Design of Smart Lighting Control for the Built Environment

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Abstract The inefficient use of electricity and the forgetting habits of humans related to manual controlling of lights results in wastage of electricity in both residential and commercial sector. The proposed design can get rid of this physical/manual switching and provides the energy-efficient environment. This lighting control design is programmable, cost effective and provides easy installation. It employs AT86C51 microcontroller with IR sensor modules for monitoring and controlling the LED light as per occupancy inside the room. Specifically, the developed design is used to monitor the entry and exit of occupants inside the room. It automatically senses the person's location and then displays the room occupancy with the glow of LED light. The LED light remains on as long as the person lies in the range of proximity of IR sensor; otherwise, it switches off. Classroom environment is considered as test bed for this analysis. The result analysis shows the effective and efficient usage of lights and thereby causes the energy saving with the rising energy demand. Keil microvision software is used in compiling the code.

Keywords Home automation · IR sensors module · Lighting control system · Microcontroller · Relay

1 Introduction

Electricity has now become a basic need for everyone. India is the world's third largest producer and third largest consumer of electricity [1] having higher energy generation capacity but lacks in insufficient framework to transform energy to end users. Around 300 million Indians are living in dark. In India, average electricity use (2017–2018) is 1149 kWh per capita. According to 2016 survey, 84.53% humans have access to electricity [2]. To ensure that everyone stays in light, it is

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high time to look forward to generate electricity as well as to reduce the energy wastage. Previously, the lighting control is based on manual on/off switching that leads to continuous power loss. The control may be done using light dependent resistors [3] with IR obstacle sensors and Arduino [4]. Meanwhile, different researches have been focused toward the significance of smart light systems [5–10]. However, home automation is the technique to smartly access the home appliances which are connected remotely to a network [11]. By smartly accessing, we mean any appliance which can be used with ease of convenience, can be secure, energy efficient and most importantly provides comfort. The system triggers events and performs the functions according to the need. Access to appliances can be from mobile using various technologies like Bluetooth, Wi-Fi, ZigBee, etc. As per the US market report, the global lighting and control system growth for the year 2017 is about USD 32.25 billion and is assumed to rise to a market value of USD 102.92 billion in 2024 [12]. This tremendous growth of smart lighting system over traditional lighting systems is beneficial for the growing modern infrastructure of commercial and residential sectors. Authors have also discussed the significance of lighting control for a specific building using dimmable control strategy and determine the relationship between internal and external luminance levels [13]. Keeping all this in mind, appropriate lighting control is a significant part for modern building in both residential and commercial sectors. Different controlling strategies [14] commonly used for modern building design are dimming, detecting human body presence, daylight harvesting and illuminance. Researchers have also discussed the method to assume the energy consumption in a building with daylight control and occupancy control [15]. This smart lighting technology leads to energy-efficient environment with high energy optimization. One of the major reasons behind the growth of smart lighting services is raising the demand of residential customers toward home automation. Smart lighting system is fragmented based on lighting source, connectivity and end users. Connectivity may be wired or wireless. Sensors as the name suggest ‘senses’ or ‘detects’ the changes in the environment. Information is mostly in the form of code/program, but sensors provide good actions. Sensors are the basic building block of home automation system. For developing smart energy buildings and to automate the surrounding environment, the machine learning and artificial neural networks are highly applicable. As an example, Amazon Echo or Google Home provides automation environment based on customer comfort and their priorities. The energy saving due to lighting control is divided into two aspects: The first one is related to dimming of artificial lights with daylight penetration, and the second one is the initial dimming while considering continuous illuminance level [16]. In 2007, the European government has introduced the standard EN15232, which provides the list of building automation and control system with some technical management functions to determine the impact of energy performance of buildings [17]. Authors have also presented the load prioritization technique for smart energy management [18] using microcontroller-based design and concept of approximately zero energy building using functional link neural network technique [19]. Authors have also discussed the lighting control strategies with daylight availability and their impact for efficient

energy environment with experimental validation and case analysis [20]. The significance of this work lies with the fact of designing an energy-saving model with cost-effective approach to control the lighting system. This proposed design saves and conserves energy in such a way that lights switch on only when a movement of an object is detected at a certain distance specified by IR sensors. This paper designs this energy-saving model using AT86C51 microcontroller with IR sensor modules.

This study is organized in the following section as: Sect. 2 presents the design of the proposed automatic lighting control system. Section 3 presents the components required for hardware design. Section 4 presents the case study of the result. Section 5 presents the advantages and disadvantages of the proposed study and Sect. 6 presents the conclusion for the entire work.

