



## Development of an IoT-Based System for Boosting Safety in Manufacturing Environments Using Arduino

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Research Article

### Abstract

The rapid advancement and affordability of Internet of Things (IoT) technologies have enabled their integration into diverse operational domains, including safety management in production environments. Modern manufacturing and operational facilities are increasingly complex, with numerous human and mechanical activities contributing to the potential risk of hazards such as fire outbreaks, toxic gas leaks, and equipment malfunctions. To address these challenges, this study presents the design and implementation of a smart safety monitoring system powered by the IoT and controlled via an Arduino microcontroller. The system integrates multiple environmental sensors—including gas, temperature, and light sensors—that continuously monitor manufacturing environment conditions. When abnormal parameters such as gas presence, sub-optimal light levels, or critical temperature deviations (below 25°C or above 35°C) are detected, the Arduino processes these signals to trigger a local alarm (buzzer), transmit Short Message Service (SMS) alerts to designated safety personnel via a GSM module, and upload real-time data to an online server for remote supervision. Experimental validation demonstrates that the proposed system delivers reliable, prompt detection of hazardous events with minimal response time and high operational accuracy across various scenarios, thereby enhancing the overall safety management framework in technical environments.

**Keywords:** Arduino, Buzzer, GSM Module, Internet of Things, Sensor, Micro-controller, Industrial safety.

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### 1. Introduction

The Internet of Things (IoT) has evolved into a robust ecosystem of interconnected devices, sensors, and networks that enable real-time data exchange and remote control of physical systems. As component costs decline and performance improves, IoT applications have proliferated across various sectors, notably in augmenting occupational safety [1]. In industries with elevated risk—such as manufacturing, oil and gas, transportation, and construction—hazard prevention is paramount to safeguard personnel and infrastructure. Traditional safety mechanisms, while essential, often lack the responsiveness and granularity required to manage dynamic environments. Incorporating smart sensing and communication devices bolsters both worker protection and incident traceability [2]. This evolution has ushered in the Industrial IoT (IIoT), which leverages advanced sensors and networking to transform conventional facilities into cyber-physical environments that optimize safety, efficiency, and asset utilization. Studies confirm that IIoT deployments not only improve operational uptime and service quality but also significantly enhance workplace safety compliance [3].

Arduino-based platforms have become popular for prototyping IoT safety solutions thanks to their affordability and open-source ecosystem. Simple microcontroller boards, when paired with sensors like MQ (metal oxide semiconductor) gas detectors, thermistors, and (light dependent resistors) LDRs, can detect environmental anomalies—such as gas leaks, fires, or poor lighting—and react by activating local alarms, sending SMS or app alerts, and transmitting data to cloud dashboards.

However, many existing systems are constrained by limited communication range (typically (wireless fidelity) Wi-Fi) and lack modularity. They also often omit integration with mobile alerts or cloud interfaces, limiting real-time accessibility. This paper introduces a cost-effective, Arduino-driven IoT safety framework that integrates multi-sensor detection (temperature, gas, and light), local visual/auditory warnings, GSM-based SMS alerts, and cloud-based monitoring. Table 1 presents the distribution of fatality rates across various industries.

**Table 1: Fatality rate across various industries**

Sector	Sector Position	Fatality Rate (%)
Agriculture, fishery, and hunting	3	10.73
Construction	1	21.16
Mining	8	1.64
Manufacturing	4	7.13
Transportation and Warehousing	2	16.89
Real estate and leasing	7	1.52
Healthcare	6	2.49
Retail trade	5	5.77
Educational services	9	0.53

Among the various sectors analyzed, the manufacturing industry accounts for a significant 7.13% of the total fatality rate coming fourth of fatality rate among industries. Although this figure is lower than construction and transportation, it remains a critical area of concern due to the constant exposure of workers to hazardous machinery, moving parts, electrical systems, and potential chemical risks [4]. These dangers highlight the pressing need for an effective safety monitoring system to prevent accidents and protect lives.

Implementing an Arduino-based safety system in manufacturing environments offers a practical and cost-effective solution. Arduino microcontrollers can be programmed to monitor essential safety parameters such as gas leakage, temperature, humidity, vibration, and proximity to dangerous equipment [5]. Real-time data collection and instant alerts via buzzers or notifications can significantly reduce the response time during emergencies, preventing injuries or fatalities. Additionally, the flexibility and scalability of Arduino make it ideal for customizing safety solutions tailored to specific manufacturing processes, ensuring enhanced workplace safety and compliance with industrial safety regulations [6].

