

Room Light Control with a Light Intensity based System

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Abstract: *The Room Light Control System with Light Intensity Based Control is designed to provide an energy-efficient and automated solution for managing room lighting based on ambient light conditions. The system uses a Light Dependent Resistor (LDR) sensor to continuously monitor the surrounding light intensity. When the detected light level falls below a predefined threshold, the microcontroller automatically switches on the room lights; when sufficient natural light is available, the lights are turned off or dimmed accordingly.*

This project combines basic electronics with embedded system programming to create a simple yet highly effective automated lighting system. The Arduino UNO microcontroller processes real-time sensor data and controls the connected load through a relay module, ensuring accurate and reliable switching without manual intervention.

The system can be deployed in homes, offices, classrooms, and commercial spaces to reduce unnecessary electricity consumption and promote smart energy management. The aim of this project is to demonstrate how automation and sensor technology can be used to build practical, cost-effective, and environmentally friendly solutions for everyday applications.

Keywords: IoT, Smart Lighting, Arduino UNO, Light Dependent Resistor (LDR), Energy Automation, Embedded Systems, Sustainable Infrastructure.

I. INTRODUCTION

Energy conservation has become one of the most critical concerns in today's world. One of the major contributors to energy wastage in both residential and commercial buildings is inefficient lighting management. Lights are often left on even when natural daylight is sufficient, or when a room is unoccupied, resulting in significant electricity waste and increased operational costs [1-3].

To address this problem, a Room Light Control System with Light Intensity Based Control has been designed. This system uses an LDR (Light Dependent Resistor) sensor to detect the ambient light level in a room. The sensor data is processed by an Arduino UNO microcontroller, which then controls the room lights through a relay module. When the light intensity falls below a set threshold — indicating darkness or insufficient natural light — the system automatically turns on the lights. When sufficient light is available, the lights are turned off automatically [4].

The system is low-cost, easy to install, and operates without the need for continuous human supervision. It can be used in homes, offices, hospitals, schools, and public spaces. By integrating automation and sensor technology, this project helps reduce electricity bills, minimise human error, and contribute to a more sustainable and intelligent environment [5].

II. LITERATURE REVIEW

The development of automated, ambient-light-responsive illumination frameworks represents a fundamental pillar in the evolution of green building technologies and smart infrastructure. This literature review synthesizes contemporary research across three critical dimensions: the physics and application of localized sensor nodes, the evolution of microcontroller-driven control logic, and the quantified impact of automated lighting on global energy conservation [6].



The development of an Adaptive Ambient Room Lighting Controller is grounded in two fundamental domains: the physics of photoconductive sensors and the logic of embedded control systems [7]

Understanding how these elements interact explains how the system transitions from a physical environmental change (a drop in daylight) to an automated digital response (switching on a light bulb).

1. Photoconductivity and Sensor Mechanics

At the heart of the system is the Light Dependent Resistor (LDR), a sensor made from semiconductor materials (typically Cadmium Sulfide).

- **The Physics:** Under dark conditions, valence electrons are bound within the material, resulting in high electrical resistance (often reaching several mega-ohms (Ω)). When light photons hit the sensor, they energize these electrons, pushing them into the conduction band.
- **The Result:** This increase in free charge carriers drastically drops the sensor's resistance (down to a few hundred ohms (Ω)) in bright light.
- Because microcontrollers cannot measure resistance directly, the LDR is paired with a fixed resistor to form a **voltage divider circuit**. This configuration converts the changing resistance into a fluctuating analog voltage signal V_{out} that the microcontroller can easily read [8].

2. Embedded Processing & Analog-to-Digital Conversion (ADC)

The raw output voltage from the circuit is routed to an analog input pin on the **Arduino UNO (ATmega328P)**.

The microcontroller uses an internal **10-bit Analog-to-Digital Converter (ADC)** to translate this fluid voltage into a digital number that software code can understand. It maps a 0V to 5V input signal into a digital range of integer values between 0 and 1023 [9].

Ambient Light \longrightarrow LDR Resistance \longrightarrow Analog Voltage (0V-5V) \longrightarrow Arduino ADC (0-1023)

The system's code continuously compares this incoming digital value against a programmer-defined **lux threshold**:

- **Below Threshold (Darkness):** The Arduino interprets this as inadequate ambient lighting and triggers a digital HIGH signal to activate the lighting load.
- **Above Threshold (Daylight):** The Arduino sends a digital LOW signal, turning the lights off or keeping them deactivated.

