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Design Document

User Interface for a Restaurant Robot
Group I-23

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Contents

1 Introduction & Block Diagram

This device features a user interface for a restaurant robot that enhances customer interaction through advanced voice and touch technologies. Utilizing the ICS43434 microphone IC, the robot captures customer voice commands, which are recorded by the ESP32 microcontroller and sent to the restaurant's main computer for processing. This computer leverages a speech recognition API to interpret the commands and generate appropriate voice responses. These responses are then transmitted back to the ESP32, which amplifies the voice signals and plays them through speakers for the customer. Additionally, a Raspberry Pi touch screen serves as an interactive menu, allowing customers to easily order food by touching and selecting items. The display also showcases the robot's reactions, such as facial expressions, to create an engaging and dynamic dining experience. The ESP32 collects user inputs and coordinates outputs displayed on the screen using a Raspberry Pi, seamlessly integrating voice and touch functionalities for a sophisticated and enjoyable customer interface.Designed to work on 5v and fit into a 10cm x 6cm x 0.16cm enclosure. Easy and Customizable setup with Low power consumption.

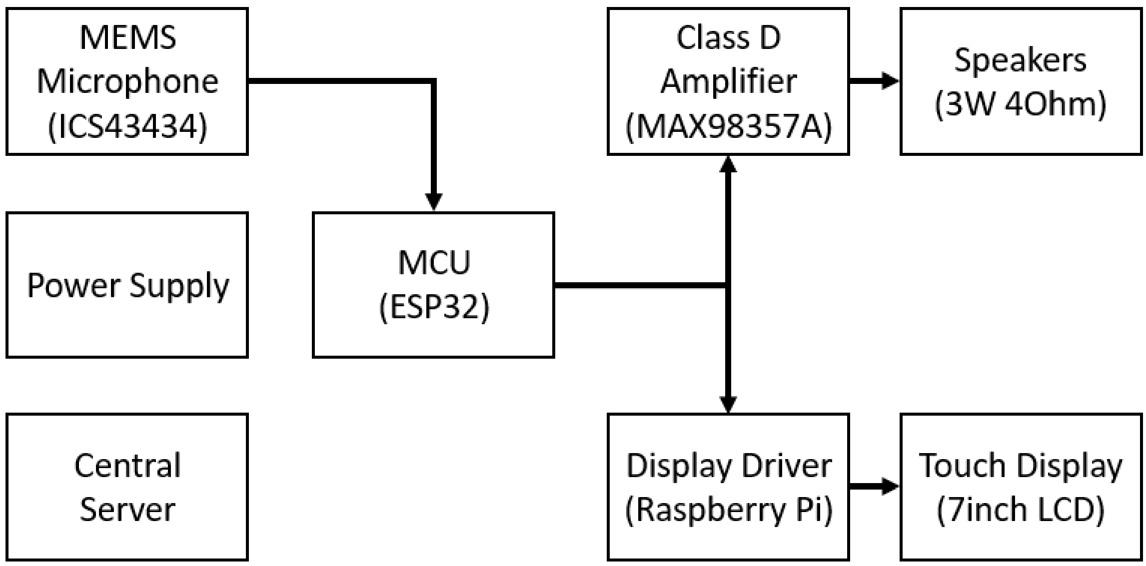


Figure 1: Block Diagram

2 Component Selection and Justification

2.1 Microcontroller Selection

ESP-WROOM-32E

Expressif micro-controllers mainly come in three different packages, which are SoC, Modules and development kits. We have chosen the Module type due to ease of solderability and the bare bones nature of it with only necessary components included inside the package.

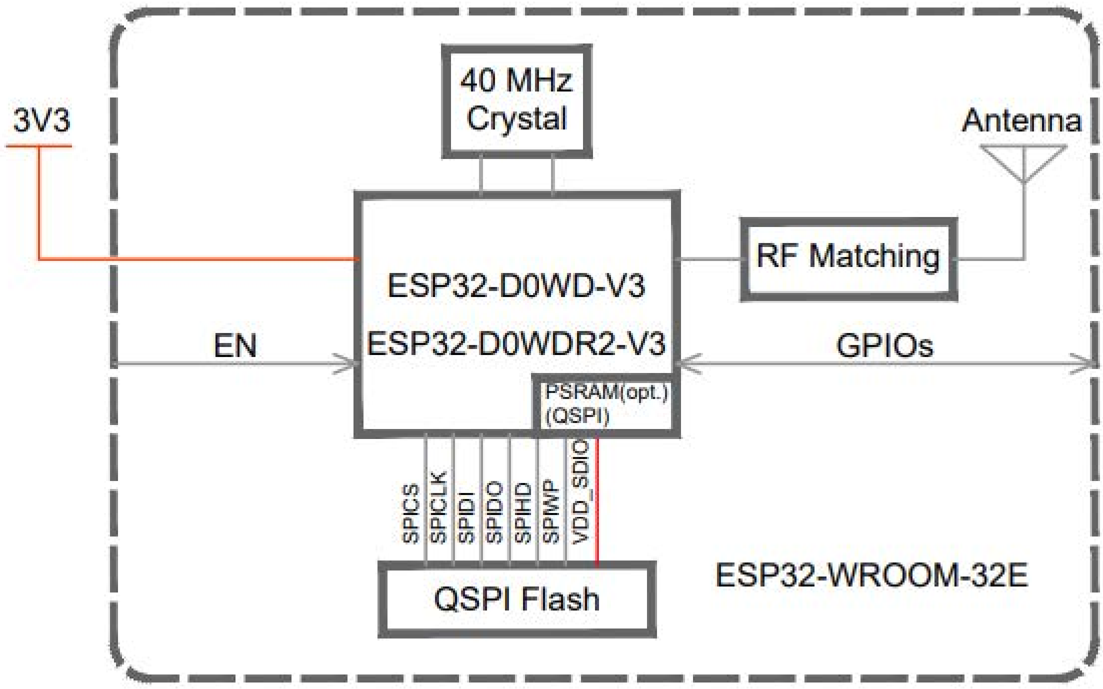


Figure 2: ESP32-WROOM-32E Block Diagram[1]

The selection of the ESP Wroom 32E microcontroller for this device is driven by several compelling reasons.

1. **Integrated Wi-Fi and Bluetooth Connectivity:** The ESP32 features built-in Wi-Fi and Bluetooth capabilities, essential for wireless communication with the main computer and other devices. This allows for seamless transmission of voice commands and responses, ensuring a smooth user experience.

2. **High Performance and Low Power Consumption:** With its dual-core processor and efficient power management, the ESP32 offers a robust performance suitable for handling multiple tasks simultaneously, such as recording audio, processing inputs, and controlling outputs, all while maintaining low power consumption.

3. **Versatile I/O Options** The ESP32 provides a wide range of input/output options, making it ideal for interfacing with various peripherals like the ICS43434 microphone, speakers, and touch screens. This flexibility ensures that the microcontroller can handle the diverse needs of the restaurant robot system.

4. **Real-Time Processing Capabilities:** The ESP32 is capable of real-time processing, which is crucial for capturing and transmitting voice commands without noticeable delays. This real-time capability enhances the overall responsiveness and effectiveness of the robot's interactions with customers.

5. **Cost-Effectiveness** Compared to other microcontrollers with similar features, the ESP32 is highly cost-effective. This makes it an attractive option for integrating advanced functionalities without significantly increasing the overall cost of the restaurant robot system.

6. **Community Support and Documentation:** The ESP32 benefits from extensive community support and thorough documentation, facilitating easier development, troubleshooting, and implementation. This strong support network helps in quickly resolving issues and optimizing the robot's performance.

7. **Robust Audio Processing:** Given its ability to handle digital signal processing (DSP) tasks, the ESP32 is well-suited for audio applications. This is crucial for effectively capturing, processing, and transmitting high-quality voice commands from the microphone.

Overall, the ESP Wroom 32D microcontroller's comprehensive feature set, combined with its reliability and efficiency, makes it an excellent choice for the restaurant robot interface, ensuring a seamless and sophisticated interaction experience for customers.

2.2 MEMS Microphone

ICS43434

We required a microphone that is capable of listening in loud and noisy environments such as a restaurant and providing low noise, high quality audio output. After going through several microphone types available in the market, we settled upon a MEMS microphone type and chose the best performing one amongst them. Our testings also confirmed the ability of this mic to perform well under high noise environments in sufficiently large radius.

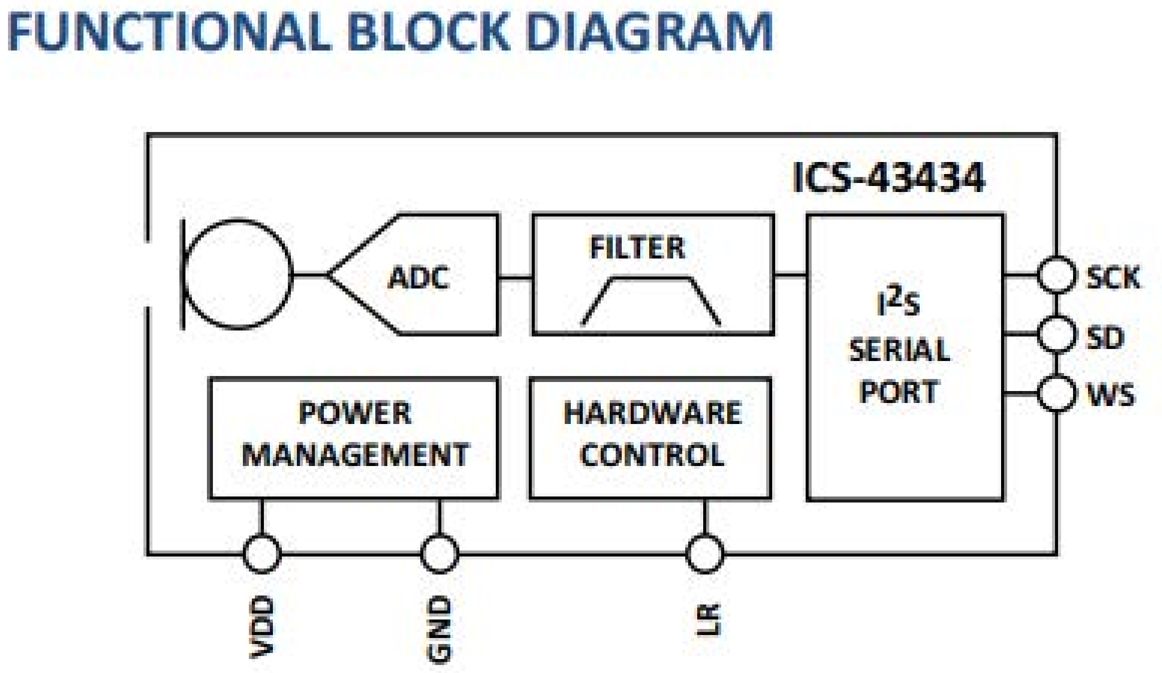


Figure 3: ICS43434 Block Diagram[4]

The selection of the ICS43434 microphone IC for the restaurant robot interface is based on several key advantages that make it particularly suitable for this application.

1. **High Signal-to-Noise Ratio (SNR)**: The ICS43434 microphone IC features a high SNR, which ensures clear and high-quality voice capture. This is crucial for accurately capturing customer voice commands in a potentially noisy restaurant environment.

2. **Low Power Consumption**: The ICS43434 is designed to operate with low power consumption, making it an efficient choice for battery-operated devices like the ESP32 microcontroller. This helps in maintaining the overall energy efficiency of the restaurant robot system.

3. **Digital Output (I2S Interface)**: The ICS43434 provides a digital I2S output, which simplifies the connection to digital signal processing units like the ESP32. This digital interface ensures a higher fidelity of audio data transmission compared to analog alternatives, reducing the risk of signal degradation.

4. **Compact Size and Ease of Integration**: The ICS43434 is a compact MEMS microphone that can be easily integrated into space-constrained designs. This is beneficial for maintaining a sleek and unobtrusive design for the restaurant robot.

5. **Wide Frequency Response**: With a wide frequency response range, the ICS43434 can accurately capture a variety of voice tones and pitches. This versatility ensures that voice commands from customers of different ages and speaking styles are reliably recognized.

6. **Robust Performance in Noisy Environments**: The ICS43434 is engineered to perform well even in noisy environments, which is typical for restaurants. Its ability to filter out background noise enhances the clarity and accuracy of voice command recognition.

7. **Ease of Use and Reliable Operation**: The ICS43434 is known for its ease of use and reliable operation. It requires minimal external components, which simplifies the design and reduces the potential for technical issues during implementation.

8. **Proven Track Record and Manufacturer Support**: The ICS43434 is a well-regarded microphone IC with a proven track record in various audio applications. It is supported by detailed documentation and application notes from the manufacturer, aiding in smooth integration and troubleshooting.

9. **Cost-Effectiveness**: The ICS43434 offers a balance of performance and cost, providing high-quality audio capture capabilities at a reasonable price point. This helps in maintaining the overall budget of the restaurant robot project without compromising on audio performance.

Overall, the ICS43434 microphone IC is an excellent choice for the restaurant robot interface due to its high audio quality, ease of integration, and reliable performance in challenging environments.

2.3 Amplifier

MAX98357 I2S 3W Class D Amplifier

The selection of the MAX98357 I2S 3W Class D amplifier for the restaurant robot interface is based on several key advantages that make it particularly suitable for this application[5]:

1. **I2S Digital Audio Interface**: The MAX98357 features an I2S digital audio interface, which allows for direct digital audio signal transmission from the ESP32 microcontroller. This ensures high-quality, noise-free audio output, essential for clear and intelligible voice responses from the robot.
2. **High Efficiency and Low Power Consumption**: As a Class D amplifier, the MAX98357 offers high efficiency, converting more power into audio output rather than heat. This makes it ideal for battery-operated devices, contributing to the overall energy efficiency of the restaurant robot.
3. **Compact Size**: The MAX98357 is compact, allowing for easy integration into the robot's design. Its small form factor is advantageous in maintaining a sleek and unobtrusive appearance for the robot.
4. **High Output Power**: With an output power of 3W, the MAX98357 can drive speakers to produce loud and clear sound. This is essential in a restaurant environment where background noise levels can be high, ensuring that the robot's voice responses are easily heard by customers.
5. **Low Distortion and High Fidelity**: The MAX98357 provides low total harmonic distortion (THD) and high signal-to-noise ratio (SNR), resulting in high-fidelity audio output. This ensures that the voice responses are clear and natural sounding, enhancing the customer interaction experience.
6. **Integrated Features**: The MAX98357 includes integrated features such as click-and-pop suppression and short-circuit protection. These features enhance the reliability and quality of the audio output, ensuring a smooth and consistent performance.
7. **Ease of Integration**: The amplifier is designed for straightforward integration with microcontrollers like the ESP32. The I2S interface simplifies the connection process, reducing the complexity of the audio signal chain and making the design process more efficient.
8. **Cost-Effectiveness**: The MAX98357 is a cost-effective solution for high-quality audio amplification. It offers excellent performance at a reasonable price point, making it an economical choice for the restaurant robot system.
9. **Thermal Efficiency**: The Class D operation of the MAX98357 means it generates less heat compared to Class A or Class AB amplifiers. This reduces the need for extensive heat dissipation mechanisms, simplifying the design and potentially lowering the cost.
10. **Wide Input Voltage Range**: The MAX98357 operates over a wide input voltage range, providing flexibility in power supply options and making it adaptable to various power configurations within the robot.

Overall, the MAX98357 I2S 3W Class D amplifier is an excellent choice for the restaurant robot interface due to its high efficiency, high output power, compact size, ease of integration, and cost-effectiveness. These features ensure that the robot can deliver clear and powerful audio responses, enhancing the customer interaction experience.

2.4 RaspberryPi LCD Display

Waveshare Raspberry Pi touch screen

The selection of the Waveshare Raspberry Pi touch screen for the restaurant robot interface is driven by several key benefits that align well with the project's requirements:

1. **Touch Interface**: The Waveshare Raspberry Pi touch screen provides an intuitive and user-friendly touch interface, allowing customers to interact directly with the robot by selecting menu items and providing inputs. This enhances the overall user experience and makes the interaction process straightforward and efficient.
2. **High Resolution and Display Quality**: Waveshare touch screens are known for their high resolution and excellent display quality. This ensures that the menu and other visual elements are clear, vibrant, and easily readable, improving the visual appeal and usability of the interface.
3. **Compatibility with Raspberry Pi**: The Waveshare touch screen is designed specifically for seamless compatibility with the Raspberry Pi, which is used to control the display. This ensures easy integration, reliable performance, and efficient communication between the touch screen and the Raspberry Pi.
4. **Durability and Build Quality**: Waveshare touch screens are built with durability in mind, which is important for a restaurant environment where the interface may be frequently used and subjected to wear and tear. The robust build quality ensures long-term reliability and reduces maintenance needs.
5. **Capacitive Touch Technology**: Many Waveshare touch screens use capacitive touch technology, which provides a smooth and responsive touch experience. This technology supports multi-touch gestures, enhancing the interactivity and responsiveness of the user interface.
6. **Comprehensive Documentation and Support**: Waveshare provides comprehensive documentation and support for their touch screens, including detailed user manuals, tutorials, and community forums. This support is invaluable for troubleshooting and optimizing the performance of the touch screen interface.
7. **Cost-Effectiveness**: Waveshare touch screens offer a good balance between quality and cost. They provide high-quality displays at a reasonable price, making them an economical choice for integrating a sophisticated touch interface into the restaurant robot system.

Overall, Waveshare Raspberry Pi touch screen is a suitable choice for the restaurant robot interface due to its high-quality display, reliable performance, ease of integration, and cost-effectiveness.

3 Schematic & PCB Design

3.1 Comprehensive Design Details

After coming up with the block diagram of the system and deciding the components, we started to draft the schematic and design of the PCB. Our schematic is adopted from the Expressif's recommended schematic for the ESP32-WROOM module and expanded to suit our needs[2].