## 2. System Block Diagram

An overview of the complete system is provided in this section. As illustrated in Figure 1, the block diagram represents the functional arrangement of the system's modules. Each sensor operates by continuously capturing data and transmitting it to the Arduino Uno microcontroller. The Arduino Uno processes this incoming information and responds appropriately based on the measured values.

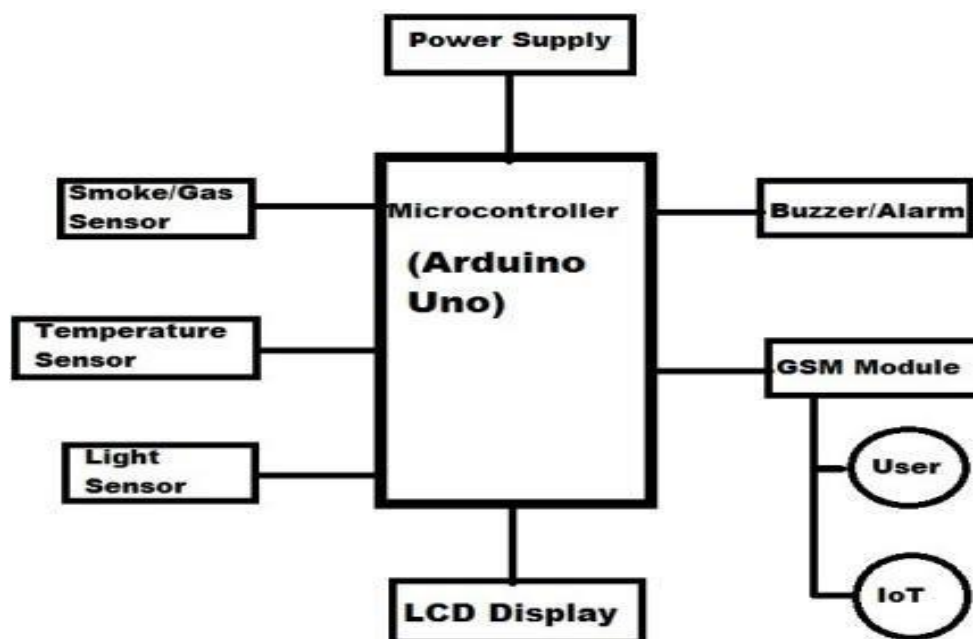


Figure 1: Block Diagram of the system

In the event of gas leakage detection by the gas sensor, abnormal temperature levels identified by the temperature sensor, or insufficient illumination sensed by the light sensor, an automated SMS notification is transmitted to the designated safety manager. Concurrently, an audible alert is activated via a buzzer to provide on-site warning. All sensor readings are systematically uploaded to a cloud-based web server, ensuring secure data storage and facilitating real-time remote access for monitoring and analysis purposes.

