Smart Energy Management System

Submitted in partial fulfillment of the requirements.

of the degree of

Bachelor of Technology in Electronics and Telecommunication

By

Ritesh Sonawane (20104A0035)

Aniruddha Gawade (20104A0011)

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2023-24

CERTIFICATE OF APPROVAL

This is to certify that the project entitled.

“Smart Energy Management System”

is a bonafide work of

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degree of

Undergraduate in **“Electronics & Telecommunication Engineering”.**

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(Ac. Yr. 2023-24)

Project Report Approval for B.E.

This project report entitled Smart Energy Management System

By

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Examiners

1. ________________________

2. ________________________

Date :

Place :

DECLARATION

We declare that this written submission represents our ideas in our own words and where others' ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Date :

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ABSTRACT

Energy management has emerged as a critical global issue due to our inadvertent wastage of resources. The pervasive problem of leaving lights, fans, and other appliances on inadvertently contributes significantly to energy loss. To address this challenge, the Smart Energy Management System presented in this report aims to identify and mitigate sources of energy wastage in residential buildings. Leveraging temperature and light intensity sensors, the system autonomously adjusts light intensity and fan speed using an Arduino microcontroller. The Light Dependent Resistor (LDR) serves as the light sensor, while the LM35 functions as the temperature sensor. Additionally, the system provides real-time information on energy consumption and tariffs. If energy usage surpasses predefined thresholds, the system activates a relay to cut off energy flow and alerts the user with a buzzer.

Expanding upon this framework, integration with an energy meter allows for precise measurement and monitoring of energy usage, enabling users to track consumption patterns and make informed decisions to optimize energy efficiency. Furthermore, the incorporation of solar power monitoring enhances the system's sustainability aspect. By capturing data on solar panel voltage, temperature, and light intensity, the system enables users to harness renewable energy effectively, reducing reliance on conventional power sources and mitigating environmental impact. Through the amalgamation of these components, the Smart Energy Management System not only addresses energy wastage but also promotes sustainable energy practices for a greener future.

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Chapter 1

Introduction

1.1 Introduction

Our world craves efficient energy use, and the Smart Energy Management System (SEMS) is here to deliver. This innovative project tackles the issue of wasted energy in lighting by employing a network of sensors. These watchful eyes detect human presence within a room, triggering a clever response from SEMS. The system seamlessly activates lights upon detecting occupants and plunges them into darkness when the room becomes vacant, eliminating unnecessary energy consumption. Also using temperature sensor, it measures the temperature and decides whether to turn on fan or not. But SEMS goes beyond simple on/off control. It empowers users with real-time data visualization through a handy LCD display. This transparency allows users to witness their energy usage firsthand, fostering informed decisions and promoting a culture of conservation.

Furthermore, SEMS expands its reach by integrating with two complementary projects. The first is an IoT-based Smart Electricity Meter. This nifty tool goes beyond just lighting, providing comprehensive monitoring of your entire home's electricity use. Equipped with remote access capabilities, the meter allows you to keep an eye on your energy consumption from anywhere via a user-friendly smartphone app. The second project, the Solar Power Monitoring System, focuses on the sun's bounty. By capturing and transmitting data on solar panel voltage, temperature, and light intensity, this system empowers users to optimize their solar energy utilization. This translates to maximizing the benefits of renewable energy sources and contributing to a more sustainable future.

In essence, SEMS isn't just about controlling lights; it's about taking control of your entire energy ecosystem. By offering real-time data, remote monitoring, and integration with renewable energy systems, SEMS empowers you to make informed decisions that save you money and benefit the environment. It's a win-win for your wallet and the planet.

1.2 Literature Review

- ❖ Smart Energy Management System (SEMS) is a system that uses sensors and communication technologies to monitor and control energy consumption in buildings, homes, and other facilities. SEMS can help to reduce energy costs, improve energy efficiency, and reduce greenhouse gas emissions.

- ❖ SEMS systems typically use a variety of sensors to collect data on energy consumption, such as electricity meters, temperature sensors, and occupancy sensors. This data is then transmitted to a central controller, which uses it to make decisions about how to manage energy consumption.

