Microcontroller Based Voltage Monitoring and Load Control with Over/Under Voltage Protection

Sonargaon University (SU)

A project report in partial fulfillment of the requirement for the Degree of Bachelor of Science in Electrical and Electronic Engineering

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Declaration

This is to certify that the project title' Microcontroller Based Voltage Monitoring and Load Control with Over/Under Voltage protection' is the result of our study in partial fulfillment of the B.Sc. Engineering degree under the supervision of Md. Ashikur Rahman, Lecturer and Coordinator, Department of Electrical and Electronic Engineering (EEE), Sonargaon University, Bangladesh. It is also hereby declared that this project or any part of it has not been submitted elsewhere for the award of any degree.

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ABSTRACT

The stability of electrical power supply is critical for the reliable operation of household and industrial appliances. Variations in voltage, such as over voltage and under voltage, can cause severe damage to sensitive loads, reduce equipment lifespan, and create safety hazard. To address this issue, an Microcontroller Based Voltage Monitoring and Load Control with Over/Under Voltage Protection. The system continuously monitors the input supply voltage through a voltage sensor and compares with predefined safe operating limits. If the voltage exceeds the upper threshold over voltage or falls below the lower threshold under voltage, the ESP32 triggers a relay to disconnect the load, thereby preventing damage. A buzzer provides an audio alert, while an LCD display or mobile interface via Wi- Fi Shows real- time voltage levels any system status. Once the voltage returns to normal limits, the ESP32 automatically reconnects the load, ensuring uninterrupted and safe operation. This intelligent protection system offers fast response, low cost, and flexibility, making it suitable for residential, commercial, and industrial applications.

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LIST OF ABBREVIATIONS

A	Ampere
AC	Alternative Current
AFH	Adaptive frequency hopping
C	Capacitance
CDI	Capacitor Discharge Ignition
CMOS	Complementary Metal Oxide Semiconductor
CT	Current Transformer
DC	Direct Current
EDR	Enhance Data Rate
EEPROM	Electrically Erasable Programmable Read-Only Memory
EN	Enable
F	Farad
FTDI	Future Technology Devices International
GHz	Giga Harz
GND	Ground
GSM	Global System for Mobile Communication
IC	Integrated Circuit
IO	Input Output
IRLED	Infrared Light Emitting Diode
IoT	Internet of Things
K	Kilo
KB	Kilo Byte
LCD	Liquid Crystal Display
LED	Light Emitting Diode
mA	Milliampere
MAC	Media Access Control

Mbps	Mega Byte per Second
MCU	Microcontroller Unit
MHz	Megahertz
MPU	Microprocessor Unit
NO	Normally Open
NC	Normally Close
PCB	printed Circuit Board
PT	Potential Transformer
PWM	Pulse Width Modulation
R	Resistance
RAM	Random Access Memory
RSR	Reset
RX	Receiver
RXD	Received Serial data
RW	Read write
SI	International System
SPDT	Single pull double throw
SPP	Serial port protocol
TTL	Transistor- Transistor logic
TX	Transmitter
TXD	Transmitted Serial Data
USB	Universal Serial Bus
V	Voltage
VCC	voltage Common Collector

CHAPTER 1

INTRODUCTION

1.1 Introduction

damage, inefficiencies, and even operational hazards in sensitive equipment, safety risks like overheating or fires. While industrial-grade voltage protection systems exist, they are often complex Voltage stability is essential for the safe operation of electrical devices, yet fluctuations such as overvoltage and undervoltage are common due to grid issues, load variations, and environmental factors. Such voltage fluctuations can lead to irreversible damage, reduced performance, and even operational hazards in sensitive equipment. Overvoltage and undervoltage conditions can result in excessive strain on electrical appliances, lead to irreversible and expensive, making them impractical for average household use. To minimize these issues we made a simple, cost-effective overvoltage and undervoltage protection system suitable for domestic use. By leveraging the capabilities of an Node MUC ESP 32 microcontroller and LCD display, this project aims to create a system that not only protects household appliances but also provides an easy- to-use interface for monitoring real-time voltage. The primary objective is to detect dangerous voltage levels and automatically disconnect the load to prevent potential damage or hazards. There is a Wi-Fi module inside of node- MUC Which is Connected with internet. Is give all kind of load information over the internet. You can control electrical and electronics load using Your smart phone and also from your computer. In this system, a 220volt AC Buzzer has been used. When over voltage and under voltage occurs, the alarm will sound.

1.2 Internet of things (IOT)

The internet of Things (IOT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

The definition of the Internet of Things has evolved due to the convergence of the multiple technologies, real-time analysis, machine learning, commodity sensors, and embedded systems. Traditional fields of embedded systems, wireless sensor networks, control systems, automation (including home and building automation), and others all contribute to enabling the Internet of Things. In the consumer market, IoT technology is most synonymous with products

pertaining to the concept of the “smart home”, covering devices and appliances (such as lighting fixtures, thermostats, home security systems and cameras, and other home appliances) that support one or more common ecosystems, and can be controlled via devices associated with that ecosystem, such as smartphones and smart speakers.

1.3 Over/Under Voltage protection

Microcontroller Based Voltage Monitoring and load Control with Over/Under protection. The main purpose of these system is to provide the protection from over voltage and under voltage in system. The ESP32 processes real-time voltage data and display it on the LED activating a real to cut off power. Node MCU based system using this system. We can monitor our load from world-wide. Using this system, we can control any kind of load from our smart phone or computer over internet. In this system a 220V AC buzzer has been used. When over voltage and under voltage occurs, the alarm will sound.

1.4 Problem statement

There is a lot of industry and factory inside our world. And this factory’s have a lot of electrical and electronics machine or appliance. In modern electrical systems, maintaining a stable voltage supply is critical for the safe and efficient operation of electrical and electronics devices. Over voltage condition can lead to overheating, insulation breakdown, and permanent damage to sensitive appliances, while under voltage and result in poor performance. Malfunction, or stalling of motors and other equipment. These irregularities not only reduce the lifespan of device but also pose significant risks of fire hazards and financial losses. Therefore, there is a need for an automatic protection system that can continuously monitor supply voltage, detect abnormal conditions, and isolate the load from the supply to prevent damage. The proposed system should be cost-effective, reliable and capable of restoring power once normal voltage are achieved.

1.5 Motivation

In modern electrical systems, stable and reliable supply is essential for the safe operation of domestic appliances, industrial machinery, and sensitive electronic devices. However, fluctuations in supply voltage- such as over voltage (higher than rated value) or under – voltage (lower than rated value)- are common due to grid disturbances, faults, poor regulation, or sudden load changes. Traditional protective devices like fuses and circuit breakers mainly protect against overcurrent and short circuits. The motivation behind this project is to design and develop a low- cost, efficient, and reliable over- voltage and under voltage protection system using modern microcontroller- based control. Such a system enhances safety, reliability, and longevity of appliances while reducing maintenance cost and power losses.

1.6 Objectives

1. To protect electrical appliances and loads from damage caused by abnormal voltage conditions (over- voltage or under voltage)
2. To monitor supply voltage continuously and take immediate action when the voltage goes beyond safe limits.
3. To automatically disconnect the load from the power supply during unsafe voltage conditions.
4. To reconnect the load safely once the voltage returns to the normal operating range.
5. To provide reliable, low- cost, and efficient protection suitable for domestic, commercial, and industrial applications.
6. To alert the user (using buzzer, indicator, LCD) during fault conditions for quick awareness.
7. To minimize downtime and ensure continuous safe operation of critical electrical system.

