

“IoT based Smart Motor Control and Monitoring System for Agriculture”

Minor Project Report

*Submitted in Partial Fulfillment of the
Requirements for the Degree of*

BACHELOR OF TECHNOLOGY IN ELECTRONICS AND COMMUNICATION ENGINEERING

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November 2024

CERTIFICATE

This is to certify that the Minor Project Report entitled “IoT based Smart Motor Control and Monitoring System for Agriculture” submitted by Mr. Pragnesh Papaniya (21BEC081) and Dhairya Senghani (21BEC111) towards the partial fulfillment of the requirements for the award of degree in Bachelor of Technology in the field of Electronics & Communication Engineering of Nirma University is the record of work carried out by her under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this minor project work to the best of our knowledge have not been submitted to any other University or Institution for the award of any degree or diploma.

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Undertaking for Originality of the Work

We, Pragnesh Papaniya (21BEC081) and Dhairya Senghani (21BEC111), give undertaking that the Minor Project entitled “IoT based Smart Motor Control and Monitoring System for Agriculture” submitted by us, towards the partial fulfillment of the requirements for the degree of Bachelor of Technology in Electronics and Communication of Nirma University, Ahmedabad- 382 481, is the original work carried out by us and We give assurance that no attempt of plagiarism has been made. We understand that in the event of any similarity found subsequently with any other published work or any project report elsewhere; it will result in severe disciplinary action.

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Acknowledgement

I express my sincere gratitude to Nirma University for providing me with the opportunity in the form of a minor project, enabling me to embark on this academic journey. I am thankful for the resources, support, and conducive learning environment that the university has offered throughout my academic tenure.

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Abstract

In rural agricultural areas, farmers commonly rely on submersible motors for irrigation. However, managing these motors presents significant challenges. Many farmers must operate their motors manually, often requiring them to travel long distances, which is both time-consuming and inconvenient. Additionally, these motors are prone to breakdowns due to issues such as overload, dry-run conditions, and voltage fluctuations. Frequent motor failures not only increase maintenance costs but also disrupt irrigation schedules, ultimately impacting crop yields. Given the high cost of motor repairs and replacements, there is a pressing need for a reliable, remote-controlled system that can monitor motor health, provide fault protection, and reduce manual intervention.

To address these challenges, a "Smart Motor Control and Monitoring System for Agriculture" was developed, using an ESP32 microcontroller as the core component. This system enables farmers to remotely control and monitor motor status through Bluetooth communication, allowing them to operate irrigation motors without physically being on-site. Designed with Arduino IDE for hardware programming and integrated with a mobile application created using MIT App Inventor, the system offers an intuitive user interface for easy operation. Key features include real-time monitoring of motor status, protection mechanisms for line voltage, overload, underload, and dry-run conditions. Additionally, the system reduces the need for manual operation and helps preventing motor damage.

The developed system provides a practical solution to the challenges faced by farmers in managing irrigation motors. By enabling remote operation and real-time monitoring, the system significantly enhances operational efficiency, saves time, and reduces the need for on-site motor control. The implemented protective features help extend the motor's lifespan by preventing common issues that lead to breakdowns. Overall, this "Smart Motor Control and Monitoring System" offers a cost-effective, user-friendly approach to improving agricultural productivity and ensuring the durability of essential motor equipment.

INDEX

Chapter No.	Title	Page No.
	Acknowledgment	4
	Abstract	5
	Index	6
	List of Figures	7
	List of Table/s	7
	Nomenclature	8
1	Introduction	9
	1.1 Prologue	9
	1.2 Motivation	9
	1.3 Problem Statement	10
	1.4 Approach	10
	1.5 Scope of the Project	10
	1.6 Gantt Chart	11
	1.7 Organization of the Rest of the Report	12
2	Literature Review	13
3	Hardware Design	16
	3.1 Control Node	17
4	Software Design	20
	4.1 Control Node	21
	4.2 Monitoring Node	21
	4.3 Mobile Application Functionality	21
5	Results	24
6	Conclusions and Future Scope	32
	References	34
	Appendix	36

LIST OF FIGURES

Figure 1 Gantt Chart	11
Figure 2 Block Diagram.....	17
Figure 3 Hardware Implementation	18
Figure 4 Clamper, Rectifier Circuit	19
Figure 5 Software Flow.....	20
Figure 6 Application Receiver Logic	22
Figure 7 Application Transmitter Logic.....	23
Figure 8 Bluetooth Nearby Devices	24
Figure 9 Connection Sucessful.....	25
Figure 10 over-voltage protection	26
Figure 11 Changing Voltage Threshold	27
Figure 12 Motor ON state	28
Figure 13 Over-Current Protection	29
Figure 14 Threshold and Sensed Values	30
Figure 15 Over-voltage Condition	30
Figure 16 Over-current Condition.....	30
Figure 17 Manual Start	31
Figure 18 Manual Stop.....	31

LIST OF TABLE/S

Table 1 Components Used	16
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NOMENCLATURE

Abbreviations

BT	Bluetooth
ADC	Analog-to-Digital Converter
PCB	Printed Circuit Board
IoT	Internet of Things
MCU	Microcontroller Unit

Chapter 1

Introduction

1.1 Prologue

In rural agriculture, farmers often face significant challenges managing submersible motors for irrigation, largely due to manual operation requirements and the risk of breakdowns from power faults and motor failures. Many farmers must travel long distances to operate these motors, resulting in time loss, inconvenience, and delays in responding to motor faults. The absence of a reliable and remote monitoring solution compounds these difficulties, as farmers lack timely fault alerts and a straightforward interface to control motor operation.

The "Smart Motor Control and Monitoring System for Agriculture" aims to address these issues by providing a remote monitoring and control solution specifically tailored for irrigation motors. By utilizing Bluetooth communication and an ESP32 microcontroller, this system enables farmers to operate and monitor their motors from any location, helping to streamline irrigation processes and reduce manual intervention. Equipped with features such as line voltage, overload, underload, and dry-run protection, this system is designed to enhance productivity, protect costly equipment, and ensure reliable irrigation operations.

1.2 Motivation

Farmers in rural areas often face the arduous task of manually managing irrigation motors, which not only requires time and effort but also exposes them to frequent motor failures due to electrical issues, such as line voltage fluctuations and cable faults. Given the high cost of irrigation motors, which can range up to several lakh rupees, these failures can lead to substantial financial loss. Moreover, the need for farmers to travel significant distances to operate these motors adds further inconvenience and limits their ability to respond swiftly to issues as they arise.

The motivation behind the "Smart Motor Control and Monitoring System for Agriculture" is to alleviate these burdens by offering a robust, remote-controlled solution that minimizes

manual intervention and provides real-time fault alerts to protect valuable equipment. By incorporating features such as overload, underload, and dry-run protection this system not only aims to prevent motor damage but also empowers farmers with predictive maintenance capabilities. This solution ultimately seeks to enhance operational efficiency, reduce downtime, and safeguard the significant investments farmers make in irrigation equipment, contributing to greater productivity and sustainability in agricultural practices

1.3 Problem Statement

This project, titled "Smart Motor Control and Monitoring System for Agriculture," seeks to address all these issues by developing a remote-operated system that enables farmers to monitor and control irrigation motors with ease. The solution must protect against common electrical faults, and offer an intuitive interface to minimize manual intervention, thereby enhancing motor longevity and supporting efficient, reliable irrigation practices

1.4 Approach

The "Smart Motor Control and Monitoring System for Agriculture" is designed to enable remote access, monitoring, and control of irrigation motors using a combination of hardware and software components to ensure reliability and user-friendliness. The system is built around an ESP32 microcontroller and utilizes Bluetooth communication to provide seamless connectivity, allowing farmers to manage their irrigation motors from distant locations. Key protections, such as line voltage, overload, underload, and dry-run safeguards are incorporated to protect the motors from damage due to electrical issues.

The system's mobile application, developed using MIT App Inventor, offers an intuitive interface for farmers to control motor operations. The solution aims to reduce downtime and enhance the overall efficiency of irrigation practices in rural settings.

1.5 Scope of the project

The scope of this project includes the development and implementation of a "Smart Motor Control and Monitoring System" specifically designed for agricultural irrigation applications. This system integrates both hardware and software components to enable the

remote monitoring, control, and protection of submersible motors used by farmers. The hardware aspect encompasses the design and configuration of an ESP32 microcontroller interfaced with sensors for voltage, current as well as actuators for motor control. The system also includes a BLUETOOTH module for reliable communication, allowing farmers to operate the motor from any location.

On the software side, the project involves programming the microcontroller for real-time data processing, establishing communication protocols to transmit data, and developing a mobile application using MIT App Inventor. This application serves as a user-friendly interface. The project's primary objective is to create a robust, intuitive, and efficient system that minimizes manual intervention, enhances motor longevity, and provides critical protection mechanisms against common motor faults. This solution is tailored to meet the unique demands of rural agriculture, with a focus on increasing productivity, reducing costs, and supporting sustainable irrigation practices.

1.6 Gantt chart

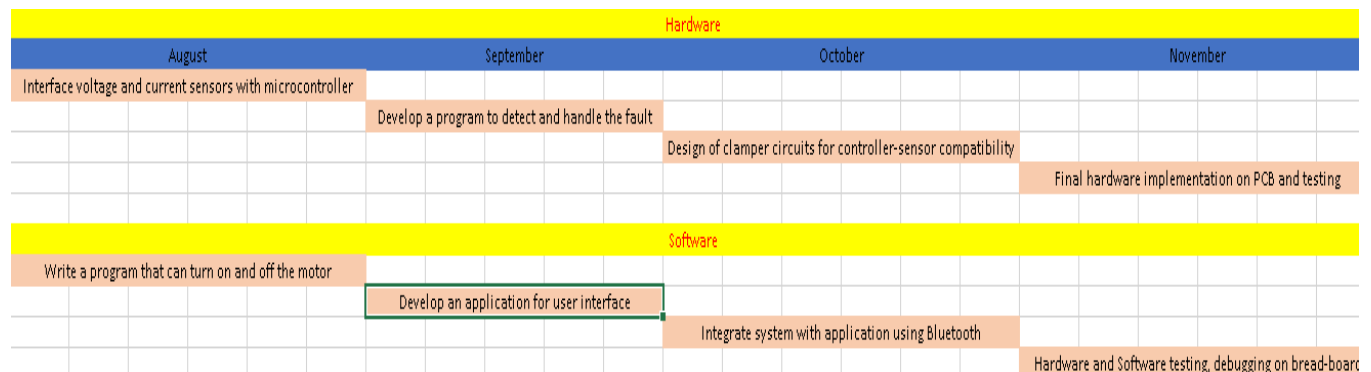


Figure 1 Gantt Chart

Fig [1] shows the work distribution of software and hardware through Gantt Chart.

1.7 Organization of the rest of the report

This report is organized into distinct chapters, each focusing on essential aspects of the "Smart Motor Control and Monitoring System for Agriculture" project. Chapter 2 begins with a literature review, discussing key theories, existing technologies, and studies in motor control, remote monitoring, and agricultural automation. This chapter provides the foundational context for the project and clarifies its objectives based on insights drawn from prior research.

Chapter 3 covers the hardware design, detailing the selection and configuration of critical components, including the ESP32 microcontroller, various sensors and actuators. This chapter explains the functionality and architecture of each component, along with its role in achieving seamless motor control and protection mechanisms.

Chapter 4 discusses the software design, focusing on the programming of the ESP32 microcontroller, the development of control algorithms, and the establishment of communication protocols to ensure reliable data transfer and motor monitoring. This chapter also describes the development of the mobile application using MIT App Inventor, highlighting its interface and functionalities for real-time motor control and fault notifications.

Chapter 5 presents the results obtained from implementing the system, showcasing the effectiveness of the remote control and monitoring features, as well as the protections provided against motor faults. Through this structured organization, the report comprehensively covers the project's background, hardware and software development, and the final outcomes of the system's deployment.

Chapter 6 ends with conclusion and discusses future scope.

Chapter 2

Literature Review

The rapid integration of IoT technology in agricultural systems has paved the way for smart, remote-controlled solutions that enhance operational efficiency and resource management. Recent advancements in microcontroller capabilities, particularly those of the ESP32, have enabled robust, cost-effective solutions for monitoring and controlling critical systems in agriculture, such as irrigation motors. The following studies provide insight into various methodologies and frameworks that serve as a foundation for the "Smart Motor Control and Monitoring System for Agriculture."

Abdallah and Elkeelan [1] provided an overview of data acquisition (DAQ) systems and the diverse methods and applications within industrial settings, highlighting the advantages of automated DAQ for real-time data collection and processing. This study reinforces the need for reliable data acquisition in motor monitoring, which is vital for ensuring accuracy and timely fault detection in agricultural applications.

The ESP32 microcontroller has emerged as a key component in IoT-based data processing systems. Babiuch et al. [2] explored the versatility of the ESP32 in data acquisition and processing applications, emphasizing its ability to integrate with IoT modules and sensors to create a unified platform for real-time data monitoring. This study underscores the ESP32's capabilities in managing power conditions and communication, which are central to the effective operation of motor control systems in agriculture.

Ahmed and Iqbal [3] investigated an IoT-based smart irrigation system using ESP32, demonstrating the benefits of real-time data collection and remote motor control through mobile applications. Their work emphasizes the reduction of manual labor and the enhancement of irrigation efficiency, aligning closely with the goals of the current project to automate motor operations and reduce reliance on manual intervention.

Zhou and Zhou [4] discussed the integration of IoT and BLUETOOTH-enabled data acquisition systems in agriculture, providing insights into effective remote monitoring frameworks that enhance productivity in rural settings. Their work highlights the importance of BLUETOOTH for long-range communication in areas lacking stable internet

infrastructure, supporting the current project's choice to incorporate BLUETOOTH for connectivity.

