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Advancing Workplace Safety with IOT Enabled Industrial Monitoring

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Abstract—This project focuses on advancing workplace safety through an IoT-enabled industrial monitoring system that integrates diverse sensors with an Arduino Mega 2560 microcontroller. The system monitors key environmental and operational parameters in real-time. A DHT11 sensor measures temperature and humidity, while fire and gas sensors (MQ135 and MQ2) detect fire hazards and harmful gases. An MLX90614 infrared sensor provides non-contact temperature readings, and an ultrasonic sensor monitors distance for potential obstructions. Additional components like an LDR sensor assess light intensity, and a motor driver with a DC motor automates mechanical responses. The system employs a NodeMCU for cloud-based data transmission, enabling real-time analysis and remote monitoring via IoT platforms. Alerts are communicated locally through an LCD display and a buzzer, with critical notifications sent via GSM. Visual indicators like bulbs and a CPU fan enhance safety measures. Powered by a 12V adapter and a reliable power supply, the system offers a comprehensive solution for ensuring workplace safety by facilitating early hazard detection and rapid response.

I. INTRODUCTION

Using an Arduino Mega 2560 microcontroller, this project creates an Internet of Things-based industrial monitoring system to increase workplace safety. To monitor critical environmental and operating factors, the system uses a variety of sensors, including temperature, humidity, fire, gas, infrared, ultrasonic, and light sensors. A NodeMCU is used for cloud-based data transmission for real-time processing and remote monitoring. A local LCD displays alerts, while messages are sent through a buzzer and GSM alerts. Visual alarms in the form of bulbs and a CPU fan serve as extra safety measures. Operated by a 12V adapter, the system provides advance hazard detection, fast response, and remote monitoring to provide a secure working condition.

II. LITERATURE SURVEY

Survey on IoT-Based Industrial Safety Monitoring System

This survey is an overview of the application of IoT in industrial safety, particularly sensor technologies (such as fire and gas detection) and their implementation on cloud platforms for remote monitoring. It elaborates on the challenges and advantages of implementing IoT for enhancing workplace safety, as well as the real-time response systems for fire, gas leakages, and environmental monitoring.

Survey of Sensor Integration in IoT-Based Monitoring Systems

The paper surveys several sensors utilized in industrial IoT systems, such as temperature, humidity, gas, and distance sensors. The paper investigates sensor integration with microcontrollers such as Arduino and cloud platforms for storing and real-time analysis of data. The paper also points to the integration of motor drivers and actuators to enable automated mechanical responses.

Cloud-Based Industrial Monitoring Systems: A Comprehensive Survey

This review discusses different cloud-based monitoring systems, with an emphasis on industrial safety and remote monitoring using IoT platforms. It addresses how IoT-powered systems can send sensor data to cloud servers in real-time, allowing for analytics and decision-making. It also highlights the need for real-time alerts, notifications, and automatic responses in industry.

Real-Time Industrial Risk Detection using IoT Technologies

The article explains real-time threat detection by the help of IoT and sensors such as smoke sensors, gas sensors, and environmental sensors. The article explains how sensors are used for threat detection and the automation of responses such as ringing alarms, sending GSM messages, or controlling mechanical devices such as fans and lights. The article also briefly explains the use of microcontrollers such as Arduino for sensor and actuator interfacing. As industries increasingly adopt IoT solutions, the ability to manage risks effectively not only improves operational efficiency but also fosters a culture of safety and sustainability in the workplace

III. PROPOSED METHOD

The suggested IoT-based industrial monitoring system overcomes these limitations by combining multi-type sensors and IoT with an Arduino Mega 2560 microcontroller. The system keeps track of essential parameters like temperature, humidity, gas composition, fire risk, and light intensity in real-time. The information is displayed locally on an LCD and sent to IoT platforms over a NodeMCU for remote processing. The alert is immediately communicated by way of a buzzer and SMS alerts, allowing for early intervention. The use of automated components such as a motor and CPU fan aids in workplace safety by reducing man-in-loop actions and providing quick hazard elimination.

