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ESP32-Based Smart Safety Helmet for Worker Protection

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Abstract - Worker safety is an important concern in industries and other workplace where workers may face hazards such as harmful gases, high temperature, fire and obstacles. This paper presents a Smart Safety Helmet for Workers that helps to monitor these conditions and provide warnings when a dangerous situation is detected. The system uses an ESP32 microcontroller to collect information from different sensors attached to the helmet. A DHT11 sensor is used to measure temperature and an MQ-2 gas sensor is used to detect harmful gases and smoke. A flame sensor helps detect fire, while an HC-SR04 ultrasonic sensor is used to detect obstacles near the worker. The sensor readings are shown on a 16X2 I2C LCD so that the worker can easily view the information. A buzzer gives an alert when the sensor values cross the set safety limits. The system also uses the Blynk IOT platform for remote monitoring. The temperature, gas level, flame condition and obstacle detection can be monitored through the platform, and alerts can be provided when an unsafe condition occurs. The proposed helmet combines different safety features in one device and provides a simple and useful way to monitor common workplace hazards. It can help workers become aware of dangerous conditions and take necessary action at the right time.

Keywords: Smart Safety Helmet, ESP32, DHT11, MQ-2 Gas Sensor, Flame Sensor, IoT, Worker Safety.

I. INTRODUCTION

Occupational safety remains a major concern in workplaces where workers may be exposed to hazardous atmospheres, fire, heat, or physical obstacles. A conventional safety helmet protects the head from certain mechanical impacts, but it does not independently identify changing environmental conditions. A wearable monitoring system can add an early-warning layer by measuring selected environmental parameters and informing the wearer when configured limits are crossed.

The system uses an ESP32 as the central controller and combines four sensing functions: gas/smoke indication, flame detection, temperature and humidity measurement, and short-range obstacle detection. A local LCD and buzzer provide alerts at the helmet, while Blynk IoT enables remote display and notifications over Wi-Fi. The objective of this paper is to present the project as a concise research-style system design, clarify its operating logic, and identify limitations that must be addressed before field deployment.

II. PROBLEM STATEMENT AND OBJECTIVES

Problem statement: A conventional helmet does not continuously monitor environmental hazards or notify the wearer when selected conditions become potentially dangerous. The project addresses this limitation with a wearable, sensor-based prototype that combines local warning and remote monitoring.

- Monitor gas/smoke sensor output, flame status, ambient temperature and humidity, and nearby obstacle distance.
- Process sensor readings on the ESP32 using predefined threshold rules.
- Provide immediate local indication through a 16×2 I2C LCD and passive buzzer.
- Transmit selected values to a Blynk IoT dashboard over Wi-Fi and support configured hazard notifications.
- Document implementation choices and identify the additional validation required for dependable workplace use.

III. PROPOSED SYSTEM ARCHITECTURE

The system follows a sensing–processing–alerting architecture. The MQ-2, flame sensor, DHT11, and HC-SR04 provide input to the ESP32. The controller reads and evaluates the values, determines a status message, updates the LCD, controls the buzzer, and communicates selected measurements to Blynk through Wi-Fi.

Layer	Components	Function

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Sensing	MQ-2; flame sensor; DHT11; HC-SR04	Collect gas/smoke, flame, temperature/humidity, and distance readings.
Processing	ESP32 microcontroller	Read sensors and compare values with configured thresholds.
Local output	16×2 I2C LCD; passive buzzer	Display measurements/status and sound an alarm when a hazard rule is triggered.
Remote monitoring	Wi-Fi; Blynk IoT	Display selected values and support configured notifications.
Power and integration	USB/power source, wiring, prototype board	Supply power and interconnect the modules.

