

ESP-32 BASED PARAMETER MEASUREMENT AND CONTROL IN RC BORING MACHINE

Submitted in partial fulfilment of requirements for the award of
Bachelor of Engineering degree in
Electronics and Communication Engineering

by

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**DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS**

SATHYABAMA
INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

CATEGORY -1 UNIVERSITY BY UGC

**Accredited with Grade “A++” by NAAC | 12B Status by UGC | Approved by AICTE
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BONAFIDE CERTIFICATE

This is to certify that this Final Year Project Report is the bonafide work of **AKASH APPADURAI (40130006), BHARATH R (40130025)** who have done the project work as an individual who carried out the project entitled "**ESP-32 BASED PARAMETER MEASUREMENT AND CONTROL IN RC BORING MACHINE**" under my supervision from November 2023 to April 2024.

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We, **AKASH APPADURAI** (40130006) and **BHARATH R** (40130025) hereby declare that the Project Report entitled "**ESP-32 BASED PARAMETER MEASUREMENT AND CONTROL IN RC BORING MACHINE**" done by us under the guidance of **Dr. G. RAJALAKSHMI M.E., Ph.D.**, Department of Electronics and Communication Engineering is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electronics and Communication Engineering.

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ABSTRACT

The hard rock mining industry has always shown a major interest in the use of TBMs for mine development, primarily for development of entries, as well as ventilation, haulage, and production drifts. In contemporary construction and mining industries, the evolution of automation and remote operation has led to significant advancements in efficiency, safety, and precision. Manual control of boring machines has several problems. Firstly, it is not very precise and not very safe. People operating the machine can get hurt, especially if they are working in dangerous places like underground tunnels. Secondly, it is tiring for the operators. They must work hard to control the machine, and this can make them tired quickly. Also, sometimes it is hard for them to reach certain places with the machine, making it tricky to do the job properly and it is not very efficient too. The proposed work “ESP-32 BASED PARAMETER MEASUREMENT AND CONTROL IN RC BORING MACHINE” is developed using ESP32 microcontroller aims at solving these problems. This project is based on Radio Frequency technology. While pressing the keypad buttons in transmitter side, the receiver side receives the signal, and the brushless dc motor would run based on the button pressed. In the receiver side, various sensors are placed and monitored, those values would be displayed in LCD of receiver side and the data would also be transmitted to the transmitter side and displayed in LCD of the transmitter side. Robot chassis is used, where the receiver setup is placed, and it moves forward and backward.

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CHAPTER 1

INTRODUCTION

Tunnel boring machines (TBMs) have been widely used as an effective tool for tunnel construction which is characterized by its large scale, high cost and long project lifecycle, and the construction process is always associated with complex technical problems and potential risks. Modern TBMs usually integrate many sensing and monitoring methods and record a series of operation parameters [such as stress, current, flow and gas pressure, etc. These monitoring data indicate the working state of TBM, and can be used to reduce construction risks, optimize construction operations, and ensure construction safety. With the development of sensing technology, some cyber-physical platforms have been built to achieve effective data management, including automatic data collection, storage, and visualization.

However, manual analysis falls short of consistent standards and poses risks for tunnel construction. In fact, some tragic construction accidents have occurred due to the lack of timely and accurate data analysis. A serious water inrush accident occurred in a tunnel project in Guangdong, China in February 2018, resulting in more than 10 fatalities and major economic losses. The cause of the accident was that the TBM entered a permeable layer that had not been identified by geological investigation. This could be avoided if the formation anomalies were recognized in advance, for example, by analyzing the real-time monitoring data. However, the real-time automatic analysis of data still faces many difficulties due to the following characteristics of TBM monitoring data.

In summary, while TBMs have revolutionized tunnel construction, ensuring their safe and efficient operation requires robust data analysis capabilities. The tragic incidents resulting from inadequate data analysis underscore the critical importance of leveraging advanced technologies and methodologies to effectively manage and analyze monitoring data in real-time, thereby mitigating risks and ensuring the success of tunnel construction projects.

1.1 OBJECTIVE

The primary objective of the "ESP-32 Based Parameter Measurement and Control in RC Boring Machine" project is to develop a comprehensive system that enables real-time measurement and precise control of critical parameters during the operation of RC boring machines. By leveraging the capabilities of the ESP-32 microcontroller, the project seeks to achieve the following specific objectives:

Parameter Measurement: Implement sensors and measurement modules to accurately monitor key parameters such as drilling depth, rotational speed, torque, temperature, and vibration levels. These measurements will provide operators with valuable insights into the machine's performance and environmental conditions, enabling proactive decision-making and optimization of drilling operations.

Data Acquisition and Analysis: Establish a robust data acquisition system that collects sensor readings at regular intervals and processes the data for analysis. Leveraging the computational power of the ESP-32 microcontroller, the system will perform real-time data processing to identify trends, anomalies, and potential safety hazards. Insights gained from data analysis will facilitate informed decision-making and optimization of drilling processes.

Remote Monitoring and Control: Enable remote monitoring and control of the RC boring machine through wireless communication protocols supported by the ESP-32 microcontroller. This feature will allow operators to access real-time operational data, receive alerts for critical events, and adjust drilling parameters remotely, enhancing operational flexibility and efficiency.

Safety Enhancement: Implement safety features such as automatic shutdown mechanisms triggered by predefined thresholds for parameters such as temperature, vibration, or torque. By proactively addressing safety concerns, the system aims to mitigate risks associated with equipment malfunction or hazardous operating conditions, safeguarding personnel, and equipment.

User Interface: Develop a user-friendly interface, accessible via web or mobile applications, to visualize real-time data, configure drilling parameters, and receive

notifications. The interface will provide operators with intuitive controls and informative visualizations, facilitating seamless interaction with the RC boring machine and enhancing overall user experience.

In summary, the "ESP-32 Based Parameter Measurement and Control in RC Boring Machine" project endeavors to revolutionize the operation of RC boring machines by leveraging advanced technology to enhance monitoring, control, and safety capabilities. Through the implementation of the objectives, the project aims to optimize drilling processes, improve operational efficiency, and ensure the safety of personnel and equipment in construction and drilling applications.

1.2 AIM

The aim of the "ESP-32 Based Parameter Measurement and Control in RC Boring Machine" project is to develop an integrated system that utilizes the ESP-32 microcontroller to enhance the monitoring, control, and safety capabilities of RC boring machines. This system aims to revolutionize drilling operations by achieving the following objectives:

Implementing sensors and measurement modules to accurately monitor key parameters such as drilling depth, rotational speed, torque, temperature, and vibration levels.

Establishing a robust data acquisition system that collects sensor readings and performs real-time data analysis to identify trends, anomalies, and safety hazards.

Enabling remote monitoring and control of the RC boring machine through wireless communication protocols, enhancing operational flexibility and efficiency.

Implementing safety features such as automatic shutdown mechanisms triggered by predefined thresholds to mitigate risks associated with equipment malfunction or hazardous conditions.

Developing a user-friendly interface accessible via web or mobile applications to visualize real-time data, configure drilling parameters, and receive notifications, thus enhancing overall user experience.

Through the achievement of these objectives, the project aims to optimize drilling processes, improve operational efficiency, and ensure the safety of personnel and equipment in construction and drilling applications.

1.3 PROBLEM STATEMENT

In the domain of construction and drilling, Remote Control (RC) boring machines serve as indispensable tools for excavating holes in soil, rock, or other materials. However, the conventional operation of RC boring machines is hindered by rudimentary control mechanisms and limited monitoring capabilities, which impede efficiency, accuracy, and safety.

The lack of real-time measurement and precise control of critical parameters such as drilling depth, rotational speed, torque, temperature, and vibration levels presents significant challenges in optimizing RC boring operations. Operators face difficulties in accurately assessing drilling progress, detecting potential malfunctions or hazards, and making informed decisions to mitigate risks and enhance efficiency. Moreover, the absence of remote monitoring and control capabilities limits operational flexibility, particularly in scenarios where physical access to the RC boring machine is restricted or impractical.

Addressing these challenges requires a comprehensive solution that leverages advanced technology to enable real-time parameter measurement and precise control in RC boring machines. By integrating the capabilities of the ESP-32 microcontroller, a versatile and powerful platform known for its computational prowess, connectivity options, and energy efficiency. This project seeks to revolutionize the monitoring, control, and optimization of RC boring operations. Through the development of a sophisticated system capable of remotely acquiring, analysing, and acting upon critical operational data, the project aims to enhance operational efficiency, accuracy, and safety in construction and drilling applications.

CHAPTER 2

LITERATURE SURVEY

An exhaustive literature survey has been carried out and the detailed summary is discussed in this chapter.

2.1 LITERATURE SURVEY

Leng, Shuo, et al. "A hybrid data mining method for tunnel engineering based on real-time monitoring data from tunnel boring machines." *IEEE Access* 8 (2020):

Tunnel engineering is one of the typical megaprojects given its long construction period, high construction costs and potential risks. Tunnel boring machines (TBMs) are widely used in tunnel engineering to improve work efficiency and safety. During the tunnelling process, large amount of monitoring data has been recorded by TBMs to ensure construction safety. Analysis of the massive real-time monitoring data still lacks sufficiently effective methods and needs to be done manually in many cases, which brings potential dangers to construction safety. This paper proposes a hybrid data mining (DM) approach to process the real-time monitoring data from TBM automatically. Three different DM techniques are combined to improve mining process and support safety management process. To provide people with the experience required for on-site abnormal judgement, association rule algorithm is carried out to extract relationships among TBM parameters. To supplement the formation information required for construction decision-making process, a decision tree model is developed to classify formation data. Finally, the rate of penetration (ROP) is evaluated by neural network models to find abnormal data and give early warning. The proposed method was applied to a tunnel project in China and the application results verified that the method provided an accurate and efficient way to analyse real-time TBM monitoring data for safety management during TBM construction field.

Cigla, M., S. Yagiz, and L. Ozdemir. "Application of tunnel boring machines in underground mine development." *17th international mining congress and exhibition of Turkey*. (2001).

Because of their demonstrated capabilities in attaining high rates of advance in civil

tunnel construction, the hard rock mining industry has always shown a major interest in the use of TBMs for mine development, primarily for development of entries, as well as ventilation, haulage and production drifts. The successful application of TBM technology to mining depends on the selection of the most suitable equipment and cutting tools for the rock and ground conditions to be encountered. In addition to geotechnical investigations and required rock testing, cutterhead design optimization is an integral part of the machine selection to ensure a successful application of the machines in a specific underground mine environment. This paper presents and discusses selected case histories of TBM applications in mining, the lessons learned, the process of laboratory testing together with machine selection and performance estimation methods.