Block Diagram:

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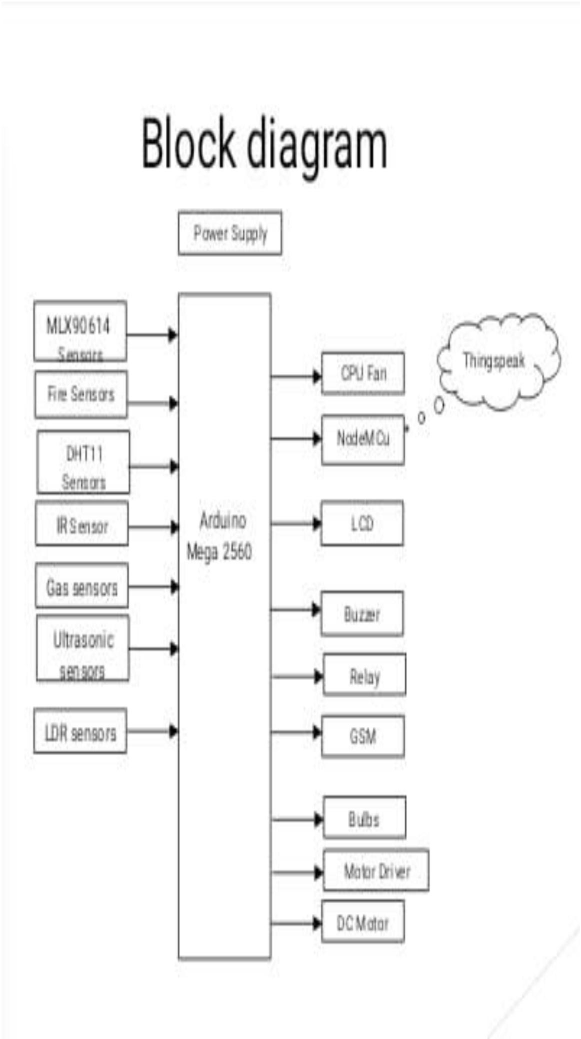


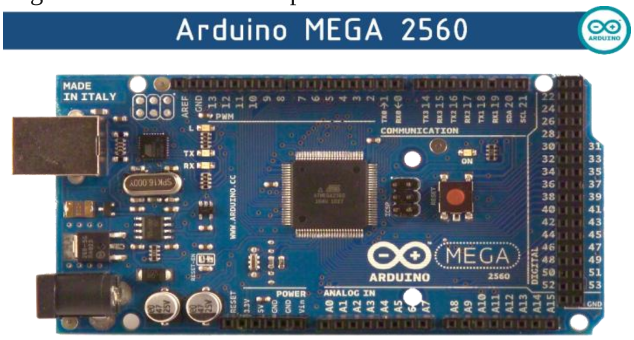
Hardware components:
Arduino Mega 2560
LCD
MLX90614 sensor
IR sensor
Buzzer
Fire sensor
MQ135 and MQ2 gas sensors

1. ARDUINO MEGA 2560

The Arduino Mega 2560 is a microcontroller board based on the ATmega2610. It has a 16 MHz crystal oscillator, four UARTs (hardware serial ports), a USB connector, a power jack, an ICSP header, a reset button, and 54 digital input/output pins, 14 of which can be utilized as PWM outputs. Everything required to power the microcontroller is included; you may use a USB cable to attach it to a computer or an AC-to-DC adapter or battery to charge it.

Programming

The Arduino Software is used to program the Mega 2560 board (IDE). Consult the tutorials and references for more details.
An external hardware programmer is not necessary to upload fresh code to the ATmega2560 because it comes preloaded with a bootloader. It uses the STK500 protocol from the beginning (see the C header files). As an alternative, you can disable the bootloader and program the microcontroller directly through the ICSP (In-Circuit Serial Programming) header using Arduino ISP or a comparable tool; see these instructions for more information. The firmware source code for the ATmega16U2 (or 8U2 for the rev1 and rev2 boards) is available in the Arduino repository. The ATmega16U2/8U2 comes with a DFU bootloader that can be activated by:
On Rev1 boards: by bridging the solder jumper on the back of the board (near the map of Italy) and then resetting the 8U2. A resistor that pulls the 8U2/16U2 HWB connector to ground makes it simpler to put Rev2 or later boards into DFU mode. The DFU programmer (Mac OS X and Linux) or Atmel's FLIP software (Windows) can then be used to install a new firmware. As an alternative, you can use an external programmer to leverage the ISP header and replace the DFU bootloader.



Warnings:

The Mega 2560 has a resetting polyfuse to prevent overcurrent and short circuits in the USB ports on your computer. Although most computers have built-in security, the fuse adds an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will instantly terminate the connection until the short or overload is remedied.