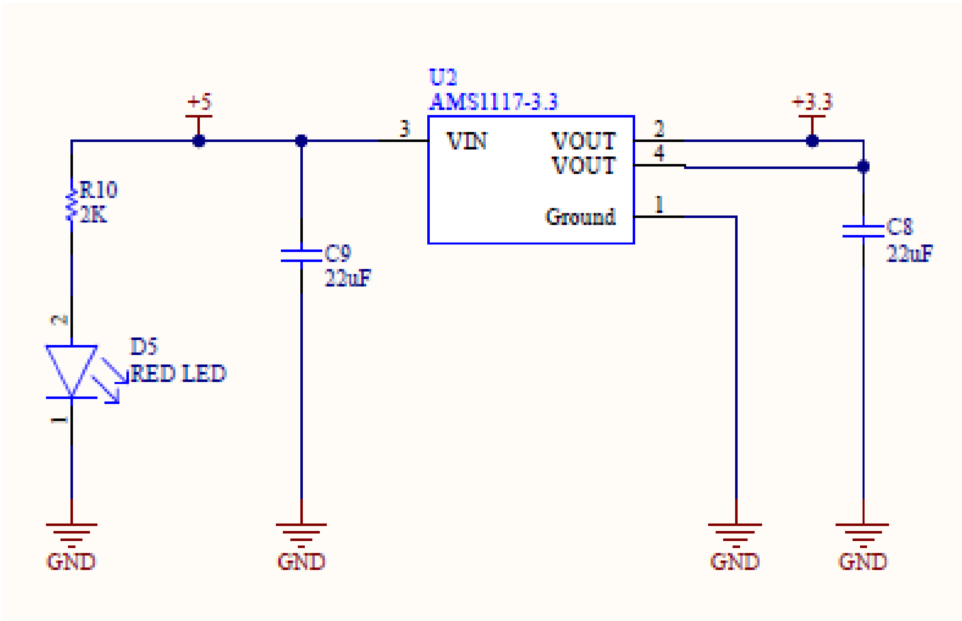


Figure 4: Our Power Supply Schematic

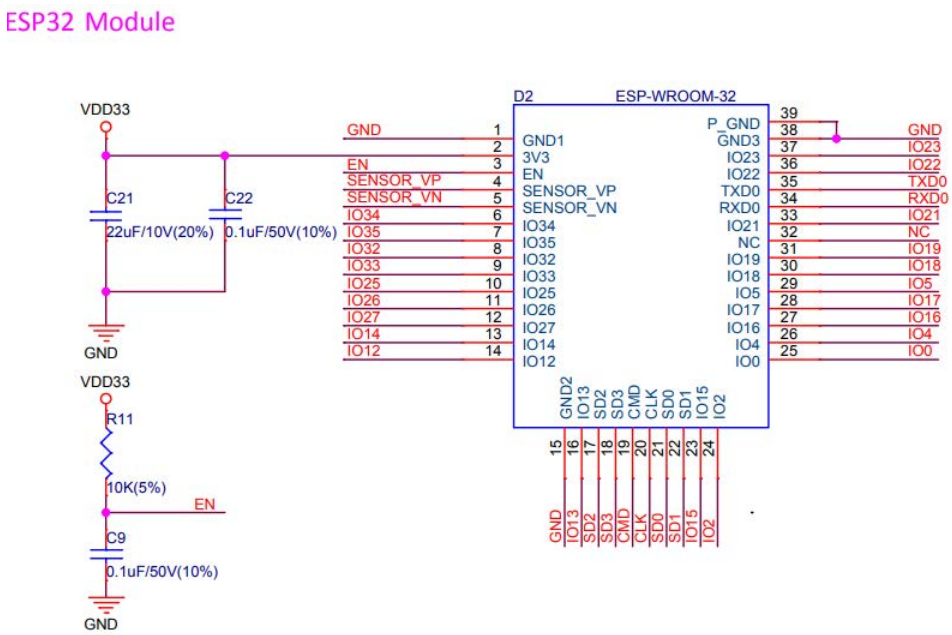


Figure 5: Expressif Recommended Schematic for the main module

Male, Female headers, Connectors, DIP Switches, LEDs, Vias, Pad Holes and Mounting Holes were added according to our needs. Testing and debugging, Heat transfer, Ease of connectivity, Low impedance path, Signal integrity were the main things that was considered when adding the above parts to our schematic.

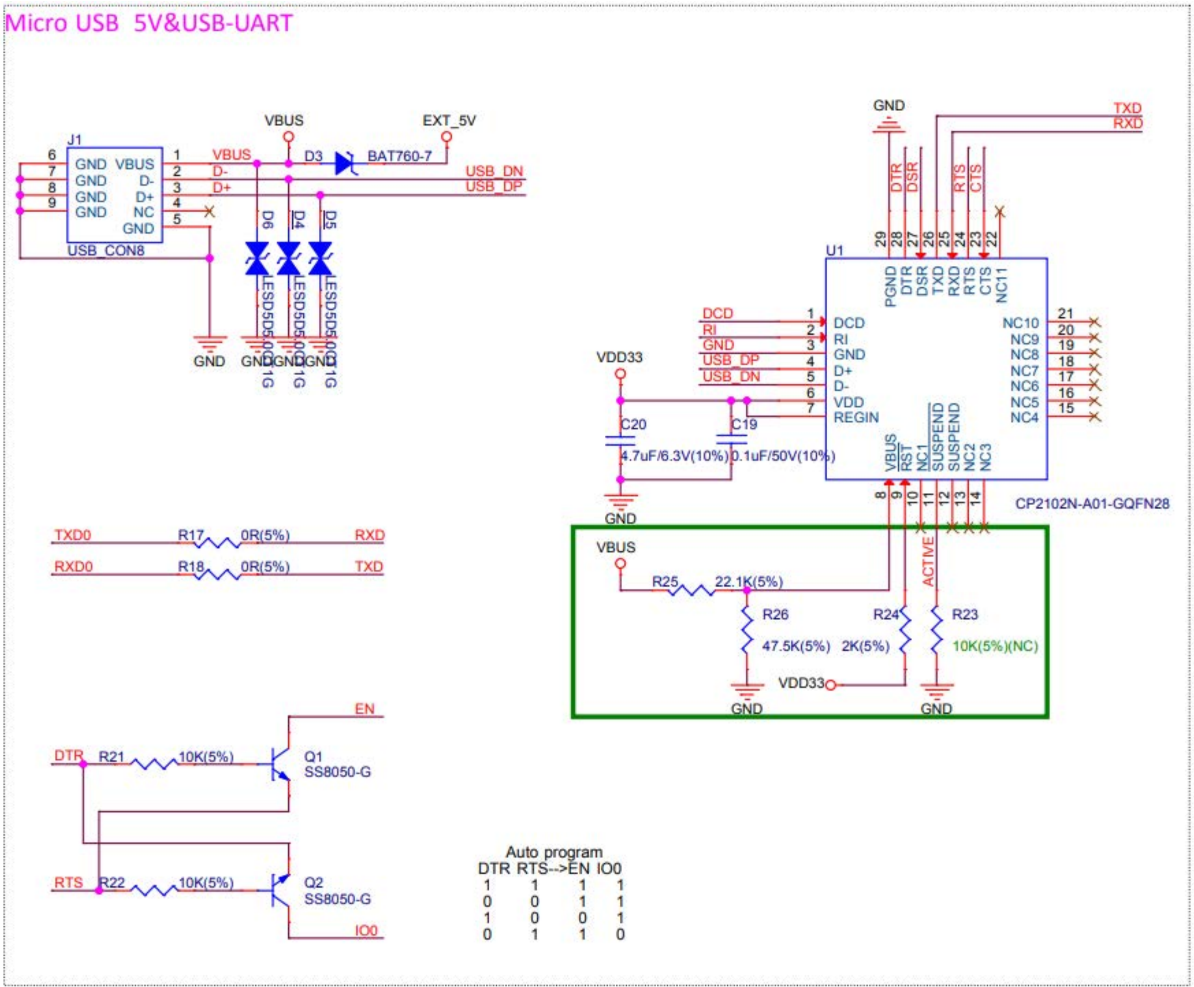


Figure 6: Expressif Recommended Schematic for the UART Controller

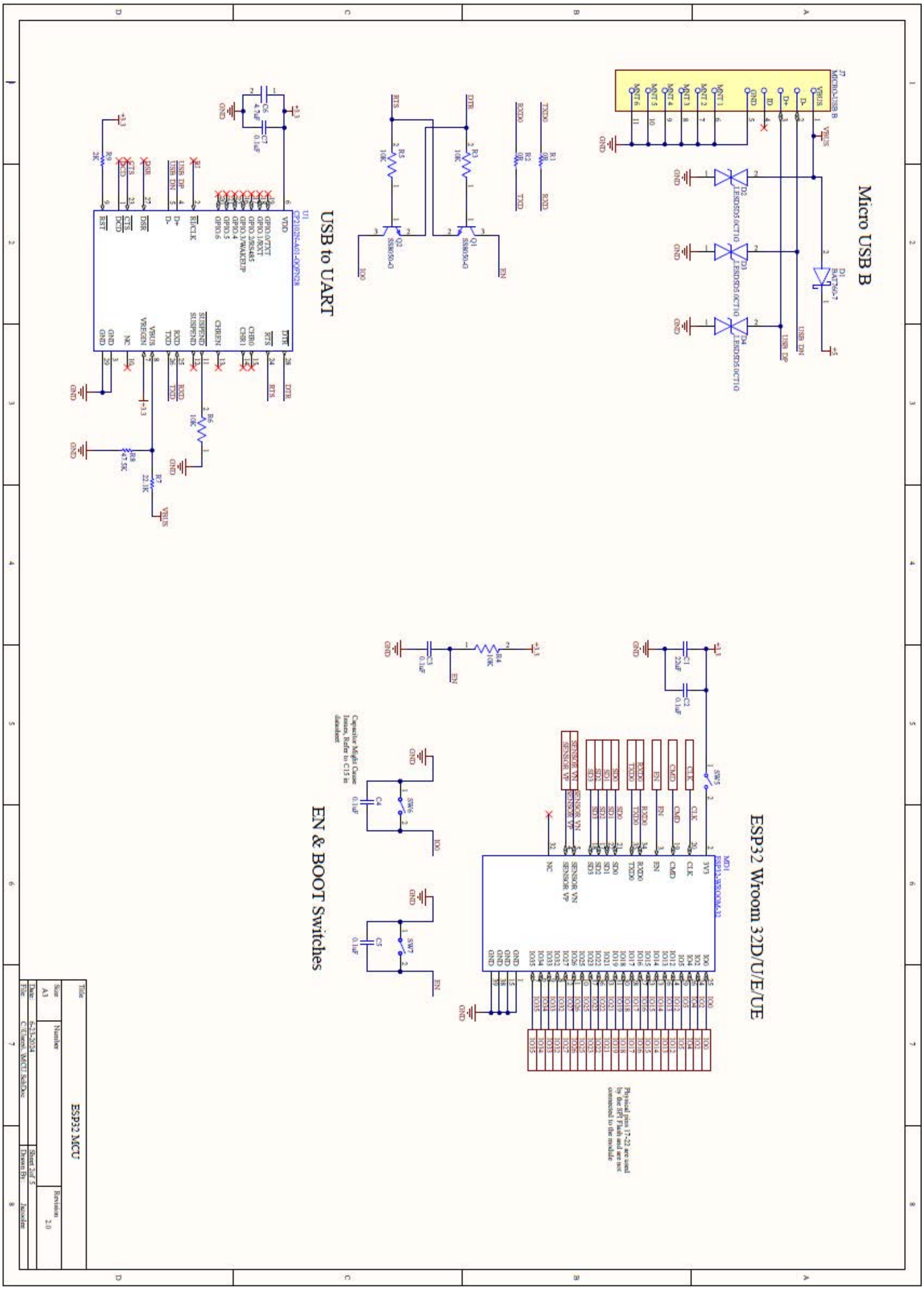


Figure 7: Our MCU Schematic

After finalizing the MCU part, we moved on to integrating the Microphone and Amplifier Modules with it. For these also we went with manufacturer recommended designs.

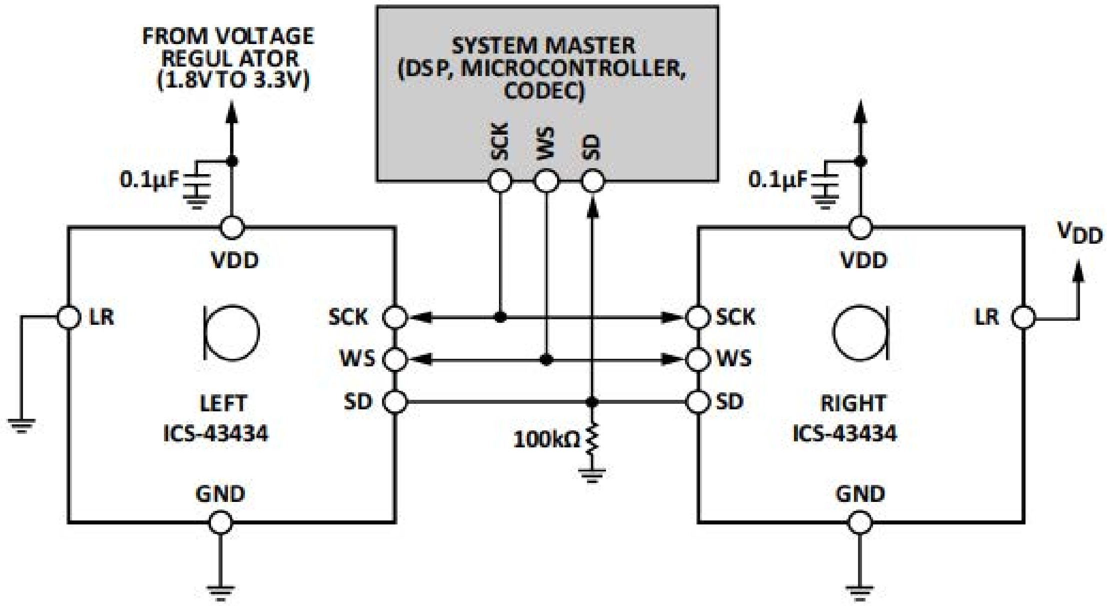


Figure 8: InvenSense Recommended Design

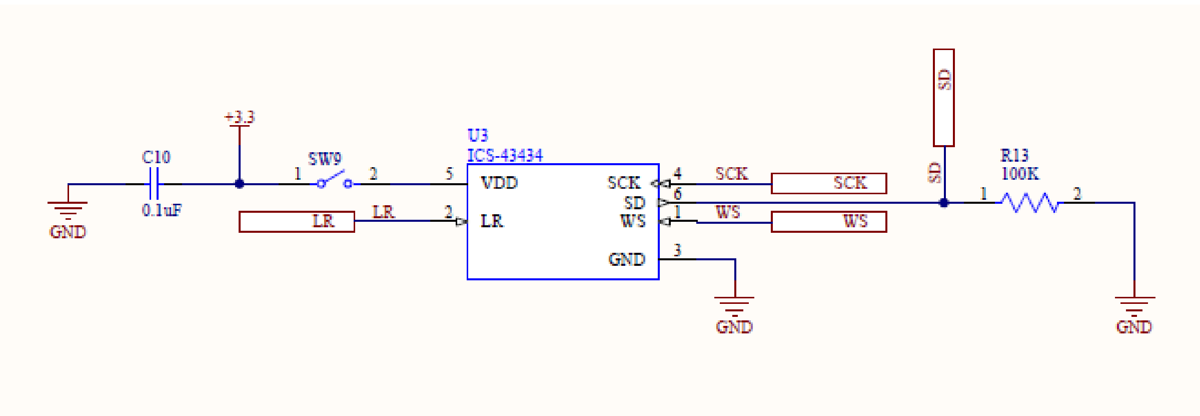


Figure 9: Our Microphone Schematic

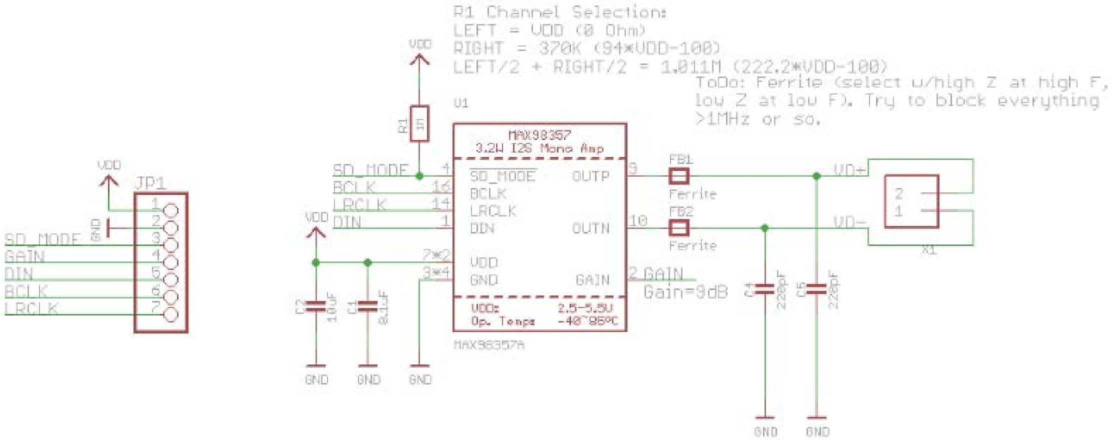


Figure 10: Adafruit Recommended Design

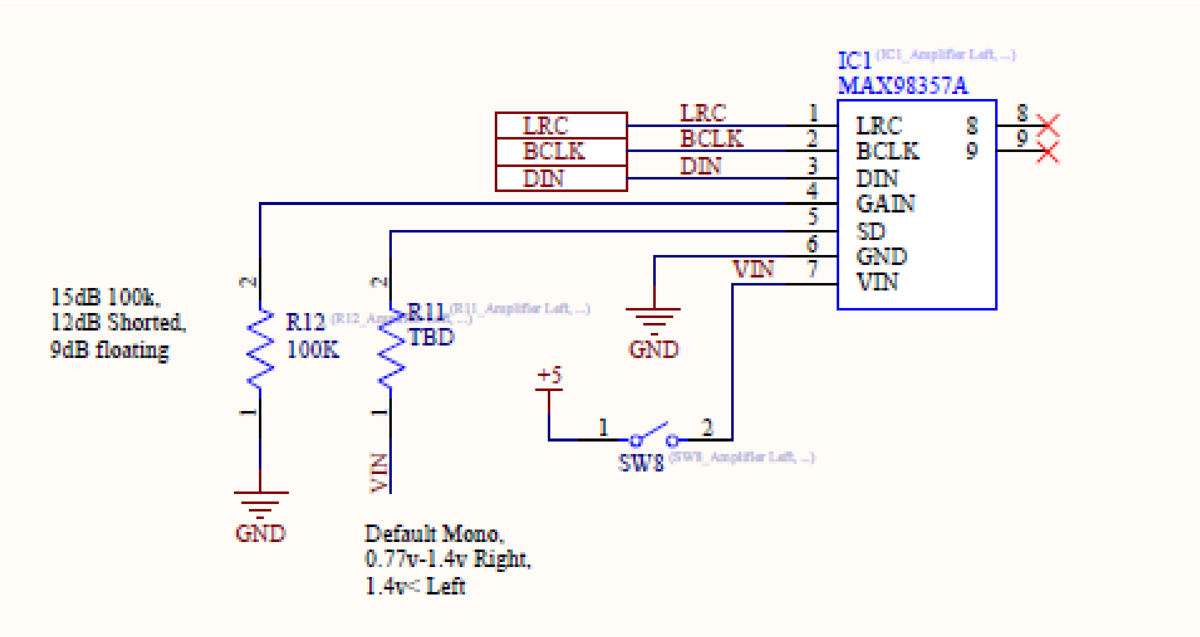


Figure 11: Our Amplifier Schematic

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.

