection will be made using the Blynk Arduino library, which will allow the ESP to get weather information and change the settings of the cube with the app. The Bluetooth connection will be made using the ESP A2DP library, which will allow for a device to be connected over Bluetooth and then stream audio.

4.7.2 Design

This block consists of code along with a Bluetooth and Wi-Fi connection. This block will be communicating with both the user and the esp32. This is all done through the usage of both Arduino code and Java.

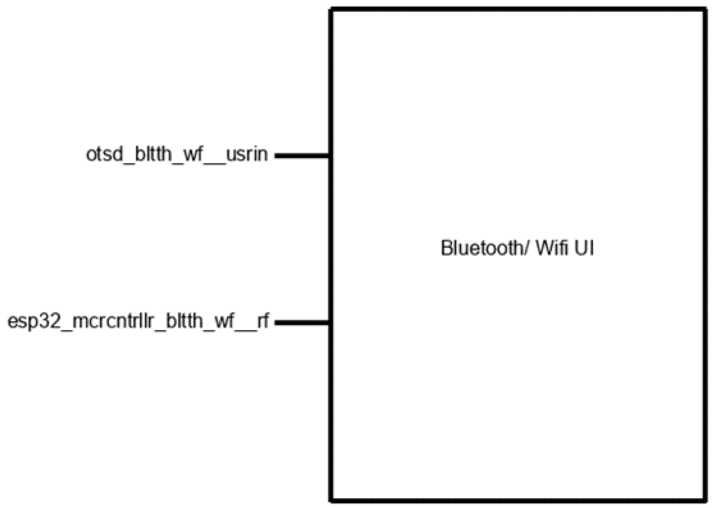


Figure 1

Looking at figure 1 there are two connections coming from the block. The first connection “outside Bluetooth Wi-Fi user input” will involve the user using the UI to communicate to the block and also the Bluetooth feature where the user just has to connect to the device to send an audio signal. The second connection “esp32 microcontroller Bluetooth Wi-Fi” will do a number of objectives such as downloading information from the web over a wifi connection and also take the inputs from the user and distribute them to their specified blocks.

4.7.3 General Validation

bluetooth

```
#include "BluetoothA2DPSink.h"

BluetoothA2DPSink a2dp_sink;

void setup() {
    i2s_pin_config_t my_pin_config = {
        .bck_io_num = 27,
        .ws_io_num = 25,
        .data_out_num = 26,
        .data_in_num = I2S_PIN_NO_CHANGE
    };
    a2dp_sink.set_pin_config(my_pin_config);
    a2dp_sink.start("MyMusic");
}

void loop() {
}
```

Figure 2

For the Bluetooth portion of this block, I have used code from A Simple ESP32 Bluetooth A2DP Library [4] as seen from figure 2. This code uses the library BluetoothA2DPSink.h to help make the bluetooth connection simpler. In order to create the I2S connection it will be converting the bluetooth audio and outputting them through pins 25, 26, and 27. The name of the bluetooth connection will be “MyMusic”. This will suffice for the bluetooth connection portion and also have audio come from the speaker.

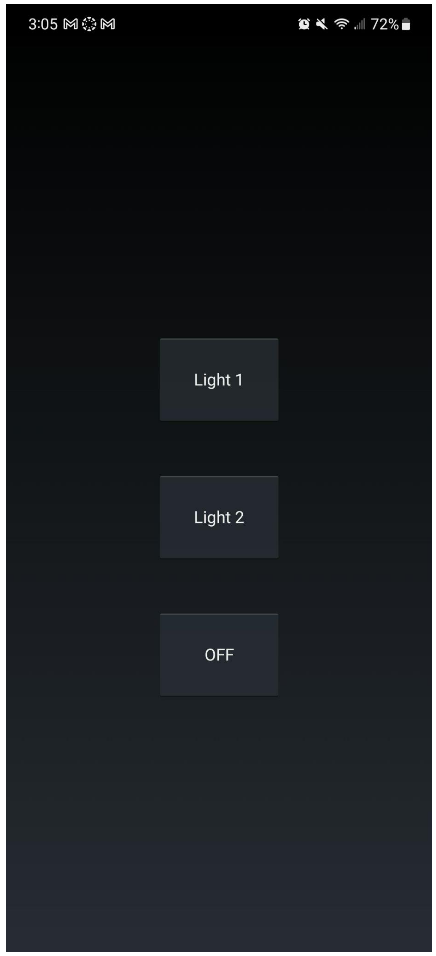


Figure 3

Figure 3 shows the UI portion of the block. Here we have a simple and clear UI so far that has three buttons that say “light 1” for the LED function 1, “light 2” for the LED function 2, and “OFF” to turn off the LEDs. This simplistic UI should be able to suffice for the requirements “user friendly” and “app”. This UI was made with code from Remotely Controlling ESP32 Using an Android App [2] and WS2812 FX Library for Arduino and ESP8266 [3]. This is a combination of both java for the UI and Arduino code for the communication between the UI and the esp32.

4.7.4 Interface Validation

esp32_mcrcntrllr_bltth_wf__rf: input

Interface property	Why is this interface property this value?	Why do you know that your design for this block meets or exceeds each property?
Other: Must download information from a web address over Wi-Fi	The esp32 must be able to collect information from the internet and display it onto our LCD screen.	We use a code that can collect data from a website in real time and display the data onto the screen.
Other: Must be able to configure a Wi-Fi connection from esp32	The user's phone will have a UI that will send signals to the esp32 using a Wi-Fi connection	We use a java code that sends signals to the esp32 which converts it to Arduino code that is then used to tell which operation to execute.
Other: Must stream audio over a Bluetooth connection from phone to esp32	The user can connect to the esp32 with a Bluetooth connection and send an audio signal.	An Arduino code for Bluetooth connection is used.

otsd_bltth_wf__usrin: input

Interface property	Why is this interface property this value?	Why do you know that your design for this block meets or exceeds each property?
Timing: Can switch between input in under a second	The UI's buttons can be quickly pushed at any given time.	User testing can determine the speed of the button signal which has consistently been under a second.
Type: Will have clearly labeled buttons on phone for user inputs	The UI must be easy to use for the user.	User testing will show it is easy to use due to its simplicity.

Usability: Clear UI that can control LEDs	The buttons labeled are clear enough that a user can understand it with ease.	User testing can determine that the button labels are clear.

4.7.5 Verification

Other: Must download information from a web address over Wi-Fi
1. Will use code from ESP32 HTTP Get [2] and upload to esp32.
2. Create a wifi connection to run code.
3. See esp32 output data onto the terminal and see if it matches real time data.

Other: Must be able to configure a Wi-Fi connection from esp32
1. This can be shown from the steps above .

Other: Must stream audio over a Bluetooth connection from phone to esp32
1. Will use code from A Simple ESP32 Bluetooth A2DP Library [4] and upload it to the esp32.
2. Will use the speaker block and connect it to the esp32.
3. Use a phone to connect to the esp32 via bluetooth and send an I2S signal.

Timing: Can switch between input in under a second
1. Using the UI, the user will be able to quickly press each button in under a second and the esp32 will be able to properly respond to each signal.

Type: Will have clearly labeled buttons on phone for user inputs
1. The UI will have clear labels for each button.
2. We will ask other users if they agree that the UI is clear.

Usability: Clear UI that can control LEDs
1. Each button will be easy to use.
2. We will ask other users if they agree that the UI is easy to use.

4.7.6 References

[1] benjineer.io. (2019, December 6). *Easy Iot – remotely controlling ESP32 using an Android app*. Instructables. Retrieved March 16, 2023, from https://www.instructables.com/Easy-IOT-Remotely-Controlling-ESP32-Using-an-Andro-1/

[2] *Esp32 HTTP get with Arduino IDE (OpenWeatherMap.org and ThingSpeak)*. Random Nerd Tutorials. (2022, October 27). Retrieved March 16, 2023, from https://randomnerdtutorials.com/esp32-http-get-open-weather-map-thingspeak-arduino/

[3] kitesurfer1404. (n.d.). *WS2812 FX Library for Arduino and ESP8266*. GitHub. Retrieved March 16, 2023, from https://github.com/kitesurfer1404/WS2812FX

[4] Schatzmann, P. (n.d.). *A simple ESP32 bluetooth A2DP library (to implement a music receiver or sender) that supports Arduino, Platformio and Espressif IDF*. GitHub. Retrieved March 16, 2023, from https://github.com/pschatzmann/ESP32-A2DP

4.7.7 Revision Table

Date	Description
2/16/2023	Added sections 5, 6, 7

4.8 Speaker

4.8.1 Description

For the product competition, our group will be creating an infinity mirror cube that is controlled by a microcontroller. One of the features that is part of the mirror cube is a speaker which is the block that I will be working on. The block's job is to take audio input from the ESP32 microcontroller using an I2S connection and output it into an 8-ohm speaker through an MAX98357B amplifier to which the user will be able to listen to music through the cube's base. The amplifier used is based on the Adafruit I2S Amplifier MAX98357. The purpose of the block is to satisfy part of the requirement titled "audio-responsive" as it will be able to take audio from the esp32 microcontroller and translate it to audio.