Ferrein, Alexander, Stephan Kallweit, and Mark Lautermann. "Towards an autonomous pilot system for a tunnel boring machine." *2012 5th Robotics and Mechatronics Conference of South Africa*. IEEE, (2012).

Modern Tunnel Boring Machines (TBMs) used in mines or for road construction often consist of several modules for the drill head and further equipment as well as wagons for carrying the mined material (dump). These machines can have a total length of up to 70 meters. In the mines, the machine has to be navigated over long stretches through the mine audits to reach the borehole. The problem is to get there without getting stuck in the galleries. Usually, these long trains are navigated manually, and theodolites deal as sensory input for the teleoperator. In this paper we outline a robot system that can deal as a pilot system for such long machines for semi-autonomously driving the TBMs right to their destination. For this, the pilot robot needs to fulfil the following tasks: (1) it must acquire an accurate 3D map of the tunnel environment, (2) plan a path from a start location to the destination and (3) guide the TBM through the tunnel. We outline the hardware and software system that we envision for our pilot system in this paper. For the hardware, we plan to deploy a Husky A200 platform which is particularly suitable for rugged terrain. For the control software we want to make use of the robot operating system ROS with its many well-implemented modules for map building, navigation, and path-planning. As the system is in the planning stage now, we are very interested to learn more

about and share experiences and ideas of operating robots in rugged mining environments at the conference.

Bai, Yun, et al. "TBMs: Capabilities, Limitations and Challenges." *Proceedings of GeoShanghai 2018 International Conference: Tunnelling and Underground Construction*. Springer Singapore, (2018).

The Tunnel Boring Machine (TBM) technology has significant advantages over conventional Drill & Blast method, and it has become one of the most common tunnel excavation methods in the world. However, weaknesses of TBM such as the poor adaptability to complex geological conditions create a bottleneck in its functionality and restrict its further development. Therefore, factors such as engineering geological conditions, construction schedule, cost, environmental impact, and other multi-disciplinary influences should be well considered in the TBM selection. This paper presents the capabilities, limitations, and challenges of TBM method by a study of various case projects and proposes effective countermeasures towards bad geological conditions. The results of this research are helpful for improving the TBM working efficiency and ensuring a smooth and safe construction.

Loy-Benitez, Jorge, et al. "Breaking new ground: Opportunities and challenges in tunnel boring machine operations with integrated management systems and artificial intelligence." *Automation in Construction* 158 (2024):

Advances in tunnel boring machines (TBM) have leveraged applied artificial intelligence to promote sustainable and automatic tunnelling construction. This paper highlights the significance of AI-based management subsystems for automatic TBM operations and presents recent key contributions in the field by identifying three key parallel subsystems: modelling, monitoring, and control. Moreover, each subsystem is evaluated from the standpoint of practical implications. In this context, specific challenges are identified, suggesting research paths that include integrated management systems, and encouraging further investigations into TBM automation by integrating the existing management subsystems from an operational perspective.

Shen, Xuesong, et al. "Tunnel boring machine positioning automation in tunnel construction." *ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction*. Vol. 29. IAARC Publications, (2012).

Tunnel construction using a tunnel boring machine (TBM) entails precise machine positioning and guidance in the underground space. In contrast to traditional laser-based machine guidance solutions, the proposed research aims to develop an automation alternative to facilitate TBM guidance and as-built tunnel alignment survey during tunnelling operations. Method A fully automated system is proposed, in which a robotic total station is employed to automate the continuous process of TBM -tracking and positioning in the 3D underground working space. ZigBee based wireless sensor networks are applied for wireless data communication inside the tunnel. A camera is mounted on the telescope of the total station to capture online operational videos. Real-time survey data are thus acquired, processed, and displayed on a tablet PC on the fly, resulting in: (i) TBM's precise coordinates in the underground space; (ii) three-axis body rotations of the TBM; (iii) tunnelling chainage progress; and (iv) line and grade deviations of the tunnel alignment. Results & Discussion For proof-of-concept, a prototype TBM-positioning automation system has been developed in-house for laboratory testing. The accuracy testing was conducted by the automation system and a specialist surveyor independently. The differences between the two sets of surveying results were less than 2mm, which sufficiently validated the high accuracy of the automation solution. In April 2012, the prototype will be field tested on a 2.4 m diameter and 1,040 m long drainage tunnel project in Edmonton, Canada

Zhang, Shengyuan, et al. "Comparative analysis of energy use in China building sector: current status, existing problems and solutions." *Frontiers of Energy and Power Engineering in China* 4 (2010):

The comparative analysis of the literature on tunnel engineering and Tunnel Boring Machine (TBM) operations reveals a multifaceted landscape of methodologies and findings aimed at addressing the complex challenges inherent in tunnel construction. One avenue of research focuses on leveraging data mining techniques to process real-time monitoring data from TBMs, enhancing safety management protocols during construction endeavours.

Through the integration of association rule algorithms, decision tree models, and neural network methodologies, this approach provides a systematic means of analysing TBM data to mitigate potential risks and ensure construction safety. In parallel, studies exploring the application of TBMs in underground mine development underscore the importance of meticulous equipment selection and cutterhead design optimization to optimize performance and advance efficiency. Moreover, the proposal of pilot systems for semi-autonomous TBM navigation within mine tunnels highlights advancements in automation technology, promising increased precision and reliability in tunnelling operations.

These innovations are complemented by efforts to assess the capabilities and limitations of TBM technology, with a keen focus on identifying challenges and proposing effective countermeasures to improve operational efficiency and safety standards. Additionally, the integration of AI-based management subsystems offers promising avenues for streamlining TBM operations through enhanced modelling, monitoring, and control mechanisms.

Finally, the exploration of automation alternatives for TBM guidance and alignment surveying showcases the potential of fully automated systems to revolutionize tunnel construction processes, offering unprecedented levels of accuracy and reliability in underground positioning and surveying tasks. Collectively, these insights contribute to a comprehensive understanding of the opportunities and challenges in tunnel engineering and TBM operations, paving the way for continued advancements in safety, efficiency, and automation within the fie

CHAPTER 3

PROPOSED SYSTEM

3.1 PROPOSED SYSTEM

The proposed methodology for the "ESP-32 Based Parameter Measurement and Control in RC Boring Machine" project encompasses a comprehensive and iterative approach to designing, implementing, and validating the system's functionality and performance.

Requirement Analysis and Specification:

- Conduct an in-depth analysis of project requirements, considering both functional and non-functional aspects.
- Define specific parameters to be measured and controlled, such as speed, temperature, orientation, and distance, based on the operational needs of the RC boring machine.

Component Selection and Integration:

- Identify and select suitable hardware components, ensuring compatibility and constructive collaboration among them.
- Integrate the ESP32 microcontroller, nRF24L01 Wireless RF Module, LCD display, gyro sensor, temperature sensor, ultrasonic sensor, ESC BLDC, A2212/13T 1000KV BLDC motor, L293D motor driver, DC motor, and keypad into a cohesive system architecture.

System Design and Architecture:

- Develop a detailed system architecture outlining the interaction between hardware components and software modules.
- Design user interfaces, including the keypad layout and LCD displays, to facilitate intuitive interaction and feedback for users.

Firmware and Software Development

- To develop firmware for the ESP32 microcontroller to manage sensor data acquisition, motor control, and communication with the nRF24L01 module.
- Implement software algorithms for sensor data processing, including calibration, filtering, and interpretation.
- Design bidirectional communication protocols to enable real-time data exchange between the transmitter and receiver units.

Hardware Implementation and Testing

- To assemble hardware components according to the system design, ensuring proper wiring and physical placement.
- Conduct rigorous testing of hardware functionality, verifying sensor accuracy, motor responsiveness, and communication reliability.
- Iterate on hardware design and implementation based on testing results, addressing any identified issues or deficiencies.

Integration and System Testing

- Integrate firmware and software modules with the hardware platform, ensuring seamless operation and compatibility.
- Perform system-level testing to validate overall functionality, including parameter measurement accuracy, control responsiveness, and user interface usability.
- Conduct simulated and real-world testing scenarios to assess system performance under various operating conditions.

Optimization and Refinement

- Optimize system parameters, algorithms, and hardware configurations to enhance performance, efficiency, and reliability.
- Refine user interfaces and feedback mechanisms based on user feedback and usability testing results.
- Address any identified bottlenecks or limitations through iterative optimization cycles.

Documentation, Deployment, and Maintenance

- Prepare comprehensive documentation, including system architecture diagrams, hardware specifications, firmware source code, and user manuals.
- Deploy the finalized system in the operational environment, providing user training and support as needed.
- Establish procedures for system maintenance, troubleshooting, and software updates to ensure long-term functionality and reliability.

By following the procedure mentioned in the proposed methodology, the development of the further work can be proceeded systematically by navigating the complexities of designing and implementing the "ESP-32 Based Parameter Measurement and Control in RC Boring Machine" project, delivering a robust and effective solution tailored to the needs of the end-users.

3.2 BLOCK DIAGRAM

The ESP32 incorporates functionalities for both transmission and reception, facilitating bidirectional wireless communication. This microcontroller seamlessly integrates transmitter and receiver capabilities, enabling versatile applications across IoT, home automation, and wireless sensor networks.