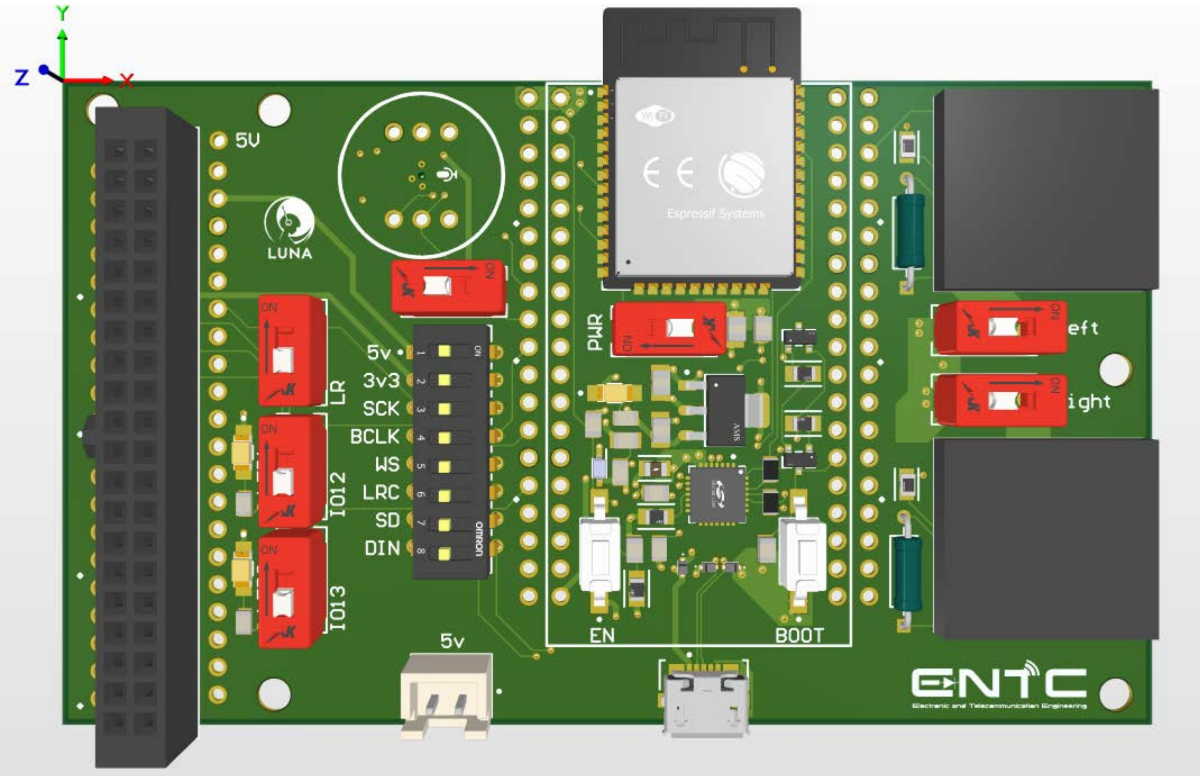


Figure 12: 3D View

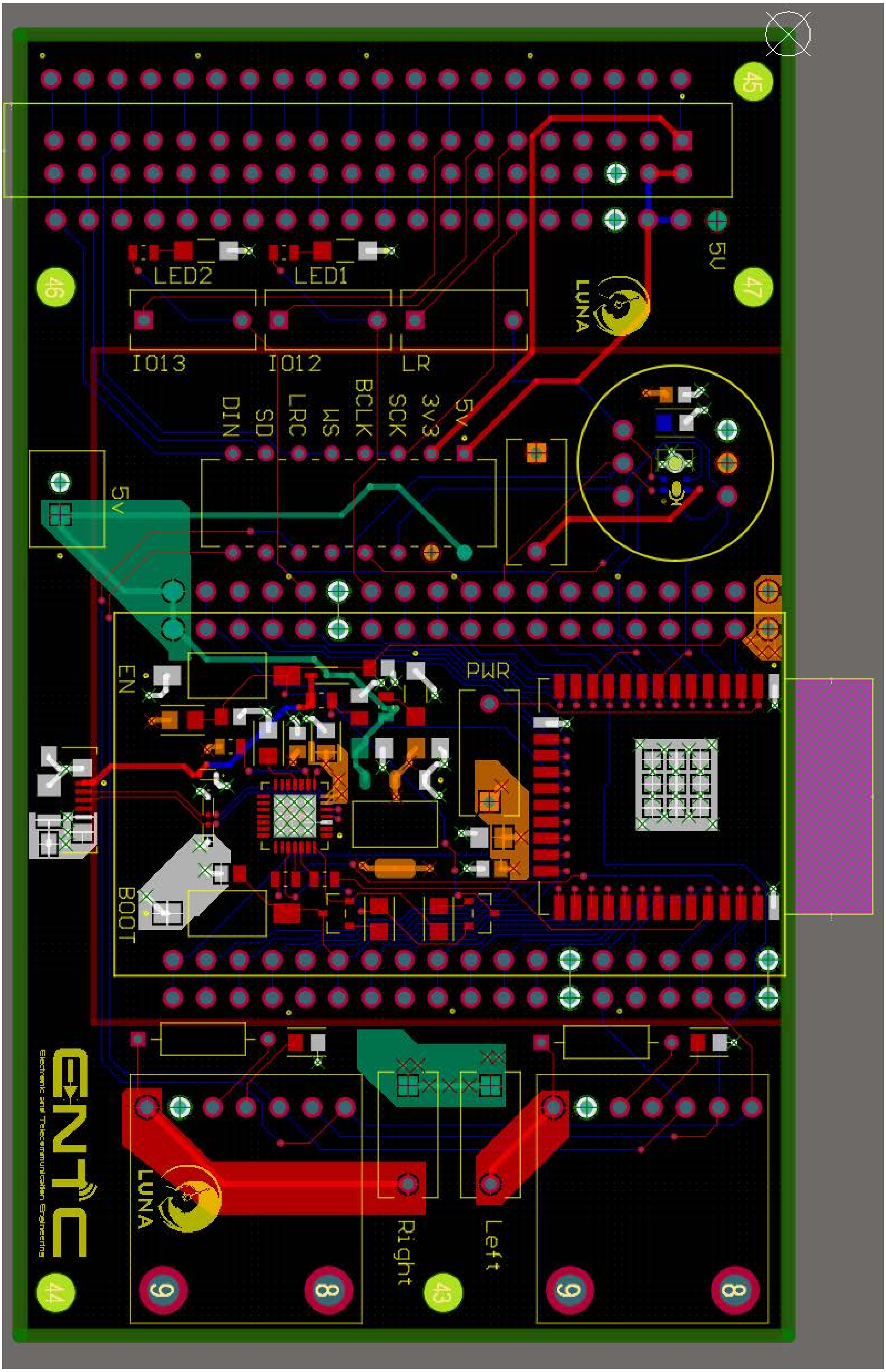


Figure 13: PCB

3.2 Soldering & Testing

- As soon as we got our hands on the PCB, we began to verify the connectivity of pads, holes and vias.
- After ensuring all the connectivity through continuity tests and testing the power traces for shorts, then only we started soldering.
- Our PCB is impedance matched in order to ensure the correct functionality of the differential signalling used by the micro USB type B.
- We also tested the necessary holes needed for placement inside the enclosure, and the microphone holes.