4.8.2 Design

For the design of the project the speaker will be a standard 8-ohm speaker, specifically the CMS-28588N-L152A. The current unit cost of this piece is $4.05, but of course if we buy this in bulk it can go down to around ~$2.50 depending on how many units we create. Additionally, there is the amplifier which will be connected to the speaker. The specific amplifier that the group would like to work with is the MAX98357A, along with a pcb we design using kicad. The MAX98357A has many pins, but for this project we will be using the sd_mode, bclk, lrclk, din, gnd, outn, outp, gain, and vdd pins . Using the datasheet for the MAX98357A, we will be using the (Left/2 + Right/2) PCM Operation with 6dB Gain schematic.

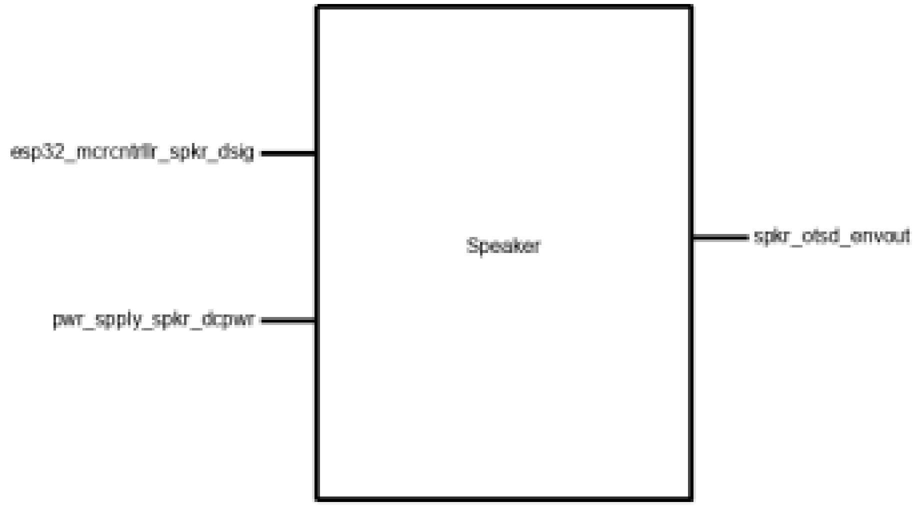


Figure 1. Block Diagram

Looking at the actual block in figure 1, there are two inputs and one output. For the first input titled "esp32_mcrcntrllr_spkr_dsig", the ESP32 will be sending the signal to the amplifier portion of the speaker block. The way it does this is by having a serial data connection for audio data, a bit clock to synch the transfer of data, and a word clock to indicate the start of a new audio sample. The MAX98357A will then amplify that data and send it through the speaker and result in the output "spkr_otsd_envout", which is audio output that the user can hear. The other input is "pwr_spply_spkr_dcpwr", which will be connected from the power supply block and will be transferring 5V at about 100mA nominal. This will power both the speaker and the amplifier. Figure 2 shows the type of connection the project has when connected.

