IoT Multi-Purpose System for Energy Monitoring and Safety

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PHYSICS MAGIC FAIR

Abstract

Many houses, institutions, and factories suffer from excessive consumption of electrical current, in addition to safety issues including gas leakage and electrical fires.
According to the Civil Defense Statistical Report 1439H, electrical short circuits accounted for most human and material losses, with a total of 828 deaths and injuries at a rate of 42.6% from all the cases recorded, and the financial losses reached 80,275,385 SAR with a rate of 73.3% of the total damages. [1]
These statistics show the serious risks of improper usage of electricity in homes and industry.
This project is designed to integrate energy consumption monitoring with safety features for homes, factories, and industrial facilities. The system tracks the energy usage of devices, rooms, and buildings, providing users with detailed cost data for each device and the overall building. This data is displayed through an IoT-based platform using the Blynk application, where the circuit is connected to the internet, allowing users to remotely monitor energy consumption and control devices by turning them on or off.
For safety, the system includes gas and smoke sensors. The gas sensor detects leaks, triggers an alarm, sends instant alerts through the IoT platform, and activates safety actions such as opening windows and shutting off the gas supply. The smoke sensor detects smoke, sends alerts via Blynk, and contacts emergency services if a fire is detected. The system provides both energy management and safety alerts, offering real-time monitoring and control.

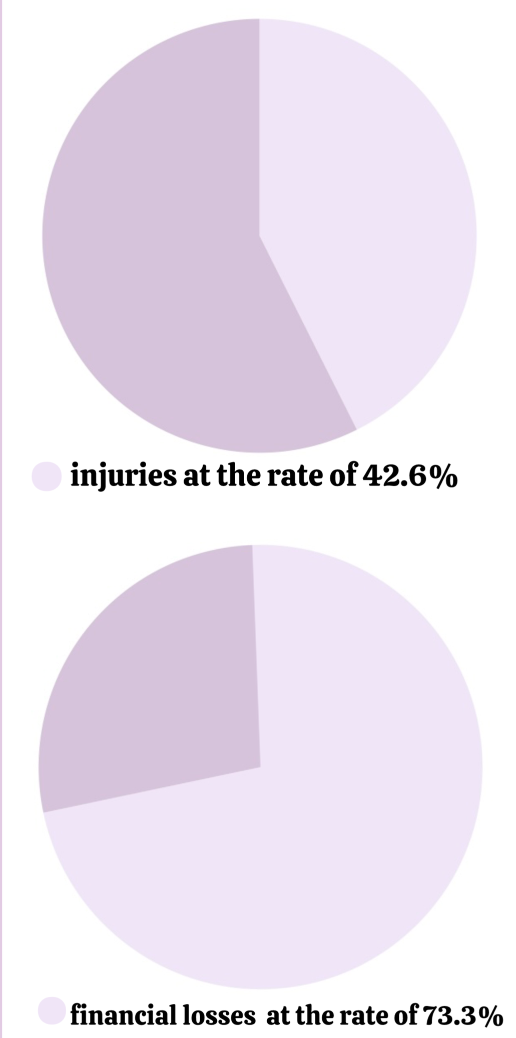

Fig. 1 Injuries and Financial losses due to safety issue

Theoretical Background

1- ESP32

The ESP32, built on the Xtensa 32-bit LX6 processor, performs logical operations (AND, OR, NOT) similar to those studied in electronics courses [2]. These bitwise instructions represent the same fundamental logic used in combinational and sequential circuits, allowing the ESP32 to efficiently process digital signals and control outputs through its GPIO and PWM modules for reliable operation in embedded system applications [3].

2- Relay

A relay is an electrically operated switch that uses an electromagnetic coil to open or close another circuit. When a small current flows through the coil, it creates a magnetic field that moves the contact, allowing higher current to pass through. This lets low-power devices, like microcontrollers, control high-power loads safely while keeping control and power circuits isolated. [5]

3- MQ Sensor

The MQ sensor is used to detect various gases and smoke. It contains a sensitive layer that changes its electrical resistance when exposed to target gases. The sensor provides an analog output that varies with the concentration of the detected substance. [6] Some MQ sensors include a comparator module that converts the analog signal into a digital output, which switches between HIGH and LOW when a set threshold is reached. This allows the sensor to be used for monitoring gas levels, controlling alarms, or triggering other devices based on gas concentration.[7]