1.7 Research Methodology

Here we designed a system Implementation of Microcontroller Based Voltage Monitoring and Load Control with Over/Under Voltage protection use. The ESP32 process real-time voltage data and displays it on the LCD activating a relay to cut off power. Node MCU based system using this system we can monitor our load from world using this system. we can control any kind of load from our smart phone or computer over internet. In this system, a 220V buzzer has been used. When over voltage and under voltage occurs, the alarm will sound. During the preparation of the report help from several sources but here some are mentioned as for the proper references.

1.8 Conclusion

The Microcontroller Based Voltage Monitoring and Load Control with Over/Under Voltage protection successfully ensures the safety of electrical appliances by monitoring supply voltage in real-time. The ESP32, combined with a voltage sensor and relay module, detects abnormal voltage conditions and automatically disconnects the load to provide damage. The LCD display and buzzer provide immediate feedback to the user, while the optional IOT feature allows remote monitoring and control through mobile devices. Testing confirmed that the system responds quickly and reliable to voltage fluctuations, making it a cost-effective and efficient solution for household and industrial protection. This project demonstrates the practical use of microcontrollers is smart protection system and can be further enhanced with data logging and IOT integration.

1.8 Project Outline

This is organized as follows

Chapter 1 Introduction.

In this chapter we discuss about this project.

Chapter 2 Analysis of the system component.

In this chapter we discuss about all component, which component we this used in this project like Nod MCU ESP32. Voltage Sensor. Relay module, LED display. SMPS, Buzzer.

Chapter 3 Hardware development.

In this chapter we discuss about hardware developing. How we develop our project. How we make this project.

Chapter 4 Result and discussions.

In this chapter we discuss about output, we check switch status and load status.

Chapter 5 Conclusions.

The ESP32-based system provides reliable over/under voltage protection, ensuring appliance safety with scope for IoT and data logging enhancements.

CHAPTER 2

ANALYSIS OF THE SYSTEM COMPONENT

2.1 Introduction

The proposed system is The Microcontroller Based Voltage Monitoring and Load Control with Over/Under Voltage Protection. The system monitoring and controlling from smart phone or computer.

The system will bear following functionalities:

1. Electrical appliances and industrial machines require stable voltage for safe operation.
2. Over-voltage and under-voltage conditions can damage sensitive devices and reduce their lifespan.
3. The ESP32 microcontroller is used as the control unit to monitor voltage continuously.
4. Voltage sensors provide real-time input, and relays control the connection od disconnection of loads.
5. Additional features like buzzer, LCD display, and mobile app connectivity enhance safety and monitoring.

2.2 Required Component

The smart Helmet has the following main component.

Table: Required Component

Component	Software
ESP32 Microcontroller	Arduino IDE
Arduino Nano	Blynk
ESP32 microcontroller base	
Voltage Sensor 2 mA	
Relay module 4 channel-5 volt	
LCD display Green	

SMPS-5Volt-2Am	
Pan regulator	
220Volt AC Buzzer	
potentiometer	
2 gang Switch	
Button Holder	
Jumper wire	
Indicator Lamp-R-Y-G	
Lota cable wire	
LED Dim light 0.5 Watt	
Connector 10 Amp	
2- pin plug	
Electric Cable casing channel	

2.3 ESP32 Microcontroller

The ESP32 is a powerful, low-cost microcontroller with integrated Wi-Fi and Bluetooth, making it ideal for IoT applications. It features a dual-core processor running up to 240 MHz, allowing it to handle multitasking with ease. You can program it using the Arduino IDE, ESP-IDF, or MicroPython, depending on your project needs. The ESP32 includes a wide range of peripherals like GPIO, ADC, DAC, I2C, SPI, and UART. It supports up to 34 GPIO pins, with some capable of touch sensing and PWM output. Wi-Fi and Bluetooth allow it to connect wirelessly to other devices or networks.
It can operate in deep sleep mode for ultra-low power consumption. The chip also supports secure boot, flash encryption, and OTA updates. Some variants have additional PSRAM for handling large applications or data buffers. You can build web servers, control devices remotely, or log sensor data to the cloud. Its flexibility makes it popular in home automation.

2.3.1 Specification ESP32 microcontroller



Fig: 1: ESP microcontroller

ESP32 Microcontroller	
Operating Voltage	2.2V to 3.6V
GPIO	36 ports
ADC	14 ports
DAC	2 ports
Flash memory	16 Mbyte
SRAM	250 Kbyte
Clock Speed	Up to 240 MHz
Wi-Fi	2.4 GHz
Sleep Current	2.5 µ A

2.3.2 Pin Function of ESP32 Microcontroller

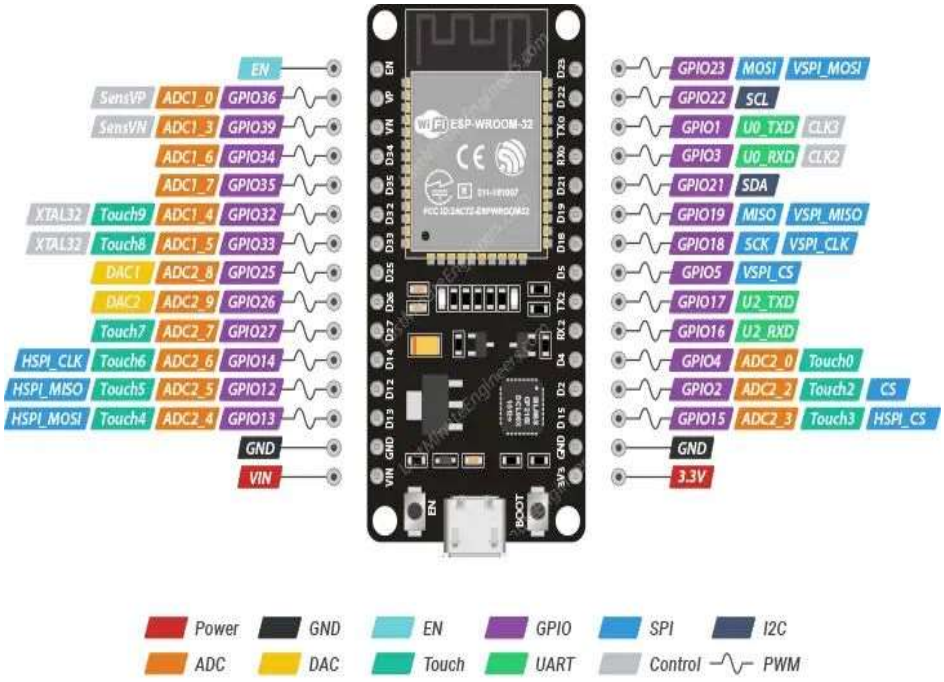


Fig: Pin Function ESP32 microcontroller.

2.4 Arduino Nano Micro Controller

Arduino Nano is a small, complete, and breadboard-friendly microcontroller board based on the ATmega328P. It is designed for compact projects where space is limited, while still providing the same functionality as the Arduino Uno. The board comes with a mini-USB interface, making it easy to program and power. Its small size, low cost, and wide compatibility make it one of the most popular boards for embedded and DIY projects.

The Arduino Nano can be programmed using the Arduino IDE, and it supports C/C++ with a wide variety of libraries. It has multiple digital and analog I/O pins, PWM channels, serial communication support (UART, SPI, I2C), and operates at 5V. Due to its compact size and simple design, the Arduino Nano is widely used in IoT devices, automation, robotics, sensor networks, and educational projects.

