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Design Methodology

User Interface for a Restaurant Robot
Group I-23

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Contents

1 Introduction

In the rapidly evolving landscape of the hospitality industry, the integration of advanced technology is becoming increasingly pivotal to enhance customer experience and operational efficiency. Our project focuses on developing a sophisticated user interface for a restaurant robot, designed to streamline the interaction between customers and the restaurant's automated services. The objective is to create an intuitive and engaging system that leverages cutting-edge technologies to offer a seamless dining experience.

The restaurant robot is equipped with a voice-command interface, touch screen interaction, and real-time responses, all orchestrated through a combination of hardware and software components. The primary control unit, an ESP32 microcontroller, captures and processes voice commands using the INMP441 microphone IC and communicates with a Raspberry Pi to manage the touch screen interface. The audio responses are amplified using the MAX98357 I2S 3W Class D amplifier to ensure clear and audible feedback, even in noisy environments.

The touch screen interface, provided by a Waveshare Raspberry Pi touch screen, displays the menu and other interactive elements, allowing customers to order food and receive visual feedback through a user-friendly graphical interface. The integration of these components is designed to facilitate natural and efficient interactions, enhancing the overall dining experience.

This report details the various stages of the project, including the selection and integration of hardware components, software development, system design, and testing. It also explores the challenges encountered and the solutions implemented to overcome them, ensuring a reliable and user-centric system. The project underscores the potential of combining robotics and user interface design to innovate within the hospitality sector, paving the way for future advancements in automated customer service.

Our journey began with a clear vision: to harness the power of technology to improve customer service in the restaurant industry. Through meticulous planning, collaborative effort, and iterative development, we have created a robust system that not only meets but exceeds the expectations of a modern dining experience. This report encapsulates our comprehensive approach, the technical intricacies, and the successful realization of our project objectives.

2 Review Progress

Previous efforts in restaurant robotics have emphasized functionalities such as food delivery and order management. However, existing designs often lack robust user interfaces tailored to meet the specific needs of restaurant staff and patrons.

2.1 Robot restaurant in Tokyo

The user interface at the Robot Restaurant in Tokyo primarily revolves around the booking process and the overall guest experience within the venue. While dining options at the Robot Restaurant may be limited compared to traditional restaurants, the user interface likely involves interactions with staff or digital menus to place orders for food and drinks. This could include options for selecting from a menu of bento boxes, snacks, and beverages. The user interface may also include features to accommodate guests with special needs, such as wheelchair accessibility, assistance for individuals with mobility impairments, and considerations for those with sensory sensitivities.

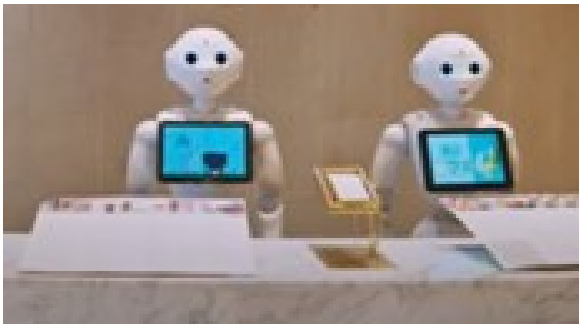


Figure 1: Robot Restaurant in Tokyo

2.2 RoboCafe (Budapest, Hungary)

RoboCafe offers customers the option to place their orders through digital interfaces such as touch-screen kiosks or tablets. The user interface of these devices would likely feature a user-friendly layout with pictures and descriptions of menu items. Customers could browse through different categories of drinks and snacks, select their choices, and specify any customization options. The user interface for payment involves traditional methods like cash or card payments at the counter, or it could include digital payment options integrated into the cafe's system. Customers have the choice to pay using mobile payment apps, credit/debit cards, or cash with clear instructions provided on the interface.

Figure 2: RoboCafe in Budapest, Hungary

2.3 The robot at Dal.komm Coffee (South Korea)

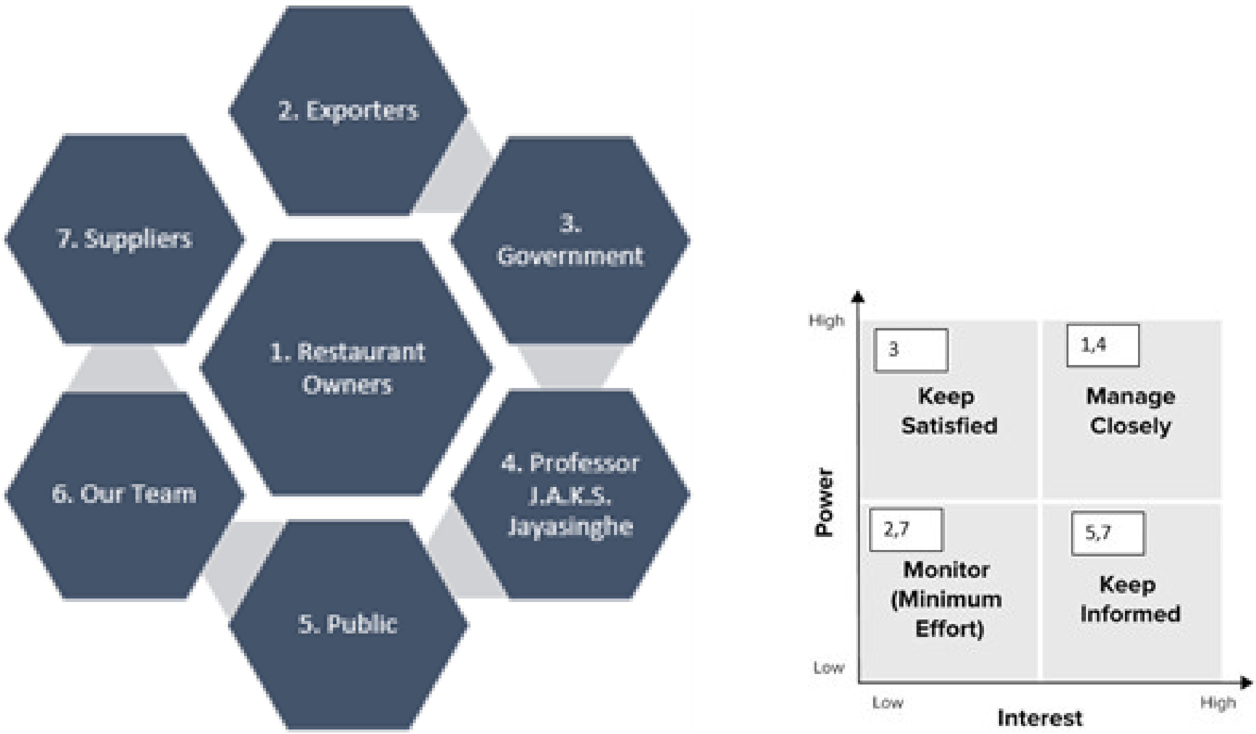
Dal.komm Coffee utilizes a robot barista to prepare and serve drinks. The user interface for interacting with the robot would involve intuitive communication methods. Customers may use touchscreens or buttons on the robot to indicate their drink preferences, specify the type of coffee, and adjust parameters such as temperature or foam level. The user interface includes options for customers to pay for their orders directly through the digital ordering system. Payment methods include mobile payment apps, credit/debit cards, or cashless transactions with clear instructions provided on the interface.

Figure 3: Robot at Dal.komm Coffee, South Korea

3 Identification of Stake Holders

Understanding the stakeholders and their interests is crucial in designing an effective user interface:

- **Restaurant Owners/Management:** Seek a user interface that enhances efficiency, customer satisfaction, and ease of operation.
- **Customers:** Prioritize a user-friendly interface for placing orders and tracking their status.
- **Restaurant Staff:** Require a straightforward interface for interacting with the robot and managing orders seamlessly.
- **Investors:** Interested in a user interface that maximizes the return on investment by improving operational efficiency and customer experience.



(a) (b)

Figure 4: Stakeholder Analysis

4 Observe Users

Our approach revolves around creating a user interface that prioritizes ease of use, efficiency, and seamless interaction between users and the restaurant robot:

- **Simple and Intuitive Design:** Craft a user interface with clear navigation and minimalistic design, ensuring ease of understanding for both customers and staff.
- **Mobile Application Integration:** Develop a mobile application for customers to place orders conveniently and track their status in real-time.
- **Kitchen Management Interface:** Implement a separate interface for restaurant staff to manage orders efficiently, identify bottlenecks, and communicate seamlessly with kitchen operations.
- **Robot Control Panel:** Design a user-friendly control panel for restaurant staff to interact with the robot, including initiating deliveries, adjusting routes, and monitoring performance.
- **Multi-Lingual Support:** Incorporate multi-lingual support in the user interface to cater to diverse customer and staff demographics.

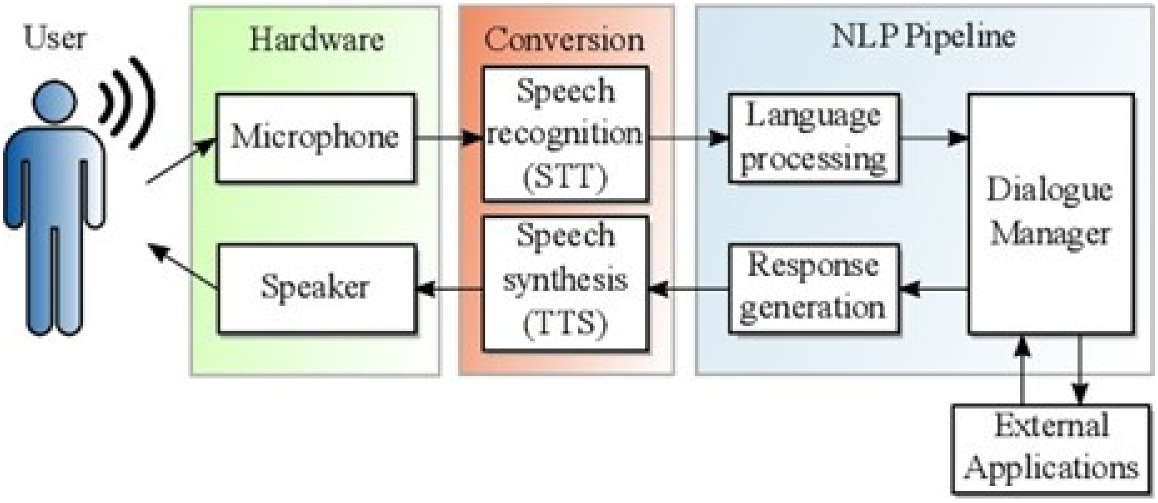


Figure 5: AI Assistant Architecture

4.1 Evaluation Criteria

- **Usability:** Evaluate how easily users can interact with the robot through the UI. Consider factors such as learnability, efficiency, memorability, error prevention, and satisfaction.
- **Accessibility:** Assess the accessibility of the UI to users with diverse needs, including those with disabilities or language barriers. Ensure that the interface is inclusive and can accommodate various users' requirements.
- **Integration with Robot Capabilities:** Evaluate how well the UI aligns with the capabilities of the restaurant robot. Ensure that the interface leverages the robot's sensors, actuators, and communication abilities effectively.
- **Feedback Mechanisms:** Determine whether the UI provides sufficient feedback to users, acknowledging their actions and guiding them through the interaction process.
- **Adaptability:** Assess the UI's ability to adapt to different scenarios and user preferences. Consider how the interface can be customized or personalized to enhance the user experience.

4.2 Experimental Steps

- **User Research:** Conduct user research to understand the needs, preferences, and pain points of potential users interacting with the restaurant robot. Use techniques such as interviews, surveys, and observation to gather insights.
- **Prototype Development:** Develop initial prototypes of the UI design based on the user research findings. Create wireframes or mockups to visualize the interface layout and functionality.
- **Usability Testing:** Conduct usability testing sessions with representative users to evaluate the prototypes. Gather feedback on the UI design, identify usability issues, and iterate on the prototypes accordingly.
- **Iterative Design:** Iterate on the UI design based on the feedback received during usability testing. Make refinements and improvements to address usability issues and enhance the user experience.
- **Validation:** Validate the final UI design through additional rounds of testing and feedback gathering. Ensure that the interface meets the needs of users and aligns with the objectives of the restaurant robot project.

4.3 Decision Making Process

- **Cross-functional Collaboration:** Involve stakeholders from various departments (e.g., design, engineering, marketing) in the decision-making process to ensure a holistic perspective.
- **Data-Driven Insights:** Base decisions on empirical data gathered from user research, usability testing, and feedback analysis. Use quantitative and qualitative data to inform design choices.
- **Prioritization:** Prioritize design decisions based on their impact on user experience, feasibility, and alignment with project goals. Focus on addressing critical issues and achieving key objectives.
- **Iterative Feedback Loop:** Establish an iterative feedback loop to continuously gather input from stakeholders and users throughout the design process. Use feedback to refine design decisions and drive improvements.

4.4 Further Steps in Project Completion

- **Implementation:** Translate the finalized UI design into a functional interface that can be integrated into the restaurant robot's software system.
- **Testing and Quality Assurance:** Conduct comprehensive testing of the implemented UI to ensure functionality, reliability, and compatibility with the robot's hardware and software components.
- **Training and Documentation:** Provide training materials and documentation for restaurant staff and users on how to interact with the robot through the UI effectively.
- **Launch and Rollout:** Deploy the restaurant robot with the finalized UI design in selected locations or pilot programs. Monitor performance and gather feedback during the initial rollout phase.
- **Continuous Improvement:** Establish processes for monitoring, evaluating, and improving the UI over time based on ongoing feedback and insights gathered from real-world usage.

By following these steps, we can plan effectively for the creation of a user interface for a restaurant robot, ensuring that the UI meets user needs, aligns with project objectives, and drives positive user experiences.

4.5 Customer Interaction

- **Intuitive Ordering Process:** Offer a seamless and user-friendly interface for customers to browse the menu, customize their orders, and place them with ease.
- **Real-time Order Tracking:** Enable customers to track the status of their orders in real-time, providing updates on preparation and delivery times.
- **Personalization:** Incorporate features that allow customers to save their favorite orders and preferences, making the ordering process quicker and more personalized for repeat visits.
- **Feedback and Support:** Integrate mechanisms for customers to provide feedback on their experience and access support if they encounter any issues with their orders.
- **Promotions and Recommendations:** Display promotional offers and personalized recommendations based on customer preferences and order history to enhance the dining experience.

4.6 User Observation Data

- Observations indicate that users appreciate interfaces that are straightforward and minimize the number of steps required to complete an action.
- Users show a preference for visual aids such as images and icons that help them quickly identify menu items and actions.
- Feedback suggests that real-time updates and transparency in the order process significantly enhance customer satisfaction.
- Customization options are highly valued, with users wanting the ability to easily modify orders according to their dietary preferences or taste.

4.7 User Requirements

We have identified the below mentioned points as the user requirements for the UI of a restaurant robot. These are the key considerations we have designed our concepts around.

- Ease of Use: The UI should be intuitive and easy for restaurant staff and customers to interact with, even if they are not familiar with advanced technology.
- Navigation Control: Restaurant Staff should be able to control the robot's movement, such as sending it to specific tables or areas of the restaurant.
- Order Management: The UI should allow staff to input and manage orders, including modifying or canceling orders as needed.
- Communication: There should be clear communication channels, such as text or voice commands, for staff to interact with the robot.
- Status Updates: The UI should provide real-time updates on the robot's status, such as its current location, battery level, and any issues it may encounter.
- Emergency Stop: A prominent emergency stop button or feature should be available in case the robot needs to be stopped immediately.
- Multilingual Support: If the restaurant serves customers who speak different languages, the UI should support multiple languages for ease of use.
- Feedback Mechanism: Users should be able to provide feedback or report issues directly through the UI, helping improve the robot's performance over time.

These requirements aim to ensure that the UI of the restaurant waiter robot is user-friendly, efficient, and capable of meeting the needs of restaurant staff and customers in a busy environment.