3.2.1 Transmitter Side

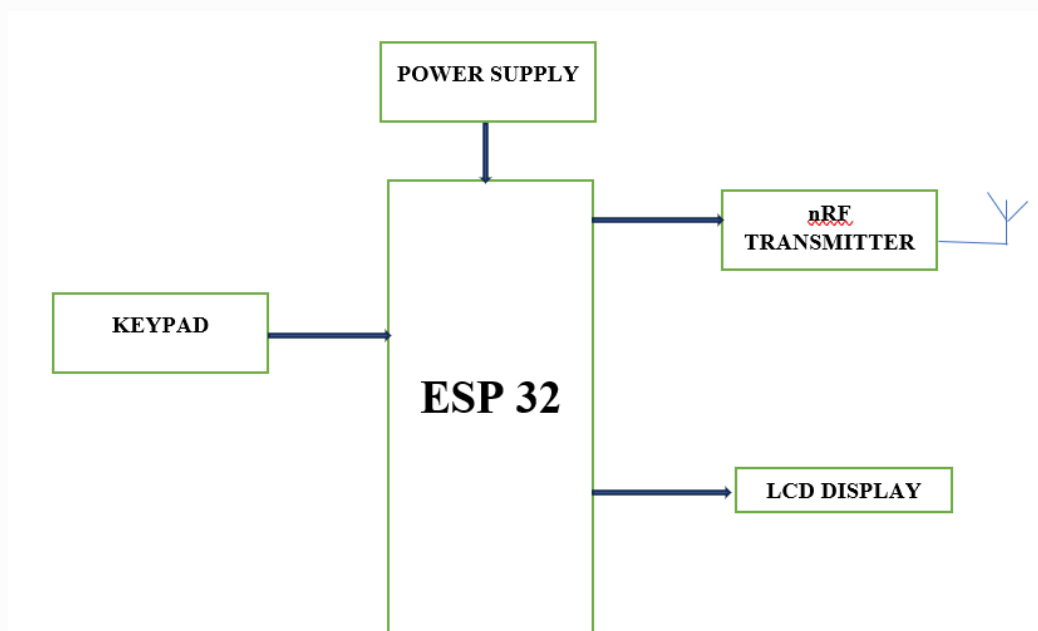


Fig: 3.1: Transmitter Side of ESP 32 DevKitC

3.2.2 Receiver Side

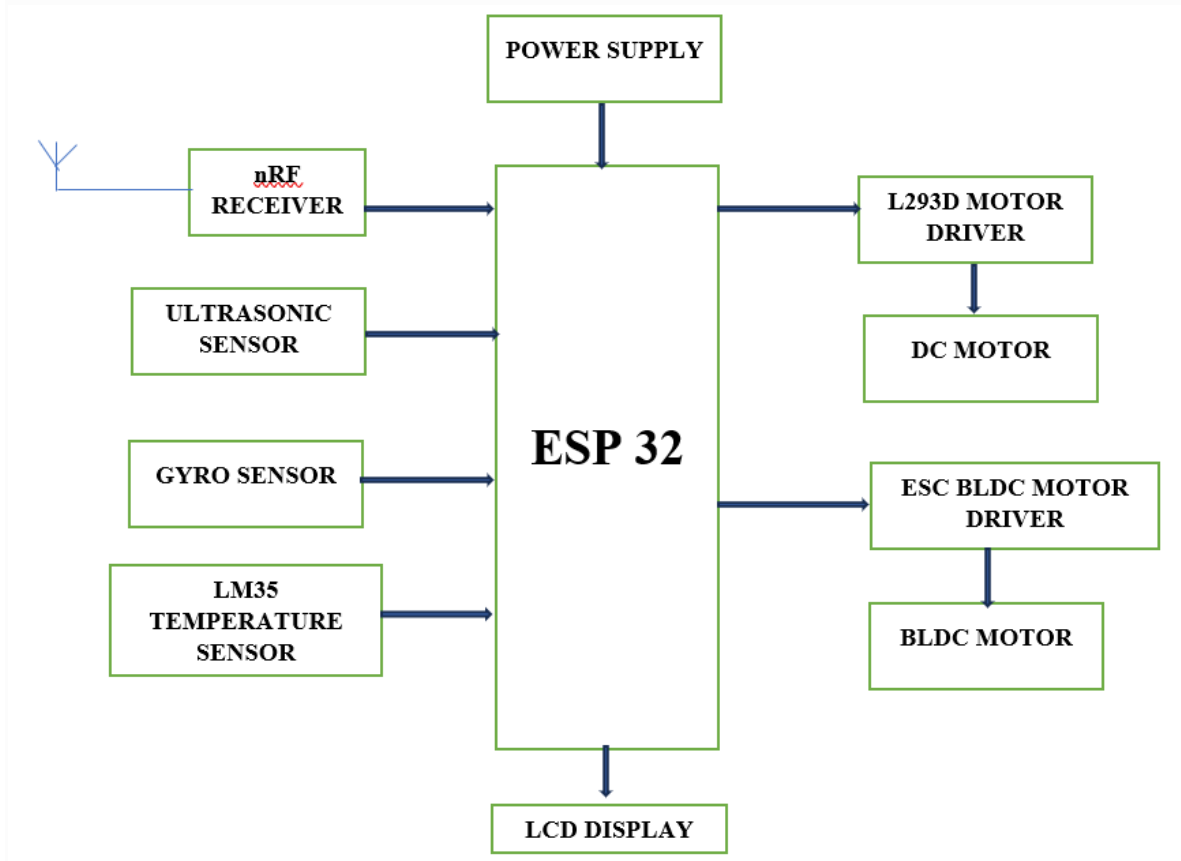


Fig: 3.2: Receiver Side of ESP 32 DevKitC

3.3 Standards

1. Safety Standards: The use of TBMs (Tunnel Boring Machines) in hard rock mining must adhere to stringent safety standards set by regulatory bodies such as the Occupational Safety and Health Administration (OSHA) and the International Organization for Standardization (ISO). These standards ensure that mining operations are conducted with minimal risk to personnel and equipment.

2. Automation Standards: As automation and remote operation become increasingly prevalent in construction and mining industries, adherence to industry standards such as ISO 17757 for Remote Control Systems for Mining Equipment is crucial. These standards provide guidelines for the design, implementation, and operation

of remote-controlled machinery, ensuring compatibility and interoperability across different systems.

3. Radio Frequency (RF) Standards: The use of RF technology in the proposed project necessitates compliance with RF emission standards established by regulatory bodies like the Federal Communications Commission (FCC). Adherence to these standards ensures that the transmission of signals between the transmitter and receiver components of the RC boring machine is conducted within safe and permissible limits.

3.4 Constraints

1. Cost Constraints: The development and implementation of the ESP-32 based parameter measurement and control system must operate within predefined budget constraints. Cost-effective component selection, efficient design practices, and streamlined manufacturing processes are essential to meet budgetary limitations without compromising system functionality or performance.

2. Space Constraints: In underground mining environments, space constraints pose significant challenges for the installation and operation of machinery. The size and form factor of the RC boring machine must be optimized to navigate narrow tunnels and confined spaces effectively while accommodating all necessary components, including sensors, microcontrollers, and communication modules.

3. Power Constraints: The power requirements of the RC boring machine, including the brushless DC motor, sensors, and communication modules, must be carefully managed to ensure reliable and continuous operation. Energy-efficient design strategies, such as power management systems and battery optimization techniques, are essential to mitigate power constraints and prolong operational uptime.

3.5 Trade-offs

1. Precision vs. Safety: The implementation of automation and remote operation in the RC boring machine aims to improve precision and safety simultaneously. However, there may be trade-offs between achieving maximum precision in drilling operations and ensuring the safety of personnel working in proximity to the machine. Balancing these competing priorities requires careful consideration of control algorithms, sensor feedback mechanisms, and fail-safe protocols.

2. Efficiency vs. Complexity: Increasing the efficiency of the RC boring machine through automation and remote operation may introduce additional complexity to the system. Trade-offs between system complexity and operational efficiency must be evaluated to strike the right balance between maximizing productivity and minimizing technical challenges during deployment, operation, and maintenance.

3. Functionality vs. Cost: The inclusion of advanced features such as multiple sensors, LCD displays, and radio frequency communication capabilities enhances the functionality of the RC boring machine but also increases manufacturing and operational costs. Trade-offs between desired functionality and cost-effectiveness must be carefully assessed to deliver a competitive and economically viable solution to end-users in the mining industry.

CHAPTER 4

HARDWARE AND SOFTWARE REQUIREMENTS

4.1 HARDWARE AND SOFTWARE REQUIREMENTS

The hardware and software required for this project is discussed in detail in this chapter.

4.1.1 *Hardware Requirements*

- ESP32
- nRF24L01 Wireless RF Module
- LM35 TEMPERATURE SENSOR
- MPU6050 GYROSCOPE SENSOR
- ULTRASONIC SENSOR
- LCD
- L293D MOTOR DRIVER
- ESC BLDC
- BLDC MOTOR
- DC MOTOR

4.1.1.1 *ESP32*

ESP32 is a low-powered, low-cost microcontroller (MCU) board, with both Wi-Fi and Bluetooth built in, and is based on a dual-core processor mechanism. The first one is a powerful processor, such as a Xtensa LX6 (~240 MHz) with 512 KiB memory and the second an ultra-low coprocessor (ULP) with only 8 KiB memory designed to run when ESP32 is in deep-sleep mode. Other components include around 48 I/O pins (variable); an array of peripheral interfaces including temperature, hall effect, and capacitive touch sensors; and an 8-centimeter LCD panel, prominently visible here in an ESP32-WROVER board by Espressif Systems.

Component Features

- ESP32 has built-in integration of both Wi-Fi and Bluetooth dual mode.
- ESP32 has 34 programmable GPIOs present on the chip.

- ADC is of 12-bit SAR and can support up to 18 channels.
- DAC is 8-bit, and it has 2 DAC channels.
- ESP32 also has 10 touch sensors embedded in it.
- ESP32 also has a Hall sensor in it.
- It supports 4 SPI channels.
- It supports 4 I²S channels.
- It also has 2 I²S channels.
- ESP32 has 2 I²C ports in it.
- It supports 3 UART channels.
- It also has 1 host (SD/eMMC/SDIO) and 1 slave (SDIO/SPI).
- ESP32 also supports the Ethernet MAC interface with dedicated DMA and IEEE 1588 support.
- It supports Two-Wire Automotive Interface (TWAI®, compatible with ISO11898-1)
- IR (TX/RX)
- Motor PWM
- LED PWM up to 16 channels

ESP32 Wi-Fi key Features

- Wireless Networking Standard: 802.11 b/g/n
- Wireless Standard: 802.11 n (2.4 GHz), up to 150 Mbps
- Wi-Fi Multimedia (WMM)
- Wi-Fi Aggregation: TX/RX A-MPDU, RX A-MSDU
- Immediate Block ACK: suitable for high bandwidth & low latency traffic.
- Automatic Beacon monitoring (hardware TSF)
- Simultaneous support for SoftAP, Infrastructure Station and Promiscuous modes.
- Diverse Antenna
- Defragmentation to smoothen the data.
- Supports 4 virtual Wi-Fi Interfaces.

ESP32 Bluetooth Key Features

- Compliant with Bluetooth v4.2 BR/EDR
- Class-1, Class-2, and Class-3 transmitter without external power amplifier
- Increased Power Control
- Transmission Power: +12 dBm
- BLE sensitivity: -94 dBm (NZIF receiver)
- Adaptive Frequency Hopping (AFH)
- Standard HCI supports SDIO/SPI/UART
- High-speed UART HCI, up to 4 Mbps
- Bluetooth 4.2 BR/EDR BLE dual-mode controller
- CVSD and SBC for audio codec
- Classic BT and BLE support Multiple connections.
- It can advertise and scan simultaneously.
- Bluetooth Piconet and Scatternet

ESP32 Microcontroller Key Features

- ESP32 uses an Xtensa® single-/dual-core 32-bit LX6 microprocessor(s).
- It supports data rate up to 600 MIPS (200 MIPS for ESP32-S0WD/ESP32-U4WDH)
- It has a Flash Memory of 448 KB.
- It has an SRAM memory of 520 KB.
- 16 KB SRAM in RTC
- QSPI supports multiple flash/SRAM chips.