2.4.1 Specification of Arduino Nano Microcontroller

Parameter	Value
Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (7V)	7V – 12V
Digital I/O Pins	14 (6 PWM outputs)
Analog Input Pins	8
Flash Memory	32 KB (2 KB used by bootloader)
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz
USB Connection	Mini-USB
Dimensions	45 × 18 mm

2.4.2 Pin function of Arduino Nano Microcontroller

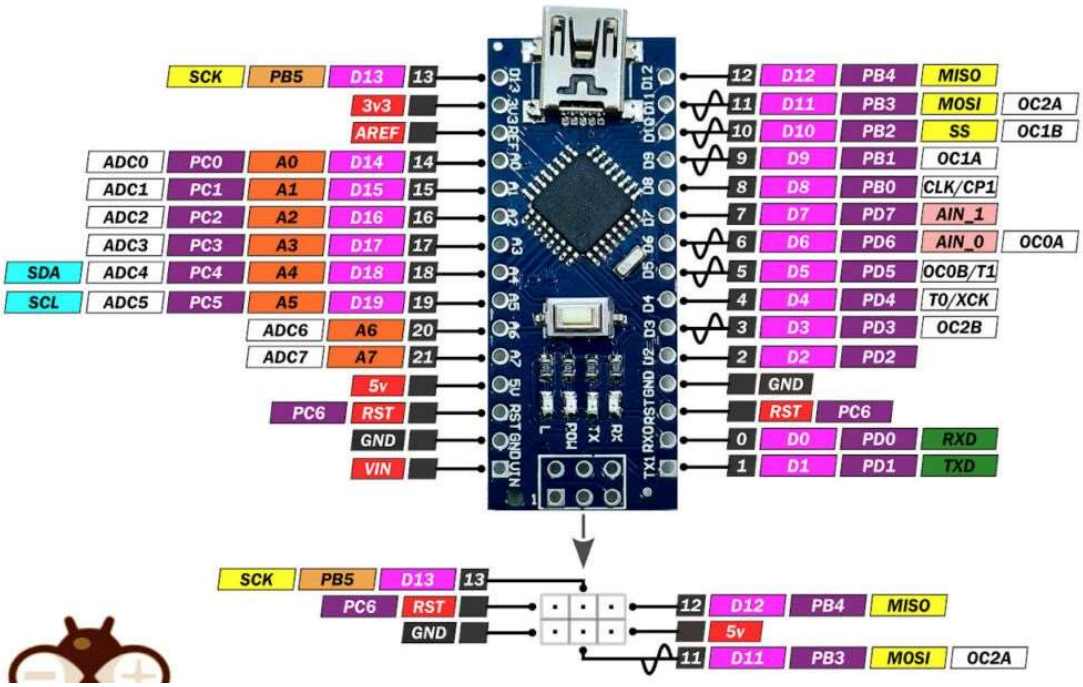


Fig: Pin function of Arduino Nano Microcontroller

2.4 Esp32 Microcontroller Based Board

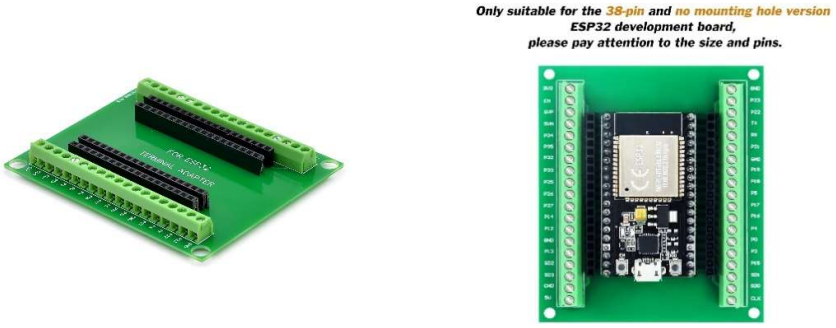


Fig: ESP32 microcontroller Based Board.

The ESP32-based board is a powerful microcontroller widely used in IoT and automation projects. It features built-in Wi-Fi and Bluetooth, making it ideal for wireless communication. The board typically includes a USB interface, voltage regulator, and multiple GPIO pins for connecting sensors and actuators. Users can program it using environments like Arduino IDE,

MicroPython, or ESP-IDF. When powered on, the board runs a bootloader that either loads existing code or waits for new firmware uploads. Developers use it to create smart devices, such as home automation systems or wireless monitors. Its low power consumption makes it suitable for battery-powered applications. Overall, the ESP32 board is a versatile and affordable choice for embedded system projects.

2.5 ZMPT101B AC Voltage Sensor

ZMPTB AC voltage Sensor is the best for the purpose of DIY project. Where we need to measure the accurate AC voltage with a transformer. This is an ideal choice to measure the AC voltage using Arduino/ESO32/Raspberry pin like an open source platform. In many electrical projects, engineer directly deals with measurements with few basic requirements like High galvanic isolation, wide Rang High accuracy onboard precision miniature voltage transformer, the active phase AC output voltage transformer module. Onboard precision op-amp circuit signal sampling and appropriate Compensation for precise functions. Modules can be measured with 250V AC voltage; the corresponding output can be adjusted. It is brand new, good quality high performance.

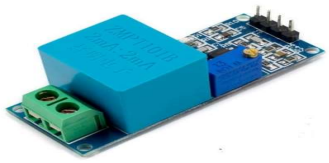


Fig: AC Voltage Sensor

Features, Low price small size and lightweight easy PCB mounting good consistency widely acclaimed. This voltage sensor module is ideal for use in various types of AC voltage measurement and monitoring applications including monitoring energy management and smart home automations. It can be used to measure AC voltage levels and output a corresponding DC voltage signal.

2.5.1 Specification of AC Voltage Sensor

General Specification	
Voltage	250V
Length	50
Width	17
Wight	21
Shipment Weight	0.025 kg
Shipment Dimensions	12*8*4 cm

2.5.2 Pin function of AC Voltage Sensor

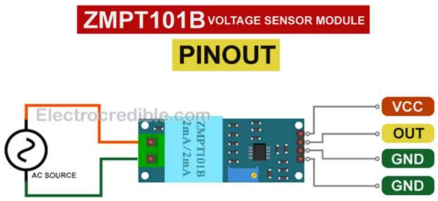


Fig: Pin function Voltage sensor.

2.6 Relay Module 4 channel- 5Volt

Arduino, ESP32 AVR, PIC, ARM and so on can control it. It is also able to control various appliance and other types of equipment with a large current.

Relay output maximum contact is AC250V 10A and DC30V 10A one can connect a microcontroller with standard interface directly to it. Red working status indicator lights are

conducive to the safe use. It has a wide range of applications such as all MCU control, industrial sector, PLC control, smart home control.

High- level trigger refers to the signal voltage between input and trigger, can be understood as a signal input with VCC cathode short-circuit triggered a way;

Low-level trigger refers to the signal voltage between the input terminal and Earth OV trigger, can be understood as the signal input terminal and the GND negative electrode short circuit triggered away 1- channel relay module.