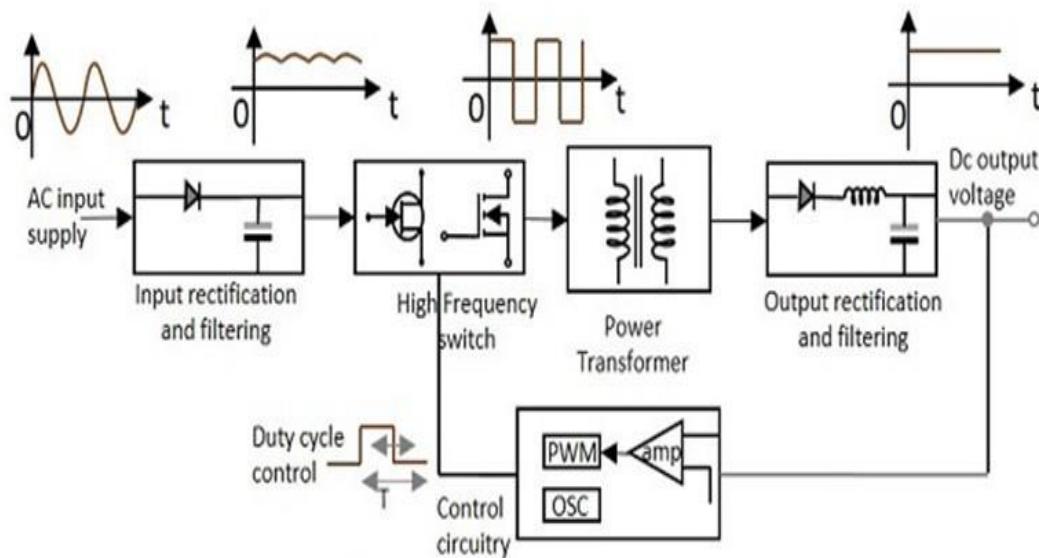
### 2.1 Hardware components

The systems consist of the following hardware:

1. Power supply unit
2. Light sensor circuit
3. Temperature sensor
4. Gas sensor
5. Arduino uno

## 3. Power Supply Unit

The designed safety system utilizes a Switched-Mode Power Supply (SMPS) to provide the required electrical power. This type of power supply converts electrical energy by rapidly switching its components on and off at high frequencies. During these switching intervals, energy is temporarily stored in components such as capacitors and inductors, ensuring a stable output when the circuit is not conducting. Due to its high efficiency and widespread applicability, the SMPS is commonly employed in various electronic systems [7]. The functional block diagram of the implemented system is illustrated in Figure 2



**Figure 2: Functional diagram of SMPS**

#### 4. Light Sensor Circuit

The light sensing unit of the system comprises an electronic circuit integrating a Light Dependent Resistor (LDR), a Darlington pair transistor configuration, a relay, diodes, resistors, and a DC power supply, as depicted in Figure 3. The primary function of this circuit is to detect variations in ambient light intensity and activate connected loads accordingly [8].

##### 4.1 Power Supply Section:

The circuit is powered by a regulated 6V DC supply derived from a 230V AC mains input. Initially, a step-down transformer reduces the 230V AC to 12V AC. This AC voltage is then rectified using a bridge rectifier composed of four diodes, producing a pulsating 12V DC output. To smooth out ripples and ensure a steady DC output, a filter capacitor is employed. The rectified and filtered 12V DC is further regulated to 6V DC using a 7806 voltage regulator Integrated Circuit (IC), ensuring a constant and reliable supply for the light sensor circuit.

##### 4.2 Sensing and Control Section:

At the core of the light sensing functionality is the LDR, whose resistance changes inversely with the intensity of incident light; as light intensity increases, its resistance decreases, and vice versa. This property allows the circuit to detect ambient light conditions effectively. The LDR is connected in a voltage divider configuration along with a fixed resistor. The divided voltage serves as an input to the Darlington pair transistors, which provide high current gain and ensure sufficient amplification of the small signal generated by the LDR.

##### 4.3 Relay Driving Section:

The amplified output from the Darlington pair transistors is used to drive a relay coil. When the ambient light falls below a predetermined threshold (indicating low light conditions), the increased resistance of the LDR results in a higher voltage at the transistor base, causing the transistors to conduct. This energizes the relay coil, closing its contacts and allowing power to be supplied to the connected load (such as a light source or alarm system).

##### 4.4 Protection Components:

A flyback diode is connected in parallel with the relay coil to protect the transistors from voltage spikes caused by the inductive load when the relay is de-energized. Additional resistors are used to set appropriate biasing and current limiting in various parts of the circuit to ensure stable operation [9].

#### 5. Temperature Sensor (LM35) Implementation and Circuit Analysis

In this project, the (linear monolithic) LM 35 temperature sensor was integrated into the system to continuously monitor ambient temperature as part of the overall safety mechanism. The primary purpose of implementing the LM35 was to ensure that temperature levels within the working environment remained within the acceptable safety threshold of 14°C to 34°C, in compliance with industrial safety standards. Any deviation from this range triggers safety alerts and system responses, contributing to the overall aim of improving workplace hazard detection and prevention [10].