- ❖ SEMS systems can use a variety of strategies to reduce energy consumption, such as:

i. Turning off lights and appliances when they are not in use.
ii. Adjusting the temperature of heating and cooling systems
iii. Managing demand for energy during peak periods
iv. Using renewable energy sources

- ❖ SEMS research from the literature:

- https://www.researchgate.net/publication/370773084_Design_and_Implementation_of_a_Smart_Home_Energy_Management_System_Using_IoT_and_Machine_Learning
- https://www.researchgate.net/publication/284922872_Smart_home_energy_management_system
- https://www.researchgate.net/publication/357092992_Smart_Energy_Management_System_for_Homes

1.3 Objectives

1. Energy Efficiency Enhancement: Enhance energy efficiency by dynamically managing room lighting in response to occupancy, ensuring lights are only active when necessary to curtail needless energy use.
2. Cost Mitigation: Mitigate expenses associated with energy consumption by minimizing lighting usage in unoccupied spaces, thereby presenting opportunities for substantial reductions in electricity expenditures.
3. Environmental Conservation: Contribute to environmental preservation by diminishing energy usage, consequently reducing the emission of greenhouse gases linked with electricity production.
4. Real-time Monitoring Capability: Provide users with the ability to monitor room occupancy and sensor data in real-time via an LCD display, fostering comprehension of system operations and promoting energy consumption awareness.
5. Automation Implementation: Implement automation features utilizing relay drivers to regulate lighting and appliance usage without requiring manual intervention, offering both energy savings and user convenience.
6. Scalable Design: Engineer the system to be scalable, facilitating its expansion to encompass multiple rooms or areas, ensuring adaptability for deployment in diverse settings.
7. Data Analytics Integration: Integrate data analysis functionalities to scrutinize sensor data, deriving insights into energy consumption trends, and refining control tactics accordingly.
8. Peak Demand Management Strategies: Deploy strategies to manage energy usage during peak periods, mitigating demand charges and alleviating strain on the electrical grid.
9. Integration of Renewable Energy Sources: Explore opportunities to integrate renewable energy sources, such as solar panels, into the system to diminish reliance on non-renewable energy reserves.
10. Robustness Assurance: Ensure the system's robustness to withstand sensor malfunctions or communication disruptions, guaranteeing uninterrupted functionality.

1.4 Scope of Project

The project sets a strong groundwork for potential growth and advancement. Here are some avenues for future development:

1. Integration with Smart Home Systems: Enabling compatibility with established smart home platforms such as Google Home or Amazon Alexa can offer users voice-controlled management and remote monitoring capabilities.
2. Occupancy Pattern Analysis: By integrating machine learning algorithms, the system can analyse occupancy trends over time. This data can be leveraged to fine-tune energy usage by predicting when lighting and ventilation are required.
3. Energy Harvesting: Exploring techniques like solar panels or kinetic energy harvesting can make the system more sustainable. This approach reduces reliance on external power sources and enhances its eco-friendliness.
4. Enhanced Sensor Capabilities: Upgrading sensors to more sophisticated versions enhance accuracy and functionality. For instance, integrating high-resolution motion sensors with wider coverage can improve human presence detection.
5. Wireless Connectivity: Implementing wireless protocols like Bluetooth or Wi-Fi enables seamless connectivity with smartphones and other devices. This empowers users to remotely manage and monitor the system.
6. Energy Consumption Analytics: Developing tools for tracking and analysing energy consumption patterns provides valuable insights. This data aids users in understanding their energy usage habits and guides decisions for further efficiency improvements.
7. Expandability: Designing the system with modular components and expandable features facilitates easy integration of future upgrades or additions. This ensures scalability and adaptability to evolving needs and technologies.

These advancements leverage developments in sensing, communication, and computational technologies to enhance system reliability and efficiency. Additionally, emerging technologies such as artificial intelligence for data processing, internet of things (IoT) for connectivity, and automation are becoming integral. This aligns with initiatives like India's 'Digital India' scheme aimed at transitioning to smart cities. Consequently, future power networks will be dynamic, responsive, eco-conscious, interconnected, and adaptable, contributing to a more sustainable and efficient energy ecosystem.

