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Design and Implementation of a Building Automation System For Smart Infrastructure

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Abstract: *This paper presents our BAS model, in which we integrate three systems:*
1. Fire and safety management system.
2. Occupancy-based intelligent lighting control system.
3. Metal detection security system.
In the fire and safety system, we use the MQ-2 gas sensor for continuous environmental monitoring, which gives early detection of gas leakage and fire outbreaks. Also, we use an alarm system to ensure a rapid response and risk management.
In occupancy-based intelligent lighting control, we use a PIR sensor to detect whether the room is vacant or occupied; on this basis, lighting should be controlled. It helps to minimize unnecessary power consumption. All systems are implemented using Esp-32 microcontroller, which allows scalability and seamless integration. Experimental results demonstrate improved response time, enhanced reliability, and measurable energy savings compared to conventional manual systems.
In the last system, which is an metal detection security system, we use a metal detector sensor on the door to detect metallic substances and enable the buzzer when metal is detected. This system helps to detect unauthorized equipment and give real-time alerts..

Keywords: Building Automation System, Smart Lighting, Fire Safety, security system ,Esp-32, MQ-2.

I. INTRODUCTION

The increasing demand for energy-efficient and intelligent infrastructure has accelerated the development of smart build- ing technologies. Modern buildings require automated systems that can monitor, control, and optimize essential operations to improve performance and sustainability. A Building Automa- tion System (BAS) integrates sensors, controllers, communi- cation networks, and software platforms to manage services such as HVAC, lighting, security, and energy consumption. By enabling real-time data collection and automated decision- making, BAS enhances operational efficiency, reduces energy usage, and improves occupant comfort and safety. However, designing a scalable and secure automation framework that ensures interoperability among various subsystems remains a significant challenge. This paper presents the design and im- plementation of a Building Automation System developed to support smart infrastructure applications, focusing on modular architecture, reliable communication, and intelligent control strategies to improve overall building performance.

II. LITERATURE REVIEW

Building Automation Systems (BAS) have evolved signif- icantly with the adoption of Internet of Things (IoT) tech- nologies, enabling real-time monitoring, improved control, and enhanced operational efficiency in smart buildings. Hua et al.[5] emphasized that IoT-based architectures facilitate seam- less communication between sensors and controllers, thereby improving scalability and system performance.

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Energy efficiency has become a key focus in modern BAS. Siano [6] discussed the role of advanced control strategies in reducing energy consumption, while Kim et al. [7] demon- strated the application of machine learning techniques for pre- dicting occupant behavior and optimizing building operations. These approaches contribute to intelligent and adaptive system performance.

In addition, security and safety are critical aspects of smart infrastructure. Siam et al. [3] proposed cyber-secure sensor frameworks to enhance system reliability, while Minoli et al.

[8] highlighted the importance of robust IoT architectures for secure and efficient building management. Furthermore, Va- sylchenko et al. [1] explored IoT-based fire detection systems for early hazard identification and response.

Despite these advancements, challenges such as interoper- ability, scalability, and integration of multiple subsystems still persist. Therefore, there is a need for a unified and efficient automation system that integrates safety, security, and energy management into a single platform.

III. SYSTEM ARCHITECTURE

The proposed system consists of:

• Sensors
• MQ2 Sensor (Fire Detection)
• PIR Sensor (Occupancy Detection)
• Inductive Metal Sensor (Security)
• Controller
– ESP32 / Control Circuit
• Output Devices
– Buzzer
– LED Indicators

IV. METHODOLOGY

FIRE ALARM SYSTEM

This system represent the design and implementation of a Fire Alarm System. It consist of MQ2 sensor, ESP32 micro-controller, Buzzer, LED, Resistor, Jumper wire, Breadboard. The system is developed to detect smoke at an early stage to prevent fire hazards. The MQ2 sensor is capable of sensing LPG, methane, propane, and smoke particles in the air. The ESP32 processes the sensor data and continuously monitors gas concentration levels. When the detected value exceeds a preset level, the controller activates an alarm system. A LED indicator is used to provide visual warning during fire detection. Buzzer is used to produce immediate sound alerts upon detection of fire in emergency situation. The hardware components are assembled on a breadboard using jumper wires for flexible prototyping. A current-limiting resistor is connected with the LED to ensure safe operation. The ESP32 offers high processing speed and built-in Wi-Fi capability for future IoT expansion. The system operates on low power and is cost-effective for domestic applications. Real-time monitoring improves response time during emergencies. The proposed model is simple, reliable, and easy to implement. Experimental testing shows accurate detection of smoke conditions. The sys- tem can be further enhanced with mobile notification features. This design provides an efficient solution for small-scale fire safety applications.