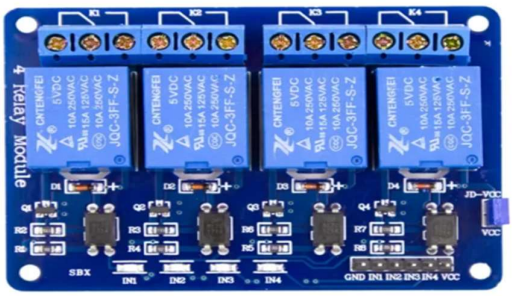
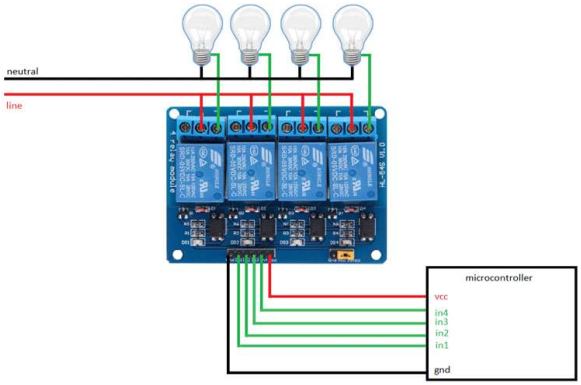


Fig: Relay module 4 channel 5Volt

2.6.1 Specification of Relay Module

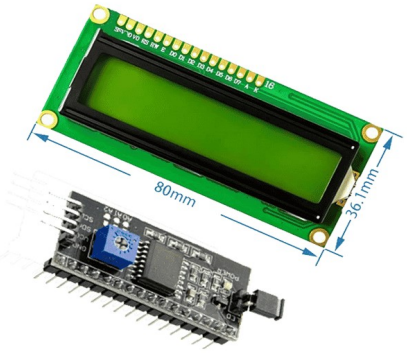
General Specification	
No. of Channel	4
Trigger Voltage VDC	5
Trigger Current mA	20
Switching Voltage VDC	25@10A
Switching Voltage VDC	30@10A
Length mm	75
Width mm	55
Height mm	18
Weight gm	55
Shipment Weight	0.059 kg
Shipment Dimensions	9*7*3 cm

2.6.2 Pin function of Relay Module



2.7 LCD Display Green

An LCD display enhances the usability of the system by providing real-time voltage readings and alerts for the user. A16x2 LCD module is used to display voltage readings and alert messages. It connects to the Arduino either through direct wiring or via an I2C adapter to



reduce wiring.

Fig: LCD Display Green

• Functionality:

The LCD displays the current voltage level and the system's operational status. This provides the user with instant feedback, allowing them to visually monitor voltage conditions. Messages like "Voltage Stable," "Overvoltage Detected" or "Undervoltage Detected" alert users to the system's state, enabling them to take any additional precautions if necessary.

2.8 SMPS- 5Volt- 2A

The 5V 2A SMPS Power Supply is a switched-mode power supply () which converts 100-264V AC to 5V DC. It can provide up to 2A maximum current. All types of protections such as over-voltage protection, over-current protection, short circuit protection, and surge-protected output are provided in the supply. These SMPS are achieved high efficiency and robust to use; By using these latest SMPS, you can reduce your electricity bill. This will provide you with a constant output of 5V 2A means we can drive applications that have a maximum current rating up to 2A. It includes any type of motor with different RPM, thermoelectric Peltier, etc.

It has passed the CE & RoHS certification. This power supply is built with high-quality and high-performance materials. This SMPS power supply has a led power supply with a metal body for hidden installation for led lighting.

Fig: SMPS- 5Volt- 2A



2.9 Fan regulator

A fan regulator is an electrical device that adjusts the speed of a ceiling or table fan by controlling the voltage supplied to its motor. By fine-tuning the power flow, it lets you choose the perfect airflow, from a soft breeze to a robust gust. Modern regulators, crafted by fan regulator companies in India, have evolved to offer enhanced efficiency, durability, and safety compared to older models. These devices are pivotal for optimizing energy consumption and tailoring comfort to your needs. With India's diverse climate and frequent fan usage, especially

in regions like Gujarat, regulators from fan regulator manufacturers in Ahmedabad are designed to meet local demands with precision.

At their core, fan regulators operate by managing the voltage delivered to a fan's motor, which directly influences its speed. Lower voltage slows the fan, while higher voltage increases its speed. Let's dive into the two main types of regulators and how they achieve this control.



Fig: fan regulator

2.10 Buzzer 220V AC

The buzzer is a sounding device that can convert audio signals into sound signals. It is usually powered by DC voltage. It is widely used in alarms, computers, printers and other electronic products as sound devices. It is mainly divided into piezoelectric buzzer and electromagnetic buzzer, represented by the letter "H" or "HA" in the circuit. According to different designs and uses, the buzzer can emit various sounds such as music, siren, buzzer, alarm, and electric bell.



Fig: Buzzer 220V AC

The piezoelectric buzzer uses the piezoelectric effect of the piezoelectric ceramics and uses the pulse current to drive the vibration of the metal plate to generate sound. Piezoelectric buzzer is mainly composed of multi-resonator, piezoelectric plate, impedance matcher, resonance box, housing, etc. Some of the piezoelectric buzzers are also equipped with light-emitting diodes.

The multi-resonator consists of transistors or integrated circuits. When the power supply is switched on (1.5~15V DC operating voltage), the multi-resonator oscillates and outputs 1.5~2.5kHz audio signal. The impedance matcher pushes the piezoelectric plate to generate sound. The piezoelectric plate is made of lead zirconate titanate or lead magnesium niobate piezoelectric ceramic, and silver electrodes are plated on both sides of the ceramic sheet. After being polarized and aged, the silver electrodes are bonded together with brass or stainless steel sheets.

2.12 2- gang Switch

A gang switch is a single electrical plate that houses multiple independent switches, where each "gang" controls a separate light or circuit. Its working principle is that each switch mechanism operates a separate electrical connection to an individual load, much like separate one-way switches, but consolidated into a single unit for convenience and to save space.



Fig: 2- gang Switch

2.13 Button Holder

The Jadroo Dome Button Holder with 23cmx15.2cmx6.7cm, making it ideal for organizing buttons of various shapes and sizes. The thoughtful design allows for easy storage without taking up excessive space, ensuring convenience and accessibility whenever you need it.

With a pack size of 12 pieces, this set of Dome Button Holders offers versatility and flexibility for your button storage requirements. Whether you're a DIY enthusiast or a professional tailor, the ample quantity ensures you have enough holders to accommodate your diverse button collection.

The JadRoo Dome Button Holder is engineered for optimal performance and has technical specifications that meet industry standards. With the Jadroo Dome Button Holder 12 Pcs 250VAC, this holder is designed to handle various button types, providing efficient and

The JadRoo Dome Button Holder is equipped with Poly Carbonet quality, adding an extra layer of durability and strength. This ensures your buttons stay secure and protected, even in demanding conditions. Invest in a button holder that organizes and safeguards your valuable button collection.



Fig: Button Holder

2.14 Jumper Wire

A jumper wire is an electric wire that connects remote electric circuits used for printed circuit boards. By attaching a jumper wire on the circuit, it can be short-circuited and short-cut (jump) to the electric circuit.

By placing the jumper wire on the circuit, it becomes possible to control the electricity, stop the operation of the circuit, and operate a circuit that does not operate with ordinary wiring. Also, when specification change or design change is necessary on the printed circuit board, reinforcement of the defective part, partial stop of the unnecessary function, and change of the circuit configuration of the unnecessary output part by attaching or detaching the jumper wire can do.

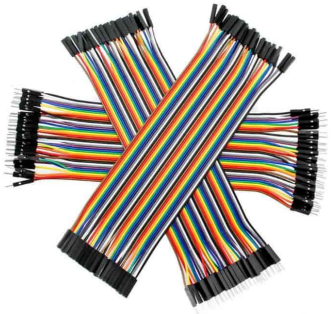


Fig: Jumper Wire

2.15 Indicator Lamp-R-Y-G

Common network devices have several indicators that monitor the status and operation of the device. These indicators are called light-emitting diodes (LEDs). By fully understanding the meaning of these indicator lights, you can easily and quickly determine the cause of the fault in the process of network fault diagnosis, achieving unexpected results.

- Wide Voltage Range: Operates seamlessly from 36V to 240V AC/DC, making it highly versatile for various electrical systems.
- Bright LED Illumination: High-visibility LED provides a fully bright signal for clear status indication, even in well-lit environments.
- 22mm Mounting Diameter: Standard panel-mount size for easy integration into control panels, machinery, and electrical boxes.
- Durable FR Body Material: Flame-retardant (FR) construction ensures safety and long-term durability in demanding environments.
- Easy to Install: Simple screw-on mounting with secure wiring terminals – no special tools required.
- Long Service Life: Energy-efficient LED technology designed for extended usage and reliability, reducing maintenance needs.