ESP32 Clocks & Timers Key Features

- ESP32 has a calibrated 8MHz crystal oscillator(internal)
- Calibrated RC oscillator(internal)
- External 2 MHz ~ 60 MHz crystal oscillator (40 MHz only for Wi-Fi/BT functionality)
- External 32 kHz crystal oscillator for RTC with calibration
- Two timer groups, including 2 × 64-bit timers and 1 × main watchdog in each group.

- ESP32 also has one RTC timer.
- RTC watchdog is also present in ESP32.

Pin diagram of ESP32 DevKitC

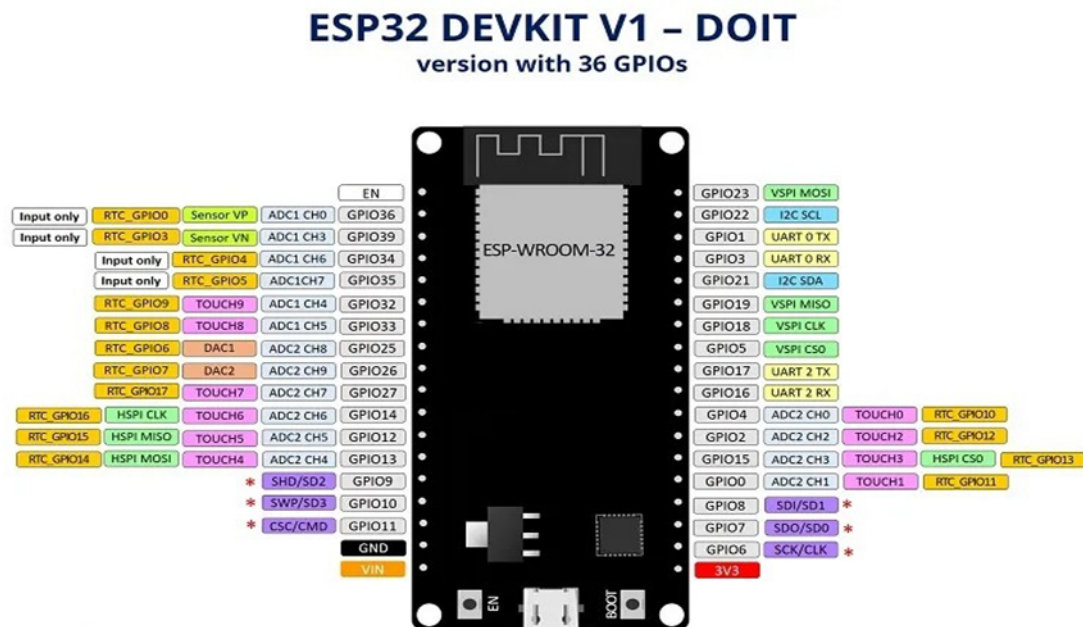


Fig: 4.1: Pinout Diagram of ESP 32 DevKitC

- Power: Power is applied through Micro-USB, 3.3V pin, 5V pin, and GND. Regulated 5V is supplied to this pin which is further regulated to 3.3V to power up the board. And 3.3V pin directly supplies the 3.3V regulated to the board. And the ground is connected to GND.
- Enable: The enable pin is represented by 'En' on the board and is used to reset the microcontroller.
- Analog Pins: Analog pins are represented as ADC1_0 to ADC1_5 and ADC2_0 to ADC2_9 on board. These pins are used to measure the analog voltage in the range from 0-3.3V which is a 12-bit 18 channel ADC.
- DAC pins: Two pins DAC1 and DAC2 are used for digital to analog conversion.
- I/O Pins: I/O pins are represented as GPIO0 to GPIO39 on board which projects there are total of 39 I/O pins on board. All of them can be used as an input or output but pins from 34 to 39 are used for input

only.

- Capacitive Touch Pins: These pins are represented as T0 to T9 on board. These are a total of 10 pins which are touch pins that are normally used for capacitive pads.
- RTC GPIO pins: These pins are represented as RTCIO0 to RTCIO17 on board which is a total of 18 pins. These pins are employed to wake up the ESP32 from deep sleep mode.
- Serial: Two serial pins are represented on boards as Tx and Rx. The Tx is used to transmit serial data while Rx is used to receive serial data.
- External Interrupts: All GPIO pins can be used as external interrupts.
- PWM: Any GPIO pin can be used as a PWM pin. These GPIO pins are activated through software.
- VSPI: These pins are represented as GPIO23 (MOSI), GPIO19 (MISO), GPIO18 (CLK) and GPIO5 (CS) which are used for SPI-1 communication.
- HSPI: These pins are represented as GPIO13 (MOSI), GPIO12 (MISO), GPIO14 (CLK) and GPIO15 (CS) which are used for SPI-2 communication.
- IIC: These pins are marked as GPIO21 (SDA), GPIO22 (SCL) which are used for I2C communication.
- AREF: It is marked as AREF which is used to provide a reference voltage for input voltage.

The ESP32 microcontroller stands as a cornerstone in a myriad of applications spanning diverse fields and levels of complexity.

- It serves as a linchpin in network projects, where its integrated Wi-Fi and Bluetooth functionalities ensure seamless connectivity and data exchange.
- Beyond professional endeavours, the ESP32 garners significant traction in the realm of DIY projects, offering an accessible platform for beginners to delve into the world of electronics and programming.
- Its user-friendly interface and extensive documentation render it a favourite among hobbyists and enthusiasts.

- The ESP32 plays a pivotal role in the prototyping phase of IoT devices, providing developers with a robust foundation to experiment with various sensor integrations, data transmission protocols, and cloud connectivity options.
- From smart home solutions to industrial automation, the ESP32's adaptability knows no bounds. In cloud-based smart security projects, it empowers the implementation of sophisticated surveillance systems, enabling remote monitoring and control functionalities via internet connectivity.
- Its low-power consumption makes it a prime candidate for battery-operated applications, extending its reach to portable devices, wearables, and IoT sensors deployed in remote or energy-constrained environments.

In essence, the ESP32's versatility, coupled with its robust feature set, positions it as a cornerstone technology driving innovation across a wide spectrum of industries and applications, from prototyping to production.



Fig: 4.2: ESP 32

Power Supply Unit

- Must be a DC adapter (i.e. it must put out DC, not AC)
- 5v DC power supply is used for this circuit.



Fig: 4.3: Power Supply Unit

4.1.1.2 nRF24L01 Wireless RF Module

The nRF24L01 is a wireless transceiver module, meaning each module can both send as well as receive data. They operate in the frequency of 2.4GHz, which falls under the ISM band and hence it is legal to use in almost all countries for engineering applications. The modules when operated efficiently can cover 100 meters (200 feet) which makes it a great choice for all wireless remote-controlled projects.

The module operates at 3.3V hence can be easily used with 3.2V systems or 5V systems. Each module has an address range of 125 and each module can communicate with 6 other modules hence it is possible to have multiple wireless units communicating with each other in a particular area.

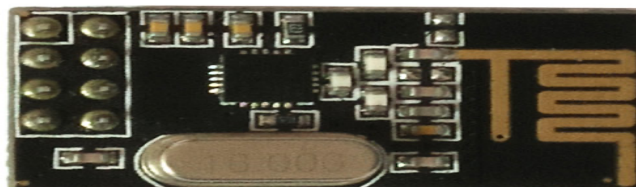


Fig: 4.4: nRF24L01 Wireless RF Modul

nRF24L01 Pinout Configuration

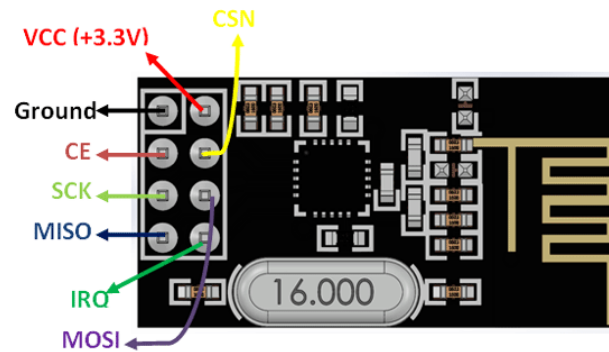


Fig: 4.5: nRF24L01 Pinout Configuration

Table: 4.1: nRF24L01 Pinout Configuration

Pin Number	Pin Name	Abbreviation	Function
1	Ground	Ground	Connected to the Ground of the system
2	Vcc	Power	Powers the module using 3.3V
3	CE	Chip Enable	Used to enable SPI communication
4	CSN	Ship Select Not	This pin has to be kept high always; else it will disable the SPI
5	SCK	Serial Clock	Provides the clock pulse using which the SPI communication works
6	MOSI	Master Out Slave In	Connected to MOSI pin of MCU, for the module to receive data from the MCU
7	MISO	Master In Slave Out	Connected to MISO pin of MCU, for the module to send data from the MCU
8	IRQ	Interrupt	It is an active low pin and is used only if interrupt is required

nRF24L01 Features

- 2.4GHz RF transceiver Module
- Operating Voltage: 3.3V
- Nominal current: 50mA
- Range: 50 – 200 feet
- Operating current: 250mA (maximum)
- Communication Protocol: SPI
- Baud Rate: 250 kbps - 2 Mbps.
- Channel Range: 125
- Maximum Pipelines/node: 6
- Low-cost wireless solution

4.1.1.3 L293D Motor Driver IC

The L293D is a popular 16-Pin Motor Driver IC. As the name suggests it is used to drive motors. A single L293D IC can run two DC motors at the same time; also, the direction of these two motors can be controlled independently. So, if the motors with the operating voltage less than 36V and operating current less than 600mA, which are to be controlled by digital circuits like Op-Amp, 555 timers, digital gates or even Microcontrollers like Arduino, PIC, ARM etc.