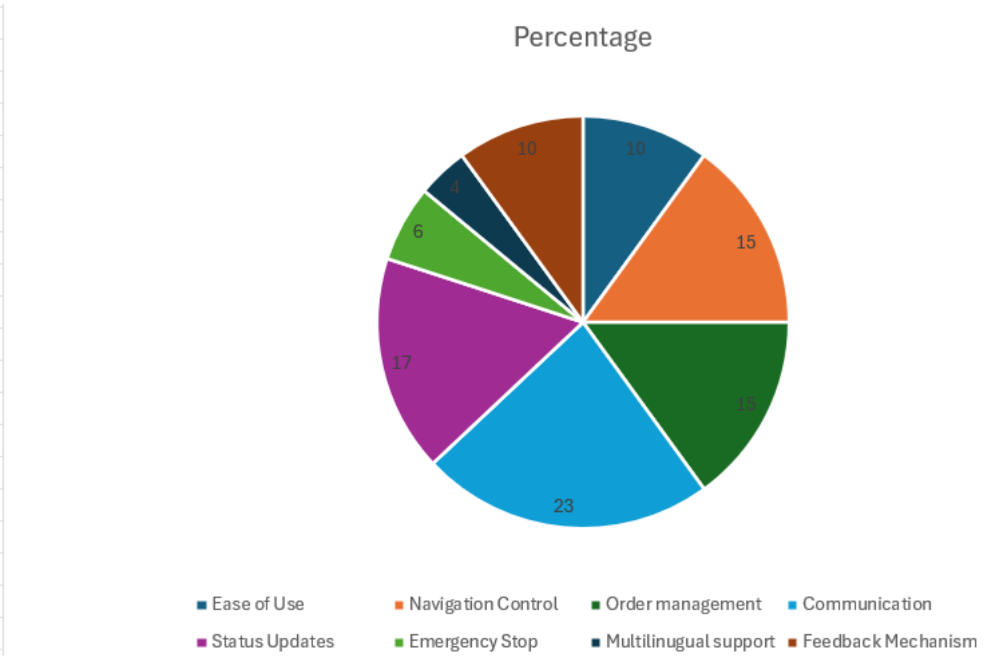


Figure 6: User Requirements

5 Need List

The development of a user interface for a restaurant robot involves several key components and resources to ensure seamless interaction between customers and the robot. Below is a comprehensive list of the needs identified for this project:

1. **ESP32 Microcontroller**:
    - **Function**: Serves as the main control unit for processing voice commands and controlling other components.
    - **Rationale**: Chosen for its integrated Wi-Fi and Bluetooth capabilities, high performance, low power consumption, and versatile I/O options.
2. **INMP441 Microphone IC**:
    - **Function**: Captures customer voice commands with high clarity.
    - **Rationale**: Selected for its high signal-to-noise ratio (SNR), digital I2S output for high-fidelity audio, and robust performance in noisy environments.
3. **Waveshare Raspberry Pi Touch Screen**:
    - **Function**: Displays the menu and enables customers to interact with the robot via touch input.
    - **Rationale**: Provides a high-resolution display, excellent touch responsiveness, seamless compatibility with Raspberry Pi, and durability suited for frequent use.
4. **Raspberry Pi**:
    - **Function**: Acts as the main computer for the touch screen interface, displaying the menu, processing touch inputs, and showing visual feedback like facial expressions.
    - **Rationale**: Chosen for its powerful processing capabilities, ease of integration with peripherals, and extensive community support.
5. **MAX98357 I2S 3W Class D Amplifier**:
    - **Function**: Amplifies the audio signals to drive the speakers for clear voice responses.
    - **Rationale**: Selected for its high efficiency, compact size, high output power, low distortion, and ease of integration with the ESP32's I2S interface.
6. **Speakers**:
    - **Function**: Outputs amplified audio for voice responses.
    - **Rationale**: Essential for delivering clear and audible responses to customers in a potentially noisy restaurant environment.
7. **Speech Recognition API**:
    - **Function**: Processes recorded voice commands and converts them into text or actionable commands.
    - **Rationale**: Provides accurate and reliable voice recognition capabilities necessary for understanding customer commands.
8. **Voice Synthesis API**:
    - **Function**: Converts text responses generated by the main computer into audible speech.
    - **Rationale**: Ensures natural-sounding and clear voice responses for effective communication with customers.

9. **Power Supply Units**:
   - **Function**: Powers all electronic components including the ESP32, Raspberry Pi, touch screen, and amplifiers.
   - **Rationale**: Provides reliable and sufficient power to ensure uninterrupted operation of the robot.
10. **Networking Components**:
    - **Function**: Enables communication between the ESP32, Raspberry Pi, and the main computer.
    - **Rationale**: Ensures seamless data transfer and synchronization between different parts of the system.
11. **Housing and Mechanical Components**:
    - **Function**: Encloses and supports all electronic components, providing protection and structural integrity.
    - **Rationale**: Ensures durability, ease of access for maintenance, and an aesthetically pleasing design suitable for a restaurant environment.
12. **Software Development Tools**:
    - **Function**: Used for programming and developing the firmware and software required for the robot's operation.
    - **Rationale**: Necessary for coding, debugging, and deploying the various functionalities of the robot.
13. **User Interface Design Software**:
    - **Function**: Facilitates the design of the graphical user interface displayed on the touch screen.
    - **Rationale**: Ensures an intuitive and user-friendly interface that enhances customer interaction.
14. **Testing and Debugging Equipment**:
    - **Function**: Used for testing the functionality and performance of the robot components.
    - **Rationale**: Essential for identifying and fixing issues to ensure the reliable operation of the robot.

This need list outlines the critical components and resources required for developing a sophisticated and effective user interface for the restaurant robot. Each element is carefully selected to ensure optimal performance, reliability, and user experience.

6 Stimulate Ideas

The development of a user interface for a restaurant robot involves creativity, innovation, and strategic thinking to create an engaging and efficient system. Here are several stimulating ideas to enhance the project:

1. **Interactive Menu Design**:
   - **Idea**: Implement a dynamic menu that updates in real-time with daily specials, popular dishes, and personalized recommendations based on previous orders.
   - **Inspiration**: Use data analytics to track customer preferences and suggest dishes they are likely to enjoy.
2. **Voice Interaction Enhancements**:
   - **Idea**: Incorporate natural language processing (NLP) to understand more complex and conversational commands from customers.
   - **Inspiration**: Leverage advancements in AI to make interactions more intuitive and less robotic, providing a more human-like experience.
3. **Facial Recognition Integration**:
   - **Idea**: Use facial recognition to identify regular customers and greet them by name, offering a personalized welcome.
   - **Inspiration**: Create a sense of familiarity and improve customer loyalty by acknowledging repeat patrons and remembering their preferences.
4. **Multilingual Support**:
   - **Idea**: Add support for multiple languages to cater to a diverse clientele, allowing customers to interact with the robot in their preferred language.
   - **Inspiration**: Enhance accessibility and inclusivity, making the dining experience enjoyable for non-native speakers.
5. **Visual and Audio Feedback**:
   - **Idea**: Implement visual cues and audio feedback to guide customers through the interaction process, reducing confusion and improving usability.
   - **Inspiration**: Use LED indicators, animations, and voice prompts to create a more engaging and user-friendly interface.
6. **Integration with Mobile Devices**:
   - **Idea**: Allow customers to interact with the robot through their smartphones, using QR codes or a dedicated app for menu browsing and ordering.
   - **Inspiration**: Provide an alternative interaction method that leverages the ubiquity of mobile devices, offering convenience and flexibility.
7. **Gamification**:
   - **Idea**: Introduce gamification elements such as reward points, challenges, and interactive games that customers can play while waiting for their food.
   - **Inspiration**: Enhance the dining experience by making it more entertaining, encouraging repeat visits, and increasing customer engagement.
8. **Health and Safety Features**:

- **Idea**: Integrate features that promote health and safety, such as contactless payment options, UV light sanitization, and real-time occupancy tracking.
- **Inspiration**: Address customer concerns about hygiene and safety, especially in the post-pandemic era, ensuring a safe dining environment.

9. **AI-Driven Order Recommendations**:
   - **Idea**: Use machine learning algorithms to analyze ordering patterns and recommend items that are likely to be popular with certain demographics or during specific times.
   - **Inspiration**: Optimize the menu presentation to increase sales and customer satisfaction by offering tailored suggestions.

10. **Augmented Reality (AR) Menus**:
    - **Idea**: Implement AR technology to allow customers to see 3D representations of menu items on their devices before ordering.
    - **Inspiration**: Enhance the visual appeal and help customers make informed decisions by providing a more immersive menu exploration experience.

11. **Environmental Impact Awareness**:
    - **Idea**: Incorporate information about the environmental impact of menu items, such as carbon footprint and sustainability ratings.
    - **Inspiration**: Appeal to environmentally conscious customers by promoting sustainable dining choices and transparency.

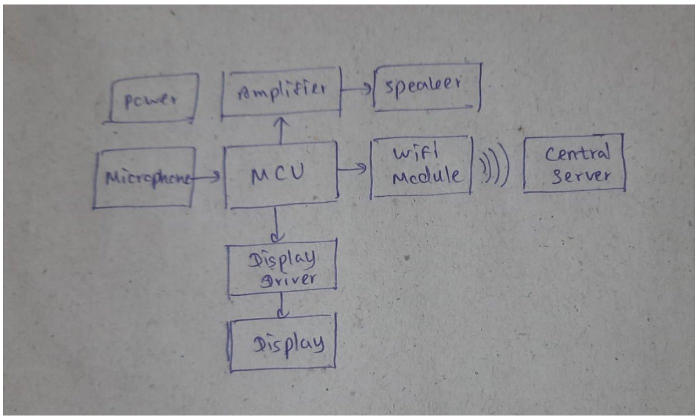
12. **Real-Time Feedback and Reviews**:
    - **Idea**: Enable customers to provide immediate feedback and reviews directly through the touch screen interface after their meal.
    - **Inspiration**: Gather valuable insights to improve service quality and customer satisfaction while showing customers that their opinions are valued.

These ideas aim to stimulate creative thinking and innovation in developing a user interface for the restaurant robot, ultimately enhancing the overall dining experience and setting the project apart with unique and customer-focused features.

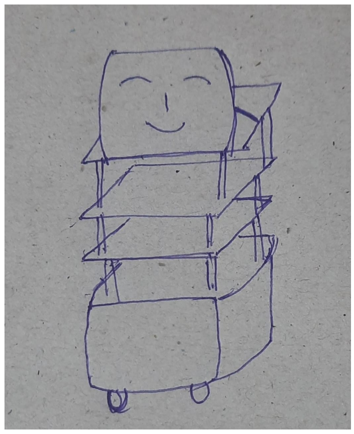
7 Develop Concepts

7.1 Design 1 : User interaction using a touch screen and voice commands of customers

This incorporates a MCU as the main brain of the device. This will communicate with a central server that is running an AI model in order to process voice commands. Using the help of a microphone, speaker and display setup it will output the respective responses. Since we are using a touchscreen display, customers can browse the menu and place their orders directly.The main electronics will be placed in the bottom container while the display will be attached to the top much like a laptop.



(a) Block Diagram 1

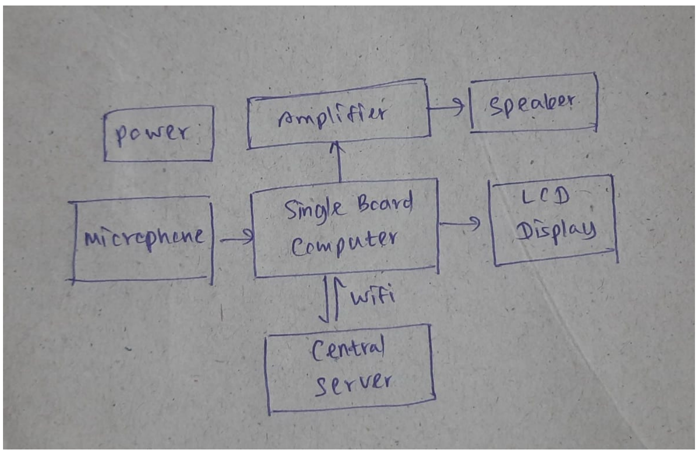


(b) Conceptual Design 1

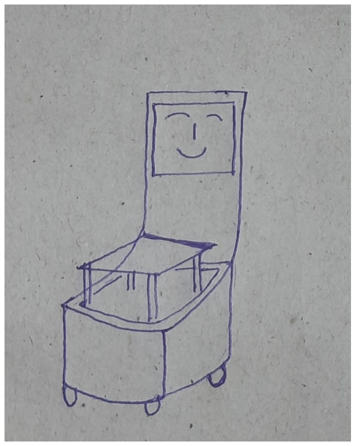
Figure 7

7.2 Design 2 : User interaction using voice commands of customers

This design uses a single board computer as the main brain of the system. Since it has an inbuilt WiFi and HDMI interfaces, this simplifies the design further. Using single board computer we can run the AI model to recognize voice commands and give responses.The display is placed in a holder above the top surface in order to emulate a human face with a neck.



(a) Block Diagram 2

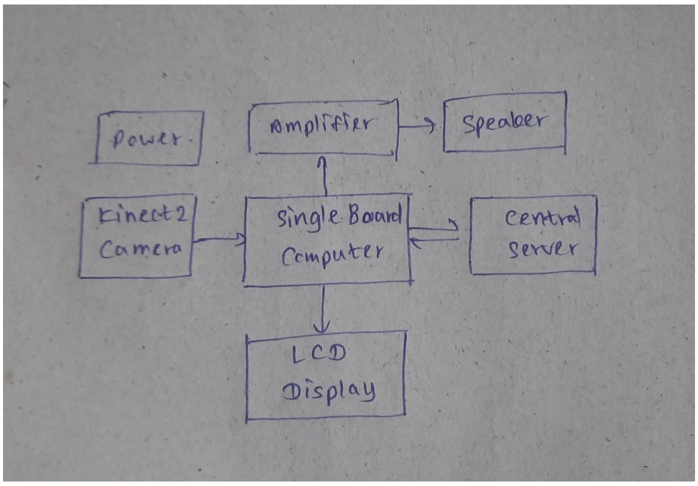


(b) Conceptual Design 2

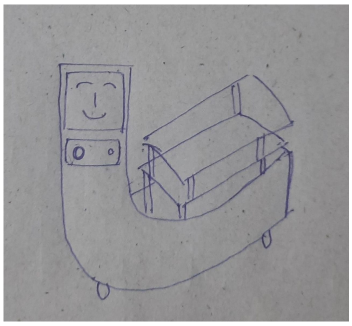
Figure 8

7.3 Design 3: User interaction using hand gestures of customers

This design uses a kinect 2 camera to recognize hand gestures of customers.It captures depth information by emitting infrared light and measuring the time it takes to reflect back. This creates a 3D map of the environment, including the user's hand positions.So customers can run the menu using their hand gestures and place the order.Here we uses a single board computer to do the processing part.



(a) Block Diagram 3



(b) Conceptual Design 3

Figure 9

8 Evaluation of Conceptual Designs

Table 1: Complete Comparison of Conceptual Designs for the UI of the Restaurant Robot

Criteria	Design 1	Design 2	Design 3
Newly Added Features	Communication with a central server	Single board computer	Kinect 2 Camera
Removed Features	Independence from local Wi-Fi	Touch screen	Voice commanding
Enclosure Design Criteria			
Functionality	9	9	7
Aesthetics	8	8	8
Heat Dissipation	8	8	7
Assembly and Serviceability	8	8	8
Ergonomics	9	7	9
Simplicity	6	8	8
Durability	7	9	7
Functional Block Design Criteria			
Functionality	9	9	8
User Experience	9	7	8
Manufacturing Feasibility	8	8	8
Cost	9	7	8
Performance	8	9	8
Future Proofing	8	9	8
Power	9	7	9
Total	115	113	111

8.1 Evaluation Criteria

8.1.1 Enclosure Design Criteria

1. **Functionality:** How well does the circuit design enable the robot to interact with customers more efficiently
2. **Aesthetics:** To what extent does the design have a visually appealing and inviting appearance for restaurant patrons?
3. **Assembly and Serviceability:** How easily can the enclosure be assembled, disassembled, and serviced for maintenance purposes?
4. **Ergonomics:** How well does the design accommodate interaction with the robot, such as retrieving food or giving instructions?
5. **Durability:** How well does the design withstand the rigors of a restaurant environment, including potential impacts and spills?
6. **Simplicity:** How easy is it for restaurant staff and customers to understand and use the robot's enclosure features?

8.1.2 Functional Block Diagram Criteria

1. **Functionality:** How well does the circuit design enable the robot to perform essential functions like obstacle avoidance and food tray stability?
2. **User Experience:** How intuitive and seamless is the interaction between restaurant staff and the robot's functional block diagram?
3. **Manufacturing Feasibility:** Evaluate the practicality and ease of manufacturing the components of the functional block diagram.
4. **Cost:** Evaluate the overall cost-effectiveness of the functional block diagram considering the desired functionalities for restaurant operations.
5. **Performance:** Evaluate the quality and reliability of signals and sensors used in the functional block diagram, ensuring accurate navigation and operation.
6. **Future Proofing:** To what extent does the design allow for easy upgrades or replacements of components to adapt to future restaurant needs or technological advancements?
7. **Power Efficiency:** How efficiently does the functional block diagram manage power consumption to maximize the robot's operating time between charges?

8.2 Selected design

Implementing a display capable of conveying emotions on a restaurant robot, along with a user-friendly menu interface, presents a novel and advantageous approach to human-robot interaction. By integrating emotive expressions into the robot's interface, such as displaying happiness when serving a dish or concern when addressing a customer's complaint, the interaction becomes more intuitive and engaging. Moreover, coupling this emotive display with a clear and accessible menu interface enhances the user experience, allowing patrons to easily navigate through meal options and place orders efficiently. This combination not only streamlines the ordering process but also fosters a sense of connection and understanding between the robot and the restaurant patrons, ultimately elevating the overall dining experience. So according to the above criteria and the score evaluation we have chosen design 1.

9 Schematic Design

9.1 Main Schematic

- We have opted for a hierarchical schematic design due to the complex nature of the overall PCB. In addition to the main sheet there are four sub sheets, Which are Micro controller unit, Power System, Amplifier and Microphone.
- The main sheet interconnects the Micro controller unit (ESP32-WROOM-32E) with the microphone (ICS43434) and the amplifier (MAX98357a). In addition to this, it also contains all the necessary headers and connectors used to mount a Raspberry pi 4B and get 5v power.
- We have added headers for most the major modules in the main sheet, so that we can test the board before soldering, using off the shelf modules and solder those modules directly to the board in case of a component failure. The raspberry pi headers are also connected with the MCU, Microphone and the Amplifier so that we can have a highly integrated system. We have also placed DIP switches in order to have different configurations of connections in the same board.
- Two Class D amplifier modules have been connected with the MCU in order to achieve stereo sound output.
- Two LEDs have been added for debugging purposes.

9.2 Micro Controller Schematic

- We have decided to use the ESP32-WROOM-32E as our Micro controller module of choice due to it's wireless capabilities and multi core processor. This schematic has been adopted from the manufacturer's recommended design.
- This module requires 3.3v in order to function properly. Which is provided by a linear low dropout voltage regulator (AMS117-3.3).
- A Micro USB B type connector is used to program and power the module. Reverse voltage protections diodes and Static discharge protection TVS diodes are used to further protect the module.
- Since the MCU only supports UART communication, a USB to UART IC (CP2102) is used to facilitate that.