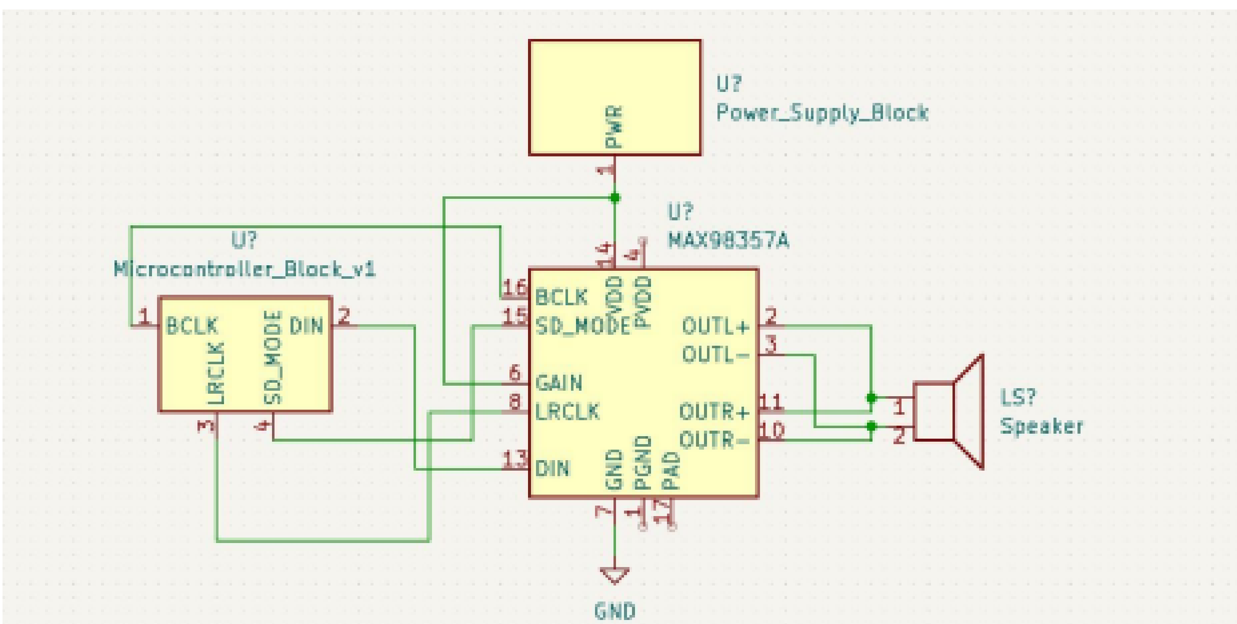


Figure 2. Block schematic

4.8.3 General Validation

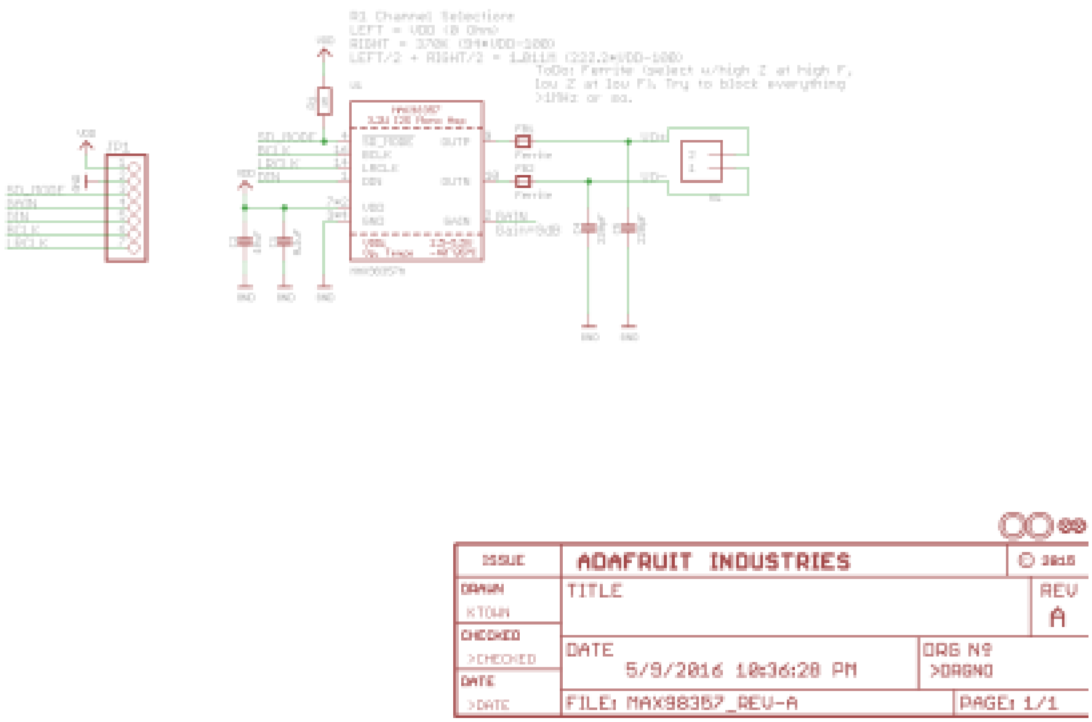


Figure 3. Adafruit Schematic

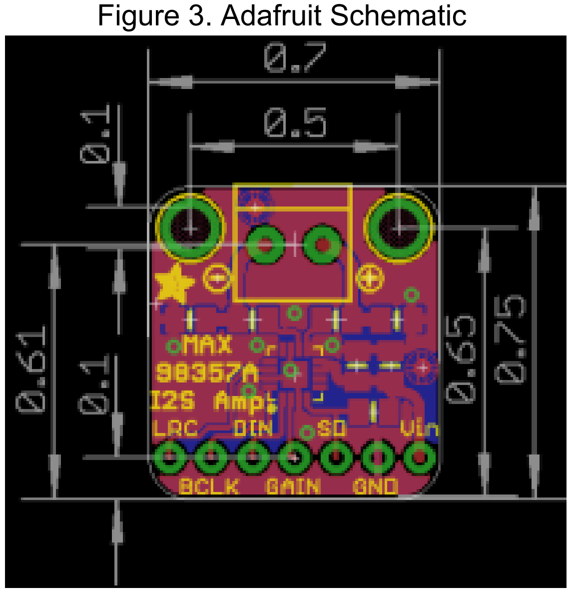


Figure 4. Adafruit PCB

For the PCB, I decided to use the PCB schematic from Adafruit, which can be seen in both Figure 3 and 4. The reasoning behind this is because Adafruit is open source so I will be able to base my schematic off of their current model. Also, if I can create a replica of their PCB, I will be able to make PCBs in bulk for much cheaper. This will satisfy the requirement titled “affordable price” where we want the block overall to be less than $50 when mass produced. For the Adafruit PCB, they use 4 capacitors with values of 10uf, 0.1uF, 220pF, a resistor with a value of 1M, and 2 ferrites. Using Digi-key, the quantity that we would be buying would be more than the hundreds, so the price for each part respectively would be $0.04, $0.05, and $0.003.

4.8.4 Interface Validation

Esp32_mcrcntrlr_spkr_dsig: input

Vmax: 5V	This voltage is provided by the ESP32 pin and will power the MAX98357 board.	• Connects to Vin of Max98357 board
I2S connection	The ESP32 will use 3 pins to create a I2S connection	• Pin 26: BCLK Used for I2S SCK • Pin 22: Din Used for I2S SD • Pin 25: LRC Used for I2S WS

4.8.5 Verification

4.8.6 References

[1] “Automotive MLCC - AVX Corporation.” [Online]. Available: https://datasheets.kyocera-avx.com/AutoMLCC.pdf. [Accessed: 12-Feb-2023].

[2] “CL21A106KAYNNNE.” [Online]. Available: https://www.digikey.com/en/products/detail/samsung-electro mechanics/CL21A106KAYNNNE/3888549. [Accessed: 11-Feb-2023].

[3] “Maxim integrated - analog, linear, and mixed-signal devices,” *MAX98357A*. [Online]. Available: https://www.analog.com/media/en/technical-documentation/data sheets/MAX98357A-MAX98357B.pdf. [Accessed: 12-Feb-2023].

[4] “RMCF / RMCP.” [Online]. Available: https://seielect.com/Catalog/SEI RMCF_RMCP.pdf. [Accessed: 12-Feb-2023].

[5] “Series: CMS-28588N-L152 description: Speaker - mouser electronics,” *CMS 28588N-L152*. [Online]. Available: https://www.mouser.com/datasheet/2/670/cms_28588n_l152-1776581.pdf. [Accessed: 12-Feb-2023].

[6] [Online]. Available: https://content.kemet.com/datasheets/F3102_MIL-PRF 55681.pdf. [Accessed: 12-Feb-2023].

4.8.7 Revision Table

Date	Description
2/11/2023	Daniel: Added sections 3 and 4. Revised errors.

5. System Verification Evidence

5.1 Universal Constraints

5.1.1 The system may not include a breadboard

Our system meets this requirement by using a custom PCB to connect all of our circuits together and to connect to the external components such as the LEDs and LCD.

5.1.2 The final system must contain a student designed PCB.

Our system uses a custom PCB for all of our circuit connections and to connect to the external components. The PCB has 141 pads, which meets the minimum requirement of 30 pads.

5.1.3 All connections to PCBs must use connectors.

Our PCB uses JST connectors for all the connections to external components such as the LCD, LEDs, and the rotary encoder. The 12V input is connected through a barrel jack connector.

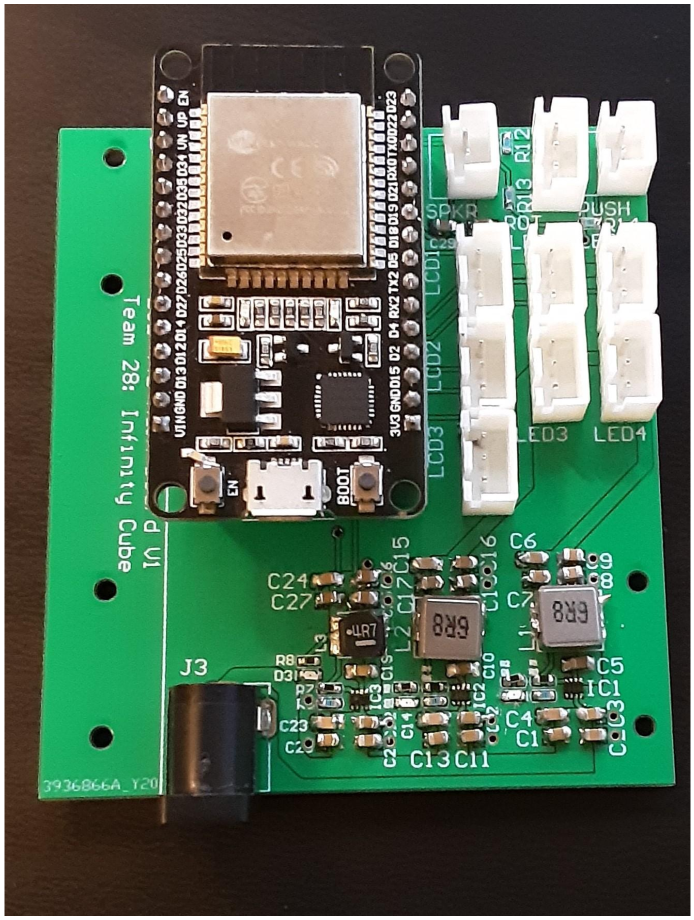


Figure 1: PCB with connectors

5.1.4 All power supplies in the system must be at least 65% efficient.

With a 12V input at .095A, our power supply supplied a .200A load at 4.95V. This means the power supply was outputting 4.95*.2=1W of power and the input was supplying 12*.095=1.14W. This means our power supply is 1/1.14 = 87.7% efficient, which meets the requirement.

Figure 2: 12V input running at .095A

!

Figure 3: 4.95V output supplying .2A

5.1.5 The system may be no more than 50% built from purchased 'modules.'

Purchased Modules	Built Modules	Total Percentage
LCD Screen	Power Supply	⅜ = 37.5%
ESP32 Microcontroller	Speaker	
RGB LEDs	Enclosure	
	PCB	

	I2S Amplifier	

The system only uses three purchase modules of the eight total blocks. The purchased modules are the LCD screen, the ESP32 microcontroller, and the LEDs. The three out of eight modules gives a percentage of 37.5% which is under the 50% limit.

5.2 Requirements

5.2.1 Compact

5.2.1.1 Project Partner Requirement
The cube will be small enough to fit on a desk

5.2.1.2 Engineering Requirement
The system will be placed inside of a cube with a total dimension that falls within a 7”x7”x7” space.