(a) PCB Samples Top View

(b) Bottom View

Figure 14: PCB Samples

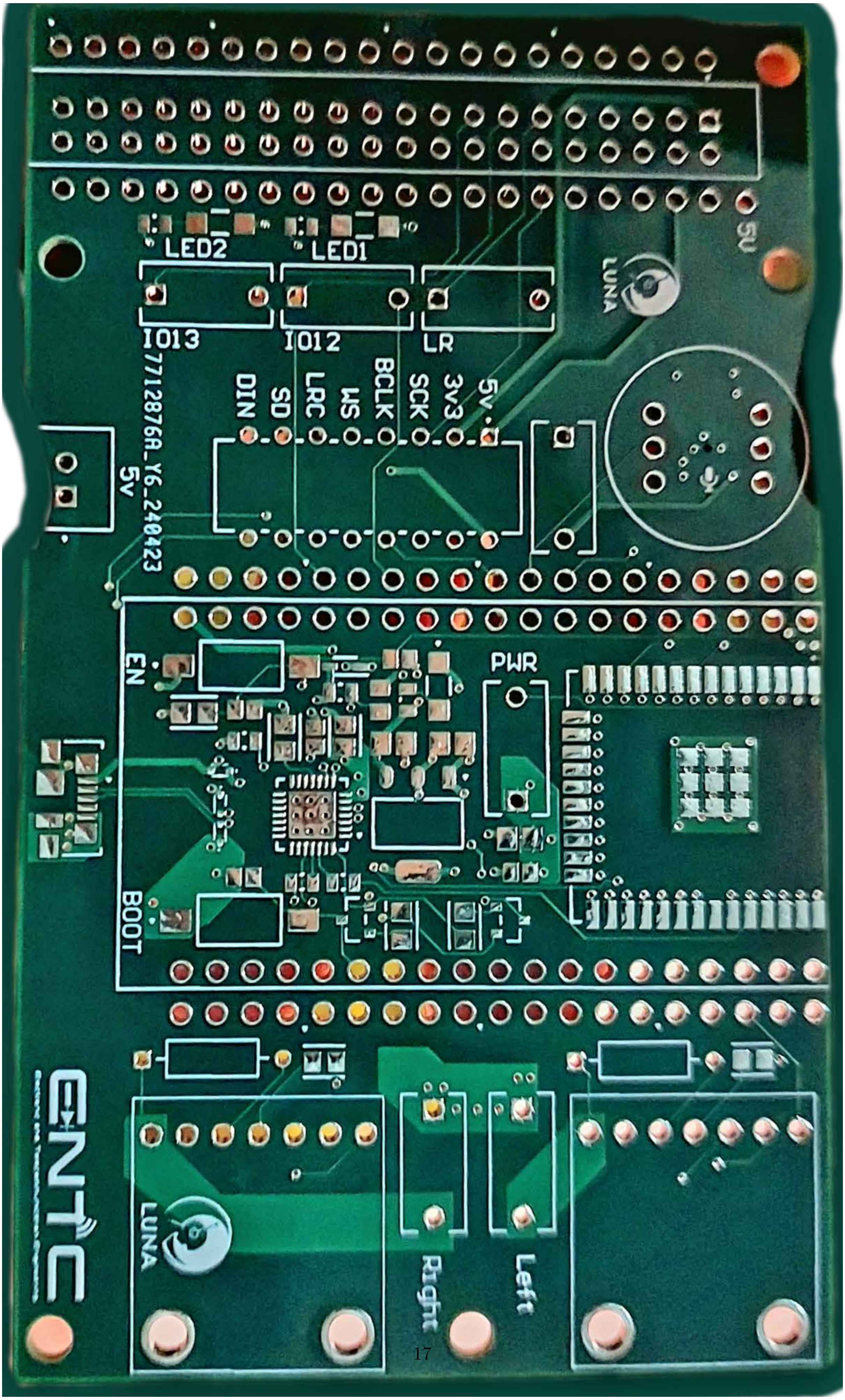


Figure 15: Bare PCB Top View

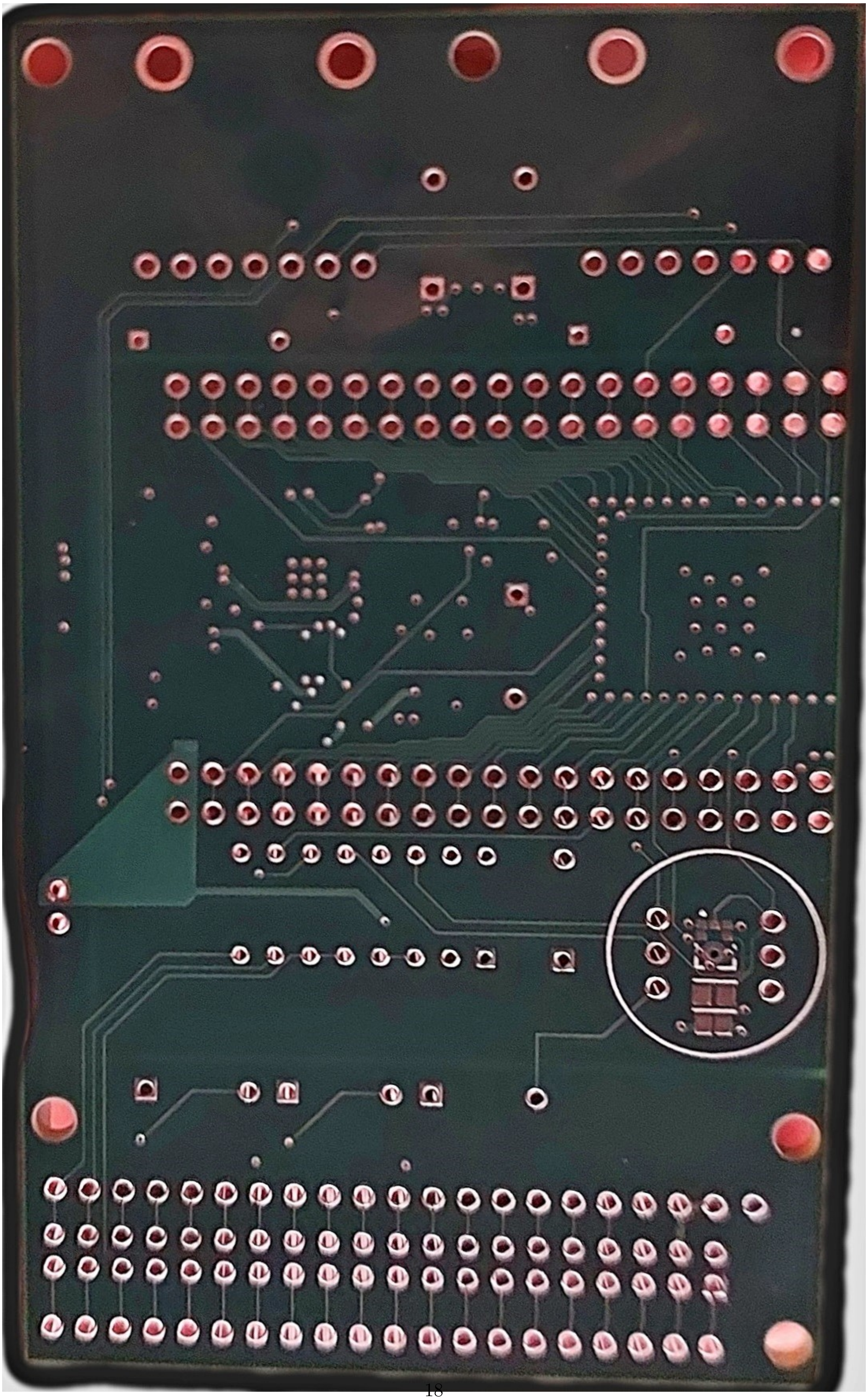


Figure 16: Bare PCB Bottom View

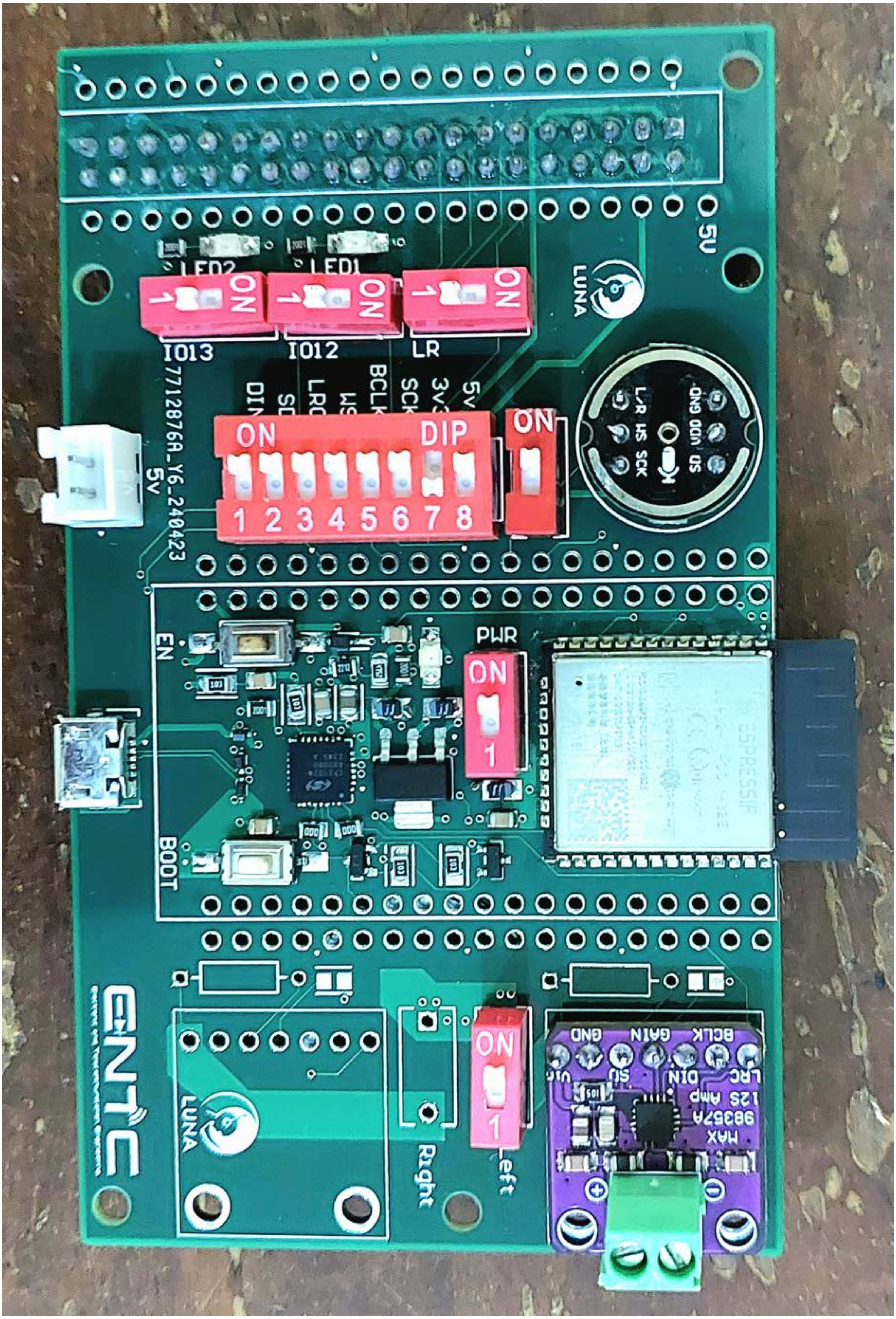


Figure 17: Soldered PCB Top View

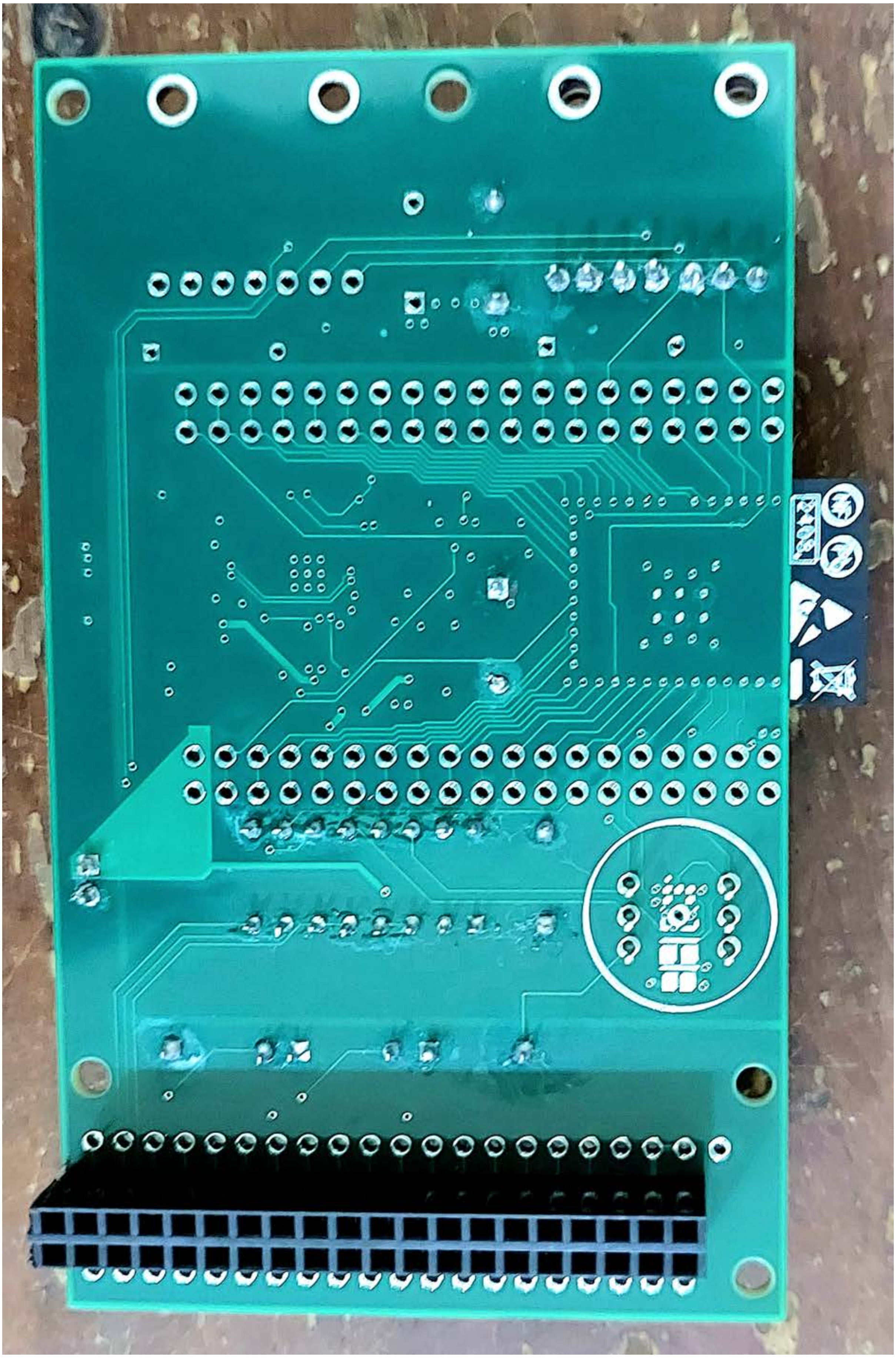


Figure 18: Soldered PCB Bottom View

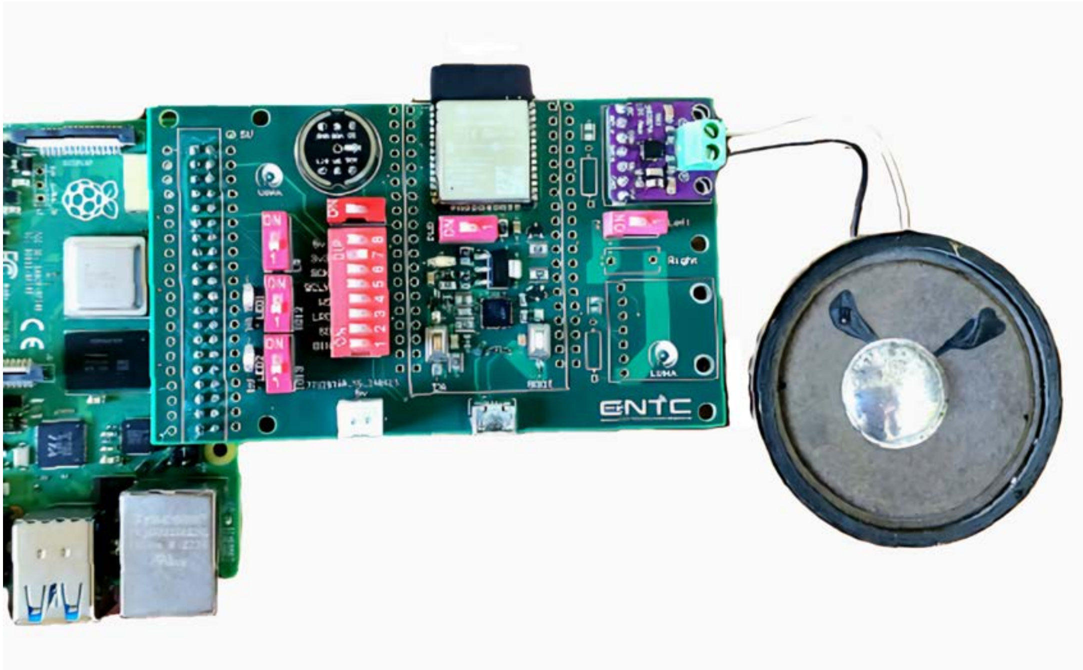


Figure 19: Raspberry Pi & Speaker Attached

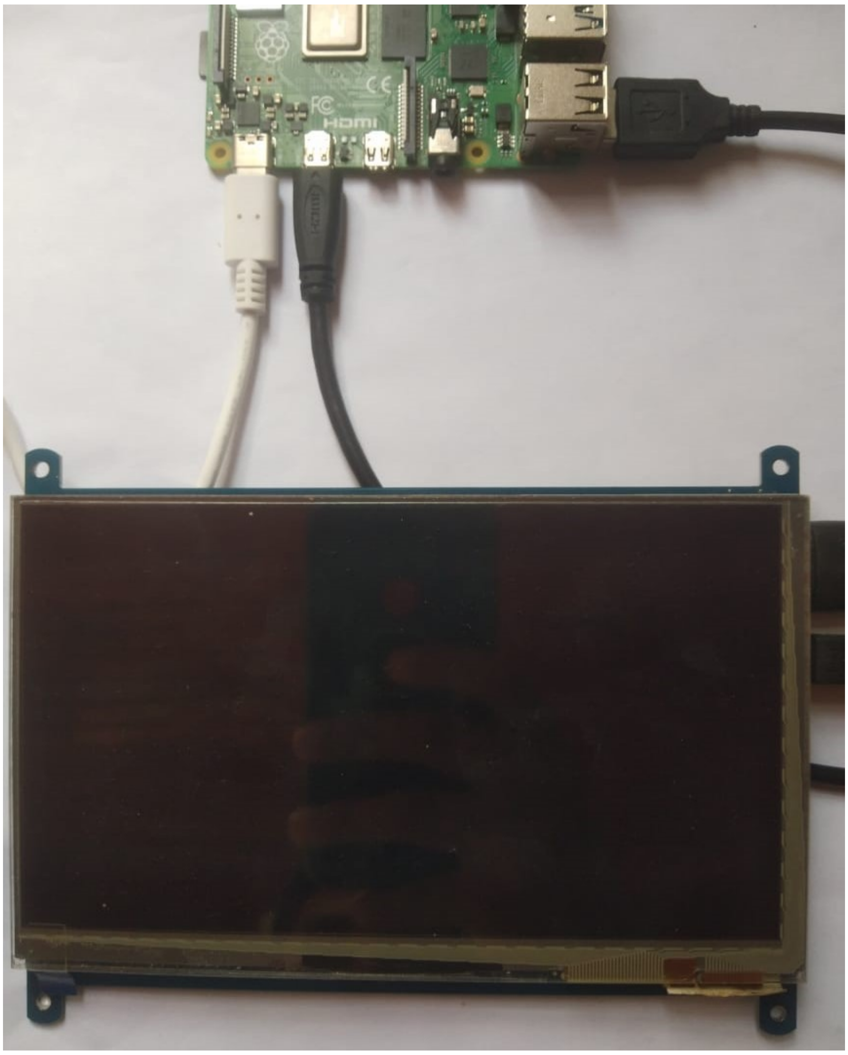


Figure 20: Raspberry Pi & Display Attached

3.3 Test Report

3.3.1 Hardware Test

Test	Pass/Fail	Comments
Physical Dimensions	PASS	100mm*60mm*2mm
Hole Dimensions	PASS	3mm Diameter for M3 Screws
Manual Inspection	PASS	Inspecting PCB surface for pits, scratches, dents, pinholes, and other defects
Continuity	PASS PASS PASS	Pads to Headers Pads to Pads Pads to Pins
Power Circuit	PASS PASS PASS	Micro USB, 5V header, Pi 5v All connects to the 5V Plane 3.3V from the regulator output Enough current delivered to the MCU, Mic and Amp
Component orientation	PASS	Polarity and Labels
DIP Switches	PASS	Works as intended
Programming IC	PASS	Detected and Works
Microphone	PASS	No interference from nearby traces, clean audio
Amplifier	PASS	No clipping due to low current, maximum power output
Protection Circuit	PASS PASS PASS	Static Discharge TVS Diodes Reverse polarity protection Diodes Failure indicator LEDs
Wireless Connectivity	PASS	No apparent interference from power lines

Table 1: List of performed tests

Note: These tests were performed using a handheld multi meter. Ideally it should've been done with an oscilloscope and spectrum analyzer or high precision multimeters.

3.3.2 Software Test

After the physical tests were completed, and the power circuit was determined to work without any fault, we started to test the individual components and their functionalities inside our PCB.