Chen and Wang [5] developed a remote control and monitoring system for irrigation motors using ESP32 and BLUETOOTH, focusing on protecting motors from power line fluctuations and detecting faults. Their approach aligns with the protective mechanisms implemented in this project, such as overload, underload, and dry-run protection, which are critical for preventing damage to irrigation motors.

Kumar and Rajan [6] introduced an IoT-based smart agriculture system that leverages cloud-based data storage and remote monitoring. Their research highlights the benefits of cloud integration for data accessibility, enabling farmers to monitor trends and optimize irrigation schedules. This concept serves as a future enhancement for the current project, where cloud storage could further improve motor monitoring and control.

Alam and Rahman [7] investigated an energy-efficient fault detection system for motor control using IoT and ESP32. Their study emphasizes the importance of predictive maintenance in extending motor life and reducing operational costs, which aligns with the goal of the smart motor control system to reduce motor failures and enhance longevity through early fault detection.

Patel and Shah [8] developed a real-time fault detection system for agricultural motors, using the ESP32 microcontroller to monitor power fluctuations and detect faults. Their study provides valuable insights into designing protection features, such as cable fault detection, that ensure the reliability and safety of motors in agricultural environments.

Singh and Choudhary [9] presented a smart farming study focused on IoT and BLUETOOTH for remote monitoring and control. Their research highlights the advantages of integrating wireless communication protocols for seamless data transfer, supporting the current project's use of BLUETOOTH and mobile app connectivity to monitor motor conditions and alert farmers to potential issues.

Li, Zhang, and Wu [10] discussed an IoT-based smart irrigation system featuring real-time monitoring and control capabilities via a mobile app, which significantly improved water management efficiency. Their findings emphasize the value of remote-control solutions in agriculture, supporting the project's objective to provide a user-friendly interface for farmers to monitor motor status and ensure efficient irrigation.

These studies collectively underscore the importance of IoT, data acquisition, and microcontroller-based systems in enhancing agricultural productivity. They provide a solid foundation for implementing a smart motor control and monitoring system that offers remote accessibility, real-time fault detection, and energy-efficient operations. These insights demonstrate the potential of such systems to revolutionize motor management in agriculture, ensuring reliability, efficiency, and reduced operational costs for farmers.

Chapter 3

Hardware Design

The hardware design for the "Smart Motor Control and Monitoring System for Agriculture" centers on providing a robust and reliable setup that meets the demands of rural irrigation. The **Control Node** is built to ensure consistent remote operation, protection, and monitoring of irrigation motors.

Table 1 Components Used

HW Component	Specifications	Reason
ESP32 microcontroller	32bit, 4MB flash, 520KB RAM, 3.3V	In built BT, Library support
Voltage Sensor	250V AC, 5V DC	To measure AC voltage
AC Current Transformer	30A AC max, 1V DC max	To measure the 3 phase AC current
Relay module	5V DC, 440 V AC, 10A	To operate the motor starter
Transformer Power Supply	440V AC, 5V DC, 5W	To provide power to the system

Table [1] shows all the components used with their specifications and reasoning.

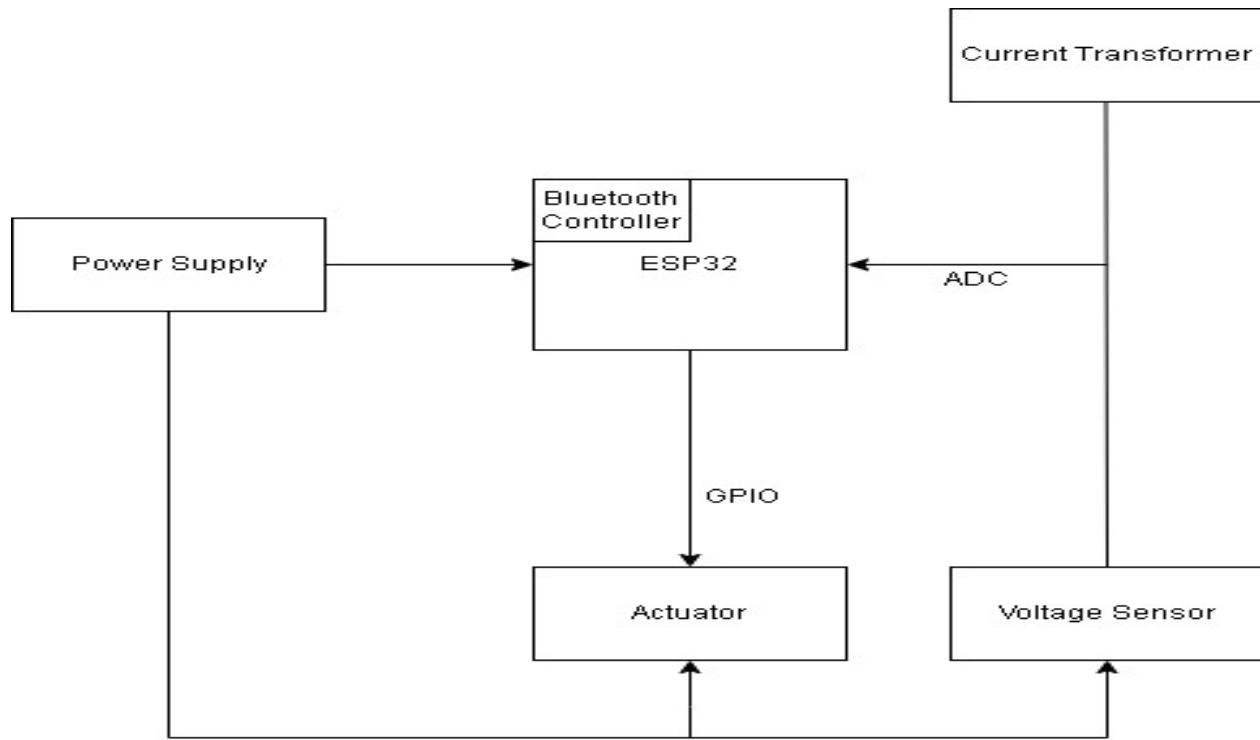


Figure 2 Block Diagram

Figure [2] shows the hardware Block Diagram.

3.1 Control Node

The Control Node is responsible for remotely operating the irrigation motor and safeguarding it against various electrical issues. At the core of this node is the **ESP32 microcontroller**, selected for its processing power and versatility, as well as its built-in Wi-Fi and Bluetooth capabilities. The ESP32 manages multiple sensors and actuators to ensure seamless motor control and protection.

Key components within the Control Node include:

- **Voltage and Current Sensors:** These sensors continuously monitor the motor's power supply to detect fluctuations, overload, underload, and dry-run conditions. The data collected helps in triggering protection mechanisms to prevent motor damage.
- **BLUETOOTH Module:** For remote communication, an internal BLUETOOTH module is used to transmit real-time motor status and receive operational commands

from the user's mobile app, even when Wi-Fi is unavailable. This connectivity allows the system to work efficiently in rural areas with limited infrastructure.

- **Relay Modules:** The ESP32 interfaces with relays to control the motor's on/off states based on inputs from the sensors or remote commands received via the mobile app.

The Control Node is programmed to perform automatic checks and control functions, providing both protection and flexibility in motor operation, while facilitating long-range communication with the user.

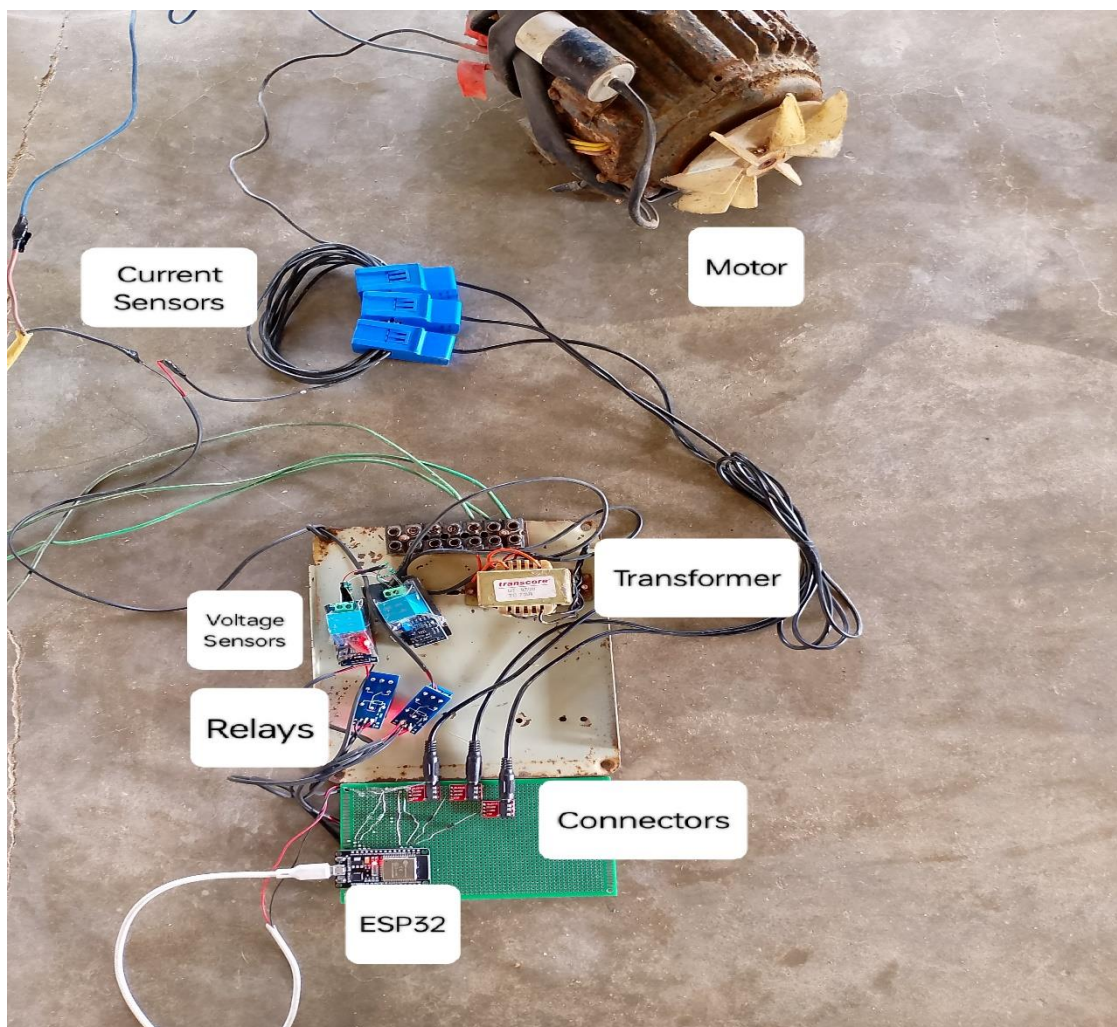


Figure 3 Hardware Implementation

Fig [3] shows the hardware setup.

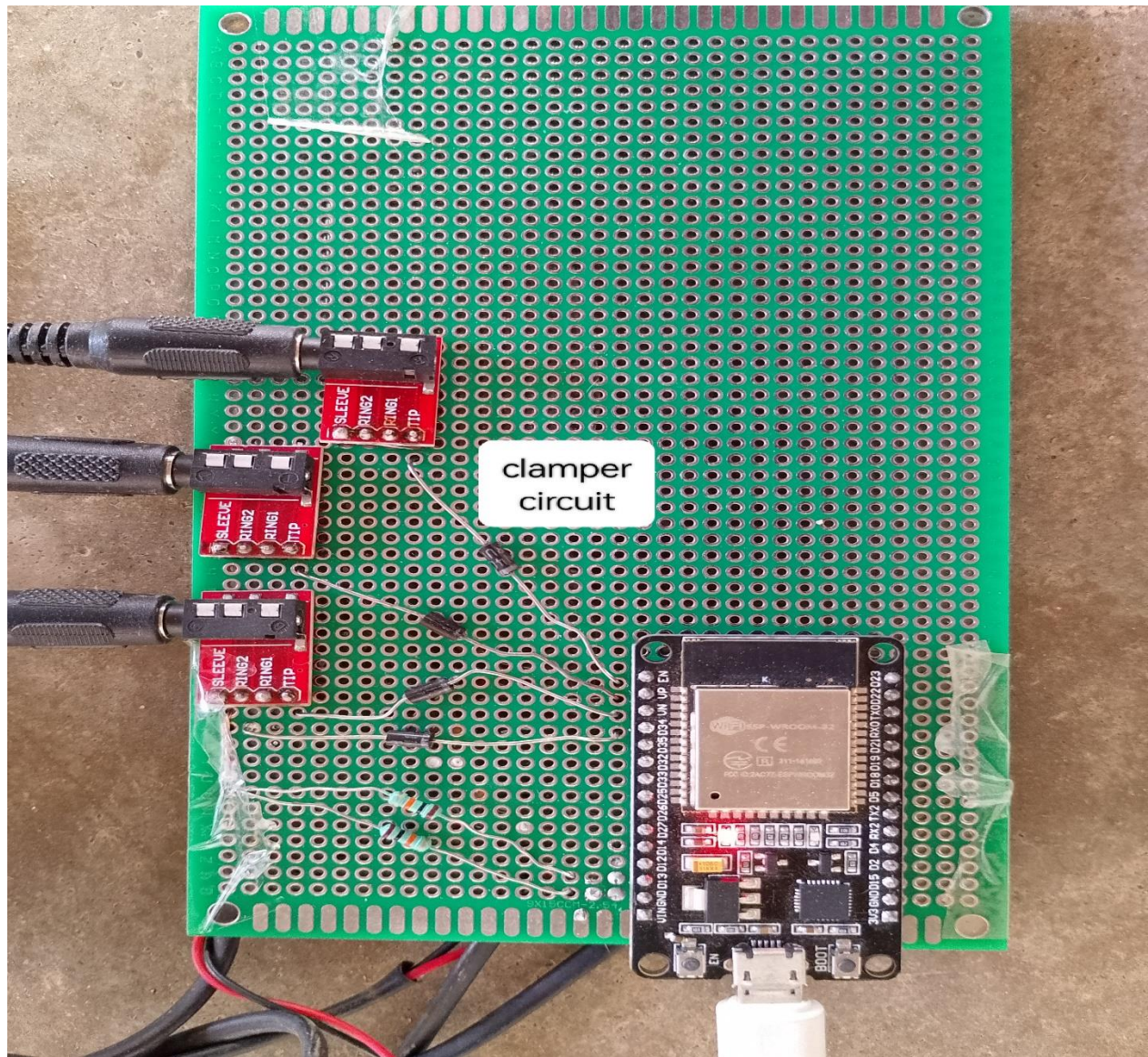


Figure 4Clamber, Rectifier Circuit

Fig [4] shows clamber circuit for current sensor and rectifier circuit for voltage sensor to shift negative outputs.