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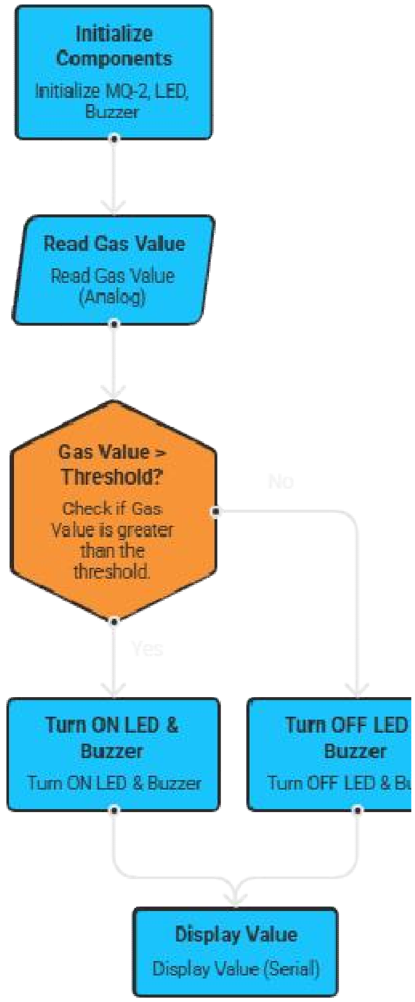

Fig. 1: Flowchart of MQ-2 based Gas Detection and Alert System

Occupancy-based intelligent lighting control system

The smart lighting system is created to automatically control a bulb . It consist of a PIR sensor, transistor, and lighting load. The PIR sensor continuously monitors infrared radiation in its identification area. When a person enters the zone, the sensor detects a change in IR levels and outputs a signal. This signal is applied to the base of a transistor, which acts as an electronic switch. The transistor then allows current to flow from collector to emitter, turning ON the bulb. When no motion is detected, the PIR output becomes LOW, switching OFF the transistor and the bulb. This method lower energy consumption by ensuring lights operate only when require. The system runs in real time, requires power, and eliminates by hand switching. The design is simple, cost-effective, and suitable for smart building automation applications such as malls, classrooms, and washrooms.

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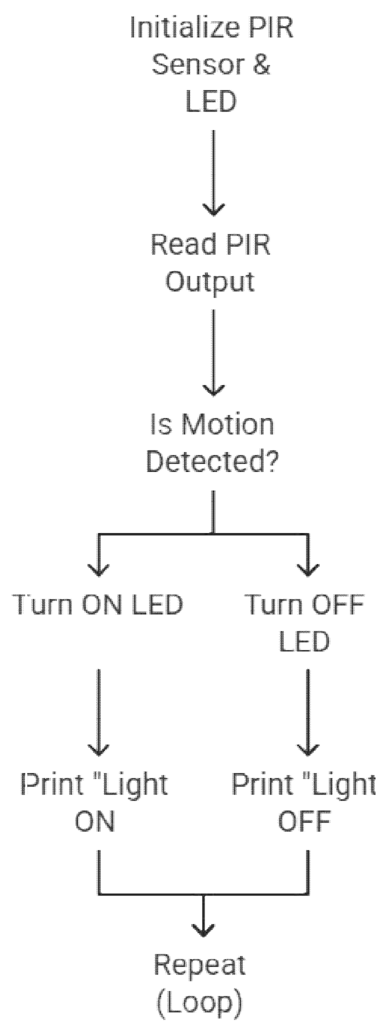

Fig. 2: Flowchart of PIR Sensor Based Occupancy Detection System.