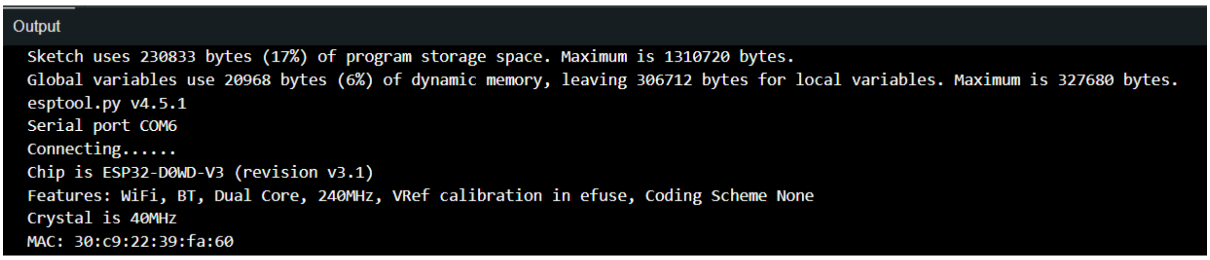


Figure 21: ESP32 Detected by the Computer and Ready for programming

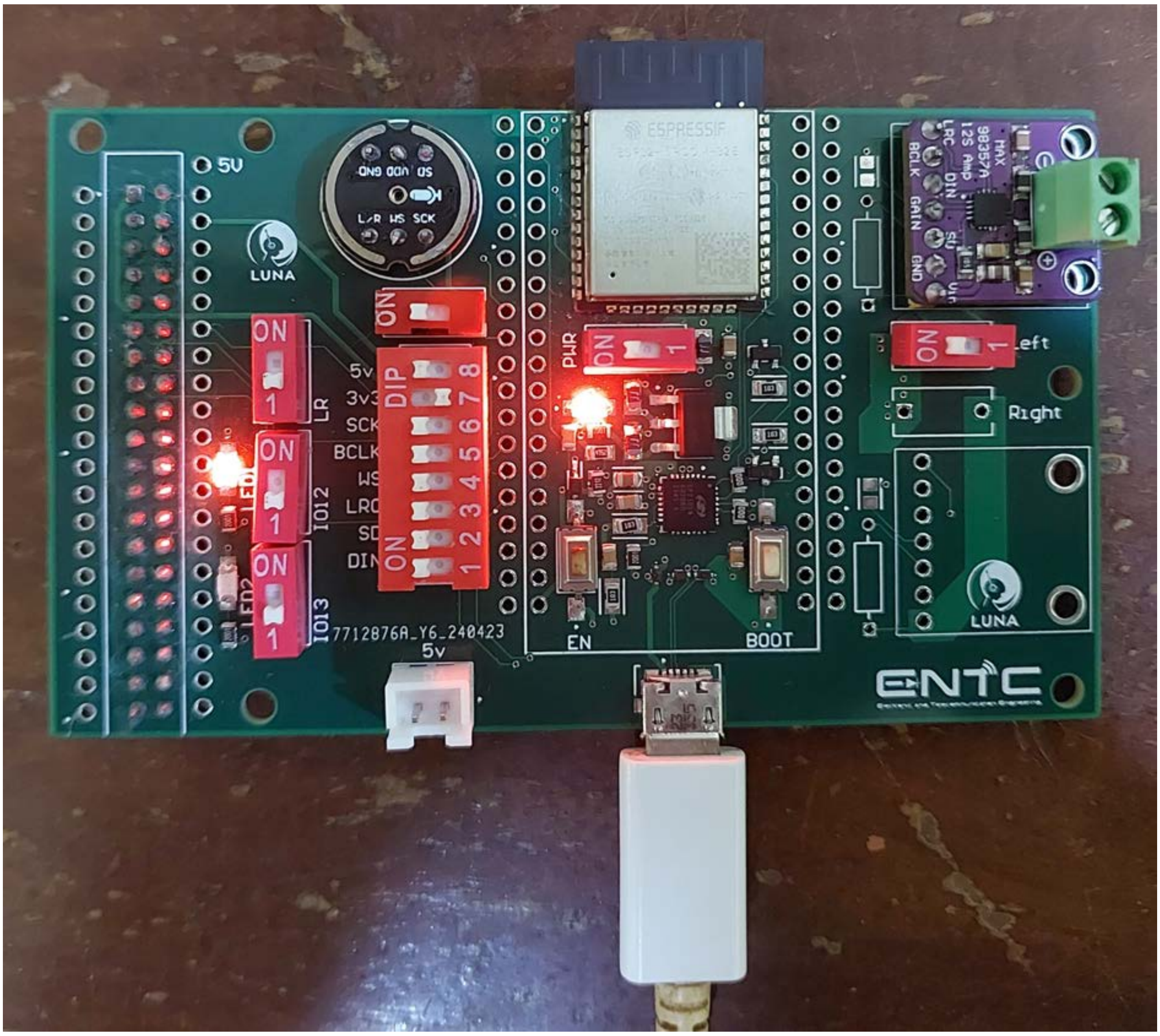


Figure 22: Testing with a blink sketch

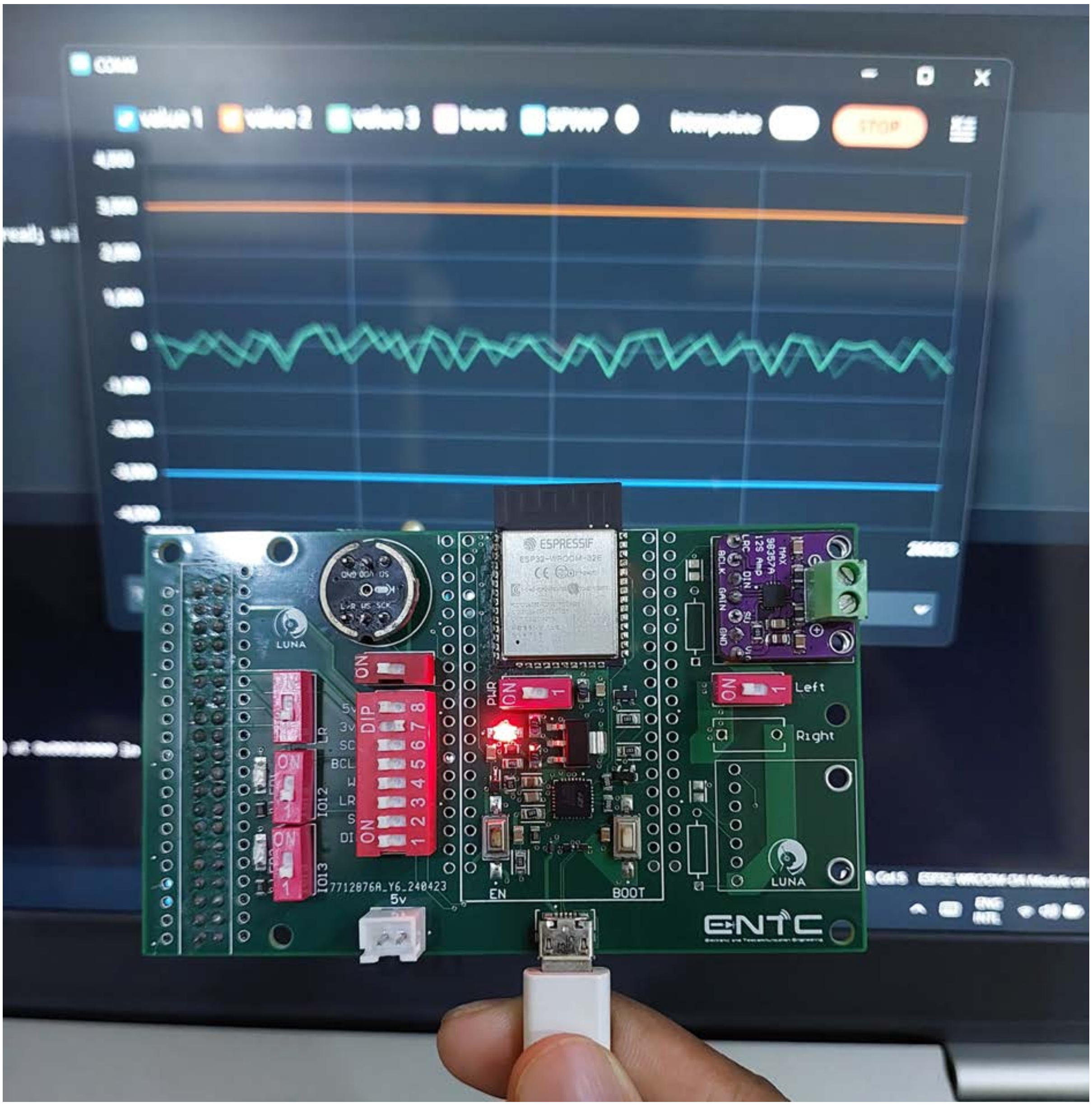


Figure 23: Testing the Microphone

```
Listening for wake word...
[01:19:54] Detected Hey-Luna
Listening...
01:19:59 you said as a restaurant robot what are your functionalities
01:20:02 'As a restaurant robot, my functionalities include taking orders, delivering food
, clearing tables, and interacting with customers in a friendly and efficient manner. \n'
['As a restaurant robot, my functionalities include taking orders, delivering food, cleari
ng tables, and interacting with customers in a friendly and efficient manner']
Generating Voice...
01:20:31 Started Playin...
Listening for wake word...
```