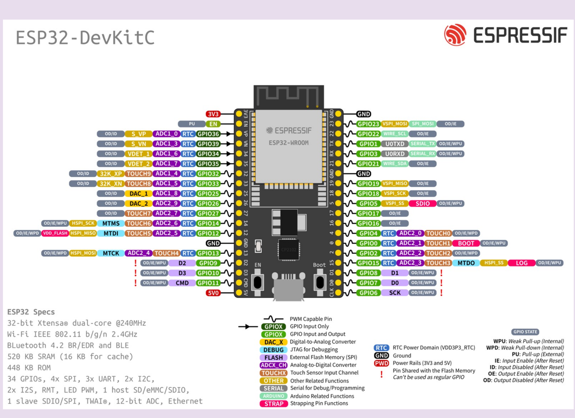

Fig. 2 ESP32 Functional Block Diagram [4]

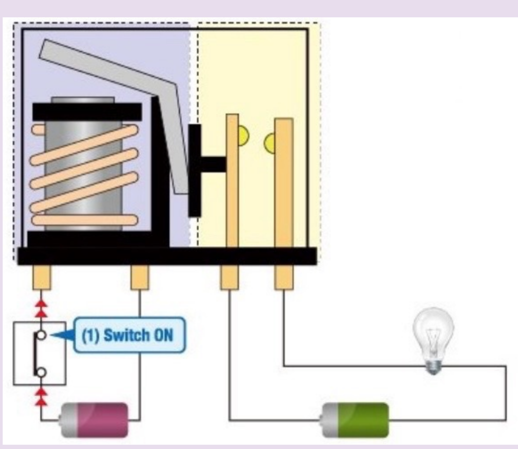

Fig. 3 Operating Mechanical Relay [5]

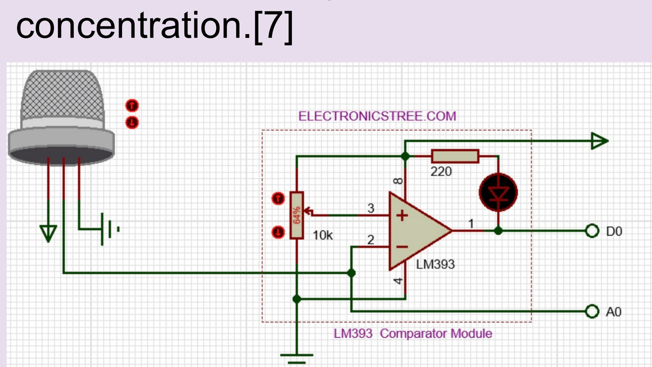

Fig. 4 MQ sensor [6]

Objectives

1. Save energy and contribute to sustainability goals through energy conservation and efficiency.
2. To provide early warning against gas leakage for better safety.
3. To apply theoretical concepts learned in the course: Sensors, Microcontrollers, and IoT Communication.
4. Design a smart, cost-effective, user-friendly system that is suitable for multiple environments.