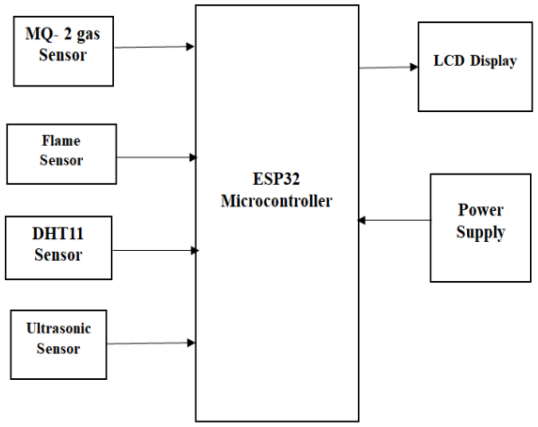


Figure 1. Block Diagram of System

IV. HARDWARE AND SOFTWARE DESIGN:

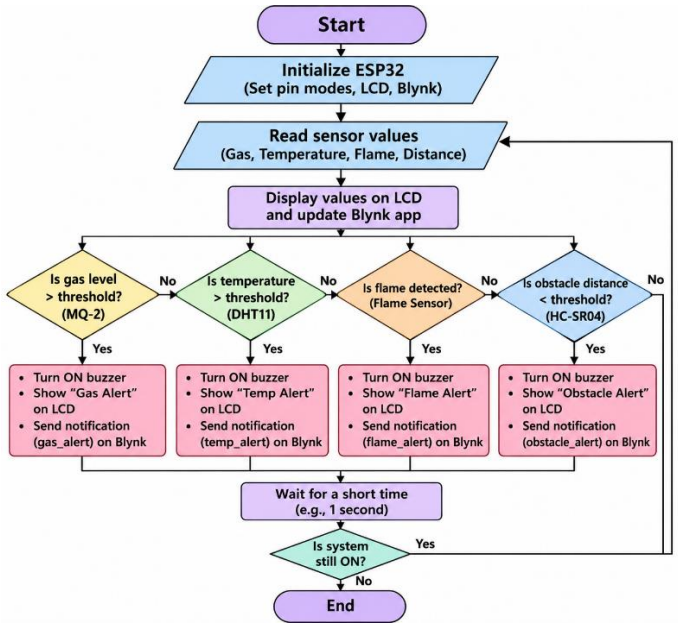
A. Hardware Components

The prototype uses the ESP32 as the controller. The DHT11 is connected to GPIO 4; the MQ-2 analog output is connected to GPIO 34; the flame sensor output is connected to GPIO 27; the HC-SR04 trigger and echo pins are connected to GPIO 5 and GPIO 18 respectively; and the passive buzzer is connected to GPIO 23. A 16×2 LCD with an I2C interface is configured at address 0x27. The report identifies a breadboard, jumper wires, and a USB/power supply for prototype integration.

B. Software Environment

Firmware is written in C/C++ in the Arduino IDE using the Wire, LiquidCrystal_I2C, and DHT libraries. The firmware reads sensor values, calculates ultrasonic distance from echo duration, evaluates hazard rules, updates the LCD and buzzer, and (in the intended integrated configuration) publishes selected readings to Blynk using Wi-Fi. The report lists Blynk virtual pins V0 for temperature, V1 for gas value, V2 for flame status, and V3 for distance, with event names gas_alert, temp_alert, flame_alert, and obstacle_alert.

V. WORKING OF THE SYSTEM:



The development of the Smart Safety Helmet for Workers was carried out in different stages.

First, the ESP32 microcontroller was programmed using the Arduino IDE to control and monitor all the connected sensors and output devices. The MQ-2 gas sensor, flame sensor, DHT11 temperature and humidity sensor, and HC-SR04 ultrasonic sensor were interfaced with the ESP32 to detect hazardous conditions such as gas leakage, fire, high temperature, and nearby obstacles.

Second, the output devices including the 16×2 I2C LCD and passive buzzer were programmed to provide immediate information and warning alerts. The LCD displays the temperature, gas status, flame status, and obstacle distance, while the buzzer produces an alert when any predefined safety threshold is exceeded.