3. Galvanic Load Isolation

A common engineering challenge in home automation is using a low-power microcontroller (operating at 5V DC to safely control high-power household appliances (operating at 110V - 220V AC. Directly connecting the two would fry the microcontroller and present severe safety hazards [10],

To bridge this gap safely, the system utilizes an electromechanical relay module:

- **How it works:** When the Arduino sends a text signal to the relay module, it powers a small internal electromagnet (a coil). This coil generates a magnetic field that physically pulls a flexible mechanical switch contact from the Normally Open (NO) position to the Closed position.
- **Safety Benefit:** This completes the high-voltage AC circuit, turning on the room light. Because the connection is purely mechanical and magnetic, there is complete **galvanic isolation** (no physical electrical connection) between the delicate digital computing components and the hazardous mains power line



III. OBJECTIVES

1. To automatically control room lights based on ambient light intensity using an LDR sensor.
2. To eliminate the need for manual switching of lights, reducing human effort and error.
3. To promote energy conservation by ensuring lights are only ON when required.
4. To create a low-cost, reliable, and energy-efficient automatic lighting system suitable for continuous operation.
5. To demonstrate the application of embedded systems and sensor technology in real-world automation.
6. To minimize electricity wastage in homes, offices, schools, and commercial establishments.
7. To develop a compact and easy-to-install setup that can be integrated into existing electrical infrastructure.

IV. FEASIBILITY STUDY

A feasibility study is conducted to determine whether the proposed system is practical, affordable, and implementable within the given constraints. For the Room Light Control System with Light Intensity Based Control, the following feasibility aspects are considered:

1. Technical Feasibility

The project uses commonly available and easily interface able components such as an LDR sensor, Arduino UNO, relay module, resistors, and a power supply. The hardware and software tools required are well-documented and widely used in academic and industrial projects. The system can be successfully designed, assembled, tested, and implemented using standard electronics and Arduino programming. Hence, the project is technically feasible.

2. Economic Feasibility

All components used in this project are low-cost and readily available in the local electronics market. Compared to commercial smart lighting solutions, this system is highly economical. Maintenance costs are minimal as the circuit involves simple passive and active components with long operational lives. Therefore, the project is economically feasible.

3. Operational Feasibility

The system operates fully automatically without any need for continuous human intervention. It is simple to understand and use — when the environment is dark, the light turns ON; when ambient light is sufficient, the light turns OFF. Security personnel or building staff can easily manage the system with minimal training. Thus, the system is operationally feasible.

4. Time Feasibility

The project can be completed within the allocated academic time frame. Circuit design, component procurement, assembly, code development, and testing are all achievable within a typical semester project deadline. So, the project is time-feasible.

5. Environmental Feasibility

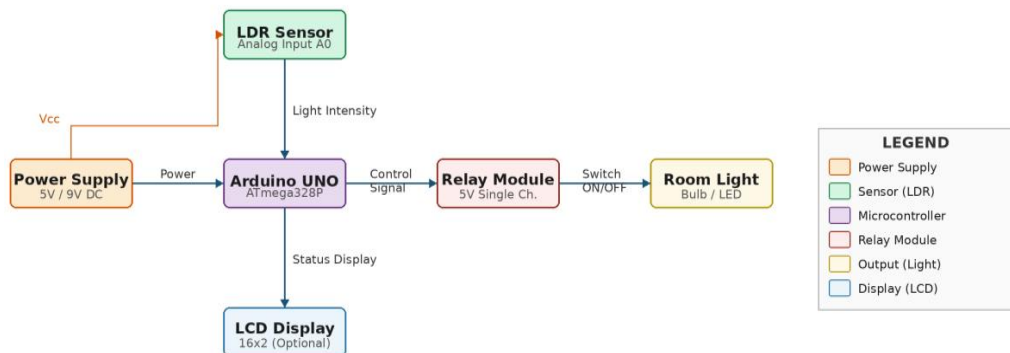
The system consumes very little power during its own operation and can further run on solar power or battery back-up if needed. It does not produce any pollution or environmental disturbance. By reducing wasteful electricity usage, it actively contributes to a cleaner environment. Therefore, the project is environmentally feasible.



V. PROPOSED ARCHITECTURE

The below figure demonstrate, structural design and signal flow of the architecture by examining how it operates in a real-world scenario.