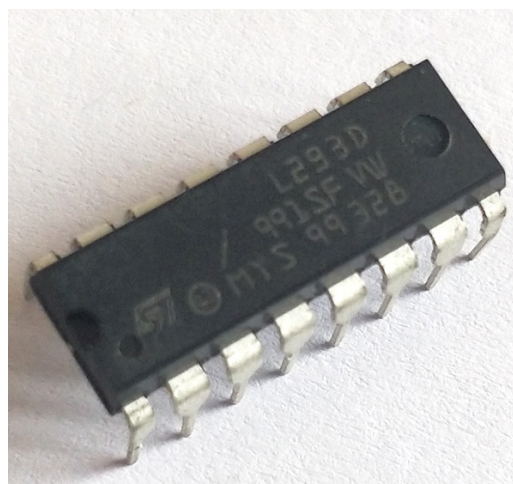


Fig: 4.6: L293D Motor Driver IC

L293D Pin Configuration

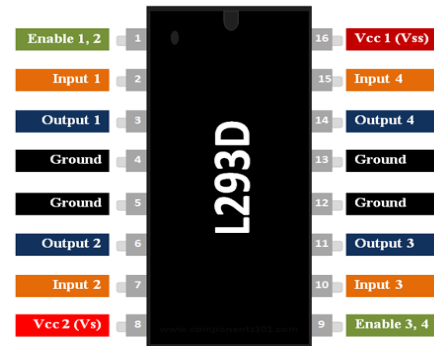


Fig: 4.7: L293D Pin Configuration

Table: 4.2: L293D Pin Configuration

Pin Number	Pin Name	Description
1	Enable 1,2	This pin enables the input pin Input 1(2) and Input 2(7)
2	Input 1	Directly controls the Output 1 pin. Controlled by digital circuits
3	Output 1	Connected to one end of Motor 1
4	Ground	Ground pins are connected to ground of circuit (0V)
5	Ground	Ground pins are connected to ground of circuit (0V)
6	Output 2	Connected to another end of Motor 1
7	Input 2	Directly controls the Output 2 pin. Controlled by digital circuits
8	Vcc2 (Vs)	Connected to Voltage pin for running motors (4.5V to 36V)
9	Enable 3,4	This pin enables the input pin Input 3(10) and Input 4(15)

10	Input 3	Directly controls the Output 3 pin. Controlled by digital circuits
11	Output 3	Connected to one end of Motor 2
12	Ground	Ground pins are connected to ground of circuit (0V)
13	Ground	Ground pins are connected to ground of circuit (0V)
14	Output 4	Connected to another end of Motor 2
15	Input 4	Directly controls the Output 4 pin. Controlled by digital circuits
16	Vcc2 (Vss)	Connected to +5V to enable IC function

Features

- Can be used to run Two DC motors with the same IC.
- Speed and Direction control is possible.
- Motor voltage Vcc2 (Vs): 4.5V to 36V
- Maximum Peak motor current: 1.2A
- Maximum Continuous Motor Current: 600mA
- Supply Voltage to Vcc1(vss): 4.5V to 7V.
- Transition time: 300ns (at 5V and 24V)
- Automatic Thermal shutdown is available.
- Available in 16-pin DIP, TSSOP, SOIC packages

4.1.1.4 A2212 Brushless Motor

2212 (BLDC) BRUSHLESS DC MOTOR is a high-speed brushless motor designed specifically for Quadcopters, Drones, or toy planes. The motor is OUTRUNNER type where outside case rotates while inside stays fixed. It is one of popular model in the market because it's low cost. It is preferred for small drones and planes. The model is available in different speeds and should be chosen appropriately.

The naming for the brushless motor goes like this 2212/13T 1000KV.



Fig: 4.8: A2212 Brushless Motor

Table: 4.3: A2212 Brushless Motor Representation

Info	Represents	Additional Details
22	Diameter of Motor (22mm in this case)	The greater the diameter more the torque.
12	Height of Motor (12mm in this case)	Bigger one can be chosen.
13T	Number of turns per pole (13 turns per pole here)	Lesser number of turns means high speed but less torque. Similarly higher number of turn's means less speed but more torque. To lift more weight the motor with more number of turns can be chosen.
1000KV	Number of revolutions done by motor per volt of supply (1000 revolutions per volt here. If supply voltage is 10 volts, then motor will rotate at 10000RPM)	For better thrust motor with higher KV can be chosen.

Brushless Motor Pin Configuration

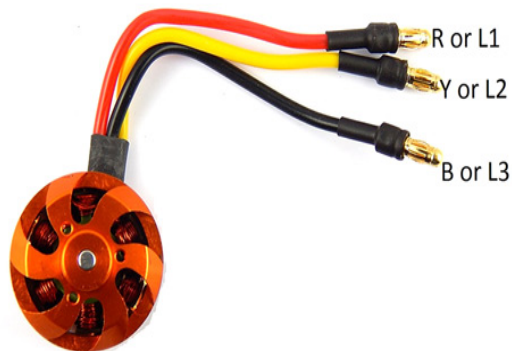


Fig: 4.9: Brushless Motor Pin Configuration

The motor has three pins as shown in figure. The internal connection between three of them is shown below.

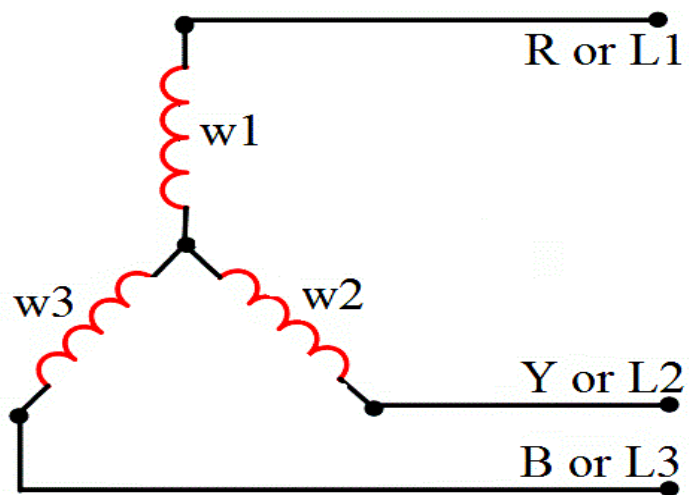


Fig: 4.10: Brushless Motor Pin Internal Configuration

Table: 4.4: Brushless Motor Pin Configuration

Pin Name	Description
R or L1	Connected to winding1 or phase1
Y or L2	Connected to winding2 or phase2
B or L3	Connected to winding3 or phase3

Features and Specifications

- Operating voltage: 7.2V to 12V (2 to 3Li-poly or 6 to10 NiCad)
- No load current:0.5Amp
- Maximum current:13Amp for 60Sec
- Maximum Watts:150 Watt
- Weight of motor:50-60 grams
- Maximum operating temperature: + 80°C
- Complete speed control because of three phase connection.
- Long life as there are no moving contacts.

4.1.1.5 30A BLDC ESC

This is fully programmable 30A BLDC ESC with 5V, 3A BEC. Can drive motors with continuous 30Amp load current. It has sturdy construction with 2 separate PCBs for Controller and ESC power MOSFETs. It can be powered with 2-4 lithium Polymer batteries or 5-12 NiMH / NiCd batteries. It has separate voltage regulator for the microcontroller for providing good anti-jamming capability. It is most suitable for UAVs, Aircrafts and Helicopters.



Fig: 4.11: 30A BLDC ESC

Specifications

- Output: 30A continuous; 40Amps for 10 seconds
- Input voltage: 2-4 cells Lithium Polymer / Lithium-Ion battery or 5-12 cells NiMH / NiCD
- BEC: 5V, 3Amp for external receiver and servos
- Max Speed: 2 Pole: 210,000rpm; 6 Pole: 70,000rpm; 12 Pole: 35,000rpm
- Weight: 32gms
- Size: 55mm x 26mm x 13mm

Features

- High quality MOSFETs for BLDC motor drive
- High performance microcontroller for best compatibility with all types of motors at greater efficiency
- Fully programmable with any standard RC remote control
- Heat sink with high performance heat transmission membrane for better thermal management.
- start modes: Normal / Soft / Super-Soft, compatible with fixed wing aircrafts and helicopters.
- Throttle range can be configured to be compatible with any remote control available in the market.

- Smooth, Linear and Precise throttle response
- Low-Voltage cut-off protection
- Over-heat protection
- Separate voltage regulator IC for the microcontroller to provide anti-jamming capability.
- Supported Motor Speed (Maximum): 210000RPM (2 poles), 70000RPM (6poles), 35000RPM (12 poles)

4.1.1.6 Ultrasonic Sensor

Ultrasonic sensors emit ultrasonic pulses, and by measuring the time of ultrasonic pulse reaches the object and back to the transducer. The sonic waves emitted by the transducer are reflected by an object and received back in the transducer. After having emitted the sound waves, the ultrasonic sensor will switch to receive mode. The time elapsed between emitting and receiving is proportional to the distance of the object from the sensor.



Fig: 4.12: Ultrasonic Sensor

Ultrasonic Sensor Pinout Configuration

Table: 4.5: Ultrasonic Sensor Pinout Configuration

Pin Number	Pin Name	Description
1	Vcc	The Vcc pin powers the sensor, typically with +5V
2	Trigger	Trigger pin is an Input pin. This pin must be kept high for 10us to initialize measurement by sending US wave.
3	Echo	Echo pin is an Output pin. This pin goes high for a period which will be equal to the time taken for the US wave to return to the sensor.
4	Ground	This pin is connected to the Ground of the system.

HC-SR04 Sensor Features

- Operating voltage: +5V
- Theoretical Measuring Distance: 2cm to 450cm
- Practical Measuring Distance: 2cm to 80cm
- Accuracy: 3mm
- Measuring angle covered: $\leq 15^\circ$
- Operating Current: $\leq 15\text{mA}$
- Operating Frequency: 40Hz

Working of HC-SR04 Ultrasonic Sensor

The HC-SR04 Ultrasonic (US) sensor is a 4-pin module, whose pin names are Vcc, Trigger, Echo, and Ground respectively. This sensor is a very popular sensor used in many applications where measuring distance or sensing objects are required. The module has two eyes like projects in the front which forms the

Ultrasonic transmitter and Receiver. The sensor works with the simple high school formula that.

$$\text{Distance} = \text{Speed} \times \text{Time}$$

The Ultrasonic transmitter transmits an ultrasonic wave, this wave travels in air and when it gets objected by any material it gets reflected toward the sensor this reflected wave is observed by the Ultrasonic receiver module.