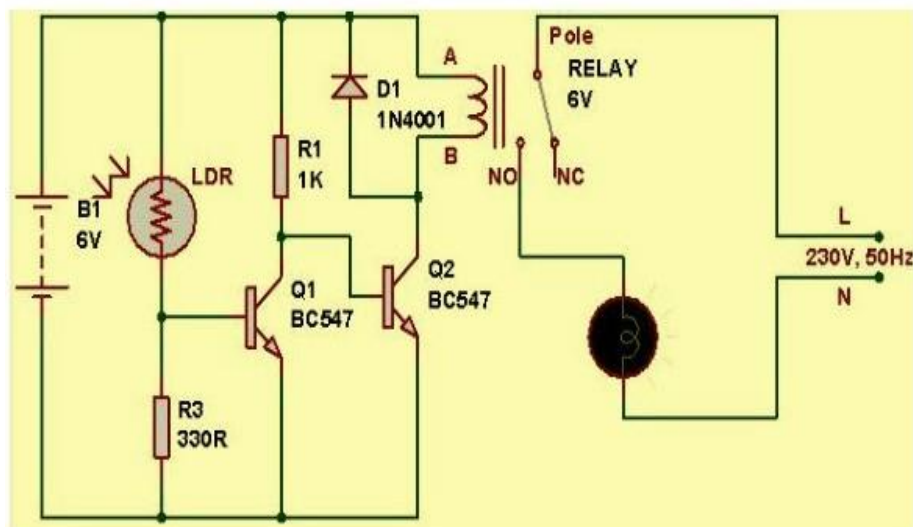


Figure 3: Schematic diagram of a light sensor circuit diagram.

## 6. Sensor Configuration and Operation

The LM35 was selected for its simplicity, high accuracy, and linear output directly proportional to temperature measured in degrees Celsius. Unlike other temperature sensors that output values Kelvin, the LM35 provides a voltage output of 10 mV per degree Celsius without requiring additional calibration or offset circuits. During system development, the sensor was powered using a stable 5V DC supply derived from the system's regulated power unit.

The output of the LM35 was connected to the analog input pin A0 of the Arduino Uno microcontroller, which reads the temperature-dependent voltage signal and converts it into digital data using its built-in 10-bit ADC (Analog-to-Digital Converter). This digital temperature value is then processed to determine if it exceeds the preset safety threshold. The inclusion of the LM35 sensor in the system enabled accurate real-time monitoring of the environment's thermal conditions, ensuring that any rise above the designated threshold was promptly detected. When the temperature exceeded the critical limit, the Arduino Uno was programmed to activate the system's buzzer alarm and send an SMS alert to the safety manager via the GSM module. The temperature data was also logged and uploaded to a web server for remote monitoring and record-keeping.

The low self-heating characteristic of the LM35 (below 0.1°C) ensured that the readings were not affected by the sensor's operation itself. Moreover, its wide operating range of -55°C to +150°C and typical accuracy of  $\pm 0.5^\circ\text{C}$  at room temperature made it a reliable choice for the industrial conditions simulated in this project.

In conclusion, the LM35 temperature sensor played a vital role in achieving the project's objective of developing an efficient and reliable IoT-based industrial safety system, capable of detecting hazardous temperature changes and initiating immediate protective measures.

## 7. Gas Sensor (MQ2) Implementation and Circuit Analysis

In this project, the MQ2 gas sensor was integrated into the industrial safety system to detect the presence of harmful gases and prevent potential hazards caused by gas leakage. The MQ2 sensor was chosen for its ability to detect a wide range of combustible and toxic gases, including LPG, methane, hydrogen, propane, alcohol, smoke, and carbon monoxide, with a detection range between 200 ppm and 10,000 ppm. Its role in this safety system is to provide continuous monitoring of the surrounding air and promptly detect gas leaks, thereby reducing the risk of fire outbreaks, explosions, or toxic gas inhalation—conditions that can cause severe health hazards or fatalities, especially from odorless gases like carbon monoxide. The MQ2 sensor operates based on the principle of resistance change in the presence of target gases. The sensing element comprises a small heater coil and a sensitive material—tin dioxide ( $\text{SnO}_2$ ). In clean air, oxygen molecules adsorb onto the surface of the tin dioxide, capturing free electrons from the conduction band and increasing the sensor's resistance, which limits the flow of electrical current [11].