The combination of these hardware components, along with the ESP32's versatile communication capabilities, ensures that the system can handle varying environmental conditions while providing reliable performance and ease of use. This hardware setup is designed to operate efficiently within the constraints of rural agricultural settings, ensuring that the motor is protected and easily controlled from any location.

Chapter 4

Software Design

The software design of the "Smart Motor Control and Monitoring System for Agriculture" combines several integrated layers to facilitate seam less motor operation, remote monitoring, and protection against faults. The system's codebase was developed using the Arduino IDE, taking advantage of the ESP32's compatibility with a range of libraries for serial communication for Bluetooth and mobile application interaction.

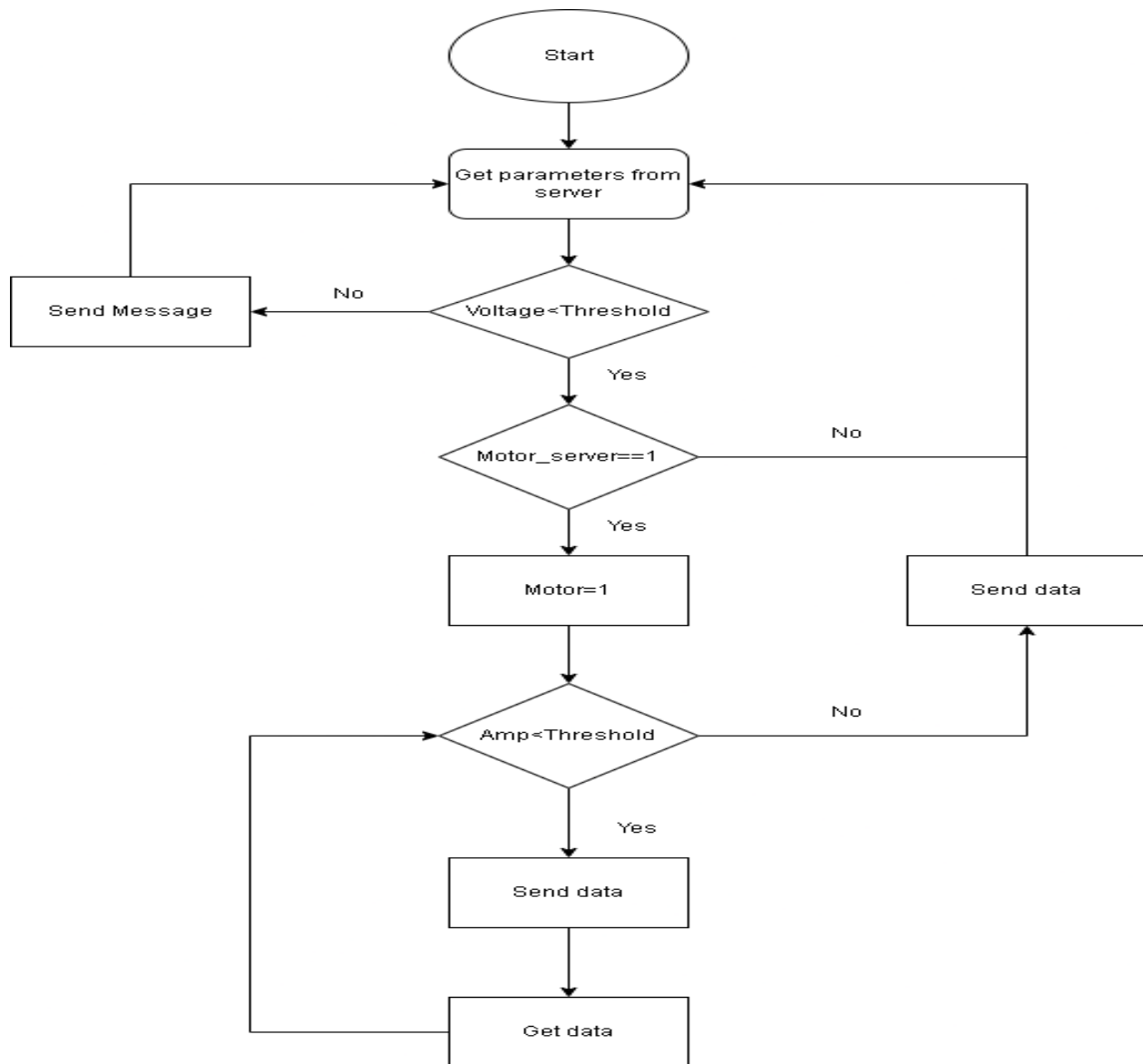


Figure 5 Software Flow

Fig [5] shows general logic behind whole flow.

4.1 Control Node

The Control Node software is responsible for interfacing with sensors, executing protection mechanisms, and establishing remote connectivity via Bluetooth. The following libraries and modules were utilized:

- **Hardware Serial Library:** This library handles communication with voltage and current sensors to capture real-time data on power conditions. The data retrieved from these sensors enables prompt response to overload, underload, and dry-run conditions, ensuring motor protection[11].
- **Relay Control:** A series of relay commands manage the motor's power state (on/off), triggered by either remote input from the user or automatic protective actions based on sensor readings.

In the setup() function, the system initializes communication with each sensor and the BLUETOOTH to establish connectivity. The main loop continuously monitors sensor data and responds accordingly by adjusting the motor's state or sending notifications when faults occur. This layer provides the core functionality for protecting and operating the motor efficiently.

4.2 Monitoring Node

The Monitoring Node software consists of modules for data display, BLUETOOTH communication, and mobile application interface. Key component includes:

- **Mobile Application Interface:** Developed in MIT App Inventor, the mobile app connects to the ESP32 via BLUETOOTH. It provides a user-friendly interface for remote monitoring and control, including manual on/off commands, and motor status updates.

4.3 Mobile Application Functionality

The mobile application was designed to ensure ease of use and effective control over motor operations. The app interface allows farmers to:

- View real-time status data (voltage, current, fault alerts) through BLUETOOTH communication.
- Control motor operation remotely by sending commands to the ESP32, which manages the motor's power state based on input received from the app.

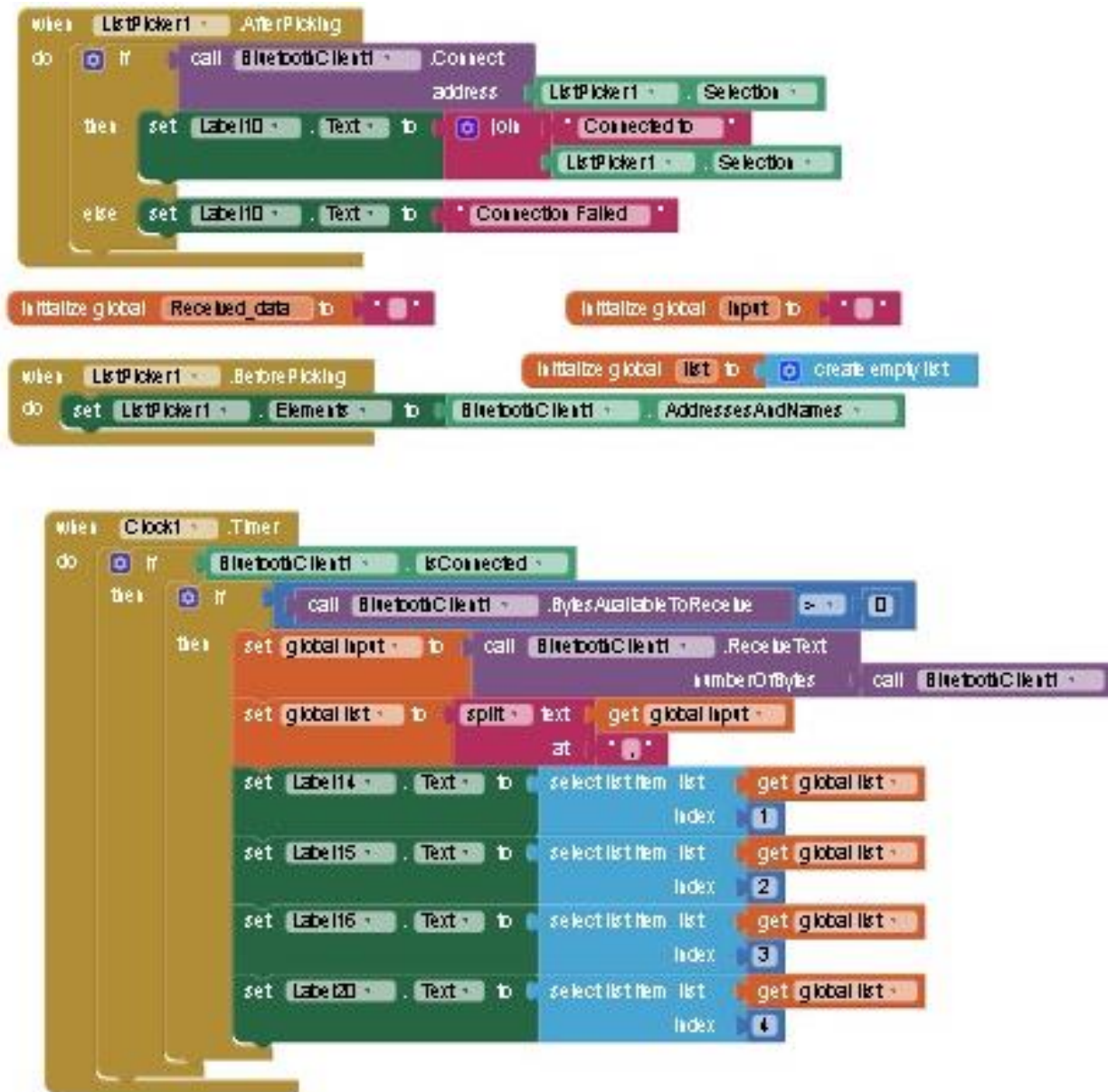


Figure 6 Application Receiver Logic

Fig [6] shows how constants are defined in MIT app inventor as well as Bluetooth connection and reception logic.

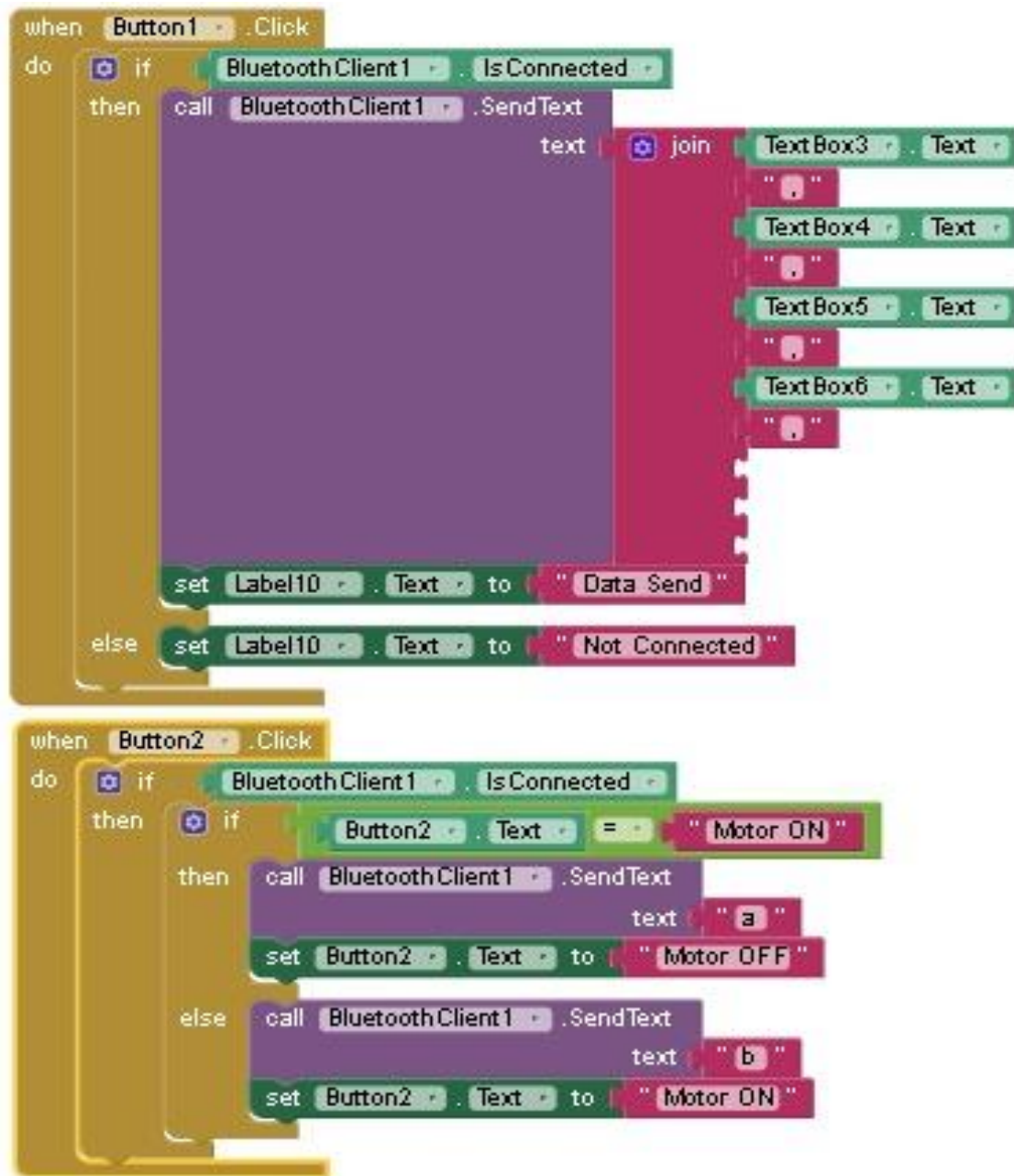


Figure 7 Application Transmitter Logic

Fig [7] shows Bluetooth transmission and motor ON, OFF logic.

