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Smart Embedded IOT System Using ESP32 Microcontroller

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Abstract: This project develops a smart embedded IoT system using the ESP32 microcontroller to monitor environmental conditions and provide automated responses. The system employs three sensors: an LPG sensor to detect gas leakage, a CO_2 sensor to evaluate indoor air quality, and a BMP180 sensor to measure temperature and pressure. Data from these sensors is processed by the ESP32 and made accessible through IoT connectivity for remote monitoring. In addition to sensing, the setup includes two relay modules: one operates a fan to enhance ventilation when harmful gases are present, while the other controls a light for intelligent illumination. By integrating sensing, communication, and automation, the system offers a cost-effective solution that improves safety, energy efficiency, and comfort in residential and industrial environments.

***Index Terms* -** Sensors, relays, ESP 32 Controller, LCD display.

I. Introduction

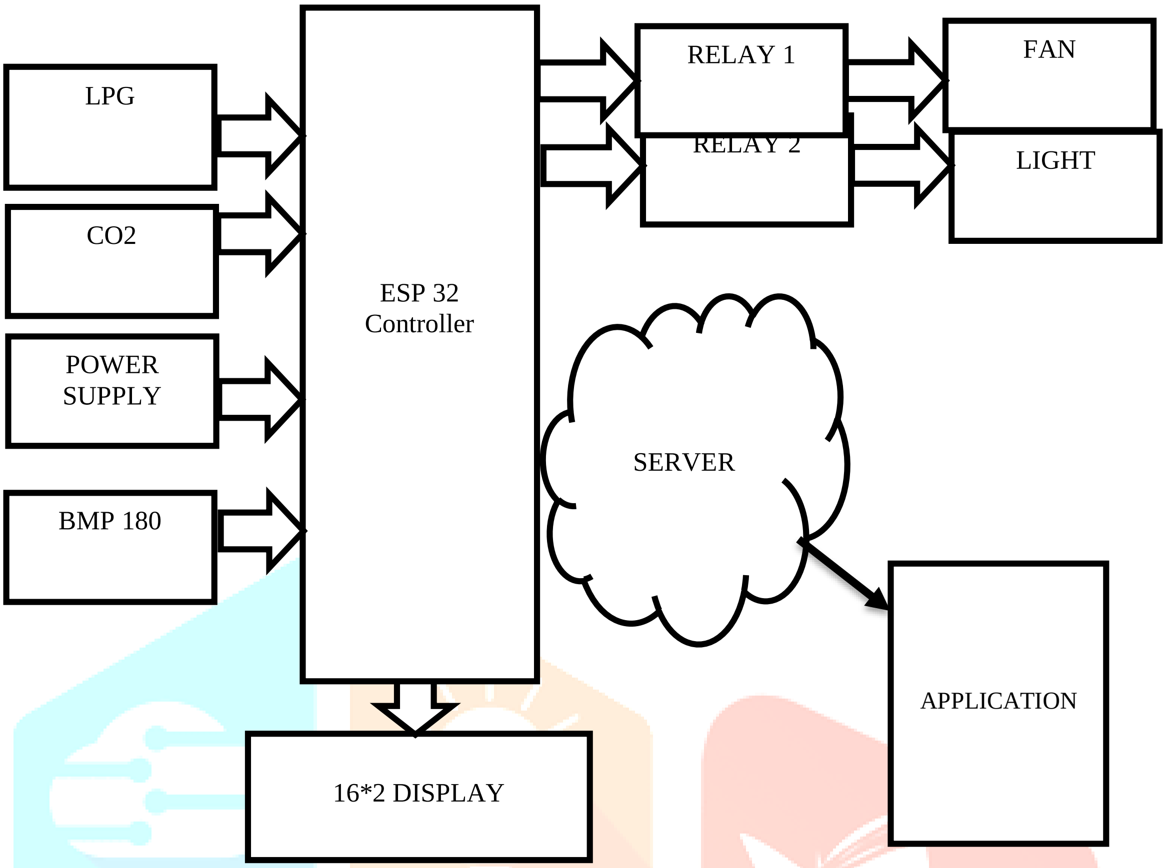
Interlinked smart systems (IoT) has emerged as one of the most notable technological trends of recent years, transforming the way devices interact, share information, and perform tasks. By enabling smooth interaction among sensors, control units, and end users, IoT systems provide intelligent solutions applicable in daily scenarios such as smart homes to industrial automation. Essentially of these systems are embedded devices, which integrate sensing, processing, and communication in a compact and efficient manner. The ESP32 microcontroller is ideal for constructing such systems due to its built-in integration of Wi-Fi and Bluetooth communication, minimal power usage, and ability to interface covering multiple sensors and actuators. Its flexibility allows developers to design scalable and cost-effective IoT solutions tailored to specific requirements.