Fig: Indicator lamp R-Y-g

2.16 Lota Cable wire

This 40/76 lota cable is a high-quality electrical cable that comes in a striking red and black color. With a capacity of 250 W and 240 V, this cable is perfect for a wide range of electrical applications. The cable is made from durable materials and is designed to withstand wear and tear, making it a reliable choice for both DIY enthusiasts and professionals. Whether you're working on a home improvement project or need a cable for your electrical tools, this lota cable is an excellent choice.

- Black & White Cable
- 100% Copper
- HT PVC insulation
- Long Lusting
- lota cable
- 40/76 count copper core
- Highly Efficient
- **PHB/TANIA CABLE**



Fig: Lota Cable wire

2.17 LED dim Light 0.5 Volt

"Dim light 0.5V" does not accurately describe a standard electrical device. Instead, the query likely refers to a 0.5-watt LED dim light, which is a low-power, energy-saving bulb used for accent or night lighting, and while it might operate on a 0.5V system, most such lights are designed to run on standard household AC voltages, such as 220-240V. -



Fig: LED Dim light 0.5V

2.18 Connector 10 Amp

A 10amp connector is an electrical connector designed to safely handle a maximum current of 10 amperes (amps). This rating specifies the amount of electrical current the connector can conduct without overheating or failing, ensuring safety for various applications such as household wiring, power tools, or electronics. A 10-amp rating is often associated with general-purpose single-phase power, supporting appliances like toasters, hair dryers, and vacuum cleaners.

These are plastic strips with multiple connection points (sometimes called barrier strips) designed for splicing wires together, often used in modeling or household lighting.



Fig: Connector 10 Amp

2.19 2- pin plug

A- 2-pin plug is an electrical connector with two metal pins that connect a device to a power source, providing a simple circuit for the live and neutral wires to supply electricity. Lacking a third "ground" pin, it's typically used for small, low-power, or double-insulated appliances like phone chargers, hair dryers, and lamps that don't require a grounding wire for electrical safety.



Fig: 2- Pin Plug

2.20 Electric Cable casing Channel

Vigo Electric Cable Casing is used to protect and route electrical wiring in a building or structure. Vigo Electric Cable Casing gives protection for cab-les and raceways against fire and is therefore an important and primary consideration in the design and industry standards.

Vigo Electric cable casing is a protective covering for electrical wires in industrial settings. It shields the wiring from physical damage and environmental factors.



Fig: Electric cable casing channel

2.21 Micro-USB- Cable

A Micro USB cable is a small connector and cable used for charging and transferring data, popular for older smartphones, cameras, and other compact electronic devices before the widespread adoption. There are two common types: the rectangular Micro-A (for host devices like computers) and the trapezoidal Micro-B (for peripheral devices). A Micro USB 3.0 variant is wider and has a dual-connector design for increased speed, commonly found in external hard drives.



Fig: USB cable

2.22 Summary

The components are studied individually. Their purpose in the system is explained along with their rating, pinouts and connections. Microcontroller Based Voltage Monitoring and Load Control with Over/Under Voltage Protection is an electronic safety system designed to protect electrical appliances from voltage fluctuations. It continuously monitors the input voltage using a voltage sensor, such as the ZMPT101B for AC voltage or a voltage divider circuit for DC voltage. The ESP32 microcontroller reads this voltage through its analog input pins and compares it against predefined safe voltage thresholds. If the voltage falls below or rises above these limits, the ESP32 immediately cuts off the power supply to the connected load by deactivating a relay module. This prevents damage to the appliances caused by over voltage or under voltage conditions. When the voltage returns to a safe range, the ESP32 reactivates the relay, restoring power to the load.

CHAPTER 3

HARDWARE DEVELOPMENT

3.1 Introduction

This chapter explains about the construction of three main section of this project.

- Main Controller
- Voltage Sensor circuit
- Relay driver Circuit
- Load connection
- Display User interface
- Power supply
- Mobile/IOT Connectivity Optional

The hardware development of the Microcontroller Based Voltage Monitoring and Load Control with Over/Under Voltage protection ensure safe and reliable operation of electrical loads. The ESP32 microcontroller acts as the central controller, processing voltage data from the sensor module. A voltage sensor continuously monitors supply voltage and sends signals to the ESO32 for analysis. A relay driver circuit is used to switch the load ON or OF based on safe voltage limits. An LCD display buzzer provides real- time monitoring and fault indication to the user. A regulated DC power supply ensures stable operation of all components.

3.2 Block Diagram

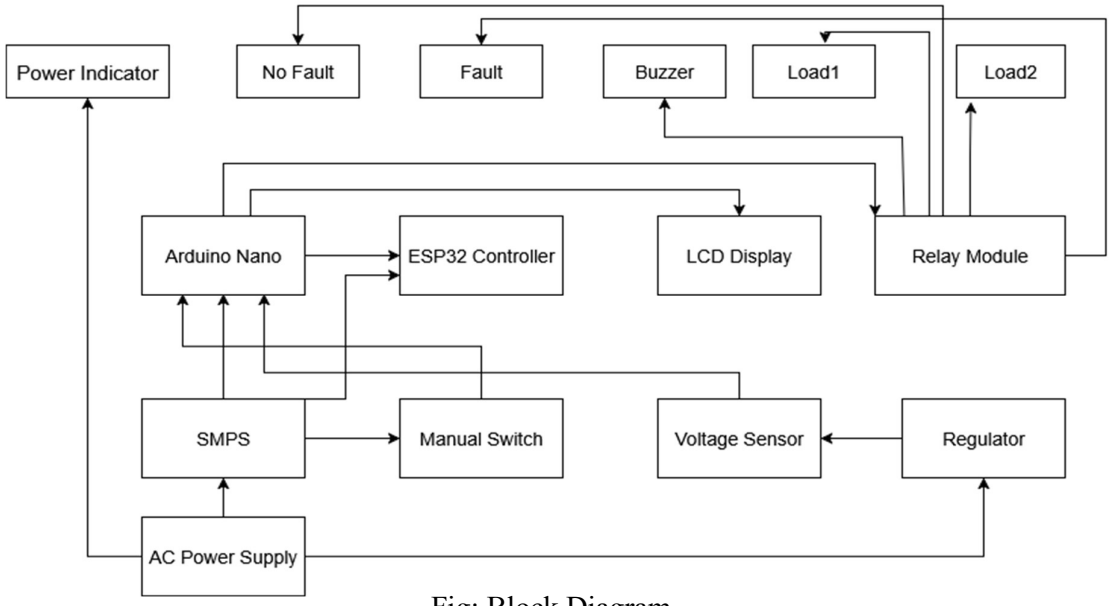


Fig: Block Diagram

This system helps protect electrical devices from voltage damage.AC mains voltage is the input to the system. A voltage sensor module (e.g., ZMPT101B) scales down the AC voltage. The sensor output is an analog signal proportional to the AC voltage. This analog signal is fed to the ESP32 ADC pin. The ESP32 reads and calculates the actual voltage level. If the voltage is too high or too low, it triggers protection. The relay module is controlled via an ESP32 GPIO pin. The relay disconnects the load when voltage is unsafe. When voltage returns to normal, the relay reconnects the load. An optional display (OLED/LCD) can show voltage and system status. Additional features can include Wi-Fi monitoring and alarms. This system helps protect electrical devices from voltage damage.

he upper threshold (over voltage), the ESP32 disconnects the load by turning off a relay through a driver circuit, thus protecting the connected devices. When the voltage returns to the normal range, the ESP32 reactivates the relay, reconnecting the load. This automated protection system helps

3.3 Designing software

There are many circuits deigning software, we prefer proteus Design Suite for deign our circuit. The proteus Design Suite is a proprietary software tool suit used primarily for electronic design automation. The software is used mainly by electronic design engineers and engineers and technicians to create schematics and electronic prints for manufacturing printed circuit bonds.