Figure 24: Testing the AI

3.5 Testing the Customer Menu

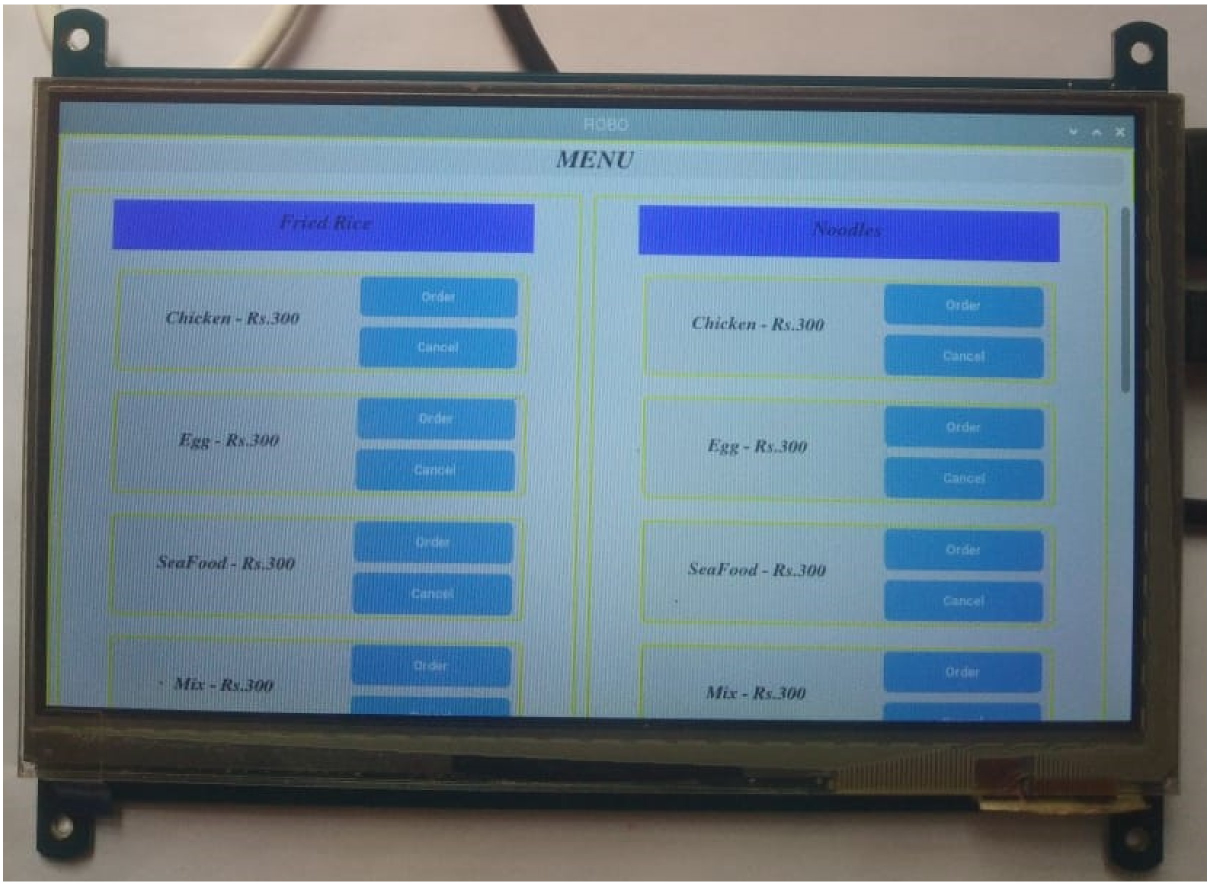


Figure 25: Menu testing - Food List

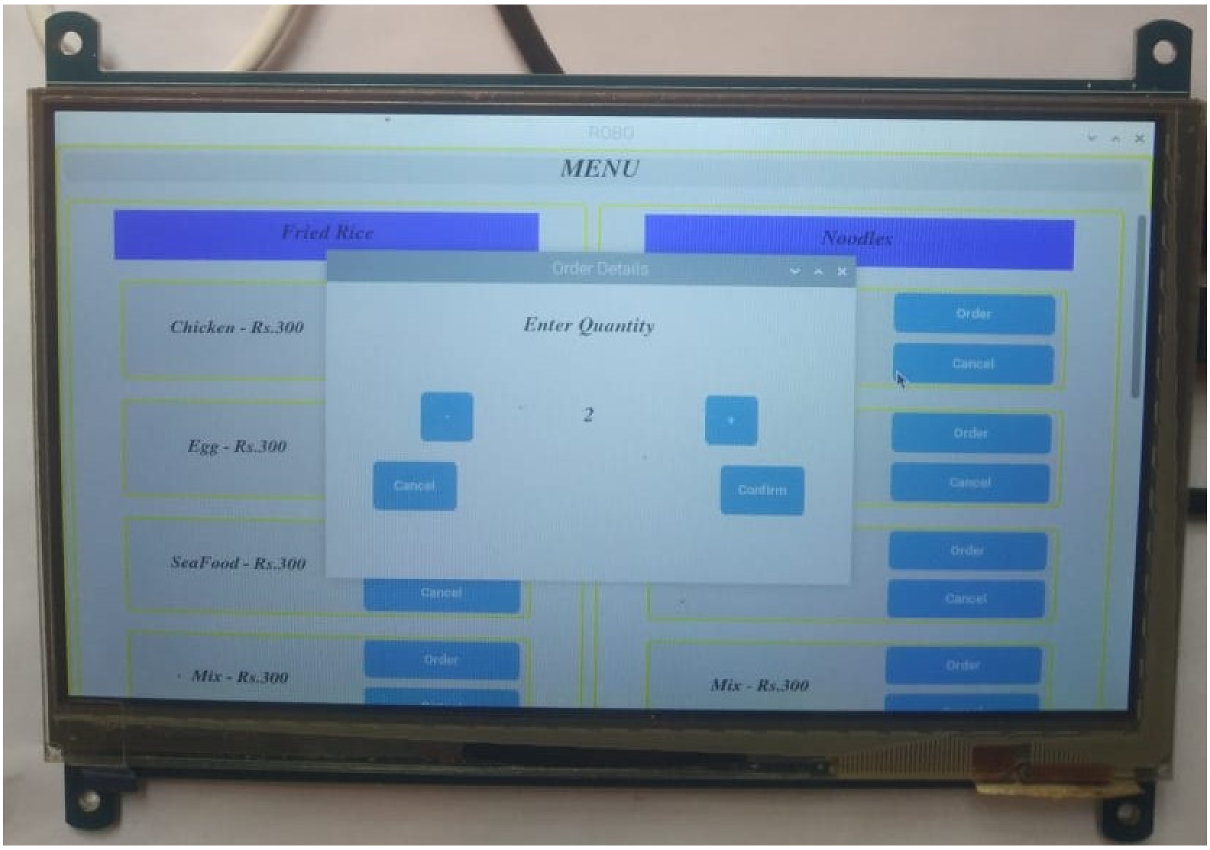


Figure 26: Menu testing - Ordering Foods

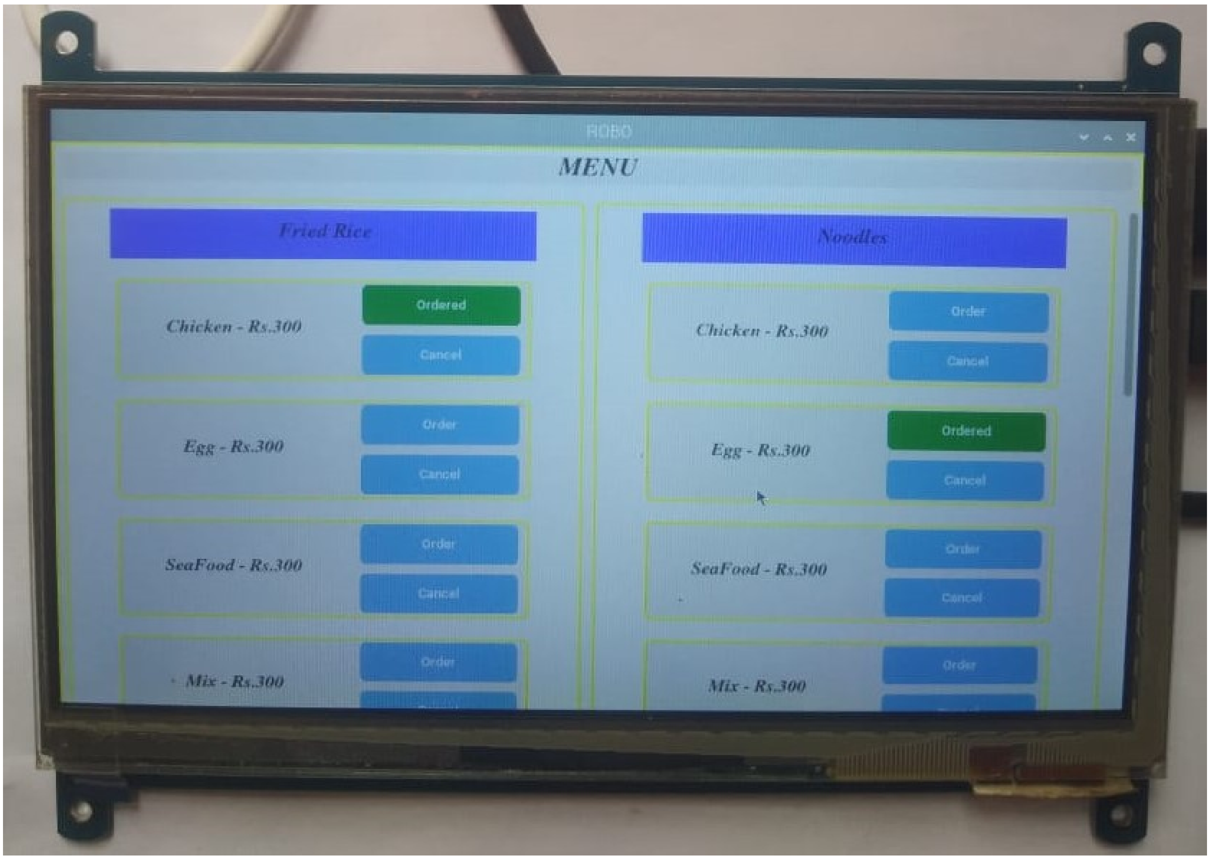


Figure 27: Menu testing - Food List after ordered

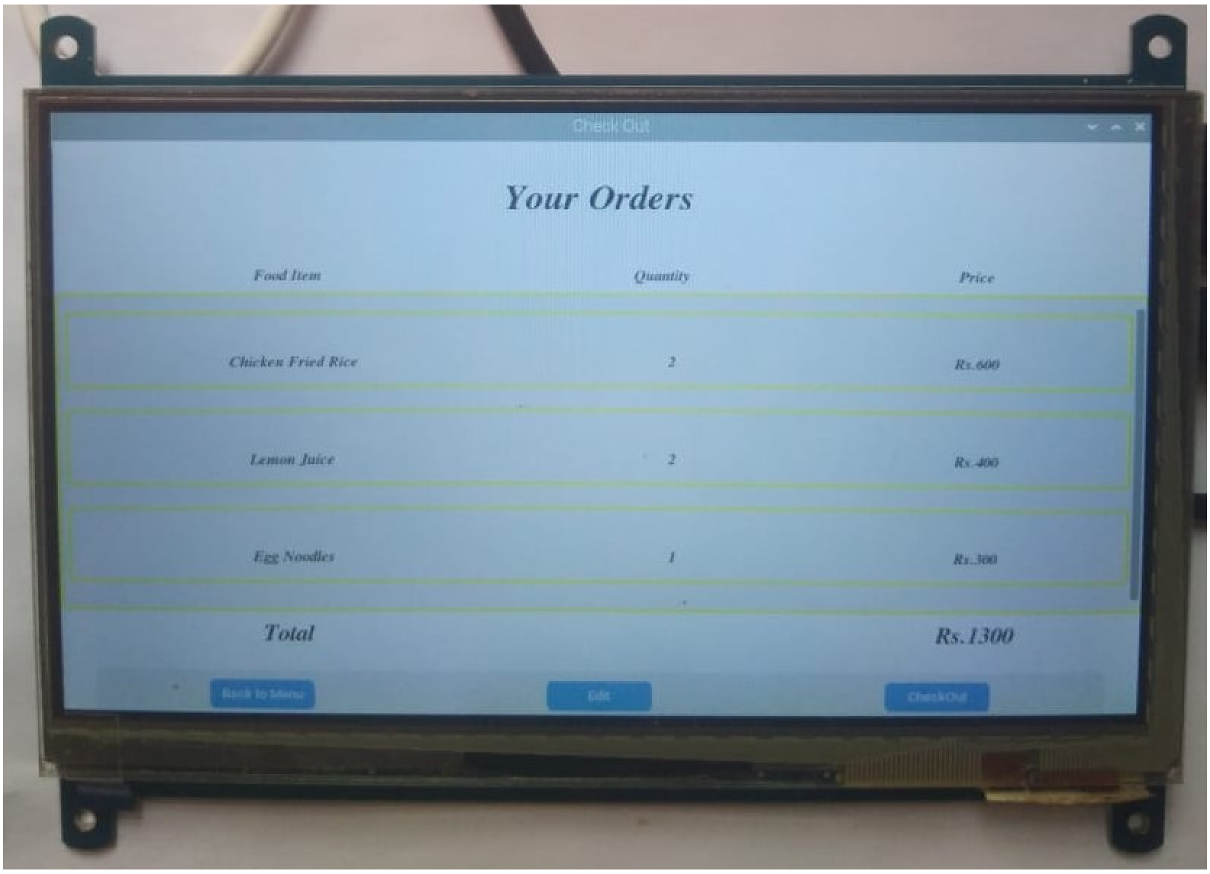


Figure 28: Menu testing - Check Out

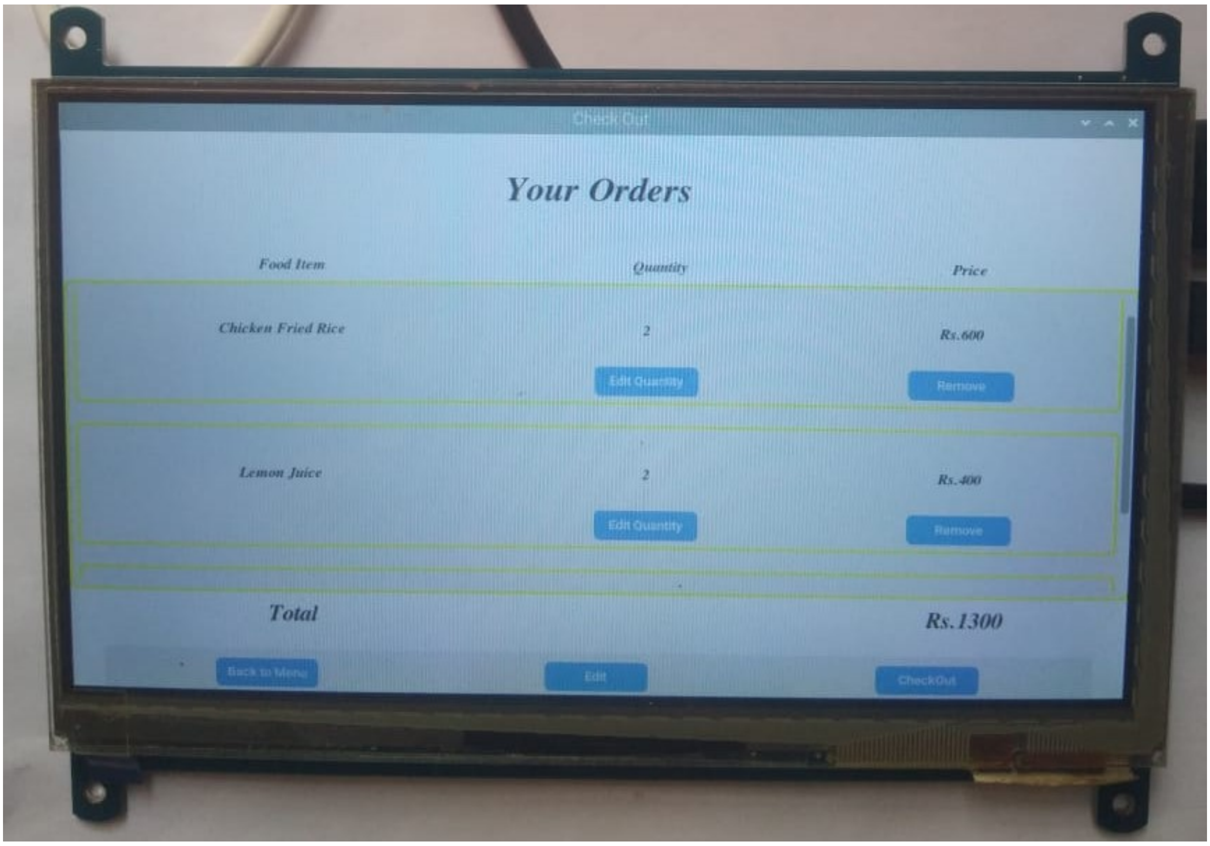


Figure 29: Menu testing - Editing the Ordered Food List

3.6 Testing Robot's Facial Expressions

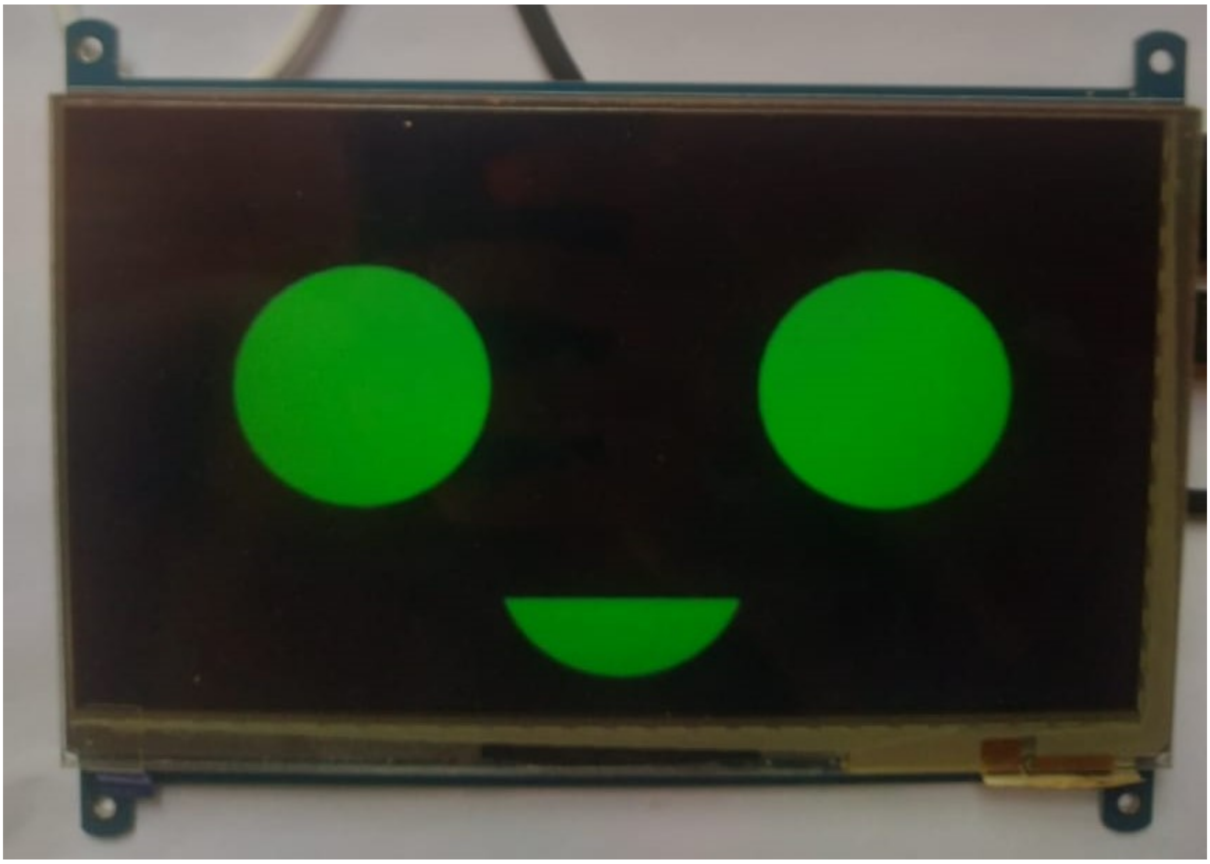


Figure 30: When Listening

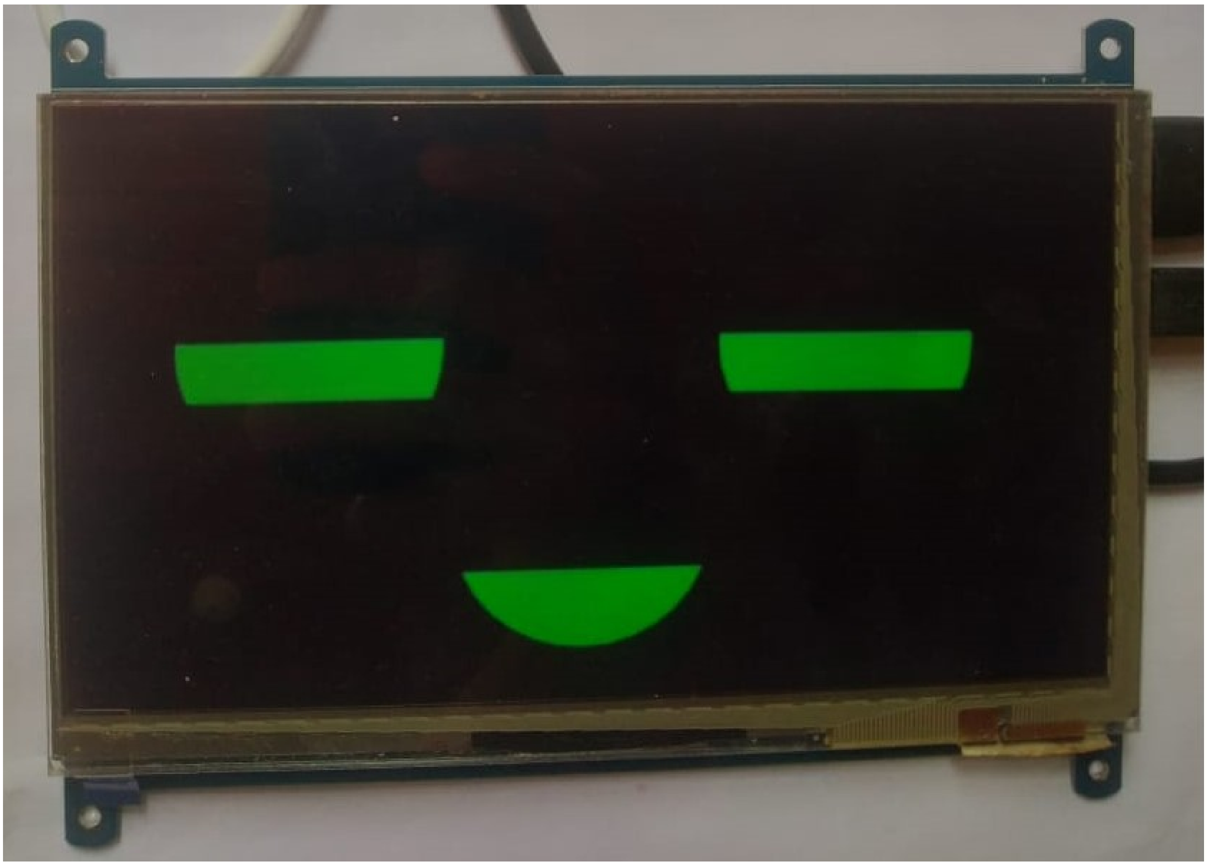


Figure 31: When Talking - Instance 1

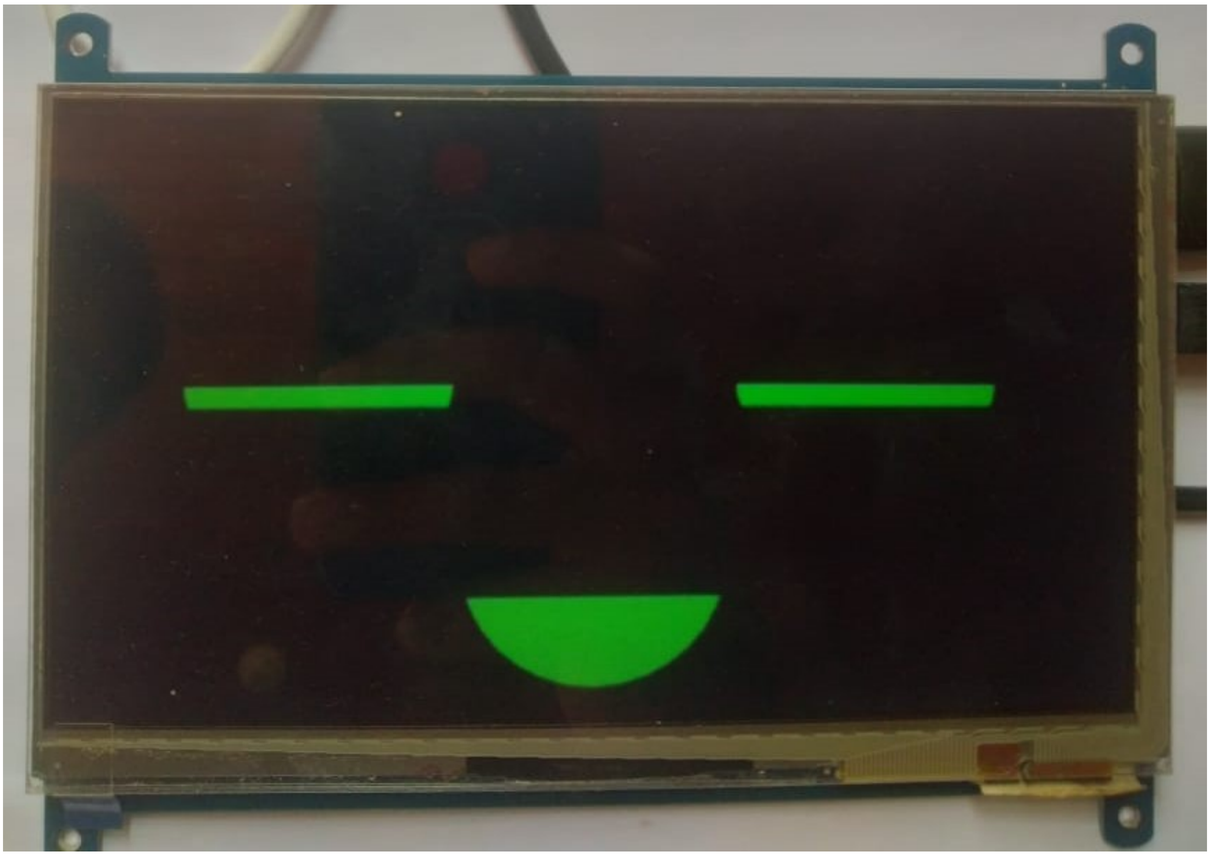


Figure 32: When Talking - Instance 2

4 Enclosure Design

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

4.1 Details of the Enclosure Design

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.

4.2 Importance of Component Placement

1. **Optimized Customer Interaction**:
   - The front-facing touch screen and clear placement of the camera ensure that customers can easily interact with the robot and receive visual feedback, enhancing the user experience.
2. **Clear Voice Capture**:
   - By placing the INMP441 microphone IC in an unobstructed location, voice commands are captured with high fidelity, ensuring accurate recognition and processing.
3. **Effective Audio Output**:
   - The strategic placement of speakers within the enclosure ensures that audio responses are loud and clear, essential for communicating effectively in a noisy restaurant environment.
4. **Protected and Organized Internal Components**:
   - Housing the PCB and Raspberry Pi inside the enclosure protects these sensitive components from external damage and environmental factors, ensuring reliable operation.

This detailed enclosure design not only enhances the aesthetic appeal of the restaurant robot but also ensures optimal functionality and customer interaction, making the overall system more efficient and user-friendly.

