Classroom Environment Controller (CEC)

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***Abstract*—This paper presents the design and implementation of a Classroom Environment Controller (CEC), a compact automation system developed using fundamental circuit analysis principles. The system integrates automatic lighting control, infrared (IR)-based presence detection, and a temperature-controlled ventilation mechanism. The design strictly adheres to the CE211 course scope and avoids the use of microcontrollers, relying instead on op-amps, logic gates, passive components, and discrete switching elements. The complete system was simulated in Proteus and later implemented on a breadboard, demonstrating reliable and energy-efficient operation.**

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I. Problem Statement

Traditional classroom infrastructure operates on static, human-dependent control systems where lighting, fans, and air conditioning are often left active in unoccupied or adequately lit spaces. This not only results in considerable energy waste and inflated operational costs but also contributes to unnecessary carbon emissions—a growing concern in educational institutions striving toward sustainability. In an era defined by smart automation and the Internet of Things (IoT), such manual systems represent an outdated approach to resource management, failing to leverage real-time environmental data for intelligent decision-making.

This project addresses these shortcomings by developing a low-cost, sensor-driven automation system that dynamically regulates classroom lighting and ventilation based on ambient light levels, human occupancy, and indoor temperature. By integrating fundamental electronic components—such as photoresistors, passive infrared (PIR) sensors, and thermistors—with basic circuit analysis and digital logic principles, the system ensures that energy is consumed only when and where it is needed. In doing so, it embodies the shift toward **ambient intelligence** and **energy-responsive environments**, aligning with global efforts to reduce energy footprints through smart, scalable electronics.

Beyond immediate energy savings, this project demonstrates how foundational engineering concepts can be applied to create meaningful, real-world solutions—bridging the gap between academic theory and sustainable innovation. It offers a replicable model for transforming conventional spaces into adaptive, efficient, and environmentally conscious environments, contributing to the broader movement toward **intelligent infrastructure** in the age of automation and climate-aware design.

II. System Overview

The Classroom Environment Controller integrates three subsystems: an automatic lighting system, an IR-based presence detection system, and a temperature-controlled fan system. The lighting and presence detection outputs are combined using logical decision-making to ensure energy-efficient operation, while the fan system operates independently via relay-based switching.

III. Automatic Lighting System

A. *Working Principle*

An LDR senses ambient illumination and forms a voltage divider whose output varies with light intensity. This voltage is compared with a reference voltage using an LM324 (or 741) op-amp configured in open-loop comparator mode. When ambient light falls below a predefined threshold, the comparator output saturates high.

B. *Components Used*

- Light Dependent Resistor (LDR)
- LM324 / 741 Operational Amplifier
- Potentiometer
- LED
- 220 Ω Resistor
- 1 kΩ Resistor

IV. IR-Based Presence Detection

A. *Working Principle*

An infrared transmitter-receiver pair detects human presence through beam interruption. Since the sensor output is active-low, an inversion stage is implemented to obtain a logic-high signal upon detection.

B. *Logic Operation*

The lighting decision follows the logical condition:

$$Output = Light_{\text{Low}} \cdot Presence_{\text{Detected}} \tag{1}$$

V. Temperature-Controlled Fan System

A. *Working Principle*

Temperature sensing is achieved using an NTC thermistor in a voltage divider configuration. The divider output is compared against a reference voltage using an LM324 op-amp in comparator mode. When the temperature exceeds the threshold, the comparator output drives an NPN transistor, energizing a 12 V SPDT relay that supplies power to a 12 V DC fan.

B. *Power Regulation*

A 7805 voltage regulator provides a stable 5 V supply for op-amps and logic circuitry.

VI. Schematic Diagram

The complete schematics for the two subsystems are presented below. These diagrams illustrate the circuit topology, component placements, and electrical connections that form the basis of the implemented design. All of the designs have been made in **Proteus.**

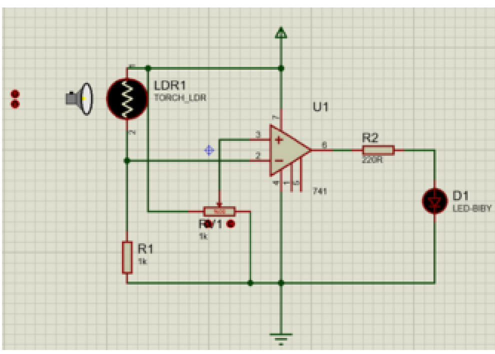

Fig. 1. Schematic of Subsystem A: Automatic Lighting System

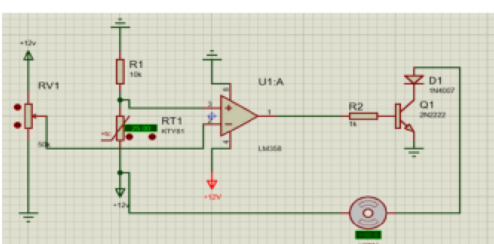

Fig. 2. Schematic of Subsystem B: Temperature Controlled Fan

VII. Component Specifications

TABLE I
Major Components and Technical Specifications

Component	Specification Summary
LM324 Op-Amp	Quad op-amp, single-supply operation [7]
7805 Regulator	Fixed 5 V output, up to 1 A [6]
NPN Transistor	Low-power silicon BJT (2N3904) [5]
NTC Thermistor	Negative temperature coefficient sensor [4]
SPDT Relay	12 V DC coil, COM-NO-NC contacts [3]
LDR	Cadmium sulfide photoresistor [2]
DC Fan	12 V DC ventilation fan [1]

VIII. Conclusion

The Classroom Environment Controller demonstrates the practical application of fundamental circuit analysis concepts to real-world automation. By integrating analog sensing, logic-based decision making, and electromechanical actuation without microcontrollers, the system achieves reliable and energy-efficient classroom environmental control while remaining fully compliant with the CE211 curriculum.

References

[1] Datasheet, ‘12 V DC Brush Motor Fan,” Generic Manufacturer.
[2] Advanced Photonix, ‘Cadmium Sulfide Light Dependent Resistor Datasheet.”
[3] Songle Relay, ‘SRD-12VDC-SL-C SPDT Relay Datasheet.”
[4] EPCOS, ‘NTC Thermistor Temperature Sensors Datasheet.”
[5] ON Semiconductor, ‘2N3904 NPN General Purpose Transistor Datasheet.”
[6] Texas Instruments, ‘LM7805 Voltage Regulator Datasheet.”
[7] Texas Instruments, ‘LM324 Quad Operational Amplifier Datasheet.”