Power:

The Mega 2560 can be powered via USB or an external power supply. It selects the power source on its own.
An AC-to-DC adapter (wall-wart) or a battery can provide external (non-USB) power. Insert a 2.1mm center-positive plug into the power connection on the board to attach the adapter. An external 6–20-volt supply can power the board. If a supply lower than 7V causes the 5V pin to produce less than 5 volts, the board may become unstable. The voltage regulator could overheat and burn the board if

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the supplied voltage is higher than 12V. The ideal voltage range is 7 to 12 volts.

2.Node MCU

The NodeMCU is an open-source Internet of Things platform designed to facilitate the development of connected devices and applications. It is based on the ESP8266 Wi-Fi module. The board's numerous GPIO pins enable it to generate PWM, I2C, SPI, and UART serial communications in addition to connecting to other peripherals. Hardware and firmware are the two main divisions of the module's interface. The former is based on the ESP8266 Wi-Fi SoC, and the latter is based on the ESP-12 module.

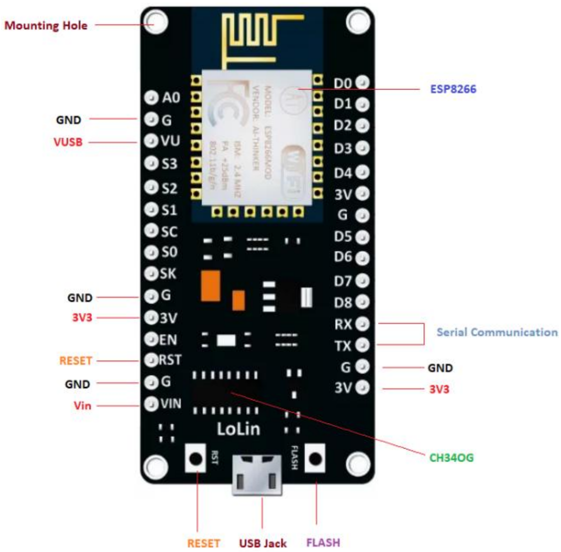

Figure: NodeMCU

The firmware is based on Lua, a fast and easy scripting language that connects you to a well-known developer community and provides a straightforward programming environment. On the other hand, open source firmware enables you to continuously modify the interface and rebuild, tweak, and modify the present module until you can customize it to your needs.

3.ULTRASONIC SENSOR

An ultrasonic sensor is a multifunctional device that uses high-frequency sound waves to measure distance or identify the presence of objects. Ultrasonic sensors are used in intrusion alarm systems, automatic door openers, and automobile backup sensors, among other devices. New application areas, like industrial automation equipment and automotive electronics, are expanding in tandem with the rapid progress of information processing technology. Using its own manufacturing process for piezoelectric ceramics, which it has perfected over many years, Murata has produced several small, extremely effective ultrasonic sensor kinds. This catalog contains information that will help you make the most of our ultrasonic sensors.

Operational HC-SR04 Ultrasonic Sensor as can be seen above, the four-pin HC-SR04 Ultrasonic (US) sensor module has the labels Vcc, Trigger, Echo, and Ground. It is extensively utilized in many different applications that call for distance measurement or object detection. The ultrasonic transmitter and receiver are formed by two eye-like projections on the front of the module. Distance = Speed × Time is the simple high school formula that the sensor uses to function. As can be seen in the picture below, the ultrasonic transmitter sends out an ultrasonic wave that travels through the atmosphere and is reflected back toward the sensor when it hits something.

Figure: Ultrasonic Sensor

In order to calculate the distance using the previously described formulas, we now need to know the speed and time. Since we are using ultrasonic waves, we are aware of the universal speed of the US wave at room temperature, which is 330 m/s. We can calculate how long it took by using the built-in circuitry of the module, which will measure the time it takes for the US wave to return and turn the echo pin high for that duration. Now simply calculate the distance using a microprocessor or microcontroller.

4.MQ2 sensor:

The modern technological environment necessitates careful monitoring of gas output. Gas monitoring is essential for everything from electric chimneys and safety systems at businesses to household equipment like air conditioners. An essential component of these systems are gas sensors. Gas sensors, which are about the size of a nostril and react spontaneously to the gas present, alert the system to any changes in the concentration of molecules in the gaseous state.