9.3 Power Schematic

- This schematic is designed to work from 5v. There are three main ways we can provide 5v to this system. First and the best one being using the 5v power connector and directly giving 5v. Secondly using the Micro USB port we can supply 5v. Lastly we can use the 5v output of the connected raspberry pi module.
- A red LED is used to indicate when there is 5v available.
- From this 5v the AMS117-3.3 provides a steady 3.3v to the rest of the PCB. Decoupling and noise filtering capacitors have been included as per the manufacturers recommendations.

9.4 Amplifier Schematic

- We have chosen the MAX98357a Class D 3W amplifier to feed our speakers. This works on 5v and can drive 4ohms and 8ohms speakers with different power outputs.

- This amplifier can directly work with digital signals using a protocol called I2S, thus providing high quality analog output. Since this module can be purchased for way cheaper price compared to the IC counter part, we have chosen to directly use the module.
- Resistors have been used to tune the gain and various configurations of the amplifier.

9.5 Microphone Schematic

- We have chosen the ICS43434 MEMS microphone due to it's dominating performance compared to any other analog microphones in the market.
- We have designed this schematic according to the manufacturers recommendations.
- This mic requires 3.3v to function and uses the I2S protocol to communicate with the MCU.

Note: Many of the headers, DIP Switches and Components such as the USB to UART bridge can be totally omitted from this schematic. Since this is a prototype and mainly used for testing purposes we are expected to have component failures. That's why multiple headers for direct mounting of modules have been used. Also for a one time programming of the MCU and future firmware updates through wireless media we don't need the USB connectors or the UART IC. Since we were planning to test multiple different firmwares we have dedicated a section of the schematic for programming components. Finally arrays of DIP switches have been included so that we can test various different hardware configurations using the same board.

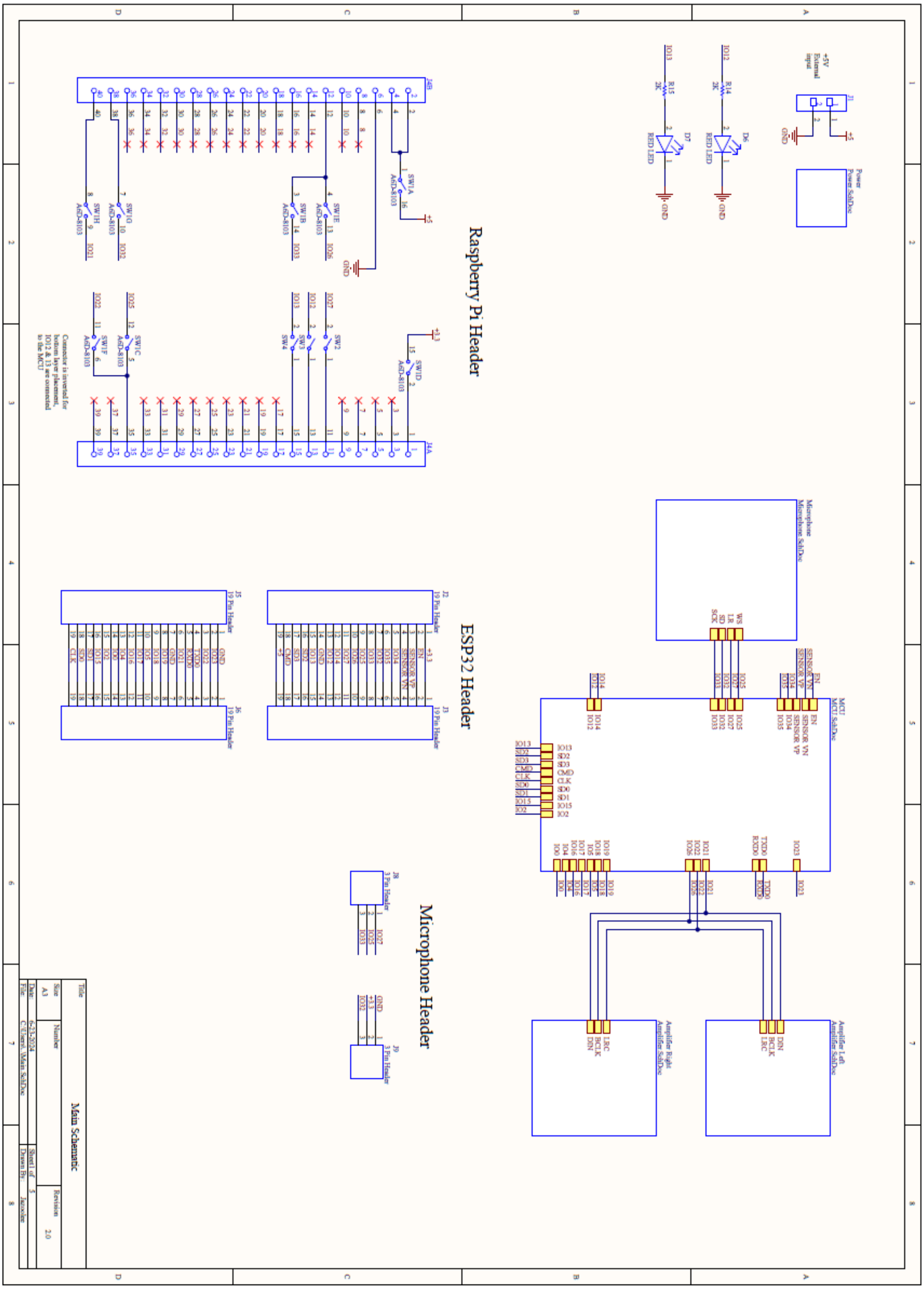


Figure 10: Main Schematic

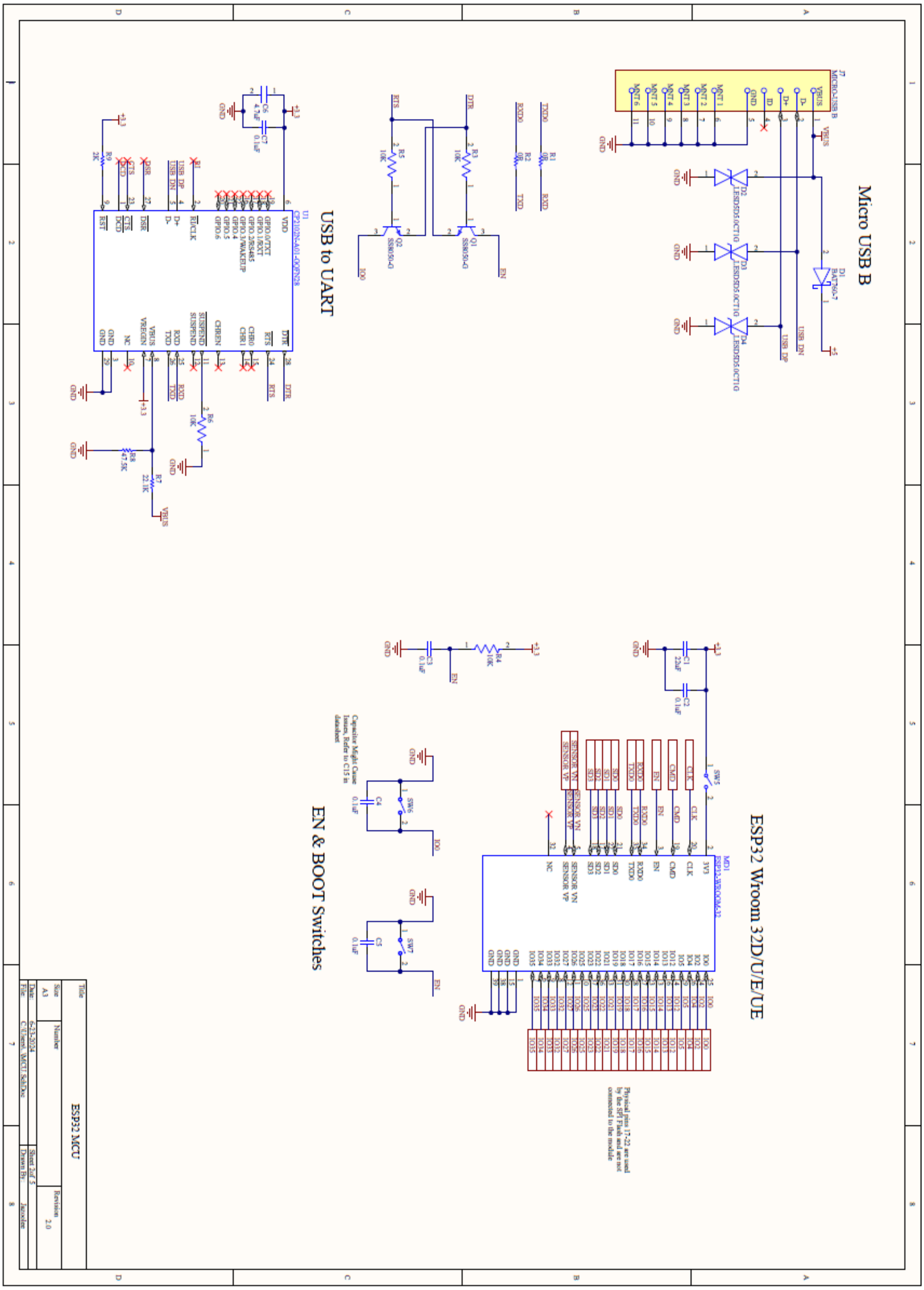


Figure 11: MCU Schematic[10]

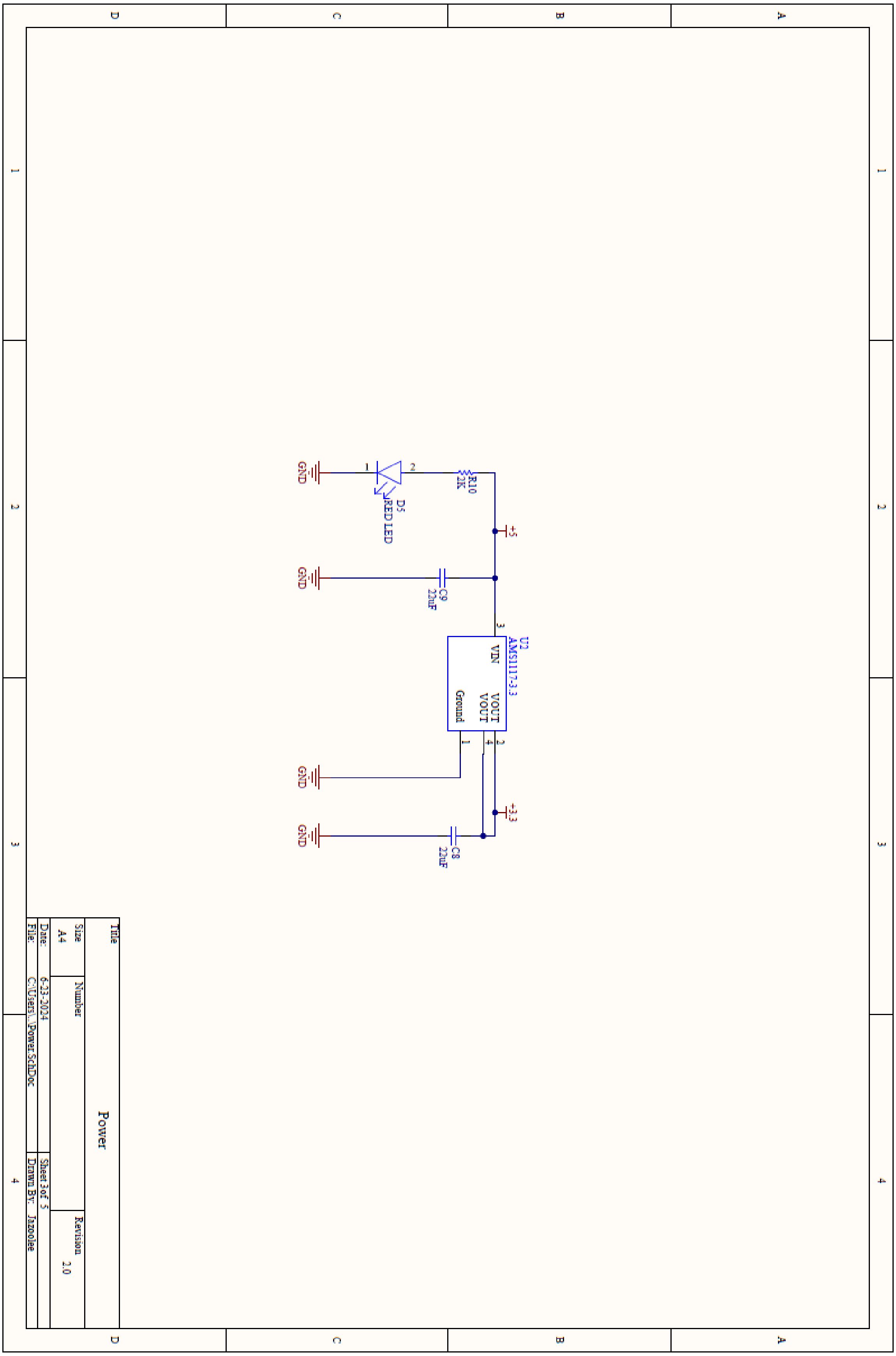


Figure 12: Power Schematic

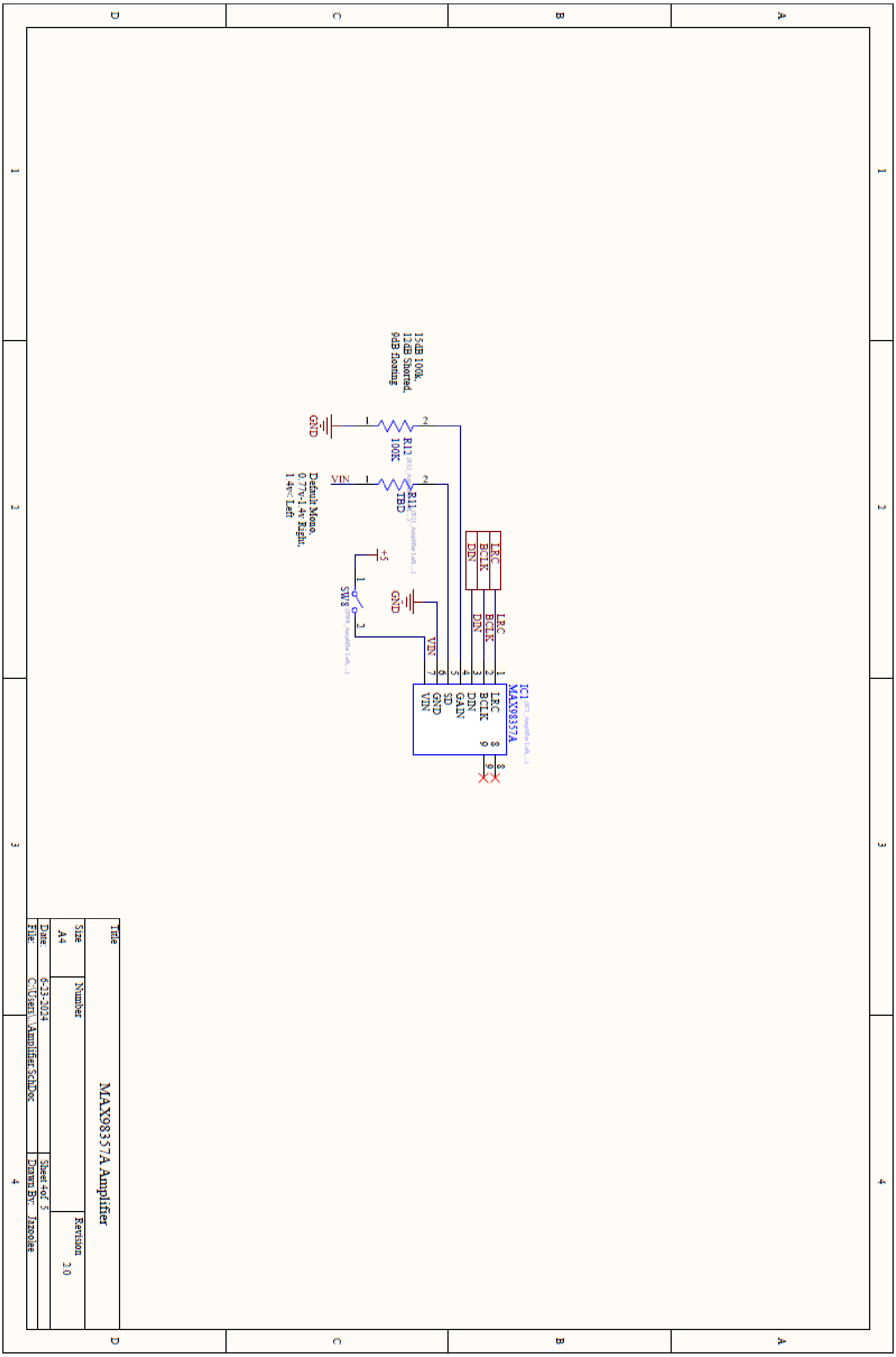


Figure 13: Amplifier Schematic[12]