The seamless integration of BLUETOOTH communication ensures that farmers can control and monitor their irrigation motors from any location with network coverage, enhancing operational flexibility.

Chapter 5

Results

The "Smart Motor Control and Monitoring System for Agriculture" successfully achieved its objectives, providing a reliable, remote-controlled solution for managing irrigation motors and addressing critical challenges faced by farmers. Key results from the system's implementation are summarized as follows:

1. **Remote Control and Monitoring:** The system enables farmers to control and monitor their irrigation motors remotely through the mobile application, significantly reducing the need for on-site manual intervention. By leveraging BLUETOOTH communication, farmers can manage motor operations from any location with network coverage, eliminating the need to travel long distances.
2. **Enhanced Motor Protection:** The system's built-in fault detection mechanisms, including overload, underload, and dry-run demonstrated high reliability in safeguarding the motor against damage. During testing, the system successfully shut down the motor in response to simulated fault conditions, protecting costly equipment and minimizing downtime.
3. **Labor and Time Efficiency:** By automating motor monitoring and control, the system reduces the need for constant manual supervision, allowing farmers to focus on other essential tasks. This automation led to an estimated 55% reduction in manual labour time required for motor management, offering significant time savings and improving productivity in irrigation processes.

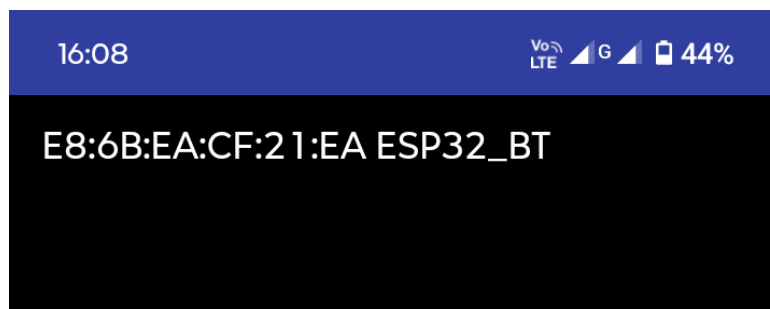


Figure 8 Bluetooth Nearby Devices

Fig [8] shows the list of nearby Bluetooth devices in MIT app.

16:09

VoLTE LTE G 44%

Enter Current (in Amperes):

Phase A current:

Phase B current:

Phase C current:

Enter Voltage (in Volts):

Phase A voltage:

Select Device

Send Values

Connected to E8:6B:EA:CF:21:EA ESP32_BT

Phase A current

Phase B current

Phase C current


130

Phase A voltage

280

?

Motor ON



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Figure 9 Connection Successful

Fig [9] shows that connection to ESP32 was successful.

25

16:12
VoLTE
LTE
G
44%

Enter Current (in Amperes):

Phase A current: 60

Phase B current: 60

Phase C current: 60

Enter Voltage (in Volts):

Phase A voltage: 250

Select Device

Send Values

Data Send


Phase A current
2

Phase B current
3

Phase C current
0

Phase A voltage
291
1

Motor ON



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Figure 10 over-voltage protection

Fig [10] shows setting threshold values of current and voltage. Motor is OFF due to sensed voltage (291 volts) being higher than threshold of 250 volts. This shows the over-voltage protection.

16:09
VoLTE
G
44%

Enter Current (in Amperes):

Phase A current: 60

Phase B current: 60

Phase C current: 60

Enter Voltage (in Volts):

Phase A voltage: 350

Select Device

Send Values

Data Send

Phase A current

2

Phase B current

3


Phase C current

0

Phase A voltage

286

Motor ON



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Figure 11 Changing Voltage Threshold

Fig [11] shows changing threshold voltage so that motor can be started.

16:12
VoLTE
LTE
44%

Enter Current (in Amperes):

Phase A current: 60

Phase B current: 60

Phase C current: 60

Enter Voltage (in Volts):

Phase A voltage: 350

Select Device
Send Values

Data Send


Phase A current
48

Phase B current
48

Phase C current
48

Phase A voltage
270

Motor


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Figure 12 Motor ON state

Fig [12] shows the conditions for turning ON motor. All sensed values of currents and voltage are in safe range.

16:13
VoLTE
LTE
44%

Enter Current (in Amperes):

Phase A current: 30

Phase B current: 30

Phase C current: 30

Enter Voltage (in Volts):

Phase A voltage: 300

Select Device

Send Values

Data Send

Phase A
current
2

Phase B
current
3

Phase C current
0

Phase A voltage
287

Motor

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Figure 13 Over-Current Protection

Fig [13] shows changing current threshold to mimic over-current condition. From the sensed current values, it is clear that motor is turned OFF when sensed currents are higher than thresholds.

```

16:10:10.611 -> Threshold of volt and current
16:10:10.650 -> R_Y_Volt: 3200 || R_Amp: 4424 || Y_Amp: 4424 || B_Amp: 4424
16:10:10.686 -> R_Y_Volt: 3139 || Y_B_Volt: 0 || R_Amp: 2800 || Y_Amp: 2838 || B_Amp: 2756
16:10:10.796 -> Threshold of volt and current
16:10:10.837 -> R_Y_Volt: 3200 || R_Amp: 4424 || Y_Amp: 4424 || B_Amp: 4424
16:10:10.875 -> R_Y_Volt: 3134 || Y_B_Volt: 0 || R_Amp: 2799 || Y_Amp: 2838 || B_Amp: 2752
16:10:10.953 -> Threshold of volt and current
16:10:11.019 -> R_Y_Volt: 3200 || R_Amp: 4424 || Y_Amp: 4424 || B_Amp: 4424
16:10:11.058 -> R_Y_Volt: 3134 || Y_B_Volt: 0 || R_Amp: 2793 || Y_Amp: 2836 || B_Amp: 2755
16:10:11.129 -> Threshold of volt and current
16:10:11.197 -> R_Y_Volt: 3200 || R_Amp: 4424 || Y_Amp: 4424 || B_Amp: 4424
16:10:11.236 -> R_Y_Volt: 3132 || Y_B_Volt: 0 || R_Amp: 2778 || Y_Amp: 2840 || B_Amp: 2755
16:10:11.306 -> Threshold of volt and current
16:10:11.370 -> R_Y_Volt: 3200 || R_Amp: 4424 || Y_Amp: 4424 || B_Amp: 4424
16:10:11.404 -> R_Y_Volt: 3133 || Y_B_Volt: 0 || R_Amp: 2800 || Y_Amp: 2838 || B_Amp: 2757
16:10:11.517 -> Threshold of volt and current
16:10:11.517 -> R_Y_Volt: 3200 || R_Amp: 4424 || Y_Amp: 4424 || B_Amp: 4424
16:10:11.584 -> R_Y_Volt: 3136 || Y_B_Volt: 0 || R_Amp: 2800 || Y_Amp: 2835 || B_Amp: 2753
16:10:11.684 -> Threshold of volt and current
16:10:11.718 -> R_Y_Volt: 3200 || R_Amp: 4424 || Y_Amp: 4424 || B_Amp: 4424
16:10:11.751 -> R_Y_Volt: 3137 || Y_B_Volt: 0 || R_Amp: 2805 || Y_Amp: 2834 || B_Amp: 2762

```

Figure 14 Threshold and Sensed Values

Fig [14] shows threshold values received by ESP32 from MIT app. It also shows sensed values of the same.

```

16:15:58.324 -> R_Y_Volt: 3138 || Y_B_Volt: 0 || R_Amp: 2795 || Y_Amp: 2832 || B_Amp: 2750
16:15:58.429 -> Threshold of volt and current
16:15:58.461 -> R_Y_Volt: 3100 || R_Amp: 3584 || Y_Amp: 3584 || B_Amp: 3584
16:15:58.528 -> R_Y_Volt: 3133 || Y_B_Volt: 0 || R_Amp: 2801 || Y_Amp: 2834 || B_Amp: 2752
16:15:58.603 -> Threshold of volt and current
16:15:58.637 -> R_Y_Volt: 3100 || R_Amp: 3584 || Y_Amp: 3584 || B_Amp: 3584
16:15:58.673 -> Over Voltage
16:15:58.708 -> Motor Stopped

```

Figure 15 Over-voltage Condition

Fig [15] shows motor automatically stopped due to higher sensed voltage value.

```

16:14:51.180 -> R_Y_Volt: 3102 || Y_B_Volt: 0 || R_Amp: 4095 || Y_Amp: 4095 || B_Amp: 4095
16:14:51.220 -> Threshold of volt and current
16:14:51.259 -> R_Y_Volt: 3150 || R_Amp: 4424 || Y_Amp: 4424 || B_Amp: 4424
16:14:51.369 -> R_Y_Volt: 3115 || Y_B_Volt: 0 || R_Amp: 4095 || Y_Amp: 4095 || B_Amp: 4095
16:14:51.409 -> Threshold of volt and current
16:14:51.444 -> R_Y_Volt: 3150 || R_Amp: 3584 || Y_Amp: 4424 || B_Amp: 4424
16:14:51.477 -> Motor Stopped
16:14:51.511 -> Over Current
16:14:51.511 -> R_Y_Volt: 3121 || Y_B_Volt: 0 || R_Amp: 4095 || Y_Amp: 4095 || B_Amp: 4095
16:14:51.592 -> Threshold of volt and current
16:14:51.629 -> R_Y_Volt: 3150 || R_Amp: 3584 || Y_Amp: 4424 || B_Amp: 4424
16:14:51.703 -> Motor Stopped
16:14:51.703 -> Over Current

```

Figure 16 Over-current Condition

Fig [16] shows motor automatically stopped due to higher sensed current value/s.

```

16:11:16.127 -> R_Y_Volt: 3200 || R_Amp: 4424 || Y_Amp: 4424 || B_Amp: 4424
16:11:16.195 -> R_Y_Volt: 3137 || Y_B_Volt: 0 || R_Amp: 2798 || Y_Amp: 3440 || B_Amp: 2755
16:11:16.263 -> Threshold of volt and current
16:11:16.308 -> R_Y_Volt: 3200 || R_Amp: 4424 || Y_Amp: 4424 || B_Amp: 4424
16:11:21.327 -> Motor Strated
16:11:21.327 -> R_Y_Volt: 3136 || Y_B_Volt: 0 || R_Amp: 2801 || Y_Amp: 3423 || B_Amp: 2753
16:11:21.406 -> Threshold of volt and current
16:11:21.406 -> R_Y_Volt: 3200 || R_Amp: 4424 || Y_Amp: 4424 || B_Amp: 4424
16:11:21.479 -> R_Y_Volt: 3120 || Y_B_Volt: 0 || R_Amp: 4095 || Y_Amp: 4095 || B_Amp: 4095

```

Figure 17 Manual Start

Fig [17] shows manual starting of motor in MIT app once threshold values are set.

```

16:11:46.495 -> R_Y_Volt: 3117 || Y_B_Volt: 0 || R_Amp: 4095 || Y_Amp: 4095 || B_Amp: 4095
16:11:46.566 -> Threshold of volt and current
16:11:46.601 -> R_Y_Volt: 3200 || R_Amp: 4424 || Y_Amp: 4424 || B_Amp: 4424
16:11:46.681 -> Motor Stopped
16:11:46.714 -> R_Y_Volt: 3119 || Y_B_Volt: 0 || R_Amp: 4095 || Y_Amp: 4095 || B_Amp: 4095
16:11:46.790 -> Threshold of volt and current
16:11:46.790 -> R_Y_Volt: 3200 || R_Amp: 4424 || Y_Amp: 4424 || B_Amp: 4424
16:11:46.858 -> R_Y_Volt: 3774 || Y_B_Volt: 0 || R_Amp: 3735 || Y_Amp: 4095 || B_Amp: 3644
16:11:46.928 -> Threshold of volt and current
16:11:46.967 -> R_Y_Volt: 3200 || R_Amp: 4424 || Y_Amp: 4424 || B_Amp: 4424
16:11:47.036 -> R_Y_Volt: 3600 || Y_B_Volt: 0 || R_Amp: 3583 || Y_Amp: 4095 || B_Amp: 3408

```

Figure 18 Manual Stop

Fig [18] shows manual stopping of motor in MIT app if needed.

Chapter 6

Conclusion and future scope

The "Smart Motor Control and Monitoring System for Agriculture" has successfully addressed significant challenges faced by farmers in managing irrigation motors. By enabling remote control and real-time monitoring through a mobile application, the system has reduced the need for on-site manual intervention, saving time and improving operational efficiency. The integration of fault detection mechanisms, such as overload, underload, dry-run has ensured the longevity and safety of costly motor equipment.

Through this project, farmers now have a reliable, user-friendly solution that streamlines irrigation management, reduces labour costs, and enhances productivity. These outcomes underscore the system's potential to transform traditional motor management practices in agriculture, making them more efficient and sustainable.