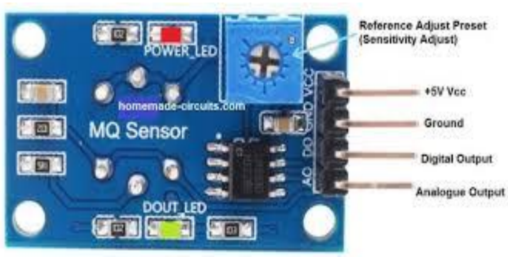

Figure:MQ-2 sensor

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Depending on sensitivity levels, the type of gas to be sensed, physical dimensions, and many other parameters, gas sensors come in a wide range of specifications. This article describes a methane gas sensor that can identify methane-produced gases, such as ammonia. After being ionized into its component parts and absorbed by the sensing element, a gas interacts with this sensor. The element creates a potential difference as a result of this adsorption, and this potential difference is sent to the processing unit as current through the output pins. The gas sensor module is made up of a sensing unit enclosed in a steel exoskeleton. Through connected leads, current is sent to this sensor piece. This modifies the sensing element's resistance, which modifies the current that exits it. More advanced gas detection systems could become possible as technology develops, offering even higher levels of workplace productivity and safety.

5.FIRE SENSOR

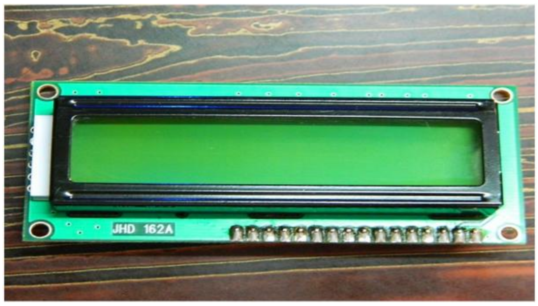
A flame sensor is a critical safety device designed to detect the presence of flames or fire in various environments, providing an essential layer of protection in industrial, commercial, and residential settings. Flame sensors are most sensitive to light, especially in the 760 nm to 1100 nm wavelength of light produced by flames. Due to this sensitivity, the sensor can easily detect flames and hence is widely utilized in flame alarms. However, due to their susceptibility to high temperatures, these sensors are typically installed at a distance from the flame. They are capable of detecting the flame at a distance of 100 cm, with a detection rate of around 60°. The sensor output can either be an analog or digital signal, depending on the use. These sensors are used in robot firefighting appliances as well as other fire detection mechanisms.

6.LCD DIPLAY

*LCD (Liquid Crystal Display) * is just one technology that has very common usage in the form of products like notebooks and small computers. In the context of technology types Unlike earlier technology types like **CRT (Cathode Ray Tube) **, LCDs, such as **LED (Light Emitting Diode) ** and **gas-plasma displays**, can have incredibly thin screens. Because LCDs use light-blocking techniques rather than producing light, they require a lot less power than gas plasma and LED panels, which is one of its main advantages.

A design known as an "active matrix" or "passive matrix" can be used to construct LCDs. The **active matrix LCD**, or also often referred to as **TFT (Thin Film Transistor) **, utilizes one transistor for each pixel to switch the display's luminance. This is not as current-consuming as passive matrix

LCDs use a grid conductor to supply the pixels with current. There is some potential with passive matrix LCDs using **dual scanning** technology, where the grid is scanned twice to improve performance, but active matrix technology is still superior.

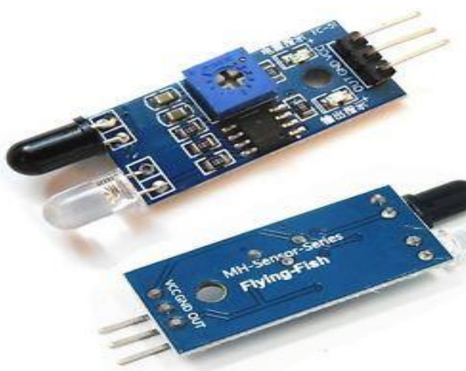


One example of a generic LCD display is the **16x2 LCD** module, which can be integrated into several devices and circuits. Its affordability, ease of programming, and capacity to display data with a high number of characters—including unique ones—make it superior to other displays like **seven-segment LEDs**. The **16x2** LCD displays **2 lines** of text and can display **16 characters on a line**. The character appears as a matrix of 5 by 7 pixels. Two primary registers are utilized by the LCD: the **Command Register**, where display control commands (i.e., screen clearing or setting cursor position) are held, and the **Data Register**, which holds the characters or symbols to be displayed. This combination of attributes makes the 16x2 LCD highly adaptable and efficient to use in numerous electronic projects.