However, when flammable or harmful gases are present in the environment, they interact with the oxygen molecules on the sensor surface, reducing the amount of adsorbed oxygen. This reaction releases the trapped electrons back into the conduction band, decreasing the sensor's resistance and allowing current to pass more easily. The variation in resistance is measured as an analog voltage signal, which correlates with the concentration of the detected gas. The MQ2 sensor in this project was powered using a stable 5V DC supply sourced from the Arduino Uno board. Its connection to the control system was configured as follows: The Vcc pin of the MQ2 was connected to the 5V output of the Arduino Uno, while the GND pin was connected to the system ground [12]. The analog output (A0) of the MQ2 sensor was linked to an analog input pin (A1) on the Arduino Uno. This output delivered a voltage level proportional to the gas concentration in the air. The Arduino reads the analog voltage produced by the MQ2 using its internal ADC (Analog-to-Digital Converter).

The ADC converts this voltage into a digital value ranging from 0 to 1023 (for a 10-bit ADC). Based on the output value and pre-set threshold levels (calibrated during system testing), the microcontroller decides whether to activate the safety alarm or send SMS alerts to the safety manager via the GSM module. To prevent erroneous triggering due to noise or fluctuations, a 10k $\Omega$  pull-down resistor was connected between the sensor's output pin and ground, ensuring a stable reference potential. A 0.1  $\mu$ F capacitor was placed between Vcc and GND to filter any power supply noise, ensuring smooth sensor operation [13].

## 8. Arduino Uno Microcontroller Unit

The Arduino Uno functions as the system's central processing unit, acquiring data from the gas, temperature, and light sensors. It processes these inputs based on predefined thresholds and controls the corresponding actuators accordingly. The complete sensor-to-microcontroller interfacing is shown in Plate 1. In this system, the Arduino Uno is programmed and interfaced with external devices via its digital communication pins pin 1 (TX) for data transmission and pin 0 (RX) for data reception—enabling serial communication. Data exchange between the board and the computer is facilitated through the Arduino IDE's Serial Monitor, with future technology device international (FTDI) drivers handling the virtual COM port connection over USB.

The onboard LEDs connected to the TX and RX lines indicate active data transfer during communication. Additionally, the Arduino Uno supports I2C and serial peripheral interface (SPI) protocols using the Wire and SPI libraries, respectively, for interfacing with multiple peripherals. For this project, the Arduino integrated development environment (IDE) was employed to load the system-specific code, with the appropriate board configuration selected to match the Uno. Programming was carried out via USB using the in-circuit serial programming (ICSP) interface provided by the IDE environment [14].

```
#include <SoftwareSerial.h>

// Pin Definitions
const int gasSensorPin = A0;    // MQ2 Gas Sensor
const int tempSensorPin = A1;   // LM35 Temp Sensor
const int lightSensorPin = A2;  // LDR Light Sensor
const int buzzerPin = 8;        // Buzzer
const int ledPin = 13;          // Built-in LED (Optional)

// GSM Module via SoftwareSerial
SoftwareSerial gsm(2, 3); // RX, TX for GSM module

// Thresholds (Adjust according to calibration)
const int gasThreshold = 300;
const int tempThreshold = 40;   // Celsius
const int lightThreshold = 500; // LDR value 0-1023

// Variables
int gasValue, tempValue, lightValue;
float voltage, temperature;

void setup() {
  Serial.begin(9600);
  gsm.begin(9600);

  pinMode(buzzerPin, OUTPUT);
```

Plate 1: Programme code for implementing the Arduino Microcontroller

## 9. Results and Discussion

### 9.1 System Performance Assessment

The developed system was assessed to verify its operational efficiency and reliability. Key performance indicators evaluated include:

**Detection Accuracy:**

This represents the system's precision in identifying variations in environmental parameters such as temperature, gas concentration, and light intensity. Consistent accuracy across multiple trials confirms the reliability of the sensor network.

**Response Time:**

This denotes the duration required for the system to react to environmental changes. A shorter response time indicates a more responsive and effective safety system.

### 9.2 Result

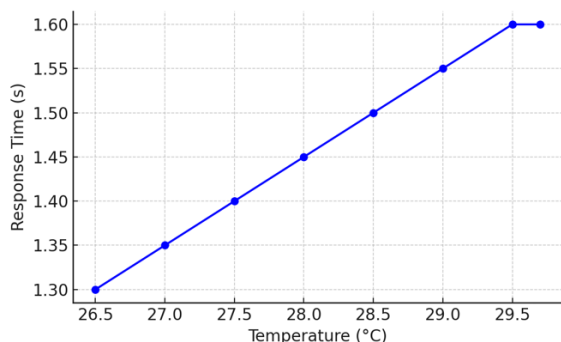
The results obtained for the temperature, light, and gas detection are presented in this section.