It was developed in Yorkshire, England by Labcenter Electronic Ltd and is available in English, French, Spanish and Chinese languages.

Schematic capture in the proteus Design Suit for both the simulation of designs and as the design phase of a PCB layout project. It is therefore a core component and is included with all product configuration.

3.4 Circuit Diagram

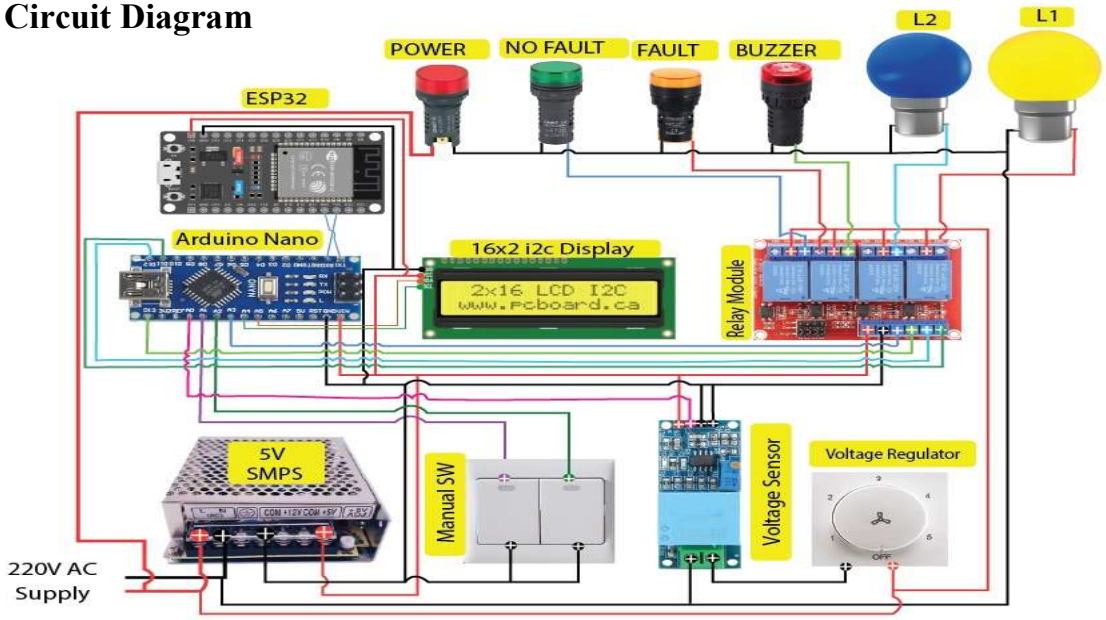


Fig: circuit diagram

3.5 Working principle

Over voltage and under voltage monitoring the ZMPT101 voltage sensor continuously monitors AC voltage levels in real- time it converts thew measured voltage into an analog signal, which is then read by the ESP32. The ESP32 processes this signal and converts it into readable voltage value, which is then displayed on the LCD.

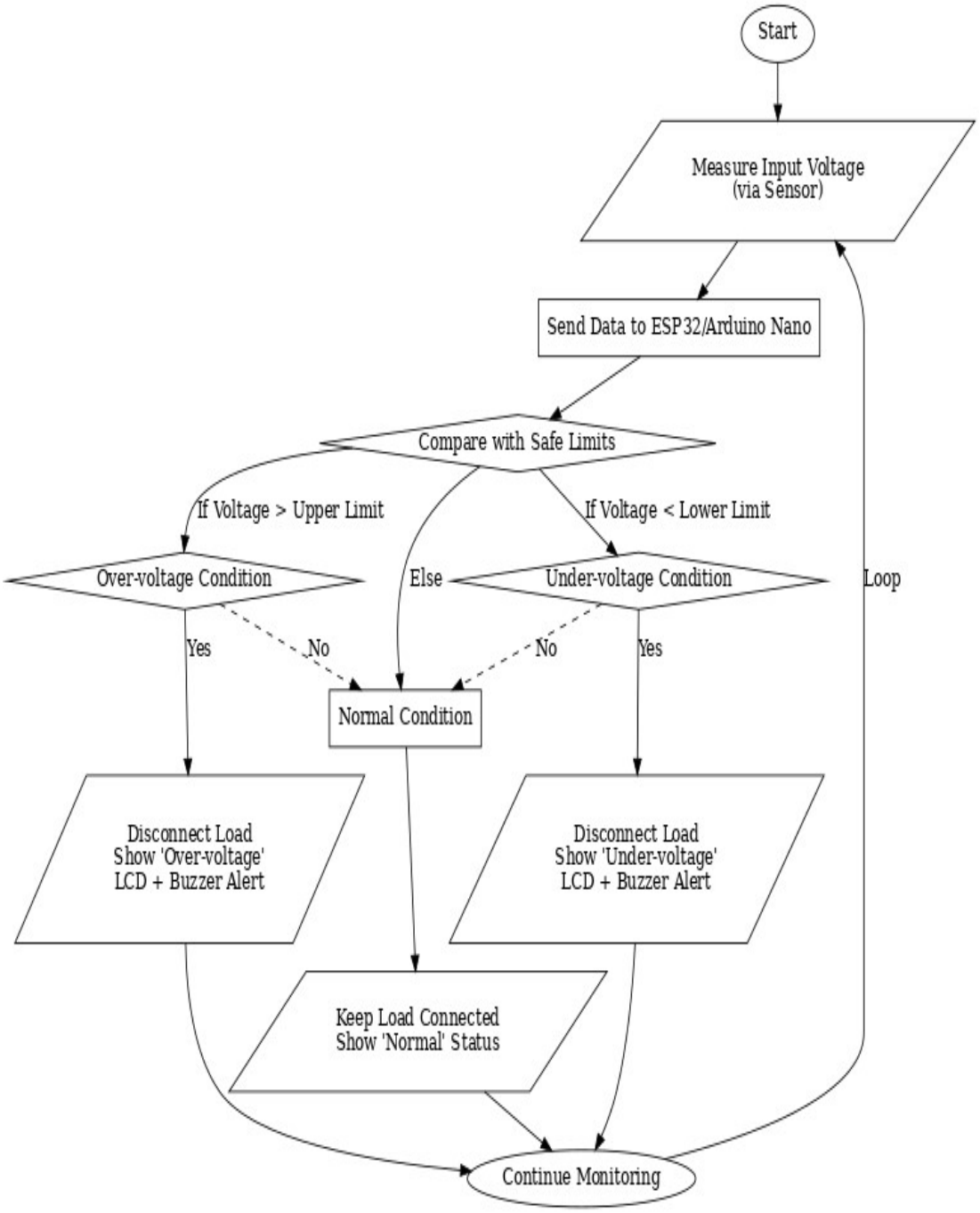
Over voltage and under voltage controlling This IOT based electrical monitoring system ESP32 based system using this system. We can control any kind of load from our smart phone or computer over internet.

The esp32 compares the measured voltage against preset safe. Thresholds for over voltage and under voltage conditions. These thresholds define the safe operational range protecting the connected load from voltage fluctuations.

Relay control over voltage and under voltage is above the over voltage limit the ESP32 outputs a Low signal to the relay. This low signal causes the relay to disconnect the load bulbs preventing potential damage. Normal voltage range.