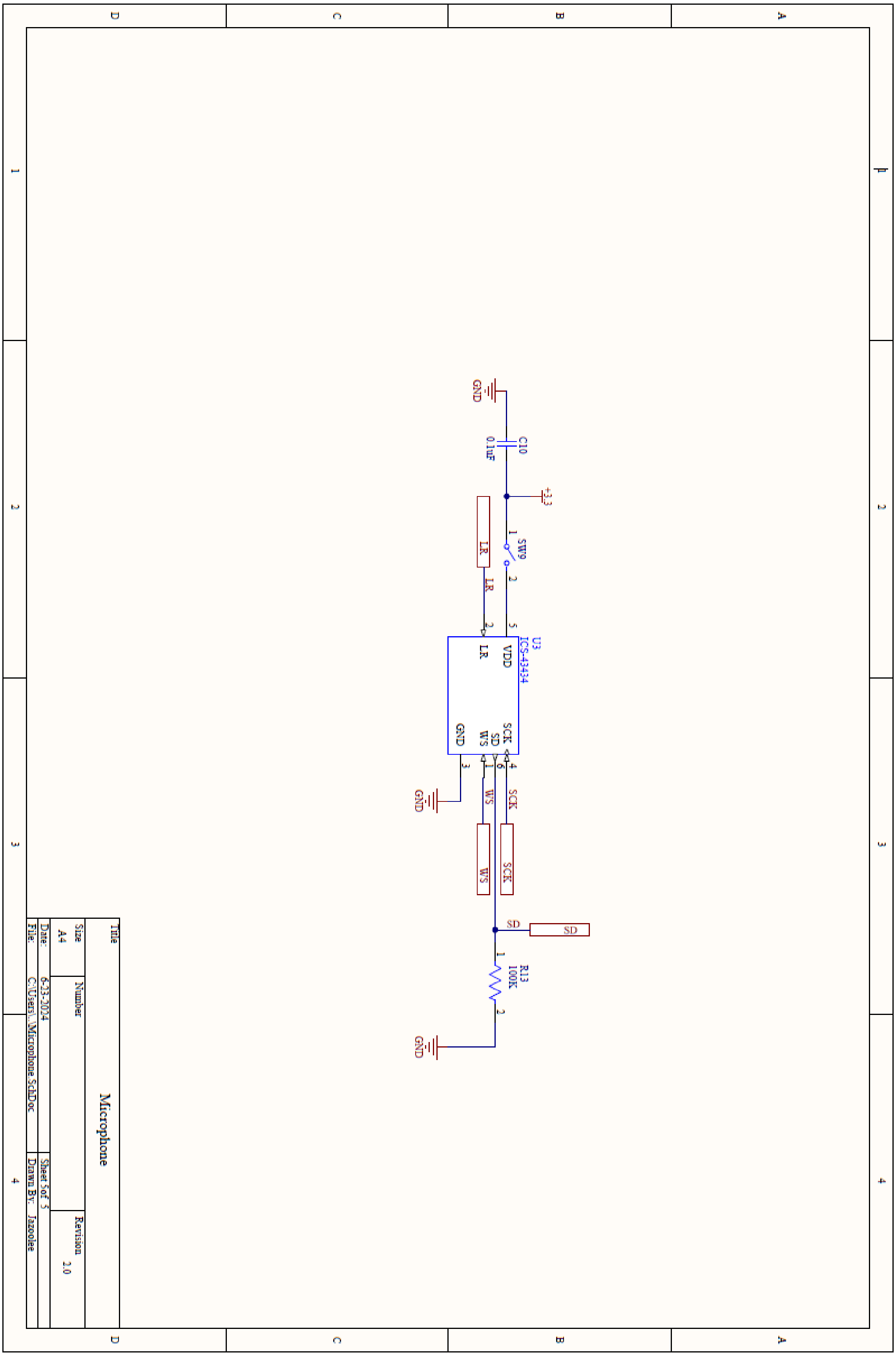


Figure 14: Mic Schematic[11]

10 PCB Design

- This is a four layer design. There is a top and a bottom signal layer. In between these there is a ground and a power plane. The physical dimensions are 100mm*60mm*1.6mm.
- Five 3mm diameter holes have been placed to help with mounting the PCB inside the enclosure.
- The power plane has been split into two section with a 25mil gap between them. They are connected to 5v and 3.3v. Components have been grouped together in such a way that they are directly above their required power planes. The use of copper polygons have been minimized and used only for creating low resistance path between power lines.
- The MCU is placed in the middle and all the other components have been spread around it strategically. Female headers for the Raspberry pi is placed on the left edge of the board so that it can fit with our board without bringing any interference. Extra pad holes have been placed on either side of headers for easy debugging and access to MCU pins.
- The amplifier modules are placed on the right edge of the board to facilitate easy connections with the speakers.
- USB connector and the power connector is placed on the bottom edge of the board so that they be easily connected with our PCB.
- MCU and related component placement have been done according to manufacturer's recommendations. PCB antenna part of the MCU module is placed outside of the board for better connectivity and less noise interference.
- Since the MEMS microphone is a PCB SMD component it is placed on the bottom side of the pcb and a hole is drilled for the microphone opening.
- 20 mil traces have been used for power lines and 6 mil for the rest. Appropriate trace width and clearance rules have been used for differential pair routing and impedance matching. 0805 size SMD components are mostly used across this pcb to facilitate easy hand soldering and space minimization.
- Ample amount of vias and pads are placed for testing points, heat transfer and better low impedance connectivity.
- Multiple design documents were reviewed before designing this PCB and industry recognized components and connectors only are used.