5.2.1.3 Verification Process
1. Assemble all components of the system
2. Measure max length,
3. Measure max width
4. Measure max height

5.2.1.4 Testing Evidence

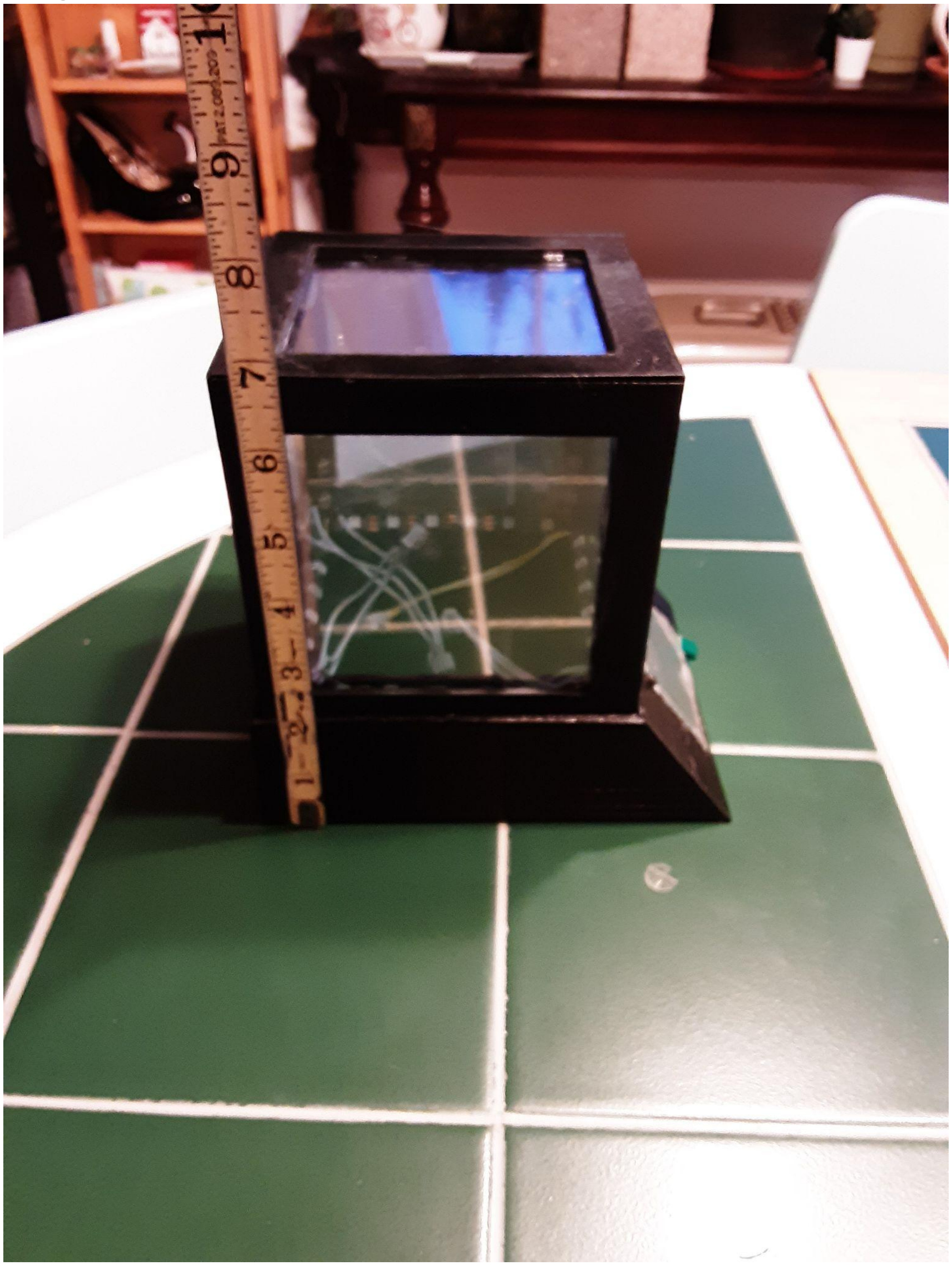


Figure 1: Height Dimension

Figure 2: Width Dimension

Figure 3: Length Dimension

5.2.2 Affordable Price

5.2.2.1 Project Partner Requirement
The infinity cube will be affordably priced

5.2.2.2 Engineering Requirement
The total cost of components and assembly will be less than $50

5.2.2.3 Verification Process
1. Create a BOM of all materials used in the system
2. Add individual components and their price to the BOM

3. Add materials that don't use a full unit e.g. filament to the BOM. The price of these items will be calculated by taking the ratio of the material used multiplied by the price of the purchased material.
4. Add the cost of all materials used together

5.2.2.4 Testing Evidence
The total cost of the system comes out to be $49.85 [1]

5.2.3 App

5.2.3.1 Project Partner Requirement
The cube will be controlled with an app

5.2.3.2 Engineering Requirement
The cube will have an app that will run on a standard android/IOS phone that can be used to change the settings of the cube

5.2.3.3 Verification Process
1. Two phones will be found for testing. One will be a phone running the Android OS and one will be running IOS.
2. The app will be downloaded onto both phones.
3. The cube will be plugged in and connected to Wi-Fi
4. The Android phone will then use each option in the app to change the appearance of the cube LEDs.
5. Steps 3 and 4 will then both be repeated using the IOS phone.

5.2.3.4 Testing Evidence
Video of android app control: Link
Video of iPhone app control: Link

5.2.4 Audio Responsive

5.2.4.1 Project Partner Requirement
The cube will have a mode that makes the LEDs audio-responsive

5.2.4.2 Engineering Requirement
The system will become brighter and dimmer based on the volume of the sound being output by the speakers and 9 out of 10 viewers will report the lights are responding to the audio.

5.2.4.3 Verification Process
1. A phone will be sourced and the app to control the cube will be downloaded.
2. The phone will be connected to the cube through the app.
3. Using the app, the cube will be set to its audio responsive mode.
4. The phone will be connected over Bluetooth
5. The phone will then play a song or video using the cube speakers as the audio output.

5.2.4.4 Testing Evidence
Video of audio responsive: Link
Survey responses: Link

5.2.5 Led Colors

5.2.5.1 Project Partner Requirement
The cube will have different modes to change the LEDs

5.2.5.2 Engineering Requirement
The system will have at least five different light modes

5.2.5.3 Verification Process
1. Set up the system and connect to a power source
2. Connect a team member's phone to the system
3. Use the app to select an LED mode
4. Cycle through possible LED modes

5.2.5.4 Testing Evidence
Video of light modes: Link

5.2.6 Screen

5.2.6.1 Project Partner Requirement
The cube will display important information

5.2.6.2 Engineering Requirement
The system will show system information including at least; current LED mode, volume, time, weather, and date.

5.2.6.3 Verification Process
1. Assemble the system and connect to a power source
2. Connect the system to a team member's phone
3. Show the current time and date displayed on the cube's screen
4. Show the volume displayed
5. Show the weather displayed
6. Show the current LED mode displayed

5.2.6.4 Testing Evidence

Figure 4: Screen displaying Date, Time, Weather, Temperature, Current Led mode, and volume

5.2.7 User Friendly

5.2.7.1 Project Partner Requirement
The cube will be user friendly

5.2.7.2 Engineering Requirement
The system will be voted as 'user-friendly' by 9 out of 10 users after they have read the user guide and made use of all the cube's features.

5.2.7.3 Verification Process
1. Find 10 users who haven't previously used the infinity cube
2. Give each user 15 minutes to familiarize themselves with the cubes features using the user guide
3. Ask each user to demonstrate several of the cubes features
4. User will be asked if they think the system is user-friendly based on their experience

5.2.7.4 Testing Evidence
Video of user using the cube: Link
Survey responses: Link

5.2.8 Wall Powered

5.2.8.1 Project Partner Requirement
The cube will be wall powered

5.2.8.2 Engineering Requirement
The system will run from a single 120VAC NEMA-12P plug.

5.2.8.3 Verification Process
1. Cube will be assembled with all components
2. A wall wart using a standard 120VAC NEMA-12P plug will be connected to a wall power outlet
3. The other end of the wall wart will be connected to the system
4. The system will be set to one of its LED modes to demonstrate normal functionality.