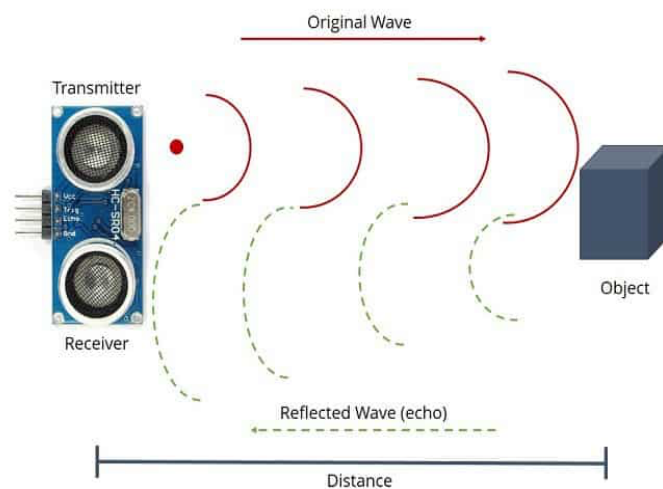


Fig: 4.13: Working of HC-SR04 Ultrasonic Sensor

4.1.1.7 LM35 Temperature Sensor

The LM35 is a temperature sensor whose electrical output is proportional to the temperature in degrees Celsius. It is a linear device which means that the voltage at the output of the LM35 increases proportionally to the temperature. LM35 is a precision Integrated circuit Temperature sensor, whose output voltage varies, based on the temperature around it. It is a small and cheap IC which can be used to measure temperature anywhere between -55°C to 150°C. It can easily be interfaced with any Microcontroller that has ADC function or any development platform like Arduino.

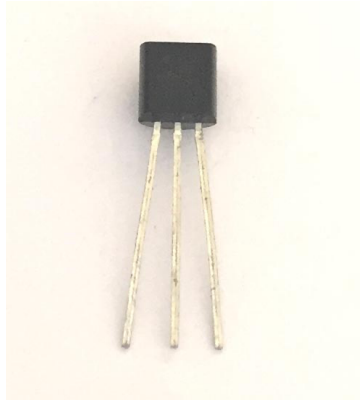


Fig: 4.14: LM35 Temperature Sensor

LM35 Sensor Pinout Configuration

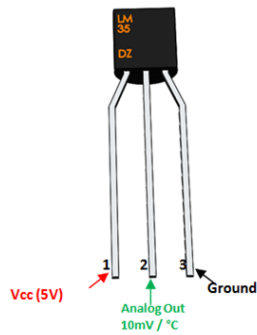


Fig: 4.15: LM35 Sensor Pinout Configuration

Table: 4.6: LM35 Sensor Pin Configuration

Pin Number	Pin Name	Description
1	Vcc	Input voltage is +5V for typical applications
2	Analog Out	There will be increase in 10mV for raise of every 1°C. Can range from -1V(-55°C) to 6V(150°C)
3	Ground	Connected to ground of circuit

LM35 Sensor Features

- Minimum and Maximum Input Voltage is 35V and -2V respectively. Typically, 5V.
- Can measure temperature ranging from -55°C to 150°C.
- Output voltage is directly proportional (Linear) to temperature (i.e.) there will be a rise of 10mV (0.01V) for every 1°C rise in temperature.
- $\pm 0.5^\circ\text{C}$ Accuracy
- Drain current is less than 60uA.
- Low-cost temperature sensor
- Small and hence suitable for remote applications
- Available in TO-92, TO-220, TO-CAN and SOIC package

4.1.1.8 Mpu-6050 Gyroscope Sensor

The MPU-6050 IMU (Inertial Measurement Unit) is a 3-axis accelerometer and 3-axis gyroscope sensor. The accelerometer measures the gravitational acceleration, and the gyroscope measures the rotational velocity. Additionally, this module also measures temperature. This sensor is ideal for determining the orientation of a moving object.

The gyroscope measures rotational velocity (rad/s). This is the change of the angular position over time along the X, Y, and Z-axis (roll, pitch, and yaw). This allows us to determine the orientation of an object.

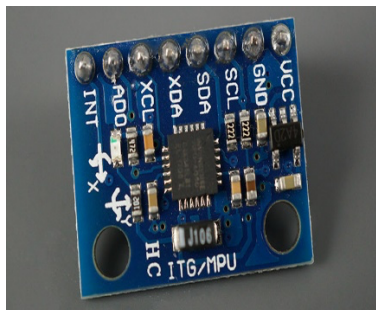


Fig: 4.16: Mpu-6050 Gyroscope Sensor

When the gyros are rotated about any of the sense axes, the Coriolis Effect causes a vibration that is detected by a MEM inside MPU6050.

- The resulting signal is amplified, demodulated, and filtered to produce a voltage that is proportional to the angular rate.
- This voltage is digitized using 16-bit ADC to sample each axis.
- The full-scale range of output are +/- 250, +/- 500, +/- 1000, +/- 2000.
- It measures the angular velocity along each axis in degree per second unit.

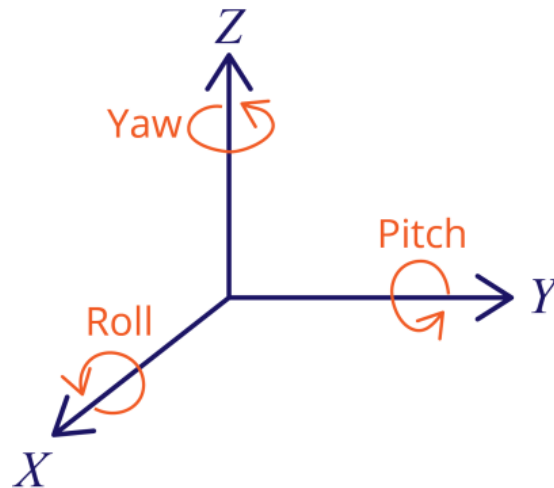


Fig: 4.17: Mpu-6050 Gyroscope Sensor Axes

MPU-6050 Pinout

Table: 4.7: MPU-6050 Pinout Configuration

VCC	Power the sensor (3.3V or 5V)
GND	Common GND
SCL	SCL pin for I2C communication (A5)
SDA	SDA pin for I2C communication (A4)
XDA	Used to interface other I2C sensors with the MPU-6050
XCL	Used to interface other I2C sensors with the MPU-6050

AD0	Use this pin to change the I2C address
INT	Interrupt pin – can be used to indicate that new measurement data is available

4.1.1.9 Liquid Crystal Display (LCD)

A liquid crystal display (LCD) is a thin, flat electronic visual display that uses the light modulating properties of liquid crystals (LCs). LCs do not emit light directly. They are used in a wide range of applications, including computer monitors, television, instrument panels, aircraft cockpit displays, etc. LCDs have displaced cathode ray tube (CRT) displays in most applications. They are usually more compact, lightweight, portable, less expensive, and more dependable.

Each pixel of an LCD typically consists of a layer of molecules aligned between two transparent electrodes and two polarizing filters, the axes of transmission of which are (in most of the cases) perpendicular to each other. With no actual liquid crystal between the polarizing filters, light passing through the first filter would be blocked by the second (crossed) polarizer. In most of the cases the liquid crystal has double refraction.

The surfaces of the electrodes that are in contact with the liquid crystal material are treated to align the liquid crystal molecules in a particular direction. Electrodes are made of a transparent conductor called Indium Tin Oxide (ITO). Before applying an electric field, the orientation of the liquid crystal molecules is determined by the alignment at the surfaces of electrodes. In a twisted nematic device, the surface alignment directions at the two electrodes are perpendicular to each other, and so the molecules arrange themselves in a helical structure, or twist.

This reduces the rotation of the polarization of the incident light, and the device appears grey. If the applied voltage is large enough, the liquid crystal molecules in the center of the layer are completely untwisted and the polarization of the incident light is not rotated as it passes through the liquid crystal layer. This light will then be polarized perpendicular to the second filter, and thus be blocked and the pixel will appear black. By controlling the voltage applied across the liquid crystal layer in each pixel, light can be allowed to pass through in varying amounts thus constituting various levels of gray.

Pin Description

The most common used LCDs found in the market today are 1 line, 2 line, or 4-line LCDs which have only one controller and support at most of 80 characters, whereas LCDs supporting more than 80 characters make use of 2HD44780 controllers. More LCDs with 1 controller have 14 pins and LCDs with 2 controllers has 16 pins.

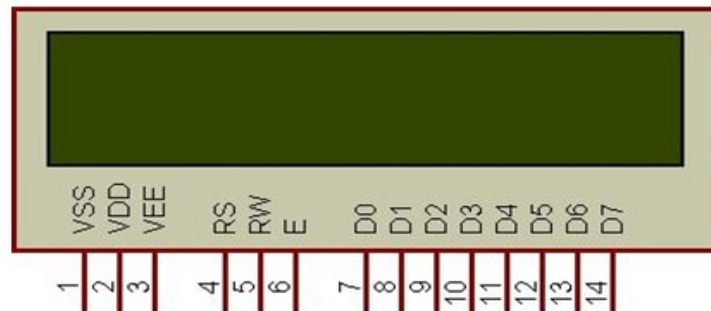


Fig: 4.18: Pin diagram of 2x16 LCD

Features

- x 8 dots with cursor.
- Built-in controller (KS 0066 or Equivalent)
- + 5V power supply (Also available for + 3V)
- 1/16 duty cycle
- B/L to be driven by pin 1, pin 2 or pin 15, pin 16 or A.K (LED)
- N.V. optional for + 3V power supply.

Table: 4.8: LCD Pin Details

PIN NO.	SYMBOL	FUNCTION
1.	Vss	GND
2.	Vdd	+3V or +5V
3.	Vo	Contrast Adjustment
4.	RS	H/L Register Select Signal
5.	R/ $\bar{W}$	H/L Read and Write Signal
6.	E	H→L Enable Signal
7.	DB0	H/L Data Bus Line
8.	DB1	H/L Data Bus Line
9.	DB2	H/L Data Bus Line
8.	DB3	H/L Data Bus Line
11.	DB4	H/L Data Bus Line
12.	DB5	H/L Data Bus Line
13.	DB6	H/L Data Bus Line
14.	DB7	H/L Data Bus Line
15.	A/Vee	+4.2V for LED/Negative Voltage Output
16.	K	Power Supply for B/L (0V)

Display Character Address Code

Display Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DD RAM Address	00	01														0F
DD RAM Address	40	41														4F

Fig: 4.19: Address code for displaying character

BF- Busy Flag

Busy flag is a status indicator flag for LCD. When we send a command or data to the LCD for processing, this flag is set (BF=1) and as soon as the instruction is executed successfully this flag is cleared (BF=0). This is helpful in producing and

exact amount of delay for the LCD processing. To read busy flag, the condition RS=0 and R/W=1 must be met and the MSB of the LCD data bus (D7) function as busy flag. When BF =1 means LCD is busy and will not accept next command or data and BF=0 means LCD is ready for the next command or data to process.

Instruction And Data Register

There are two 8-bit registers in HD44780 controller Instruction and Data register. Instruction register corresponds to the register where commands are sent to LCD e.g., LCD shift command, LCD clear, LCD address etc. and Data register is used for storing data which is to be displayed on LCD. when send the enable signal of the LCD is asserted, the data on the pins is latched into the data register and data is then moved automatically to the DDRAM and hence is displayed on the LCD. Data register is not only used for sending data to DDRAM but also for CGRAM, the address where the data to be sent, is decided by the instruction sent to LCD. We will discuss more on LCD instruction set further in this chapter.