Chapter 2

Methodology

2.1 Mechanism

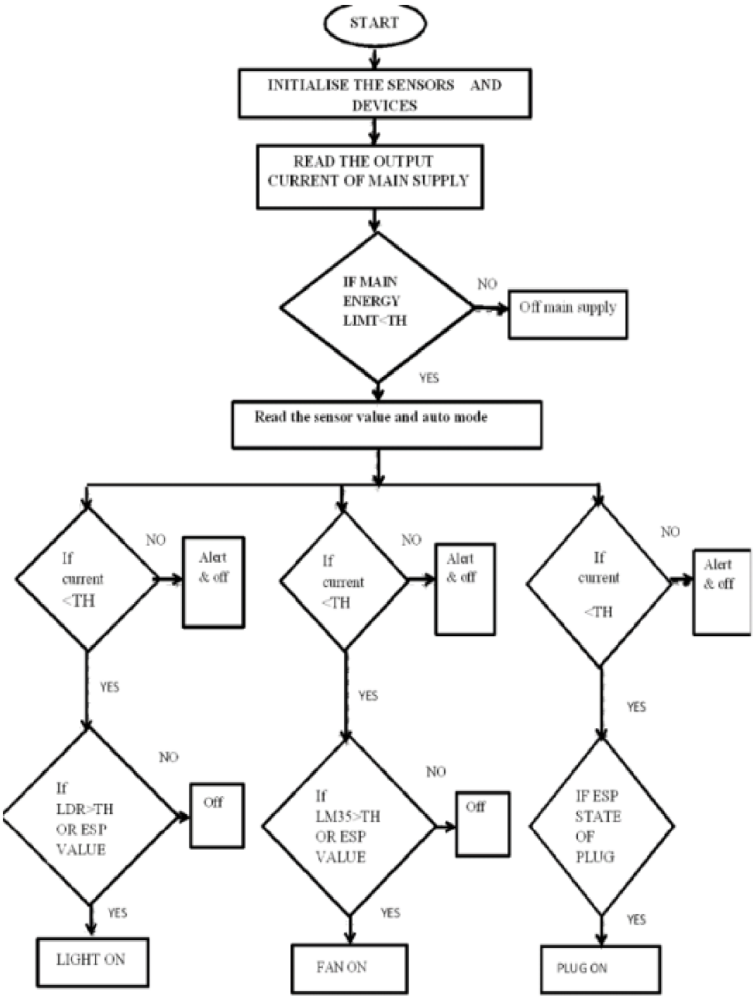
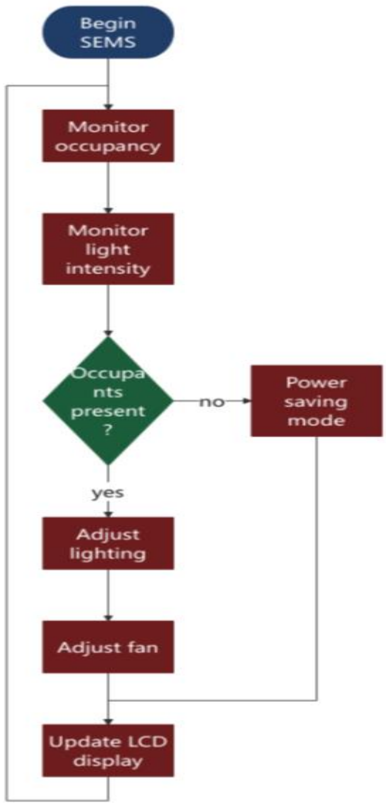


Fig 1 - Flow Chart



Breakdown:

Power Supply:

- **LM7805:** The LM7805 is a linear voltage regulator designed to provide a constant 5V DC output, which is suitable for powering microcontrollers and other digital devices. To operate this device with a 220V AC mains supply, the AC must first be transformed to DC. This process involves using a transformer to reduce the voltage level and a rectifier to change AC to DC. The resulting DC should fall within 7V to 35V, the acceptable input voltage range for the LM7805. With the input appropriately set, the LM7805 will efficiently deliver a steady 5V DC output.

- **C1 and C2:** These are capacitors that help to smooth out the DC output from the voltage regulator and prevent voltage spikes.

Microcontroller:

- **AT89S52:** This is the brains of the operation. It is an 8-bit microcontroller that reads data from sensors, makes decisions based on that data, and controls the outputs to devices like lights, fans, and motors.

Sensors:

- **MCP3202:** This is an analog-to-digital converter (ADC) that converts analog signals from sensors like temperature sensors and light sensors into digital signals that the microcontroller can understand.

- **LM35:** This is a temperature sensor that outputs a voltage proportional to the temperature.

- **Photoresistor:** This is a light sensor that changes its resistance in response to changes in light intensity.

Outputs:

- **ULN2803:** This is a Darlington transistor array that amplifies the output signals from the microcontroller to drive high-power devices like motors and relays.

- **Relays:** These are electromechanical switches that are controlled by the ULN2803. They are used to switch on and off devices like lights, fans, and pumps.

- **LCD 1602:** This is a liquid crystal display (LCD) that is used to display information to the user, such as the current temperature, light level, and the status of devices.