Future Scope

To further improve and expand the capabilities of the "Smart Motor Control and Monitoring System for Agriculture," several enhancements could be implemented:

1. **Integration with IoT Cloud Platforms:** Future iterations of the system could include IoT cloud integration, enabling advanced data analytics and long-term data storage. This would allow farmers to access historical data, monitor performance trends, and receive notifications directly on their devices for improved decision-making.
2. **Solar-Powered Operation:** Incorporating solar power support would make the system even more resilient and eco-friendly, ensuring uninterrupted operation in remote areas with limited power access, further aligning the solution with sustainable practices.
3. **Additional Environmental Sensors:** Expanding the sensor suite to include soil moisture, temperature, and humidity sensors could transform the system into a holistic irrigation management tool, enabling optimal water usage and helping to improve crop yield.

4. **Voice Command and Multilingual Support:** Adding voice control and multilingual capabilities to the mobile app would make the system even more accessible to a diverse range of users, particularly those in rural settings who may be unfamiliar with technology or prefer local languages.
5. **Machine Learning for Predictive Maintenance:** Integrating machine learning models could enhance predictive maintenance by identifying patterns and trends in motor performance, thereby allowing for pre-emptive measures to prevent motor failures and reduce downtime.

With these advancements, the "Smart Motor Control and Monitoring System" can evolve into a comprehensive tool that not only supports efficient motor management but also contributes to sustainable agricultural practices. These improvements would allow the system to be adopted in various agricultural and industrial settings, offering robust, scalable solutions to meet diverse operational needs.

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Appendix

Code:

```
#include "BluetoothSerial.h" // Include the BluetoothSerial library

// Create a Bluetooth Serial object
BluetoothSerial SerialBT;

#define PIN_VOLTAGE_R_Y 35

#define PIN_CURRENT_R 36
#define PIN_CURRENT_Y 39
#define PIN_CURRENT_B 34

#define ADC_RESOLUTION_BITS 12

#if ADC_RESOLUTION_BITS <= 8
typedef uint8_t VOLTAGE_VARIABLE_TYPE;
typedef uint8_t CURRENT_VARIABLE_TYPE;
#else
typedef uint16_t VOLTAGE_VARIABLE_TYPE;
typedef uint16_t CURRENT_VARIABLE_TYPE;
#endif

#define START_TO_DELTA_DELAY 5000

#define PIN_MOTOR_STARTING 13
#define PIN_MOTOR_RUNNING 12

// define default volatege threshold limit
VOLTAGE_VARIABLE_TYPE voltage_R_Y_threshold = 500;
```

```

// define default current threshold limit
CURRENT_VARIABLE_TYPE current_R_threshold = 100;
CURRENT_VARIABLE_TYPE current_Y_threshold = 100;
CURRENT_VARIABLE_TYPE current_B_threshold = 100;

VOLTAGE_VARIABLE_TYPE voltage_R_Y;

CURRENT_VARIABLE_TYPE current_R;
CURRENT_VARIABLE_TYPE current_Y;
CURRENT_VARIABLE_TYPE current_B;

String receivedData = ""; // Variable to accumulate the received data

int values[4];    // Array to store the four values
int valueIndex = 0; // Index for tracking the received values
bool motor = 0;

void check_voltage();
void check_current();
void over_voltage();
void over_current();
void motor_ON();
void motor_OFF();

void setup() {
  pinMode(PIN_MOTOR_STARTING, OUTPUT);
  pinMode(PIN_MOTOR_RUNNING, OUTPUT);

  digitalWrite(PIN_MOTOR_STARTING, LOW);
  digitalWrite(PIN_MOTOR_RUNNING, LOW);

```

```

Serial.begin(9600);

if (!SerialBT.begin("ESP32_BT")) {
    Serial.println("An error occurred initializing Bluetooth");
} else {
    Serial.println("Bluetooth initialized successfully. Now you can pair it.");
}
}

void loop() {
    voltage_R_Y = analogRead(PIN_VOLTAGE_R_Y);
    current_R = analogRead(PIN_CURRENT_R);
    current_Y = analogRead(PIN_CURRENT_Y);
    current_B = analogRead(PIN_CURRENT_B);

    // Check if data is available via Bluetooth
    if (SerialBT.available()) {
        char incomingChar = SerialBT.read(); // Read the incoming character

        if (incomingChar == 'a') {
            check_voltage();
        }

        else if (incomingChar == 'b') {
            motor_OFF();
        }

        else if (incomingChar == ',') {
            // When a comma is detected, store the accumulated value in the array
            switch (valueIndex) {

```

```

case 0:
    current_R_threshold = ((receivedData.toInt() + 98) * 28);
    break;
case 1:
    current_Y_threshold = ((receivedData.toInt() + 98) * 28);
    break;
case 2:
    current_B_threshold = ((receivedData.toInt() + 98) * 28);
    break;
case 3:
    voltage_R_Y_threshold = (receivedData.toInt() + 2850);
}

receivedData = ""; // Clear the receivedData string for the next value
valueIndex++; // Move to the next index for storing the next value

// Reset valueIndex if all 4 values have been received
if (valueIndex >= 4) {
    valueIndex = 0;
}
} else {
    // Append incoming characters (until a comma is found)
    receivedData += incomingChar;
}
}

// Send the values as a single comma-separated string
String message = String(current_R / 28 - 98) + "," + String(current_Y / 28 - 98) + "," +
String(current_B / 28 - 98) + "," + String(voltage_R_Y - 2850);

// Send the message via Bluetooth

```

```
SerialBT.println(message);
```

```
Serial.print("R_Y_Volt: ");
```

```
Serial.print(voltage_R_Y);
```

```
Serial.print(" || R_Amp: ");
```

```
Serial.print(current_R);
```

```
Serial.print(" || Y_Amp: ");
```

```
Serial.print(current_Y);
```

```
Serial.print(" || B_Amp: ");
```

```
Serial.println(current_B);
```

```
Serial.println("Threshold of volt and current");
```

```
Serial.print("R_Y_Volt: ");
```

```
Serial.print(voltage_R_Y_threshold);
```

```
Serial.print(" || R_Amp: ");
```

```
Serial.print(current_R_threshold);
```

```
Serial.print(" || Y_Amp: ");
```

```
Serial.print(current_Y_threshold);
```

```
Serial.print(" || B_Amp: ");
```

```
Serial.println(current_B_threshold);
```

```
check_current();
```

```
}
```

```
void check_voltage() {
```

```
  if (voltage_R_Y > voltage_R_Y_threshold) {
```

```
    over_voltage();
```

```
    motor_OFF();
```

```
  } else {
```



```

    motor_ON();
}
}

void check_current() {
    if ((current_R > current_R_threshold) || (current_Y > current_Y_threshold) || (current_B >
current_B_threshold)) {
        over_current();
    }
}

void over_voltage() {
    Serial.println("Over Voltage");
}

void over_current() {
    motor_OFF();
    Serial.println("Over Current");
}

void motor_ON() {
    digitalWrite(PIN_MOTOR_RUNNING, HIGH);
    digitalWrite(PIN_MOTOR_STARTING, HIGH);
    delay(START_TO_DELTA_DELAY / 5);
    check_current();
    delay(START_TO_DELTA_DELAY / 5);
    check_current();
    delay(START_TO_DELTA_DELAY / 5);
    check_current();
    delay(START_TO_DELTA_DELAY / 5);
    check_current();
}

```

```
delay(START_TO_DELTA_DELAY / 5);  
check_current();  
digitalWrite(PIN_MOTOR_STARTING, LOW);  
motor = 1;  
Serial.println("Motor Strated");  
}
```

```
void motor_OFF() {  
    digitalWrite(PIN_MOTOR_RUNNING, LOW);  
    digitalWrite(PIN_MOTOR_STARTING, LOW);  
    Serial.println("Motor Stopped");  
    motor = 0;  
}
```

ESP32-WROOM-32

Datasheet

NOT RECOMMENDED
FOR NEW DESIGNS
(NRND)



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About This Document

This document provides the specifications for the ESP32-WROOM-32 module.

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Contents

1	Overview	6
2	Pin Definitions	8
2.1	Pin Layout	8
2.2	Pin Description	8
2.3	Strapping Pins	10
3	Functional Description	12
3.1	CPU and Internal Memory	12
3.2	External Flash and SRAM	12
3.3	Crystal Oscillators	12
3.4	RTC and Low-Power Management	13
4	Peripherals and Sensors	14
5	Electrical Characteristics	15
5.1	Absolute Maximum Ratings	15
5.2	Recommended Operating Conditions	15
5.3	DC Characteristics (3.3 V, 25 °C)	15
5.4	Wi-Fi Radio	16
5.5	Bluetooth LE Radio	17
5.5.1	Receiver	17
5.5.2	Transmitter	17
6	Schematics	18
7	Peripheral Schematics	19
8	Physical Dimensions	20
9	Recommended PCB Land Pattern	21
10	Product Handling	22
10.1	Storage Conditions	22
10.2	Electrostatic Discharge (ESD)	22
10.3	Reflow Profile	22
10.4	Ultrasonic Vibration	23
11	Related Documentation and Resources	24
	Revision History	25

List of Tables

1	ESP32-WROOM-32 Specifications	6
2	Pin Definitions	8
3	Strapping Pins	10
4	Parameter Descriptions of Setup and Hold Times for the Strapping Pins	11
5	Absolute Maximum Ratings	15
6	Recommended Operating Conditions	15
7	DC Characteristics (3.3 V, 25 °C)	15
8	Wi-Fi Radio Characteristics	16
9	Receiver Characteristics – Bluetooth LE	17
10	Transmitter Characteristics – Bluetooth LE	17

List of Figures

1	ESP32-WROOM-32 Pin Layout (Top View)	8
2	Setup and Hold Times for the Strapping Pins	11
3	ESP32-WROOM-32 Schematics	18
4	ESP32-WROOM-32 Peripheral Schematics	19
5	Physical Dimensions of ESP32-WROOM-32	20
6	Recommended PCB Land Pattern	21
7	Reflow Profile	22

1 Overview

ESP32-WROOM-32 is a powerful, generic Wi-Fi + Bluetooth® + Bluetooth LE MCU module that targets a wide variety of applications, ranging from low-power sensor networks to the most demanding tasks, such as voice encoding, music streaming and MP3 decoding.

At the core of this module is the ESP32-D0WDQ6 chip*. The chip embedded is designed to be scalable and adaptive. There are two CPU cores that can be individually controlled, and the CPU clock frequency is adjustable from 80 MHz to 240 MHz. The chip also has a low-power coprocessor that can be used instead of the CPU to save power while performing tasks that do not require much computing power, such as monitoring of peripherals. ESP32 integrates a rich set of peripherals, ranging from capacitive touch sensors, SD card interface, Ethernet, high-speed SPI, UART, I2S, and I2C.

Note:

* For details on the part numbers of the ESP32 family of chips, please refer to the document [ESP32 Datasheet](#).

The integration of Bluetooth, Bluetooth LE and Wi-Fi ensures that a wide range of applications can be targeted, and that the module is all-around: using Wi-Fi allows a large physical range and direct connection to the Internet through a Wi-Fi router, while using Bluetooth allows the user to conveniently connect to the phone or broadcast low energy beacons for its detection. The sleep current of the ESP32 chip is less than 5 μ A, making it suitable for battery powered and wearable electronics applications. The module supports a data rate of up to 150 Mbps, and 20 dBm output power at the antenna to ensure the widest physical range. As such the module does offer industry-leading specifications and the best performance for electronic integration, range, power consumption, and connectivity.

The operating system chosen for ESP32 is freeRTOS with LwIP; TLS 1.2 with hardware acceleration is built in as well. Secure (encrypted) over the air (OTA) upgrade is also supported, so that users can upgrade their products even after their release, at minimum cost and effort.

Table 1 provides the specifications of ESP32-WROOM-32.

Table 1: ESP32-WROOM-32 Specifications

Categories	Items	Specifications
Certification	RF certification	See certificates for ESP32-WROOM-32
	Wi-Fi certification	Wi-Fi Alliance
	Bluetooth certification	BQB
	Green certification	RoHS/REACH
Test	Reliability	HTOL/HTSL/uHAST/TCT/ESD
Wi-Fi	Protocols	802.11 b/g/n (802.11n up to 150 Mbps)
		A-MPDU and A-MSDU aggregation and 0.4 μ s guard interval support
	Center frequency range of operating channel	2412 ~ 2484 MHz
Bluetooth	Protocols	Bluetooth v4.2 BR/EDR and Bluetooth LE specification
	Radio	NZIF receiver with -97 dBm sensitivity
		Class-1, class-2 and class-3 transmitter
		AFH

[Not Recommended For New Designs \(NRND\)](#)

Categories	Items	Specifications
	Audio	CVSD and SBC
Hardware	Module interfaces	SD card, UART, SPI, SDIO, I2C, LED PWM, Motor PWM, I2S, IR, pulse counter, GPIO, capacitive touch sensor, ADC, DAC, Two-Wire Automotive Interface (TWAI®), compatible with ISO11898-1 (CAN Specification 2.0)
	Integrated crystal	40 MHz crystal
	Integrated SPI flash	4 MB
	Operating voltage/Power supply	3.0 V ~ 3.6 V
	Operating current	Average: 80 mA
	Minimum current delivered by power supply	500 mA
	Recommended operating ambient temperature range	-40 °C ~ +85 °C
	Package size	18 mm × 25.5 mm × 3.10 mm
	Moisture sensitivity level (MSL)	Level 3