Commands And Instruction Set

Only the instruction registers (IR) and the data register (DR) of the LCD can be controlled by the MCU. Before starting the internal operation of the LCD, control information is temporarily stored into these registers to allow interfacing with various MCUs, which operate at different speeds, or various peripheral control devices. The internal operation of the LCD is determined by signals sent from the MCU. These signals, which include register selection signal (RS), read/write signal (R/W), and the data bus (DB0 to DB7), make up the LCD instructions.

Commands

There are four categories of instructions that:

- Designate LCD functions, such as display format, data length, etc.
- Set internal RAM addresses.
- Perform data transfer with internal RAM.
- Perform the miscellaneous functions.

4.2.1 Software Requirements

1. Arduino IDE
2. Embedded C

4.2.1.1 Arduino IDE

The Arduino Integrated Development Environment or Arduino Software (IDE) contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them. Programs written using Arduino Software (IDE) are called sketches. These sketches are written in the text editor and are saved with the file extension (.ino). The toolbar buttons allow to verify and upload programs, create, open, and save sketches, and open the serial monitor. The development of electronics is now easier thanks to Arduino software (IDE), and Arduino boards (hardware). This set help to build digital and interactive devices with the help of other components.

The Arduino software (IDE) is an open-source software, which is used to program the Arduino boards, and is an integrated development environment, developed by arduino.cc. Allow to write and upload code to Arduino boards. And it consists of many libraries and a set of examples of mini projects. Arduino software (IDE) is compatible with different operating systems (Windows, Linux, Mac OS X), and supports the programming languages (C/C++). The Arduino software is easy to use for beginners, or advanced users. It uses to get started with electronics programming and robotics and build interactive prototypes. So, Arduino software is a tool to develop new things. and create new electronic projects, by Anyone (children, hobbyists, engineers, programmers, ... etc.). The Arduino IDE has a simple and intuitive interface, making it easy for beginners to get started with programming. With tools like syntax highlighting, code completion, and auto-indentation, the integrated development environment (IDE) enables developers to create code more quickly. Several pre-built examples that show users how to use different Arduino functions and libraries are included with the Arduino IDE. When learning how to program Arduino boards, these examples are an excellent place to start. Installing and managing libraries for Arduino projects is made simple for users by the library manager included in the Arduino IDE. Code libraries are sets of

functions that offer extra features like network communication or a sensor interface.

The IDE includes a serial monitor that allows users to communicate with their Arduino board over the serial port. This is useful for debugging and testing purposes. The IDE includes a board manager that allows users to easily add support for new Arduino-compatible boards. This makes it easy to use a wide range of microcontrollers with the IDE. The IDE includes an upload manager that allows users to easily upload their code to their Arduino board. Users can select the correct board and port from a drop-down menu, making the upload process simple and straightforward. While the Arduino IDE does not have a built-in debugger, there are third-party tools and plugins available that add debugging capabilities to the IDE. The Arduino IDE is available for Windows, macOS, and Linux, making it accessible to users on a wide range of operating systems.

4.2.1.2 Embedded C

Embedded c is a set of language extension for the C Programming language by the C Standards committee to address commonality issues that exist between C extensions for different embedded systems. Historically embedded C programming requires nonstandard extensions to the C language to support exotic features such as fixed-point arithmetic, multiple distinct memory banks, and basic I/O operations. Embedded C uses most of the syntax and semantics of standard C, e.g., main () function, variable definition, data type declaration, conditional statements (if, switch, case), loops (while, for), functions, arrays and strings, structures and union, bit operations, macros, etc. During infancy years of microprocessor-based systems, programs were developed using assemblers and fused into the EPROMs. There used to be no mechanism to find what the program was doing. LEDs, switches, etc. were used to check for correct execution of the program. But they were too costly and were not dependable as well. As time progressed, use of microprocessor-specific assembly-only as the programming language reduced and embedded systems moved onto C as the embedded programming language of choice. C is the most widely used programming language for embedded processors/controllers.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 RESULTS

The results obtained from the implementation of the ESP-32 based parameter measurement and control system in the RC boring machine demonstrate promising performance and functionality. Through rigorous testing and experimentation, various parameters such as speed, depth, and temperature were accurately measured and controlled in real-time, showcasing the effectiveness of the developed system. The accompanying images vividly illustrate the output of the project, providing visual evidence of the system's capabilities in action. These results not only validate the feasibility of utilizing ESP-32 technology for precise measurement and control tasks but also highlight its potential for enhancing the efficiency and accuracy of RC boring operations. Further analysis and discussion of these findings will be presented to elucidate their implications and potential avenues for future research and development.

5.1.1 RC BORING MACHINE- ACTUATOR UNIT

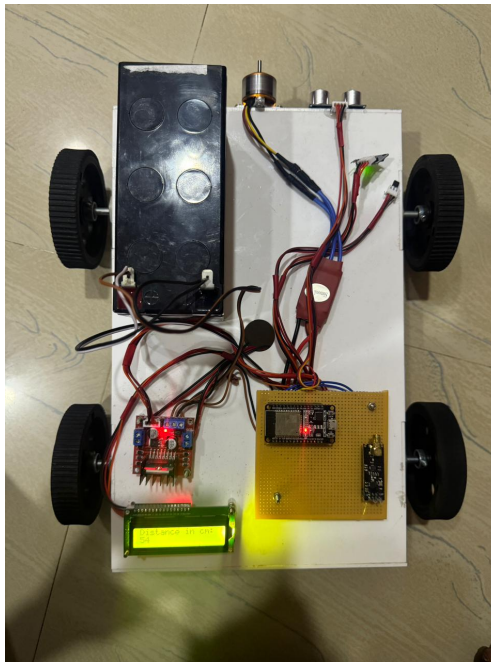


Fig: 5.1: ESP-32 BASED PARAMETER MEASUREMENT AND CONTROL IN RC BORING MACHINE- actuator unit

The provided image captures the intricate components and functionalities of the RC boring machine's actuator unit, representing a pivotal component in the overall system architecture. Central to its design is the Brushless Direct Current (BLDC) motor, meticulously housed within the unit, serving as the primary drilling mechanism. This high-performance motor enables precise and efficient drilling operations, essential for achieving desired outcomes in various applications. Complementing the BLDC motor is a robust battery system, serving as the power source for all operations within the unit, ensuring sustained functionality and mobility. Furthermore, the integration of the nRF24L01 Wireless RF Module enables seamless communication with the remote control unit, facilitating real-time command reception and execution, thereby enhancing operational flexibility and control. Additionally, the inclusion of various sensors such as the temperature sensor, gyroscope, and ultrasonic sensor expands the unit's capabilities, enabling advanced functionality such as environmental monitoring, orientation detection, and obstacle avoidance. The LED display embedded within the unit provides critical feedback by presenting vital readings and data, enhancing user interaction and decision-making processes. This comprehensive description underscores the sophistication and versatility of the actuator unit, highlighting its pivotal role in driving the RC boring machine's performance and functionality. The integration of advanced components and features not only enhances operational efficiency but also sets a precedent for future advancements and innovations in the field of remote-controlled drilling technology.

5.1.2 RC BORING MACHINE REMOTE CONTROL UNIT



Fig: 5.2: RC boring machine Remote control unit

The image presents a pivotal component of the RC boring machine project: the prototype remote control system. Integrated with cutting-edge technology, including the ESP-32 microcontroller and nRF24L01 Wireless RF Module, this remote facilitates wireless operation of the drilling process. Notably, these components are meticulously soldered onto a solder board, ensuring durability and stability during operation. The remote features five buttons, strategically designed to enable precise control over various aspects of the RC boring machine's functionality. Two buttons are dedicated to regulating the speed of the Brushless Direct Current (BLDC) motor within the actuator unit, essential for controlling drilling speed and accuracy. Additionally, another pair of buttons facilitates forward and backward movement control of the vehicle unit, housing the drill and battery area. Meanwhile, the fifth button, positioned at the centre, serves as an emergency cut-off, providing a failsafe mechanism for halting operations in critical situations. Moreover, the remote boasts a sophisticated 2x16 LCD display, delivering vital information such as temperature readings from the actuator unit, fall alerts utilizing the gyroscope data, and distance measurements. This integration of advanced features not only enhances operational efficiency but also prioritizes safety and real-time monitoring. The comprehensive design and functionality of the remote control system underscore its pivotal role in driving the success of the RC

boring machine project, laying the groundwork for further advancements in remote-controlled drilling technology.



Fig: 5.3: RC boring machine Remote control unit with data shown

5.1.3 FALL ALERT

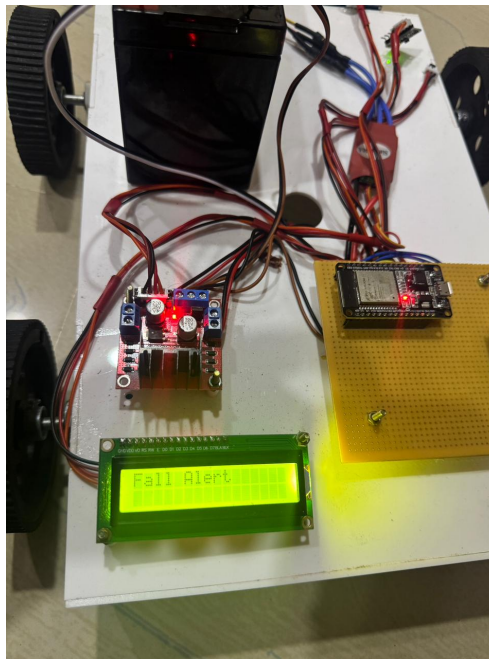


Fig: 5.4: Fall Alert Warning Message on LCD Display

The displayed image encapsulates a critical safety feature integrated into the RC-boring machine: the fall alert warning system. Central to this system is the gyroscope housed within the machine, which diligently monitors its orientation. When a tilt exceeding 15 degrees is detected, indicative of a potential fall or destabilization, the gyroscope triggers the fall alert mechanism. The LCD display prominently showcases the warning message, providing real-time feedback to operators about the precarious situation. This innovative safety measure not only mitigates the risk of accidents but also underscores the commitment to prioritizing personnel safety in the operational environment. The integration of such advanced monitoring and alert systems not only enhances operational safety but also demonstrates a proactive approach towards mitigating risks and ensuring a secure working environment for personnel involved in RC-boring operations.