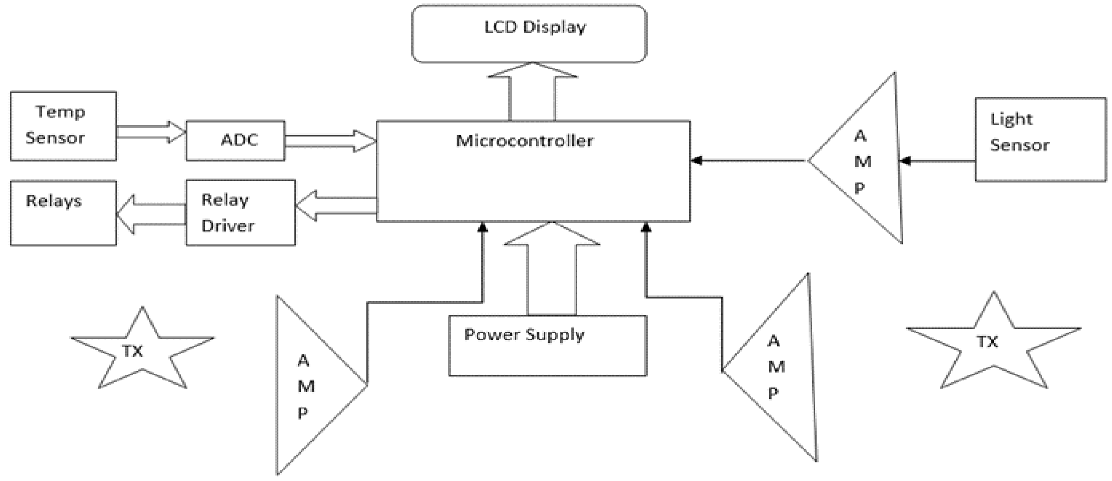
Other components:

- **Crystal oscillator:** This component provides the clock signal for the microcontroller.

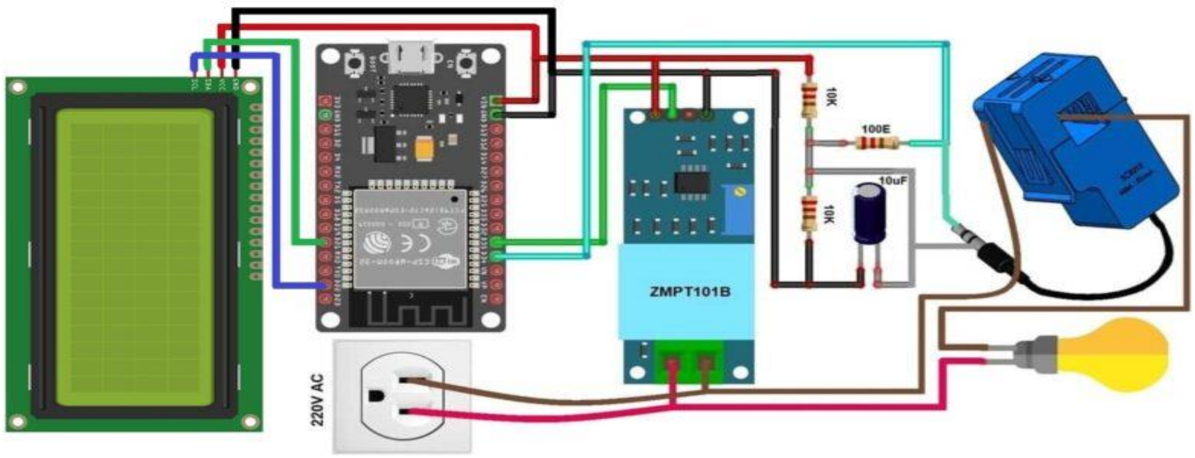
- **Resistors:** These are used to limit the current flow to various components in the circuit.

- **LEDs:** These are used as indicators to show the status of the system.

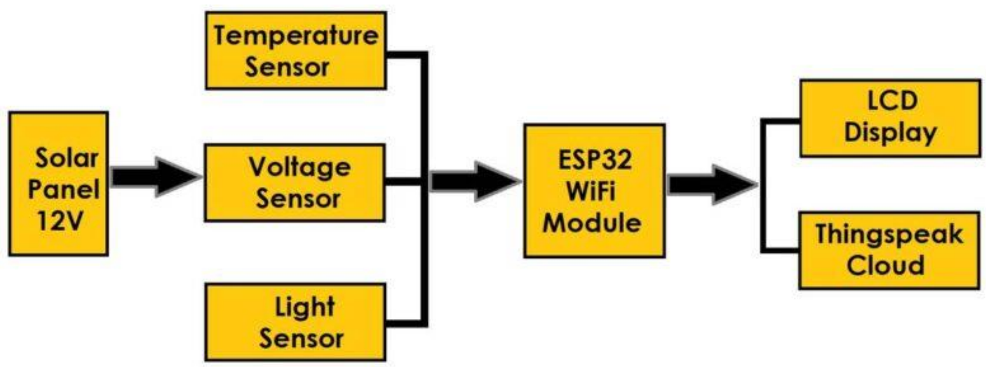
2.2 Block Diagram



(a) SHEMS Main circuit



(b)