5.2.8.4 Testing Evidence


Figure 5: System powered by 120VAC wall plug

5.3 References

[1] "Estimated Project Costs" Accessed: Mar 15, 2023 [Online] Available:
Estimated Project Costs

5.4 Revision Table

3/15/2023	Kelton: Added justifications to Universal constraint sections Added content to system requirements sections
5/7/2023	Kelton: Added content to sections 3-8

6. Project Closing

6.1 Future Recommendations

6.1.1 Technical Recommendations

A current issue with the infinity cube is the fact that the infinity effect is greatly diminished when the cube is in an area with bright light. To improve this issue, new mirror panels could be researched and implemented. The goal would be to find a one mirror film or panel that has a greater reflectivity than the panels that are currently being used. One possible solution would be to use one way mirror panels which are made to be reflective as part of their creation process instead of with a film that is applied. There are several vendors that will sell custom one way panels, and they could be used as a solution to this problem [1].

Another issue with the infinity cube is the difficulty involved with creating the right angle connections for the LED strips. The current method is to cut the strips to length and solder wires between the pads, then bend the strips to 90 degrees. This often puts the LED pads under too much stress and the pads are ripped off. A possible solution would be to create custom flexible PCBs that would connect together in a more durable manner. OSHPARK and JLCPCB both offer a flexible PCB service which could be used to create these custom PCBs[2][3].

A potential improvement to the usability of the cube would be to use the LCDs touch functionality for user inputs. Currently, the user can control the cube using a rotary encoder with a push input. This is a very limited input method and makes it difficult to input complicated information such as wifi credentials. The solution would be to redesign the PCB to add connections for the additional pins of the LCD [4]. New code would also need to be written to support a touch input with the current UI.

Another potential point of improvement would be to create a separate version of the infinity cube that is battery powered. Using a 12V wall wart for the power input means that users are restricted in where they can display the cube. Adding a battery eliminates this problem and makes the cube a more desirable product to a larger consumer base. To implement this solution, a small enough battery would need to be found that could fit in the case while also providing reasonable operating life. An 18650 Li-ion battery might be an option for this and can be easily sourced in bulk [5]. The PCB would also need to be redesigned to include charging circuitry and a connection for the battery.

6.1.2 Global Impact Recommendations

An area to look at in regard to the cube is the usage of plastic for the enclosure. The cube is currently standing at 7x7x7 inches, which is made through the use of a 3D printer. This could be an issue in the future due to their being a large amount of plastic that could potentially become waste in the future. A solution that can be looked into is reducing the amount of plastic that we use for the enclosure. This can range from either reducing the overall size of the enclosure, or to try and find a more compact way to store the circuitry into the base. Another way can be using a different 3D printing filament, such as PLA, which is a biodegradable material [6].

The next issue involves the components of the cube. We are currently unsure where some of the components came from, as some of them could have come from places that have unfair labor laws. A good way to do this would be to either source from local retailers, or to try to find companies that have certificates for fair labor practices. These certificates can include SA8000 (Social Accountability International) or Fairtrade [7].

6.1.3 Teamwork Recommendations

A problem our team faced during this project was difficulty communicating about what each team member was working on and what help a team member needed at any given moment. Our recommendation to combat this is to establish a common platform that the whole team can use to communicate (e.g., Discord, Microsoft Teams, Google Document, emails). This will allow the team to have the best flexibility to collaborate, update, and share concerns about the way how the project is going. There are many resources that can help a team more effectively communicate. One suggested resource is “Teamwork and Collaboration: The Key to Success in Engineering Projects” who says "Communication and collaboration are critical to the success of any engineering project. No single individual has all the skills, experience, and perspectives necessary to solve every problem that arises during the design and development process." [8].

Another issue that we faced was difficulty defining individual roles in the beginning, which led to wasted time from redundant work efforts. The recommendation to prevent this is to have clear roles for each team member to make sure every team member is being assigned to a task. This has the benefit of making sure that each team member knows what they should be working on and allows them to work on tasks they are most suited for. This will prevent what is called a duplication of effort to prevent two people doing the same task. "The Importance of Defining Employee Roles," is an excellent article about this idea that says, "Clearly defined roles allow each employee to know what is expected of them and how their work affects the overall success of the company. It also eliminates confusion and reduces misunderstandings, making it easier for employees to work together." [9]

6.1.4 References

[1] “One way mirror,” Gavrieli, 12-Jan-2022. [Online]. Available: https://gavrieli.com/one-way-mirror/. [Accessed: 28-Apr-2023].

[2] "Flex PCBS," *OSH Park Docs ~ Services ~ Flex PCBs*. [Online]. Available: https://docs.oshpark.com/services/flex/. [Accessed: 28-Apr-2023].

[3] "Flex PCB now available at JLCPCB from special offer of $25 - JLCPCB news". [Online]. Available: https://jlcpcb.com/help/newsdetail/113-Flex-PCB-Now-Available-at-JLCPCB-From-Special-Offer-of-$25. [Accessed: 28-Apr-2023].

[4] W. by M. Damirchi, "Interfacing 2.8 inch TFT LCD touch screen with ESP32," Electropeak, https://electropeak.com/learn/interfacing-2-8-inch-tft-lcd-touch-screen-with-esp32/ (accessed May 14, 2023).

[5] "18650 batteries," 18650BatteryStore.com, https://www.18650batterystore.com/collections/18650-batteries (accessed May 14, 2023).

[6]"SA8000® standard," SAI, https://sa-intl.org/programs/sa8000/ (accessed May 14, 2023).

[7] "Pla 3D Printer Filament, 3D printer PLA filament 1.75mm ," *Amazon.com*. [Online]. Available: https://www.amazon.com/Comgrow-3D-Printer-PLA-Filament/dp/B085RFCYH7. [Accessed: 29-Apr-2023].

[8] M. Harris, "Teamwork and Collaboration: The Key to Success in Engineering Projects," Engineering.com, July 12, 2017. [Online]. Available: https://www.engineering.com/DesignerEdge/DesignerEdgeArticles/ArticleID/15199/Teamwork-and-Collaboration-The-Key-to-Success-in-Engineering-Projects.aspx. [Accessed: 28-Apr-2023].

[9] J. Rampton, "The Importance of Defining Employee Roles," Forbes, April 26, 2018. [Online]. Available: https://www.forbes.com/sites/johnrampton/2018/04/26/the-importance-of-defining-employee-roles/?sh=37d3b3a34a8a. [Accessed: 28-Apr-2023].

6.2 Project Artifact Summary with Links

Project GitHub Repository:
https://github.com/DanielAMaestas/Senior_Capstone

Circuitmaker PCB Files:
Note: In order to access the PCB files, an account must be created because Circuitmaker hosts all files online and doesn't allow the PCB or schematic files to be downloaded
https://365.altium.com/files/F415E748-1E26-4AC1-886D-686D96035B59

Inventor Enclosure Files:
https://drive.google.com/drive/folders/12-Z8xJjOstkEOZ1uyNAastyWT8Js4uAE?usp=share_link

User Guide Document:
https://docs.google.com/document/d/1PdhMV6A3MhZz50Q3vtyATTnIV1Asj3ar/edit