7. INFRARED SENSOR

An electronic device known as an infrared (IR) sensor detects and quantifies infrared radiation, which is often emitted by objects as light or heat. Numerous environmental elements, including movement and item temperature, can be detected by infrared sensors.

Passive IR sensors specifically measure infrared radiation without radiating any themselves. All infrared-range objects emit heat energy, unseen to the human eye but receivable by an IR sensor.



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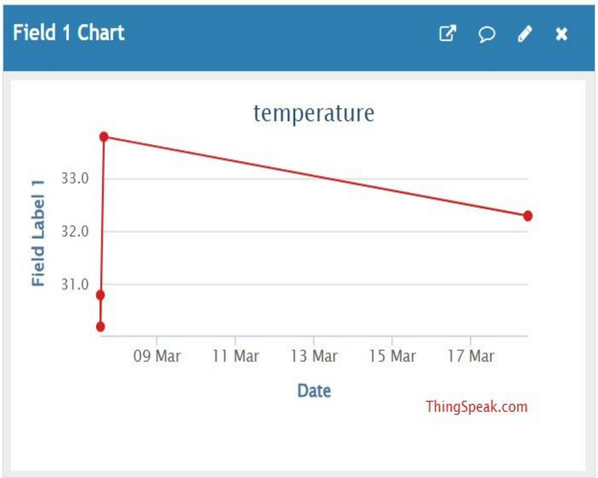
In a system of IR sensors, an IR LED is usually used as the emitter that sends out infrared light. Usually used as the IR detector, a photodiode detects the same spectrum of infrared light that the LED emits. Upon encountering infrared light, the photodiode's resistance changes, resulting in a variance in the output voltage. The sensor can detect and quantify the infrared radiation of things surrounding it because of the voltage change, which is proportional to the received infrared light. A radiation-sensitive optoelectronic component having a spectral sensitivity in the 780 nm to 50 µm infrared wavelength range is called an infrared sensor (IR sensor). These days, infrared sensors are frequently found in motion detectors, which are utilized in alarm systems to identify unwanted intruders or in building services to turn on lights.

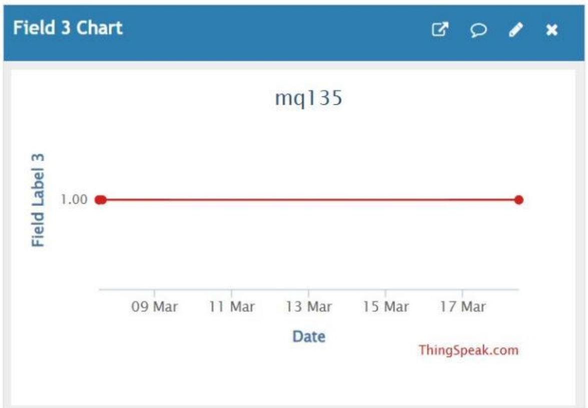
V. SIMULATION RESULTS

Real-time surveillance and advanced safety management of potential hazards have greatly improved workplace safety through the deployment of **IoT-based industrial monitoring**.

threats. Workplaces can monitor crucial environmental factors such as gas leakage, temperature, air quality, and machine condition continuously through IoT sensors. IoT-based technology helps in **predictive maintenance**, allowing it to perform repair at the correct time before equipment breakdown, thereby preventing accidents. Other than that, IoT wearables can monitor the physical status of workers, i.e., heart rate and fatigue, to ensure the workers are physically fit to work and attentive to dangerous conditions. During emergencies, IoT systems spontaneously send automatic notifications and warning messages, improve evacuation procedures and safety. In all, IoT-enabled monitoring enhances **data-driven decision-making**, enhances safety compliance, and provides a safer, more effective workplace through real-time information and risk avoidance. Overall, these simulations underscore the transformative impact of IoT technologies in creating safer industrial environments, highlighting their potential to not only protect workers but also improve operational efficiency and compliance with safety regulations.



Output diagram



Output Diagram

VI. CONCLUSION

IoT industrial monitoring has transformed workplace safety by providing real-time data, predictive analytics, and proactive risk management. Through constant monitoring of environmental conditions, equipment status, and workers' conditions, IoT technology ensures potential risks are detected and mitigated before they cause accidents. Through automated emergency response, improved compliance, and data-informed decision-

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making, IoT develops a safer, more efficient working environment. As businesses continue to adopt these technologies, the integration of IoT with safety systems will be instrumental in safeguarding employees, minimizing risks, and increasing overall operational efficiency.

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