(c)

Fig 2 – Block Diagram

(A) It consists of sensor networks, the microcontroller, power supply, load control/switching and the regulated power supply units. The sensor network captures different information across the system to perform the desired autonomous energy management, the microcontroller performs the smart operations, the battery bank provides energy storage for the system, the load control circuit receives signals from the microcontroller for automatic switching of different loads, while the 5-volt regulated power supply provides the needed 5V for the operation of the whole system. The smart energy management system works by monitoring the power consumption of different loads and adjusting the power supply accordingly. The system can also be used to schedule the operation of different loads. The system collects data from the different sensors and sends it to the cloud server. The cloud server can then be used to analyse the data and generate reports. The mobile device can be used to access the cloud server and monitor the system remotely.

(B) This project represents a significant advancement in energy monitoring technology with the introduction of a Smart Energy Meter. Engineered to transform the way we track electricity usage; this innovative meter seamlessly integrates with our existing Smart Energy Management System. By harnessing the power of cutting-edge sensors, the meter provides unparalleled accuracy in measuring electricity consumption. Through the utilization of advanced technology, users can conveniently access real-time data on their electricity usage via the intuitive Blynk 2.0 application. Even in the event of power disruptions, the meter ensures the continuity of data collection by storing information internally, safeguarding against any potential data loss.

(C) Furthermore, this project extends its scope to include the development of a Solar Power Monitoring System, aimed at monitoring and optimizing solar energy production. Aligned with the global shift towards renewable energy sources, this system plays a pivotal role in maximizing the efficiency of solar power generation. By continuously monitoring key parameters such as solar panel voltage and light intensity, the system provides valuable insights into the performance of solar energy systems. Integrated seamlessly with our Smart Energy Management System, it offers a comprehensive approach to energy monitoring and optimization, empowering users to make informed decisions for sustainable energy usage.

Benefits of Using a Smart Energy Management System

i. Reduced energy costs: The system can help to reduce energy costs by optimizing the power consumption of different loads.
ii. Increased energy efficiency: The system can help to increase energy efficiency by scheduling the operation of different loads and by reducing energy waste.
iii. Improved sustainability: The system can help to improve sustainability by reducing greenhouse gas emissions.

2.3 Hardware and Software Requirements

Hardware and Software Requirement

Hardware:

- Microcontroller – AT89S52- PU
- Arduino
- Transformer
- Voltage Regulator – LM7805
- IR Sensor
- LM324
- OP AMP LM358
- Thermostat
- LDR
- Analog to Digital Converter (ADC) - MCP3202
- Display Block
- Relay
- ESP32 WiFi Module
- ZMPT101B AC Voltage Sensor Module
- SCT-013-030 Non-invasive AC Current Sensor
- Solar Panel (3-25V)
- Voltage Sensor Module

Software:

- Arduino IDE
- KEIL Software
- ThingSpeak
- Easy EDA
- Blynk

2.4 Datasheet

AT89S52 – 24PU Microcontroller:

The AT89S52 microcontroller, which is an 8-bit device with 8K bytes of in-system programmable flash memory. This microcontroller is compatible with MCS-51 products and operates between 0 Hz to 33 MHz. It includes features such as 256 bytes of RAM, 32 programmable I/O lines, three 16-bit timer/counters, and several modes for power saving and efficient operation.

It supports both serial and parallel flash programming, with a detailed guide on how to perform each. The AT89S52 is suitable for a variety of embedded control applications due to its rich feature set which includes multiple operating modes, a watchdog timer, dual data pointers, and various interrupt and I/O configurations.

For programming, the device supports both parallel and serial interfaces. The parallel mode requires a high-voltage (12V) signal for programming, while the serial mode utilizes a standard serial ISP interface. The microcontroller can also be programmed using various lock bits to protect against unauthorized code modifications.

The microcontroller is designed to operate within a voltage range of 4.0V to 5.5V and includes power management features like idle and power-down modes to conserve power. It also has extensive support for interrupt handling and timer configurations which makes it highly versatile for managing complex tasks in embedded systems.

ULN2803 Relay Driver:

The ULN2803 is a linear integrated circuit featuring eight Darlington transistor pairs, capable of handling high-voltage and high-current outputs up to 500mA and 50V. This versatility makes it ideal for driving relays, hammers, lamps, and LEDs. It includes output clamp diodes for inductive loads and is compatible with various logic types, facilitating easy integration into digital systems. Available in DIP-18 and

SOP-18 packages, it accommodates different mounting needs. The ULN2803 operates within a voltage range of -0.5V to 30V, with power dissipation ranging from 0.54 to 1.47 watts depending on the package. Its operational temperature range of -40 to +85°C ensures reliability under diverse environmental conditions.