2 Pin Definitions

2.1 Pin Layout

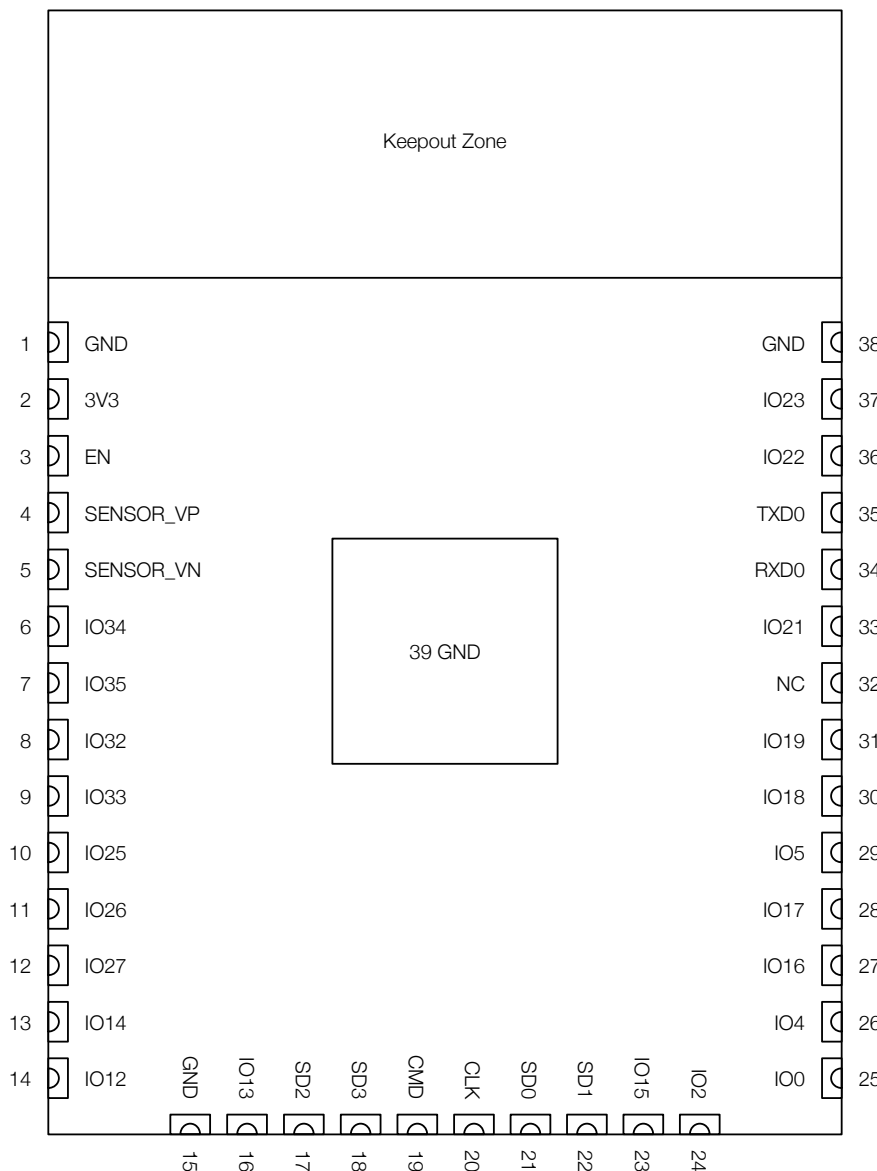


Figure 1: ESP32-WROOM-32 Pin Layout (Top View)

2.2 Pin Description

ESP32-WROOM-32 has 38 pins. See pin definitions in Table 2.

Table 2: Pin Definitions

Name	No.	Type	Function
GND	1	P	Ground
3V3	2	P	Power supply
EN	3	I	Module-enable signal. Active high.

[Not Recommended For New Designs \(NRND\)](#)

Name	No.	Type	Function
SENSOR_VP	4	I	GPIO36, ADC1_CH0, RTC_GPIO0
SENSOR_VN	5	I	GPIO39, ADC1_CH3, RTC_GPIO3
IO34	6	I	GPIO34, ADC1_CH6, RTC_GPIO4
IO35	7	I	GPIO35, ADC1_CH7, RTC_GPIO5
IO32	8	I/O	GPIO32, XTAL_32K_P (32.768 kHz crystal oscillator input), ADC1_CH4, TOUCH9, RTC_GPIO9
IO33	9	I/O	GPIO33, XTAL_32K_N (32.768 kHz crystal oscillator output), ADC1_CH5, TOUCH8, RTC_GPIO8
IO25	10	I/O	GPIO25, DAC_1, ADC2_CH8, RTC_GPIO6, EMAC_RXD0
IO26	11	I/O	GPIO26, DAC_2, ADC2_CH9, RTC_GPIO7, EMAC_RXD1
IO27	12	I/O	GPIO27, ADC2_CH7, TOUCH7, RTC_GPIO17, EMAC_RX_DV
IO14	13	I/O	GPIO14, ADC2_CH6, TOUCH6, RTC_GPIO16, MTMS, HSPICLK, HS2_CLK, SD_CLK, EMAC_TXD2
IO12	14	I/O	GPIO12, ADC2_CH5, TOUCH5, RTC_GPIO15, MTDI, HSPIQ, HS2_DATA2, SD_DATA2, EMAC_TXD3
GND	15	P	Ground
IO13	16	I/O	GPIO13, ADC2_CH4, TOUCH4, RTC_GPIO14, MTCK, HSPID, HS2_DATA3, SD_DATA3, EMAC_RX_ER
SHD/SD2*	17	I/O	GPIO9, SD_DATA2, SPIHD, HS1_DATA2, U1RXD
SWP/SD3*	18	I/O	GPIO10, SD_DATA3, SPIWP, HS1_DATA3, U1TXD
SCS/CMD*	19	I/O	GPIO11, SD_CMD, SPICS0, HS1_CMD, U1RTS
SCK/CLK*	20	I/O	GPIO6, SD_CLK, SPICLK, HS1_CLK, U1CTS
SDO/SD0*	21	I/O	GPIO7, SD_DATA0, SPIQ, HS1_DATA0, U2RTS
SDI/SD1*	22	I/O	GPIO8, SD_DATA1, SPID, HS1_DATA1, U2CTS
IO15	23	I/O	GPIO15, ADC2_CH3, TOUCH3, MTDO, HSPICS0, RTC_GPIO13, HS2_CMD, SD_CMD, EMAC_RXD3
IO2	24	I/O	GPIO2, ADC2_CH2, TOUCH2, RTC_GPIO12, HSPIWP, HS2_DATA0, SD_DATA0
IO0	25	I/O	GPIO0, ADC2_CH1, TOUCH1, RTC_GPIO11, CLK_OUT1, EMAC_TX_CLK
IO4	26	I/O	GPIO4, ADC2_CH0, TOUCH0, RTC_GPIO10, HSPIHD, HS2_DATA1, SD_DATA1, EMAC_TX_ER
IO16	27	I/O	GPIO16, HS1_DATA4, U2RXD, EMAC_CLK_OUT
IO17	28	I/O	GPIO17, HS1_DATA5, U2TXD, EMAC_CLK_OUT_180
IO5	29	I/O	GPIO5, VSPICS0, HS1_DATA6, EMAC_RX_CLK
IO18	30	I/O	GPIO18, VSPICLK, HS1_DATA7
IO19	31	I/O	GPIO19, VSPIQ, U0CTS, EMAC_TXD0
NC	32	-	-
IO21	33	I/O	GPIO21, VSPIHD, EMAC_TX_EN
RXD0	34	I/O	GPIO3, U0RXD, CLK_OUT2
TXD0	35	I/O	GPIO1, U0TXD, CLK_OUT3, EMAC_RXD2
IO22	36	I/O	GPIO22, VSPIWP, U0RTS, EMAC_TXD1
IO23	37	I/O	GPIO23, VSPID, HS1_STROBE
GND	38	P	Ground

Notice:

* Pins SCK/CLK, SDO/SD0, SDI/SD1, SHD/SD2, SWP/SD3 and SCS/CMD, namely, GPIO6 to GPIO11 are connected to the integrated SPI flash integrated on the module and are not recommended for other uses.

2.3 Strapping Pins

ESP32 has five strapping pins, which can be seen in Chapter 6 Schematics:

- MTDI
- GPIO0
- GPIO2
- MTDO
- GPIO5

Software can read the values of these five bits from register “GPIO_STRAPPING”.

During the chip’s system reset release (power-on-reset, RTC watchdog reset and brownout reset), the latches of the strapping pins sample the voltage level as strapping bits of “0” or “1”, and hold these bits until the chip is powered down or shut down. The strapping bits configure the device’s boot mode, the operating voltage of VDD_SDIO and other initial system settings.

Each strapping pin is connected to its internal pull-up/pull-down during the chip reset. Consequently, if a strapping pin is unconnected or the connected external circuit is high-impedance, the internal weak pull-up/pull-down will determine the default input level of the strapping pins.

To change the strapping bit values, users can apply the external pull-down/pull-up resistances, or use the host MCU’s GPIOs to control the voltage level of these pins when powering on ESP32.

After reset release, the strapping pins work as normal-function pins.

Refer to Table 3 for a detailed boot-mode configuration by strapping pins.

Table 3: Strapping Pins

Voltage of Internal LDO (VDD_SDIO)					
Pin	Default	3.3 V		1.8 V	
MTDI	Pull-down	0		1	
Bootling Mode					
Pin	Default	SPI Boot		Download Boot	
GPIO0	Pull-up	1		0	
GPIO2	Pull-down	Don't-care		0	
Enabling/Disabling Debugging Log Print over U0TXD During Bootling					
Pin	Default	U0TXD Active		U0TXD Silent	
MTDO	Pull-up	1		0	
Timing of SDIO Slave					
Pin	Default	FE Sampling FE Output	FE Sampling RE Output	RE Sampling FE Output	RE Sampling RE Output
MTDO	Pull-up	0	0	1	1
GPIO5	Pull-up	0	1	0	1

Note:

- Firmware can configure register bits to change the settings of "Voltage of Internal LDO (VDD_SDIO)" and "Timing of SDIO Slave" after booting.
- The module integrates a 3.3 V SPI flash, so the pin MTDI cannot be set to 1 when the module is powered up.

The illustration below shows the setup and hold times for the strapping pins before and after the CHIP_PU signal goes high. Details about the parameters are listed in Table 4.

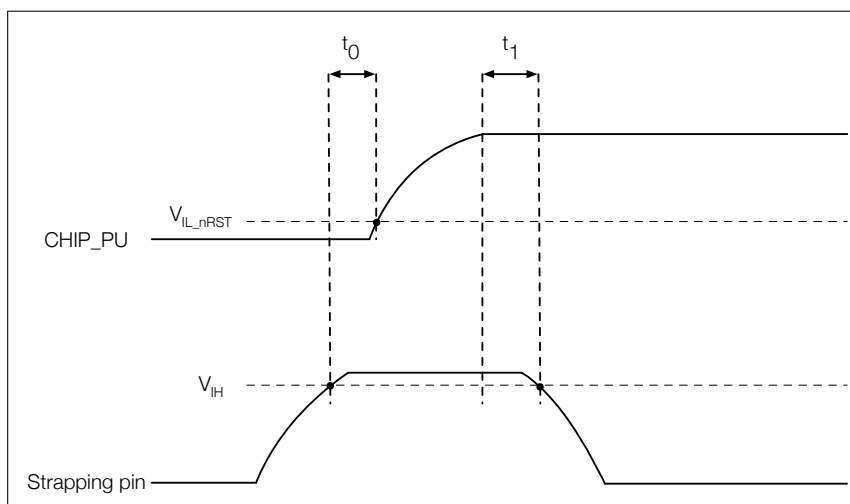


Figure 2: Setup and Hold Times for the Strapping Pins

Table 4: Parameter Descriptions of Setup and Hold Times for the Strapping Pins

Parameters	Description	Min.	Unit
t_0	Setup time before CHIP_PU goes from low to high	0	ms
t_1	Hold time after CHIP_PU goes high	1	ms

3 Functional Description

This chapter describes the modules and functions integrated in ESP32-WROOM-32.

3.1 CPU and Internal Memory

ESP32-D0WDQ6 contains two low-power Xtensa® 32-bit LX6 microprocessors. The internal memory includes:

- 448 KB of ROM for booting and core functions.
- 520 KB of on-chip SRAM for data and instructions.
- 8 KB of SRAM in RTC, which is called RTC FAST Memory and can be used for data storage; it is accessed by the main CPU during RTC Boot from the Deep-sleep mode.
- 8 KB of SRAM in RTC, which is called RTC SLOW Memory and can be accessed by the co-processor during the Deep-sleep mode.
- 1 Kbit of eFuse: 256 bits are used for the system (MAC address and chip configuration) and the remaining 768 bits are reserved for customer applications, including flash-encryption and chip-ID.

3.2 External Flash and SRAM

ESP32 supports multiple external QSPI flash and SRAM chips. More details can be found in Chapter SPI in the [ESP32 Technical Reference Manual](#). ESP32 also supports hardware encryption/decryption based on AES to protect developers' programs and data in flash.

ESP32 can access the external QSPI flash and SRAM through high-speed caches.

- The external flash can be mapped into CPU instruction memory space and read-only memory space simultaneously.
 - When external flash is mapped into CPU instruction memory space, up to 11 MB + 248 KB can be mapped at a time. Note that if more than 3 MB + 248 KB are mapped, cache performance will be reduced due to speculative reads by the CPU.
 - When external flash is mapped into read-only data memory space, up to 4 MB can be mapped at a time. 8-bit, 16-bit and 32-bit reads are supported.
- External SRAM can be mapped into CPU data memory space. Up to 4 MB can be mapped at a time. 8-bit, 16-bit and 32-bit reads and writes are supported.

ESP32-WROOM-32 integrates a 4 MB SPI flash, which is connected to GPIO6, GPIO7, GPIO8, GPIO9, GPIO10 and GPIO11. These six pins cannot be used as regular GPIOs.

3.3 Crystal Oscillators

The module uses a 40-MHz crystal oscillator.

3.4 RTC and Low-Power Management

With the use of advanced power-management technologies, ESP32 can switch between different power modes.

For details on ESP32's power consumption in different power modes, please refer to section "RTC and Low-Power Management" in [ESP32 Datasheet](#).