This project focuses on developing a smart embedded IoT device that combines sensing, processing, and automation. It integrates three sensors—LPG, CO_2, and BMP180—for monitoring environmental conditions, along with two relay modules that control a fan and a light. The system not only processes data locally but also supports IoT-based connectivity, enabling remote monitoring and intelligent decision-making. By addressing both safety and convenience, the project demonstrates how IoT systems can strengthen quality of life and energy efficiency in residential and industrial contexts.

II. Objectives

The main goal of this project is that the rapid growth of interlinked smart systems (IoT) has increased the need for embedded systems which are intelligent, adaptable, and energy-efficient. Among the available options, the ESP32 microcontroller is an excellent solution due to its low cost, integrated Wi-Fi and Bluetooth connectivity, and compatibility with a wide variety of external devices.

III. Block Daigram Representation



IV. Components

4.1 ESP 32 Microcontroller

The ESP32 is a compact yet powerful microcontroller that integrates key components such as an antenna, amplifiers, filters, and a power management unit. It operates on a 2.4 GHz dual-mode Wi-Fi and Bluetooth chip built on low-power 40 nm technology, ensuring reliable wireless connectivity and energy efficiency. Compared to the ESP8266, it offers enhanced performance, advanced features, and greater flexibility. Paired with the Arduino platform, the ESP32 enables beginners and developers to easily experiment with sensors, modules, and IoT applications, making it suitable for both learning and prototyping.

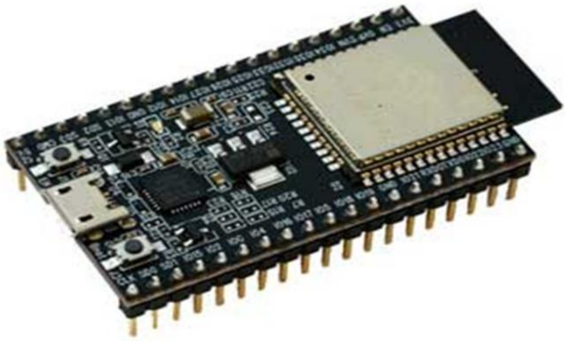


Fig 4.1: ESP 32 Microcontroller

4.2 BMP 180 Sensor

The BMP180 is a digital sensor suitable for observing air pressure conditions and includes a built-in temperature sensor to enhance accuracy. Its upgraded version, the BME280, extends functionality by also measuring humidity, alongside pressure and temperature, with high precision across a wide operating range.

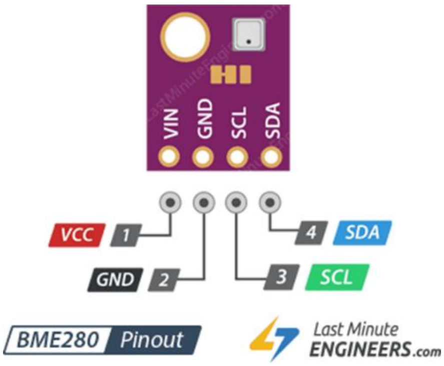


Fig 4.2: Pinout of BMP 180

4.3 LCD Display

A Liquid Crystal Display (LCD) is a common electronic screen widely used in embedded projects and consumer devices. The 16x2 LCD module is especially popular due to economical nature, simple usability, and ability to display a wide range of characters, including custom symbols and basic animations, unlike seven-segment or LED displays. It operates with two key registers: the command register, which manages functions such as display control, clearing the screen, and cursor positioning, and the data register, which stores the ASCII values of the characters to be displayed.

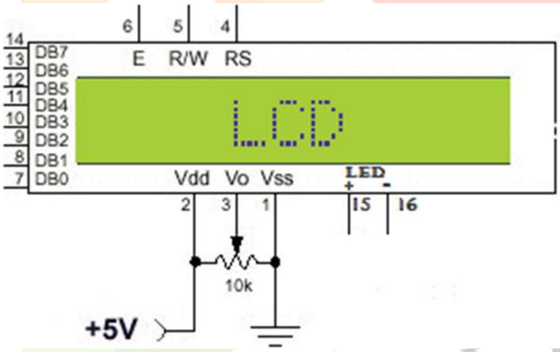


Fig 4.3: LCD Display

4.4 Relay

A relay is an electromechanical switch that operates through a magnetism produced when electricity travels through its coil. This magnetic force shifts a lever to change the circuit connection, allowing the device to toggle between two states. Often designed as a double-throw switch, it can alternate control between two separate circuits.