12 V Relay Driver:

The relay is a compact, high-capacity component suitable for high-density PCB mounting. It handles up to 10A, with options for 3V to 48V coil voltages and different forms for various applications. UL, CUL, and TUV certified, it uses high-temperature and chemical-resistant materials, available in sealed and flux-free types. Key features include rapid operation and release times, high insulation resistance, and durability across -25°C to +70°C, making it ideal for household appliances, office machines, and automotive applications.

MCP3202:

The MCP3202 is a 12-bit dual-channel Analog-to-Digital Converter (A/D) with SPI interface, suitable for high-speed data acquisition. It offers programmable single-ended or pseudo-differential inputs and operates over a 2.7V to 5.5V range, with a maximum sampling rate of 100 ksps at 5V. Featuring low power consumption and a wide operational temperature range (-40°C to +85°C), the MCP3202 is ideal for sensor interfacing, process control, and battery-operated systems. It is available in PDIP, SOIC, and TSSOP packages.

LM35:

The LM35 is a precision temperature sensor with an output voltage directly proportional to the Celsius temperature. It offers high accuracy without the need for external calibration, achieving typical accuracies of ±0.25°C at room temperature. The sensor operates on a low power supply (4 to 30 volts) and has minimal self-heating. It is available in multiple package types including TO-46, TO-92, and TO-220, making it suitable for diverse applications from remote temperature sensing to embedded electronics. Its simplicity and low cost make it a popular choice for temperature monitoring in various systems.

LM7805:

The LM7805 is a three-terminal positive voltage regulator available in a TO-220 package, providing a fixed output voltage of 5.0 V with a typical output current of up to 1A. It features internal mechanisms for current limiting, thermal shutdown, and safe area operation, enhancing its reliability and making it virtually indestructible with proper heat sinking. This regulator operates over a temperature range of 0 to 125°C and supports input voltages up to 35 V. It's designed primarily for stable fixed-voltage applications but can also be adapted for adjustable outputs with external components. Common characteristics include a quiescent current of 5 to 8 mA and excellent ripple rejection of 62 to 73 dB, making it suitable for a variety of electronic applications.

LM358:

The LM358 operational amplifier is commonly paired with an IR sensor to enhance the weak electrical signals that the sensor generates upon detecting infrared light from nearby objects. This configuration is primarily used in applications involving proximity or object detection. The LM358 amplifies the IR sensor's signal, making it suitable for further analysis by a microcontroller or other digital systems.

This operational amplifier supports a broad input voltage range (3.0 V to 32 V) and features dual amplifiers with a true differential input stage, low input bias, and internal compensation. It is designed to operate efficiently with low power consumption and can handle continuous output short circuits, making it robust for various electronic applications. Its ability to work with both single and split power supplies and its compatibility with different digital logic levels enhance its versatility in consumer electronics and industrial systems. The LM358 operates effectively within a temperature range of 0 to 70°C and is often packaged in an SOP-8 format.

LM324:

The LM324 is a low-cost, quad operational amplifier with true differential inputs, capable of operating from a single power supply of 3.0 V to 32 V. Each amplifier within the LM324 chip has a unique capability to handle a wide range of input voltage levels, making it highly suitable for interfacing with various sensors, including LDRs (Light Dependent Resistors).

When using the LM324 with an LDR to detect light levels, the operational amplifier can amplify the small voltage changes across the LDR that occur in response to light intensity variations. This setup is typically configured with the LDR as part of a voltage divider network, where the varying resistance of the LDR alters the voltage at the input of the LM324 based on light exposure. The LM324 amplifies this signal, making it easier to read and process by digital systems, such as microcontrollers, for applications like automatic lighting control, light level monitoring, or creating light-sensitive triggers.