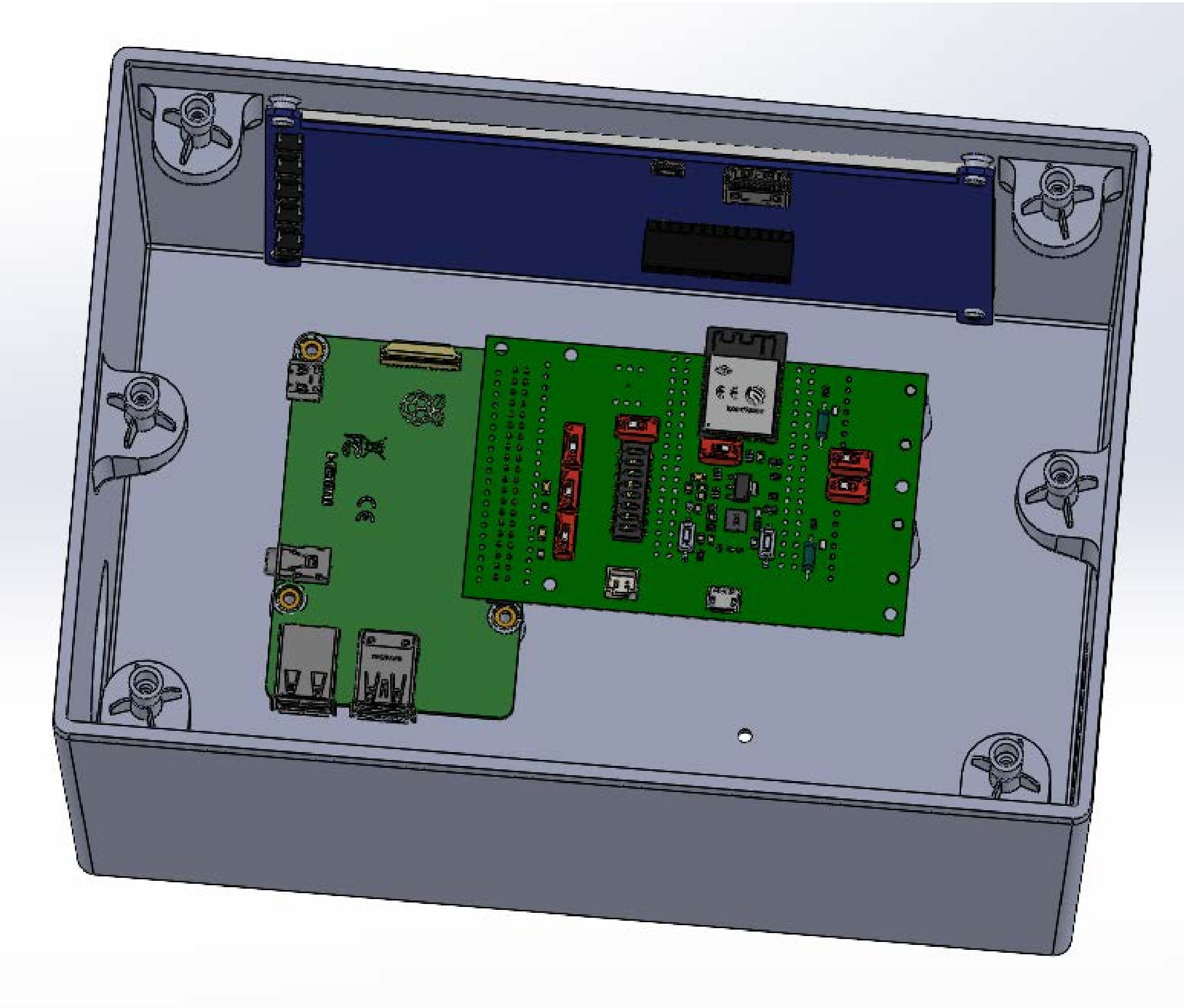


Figure 33: Component placement inside the enclosure

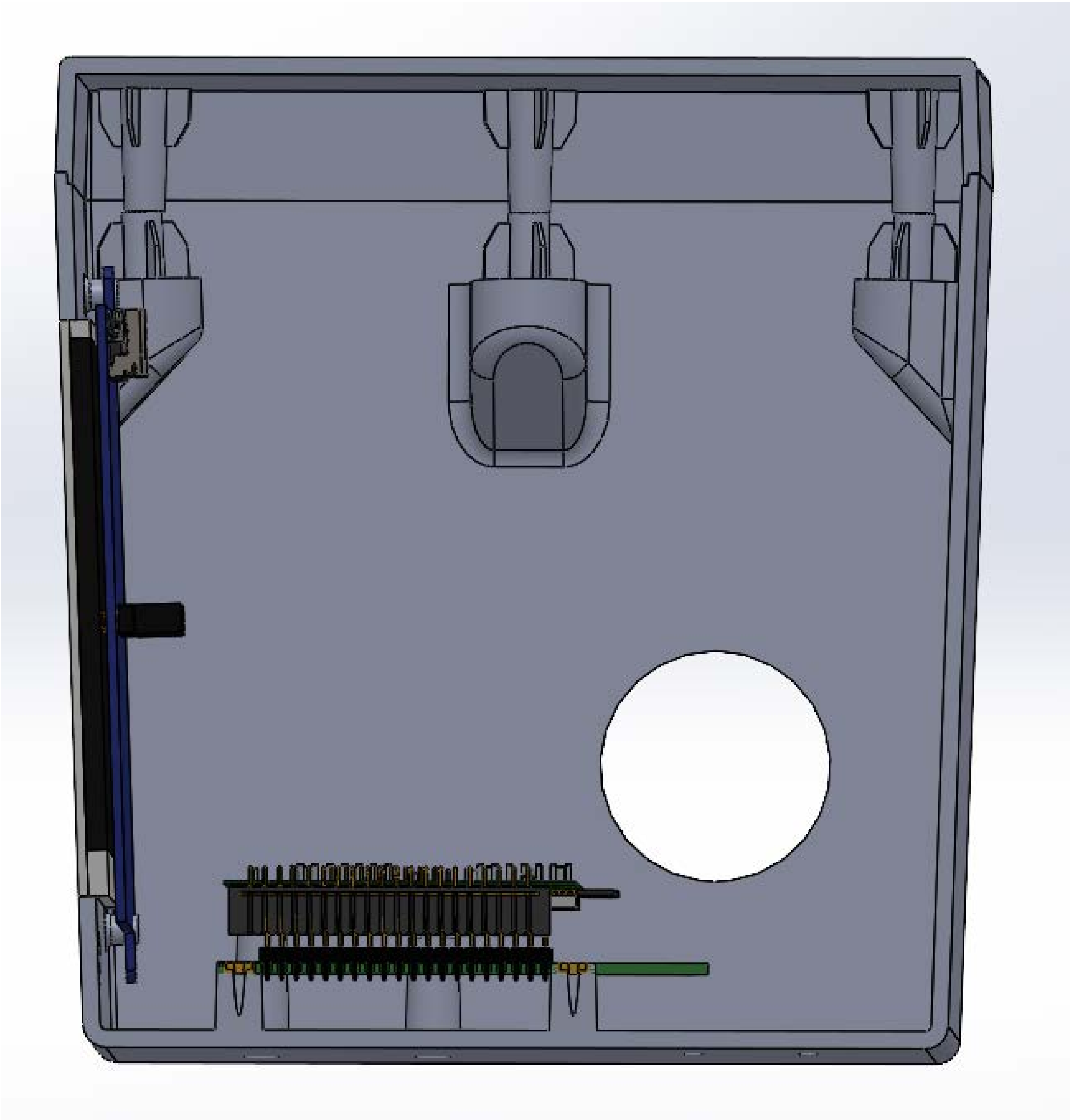


Figure 34: Component placement inside the enclosure

4.3 Moldability of the Design

The design of our enclosure has been meticulously crafted to ensure high moldability, making it both cost-effective and efficient to manufacture. Moldability is a crucial factor in our design process, as it impacts the overall quality of the final product.

1. **Draft Angles**:
    - **Optimized Draft Angles**: The design incorporates appropriate draft angles to facilitate easy ejection from the mold, reducing the risk of damage and ensuring a smooth surface finish.
    - **Consistency**: Consistent draft angles across the design prevent warping and ensure uniformity in the final product.
2. **Wall Thickness**:
    - **Uniform Thickness**: Maintaining a uniform wall thickness throughout the enclosure minimizes the risk of defects such as sink marks and warping.
3. **Simplicity and Efficiency**:
    - **Single-Part Mold**: Our enclosure design allows for a single-part mold, reducing manufacturing complexity and cost.
    - **Minimal Undercuts**: By minimizing undercuts, we ensure that the mold design is straightforward and easy to produce.

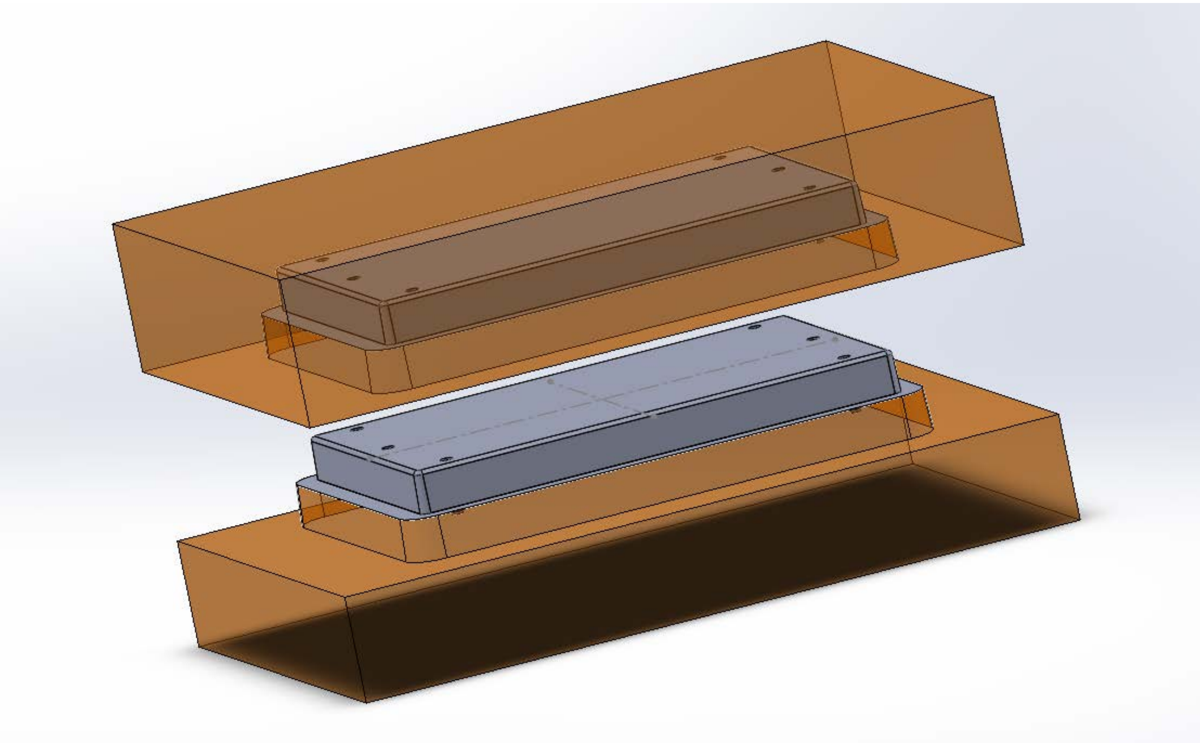


Figure 35: Mold Design 1 of our enclosure

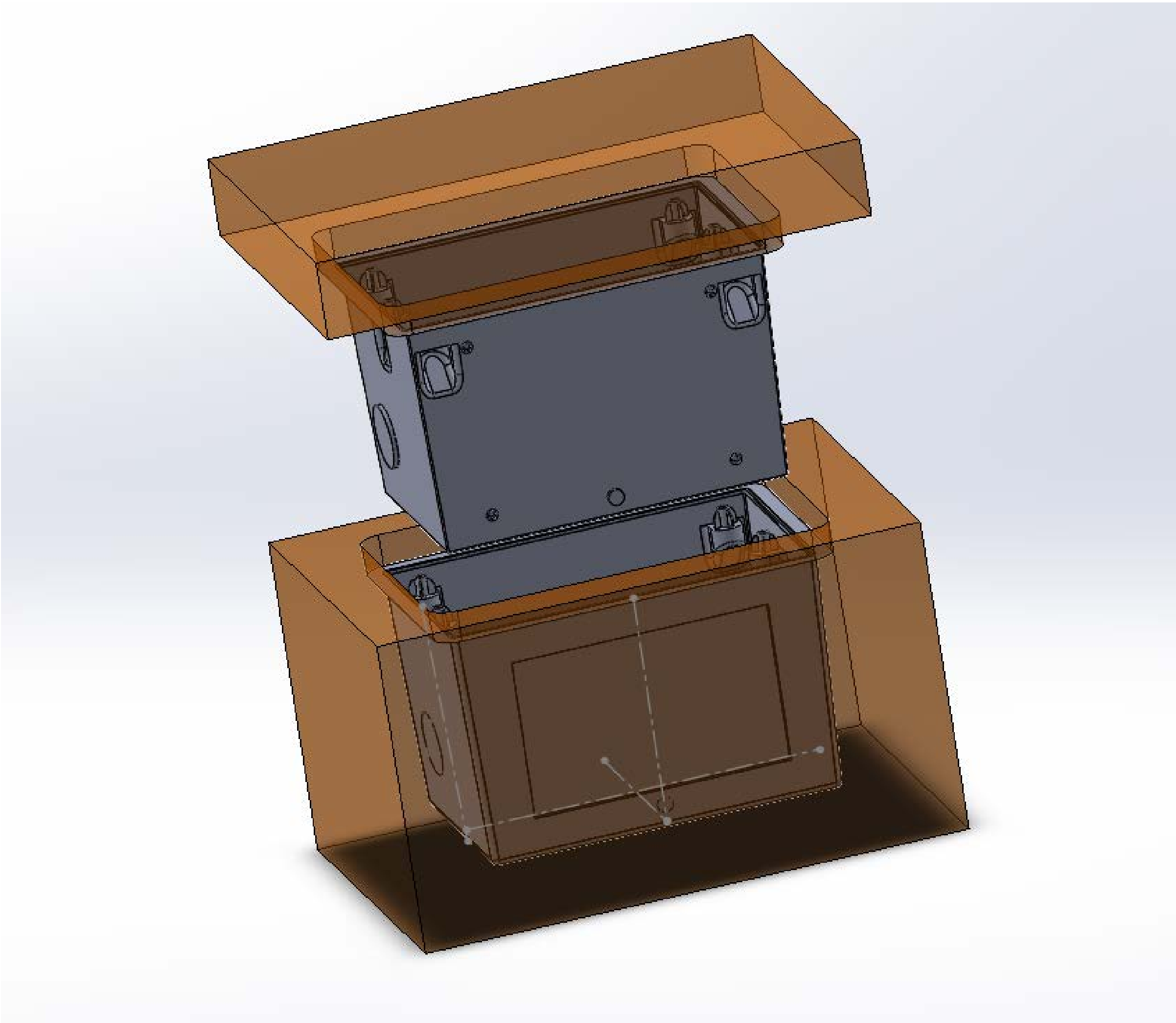
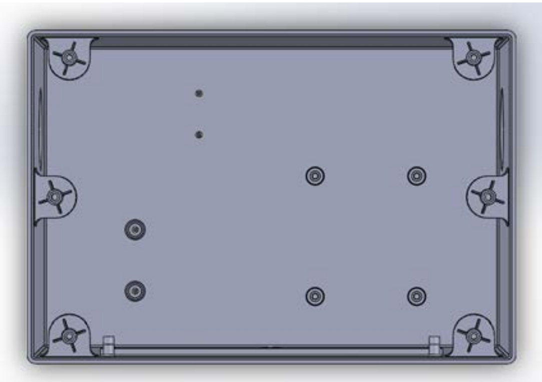


Figure 36: Mold Design 2 of our enclosure

4.4 Stability and the Connectivity of the enclosure

Our enclosure consists of two main parts, the lid and the bottom part. This modular design allows for easy assembly and disassembly.We use a lip and groove technique to ensure a secure and precise fit between the lid and the bottom part. This technique enhances the stability and integrity of the enclosure.To achieve a stable connection between the lid and the bottom part, we use six strategically placed screws. This not only ensures a tight seal but also enhances the overall durability of the enclosure.



(a) Bottom Part

(b) Lid

Figure 37: Placement of Skrew Holders to Ensure Stability

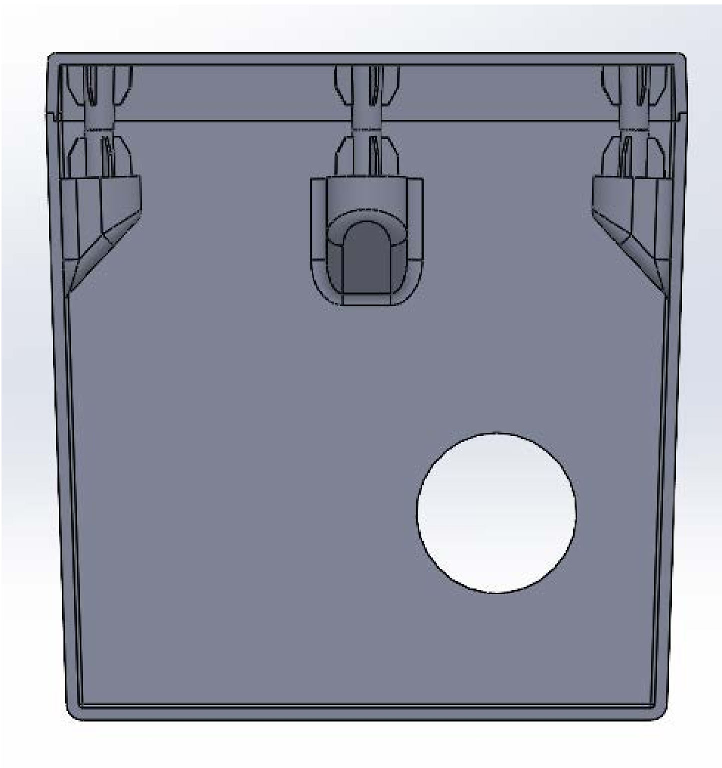


Figure 38: Connectivity using Skrews and lip and groove technique

5 Setup

In the above sections we have comprehensively explained from the initial block diagram to all the way upto enclosure design. Those are all the conceptual and hardware stages. Now we move on to the software and setup stage. In the process of giving our restaurant robot a personality we have divided it into two main category.

1. It's behaviours in terms of voice.
2. It's expressions in terms of it's face.

These are the two main ways we can interact with the robot and we need both of them to work seamlessly and synchronously for a good experience of the customer.

5.1 Wake word detection & Speech Recognition

In terms power consumption and privacy letting our robot process all the data it listens, is not a good idea. That's why we need some way of initializing the conversation with our robot. The most preferred industrial practice is to use a "Wake word". The wake-word engine will listen for a specific predefined wake word and will get activated only if the correct prompt is heard. Since micro controllers don't have the inherent capabilities to process large amounts of data and run a machine learning model, we decided to use a well known online service called "Pico Voice Porcupine". We can train this model for a specific keyword and it will learn to recognize that prompt from any person. This prevents our server from processing all the unnecessary unprompted background voices and keep it in a low power state. Even though the initial training is done online, the detection is done on device.