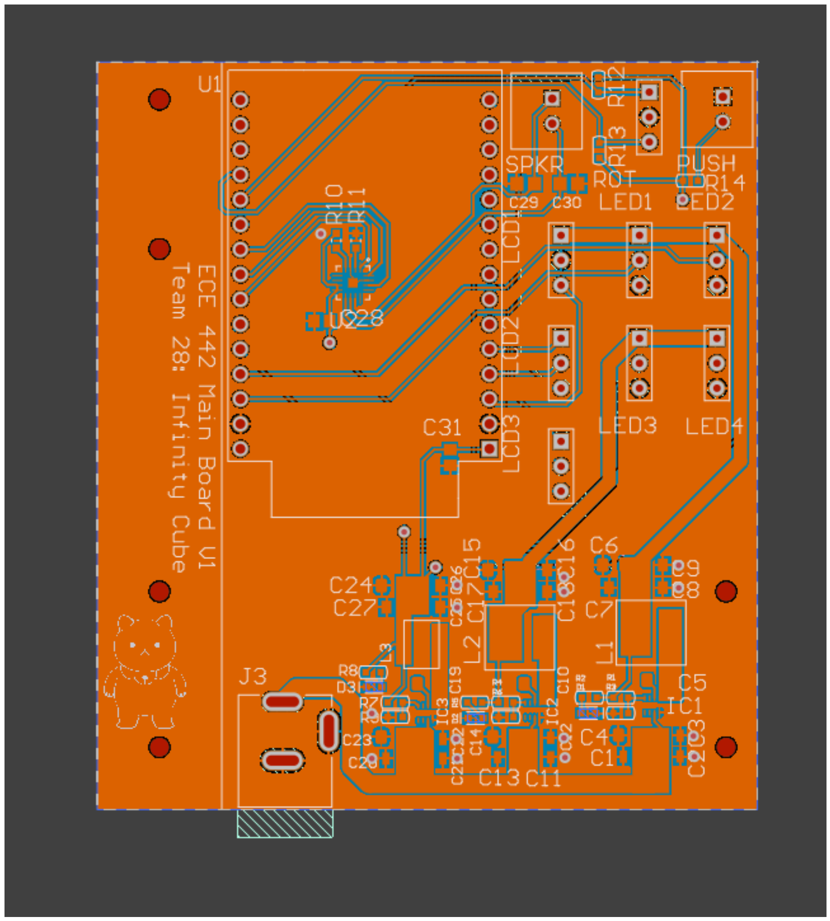


Figure 1: Project PCB

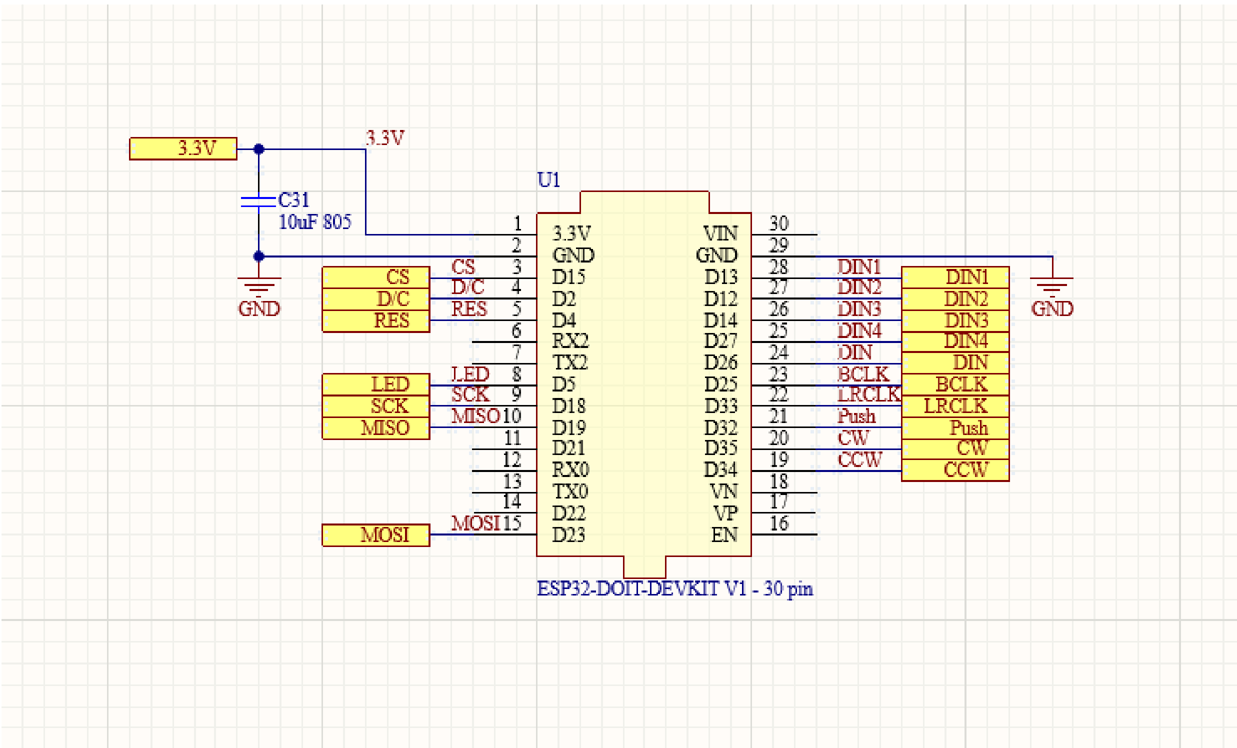


Figure 2: ESP32 Schematic

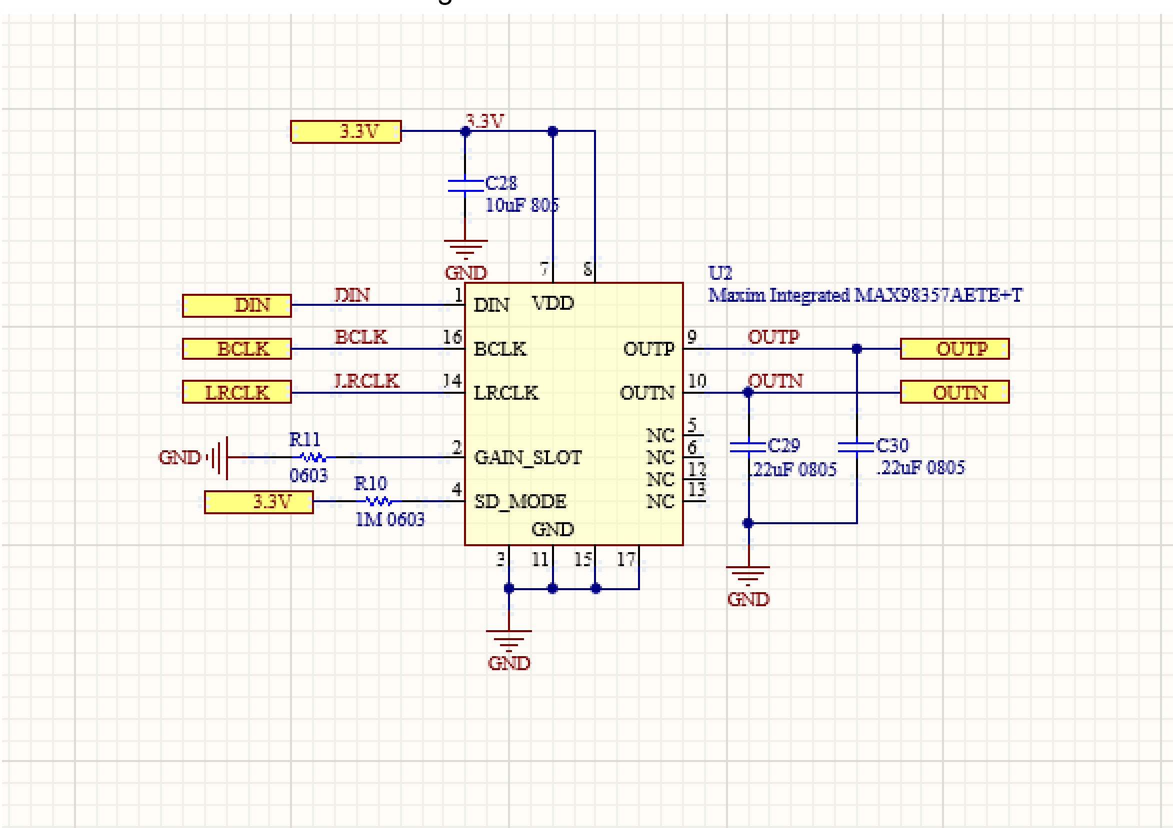


Figure 3: I2S Amplifier Schematic

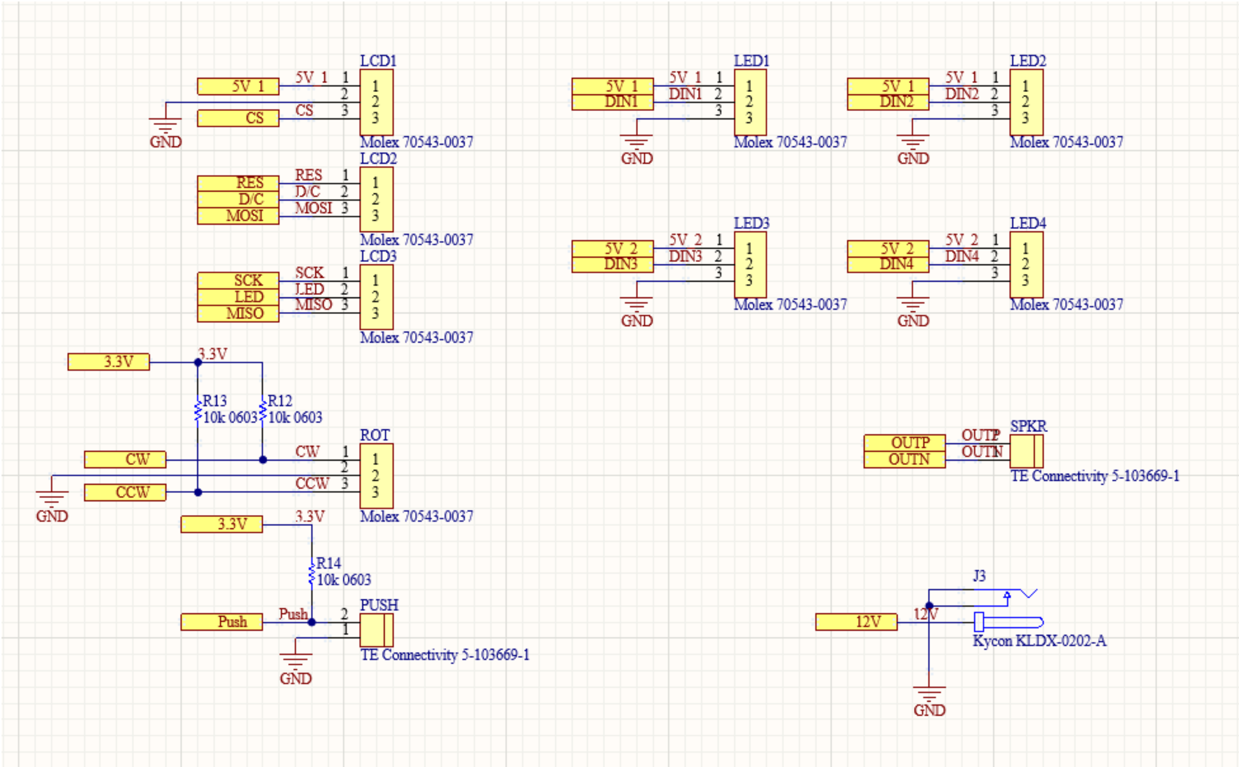