Fig 4.4: Relay

4.5 Power supply

A power supply refers to a source that delivers electrical energy. Any device or system designed to provide electrical or other forms of energy to an output load or a set of loads is known as a power supply unit (PSU) or power source. In this project, a +5 V DC regulated power source is obtained from the designed and implemented power supply unit. The figure illustrates the circuit layout developed to achieve the +5 V regulated DC output required for the system. A full-wave rectifier makes use of two or more diodes arranged in such a way that the load current maintains the same direction during both the positive and negative half cycles of the AC input. In this project, a +5 V DC regulated power source is obtained from the designed and implemented power supply unit. The figure illustrates the circuit layout developed to achieve the +5 V regulated DC output required for the system. A full-wave rectifier makes use of two or more diodes arranged in such a way that the load current maintains the same direction during both the positive and negative half cycles of the AC input. Terminal regulator ICs, such as the 78xx family for positive voltage regulation and the 79xx series for negative voltage regulation, come with features like built-in foldback current limiting and thermal protection. These integrated circuits are produced in different versions, offering a range of output voltages and current ratings, which are specified by their part numbers. In these regulators, the 'xxx' suffix specifies both current and voltage ratings. The initial digit(s) in the suffix denote the current capacity, while the last two digits indicate the output voltage. For instance, the 7805 regulator provides a +5 V DC output with a defined current rating a 1a for example, a 79L15 regulator delivers a –15 V output with a maximum current capacity of 100 mA.

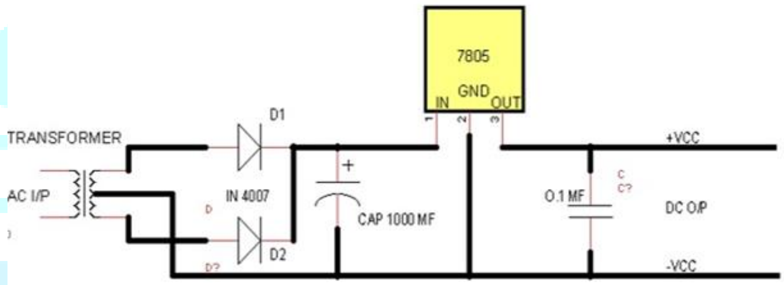


Fig 4.5: Power supply circuit

4.6 LPG Sensor

This project makes use of a gas detection module like the MQ-2 or MQ-6, both of which are commonly used to detect gas leaks in environments such as kitchens, workshops, or industrial areas. These sensors are sensitive to gases namely LPG, methane, and propane and smoke. They function by detecting changes in resistance when exposed to gas, which results in a varying analogy signal output built upon the gas concentration dispersed in the air.