METAL DETECTION SECURITY SYSTEM

The security system is evolved to detect metallic objects and trigger alerts using an inductive metal sensor integrated with output indicators. The inductive sensor produce an electro- magnetic field in front of its transducer surface. When a metal object enters this field, the field is disturbed, and the sensor output changes state. This signal is read by the controller, which activates a buzzer to produce an audible alarm and an LED for display. Simultaneously, a message is displayed on the LCD to notify “Metal Detected.” A relay module is used to control external security devices such as a door lock or high-power alarm. The system continuously scans for metallic presence, providing real-time monitoring and quick action. The proposed method make sure reliable detection, immediate actions, and simple hardware execution, making it suitable for entry-point security in smart Mall, laboratories, and restricted access zones.

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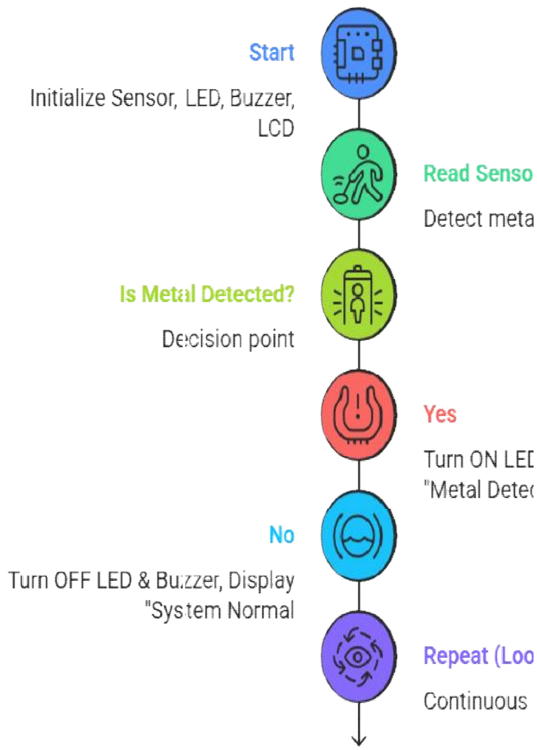

Fig. 3: Flowchart of Metal Detection System with Alarm and LCD Display

IV. RESULT AND DISCUSSION

The developed building automation prototype integrating fire alarm, smart lighting, and metal detection security systems demonstrated reliable and efficient performance during testing. The fire alarm system successfully detected smoke and tem- perature rise conditions and activated the buzzer alert within seconds, proving its effectiveness for early hazard detection.

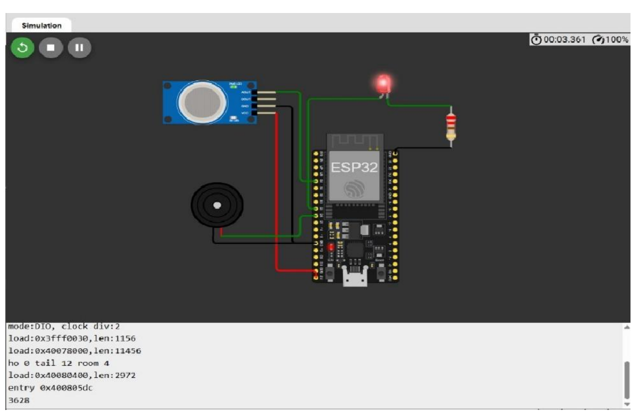

Fig. 4: Simulation of MQ-2 Gas Detection System

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Sr No	MQ-2 Gas Value (Analog)	Condition	LED Status	Buzzer Status
1	1800	< Threshold (2000)	OFF	OFF
2	2100	> Threshold (2000)	ON	ON

Fig. 5: Observation table of MQ-2 Gas Detection System

The smart lighting system responded accurately to human motion using the PIR sensor, automatically turning lights ON when presence was detected and OFF when the area was vacant, thereby confirming energy-saving capability