Figure 4: Connectors Schematic

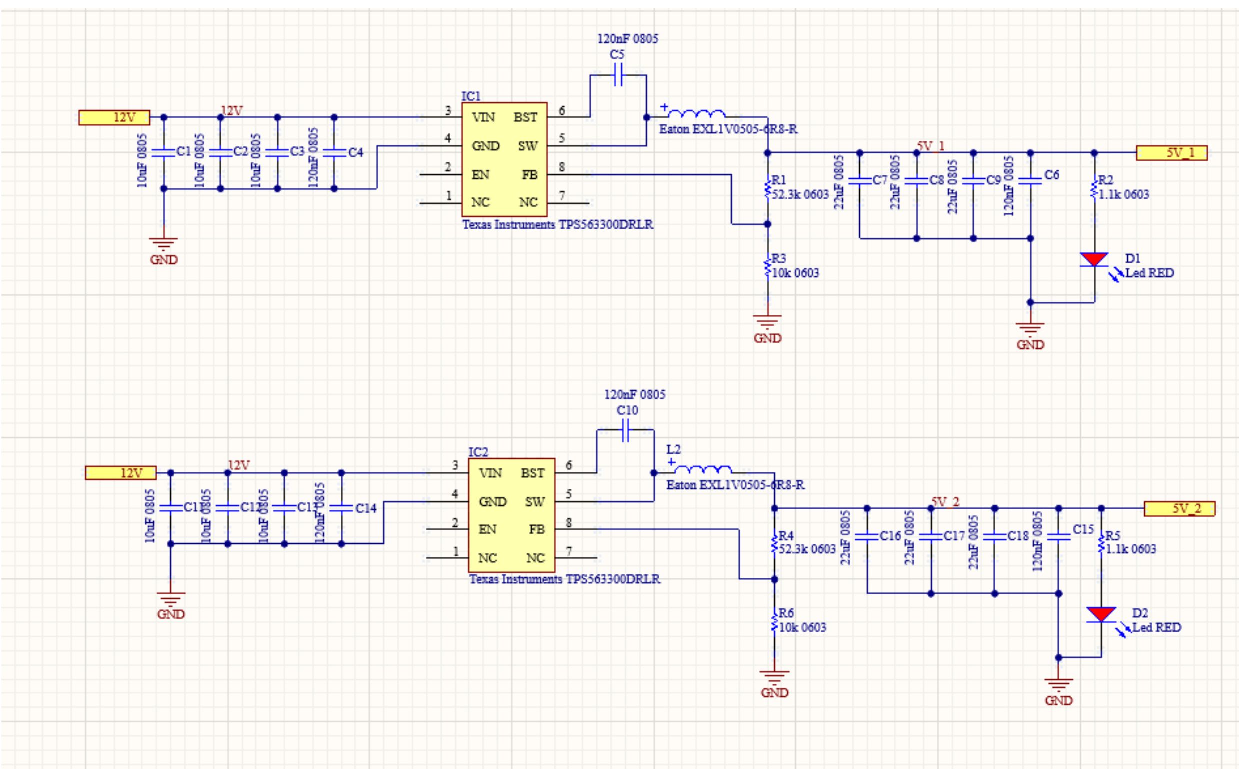


Figure 5: 12V-5V Buck Converter Schematic

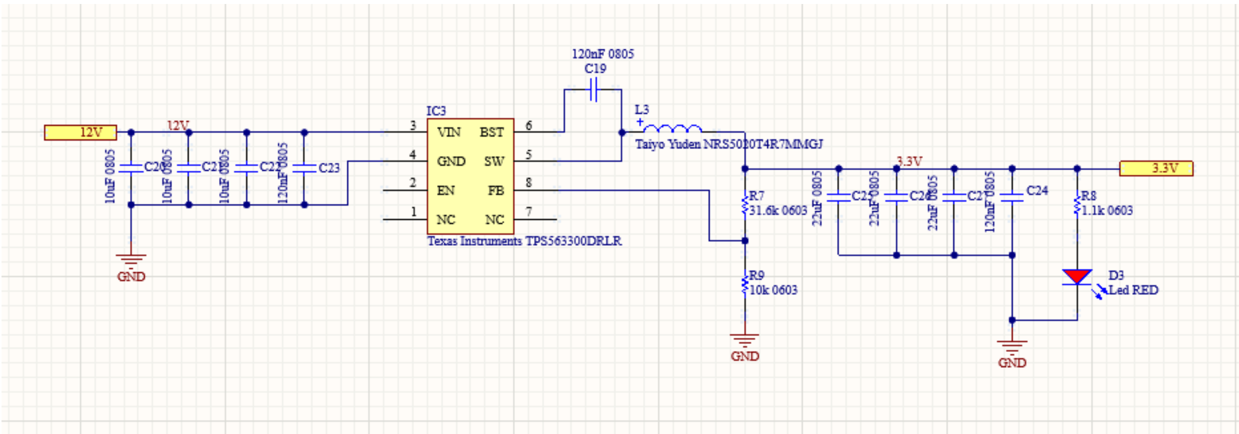


Figure 6: 12V-3.3V Buck Converter Schematic

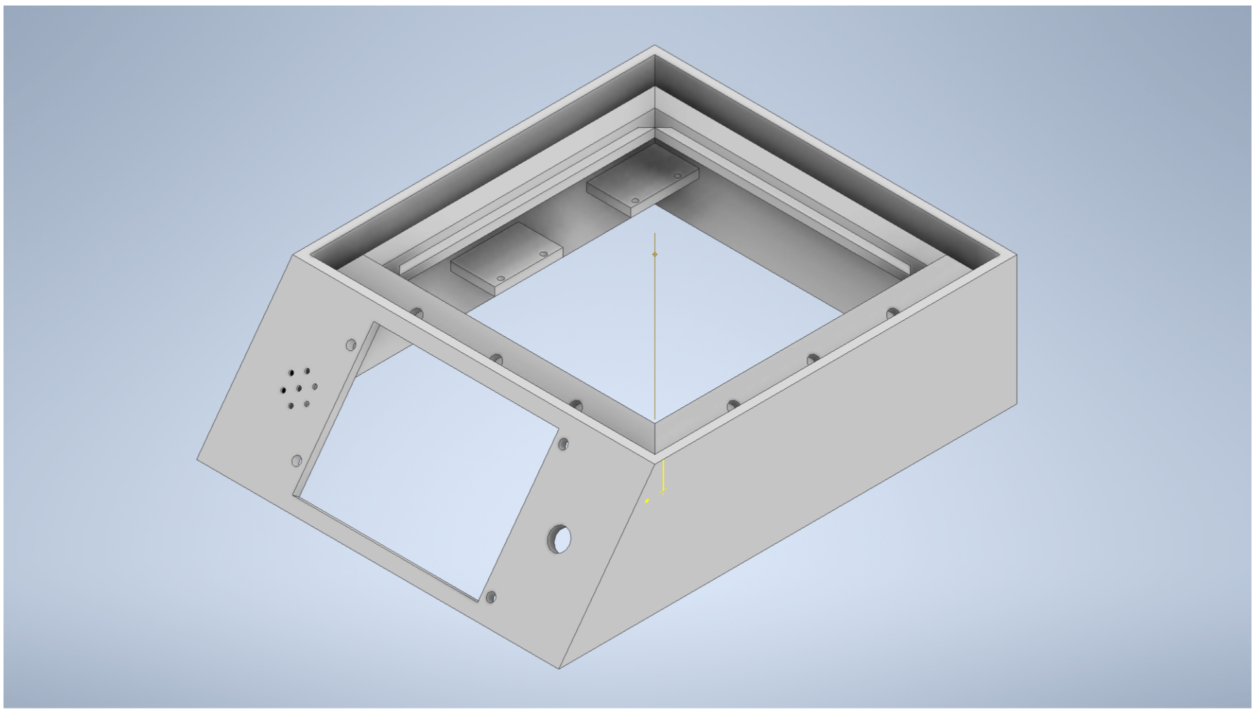


Figure 7: Enclosure Base