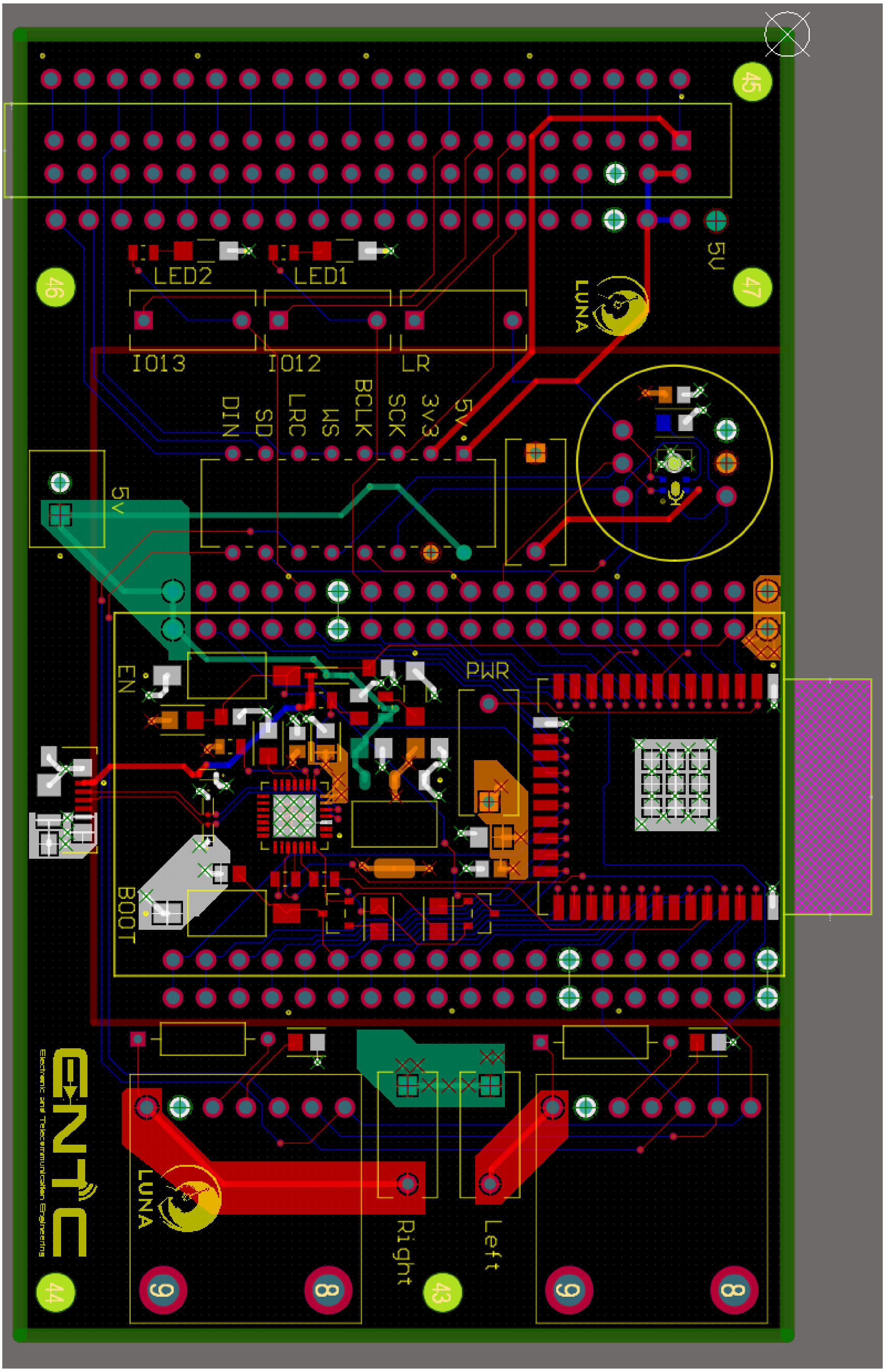


Figure 15: PCB

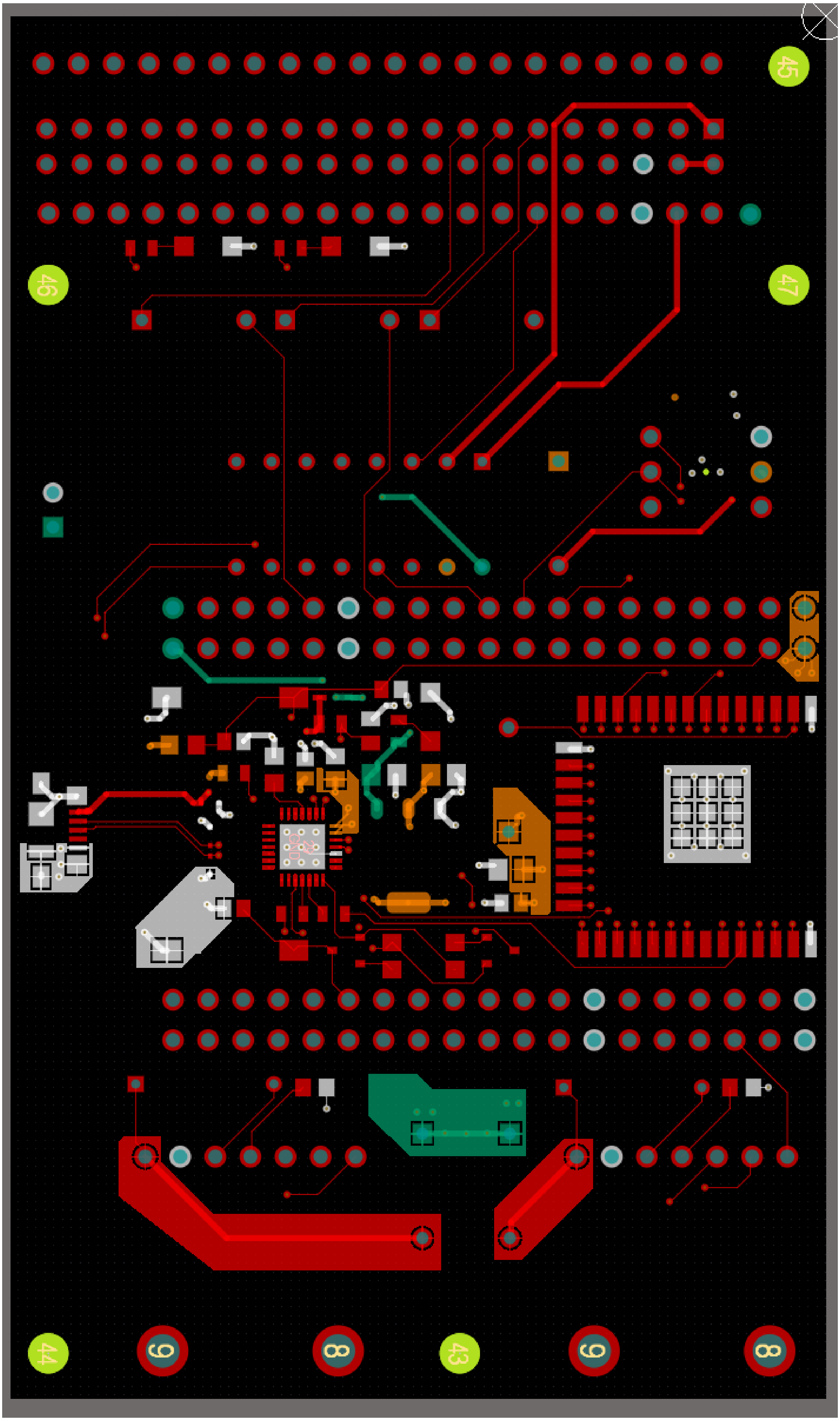


Figure 16: Top Layer

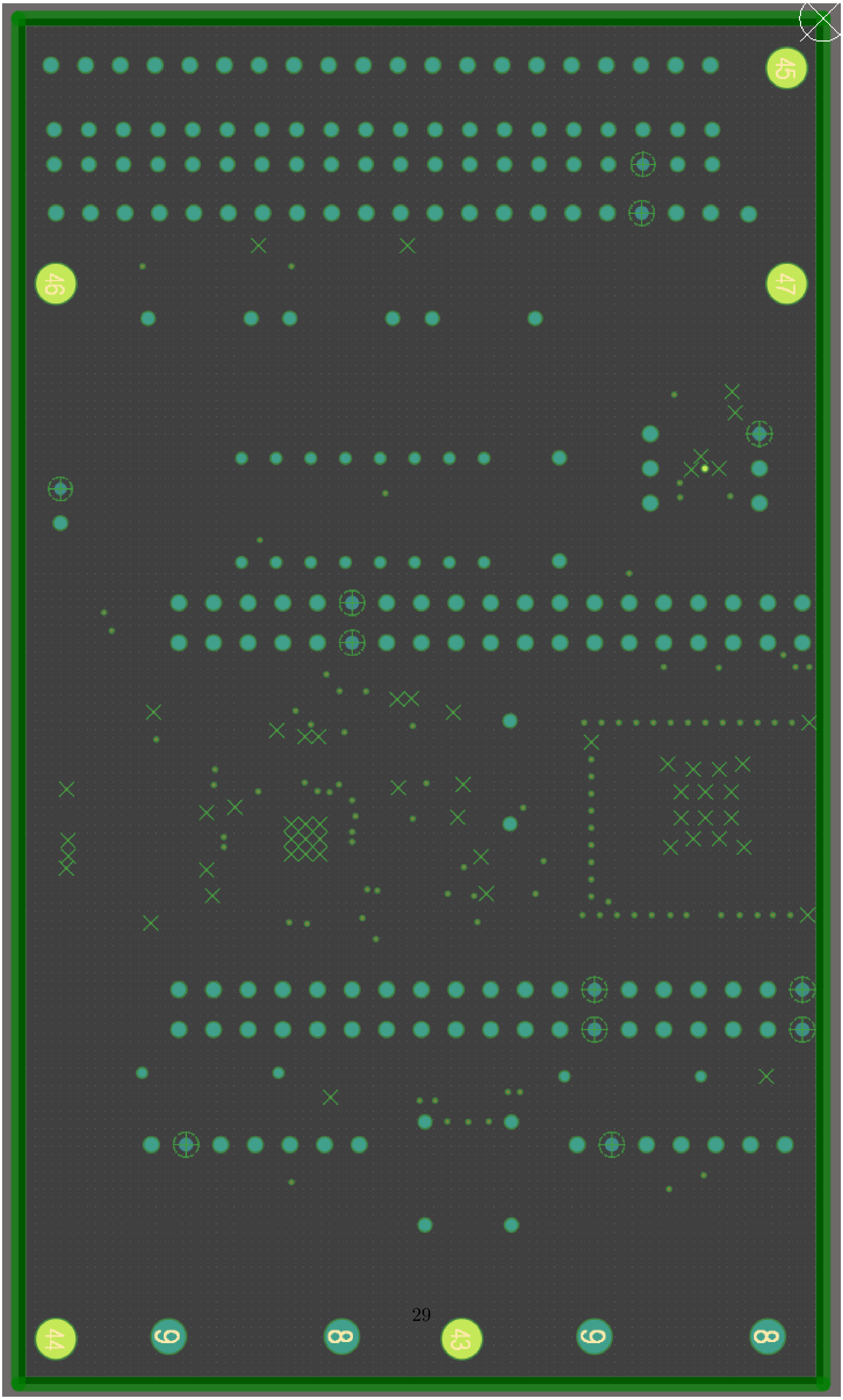


Figure 17: Ground Plane

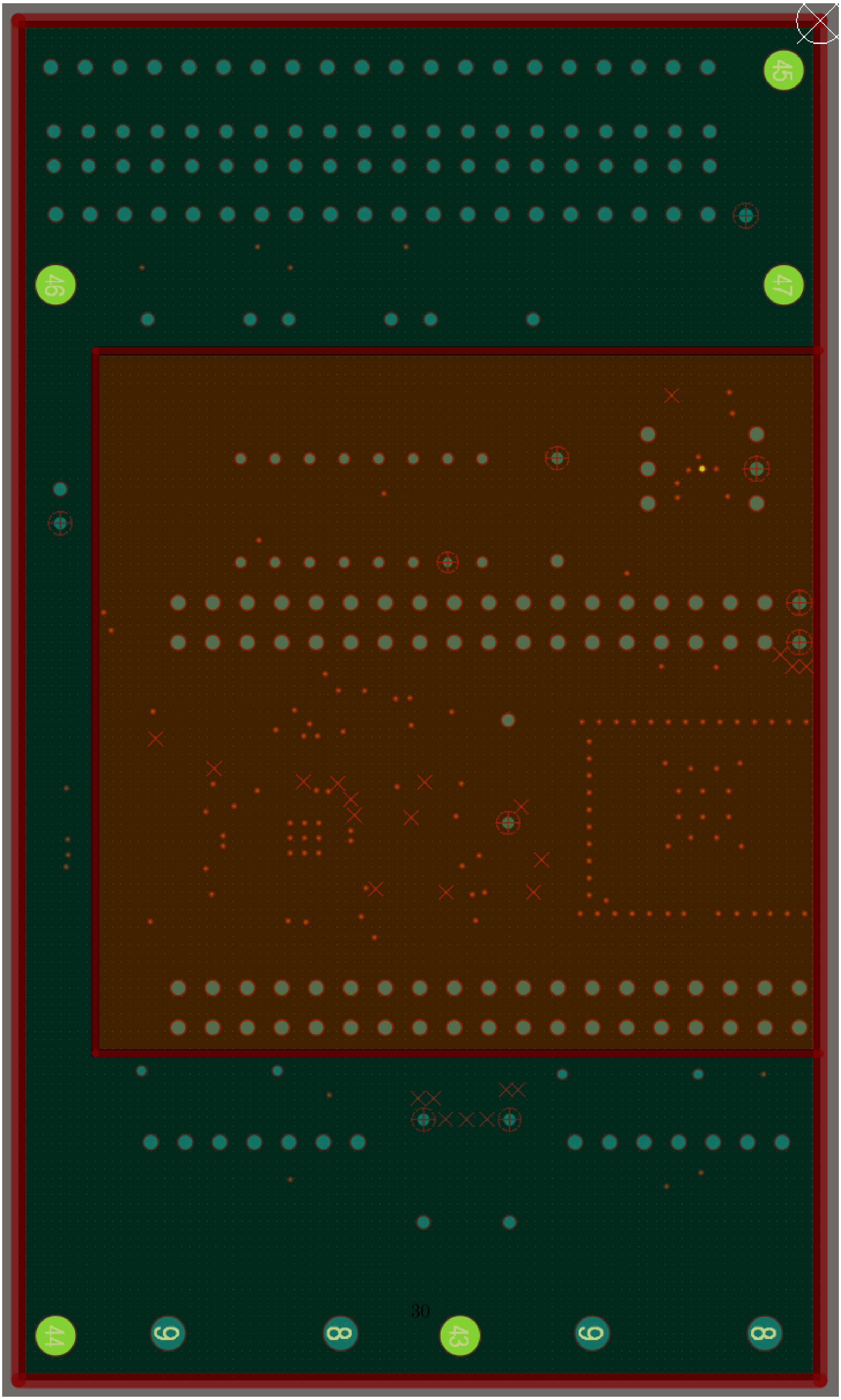


Figure 18: Power Plane

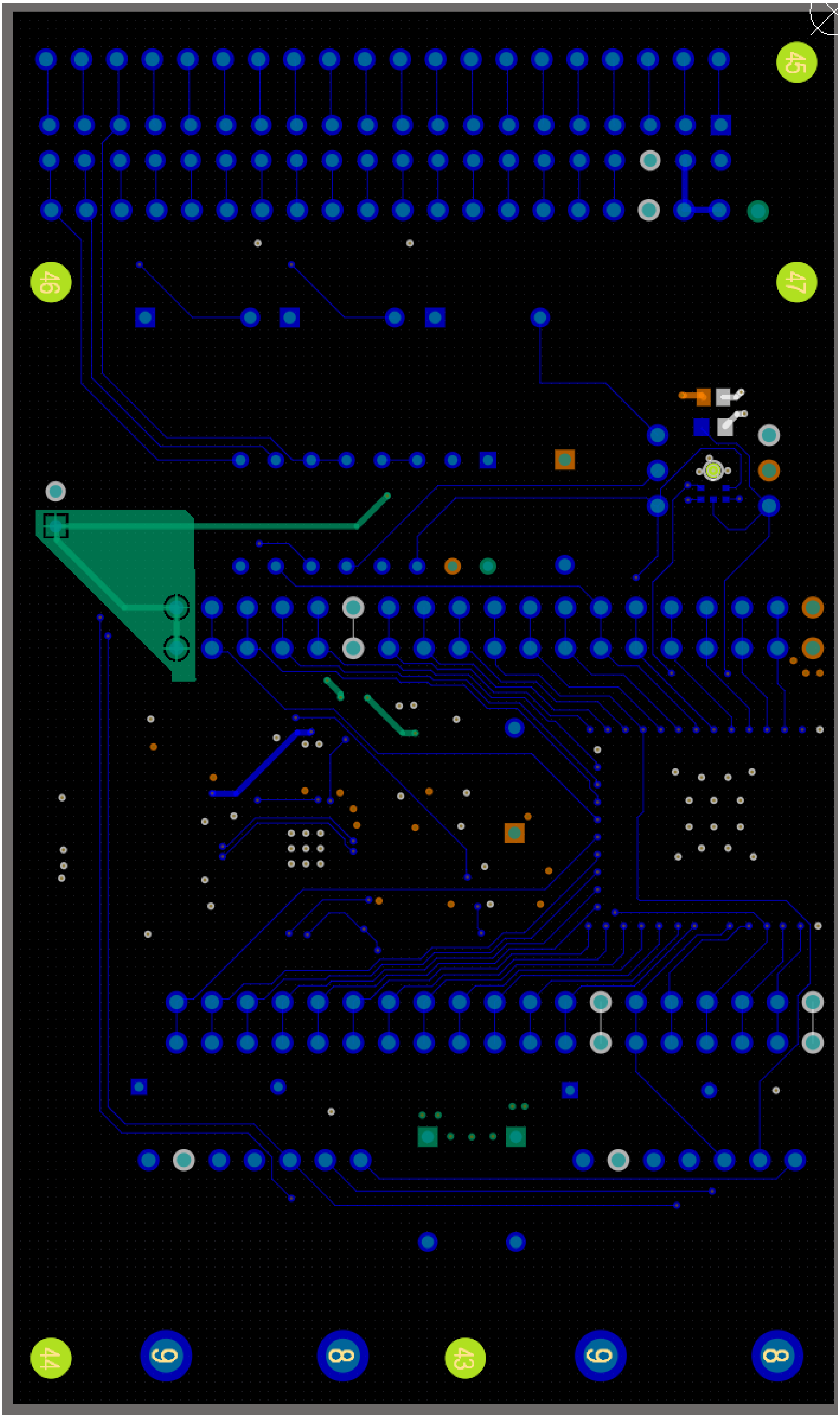


Figure 19: Bottom Layer

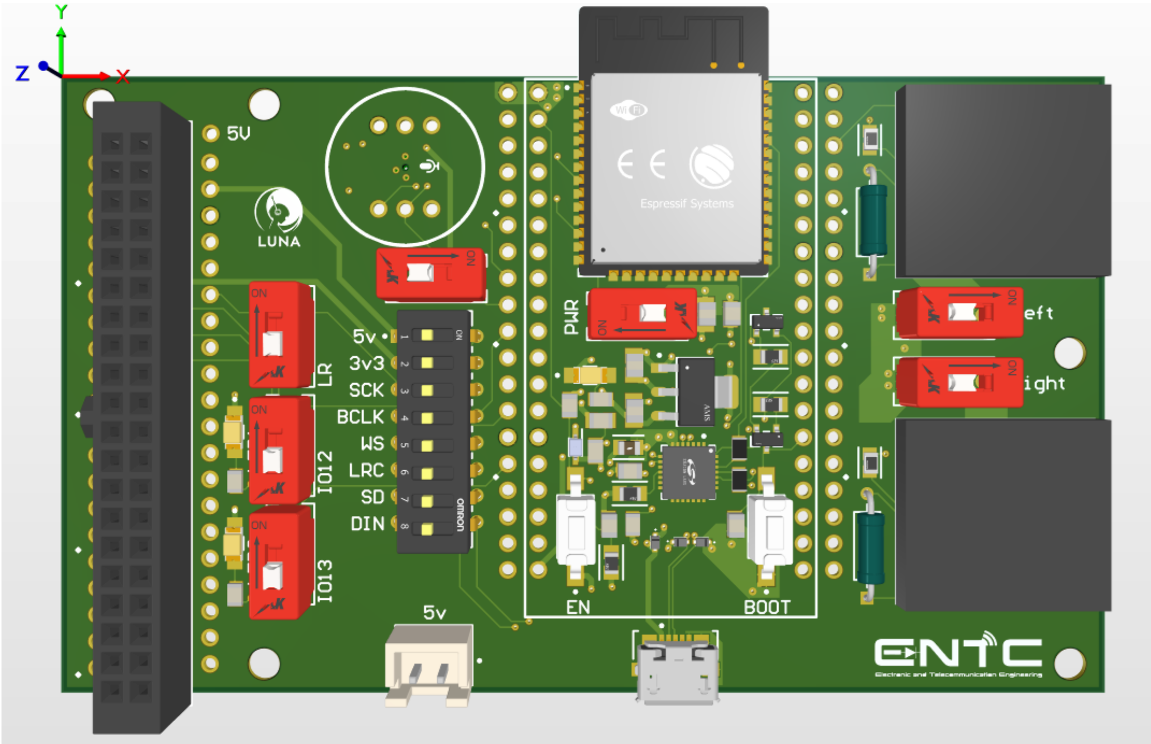


Figure 20: 3D Top View

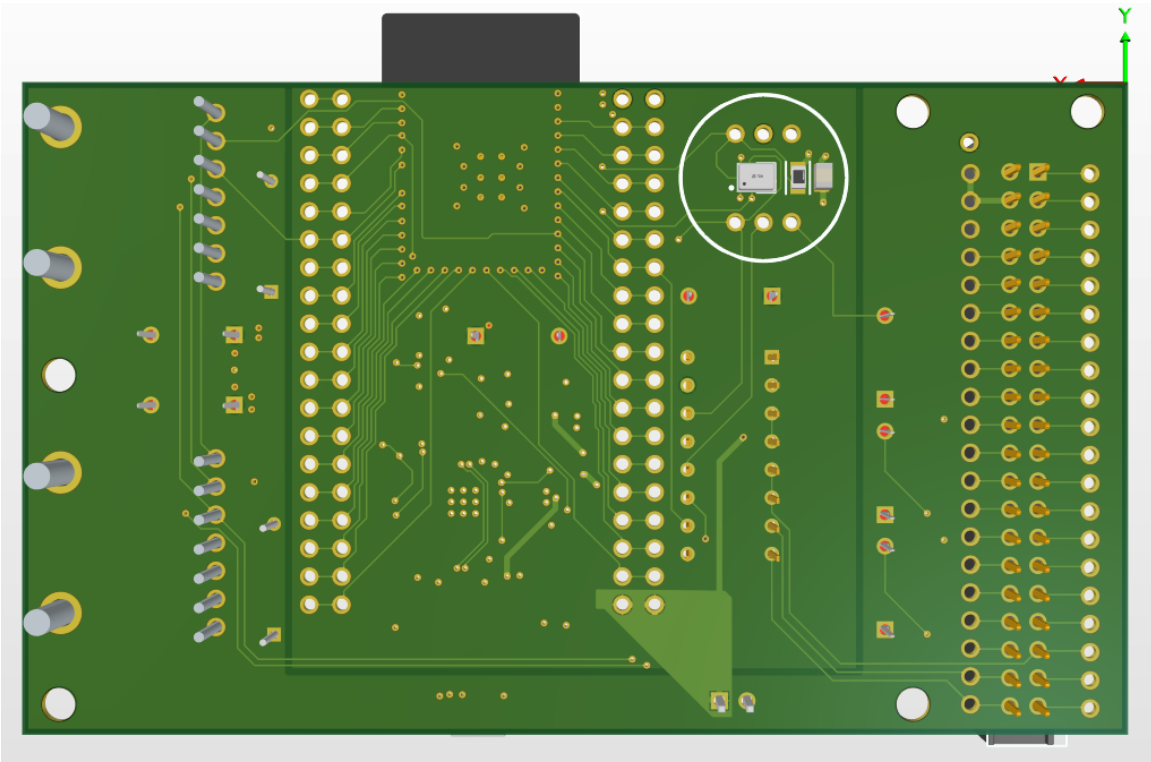


Figure 21: 3D Bottom View

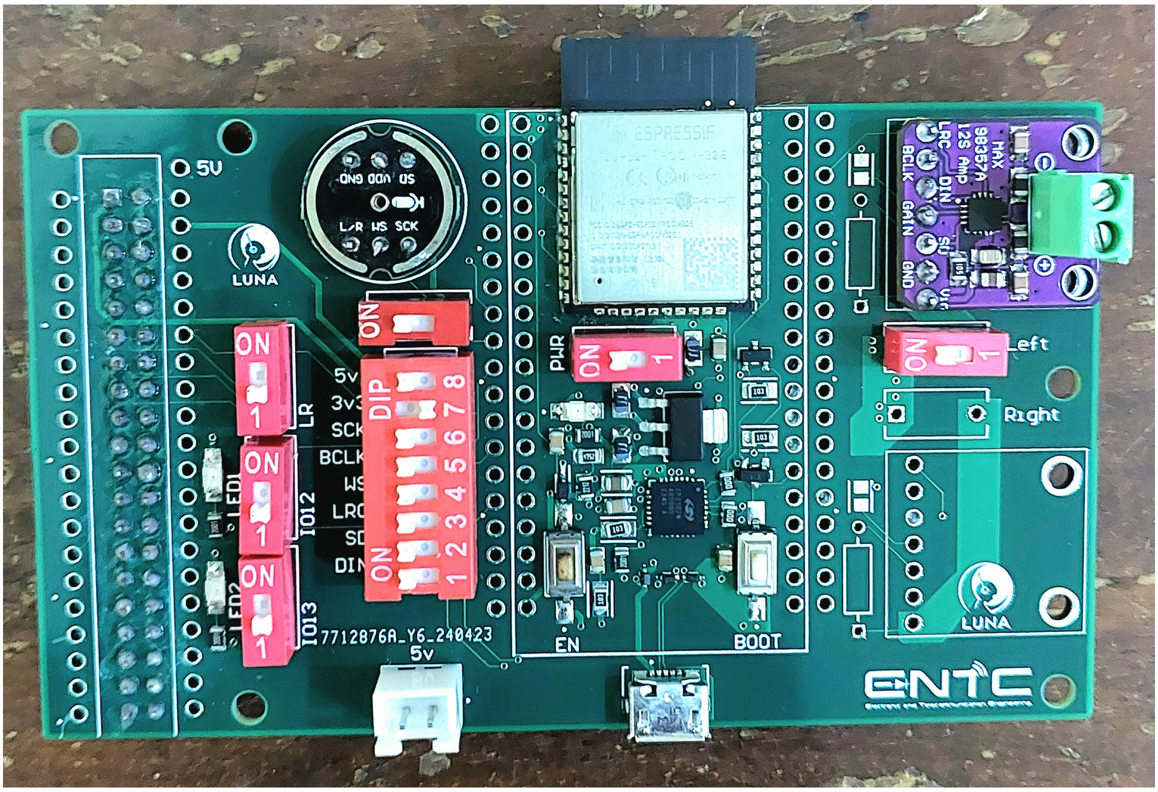


Figure 22: Soldered PCB Top View

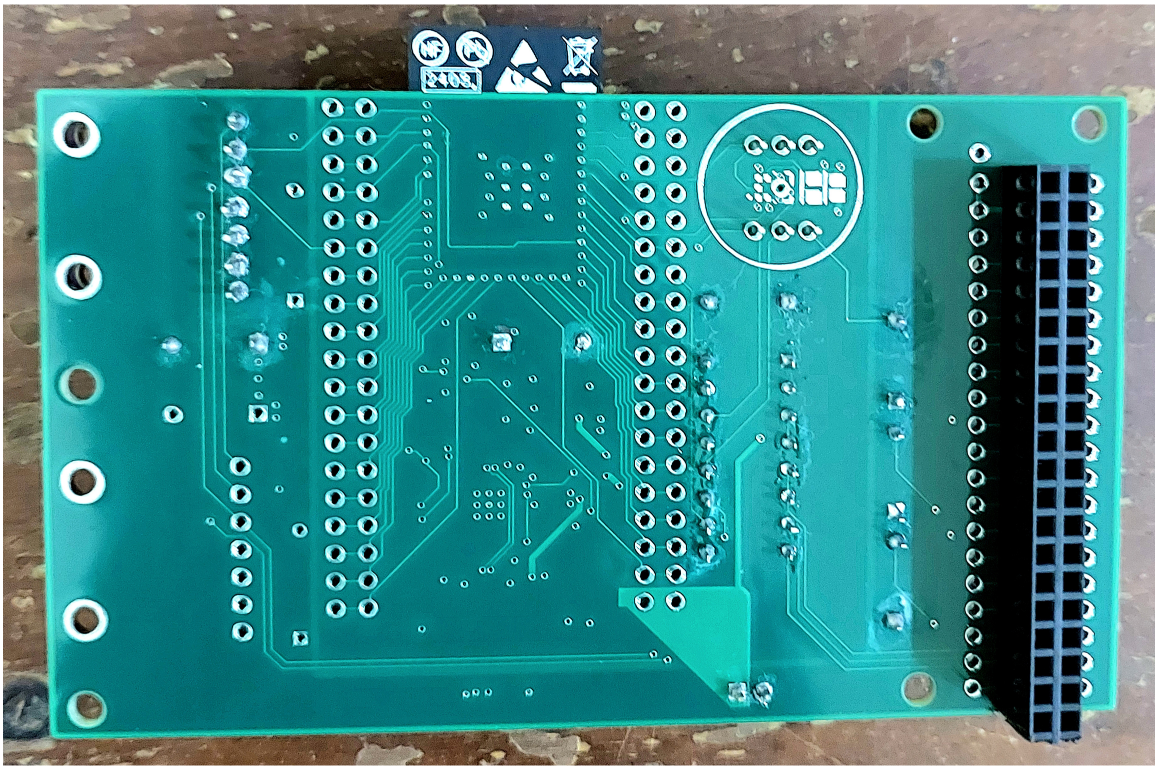


Figure 23: Soldered PCB Bottom View

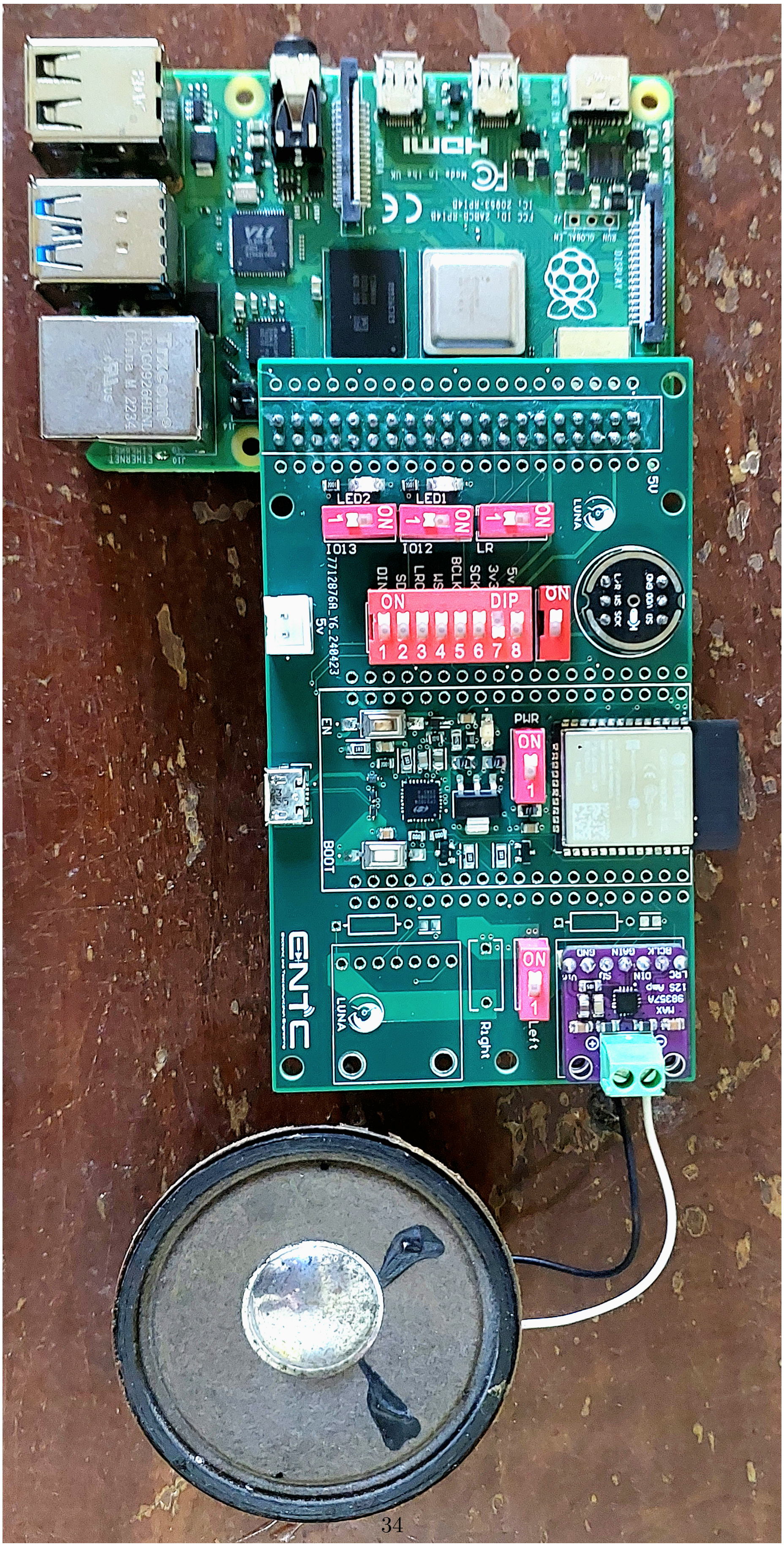


Figure 24: Raspberry Pi & Speaker Attached

11 Enclosure Design

The enclosure for this project is designed to resemble as a head of a restaurant robot, ensuring an engaging and functional appearance. Below are the detailed points about the enclosure design and the importance of component placement:

1. **Front Placement of Raspberry Pi Screen**:
    - **Explanation**: The Raspberry Pi touch screen is positioned at the front of the enclosure.
    - **Importance**: This placement provides an optimal view for customers, making it easy to interact with the menu and see visual feedback from the robot.
2. **Internal PCB and Raspberry Pi Housing**:
    - **Explanation**: Inside the enclosure, there is space allocated for the PCB and the Raspberry Pi.
    - **Importance**: Housing these components internally protects them from damage and reduces clutter, maintaining a clean and professional appearance.
3. **Space for Two Speakers**:
    - **Explanation**: The enclosure design includes dedicated spaces for two speakers.
    - **Importance**: Proper placement of the speakers ensures that the audio output is clear and evenly distributed, enhancing the customer's auditory experience.
4. **INMP441 Microphone IC Placement**:
    - **Explanation**: A specific location within the enclosure is designed for the INMP441 microphone IC, ensuring it is not covered.
    - **Importance**: This placement is crucial for efficiently capturing voice commands without obstructions, ensuring clear and accurate voice input from customers.
5. **Li Ion Battery Cover Placement**:
    - **Explanation**: Since we are giving power to the PCB using two Li ion batteries battery cover is placed near the PCB.
    - **Importance**: This placement is crucial for reduce unwanted lengthy wires.Since we placed battery cover near to the PCB it is easy connect them using two short wires.