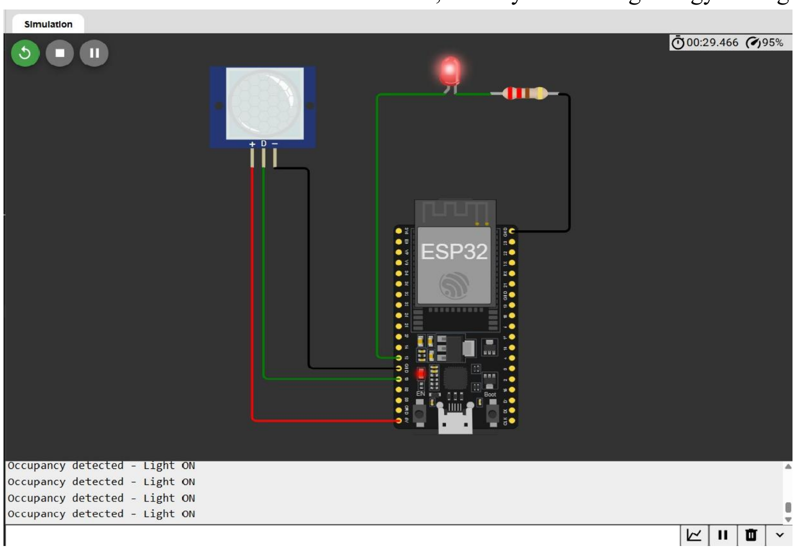

Fig. 6: Simulation of PIR Occupancy Detection System

Sr No	PIR Output (Digital)	Condition	LED Status	Message Displayed
1	LOW (0)	No motion	OFF	No occupancy - Light OFF
2	HIGH (1)	Motion detected	ON	Occupancy detected - Light ON

Fig. 7: Observation table of PIR Occupancy Detection System

The metal detection security system correctly identified metallic objects placed near the inductive sensor and triggered visual and audible alerts along with LCD notifications.

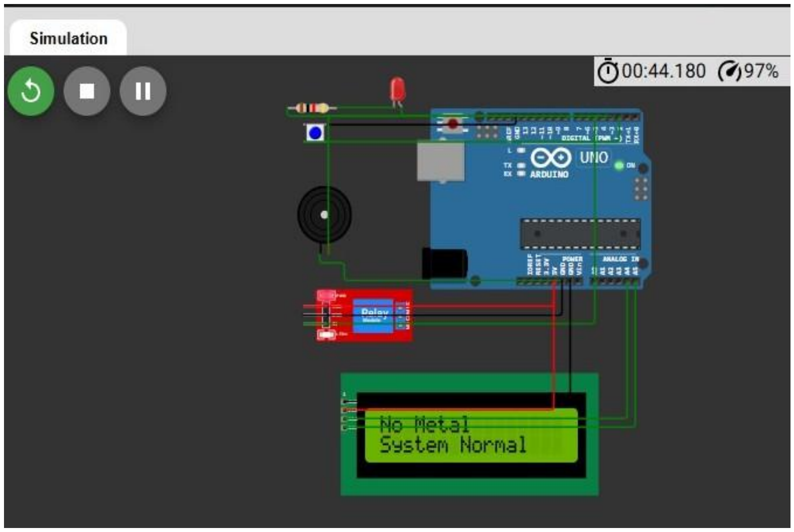

Fig. 8: Simulation of Metal Detection System

Sr No	Sensor Output	Condition	LED Status	Buzzer Status	LCD Display Message
1	LOW (0)	No metal	OFF	OFF	No Metal / System Normal
2	HIGH (1)	Metal detected	ON	ON	Metal Detected! Alert

Fig. 9: Observation table of Metal Detection System

All three systems operated simultaneously without sig- nal interference, indicating stable circuit design and proper component interfacing. The response time of each module was observed to be fast and consistent, making the system suitable for real-time applications. The relay module success- fully controlled external loads, demonstrating scalability for real building devices. Overall, the integrated system proved cost-effective, reliable, and practical for smart building automation. The results validate that combining safety, security, and energy management modules into a single platform en- hances building intelligence and reduces manual monitoring

V. CONCLUSION

The present study focused on the design and practical implementation of a Building Automation System (BAS) developed to enhance smart infrastructure. The system successfully integrates three essential subsystems: a fire alarm system for emergency detection, a smart lighting system for energy-efficient operation, and a metal detection security system for controlled access and safety monitoring. The implemented framework demonstrates how combining safety, security, and energy management within a single automated platform improves overall building performance. The fire detection mechanism enables timely alerts and reduces potential damage during hazardous situations. The smart lighting module minimizes unnecessary power consumption through automated control strategies. The metal detection system strengthens security by preventing unauthorized entry and ensuring continuous monitoring.

