ES116 ELECTRICAL PROJECT

Automated Room Occupancy Detection and Lighting Control

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***Abstract*—This report is made as part of the project in Principles and Applications of Electrical Engineering (ES-116) course. It explains the design and implementation of an automated lighting control system that is achieved by detecting room occupancy. By interfacing laser modules, photodiodes, and a relay with an Arduino microcontroller, the system not only controls lighting based on occupancy but also logs energy usage data, fostering energy conservation in indoor environments.**

Keywords—arduino, laser, photodiode, relay

I. Aim

This project aims to create an automated system using laboratory equipment with the goal to address energy wastage in unoccupied rooms by accurately controlling the lighting and fans based on human presence. The data regarding the power consumed by the bulb is logged in a separate file in order to keep a track of the energy usage.

II. Theory

The foundation of this project is based on interruption-based detection mechanisms to determine room occupancy and then determining the energy consumed by the operational lights and fans. It involves placing laser beams and photodiodes at the entrance of a room to monitor the presence of individuals. The major concepts are :-

1. Laser Modules and Photodiodes Interaction: The major component of this project is the photodiode.Photodiodes are semiconductor devices that convert light into electrical current. In this project, the laser modules emit a continuous narrow beam of light over the photodiodes across the room's entrance. A noticeable drop in the current generated by the photodiode is detected when an individual interrupts the laser beam causing a decrease in light which the system interprets as an entry or exit event.
2. Arduino Processing: The varying electrical signals from the photodiodes are fed into the Arduino Uno microcontroller as analog inputs. These signals fluctuate with changes in light intensity. The Arduino is programmed to convert these analog signals into digital data that decide whether the room is occupied. The thresholds for these fluctuations were calibrated prior on the basis of the lighting of the room.
3. Control Mechanism via a Relay Module: After detecting if the room is occupied, this information is processed by Arduino to control a relay module which in turn manages the power supply to the room's lights. The relay acts as an electronic switch that can be opened or closed based on signals from the Arduino, effectively allowing the system to conserve energy by turning lights on only when the room is occupied.
4. Algorithm and Logic Flow: The system uses a logical algorithm that increases the count every time an entry is detected and decreases it during an exit. The state of the relay is determined on the basis of the count. If the count is greater than zero, the relay closes to turn the lights on and when the count turns zero it opens to turn the lights off.
5. Real-time Data Processing and Energy Consumption Logging: The data regarding the duration for which the bulb was active is logged and hence gives insight into the energy consumed using the formula for power over time. This data is transmitted serially from the Arduino to a computer, where it is logged into a file for analysis, providing insights into usage patterns and potential energy savings.

III. Methodology

1. Design and Planning: Initially, during 2-3 lab sessions, we planned detailed sketches in order to visualize the setup and how we will implement it focusing on the interactions between the laser

modules, photodiodes, Arduino Uno, and relay module.