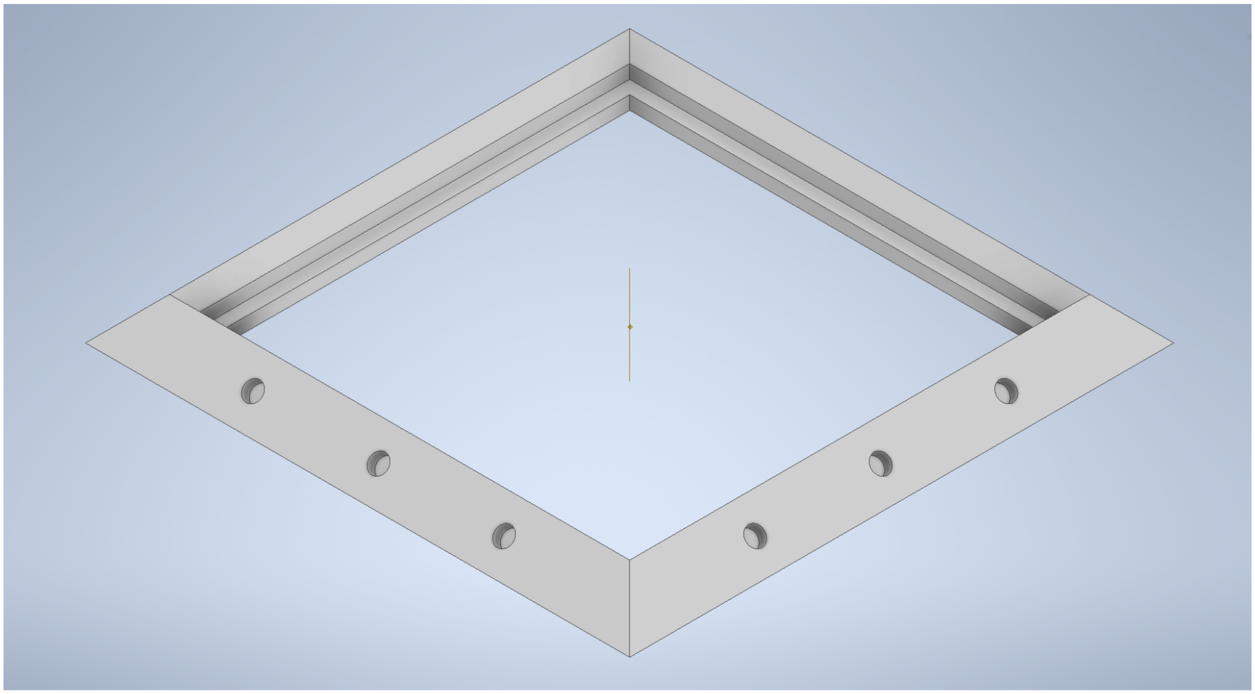


Figure 8: Enclosure Sides

6.3 Presentation Materials

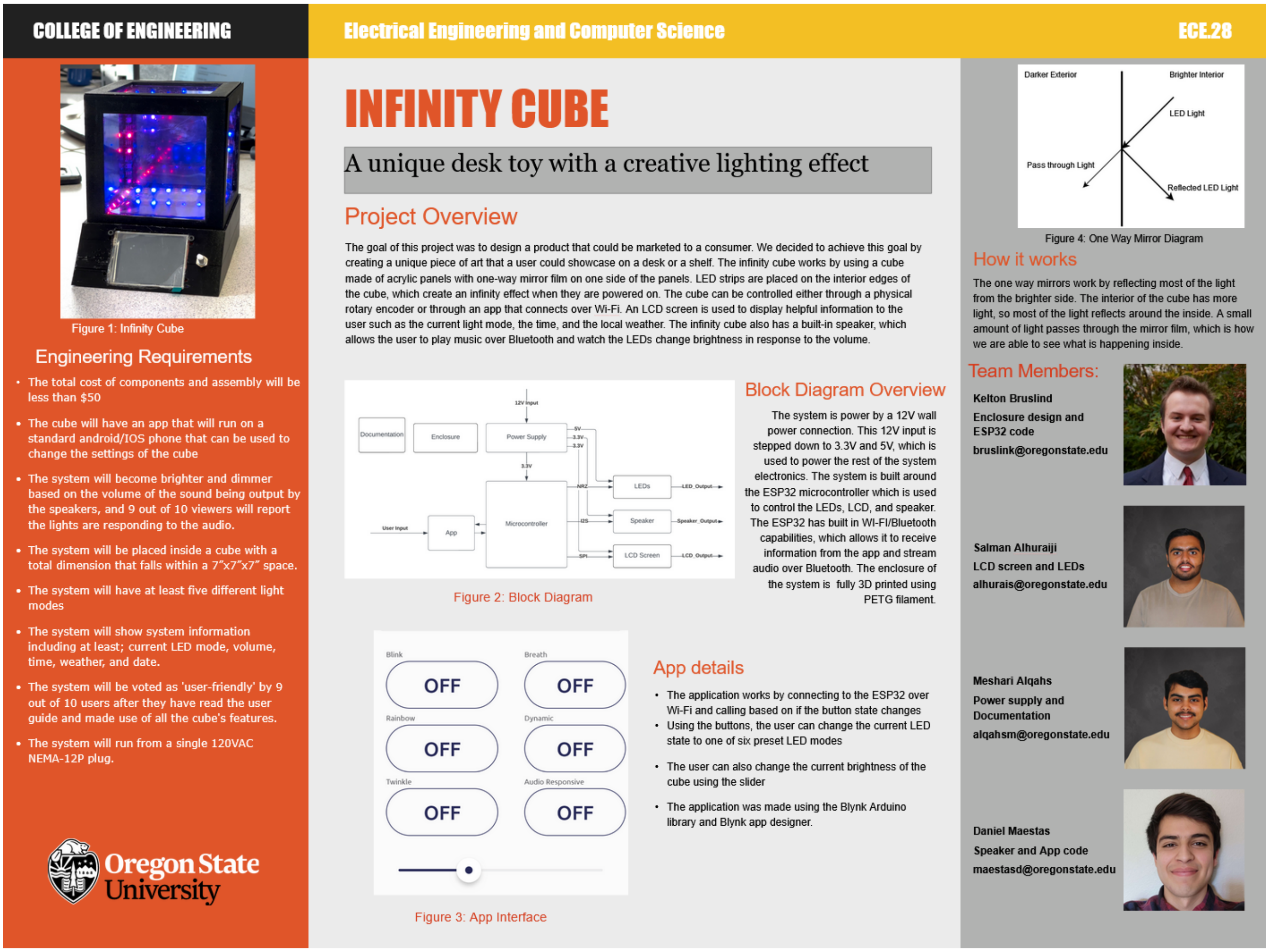


Figure 1: Project Poster

Project Showcase Link:
https://eecs.engineering.oregonstate.edu/project-showcase/projects/?id=XmiuwP8VkwFnDSbR