Equipment

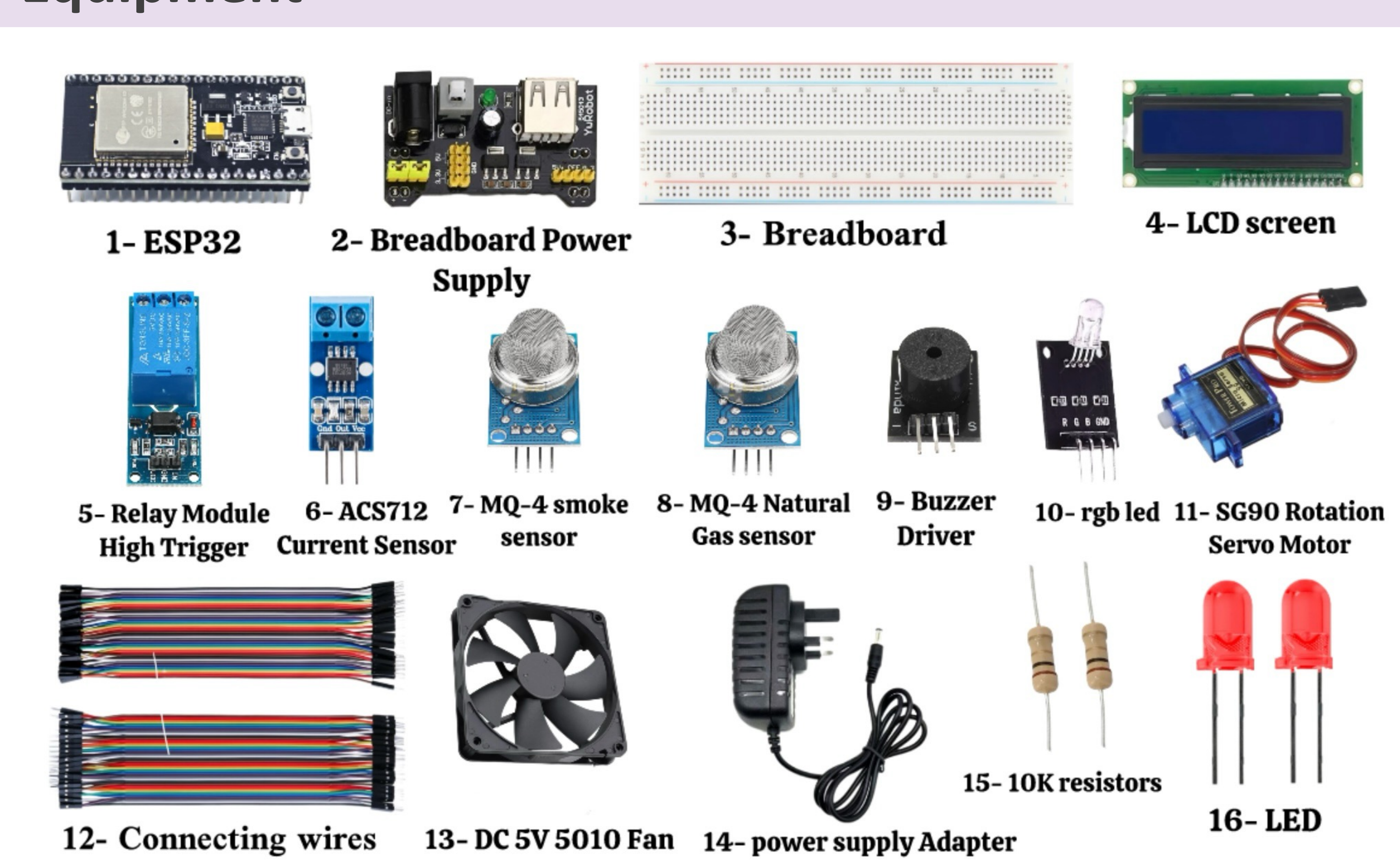

Fig. 5 Equipment used in the project

Methodology

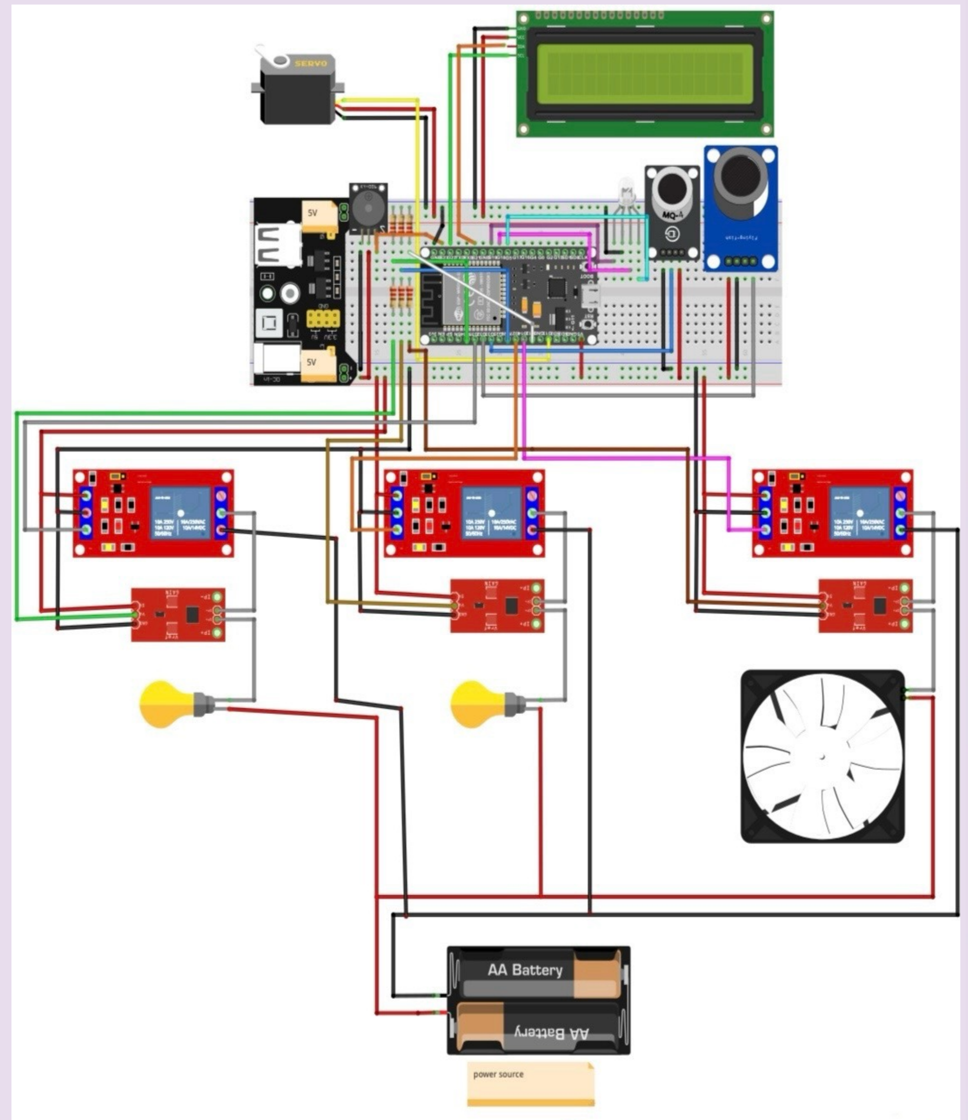

Fig. 6 circuit diagram

Short video that explain how you connect the circuit:

Connection steps

1- The ESP32 and the power supply were connected to the breadboard. The power supply was connected to the breadboard's positive and negative rails, so that one side serves as ground (GND) and the other provides power to the entire circuit.

2- The RGB LED, Buzzer Driver, Smoke Sensor, and Natural Gas Sensor were connected.

3- The resistors were connected, and the previous components were linked to ground (GND) and voltage (VCC).

4- The Relay and the Current Sensor were connected to ground (GND) and voltage (VCC).

5- All the previous components were connected to the ESP32.

6- A second circuit for the load, whose power consumption is being measured, was built, and its positive terminals were connected to the battery.

7- The Relay and the Current Sensor were connected together; then the Relay was connected to the negative terminal of the new circuit, and the Current Sensor was connected to the negative terminal of the circuit.