Chapter 3

Cost Analysis

Table 1

Components	Units	Cost (Rupees)
Microcontroller – AT89S52	2	300
Microcontroller Development Kit	1	1200
Transformer	1	150
Voltage Regulator – LM7805	1	50
IR Sensor	2	120
LM324	4	40
LM358 op-amp	2	30
10K POT	5	100
LDR	4	20
Display Block	3	500
Relay	1	100
Analog to Digital Converter	1	300
ESP32 WiFi Module	2	1000
ZMPT101B AC Voltage Sensor Module	1	90

SCT-013-030 Non-invasive AC Current Sensor	1	170
Micro-USB Cable	1	25
Solar Panel (3-25V)	1	150
Voltage Sensor Module	1	50
LM35 Temperature Sensor	3	180
Zero PCB Board	3	50
Other Accessories	1	2000
Total Estimation		7000

Chapter 4

Result & Working

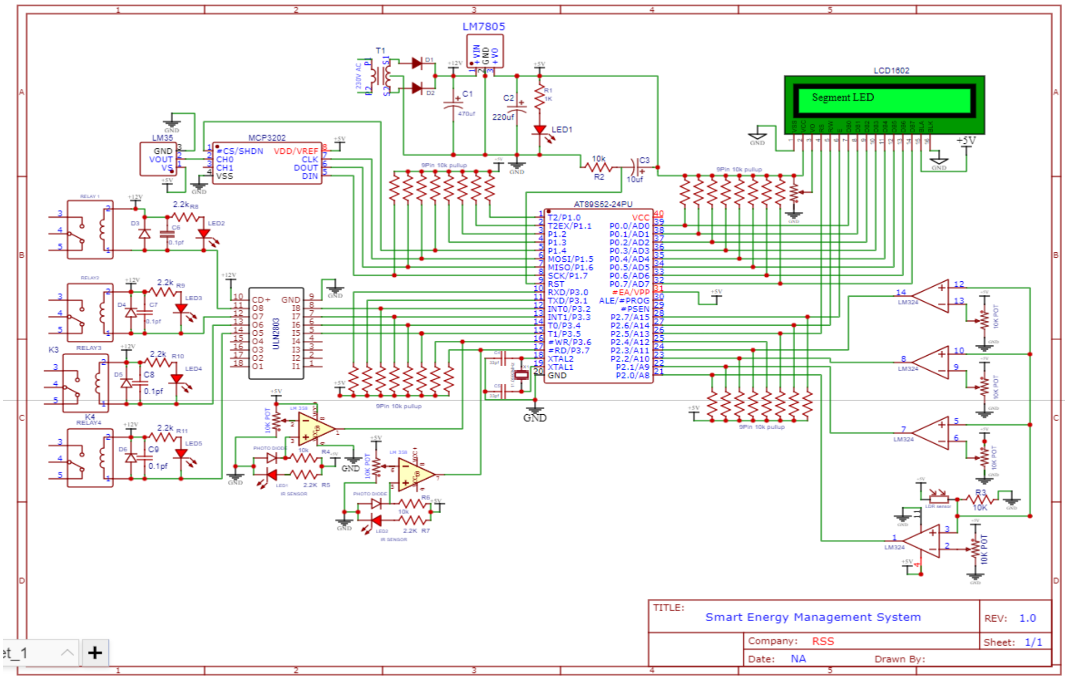


Fig. 3(a) - Simulation

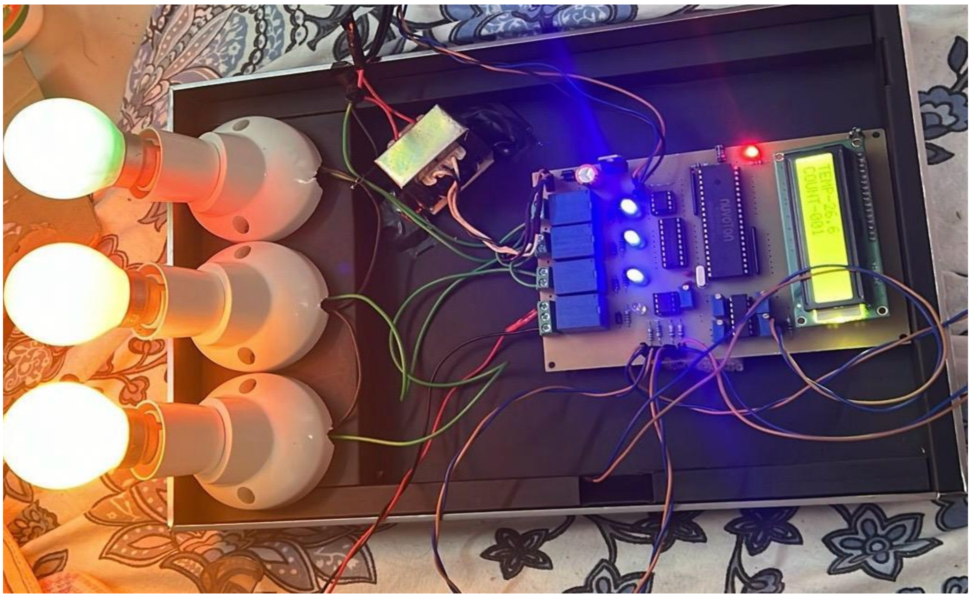


Fig. 3(b) - Working

Central Control

AT89S52 Microcontroller: This microcontroller serves as the brain of the system. It coordinates all the activities by receiving data from various sensors, processing this information, and executing actions based on predefined logic and thresholds. It controls all other modules by sending commands and handling input/output operations efficiently.