2 Proposed Automatic Lighting System

In this study, the automatic lighting control system using 8051 microcontroller and IR sensors is designed to sense the nearby objects and then automatically switch on/off the LED lights.

At the input side of the module, two IR sensors are used to interface with microcontroller. This designing circuit includes IR sensor connected to one of the AT89C51 input pins on Port 2. All IR sensors work on 5 V supply given by AT89C51 microcontroller. Furthermore, both the sensors must be placed on the either side of the door and entrance of the room, and 5 V supply is also applied to relay. This design includes a connection between the AT89C51 microcontroller and a laptop. The connection is served to send the code regarding sensing of object from laptop to AT89C51 microcontroller which forms the brain of the circuit. At the receiving side, the microcontroller sends command to relay in the form of code. Relay signals the code and sends it to IR sensors. On receiving the command, IR transmitter transfers that IR signal within a specified range and at desired frequency to the IR receiver in such a way that IR receiver senses it and then forwards the command signal for the LED bulb to glow. If the reflecting surface absorbs the IR radiations, then there is no reflection, and the object is unable to be detected by sensor leading to no glow of bulb. The same occurs if the object is not present. A software program was developed for this design to perform various actions on the hardware. A Keil microvision software was used to compile the code.

3 Hardware Requirements

The components required in this proposed design of automatic lighting control system are given in Table 1. The internal connection established among different devices such as IR sensors, microcontroller and relay is shown in Fig. 1.

Table 1 Components required

S. no.	Components required	Specification
1	AT89C51 microcontroller chip	Completely static operation: 0 Hz to 24 MHz, three-level program memory lock, 128 × 8-bit internal RAM, 32 programmable I/O lines, two 16-bit counters
2	8051 development board	Programmable on-board Flash EPROM and ISP capabilities
3	2 infrared sensors	Vcc to the power supply 3–5 V DC
4	5 V, 4 channel relay module	5 V, 4-channel relay interface board with 15–20 mA driver current
5	Connecting wires	As per requirement

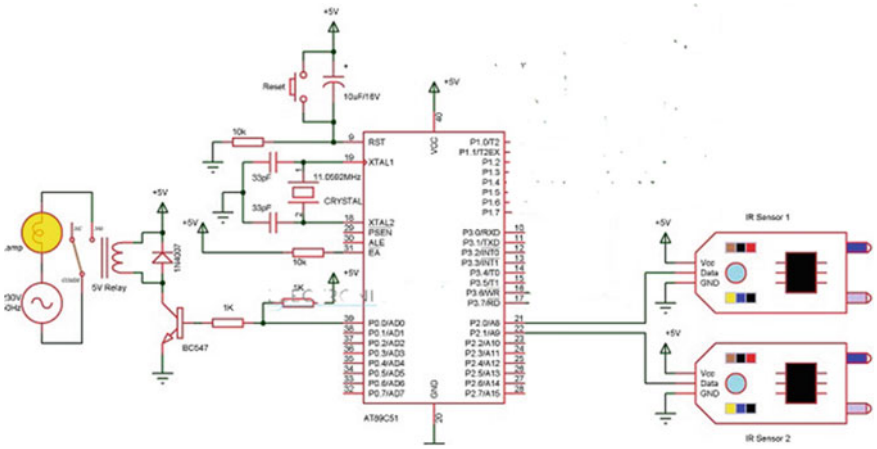


Fig. 1 Circuit diagram of the proposed system

As the object entered in the range of IR sensor 1, then the activation signal is sent to IR sensor 2. This signal sends the activation command to microcontroller used in this proposed design. This process is responsible for the glow of bulb. But, as the object leaves the room or lying outside, the IR sensor 1 rang, and then, bulb turns off. This process is presented in Fig. 2.

4 Result Analysis

Case 1 When an object enters within the range of IR sensor, sensor 1 detects the presence of object, and sensor 2 sends an activation signal to microcontroller. On receiving the command, microcontroller sends signal to relay, and it shows the turning on of LED light on relay as the output as shown in Fig. 3.