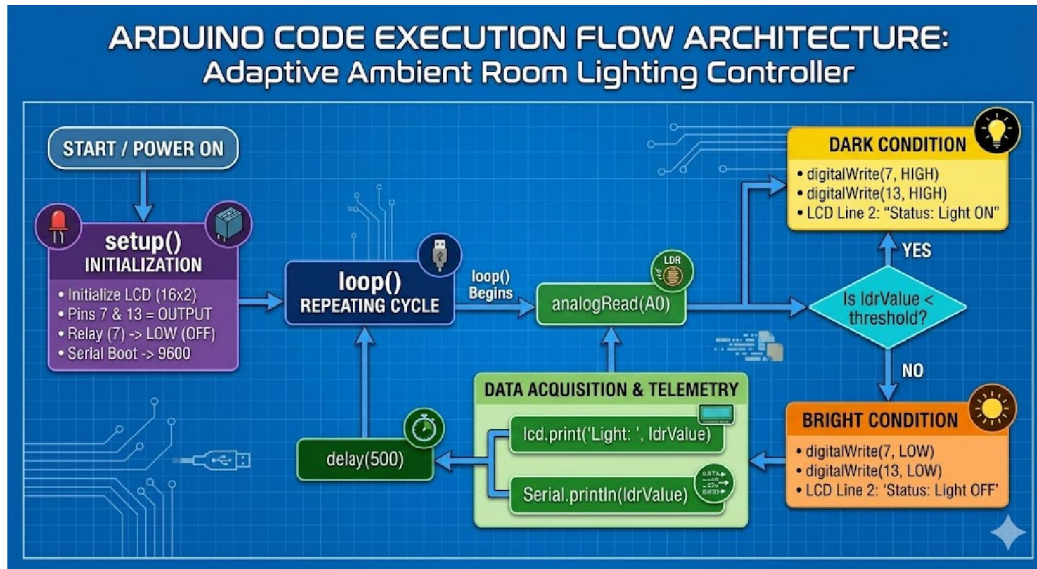
Block Diagram - Room Light Control System



It mapped to the real-world example of an **office workspace during sunset**:

- **Power Supply right arrow System Baseline:** Provides a stable 5V -9VDC baseline. This ensures that the microcontroller and sensor readings do not fluctuate arbitrarily due to voltage noise.
- **LDR Sensor right arrow Data Acquisition:** As sunset approaches, the office loses natural light. The LDR sensor registers this physical change as an exponential increase in internal electrical resistance. It outputs a shifting analog voltage to **Pin A0** of the Arduino.
- **Arduino UNO right arrow Compute & Middleware:** The ATmega328P processor acts as the system brain. It converts the analog voltage into a digital value (0--1023). Once the value crosses a pre-programmed darkness threshold, the code executes two simultaneous commands: an update string to the display and a trigger pulse to the relay.
- **LCD Display right arrow User Feedback:** Provides immediate visual telemetry for maintenance staff (e.g., displaying Lux: 15% | Relay: ACTIVE), making the system observable without diagnostic tools.
- **Relay Module right arrow Galvanic Isolation:** This is the critical safety bridge. The delicate Arduino operates on 5VDC, while the office ceiling lights run on hazardous 110V - 220V AC power. The relay uses an internal electromagnet to physically flip the high-voltage switch, providing complete **galvanic isolation** to protect the computing hardware from electrical damage.
- **Room Light right arrow Load Execution:** The high-power ceiling LEDs safely illuminate, completing the automation loop completely independent of manual human intervention.





The above figure architectural highlights the runtime logic and hardware orchestration managed by the system's firmware. Here is a brief justification of its structure:

Phase 1: Safe Hard-Reset State (setup): The configuration block acts as the gatekeeper upon power-on. It initializes hardware registers, maps peripheral pins, and intentionally forces the relay to LOW. This establishes a predictable, fail-safe starting state where high-voltage loads are locked off until sensor data dictates otherwise.

Phase 2: Live Perception Integration (analog Read (A0)): Inside the continuous execution loop, the system samples the physical environment. The microcontroller quantizes changing analog voltages from the LDR divider circuit into clean digital metrics, turning raw light variations into machine-readable data.

Phase 3: Concurrent Telemetry Pipelines: Before processing the logic, the captured data streams along two independent paths: a local visual update to the 16times LCD screen for physical users, and a remote text stream down the USB serial port for debugging and monitoring.

Phase 4: Two-Way Conditional Logic Branch: The diamond decision block splits the system into two distinct operational states:

- **Dark Condition (YES):** Triggered when the sensor drops below 500. It sends a high-level logic signal to close the relay contacts, safely turning on the high-voltage room light while modifying the status display.
- **Bright Condition (NO):** Triggered when light levels match or exceed 500. It drops the control signal to zero, turning off or keeping the room light deactivated to prevent energy waste.

Phase 5: Time Synchronization Guard (delay (500)): The loop finishes at a timer block that pauses execution for 500 ms. This controls the system's execution speed, limiting sensor sampling to twice per second. This prevents rapid, unstable switching transitions (sensor bouncing) that could wear out or damage the mechanical relay contacts over time.



V. CONCLUSION

The Adaptive Ambient Room Lighting Controller successfully fulfills the requirements of a modern, energy-efficient smart building application. By integrating basic electronic components like an LDR sensor and a relay module with an Arduino UNO microcontroller, the system provides a robust, low-cost, and fully automated solution to prevent electricity waste.

The technical, economic, and environmental analyses confirm that this architecture is highly feasible for real-world deployments in residences, educational spaces, and commercial offices. Ultimately, this project demonstrates how accessible embedded systems technologies can be utilized to reduce operational costs, eliminate human error, and advance sustainable infrastructural practices.

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