#### Result for temperature

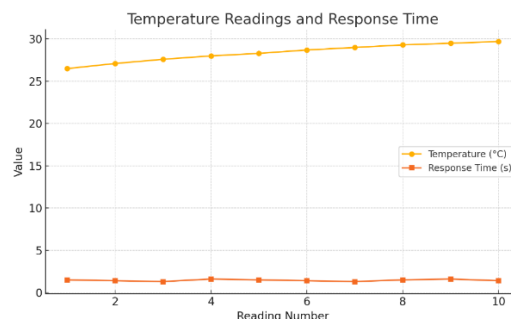
The effectiveness of the LM35 sensor in capturing ambient temperature variations within the manufacturing environment was presented in Table II and demonstrated in Figs 5. It was revealed that temperatures remained within a narrow operational range (26.5°C to 29.7°C), and that the response time for sensor activation was consistently between 1.3 to 1.6 seconds.

**Table II: Temperature Reading with Response Time**

Reading Number	Temperature (°C)	Response Time (s)
1	26.5	1.5
2	27.1	1.4
3	27.6	1.3
4	28.0	1.6
5	28.3	1.5
6	28.7	1.4
7	29.0	1.3
8	29.3	1.5
9	29.5	1.6
10	29.7	1.4



**Figure 5: Temperature Readings and Response Time**



**Figure 6: Temperature Readings and Response Time Combined**

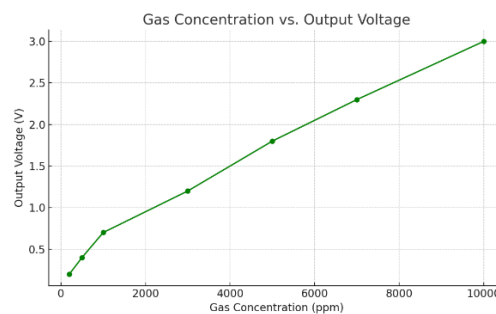
This performance confirms that the system reacts swiftly and accurately to changes in environmental temperature, which is essential for preventing thermal hazards and equipment overheating.

#### Result for Gas

The plot in Fig 7 and Table III illustrates the MQ2 sensor's analog voltage output in response to increasing gas concentrations ranging from 200 ppm to 10,000 ppm. The output voltage rises proportionally, highlighting the sensor's sensitivity and reliability in detecting combustible and harmful gases.

**Table III: gas concentration vs voltage**

Gas Concentration (ppm)	Output Voltage (V)
200	0.2
500	0.4
1000	0.7
3000	1.2
5000	1.8
7000	2.3
10000	3.0



**Figure 7: MQ2 Gas Sensor Output vs. Gas Concentration**

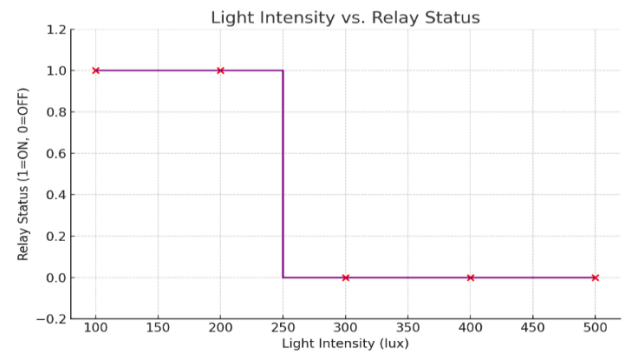
A well-defined threshold allows the Arduino to trigger alarms when gas concentration exceeds safe levels, minimizing the risk of explosions or toxic exposure, especially from odorless gases like carbon monoxide.

### Result for light

The graph in Fig 8 models the behavior of the light sensor circuit using an LDR based on Table IV. The system activates the relay when ambient light falls below 300 lux, signaling poor lighting conditions. This automation ensures that supplementary lighting or visual alarms are triggered promptly

**Table IV: Light Sensor Reading**

Light Intensity (lux)	Relay Status (1=ON, 0=OFF)
100	1
200	1
300	0
400	0
500	0



**Figure 8: Relay Activation Based on Light Intensity**

Such responsive illumination is critical for ensuring safety in low-visibility conditions, particularly during nighttime shifts or unexpected power outages in industrial zones.

### Acknowledgements

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