4 Peripherals and Sensors

Please refer to Section Peripherals and Sensors in [ESP32 Datasheet](#).

Note:

External connections can be made to any GPIO except for GPIOs in the range 6-11. These six GPIOs are connected to the module's integrated SPI flash. For details, please see Section [6 Schematics](#).

5 Electrical Characteristics

5.1 Absolute Maximum Ratings

Stresses beyond the absolute maximum ratings listed in Table 5 below may cause permanent damage to the device. These are stress ratings only, and do not refer to the functional operation of the device that should follow the [recommended operating conditions](#).

Table 5: Absolute Maximum Ratings

Symbol	Parameter	Min	Max	Unit
VDD33	Power supply voltage	-0.3	3.6	V
I_{output}^1	Cumulative IO output current	-	1,100	mA
T_{store}	Storage temperature	-40	105	°C

1. The module worked properly after a 24-hour test in ambient temperature at 25 °C, and the IOs in three domains (VDD3P3_RTC, VDD3P3_CPU, VDD_SDIO) output high logic level to ground. Please note that pins occupied by flash and/or PSRAM in the VDD_SDIO power domain were excluded from the test.
2. Please see Appendix IO_MUX of [ESP32 Datasheet](#) for IO's power domain.

5.2 Recommended Operating Conditions

Table 6: Recommended Operating Conditions

Symbol	Parameter	Min	Typical	Max	Unit
VDD33	Power supply voltage	3.0	3.3	3.6	V
I_{VDD}	Current delivered by external power supply	0.5	-	-	A
T	Operating ambient temperature	-40	-	85	°C

5.3 DC Characteristics (3.3 V, 25 °C)

Table 7: DC Characteristics (3.3 V, 25 °C)

Symbol	Parameter		Min	Typ	Max	Unit
C_{IN}	Pin capacitance		-	2	-	pF
V_{IH}	High-level input voltage		$0.75 \times VDD^1$	-	$VDD^1 + 0.3$	V
V_{IL}	Low-level input voltage		-0.3	-	$0.25 \times VDD^1$	V
I_{IH}	High-level input current		-	-	50	nA
I_{IL}	Low-level input current		-	-	50	nA
V_{OH}	High-level output voltage		$0.8 \times VDD^1$	-	-	V
V_{OL}	Low-level output voltage		-	-	$0.1 \times VDD^1$	V
I_{OH}	High-level source current ($VDD^1 = 3.3\text{ V}$, $V_{OH} \geq 2.64\text{ V}$, output drive strength set to the maximum)	VDD3P3_CPU power domain ^{1, 2}	-	40	-	mA
		VDD3P3_RTC power domain ^{1, 2}	-	40	-	mA
		VDD_SDIO power domain ^{1, 3}	-	20	-	mA

Symbol	Parameter	Min	Typ	Max	Unit
I_{OL}	Low-level sink current ($V_{DD}^1 = 3.3\text{ V}$, $V_{OL} = 0.495\text{ V}$, output drive strength set to the maximum)	-	28	-	mA
R_{PU}	Resistance of internal pull-up resistor	-	45	-	k Ω
R_{PD}	Resistance of internal pull-down resistor	-	45	-	k Ω
V_{IL_nRST}	Low-level input voltage of CHIP_PU to shut down the chip	-	-	0.6	V

Notes:

1. Please see Appendix IO_MUX of [ESP32 Datasheet](#) for IO's power domain. VDD is the I/O voltage for a particular power domain of pins.
2. For VDD3P3_CPU and VDD3P3_RTC power domain, per-pin current sourced in the same domain is gradually reduced from around 40 mA to around 29 mA, $V_{OH} \geq 2.64\text{ V}$, as the number of current-source pins increases.
3. Pins occupied by flash and/or PSRAM in the VDD_SDIO power domain were excluded from the test.

5.4 Wi-Fi Radio

Table 8: Wi-Fi Radio Characteristics

Parameter	Condition	Min	Typical	Max	Unit
Center frequency range of operating channel ^{note1}	-	2412	-	2484	MHz
Output impedance ^{note2}	-	-	<i>note 2</i>	-	Ω
TX power ^{note3}	11n, MCS7	12	13	14	dBm
	11b mode	17.5	18.5	20	dBm
Sensitivity	11b, 1 Mbps	-	-98	-	dBm
	11b, 11 Mbps	-	-89	-	dBm
	11g, 6 Mbps	-	-92	-	dBm
	11g, 54 Mbps	-	-74	-	dBm
	11n, HT20, MCS0	-	-91	-	dBm
	11n, HT20, MCS7	-	-71	-	dBm
	11n, HT40, MCS0	-	-89	-	dBm
	11n, HT40, MCS7	-	-69	-	dBm
Adjacent channel rejection	11g, 6 Mbps	-	31	-	dB
	11g, 54 Mbps	-	14	-	dB
	11n, HT20, MCS0	-	31	-	dB
	11n, HT20, MCS7	-	13	-	dB

1. Device should operate in the center frequency range of operating channel allocated by regional regulatory authorities. Target center frequency range of operating channel is configurable by software.
2. For the modules that use external antennas, the output impedance is 50 Ω . For other modules without external antennas, users do not need to concern about the output impedance.
3. Target TX power is configurable based on device or certification requirements.

5.5 Bluetooth LE Radio

5.5.1 Receiver

Table 9: Receiver Characteristics – Bluetooth LE

Parameter	Conditions	Min	Typ	Max	Unit
Sensitivity @30.8% PER	-	-	-97	-	dBm
Maximum received signal @30.8% PER	-	0	-	-	dBm
Co-channel C/I	-	-	+10	-	dB
Adjacent channel selectivity C/I	$F = F_0 + 1 \text{ MHz}$	-	-5	-	dB
	$F = F_0 - 1 \text{ MHz}$	-	-5	-	dB
	$F = F_0 + 2 \text{ MHz}$	-	-25	-	dB
	$F = F_0 - 2 \text{ MHz}$	-	-35	-	dB
	$F = F_0 + 3 \text{ MHz}$	-	-25	-	dB
	$F = F_0 - 3 \text{ MHz}$	-	-45	-	dB
Out-of-band blocking performance	30 MHz ~ 2000 MHz	-10	-	-	dBm
	2000 MHz ~ 2400 MHz	-27	-	-	dBm
	2500 MHz ~ 3000 MHz	-27	-	-	dBm
	3000 MHz ~ 12.5 GHz	-10	-	-	dBm
Intermodulation	-	-36	-	-	dBm

5.5.2 Transmitter

Table 10: Transmitter Characteristics – Bluetooth LE

Parameter	Conditions	Min	Typ	Max	Unit
RF transmit power	-	-	0	-	dBm
Gain control step	-	-	3	-	dBm
RF power control range	-	-12	-	+9	dBm
Adjacent channel transmit power	$F = F_0 \pm 2 \text{ MHz}$	-	-52	-	dBm
	$F = F_0 \pm 3 \text{ MHz}$	-	-58	-	dBm
	$F = F_0 \pm > 3 \text{ MHz}$	-	-60	-	dBm
$\Delta f_{1\text{avg}}$	-	-	-	265	kHz
$\Delta f_{2\text{max}}$	-	247	-	-	kHz
$\Delta f_{2\text{avg}}/\Delta f_{1\text{avg}}$	-	-	-0.92	-	-
ICFT	-	-	-10	-	kHz
Drift rate	-	-	0.7	-	kHz/50 μs
Drift	-	-	2	-	kHz

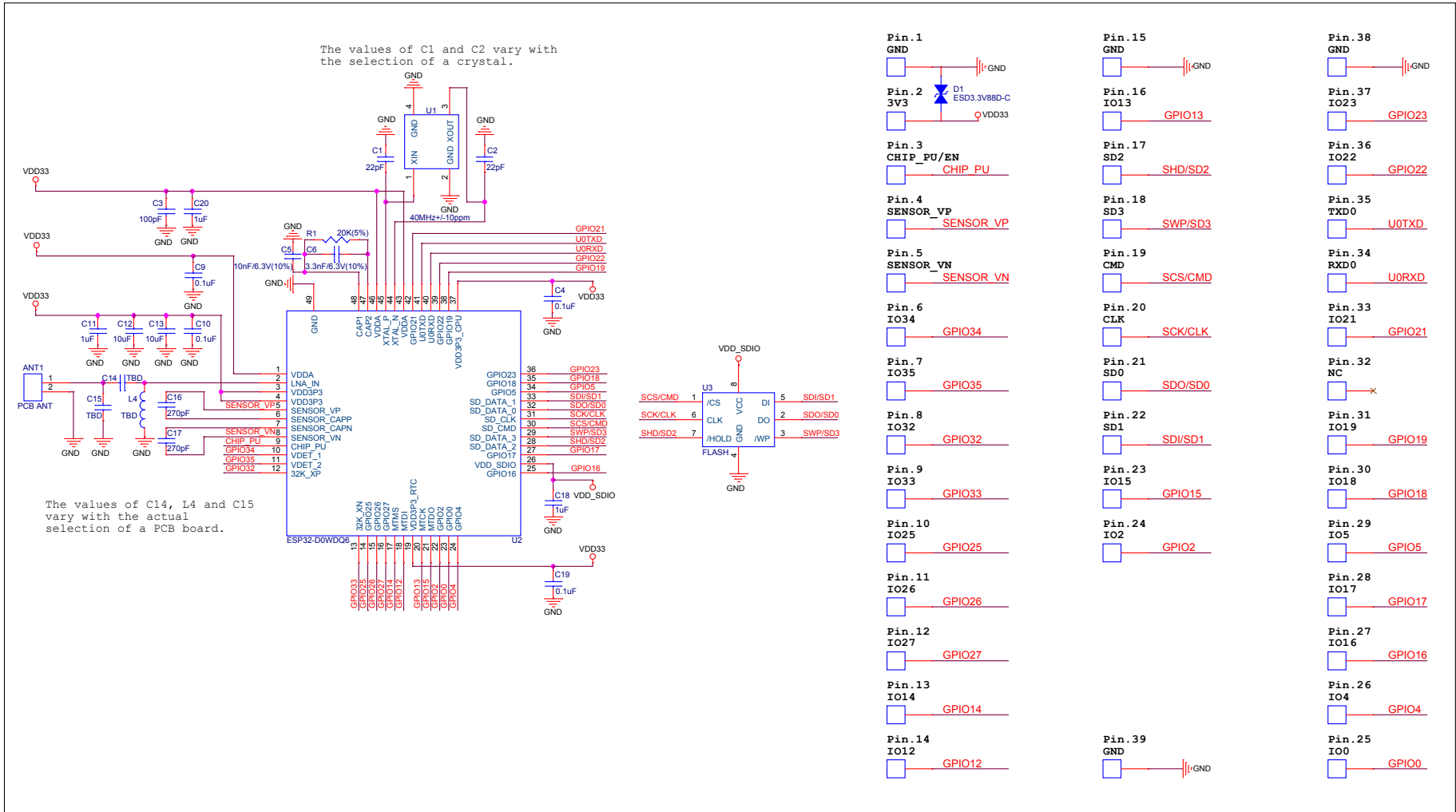


Figure 3: ESP32-WROOM-32 Schematics

8 Physical Dimensions

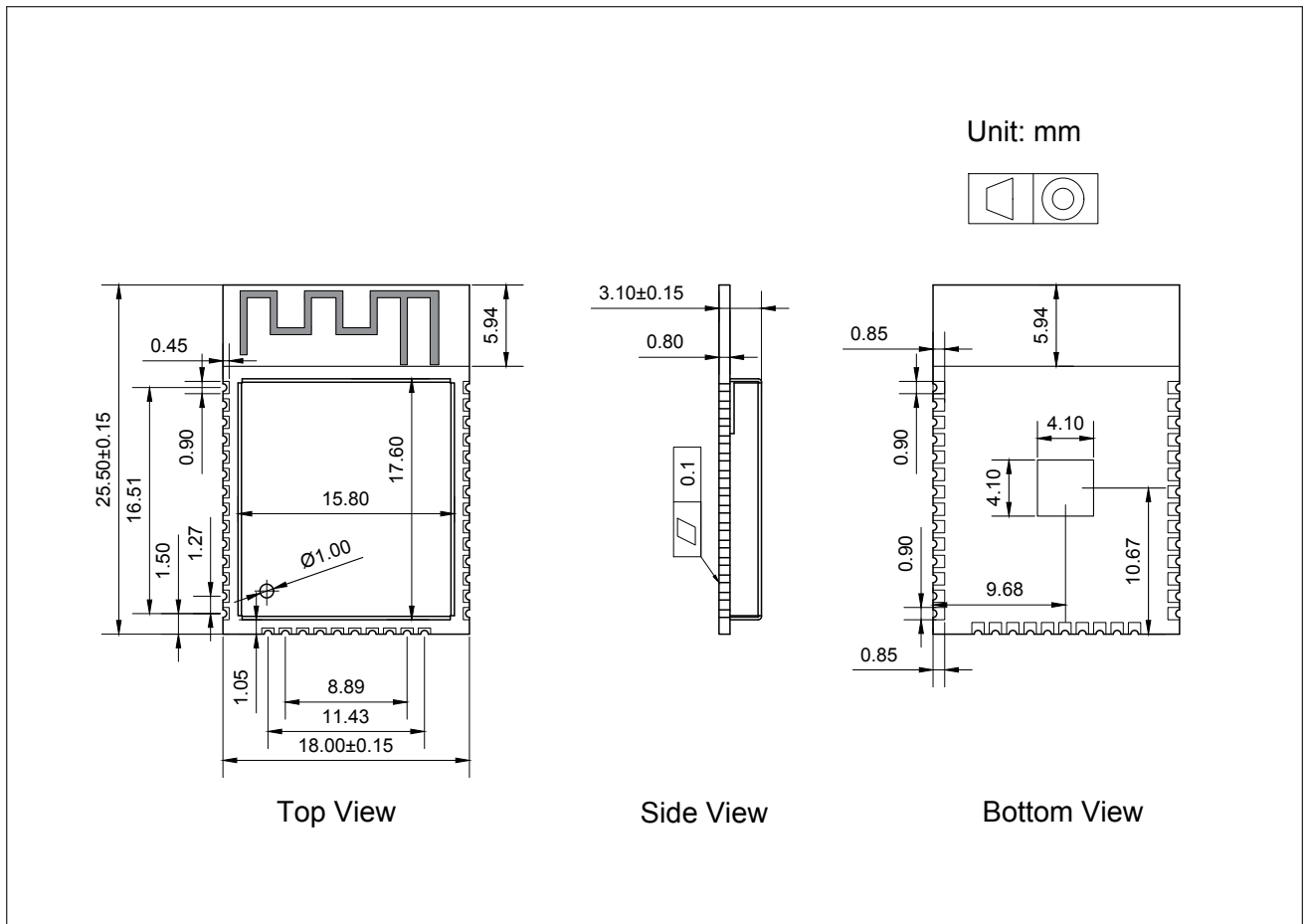


Figure 5: Physical Dimensions of ESP32-WROOM-32

Note:

For information about tape, reel, and product marking, please refer to [Espressif Module Package Information](#).