Results

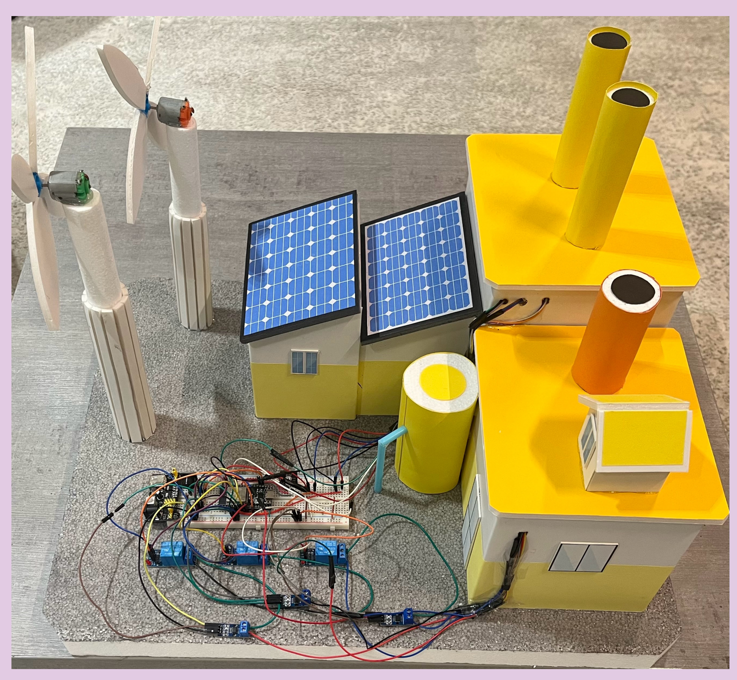

Fig. 7 Final prototype

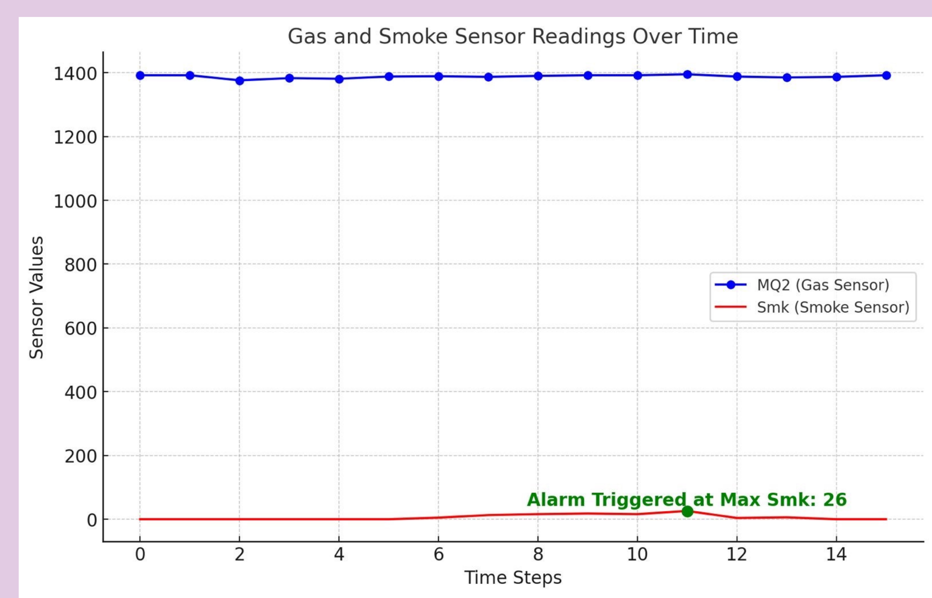

Fig. 9 shows the MQ2 gas sensor stable around 1390, while the smoke sensor peaks at step 12, triggering the alarm.

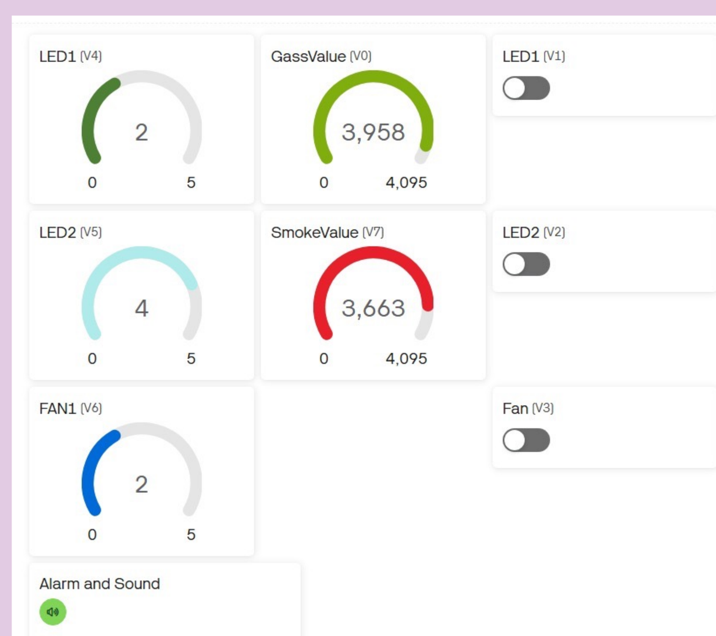

Fig. 8 The Web dashborde

The ESP32 serves as the central controller of our smart safety and energy system. It continuously monitors gas, smoke, and current sensors, processes the data, and updates a web dashboard with real-time device status, energy consumption, and associated costs. The system can alert and identify affected rooms, automatically shut gas lines, open windows, or contact emergency services if necessary. Demonstrated on a miniature factory model, it also manages devices such as fans and lights, ensuring constant monitoring, efficient energy tracking, and comprehensive protection.
A QR code is provided to watch a video of the project in operation.

Discussion

As shown in Final Circuit Model above, the system's methodology demonstrates an efficient integration of all components. The ESP32 functions as the central controller, linking the sensors, relay, and indicators to ensure coordinated operation. The placement of the current sensor and relay within the load circuit enables accurate power-consumption measurement, while the gas and smoke sensors enhance the safety layer. Overall, the configuration confirms the system's effectiveness in providing both energy monitoring and hazard detection.

Challenges & Recommendations

Challenges
- Challenges in coding and debugging the sensors and website interface.
- Difficulties in manually integrating two circuits without a pre-designed layout.

Recommendations
- Enhancing the website interface to make it more interactive and user-friendly.
- Employ advanced and more precise sensors in the next version.
- Add mobile notifications to alert users in real-time in case of danger.
- Extend the system to include temperature and humidity monitoring for greater safety.

We sincerely thank our near-peer advisor, Haneen Aljebarh, for supporting us as part of "What If" initiative.

References

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[2](Xtensa ISA, pp. 43–44)
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