The results confirm that centralized automation reduces human dependency, improves operational efficiency, and increases reliability. The proposed system is scalable and can be adapted to various infrastructures such as commercial

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complexes, educational institutions, and smart malls. Future enhancements may include IoT-based remote access, real-time cloud monitoring, and intelligent analytics for predictive decision-making.

REFERENCES

[1] Y. Vasylchenko and S. Sotnik, "IoT-based intelligent fire control and access system design," WSEAS Transactions on Systems, 2025.

[2] "Self-powered smart fire-alarm materials: advances and perspective, "Journal of Safety and Sustainability, vol. 2, no. 2, pp. 81–94, 2025.

[3] Md. A. Siam et al., "Cybersecure intelligent sensor framework for smart buildings: AI-based intrusion detection and resilience against IoT attacks," Sensors, 2025.

[4] "Integration of Industry 4.0 technologies in fire and safety management," Fire, vol. 7, no. 10, 2024.

[5] G. Hua, Y. Zhang, and L. Wang, "IoT-enabled smart building automation systems: Architecture and applications," IEEE Access, vol. 8, pp.123456–123468, 2020.

[6] P. Siano, "Demand response and smart grids—A survey," Renewable and Sustainable Energy Reviews, vol. 30, pp. 461–478, 2014.

[7] J. Kim and H. Kim, "Machine learning-based intelligent building automation system for energy optimization," Energy and Buildings, vol.158, pp. 1643–1652, 2018.

[8] D. Minoli, K. Sohraby, and B. Occhiogrosso, "IoT considerations, requirements, and architectures for smart buildings—Energy optimizationand next-generation building management systems," IEEE Internet of Things Journal, vol. 4, no. 1, pp. 269–283, 2017.

[9] A. Al-Fuqaha et al., "Internet of Things: A survey on enabling technologies, protocols, and applications," IEEE Communications Surveys & Tutorials, vol. 17, no. 4, pp. 2347–2376, 2015.

[10] S. Kumar, P. Tiwari, and M. Zymbler, "Internet of Things is a revolutionary approach for future technology enhancement: A review," Journalof Big Data, vol. 6, no. 1, pp. 1–21, 2019.

[11] H. Boyes, B. Hallaq, J. Cunningham, and T. Watson, "The industrial internet of things (IIoT): An analysis framework," Computers in Industry,vol. 101, pp. 1–12, 2018.

[12] L. Da Xu, W. He, and S. Li, "Internet of Things in industries: A survey,"IEEE Transactions on Industrial Informatics, vol. 10, no. 4, pp. 2233–2243, 2014.

[13] C. Perera, A. Zaslavsky, P. Christen, and D. Georgakopoulos, "Context aware computing for the Internet of Things: A survey," IEEE Communications Surveys & Tutorials, vol. 16, no. 1, pp. 414–454, 2014.

[14] M. A. Razzaque et al., "Middleware for Internet of Things: A survey,"IEEE Internet of Things Journal, vol. 3, no. 1, pp. 70–95, 2016.

[15] S. Madakam, R. Ramaswamy, and S. Tripathi, "Internet of Things (IoT):A literature review," Journal of Computer and Communications, vol. 3,no. 5, pp. 164–173, 2015.

[16] A. Zanella et al., "Internet of Things for smart cities," IEEE Internet of Things Journal, vol. 1, no. 1, pp. 22–32, 2014.

[17] V. Gungor and G. Hancke, "Industrial wireless sensor networks: Challenges, design principles, and technical approaches," IEEE Transactions on Industrial Electronics, vol. 56, no. 10, pp. 4258–4265, 2009.

[18] R. Want, B. Schilit, and S. Jenson, "Enabling the Internet of Things,"Computer, vol. 48, no. 1, pp. 28–35, 2015.

[19] J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, "Internet of Things(IoT): A vision, architectural elements, and future directions," Future Generation Computer Systems, vol. 29, no. 7, pp. 1645–1660, 2013.

[20] K. Ashton, "That 'Internet of Things' thing," RFID Journal, vol. 22, no.7, pp. 97–114, 2009.