Finally, Blynk IoT was integrated with the ESP32 to provide wireless monitoring of the detected parameters. The sensor values are transmitted through Wi-Fi and

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displayed on the Blynk application using widgets for temperature, gas level, flame status, and obstacle distance. Alert notifications are generated when dangerous conditions are detected.

The complete system was then tested by simulating different hazardous conditions, including gas leakage, flame detection, increased temperature, and nearby obstacles. The sensor readings, LCD display, buzzer alerts, Wi-Fi communication, and Blynk monitoring were verified to ensure that the Smart Safety Helmet operates correctly and provides timely safety information to the worker.

VI. RESULTS:

The developed Smart Safety Helmet for Workers demonstrates the practical integration of ESP32, MQ-2 gas sensor, flame sensor, DHT11, HC-SR04 ultrasonic sensor, I2C LCD, passive buzzer, Wi-Fi, Blynk IoT, and email notifications into a single safety monitoring system. The system continuously monitors important environmental conditions and provides timely local and remote alerts when unsafe conditions are detected. Thus, the developed system provides a practical IoT-based approach for improving worker safety, hazard detection, real-time monitoring, and emergency awareness

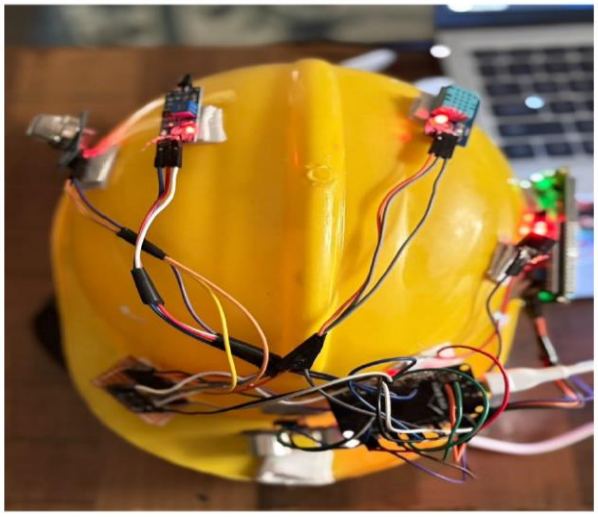


Figure 2: Smart Helmet Hardware components



Figure 3: Smart Helmet fire alert Display

VII. ADVANTAGES OF THE SYSTEM:

- **Real-Time Hazard Detection:** The system continuously monitors the worker's surrounding environment using multiple sensors.
- **Immediate Warning Alerts:** When a hazardous condition is detected, the **passive buzzer** produces an audible warning and allows worker to become aware of the danger immediately and take appropriate safety precautions.
- **IoT-Based Remote Monitoring:** The **ESP32** provides Wi-Fi connectivity and communicates with the **Blynk IoT platform**. Sensor readings can therefore be monitored remotely through the connected mobile application.
- **Email Notifications:** The system can send **email notifications** when predefined hazardous conditions are detected. This allows a concerned person to receive information about gas leakage, high temperature, flame detection, or other configured safety alerts.

VIII. CONCLUSION:

The **Smart Safety Helmet for Workers** is designed to provide an additional layer of protection for workers operating in hazardous environments such as construction sites, factories, mines, and chemical industries. The main objective of this project is to detect different workplace hazards in real time and provide immediate warnings to the worker. The system uses an ESP32 microcontroller, MQ-2 gas/smoke sensor, flame sensor, DHT11 temperature/humidity sensor, HC-SR04 ultrasonic sensor, LCD, buzzer, and Blynk IoT monitoring. Whenever a hazardous condition is detected, such as **excessive gas concentration, high temperature, flame, or an obstacle**

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within the defined distance, the system activates a **buzzer** to alert the worker. This immediate warning can help the worker become aware of dangerous conditions and take necessary precautions. The project provides a **compact, portable, low-cost, and multi-functional safety solution** by combining several monitoring functions into a single helmet. It demonstrates the practical use of embedded systems and sensor technology for improving workplace safety.

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