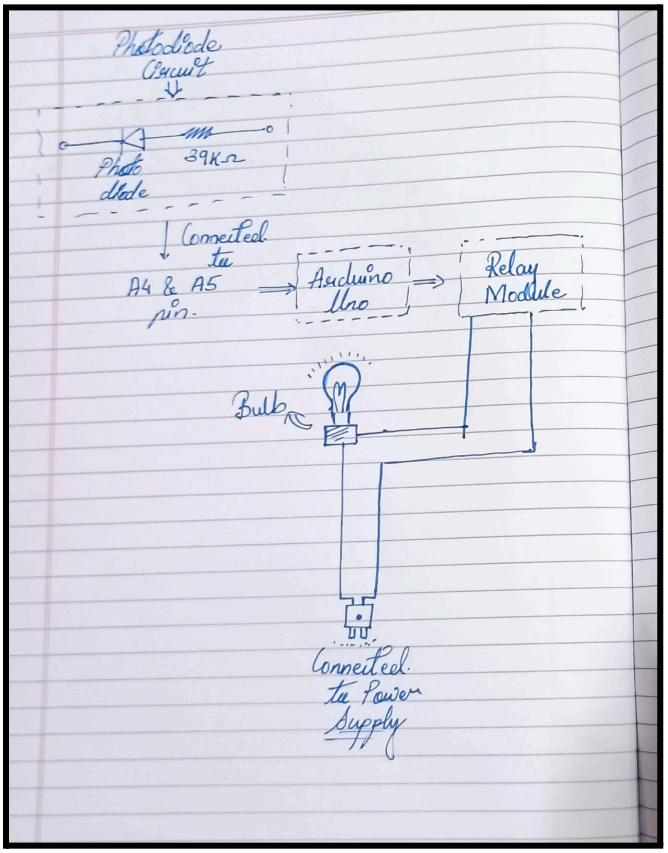

Fig. 1. Initial sketch of the Circuit Assembly

2. Assembly of Components: Components were strategically placed according to the design diagrams. Laser modules were positioned to ensure uninterrupted beams across the doorway, while photodiodes were aligned to detect the slightest interruption in the laser path. The relay module was integrated to control the main lighting circuit, with all components connected via jumper wires ensuring a clean and organized layout for easy adjustments and maintenance.
3. Programming: The Arduino Uno was programmed to continuously monitor the signals from the photodiodes as analog inputs. Logical conditions were implemented to control the relay
4. System Testing and Validation: Upon completion of the circuit assembly and initial programming, we tested various occupancy scenarios including varying pace of entry and exit and varying lighting conditions. Several adjustments were made to the system based on test outcomes in order to accurately determine the sensitivity of the photodiodes.
5. Energy consumption data: The data logging function was tested to ensure accurate and timely records of the bulb being on and the corresponding energy usage.

IV. Components

1. Arduino Uno microcontroller (1)
2. Laser modules (2)
3. Photodiodes (2)
4. Relay module (1)
5. Jumper wires
6. Breadboard (1)
7. Power Supply
8. Bulb
9. Plug
10. 39 kΩ Resistors(2)

V. Circuit Assembly

1. Circuit Layout and Setup: Connect the laser modules and photodiodes across the entrance so that the laser beams directly hit the photodiodes under normal, uninterrupted conditions.
2. Connecting Photodiodes: Connect the output of the photodiodes to the analog input pins of the Arduino to monitor the intensity of received light.
3. Integrating the Relay Module: The relay module is connected to another digital pin on the Arduino, which controls the power to the bulb.
4. Power Supply: The system operates at 5V, which is supplied directly from the Arduino's regulated 5V pin across the voltage divider junction in the photodiode and resistor
5. Programming and Testing: Now, upload the control program to the Arduino sketch and test the system for various situations.

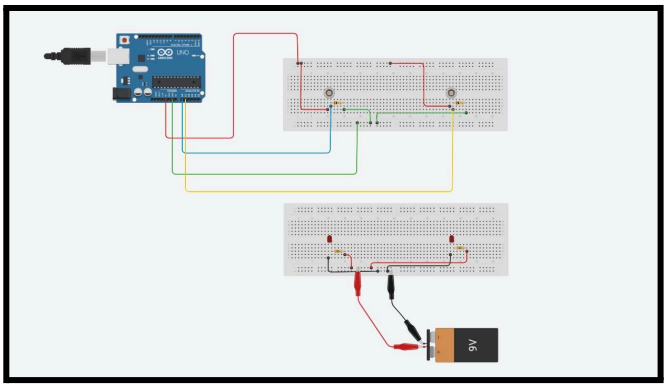

Fig. 2. Tinkercad sketch of the Circuit Assembly

VI. Procedure

1. Circuit Assembly: Precisely arranging and connecting parts on the breadboard. This is followed by calibrating the laser and photodiode setups to define the threshold at which an interruption is recognized, taking into account the ambient light conditions.

2. Logic for Lighting Control: The Arduino Uno is programmed using the Arduino IDE with the logic to continuously monitor the analog values from the photodiodes, compare these against the set thresholds, and adjust the count of occupants based on the sequence of beam interruptions.
3. Control Mechanism via a Relay Module: Then, logic is implemented to control the relay based on the occupancy count, ensuring lights are turned on or off appropriately.
4. Testing at different locations: The system is tested for its ability to accurately detect entry and exit events and to control lighting effectively. Adjustments are made to improve accuracy and responsiveness.
5. Real-time Data Processing and Energy Consumption Logging: The system is connected to a computer for real-time data logging, monitoring how long lights stay on and calculating energy consumption.

VII. Results And Discussion

The Automated Room Occupancy Detection and Lighting Control system was tested under various scenarios to evaluate its effectiveness and reliability. Following results were observed during the testing phase:-

Accuracy of Detection: Over 90% of entry and exit events were correctly detected with false detections mainly occurring due to simultaneous multiple entries which were beyond the initial scope of the design.
Response Time: The system instantly responded to changes in room occupancy with an average time of 0.2 seconds.
Energy Consumption Logging: We found the energy consumed to be reduced by 15% compared to manual lighting control systems.

Future Scope of Modification:

System Scalability: This system can be further improved to overcome the present limitations such as multiple people entering in the room together by adjusting the control logic accordingly.
Sensor Sensitivity: When the system was not able to detect the entry and exit of a person accurately was majorly due to the misalignment of lasers and hence it can be improved in the future iterations of this system.

VIII. Conclusion

The Automated Room Occupancy Detection and Lighting Control project successfully demonstrated how a relatively simple electronic setup can significantly contribute to energy efficiency. It serves as a practical example of integrating electronic hardware with software to solve real-world problems. In conclusion, this project not only achieved its goal of automating lighting control based on occupancy but also highlighted areas for further research and development that could enhance functionality and applicability in commercial and residential settings.

IX. Acknowledgement

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X. References

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