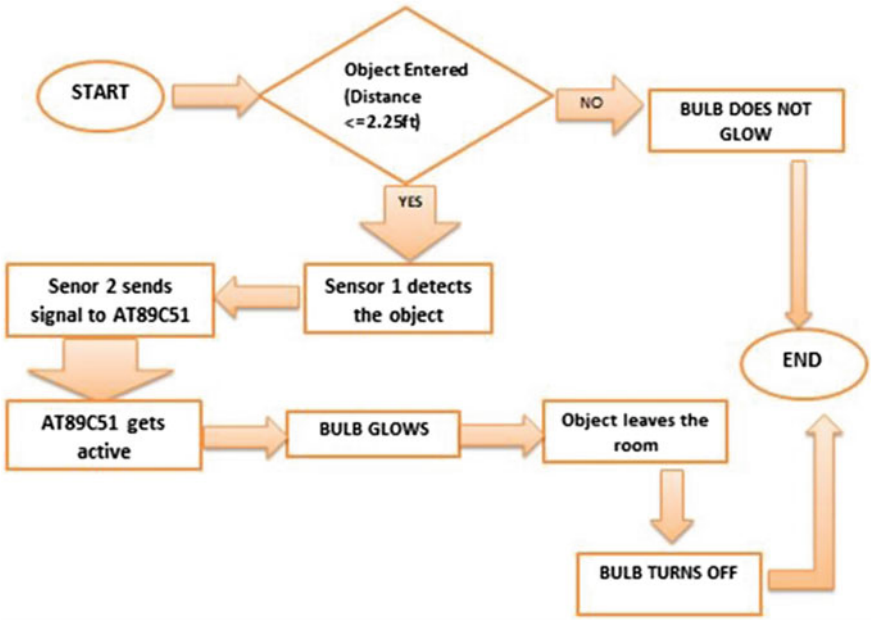
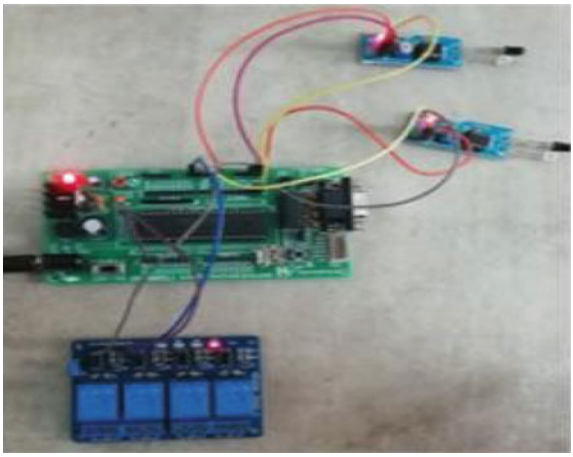


Fig. 2 Block diagram of the proposed technique

Fig. 3 Object entered inside the room



Case 2 When no object has entered or been detected within the range of 2.25 ft, then there is no glowing of light on relay as shown in Fig. 4 and thus signifying that there is no one inside the room and thereby saving electricity.

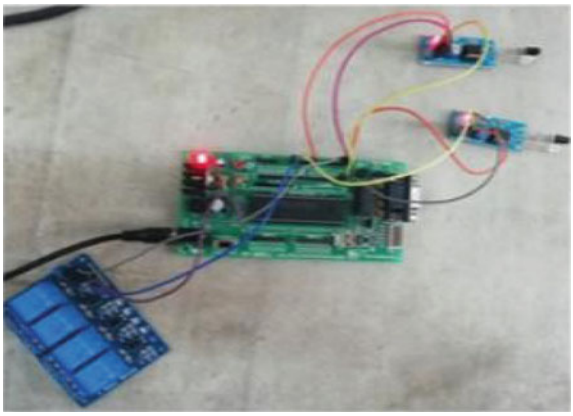


Fig. 4 No object inside the room

5 Advantages/Disadvantages of Proposed Design

5.1 Advantages

- Since the system is an automatic, no human action is needed to operate it. We have used microcontroller to do all the things.
- A more relaxing and comfortable living environment will also be made feasible by the system.
- The system will also take care of the careless mistake made by the majority of the home residents leading to reduction in the wastage of electricity.
- Simple, efficient and safest way to save energy.
- Power Consumption is much lower.
- System scalability.
- Easy extension—any change can be easily made in wireless, so extension is necessary.

5.2 Disadvantages

- Professional installation is required.
- Maintenance cost is high.

6 Conclusion

This proposed work has presented the design and implementation of an automatic lighting control system using 8051 microcontroller, to avoid manual switching of light. Since the nonrenewable energy resources are exhausting at higher speed, so it

is the time to find its alternative. In order to save and conserve energy in an efficient manner, this study has presented the design to switch on the lights only when a movement of an object is detected at a certain distance; otherwise, it remains off. Keeping in view the long-term benefits, this project can be implemented at a larger scale. Implementation of circuit is simple, and also, the power consumed by the circuit is low because only few components are used in the circuit. As a future scope, this work may be expanded to many areas by not restricting to only home or classrooms. A security system can be added by adding an alarm system or a camera. In case, if any tragedy happens such as thefts, the owner receives a message. The system can be tested on different platforms such as Arduino. Dimming light feature can also be added to save a lot of energy and also can be used according to the darkness of the area.

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