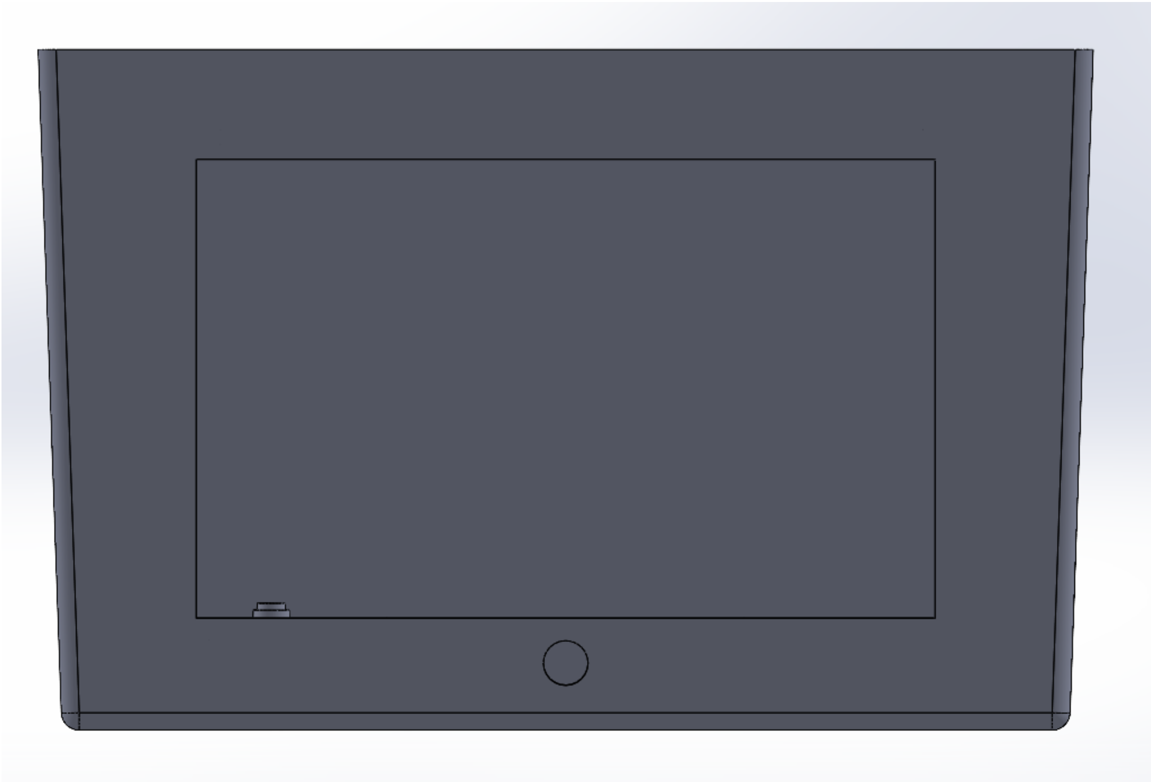


Figure 25: Bottom - Front View

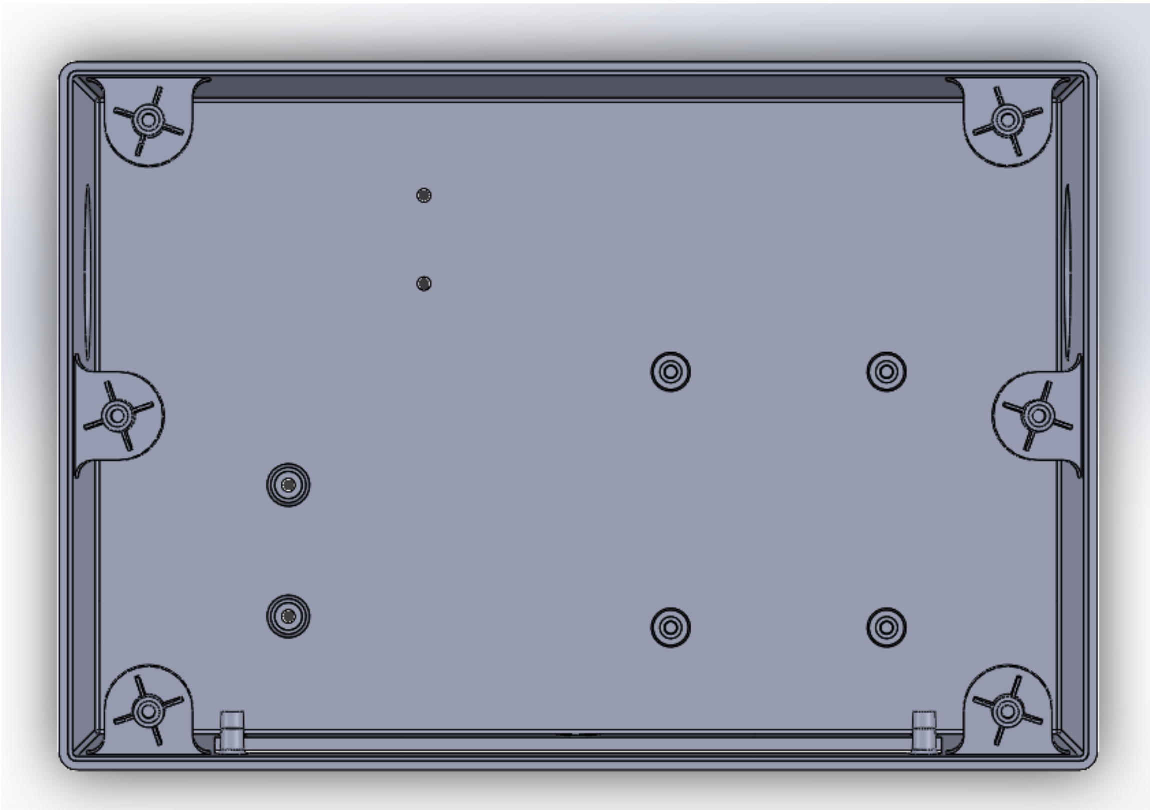


Figure 26: Bottom - Top View

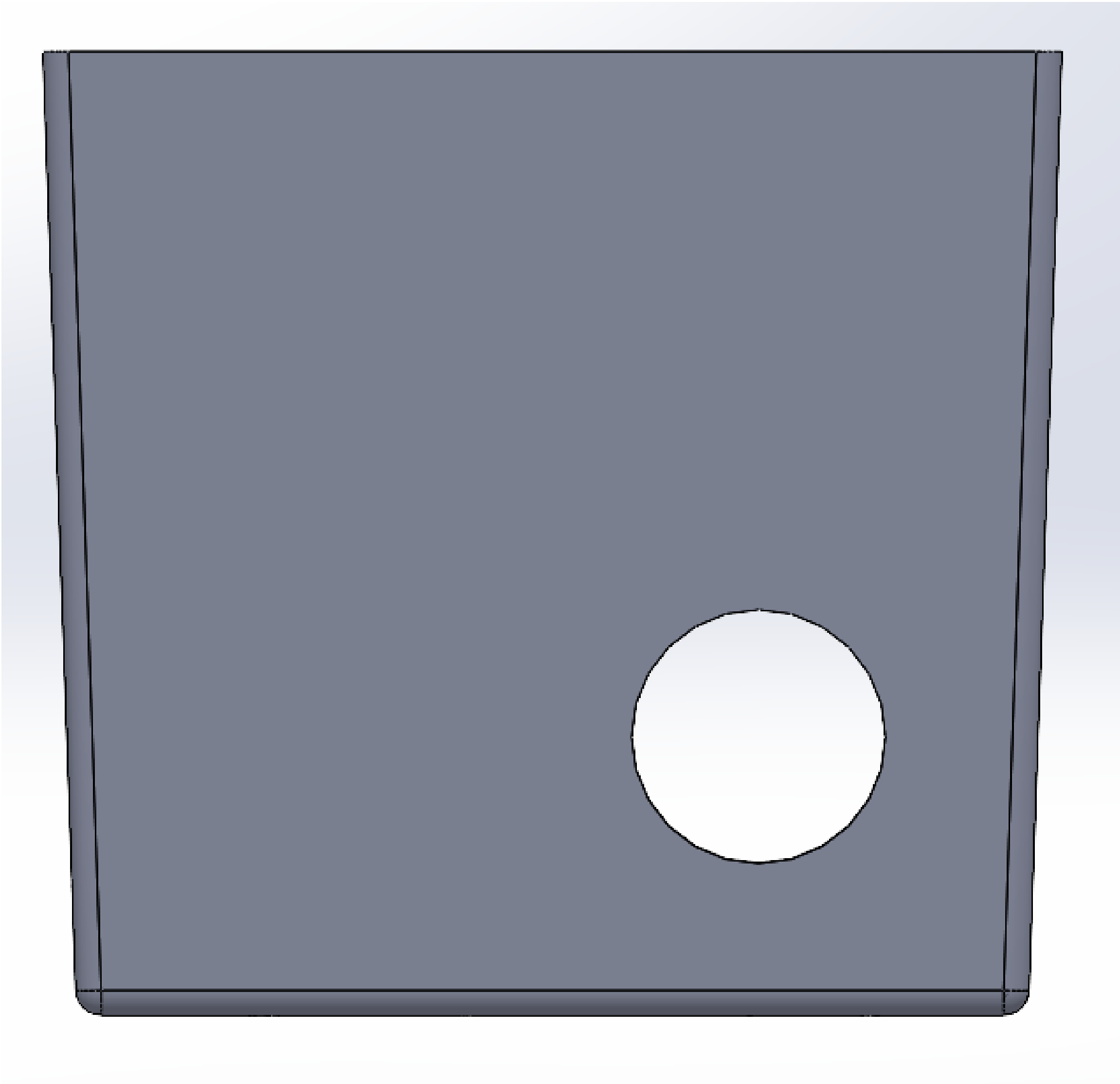


Figure 27: Bottom - Side View

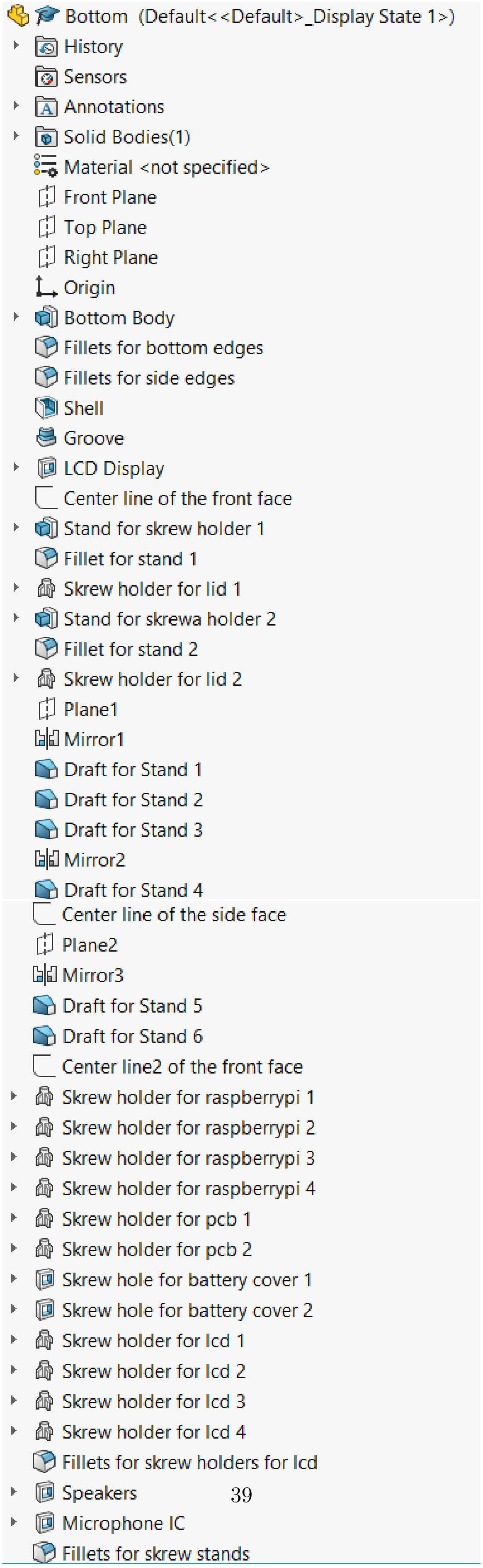


Figure 28: Bottom - Model Tree

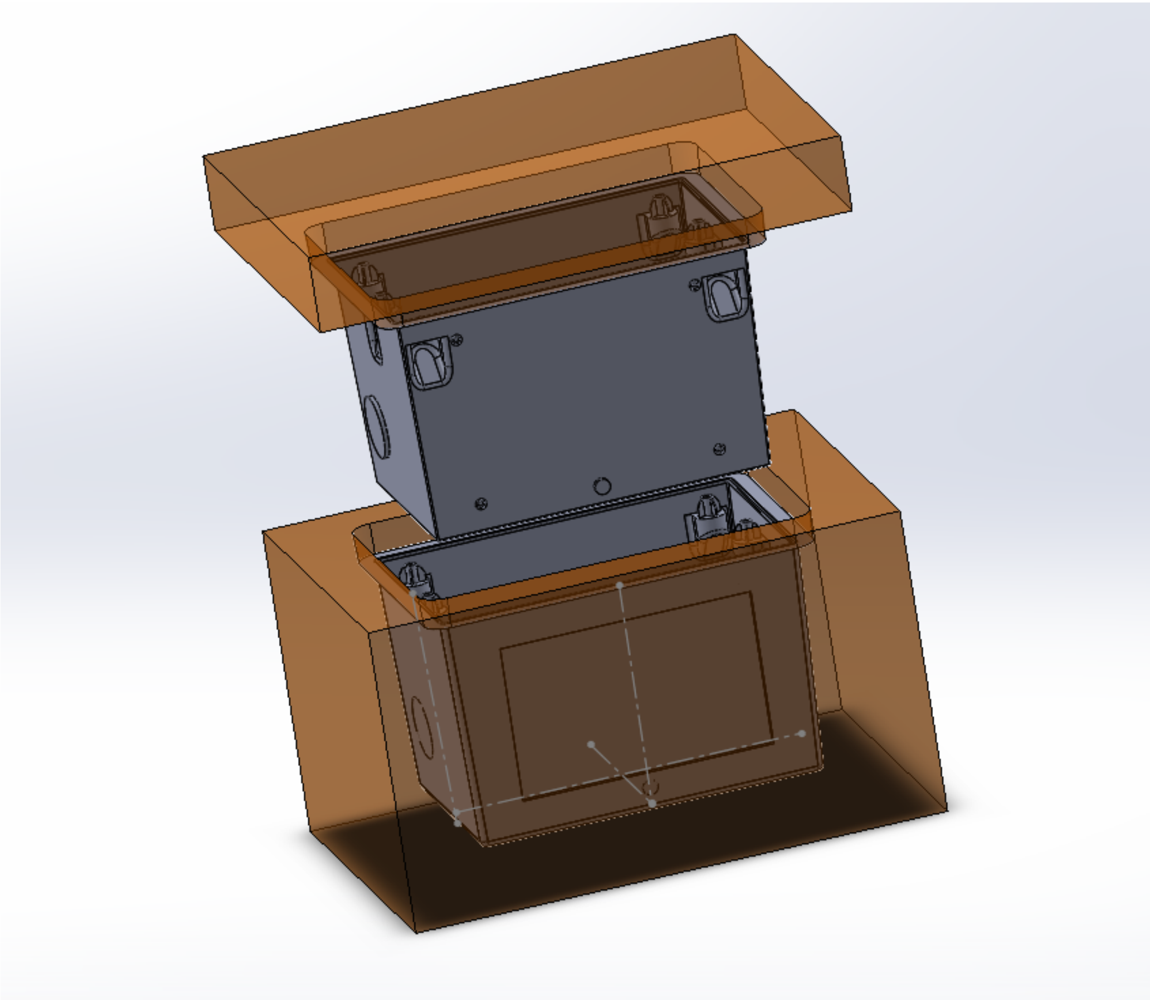


Figure 29: Bottom - Mold Design

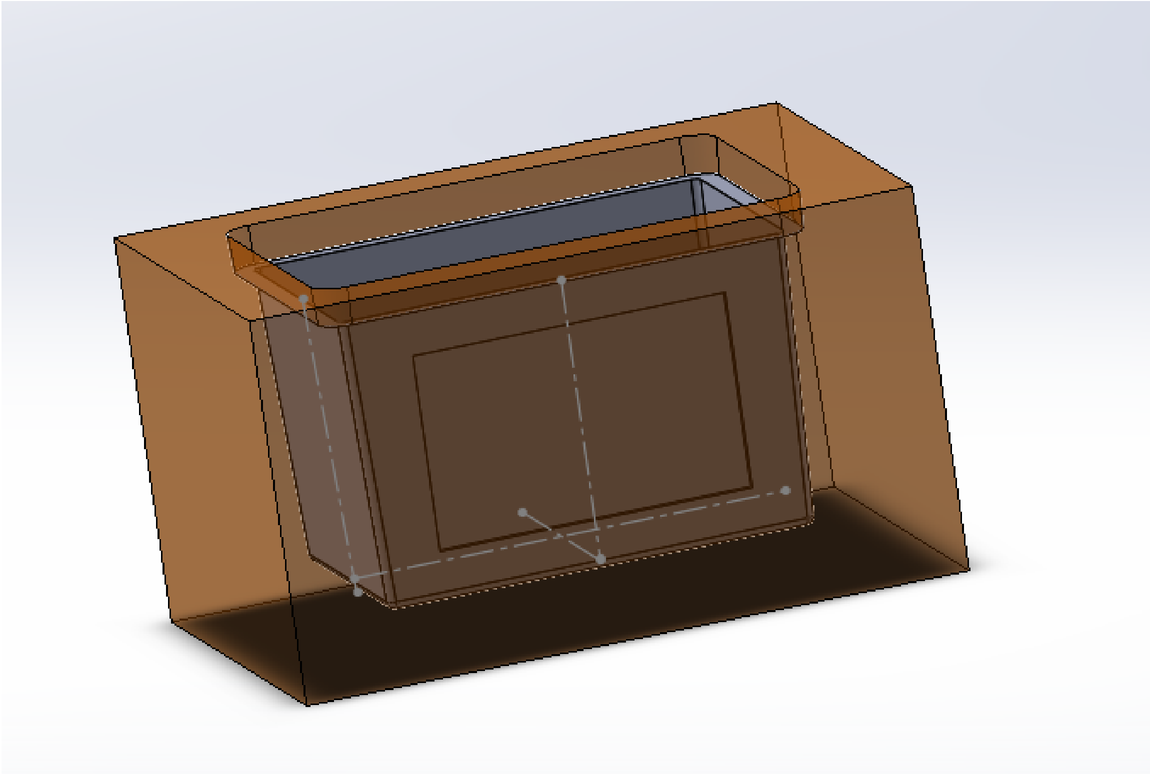


Figure 30: Bottom - Mold Design - Core

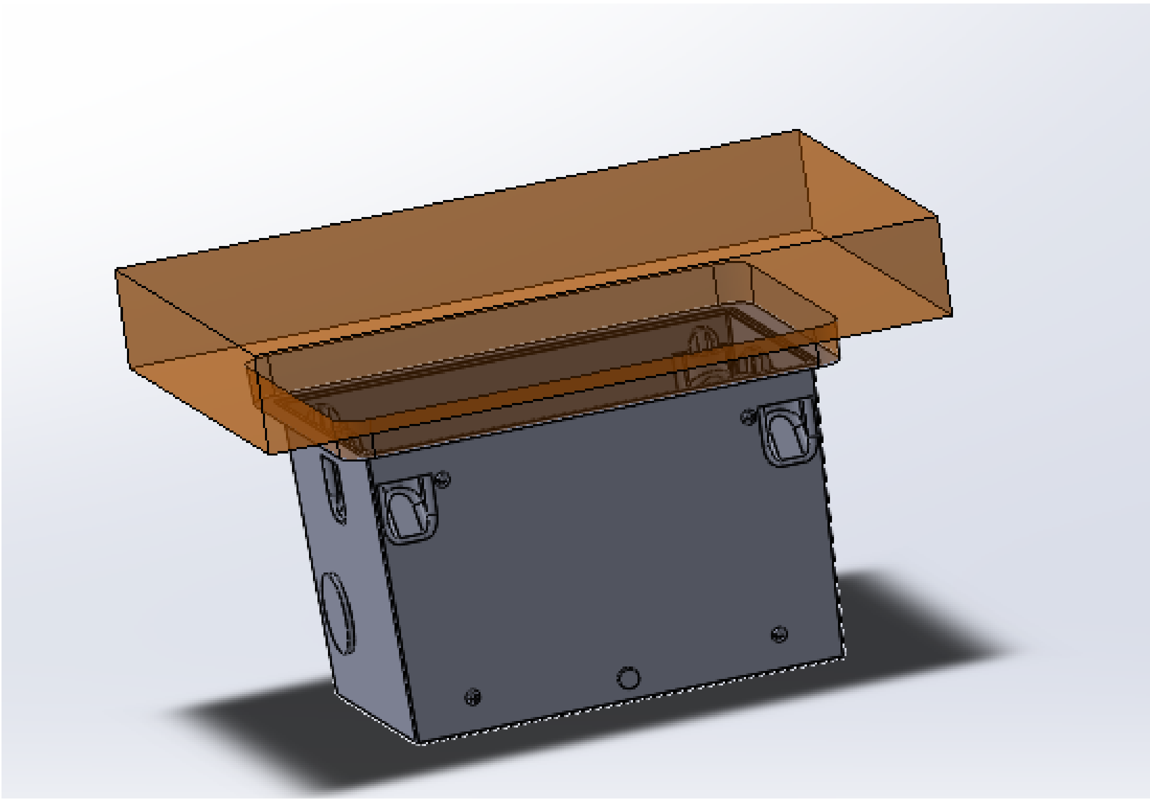


Figure 31: Bottom - Mold Design - Cavity

Figure 32: Lid - Top View

Figure 33: Lid - Bottom View

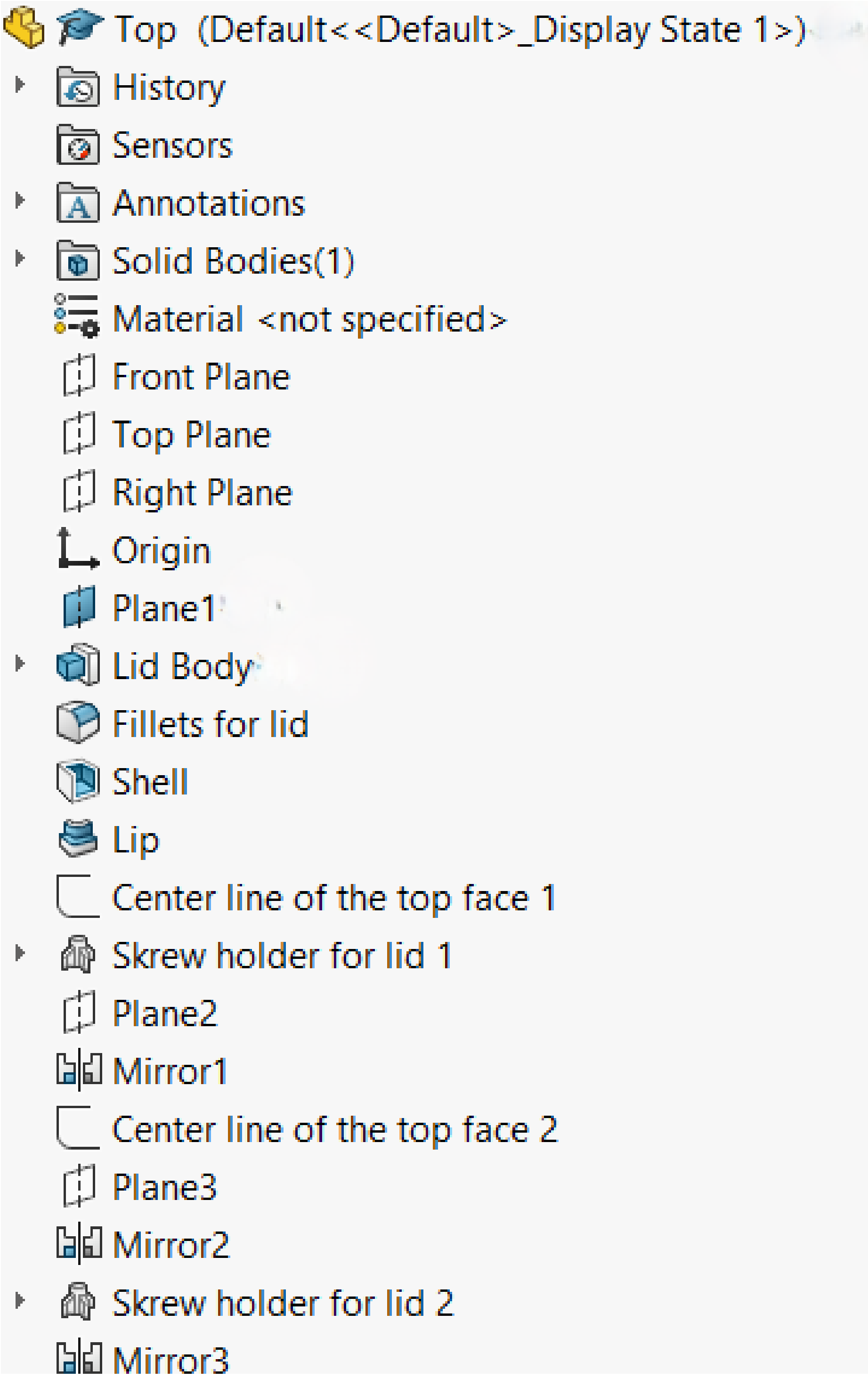