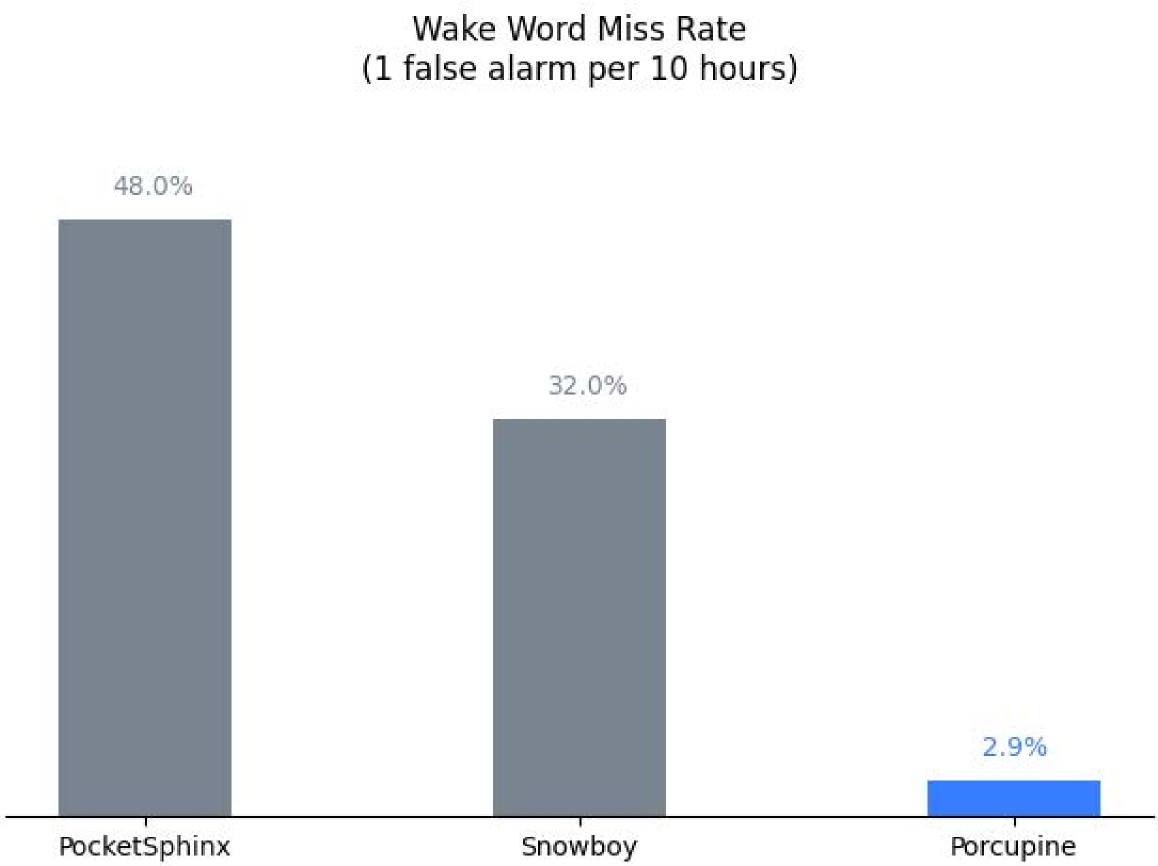


Figure 39: Comparison of popular wake-word engines

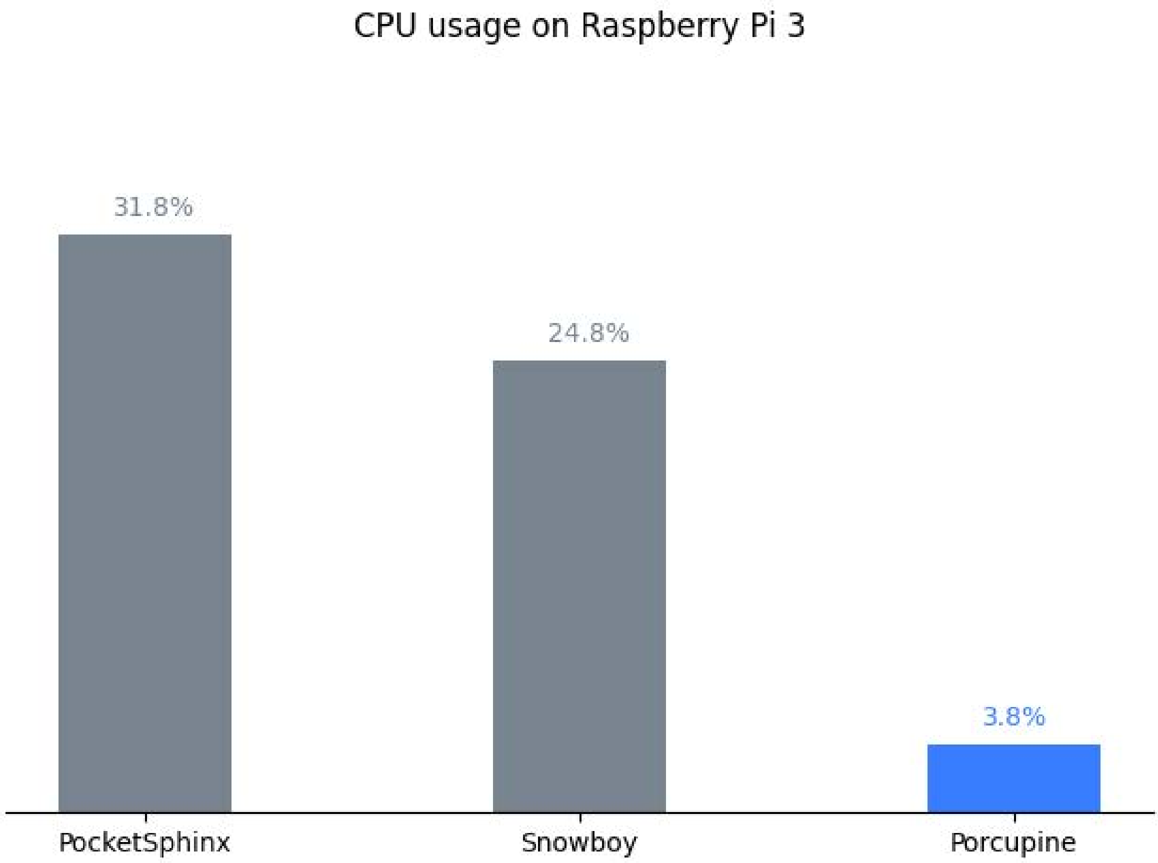


Figure 40: CPU Usage Compared

After the wake word is recognized, the MCU records a 3 second prompt and sends it to the server for Speech to Text recognition. Three second is chosen as the sweet spot for many user commands after many trials and errors. For the speech to text we are using google's stt engine, Which during our testing performed very good even with different accents, speeds and environments. Even though there are other similarly good models available, for our needs this was determined to be enough.

5.2 Intent Processing

After transcribing the speech to text, we need to process that information and give appropriate response. The best candidate for this would be a large language model(LLM). For this we decided to use Google's Gemini LLM and customize it for a restaurant robot. When specific questions related to the robot personality and the restaurant are prompted we handle it using prerecorded responses. General questions are handled by the LLM.

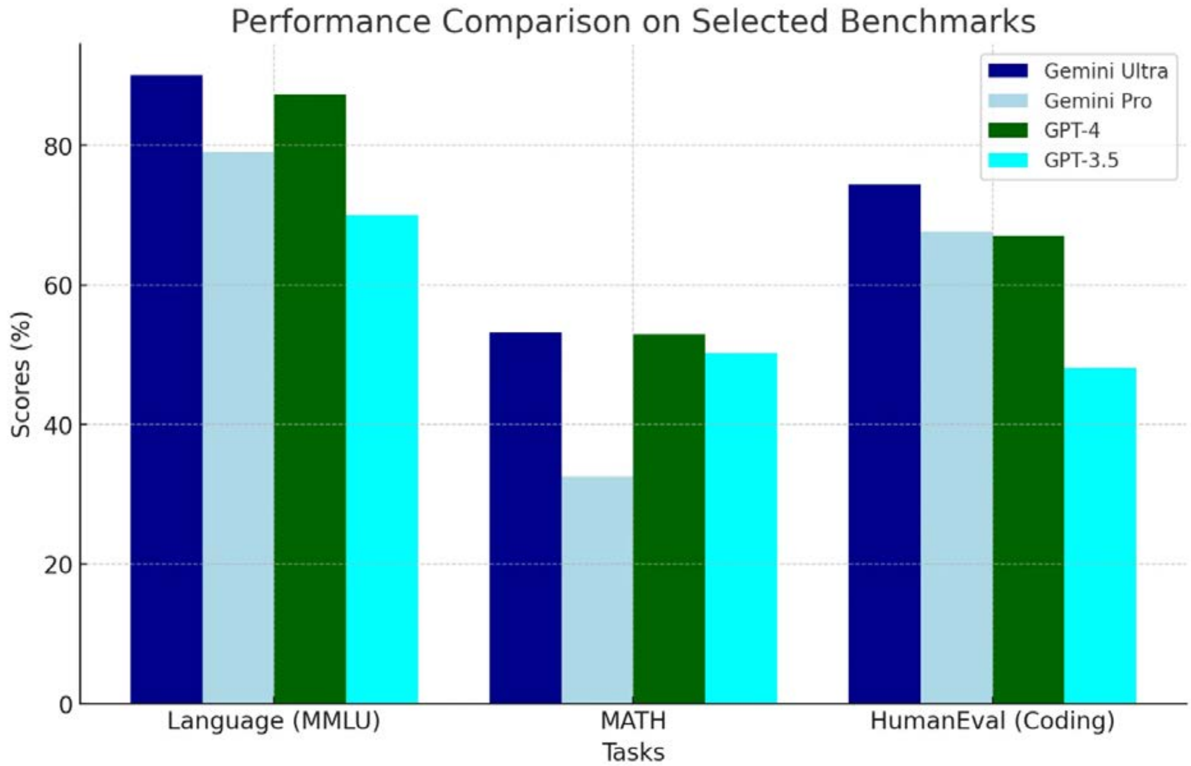


Figure 41: Comparison of popular LLMs

5.3 Voice Generation

The response generated from above is given as a speech output. In order to have a realistic, high quality, human like voice we are using the on device text to speech engine called "Piper TTS". It supports a wide range voice models and languages. During out testings we found out that it uses a reasonable amount of resources and time to generate the voice.

5.4 Facial Expressions

Incorporating facial expressions into the user interface of the restaurant robot enhances the interactive experience and adds a touch of personality to the robot. This section details the implementation and significance of displaying facial expressions on the Raspberry Pi screen.

Implementation of Facial Expressions

1. **Hardware Setup**:
   - **Raspberry Pi**: Acts as the main controller for the display screen.
   - **Waveshare Raspberry Pi Touch Screen**: Used to show the graphical facial expressions.
2. **Software Development**:
   - **Graphics Design**: Create a library of facial expression graphics (happy, sad, surprised, etc.) using graphic design software.
   - **Animation Scripts**: Develop scripts in Python to control the display of these expressions. Utilize libraries such as Pygame or Pillow for rendering the graphics.
   - **Integration with Robot Logic**: Connect the display logic with the robot's interaction logic, so expressions change in response to specific events or customer interactions.
3. **Expression Triggers**:
   - **Voice Commands**: Change expressions based on the tone and content of the customer's voice commands. For example, a happy face when a customer greets the robot or a thinking face when processing an order.
   - **Touch Inputs**: Display different expressions based on touch interactions. For instance, a smile when an order is confirmed or a neutral face when the menu is being browsed.
   - **Environmental Feedback**: Use the Kinect camera to detect customer proximity and expressions, triggering appropriate facial responses from the robot.

Importance of Facial Expressions

1. **Enhanced User Engagement**:
   - Facial expressions make the robot more relatable and engaging. Customers, especially children, are likely to find the interaction more enjoyable when the robot displays emotions.
2. **Non-Verbal Communication**:
   - Facial expressions serve as non-verbal cues that can help convey messages more effectively. For instance, a confused face can indicate that the robot didn't understand a command, prompting the customer to repeat it.
3. **Feedback and Interaction**:
   - Expressions provide immediate visual feedback to customers. A happy face after placing an order reassures the customer that their order was received correctly.
4. **Personalized Experience**:
   - The ability to display a range of emotions can make interactions feel more personalized. Customers may feel that the robot is responsive and attentive to their actions and commands.
5. **Aesthetic Appeal**:
   - Adding facial expressions improves the overall aesthetic appeal of the robot. It makes the robot appear friendlier and more approachable, which can enhance the dining atmosphere.

Technical Details

1. **Expression Graphics**:

    - Design a set of high-resolution facial expressions. Each expression should be clear and recognizable from a distance.

2. **Animation Control**:

    - Implement smooth transitions between expressions to make the changes appear natural. This can involve fading effects or gradual changes in facial features.

3. **Real-Time Updates**:

    - Ensure that the expressions update in real-time based on interactions. The responsiveness of the facial expressions is crucial for maintaining an immersive experience.

4. **Customization and Extensibility**:

    - Develop the system to be easily extensible. New expressions or animations can be added without significant changes to the underlying codebase. This allows for future updates and customization based on feedback or new interaction scenarios.

Conclusion

Displaying facial expressions on the Raspberry Pi screen significantly enriches the interaction between customers and the restaurant robot. This feature not only makes the robot more engaging and user-friendly but also enhances the overall dining experience by adding a layer of emotional intelligence to the robot's responses. The thoughtful design and implementation of facial expressions ensure that the robot can communicate effectively and provide a memorable experience for customers.

5.5 Touch Controls for Ordering Foods

The touch controls for ordering food through the menu displayed on the Raspberry Pi screen are a crucial part of the restaurant robot's user interface. This section provides a detailed explanation of how the touch controls are implemented and their importance in enhancing the customer experience.

Implementation of Touch Controls

1. **Hardware Components**:
   - **Raspberry Pi**: Acts as the main processor, running the user interface and handling touch inputs.
   - **Waveshare Raspberry Pi Touch Screen**: A responsive touch screen that displays the menu and registers customer touch inputs.
2. **Software Development**:
   - **User Interface Design**: The menu is designed using Python and custom tkinter graphical library . The interface includes clearly labeled buttons and interactive elements.
   - **Touch Input Handling**: The software captures touch inputs from the screen, processes them, and translates them into corresponding actions such as selecting a menu item.
   - **Backend Integration**: The system communicates with the backend server to update order information in real-time, ensuring accurate tracking and processing of customer orders.
3. **Menu Navigation**:
   - **Scrollable Menus**: Customers can scroll through the menu using swipe gestures. This allows for easy browsing of all available food items.
   - **Categorized Sections**: The menu is divided into categories (e.g., appetizers, main courses, desserts) for quick and easy navigation.
4. **Order Selection and Confirmation Process**:
   - **Item Selection**: Customers tap on a menu item to select it. Detailed information about the item, including a description, price, and customization options (e.g., add-ons, quantity), is displayed.
   - **Order Review**: Customers can review their order in a dedicated section, where they can modify item quantities or remove items before finalizing the order.
   - **Order Confirmation**: Once the customer has finalized their selection, they can proceed to the order confirmation screen. Here, they can review their entire order and make any last-minute adjustments.

Importance of Touch Controls

1. **User-Friendly Interface**:
   - The touch screen interface is intuitive and easy to use, catering to customers of all ages and technical proficiency levels. The simple tap-and-select mechanism makes it straightforward for customers to navigate the menu and place orders.
2. **Efficiency and Speed**:
   - Touch controls streamline the ordering process, reducing the time customers spend ordering food. This efficiency helps improve table turnover rates and overall restaurant productivity.
3. **Customization and Flexibility**:
   - Customers can easily customize their orders through the touch interface. This flexibility enhances the dining experience by allowing customers to tailor their meals to their preferences.
4. **Real-Time Updates**:

- The touch controls ensure that orders are updated in real-time, reducing the chances of errors and miscommunication between customers and kitchen staff.

5. **Enhanced Customer Engagement**:

    - Interactive touch controls create an engaging and modern dining experience. The ability to browse and select items at their own pace empowers customers and enhances their overall satisfaction.

6. **Accessibility**:

    - The touch screen interface can be designed to accommodate various accessibility needs, such as larger buttons for visually impaired customers and multi-language support for non-native speakers.

Conclusion

The implementation of touch controls for ordering food significantly enhances the functionality and user experience of the restaurant robot. By providing an intuitive, efficient, and flexible way for customers to interact with the menu and place orders, the touch screen interface ensures a smooth and enjoyable dining experience. The strategic integration of hardware and software components ensures that the system is robust, responsive, and capable of meeting the diverse needs of restaurant patrons.

6 Log Entries

Date	Log Entry
01/02/2024	• Start initial research about the project user interface for a restaurant robot. • Created a preliminary project plan outlining resources, phases, tasks, and timeline. • Discussed different approaches we can take to do the design.
07/02/2024	• Searched for existing restaurant robots and analyzed their user interfaces and how they interact with customers. • Read articles, papers related to user interface design for a restaurant robot.
14/02/2024	• Created the stakeholder map. • Identified user requirements. • Planned next steps.
21/02/2024	• Analyzed how we take our approach to overcome challenges and fulfill user requirements.
22/02/2024	• Discussed about different conceptual designs. • Evaluated them according to a criterion and selected the most suitable design.
28/02/2024	• Start initial steps in enclosure design and circuit design. • Discussed about the microcontroller circuit, voice recording part, and the amplifying part. • Discussed how the enclosure should look like and what are the components going to be inside it.
07/03/2024	• Drew a rough schematic of the circuit and looked for possible issues and optimized the circuit. • Discussed about the component placement inside the enclosure and came up with an initial sketch to get started in the Solidworks design.

10/03/2024	• Started schematic design using hierarchical schematic design procedure. • Started designing the enclosure in Solidworks.
17/03/2024	• Continued designing schematic while making sure all the components and connections are represented. • Reviewed every part in the designed schematic for completeness. • Continued designing the enclosure on Solidworks.
20/03/2024	• Started PCB layout design after successfully completing the schematic design. • Discussed about the optimal component placement for a quality design. • Continued designing the enclosure on Solidworks.
23/03/2024	• Started routing between components while making sure about proper trace width for power lines and signal lines. • Continued designing the enclosure on Solidworks.
30/03/2024	• After successfully finishing the routing and the designing of PCB layout conducted a review about the whole PCB design procedure. • Checked PCB layout with the schematic and made sure there are no mistakes. • Made final adjustments based on the review.
04/04/2024	• Completed the design of the enclosure. • Checked for measurement errors or other potential issues that can happen.
08/04/2024	• Ordered necessary components.
10/04/2024	• Submitted finalized PCB design files to a PCB manufacturer for production.
24/04/2024	• PCB arrived.

26/04/2024	• Components arrived.
27/04/2024	• Began assembling components on the PCB according to the design. • Carefully placed and soldered each component starting from smaller ones to larger ones.
29/04/2024	• Finished PCB soldering process. • Checked connectivity to ensure all the components are soldered perfectly.
03/05/2024	• Did the initial power-up and checked power line connections.
07/05/2024	• Checked the working of different parts in the PCB such as the microcontroller part, audio capturing part, and the amplifier part.
10/05/2024	• Finished all hardware and software testing.
11/05/2024	• Performed all final tweaks, generated data and created the final documents.

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