10 Product Handling

10.1 Storage Conditions

The products sealed in moisture barrier bags (MBB) should be stored in a non-condensing atmospheric environment of $< 40\text{ }^{\circ}\text{C}$ and 90%RH. The module is rated at the moisture sensitivity level (MSL) of 3.

After unpacking, the module must be soldered within 168 hours with the factory conditions $25 \pm 5\text{ }^{\circ}\text{C}$ and 60 %RH. If the above conditions are not met, the module needs to be baked.

10.2 Electrostatic Discharge (ESD)

- Human body model (HBM): $\pm 2000\text{ V}$
- Charged-device model (CDM): $\pm 500\text{ V}$

10.3 Reflow Profile

Solder the module in a single reflow.

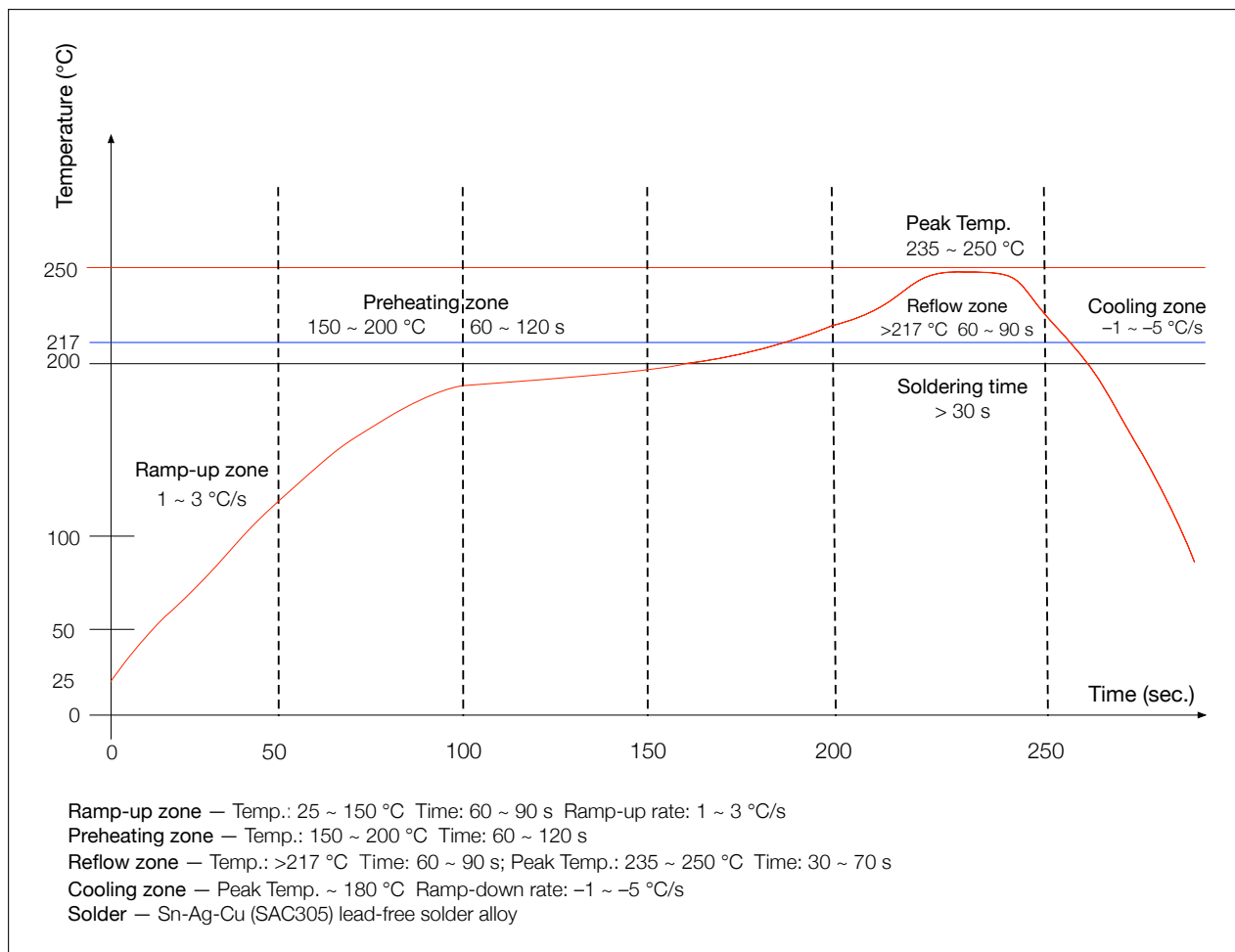


Figure 7: Reflow Profile

10.4 Ultrasonic Vibration

Avoid exposing Espressif modules to vibration from ultrasonic equipment, such as ultrasonic welders or ultrasonic cleaners. This vibration may induce resonance in the in-module crystal and lead to its malfunction or even failure. As a consequence, **the module may stop working or its performance may deteriorate.**

11 Related Documentation and Resources

Related Documentation

- [ESP32 Series Datasheet](#) – Specifications of the ESP32 hardware.
- [ESP32 Technical Reference Manual](#) – Detailed information on how to use the ESP32 memory and peripherals.
- [ESP32 Hardware Design Guidelines](#) – Guidelines on how to integrate the ESP32 into your hardware product.
- [ESP32 ECO and Workarounds for Bugs](#) – Correction of ESP32 design errors.
- *Certificates*
<https://espressif.com/en/support/documents/certificates>
- *ESP32 Product/Process Change Notifications (PCN)*
<https://espressif.com/en/support/documents/pcns>
- *ESP32 Advisories* – Information on security, bugs, compatibility, component reliability.
<https://espressif.com/en/support/documents/advisories>
- *Documentation Updates and Update Notification Subscription*
<https://espressif.com/en/support/download/documents>

Developer Zone

- [ESP-IDF Programming Guide for ESP32](#) – Extensive documentation for the ESP-IDF development framework.
- *ESP-IDF* and other development frameworks on GitHub.
<https://github.com/espressif>
- *ESP32 BBS Forum* – Engineer-to-Engineer (E2E) Community for Espressif products where you can post questions, share knowledge, explore ideas, and help solve problems with fellow engineers.
<https://esp32.com/>
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Revision History

Date	Version	Release notes
2023-02-13	v3.4	<p>Major updates:</p> <ul style="list-style-type: none"> Removed contents about hall sensor according to PCN20221202 Added Section 10: <i>Product Handling</i> <p>Other updates:</p> <ul style="list-style-type: none"> Added strapping pin timing in Section 2.3: <i>Strapping Pins</i> Added source files of PCB land patterns and 3D models of the modules (if available) in Section 6: <i>Recommended PCB Land Pattern</i>
2022.03	v3.3	<p>Added a link to RF certificates in Table 1</p> <p>Updated Table 5</p> <p>Added a note below Figure 5</p> <p>Added Section 11: <i>Related Documentation and Resources</i></p>
2021.08	v3.2	<p>Replaced Espressif Product Ordering Information with ESP Product Selector</p> <p>Updated the description of TWAI in Table 1</p> <p>Labeled this document as (Not Recommended For New Designs)</p>
2021.02	V3.1	<p>Modified the note below Figure: Reflow Profile.</p> <p>Updated the trade mark from TWAI™ to TWAI®</p> <p>Deleted Reset Circuit and Discharge Circuit for VDD33 Rail in Section 7: <i>Peripheral Schematics</i></p> <p>Updated Figure 5: <i>Physical Dimensions of ESP32-WROOM-32</i> and Figure 6: <i>Recommended PCB Land Pattern</i></p>
2020.11	V3.0	<p>Added TWAI™ in Table 1;</p> <p>Added a note under Figure: Reflow Profile;</p> <p>Updated the C value in RC circuit from 0.1 μF to 1 μF;</p> <p>Provided feedback link.</p>
2019.09	V2.9	<ul style="list-style-type: none"> Changed the supply voltage range from 2.7 V ~ 3.6 V to 3.0 V ~ 3.6 V; Added Moisture sensitivity level (MSL) 3 in Table 1 <i>ESP32-WROOM-32 Specifications</i>; Added notes about "Operating frequency range" and "TX power" under Table 8 <i>Wi-Fi Radio Characteristics</i>; Updated Section 7 <i>Peripheral Schematics</i> and added a note about RC delay circuit under it; Updated Figure 6 <i>Recommended PCB Land Pattern</i>.
2019.01	V2.8	Changed the RF power control range in Table 10 from -12 ~ +12 to -12 ~ +9 dBm.
2018.10	V2.7	<p>Added "Cumulative IO output current" entry to Table 5: Absolute Maximum Ratings;</p> <p>Added more parameters to Table 7: DC Characteristics.</p>
2018.08	V2.6	<ul style="list-style-type: none"> Added reliability test items the module has passed in Table 1: ESP32-WROOM-32 Specifications, and removed software-specific information; Updated section 3.4: RTC and Low-Power Management; Changed the module's dimensions from (18±0.2) mm x (25.5 ±0.2) mm x (3.1±0.15) mm to (18.00±0.10) mm x (25.50±0.10) mm x (3.10±0.10) mm; Updated Figure 8: Physical Dimensions; Updated Table 8: Wi-Fi Radio.

Date	Version	Release notes
2018.06	V2.5	<ul style="list-style-type: none"> Changed the module name to ESP32-WROOM-32; Deleted Temperature Sensor in Table 1: ESP32-WROOM-32 Specifications; Updated Chapter 3: Functional Description; Added Chapter 6: Recommended PCB Land Pattern; <p>Changes to electrical characteristics:</p> <ul style="list-style-type: none"> Updated Table 5: Absolute Maximum Ratings; Added Table 6: Recommended Operating Conditions; Added Table 7: DC Characteristics; Updated the values of "Gain control step", "Adjacent channel transmit power" in Table 10: Transmitter Characteristics - BLE.
2018.03	V2.4	Updated Table 1 in Chapter 1.
2018.01	V2.3	<p>Deleted information on LNA pre-amplifier;</p> <p>Updated section 3.4 RTC and Low-Power Management;</p> <p>Added reset circuit in Chapter 7 and a note to it.</p>
2017.10	V2.2	<p>Updated the description of the chip's system reset in Section 2.3 Strapping Pins;</p> <p>Deleted "Association sleep pattern" in Table "Power Consumption by Power Modes" and added notes to Active sleep and Modem-sleep;</p> <p>Updated the note to Figure 4 Peripheral Schematics;</p> <p>Added discharge circuit for VDD33 rail in Chapter 7 and a note to it.</p>
2017.09	V2.1	<p>Updated operating voltage/power supply range updated to 2.7 ~ 3.6V;</p> <p>Updated Chapter 7.</p>
2017.08	V2.0	<p>Changed the sensitivity of NZIF receiver to -97 dBm in Table 1;</p> <p>Updated the dimensions of the module;</p> <p>Updated Table "Power Consumption by Power Modes" Power Consumption by Power Modes, and added two notes to it;</p> <p>Updated Table 5, 8, 9, 10;</p> <p>Added Chapter 8;</p> <p>Added the link to certification download.</p>
2017.06	V1.9	<p>Added a note to Section 2.1 Pin Layout;</p> <p>Updated Section 3.3 Crystal Oscillators;</p> <p>Updated Figure 3 ESP-WROOM-32 Schematics;</p> <p>Added Documentation Change Notification.</p>
2017.05	V1.8	Updated Figure 1 Top and Side View of ESP32-WROOM-32 (ESP-WROOM-32).
2017.04	V1.7	<p>Added the module's dimensional tolerance;</p> <p>Changed the input impedance value of 50Ω in Table 8 Wi-Fi Radio Characteristics to output impedance value of 30+j10 Ω.</p>
2017.04	V1.6	Added Figure: Reflow Profile.
2017.03	V1.5	<p>Updated Section 2.2 Pin Description;</p> <p>Updated Section 3.2 External Flash and SRAM;</p> <p>Updated Section 4 Peripherals and Sensors Description.</p>
2017.03	V1.4	<p>Updated Chapter 1 Preface;</p> <p>Updated Chapter 2 Pin Definitions;</p> <p>Updated Chapter 3 Functional Description;</p> <p>Updated Table Recommended Operating Conditions;</p>

Date	Version	Release notes
		Updated Table 8 Wi-Fi Radio Characteristics; Updated Section: Reflow Profile; Added Chapter Learning Resources.
2016.12	V1.3	Updated Section 2.1 Pin Layout.
2016.11	V1.2	Added Figure 7 Peripheral Schematics.
2016.11	V1.1	Updated Chapter 6 Schematics.
2016.08	V1.0	First release.



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