Sensing Units

IR Sensor: This sensor is pivotal for detecting the presence of individuals within a room. It operates by emitting an infrared signal and detecting the reflection off moving objects (like people). The microcontroller interprets changes in sensor output to determine whether to activate or deactivate the room's systems, such as lights and fans, based on occupancy.

LDR (Light Dependent Resistor): The LDR is used to gauge the intensity of ambient light. It is sensitive to changes in light levels, and its resistance varies accordingly. The system uses this variable resistance to assess whether additional artificial lighting is needed, helping to conserve energy by using natural light when sufficient.

LM35 Temperature Sensor: This component continuously monitors the ambient temperature. It is a precision integrated-circuit sensor whose output voltage is linearly proportional to the Celsius temperature. The microcontroller uses this data to decide whether to activate cooling systems (like a fan) when room temperature exceeds comfort levels.

Signal Conditioning and Data Conversion

LM358 Operational Amplifier: Used with the IR sensor, this operational amplifier enhances the minor changes in the received signal to ensure the microcontroller can accurately interpret the presence or absence of people.

LM324 Operational Amplifier: This amplifier works with the LDR, enhancing its signal for more precise light level measurement. It ensures that the microcontroller receives clear and amplified input for making lighting decisions.

MCP3202 ADC: This Analog-to-Digital Converter takes the analog signals from the LM35 temperature sensor and converts them into a digital format that the microcontroller can easily process and use to make decisions regarding environmental controls.

Actuation and Power Control

ULN2803 Darlington Array: This component acts as a driver for the relays, providing the necessary current and voltage to activate them. It interfaces between the low-power parts of the circuit (like the microcontroller and sensors) and the high-power components (like relays and fans).

12V Relay: These electromechanical switches control the high-power loads such as the room's lighting and fans. They operate under the command of the microcontroller, which decides when to open or close these relays based on the sensor inputs.

Power Management

Transformer and Rectifier: These components convert the high-voltage AC from the mains supply into a lower-voltage DC. The transformer steps down the voltage, while the rectifier converts it from AC to DC, preparing it for use by the circuit.

LM7805 Voltage Regulator: This regulator stabilizes the DC voltage to a constant 5V, which is safe for the microcontroller and other sensitive components. It ensures that fluctuations in the power supply do not affect the operation of the electronic components.

User Interface

Seven Segment LED Display: This display provides a user-friendly interface to show important information such as current temperature, system status (e.g., "Fan ON", "Light OFF"), and other alerts. It allows for easy monitoring of the system's performance and immediate feedback on changes made by the system.

Working of the Project:

Detection and Action:

- When a person enters the room, the IR sensor detects this change and signals the microcontroller.
- The microcontroller checks the ambient light via the LDR and decides whether or not to turn on the lights.
- It also reads the temperature from the LM35 sensor and, if the temperature is above the set threshold, turns on the fan using the relay.

Feedback and Control:

- The system constantly monitors the environment through its sensors and adjusts the controls accordingly to ensure efficient energy use.
- Outputs such as the status of lights and fan are displayed on the LED display for real-time feedback.
- This smart energy management system efficiently uses energy by automating control of lights and fans, thus ensuring comfort while minimizing unnecessary power consumption.

Chapter 5

Conclusion

In conclusion, the Smart Energy Management System (SEMS) presented here offers a comprehensive solution for optimizing energy usage in indoor environments. By intelligently monitoring and controlling lighting, fan operation, and other energy-consuming devices based on real-time environmental data and occupancy levels, SEMS ensures both energy efficiency and user comfort.

Through the integration of sensors, relays, and an LCD display, SEMS provides users with valuable insights into their energy consumption patterns, allowing for informed decision-making and promoting a culture of energy conservation. Furthermore, the system's ability to adapt to changing conditions and adjust energy usage accordingly helps to minimize wastage and reduce overall energy costs.

With its modular design and scalable architecture, SEMS can be easily adapted to various indoor settings, from residential homes to commercial buildings. Its versatility and effectiveness make it a valuable tool for achieving sustainable energy management goals and contributing to a greener future.

In summary, SEMS represents a significant step forward in the quest for efficient energy management systems, offering a practical solution that balances environmental responsibility with user convenience and cost-effectiveness.

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