Figure 34: Lid - Model Tree

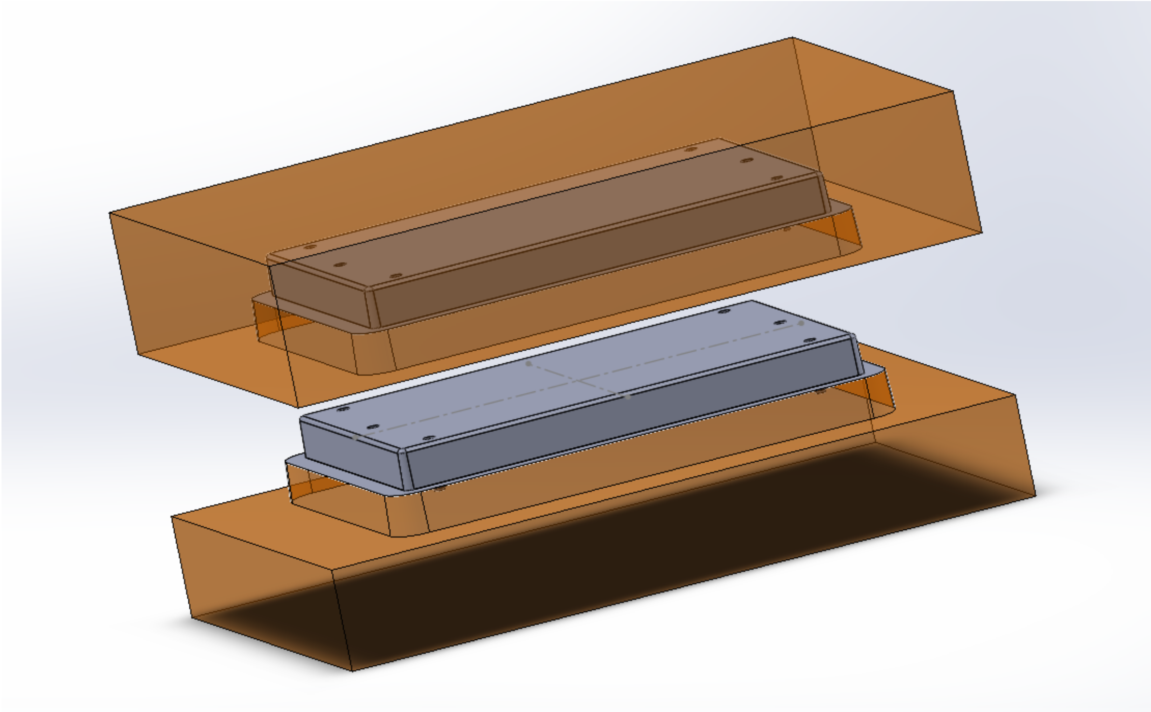


Figure 35: Lid - Mold Design

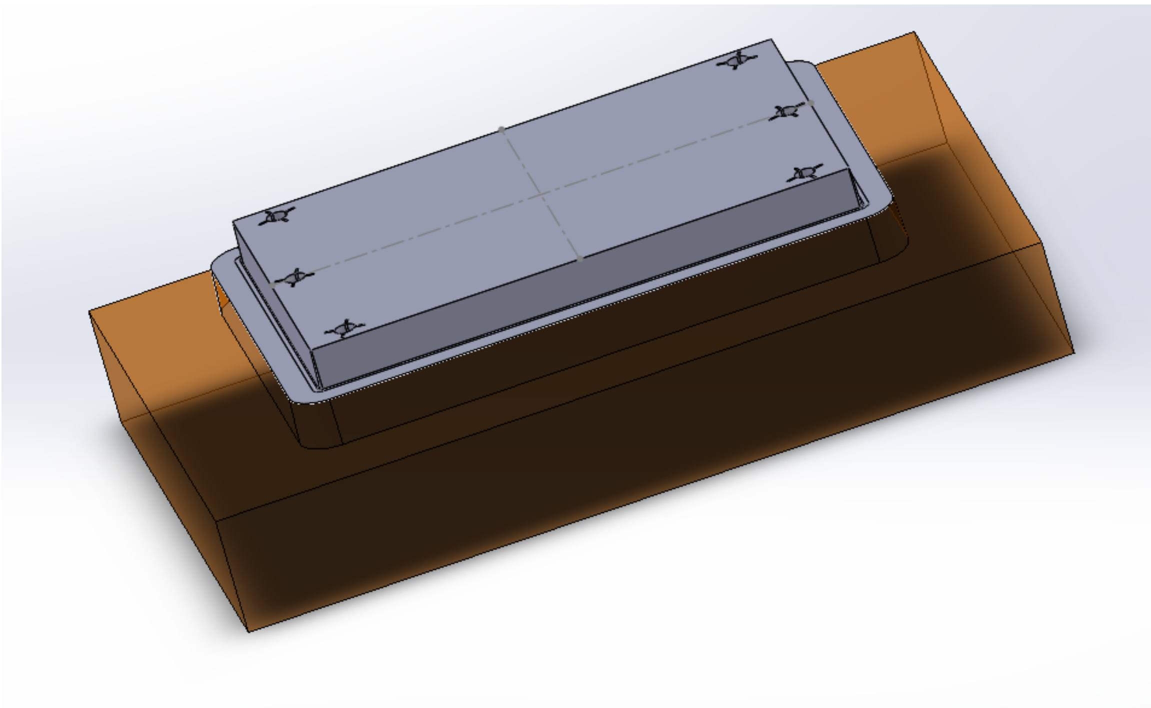


Figure 36: Lid - Mold Design - Core

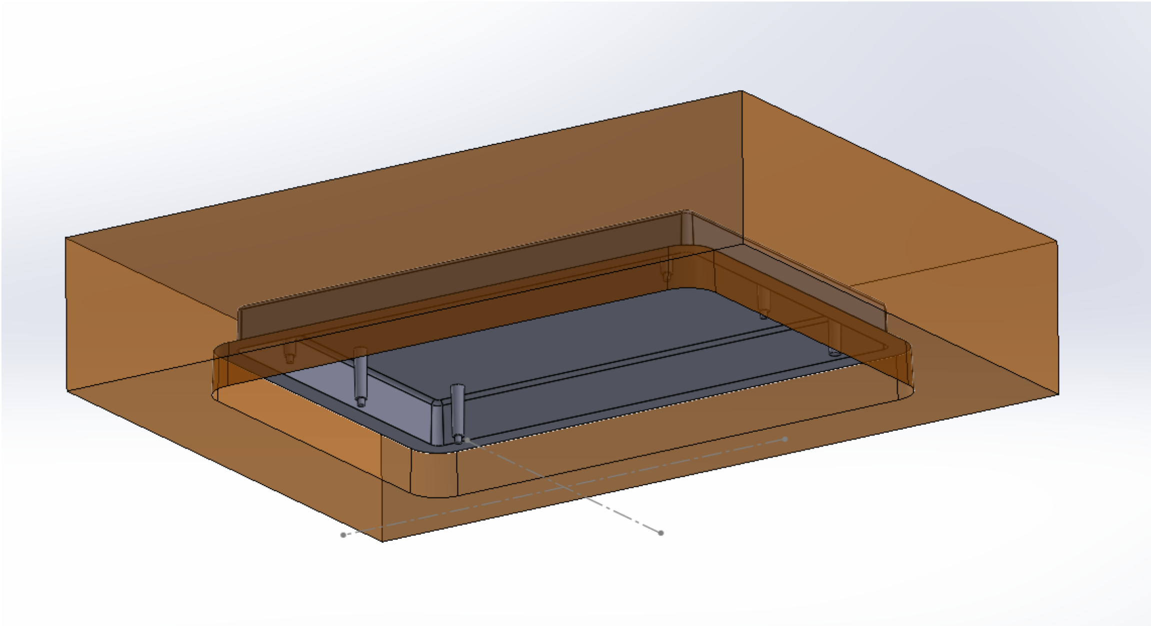


Figure 37: Lid - Mold Design - Cavity

Figure 38: Assembly - Front

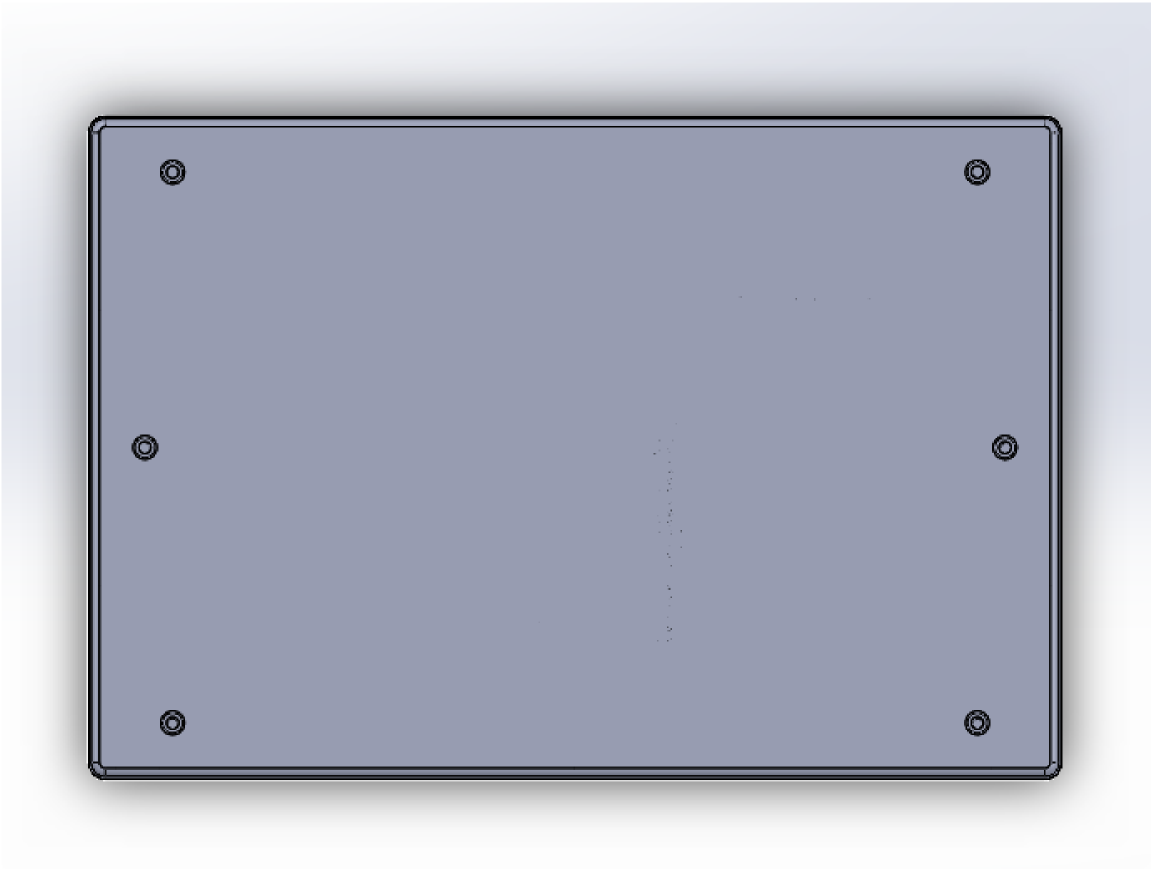


Figure 39: Assembly - Top

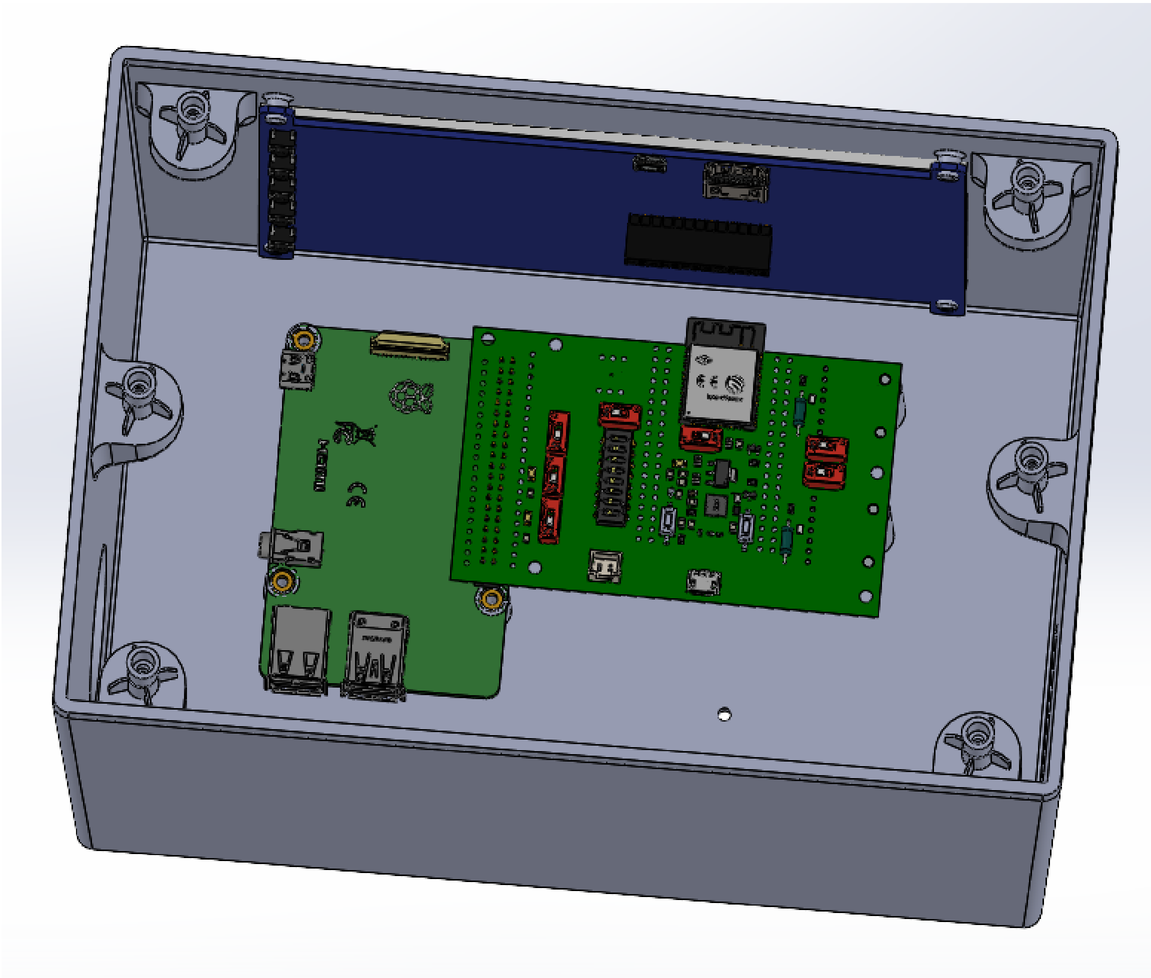


Figure 40: Assembly - Inside View 1

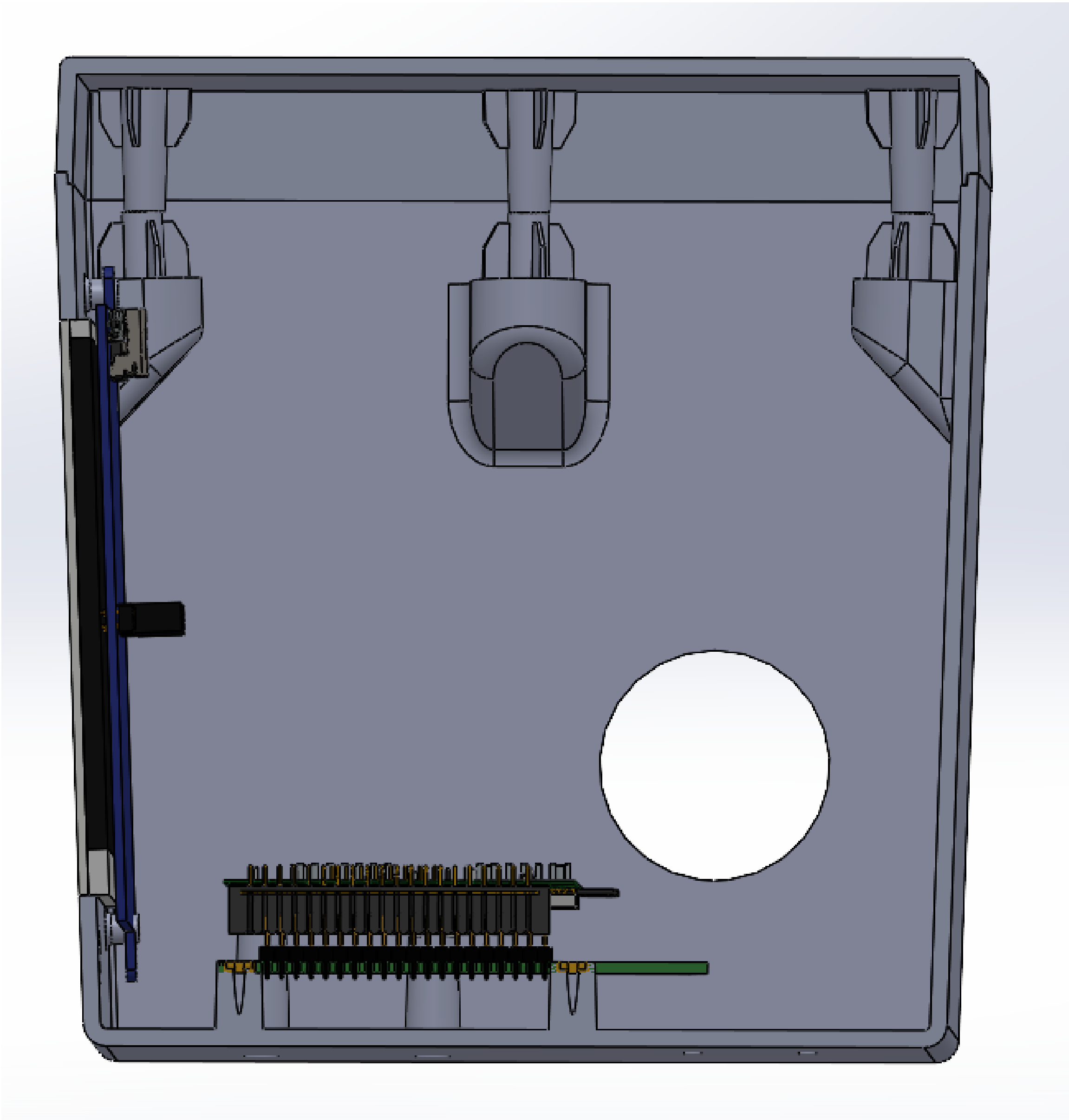


Figure 41: Assembly - Inside View 2

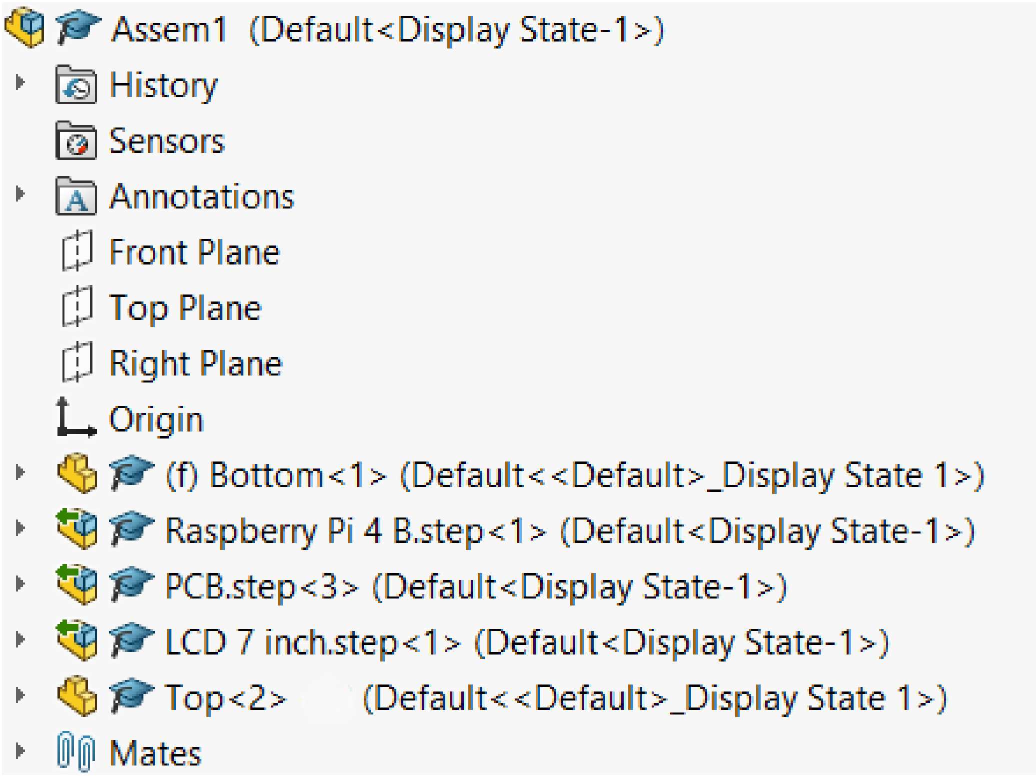


Figure 42: Assembly - Model Tree

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