Fig 4.6: LPG Sensor

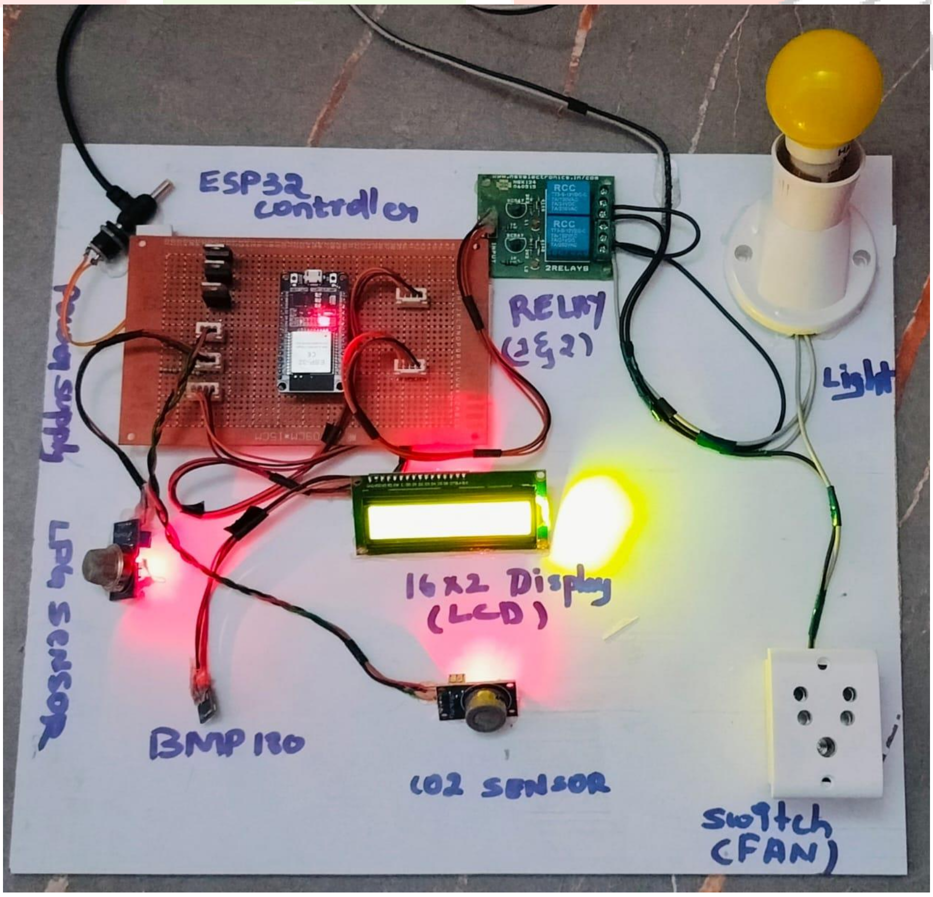
4.7 CO2 Sensor

A CO_2 sensor is an electronic device used to measure the concentration presence of carbon dioxide in the surrounding air. It typically works using infrared or chemical sensing principles to detect gas levels and provide readings in digital or analogy form. These sensors have widespread usage in monitoring air quality, controlling ventilation systems, and ensuring safety in environments where excessive CO_2 buildup may occur.

Fig 4.7: CO2 Sensor

V. RESULTS AND DISCUSSION

This project demonstrates the application of an IoT-based embedded system for smart monitoring and control of environmental conditions. It integrates LPG, CO_2, and BMP180 sensors to measure multiple parameters at the same time, making it suitable for residential, commercial, and industrial use. The inclusion of relays allows automated operation of fans and lights, improving both safety and energy efficiency by activating devices only when required. IoT connectivity further extends system functionality by enabling remote monitoring and control, offering greater convenience and adaptability. The design is also scalable, allowing additional sensors or actuators to be integrated with minimal modifications.



VI. FUTURE SCOPE

Although this design has exhibited that the proposed smart embedded IoT system can be further enhanced to increase its efficiency, scalability, and practicality. Incorporating additional sensors, such as smoke, flame, humidity, or advanced air quality detectors, would expand its monitoring and safety features. A dedicated mobile application with user-friendly dashboards, real-time charts, and instant alerts via SMS, WhatsApp, or email could improve accessibility and responsiveness. Linking the system to cloud services would enable long-term data storage and analysis, creating opportunities for machine learning to predict trends, detect anomalies, and optimize performance. Beyond simple threshold-based switching, AI-driven automation could provide more intelligent control of appliances, ensuring energy-efficient operation. The system could equally be adapted to manage devices like air conditioners, alarms, exhaust fans, or purifiers, making it suitable for larger residential, commercial, or industrial applications. Finally, adopting solar power, backup batteries, and deeper utilization of the ESP32's low-power modes could improve portability and ensure continuous operation with reduced energy consumption.

VII. Conclusion

The development of this ESP32-based system demonstrates how modern microcontrollers can deliver cost-effective, flexible, and efficient solutions for real-world applications. By integrating multiple sensors, it enables real-time monitoring of environmental and physiological parameters while supporting wireless connectivity through wireless protocols such as Wi-Fi and Bluetooth for remote access and control. Its adaptability makes it well-suited to diverse uses such as smart homes, health tracking, and automation, while its compact size and minimal power consumption needs also support portable devices. Beyond practical applications, the ESP32 ensures a superior learning platform, helping users gain skills in sensor integration, wireless communication, and data management. Overall, this project highlights the potential of IoT innovation, showing how a single microcontroller can power versatile and scalable smart systems.

VIII. Advantages

1. Real time response.
2. Wide applicability.
3. Easy expandable.
4. Multiple sensing capabilities.
   Built in connectivity.

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