5.1.4 DISTANCE MEASUREMENT

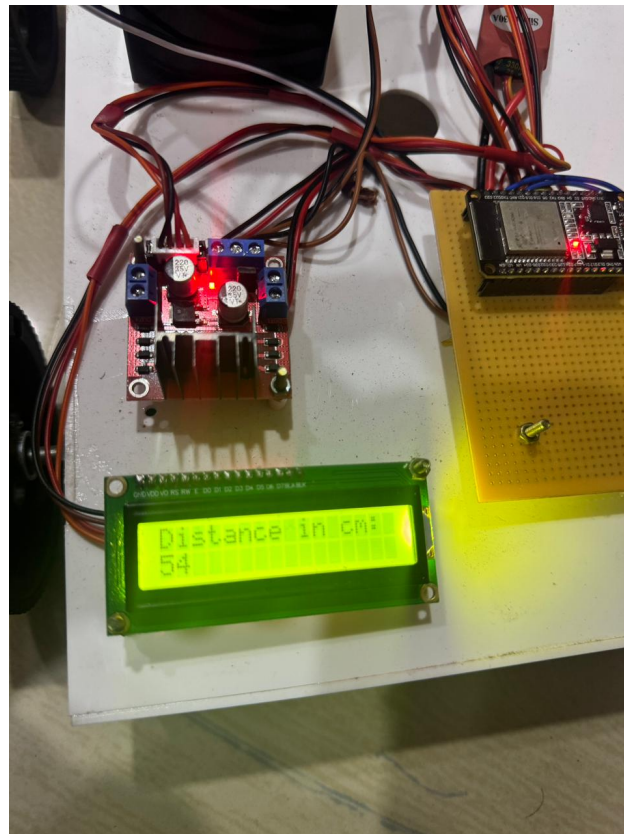


Fig: 5.5: LCD display showing Distance using ultra sonic sensor

The displayed image showcases a critical aspect of the RC-boring machine's functionality, highlighting the integration of an LCD display unit that provides real-time distance measurements in centimetres. This LCD display serves as a vital interface for conveying crucial information recorded by the machine's ultrasonic sensor, which accurately measures the distance from the operation location. The utilization of ultrasonic technology ensures precise and reliable distance measurements, enabling operators to assess the proximity to obstacles or target areas with precision and efficiency. This feature not only enhances the operational safety of the RC-boring machine but also streamlines the drilling process by providing operators with valuable data to inform decision-making. The inclusion of the LCD display unit represents a key advancement in the machine's user interface, facilitating seamless interaction and data interpretation for enhanced performance and productivity in drilling operations.

5.1.5 TEMPERATURE MEASUREMENT

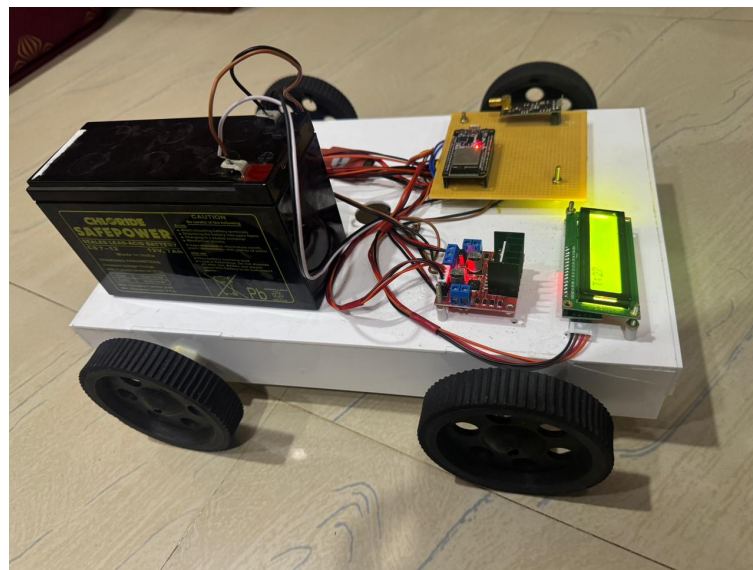


Fig: 5.6: LCD display showing Temperature

The displayed image showcases a critical aspect of the RC-boring machine's monitoring and safety system: the LCD display exhibiting real-time temperature readings in Celsius. This temperature data is acquired by the integrated temperature sensor housed within the RC-boring machine, which continuously measures the ambient temperature of the surrounding environment. The displayed

temperature serves as a vital indicator for monitoring operational conditions, ensuring optimal performance and safety during drilling operations. Notably, the system is designed with a pre-set threshold, triggering a warning message on the LCD display if the temperature exceeds 40 degrees Celsius, signifying potential overheating risks. This proactive warning mechanism enables operators to promptly address temperature-related concerns, mitigating potential hazards and ensuring the longevity of the equipment. The integration of such monitoring and warning features underscores the commitment to safety and efficiency in the design and operation of the RC-boring machine, facilitating informed decision-making and proactive risk management in challenging drilling environments.

5.2 ADVANTAGES

1. **Enhanced Precision:** The integration of ESP-32 technology enables precise measurement and control of critical parameters such as speed, depth, and temperature in the RC boring machine, ensuring optimal performance and accuracy during drilling operations.
2. **Wireless Connectivity:** Leveraging the ESP-32 and nRF24L01 Wireless RF Module enables wireless communication between the remote-control unit and the RC boring machine, eliminating the need for cumbersome wired connections, and enhancing mobility and flexibility in operation.
3. **Real-Time Monitoring:** With the ability to transmit data wirelessly, the project enables real-time monitoring of drilling parameters, providing operators with instant feedback on performance metrics and allowing for prompt adjustments as needed.
4. **Remote Operation:** The remote-control unit allows operators to manipulate the RC boring machine from a safe distance, reducing the risk of accidents and improving operational efficiency, particularly in hazardous or hard-to-reach environments.
5. **Safety Features:** Incorporating features such as an emergency cut-off button and temperature threshold warnings enhances safety protocols,

empowering operators to swiftly intervene in case of emergencies or adverse operating conditions, thereby minimizing risks to personnel and equipment.

6. Versatility: The project's modular design and integration with various sensors (e.g., temperature, gyroscope, ultrasonic) offer versatility in monitoring and controlling different aspects of the RC boring machine, catering to diverse drilling requirements and environmental conditions.

7. Efficiency and Productivity: By providing precise control over drilling parameters and offering real-time feedback, the project optimizes the efficiency and productivity of RC boring operations, reducing downtime, minimizing errors, and ultimately improving overall project timelines and outcomes.

5.3 APPLICATION

- **Construction Industry:** This project can find extensive applications in the construction sector, where RC (Remote Controlled) boring machines are commonly used for drilling holes in various materials such as concrete, rock, and soil. The precise parameter measurement and control capabilities offered by This system can significantly enhance the efficiency and accuracy of drilling operations in construction projects.
- **Mining Operations:** In the mining industry, RC boring machines are utilized for exploration and extraction purposes. This project can be applied to improve the measurement and control of drilling parameters in mining operations, aiding in the extraction of minerals and ores with greater precision and safety.
- **Geotechnical Engineering:** Geotechnical engineers often use RC boring machines for soil investigation, sampling, and analysis. This system's ability to accurately measure and control parameters such as speed, depth, and temperature can be invaluable in geotechnical studies, enabling more reliable data collection and analysis for engineering projects like foundation design and slope stability assessment.

- **Infrastructure Development:** Infrastructure projects such as tunneling, bridge construction, and roadworks require precise drilling operations. This project can contribute to the efficient execution of these projects by providing better control over drilling parameters, thereby ensuring structural integrity and safety standards are met.
- **Environmental Monitoring:** RC boring machines are also employed in environmental studies for tasks like groundwater monitoring, soil sampling, and pollution remediation. By integrating This system's parameter measurement capabilities, environmental researchers can gather accurate data for assessing environmental conditions and developing remediation strategies effectively.
- **Research and Development:** This project can serve as a platform for further research and development in the field of drilling technology. Researchers and engineers can use This system as a foundation for exploring new drilling techniques, optimizing drilling processes, and integrating additional sensors or control mechanisms to address specific industry needs.

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 Summary

In this chapter, we provide a comprehensive summary of the key findings, contributions, and implications of the research conducted on the development and evaluation of Esp-32 Based Parameter Measurement and Control in RC Boring Machine.

The "RC Boring Machine" project revolutionizes hard rock mining by employing the ESP32 microcontroller and RF technology for remote operation. Keypad inputs on the transmitter initiate actions on the receiver, controlling a brushless DC motor for tunnel excavation. Sensor-equipped receivers display real-time data on an LCD screen, ensuring operators have vital insights into working conditions. The system's mobility, facilitated by a robot chassis, enhances manoeuvrability in confined spaces. This innovation addresses the imprecision, safety hazards, and operator fatigue associated with manual control, ushering in a new era of efficiency and safety in mine development.

6.2 Conclusions

Increasing demands for better underground infrastructure have spurred tunnel construction all over the world, within which the TBM tunneling method is the most applied. The lack of effective TBM guidance solutions, however, potentially contributes to increased risks and uncertainties in tunnel construction.

Thus, in this project, we have developed an automation solution for Boring Machine, which integrates automation control mechanisms, innovative computing algorithms, and wireless network technologies.

6.3 Contributions

The project makes several significant contributions to the efficiency and safety in mine development:

- Development of an Esp-32 Based Parameter Measurement and Control in

Rc Boring Machine.

- Conducted thorough analysis of project requirements for clarity on operational needs.
- Assisted in selecting and integrating compatible hardware components for functionality.
- Contributed to system design and firmware/software development to ensure a cohesive architecture.
- Engaged in rigorous hardware testing to verify functionality and reliability.
- Participated in system integration and testing to validate overall performance.
- Contributed to optimization, refinement, and creation of detailed documentation for enhanced efficiency and reliability, aiming to deliver a tailored solution focused on safety, efficiency, and precision in RC boring machine operations.

6.4 Future Work

The future enhancement of this project involves integrating advance technology like artificial intelligence, IoT, machine learning and integrating multi sensors to provide comprehensive data on subsurface conditions, developing enhanced remote-control interface etc. By incorporating these enhancements, remote-controlled boring machines can become more efficient, safer, and versatile tools for various applications in construction, mining, tunneling, and infrastructure development.

6.5 Final Remarks

In conclusion, the "ESP-32 Based Parameter Measurement and Control in RC Boring Machine" project represents a significant advancement in the field of mining technology. By employing a structured methodology encompassing thorough requirement analysis, meticulous component selection, rigorous testing, and continuous optimization, the project aims to deliver a robust and effective solution tailored to the specific needs of the mining industry. Through collaboration and dedication, the project team has worked towards ensuring safety, efficiency, and

precision in RC boring machine operations. With the implementation of innovative technologies and a focus on user-centric design, this project holds promise for revolutionizing mine development processes and improving overall productivity in the industry.

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