In this system a 220V AC buzzer has been used. When over-voltage or under-voltage occurs. The alarm will sound.

3.6 Flow chart



An Microcontroller Based Voltage Monitoring and Load Control with Over/Under Voltage protection is designed to monitor the AC mains voltage and disconnect the load if the voltage

goes beyond a safe threshold (either too high or too low). The flowchart for this system outlines the step-by-step logic that the microcontroller (ESP32) follows to protect connected appliances.

The over voltage and under voltage protection system using ESP32 starts when power is switched on, and the ESP32 initializes all components such as the voltage sensor. Relay, LCD display, and buzzer. Predefined threshold values for over- voltage condition are already set in the program. The ESP32 continuously reads the input voltage from the sensor and compares it with the safe limits. If the measured voltage falls below the lower threshold, it is considered an under-voltage condition. And the relay immediately disconnects the load while a warning message is shown on the LCD and the buzzer gives an alert. Similarly, if the voltage rises above the upper threshold, if is detected as an over-voltage condition, and the load is disconnected for safety with an alert on the display and buzzer. However, if the voltage remains within the safe operating range, the relay stays on, the load condition running normal. This process runs continuously in a monitoring loop ensure real-time protection of the electrical system.

3.6 Step by Step operation

- Use an ESP32 to monitor input voltage via its ADC pin.
- Connect a voltage sensor (like ZMPT101B for AC or voltage divider for DC).
- Wire a relay module to control the load based on voltage levels.
- Set under-voltage and over-voltage thresholds in the code.
- Read analog voltage from the sensor using analog Read.
- Convert ADC value to actual voltage using calibration or scaling formula.
- Compare the voltage with preset thresholds.
- If voltage is out of range, turn relay OFF (disconnect load).
- If voltage is within range, turn relay ON (connect load).
- Use digital Write () to control the relay pin.
- Display voltage and status on Serial Monitor (or OLED optionally).
- Add delay for regular voltage checks (e.g., 1 second).
- Ensure proper isolation and safety, especially with AC input.
- Test the system by varying voltage and observing relay behavior.
- Enhance with alarms, web interface, or memory for better functionality.

3.8 Summary

A circuit diagram electrical diagram, elementary diagram, electronic schematic is a graphical representation of an electrical circuit. A pictorial circuit diagram uses simple images of component, while a schematic diagram shows the components and interconnections of the circuit using standardized symbolic representation. The presentation of the interconnection between circuit components in the schematic diagram dose not necessarily correspond to the physical arrangements in the finished device.

CHAPTER 4

RESUTL AND DISCUSSION

4.1 Introduction

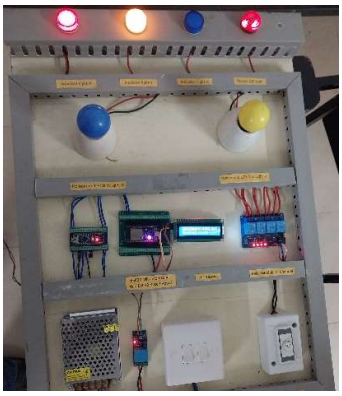
Microcontroller based voltage protection system was tested successfully under various conditions. It accurately detected both over-voltage and under-voltage scenarios using a calibrated voltage sensor. When voltage exceeded the safe range, the system disconnected the load using a relay. Upon return to normal voltage, the system reconnected the load after a 5-second delay to prevent false triggering. All test cases showed the expected behavior, confirming system reliability. The ESP32 provided fast processing and stable performance. The sensor worked well, though occasional noise suggested a need for better filtering. The system is suitable for small-scale applications like homes and offices. However, it lacks multi-phase support and backup power. Future improvements could include Wi-Fi monitoring, logging, and enhanced safety features. The Microcontroller based voltage protection system was tested successfully under various conditions. It accurately detected both over-voltage and under-voltage scenarios using a calibrated voltage sensor. When voltage exceeded the safe range, the system disconnected the load using a relay. Upon return to normal voltage, the system reconnected the load after a 5-second delay to prevent false triggering. All test cases showed expected behavior, confirming system reliability. The ESP32 provided fast processing and stable performance. The sensor worked well, though occasional noise suggested a need for better filtering. The system is suitable for small-scale applications like homes and offices. However, it lacks multi-phase support and backup power. Future improvements could include Wi-Fi monitoring, logging, and enhanced safety features.

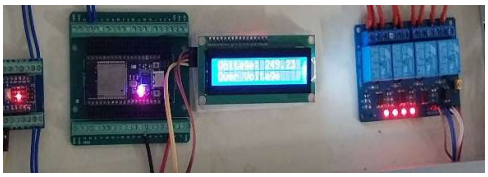
4.2 Result

The Microcontroller Based Voltage Monitoring and Load Control with Over/Under Voltage protection was successfully implemented and tested. The system continuously monitored the input voltage and disconnected the load whenever the voltage went beyond the safe range. It reconnected the load automatically once the voltage returned to normal. The ESP32 ensured fast and reliable operation, protecting appliances from damage. Overall, the system proved to

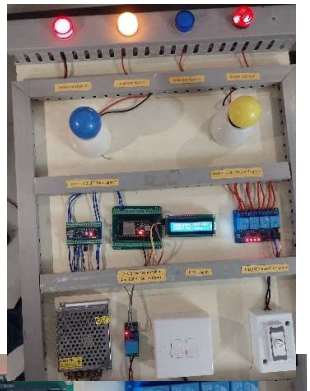
be efficient, accurate, and suitable for real-time voltage protection. The over voltage and under voltage load protection system using ESP32 was successfully implemented and tested. The system continuously monitored the input voltage and disconnected the load whenever the voltage -went beyond the safe range. It reconnected the load automatically once the voltage returned to normal. The ESP32 ensured fast and reliable operation, protecting appliances from -damage. Overall, the system proved to be efficient, accurate, and suitable for real-time voltage protection.

Over voltage





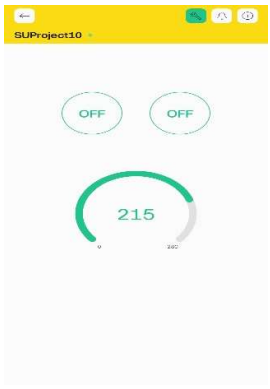
Under Voltage



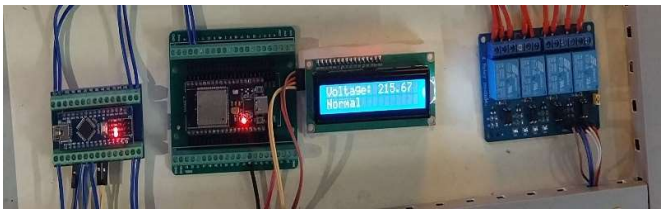


Normal voltage--------









4.3 Advantages of over voltage under voltage system

- Accurate voltage sensing via built-in ADCs for real-time monitoring.
- Relay control through GPIOs to disconnect load on abnormal voltage.
- Wi-Fi/Bluetooth allows remote monitoring, control, and alerts.
- Custom thresholds can be set via web or mobile interface.
- Data logging locally or to cloud for analysis and diagnostics.
- Low power consumption supports 24/7 operation with minimal energy use.
- OTA updates enable remote firmware upgrades without physical access.

4.4 Disadvantages

- ESP32's ADC is inaccurate and noisy, affecting voltage sensing precision.
- It lacks electrical isolation, posing safety risks in high-voltage systems.
- Not real-time safe; delays in response can occur under load or wireless use.
- Power instability can cause ESP32 to reset, leaving loads unprotected.
- Requires complex firmware and lacks hardware-level fail-safe mechanisms.

4.6 Application

- ✓ The ESP32 monitors AC voltage using a sensor like ZMPT101B.
- ✓ If voltage goes below or above safe thresholds, it disconnects the load via a relay.
- ✓ Normal voltage reconnects the load automatically.
- ✓ The system protects appliances from voltage damage.
- ✓ Optional features include display, Wi-Fi alerts, and data logging.

4.7 Summary

The ESP32-based system effectively detects over-voltage and under-voltage conditions to protect electrical loads. It disconnects the load during abnormal voltages and reconnects it when safe levels are restored. The system responds quickly and accurately, ensuring device safety. It can be enhanced with IoT features and better sensors for advanced applications.

CHAPATER 5

CONCLUSION

3.7 Conclusion

- This project successfully implemented an Microcontroller Based Voltage Monitoring and Load Control with Over/Under Voltage protection.
- The system monitors voltage levels in real-time and protects electrical loads by disconnecting them during unsafe conditions.
- Threshold values were set to automatically detect abnormal voltages and trigger a relay-based cutoff mechanism.
- The ESP32 provided fast processing, reliability, and easy integration with sensors and output devices.
- The system is cost-effective, efficient, and suitable for home and industrial applications. It ensures safety and extends the life of connected electrical appliances. Optional features like IoT monitoring and mobile alerts can be added. The compact design makes it scalable and user-friendly. Overall, the system performed as expected with accurate voltage detection and response

3.8 Future scopes Of Modification

In the future, the system can be enhanced with IoT capabilities to enable remote monitoring and control through mobile apps or web dashboards. Integration with cloud platforms would allow real-time alerts and data logging for better analysis and fault tracking. Auto-recovery features with configurable delay timers can prevent unnecessary disconnections during brief fluctuations. Overcurrent and short-circuit protection can be added to make the system more robust and reliable. For industrial applications, multi-phase voltage monitoring and protection can be implemented. The system can also support OTA (Over-the-Air) firmware updates to allow easy upgrades and feature additions. Incorporating an SD card module would enable local storage of

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APPENDIX

```
#include <ZMPT101B.h>

#include <Wire.h>

#include <LiquidCrystal_I2C.h>


#define ZMPT_PIN A0        // Sensor connected to A0

#define FREQ 50.0          // AC frequency (50Hz or 60Hz)


// Pin definitions

const int switch1Pin = A1;

const int switch2Pin = A2;

const int load1Pin = 11;

const int load2Pin = 12;

const int Status = A3;

const int Buzzer = 13;


// Create sensor objects

ZMPT101B voltageSensor(ZMPT_PIN);

LiquidCrystal_I2C lcd(0x27, 16, 2);


// Variables to store load states
```

```
bool load1State = false;

bool load2State = false;


// 1s Timer

unsigned long startMillis;

unsigned long currentMillis;

const unsigned long period = 1000;


// Old voltage for change detection

float oldVoltage = 0;


void setup() {

  pinMode(switch1Pin, INPUT_PULLUP);

  pinMode(switch2Pin, INPUT_PULLUP);

  pinMode(load1Pin, OUTPUT);

  pinMode(load2Pin, OUTPUT);

  pinMode(Status, OUTPUT);

  pinMode(Buzzer, OUTPUT);


  Serial.begin(9600);
```

```
  // Initialize LCD
  lcd.init();
  lcd.backlight();
  lcd.clear();

  // Voltage sensor calibration
  voltageSensor.setSensitivity(220);

  startMillis = millis();
}

void loop() {
  // Read switches (active LOW)
  bool switch1 = digitalRead(switch1Pin) == LOW;
  bool switch2 = digitalRead(switch2Pin) == LOW;

  // Check serial input
  if (Serial.available() > 0) {
    char command = Serial.read();

    switch (command) {
```

```
      case 'A': load1State = true; Serial.println("Load 1 ON"); break;
      case 'B': load2State = true; Serial.println("Load 2 ON"); break;
      case 'C': load1State = false; Serial.println("Load 1 OFF"); break;
      case 'D': load2State = false; Serial.println("Load 2 OFF"); break;
      //default: Serial.print(""); Serial.println(command); break;
    }
  }

  // Read voltage and manage loads
  ZMPT101B_Read();

  // Apply manual control if voltage is normal
  // Load is ON if switch pressed OR serial command active AND voltage is normal
  // Handled inside ZMPT101B_Read()

  delay(50); // small debounce
}

void ZMPT101B_Read() {
  currentMillis = millis();
```

```
if (currentMillis - startMillis >= period) {
  float voltage = voltageSensor.getRmsVoltage(FREQ);

  // Only update if significant change
  if (voltage != oldVoltage) {
     Serial.print("V: "); Serial.print(voltage, 2); Serial.println(" V");

     // Print on LCD
     lcd.setCursor(0,0);
     lcd.print("Voltage: ");
     lcd.setCursor(9,0);
     lcd.print(voltage);
     lcd.print(" V ");

     // Fault detection
     if (voltage < 215) {
       lcd.setCursor(0,1);
       lcd.print("Under Voltage   ");
       digitalWrite(load1Pin, LOW);
       digitalWrite(load2Pin, LOW);
       digitalWrite(Buzzer, LOW); // Alarm ON
```

```
  digitalWrite(Status, LOW);
 }
 else if (voltage > 225) {
  lcd.setCursor(0,1);
  lcd.print("Over Voltage    ");
  digitalWrite(load1Pin, LOW);
  digitalWrite(load2Pin, LOW);
  digitalWrite(Buzzer, LOW); // Alarm ON
  digitalWrite(Status, LOW);
 }
 else {
  lcd.setCursor(0,1);
  lcd.print("Normal          ");
  digitalWrite(Status, HIGH);
  digitalWrite(Buzzer, HIGH);
  // Apply manual / serial control
  digitalWrite(load1Pin, (digitalRead(switch1Pin) == LOW) || load1State ? HIGH : LOW);
  digitalWrite(load2Pin, (digitalRead(switch2Pin) == LOW) || load2State ? HIGH : LOW);
 }

 oldVoltage = voltage;
```

```
    }


    startMillis = currentMillis;
  }
}


#define BLYNK_TEMPLATE_ID   "TMPL6fZdTL6uI"
#define BLYNK_TEMPLATE_NAME "SUProject10"   // <-- add this
#define BLYNK_DEVICE_NAME   "SUProject10"
#define BLYNK_AUTH_TOKEN    "GtTFH_5bZSSesuV3RWJYo_oa9gT1m1gV"


#include <WiFi.h>
#include <BlynkSimpleEsp32.h>



// WiFi credentials
char ssid[] = "KM MOFIZUL";
char pass[] = "1710584064";


// Blynk Virtual Pins
#define VLOAD1   V1   // Button for Load 1
```

```
#define VLOAD2   V2   // Button for Load 2

#define VANALOG  V5   // Analog value display


// Serial communication with Arduino

#define BAUD_RATE 9600


BLYNK_WRITE(VLOAD1) {

  int state = param.asInt();

  if (state == 1) {

    Serial.println("A");   // Load 1 ON

  } else {

    Serial.println("C");   // Load 1 OFF

  }

}


BLYNK_WRITE(VLOAD2) {

  int state = param.asInt();

  if (state == 1) {

    Serial.println("B");   // Load 2 ON

  } else {

    Serial.println("D");   // Load 2 OFF
```

```
  }
}

void setup() {
  Serial.begin(BAUD_RATE);
  Serial.setTimeout(50);

  Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);
}

void loop() {
  Blynk.run();

  // Check if Arduino sent data
  if (Serial.available()) {
    String data = Serial.readStringUntil('\n');
    data.trim();

    if (data.startsWith("V:")) {
      float value = data.substring(2).toFloat();
      Blynk.virtualWrite(VANALOG, value);
```

```
        }


    }

}
```