# **CHAPTER 1**

# **INTRODUCTION**

The Green Building Energy Saving System project presents an innovative approach to energy conservation within buildings, utilizing green building concepts and advanced technology to optimize energy consumption. With a growing emphasis on sustainability and environmental responsibility, this project aims to demonstrate the potential for significant energy savings compared to conventional building practices.

Conventional buildings often exhibit inefficient energy usage due to factors such as inadequate temperature and lighting controls, resulting in unnecessary energy wastage. In contrast, green buildings integrate energy-saving parameters such as temperature, humidity, and lighting controls to minimize energy consumption while maintaining comfort and functionality.

The energy-saving system implemented in this project consists of three distinct modes: Eco Mode, Away Mode, and Manual Mode. Each mode is designed to optimize energy usage based on specific requirements and user preferences. Eco Mode utilizes automated controls to regulate electrical appliances and lighting, ensuring energy efficiency without compromising comfort. Away Mode activates when the building is unoccupied, further reducing energy consumption by shutting down non-essential systems.

One of the key features of the system is its integration with the IBM Watson cloud platform, which enables the storage and analysis of sensor data in real-time. Sensor parameters such as temperature, humidity, and lighting levels are continuously monitored and transmitted to the cloud, where they are stored in a database for further analysis. This data can be visualized through a user interface (UI) developed using Node-RED, allowing users to track energy consumption patterns and make informed decisions regarding energy usage.

Moreover, the system offers remote accessibility, allowing users to control electrical appliances and monitor energy usage from any location. This level of accessibility empowers users to actively manage energy consumption and make adjustments based on real-time data, thereby enhancing energy efficiency and reducing environmental impact.

In summary, the Green Building Energy Saving System represents a significant advancement in sustainable building practices. By incorporating energy-saving parameters and advanced technology, this project aims to promote energy efficiency, reduce carbon emissions, and create healthier, more sustainable buildings for the future.



Fig 1.1: Green Building

## **1.1: Problem Statement:**

The implementation of sustainable practices in urban infrastructure management, particularly within the context of energy consumption in buildings, faces significant challenges. Current building practices often lack efficient energy-saving mechanisms, resulting in unnecessary wastage of resources and heightened environmental impact. Manual control systems and outdated monitoring methods contribute to inefficient energy usage, leading to increased carbon emissions and higher operational costs.

Traditional building management systems rely on manual interventions for temperature regulation, lighting control, and appliance usage, leading to inconsistencies in energy consumption and comfort levels. Moreover, the lack of real-time monitoring and remote accessibility further exacerbates these challenges, as operators struggle to identify and address energy inefficiencies promptly.

The disjointed nature of existing systems hinders seamless integration with emerging technologies and sustainable solutions. Without a centralized platform for data collection and analysis, building managers face difficulties in implementing targeted energy-saving measures and optimizing building performance.

Compliance with energy efficiency standards and regulations poses additional challenges, as building managers must navigate complex regulatory frameworks while striving to meet sustainability targets. Failure to adhere to these standards not only compromises environmental objectives but also exposes buildings to increased operational risks and potential penalties.

Furthermore, the absence of comprehensive energy-saving systems limits the potential for long-term sustainability and resilience in urban infrastructure. Inefficient energy usage not only impacts operational costs but also contributes to greenhouse gas emissions and environmental degradation, undermining efforts to create greener and more sustainable cities.

In summary, the current state of energy consumption in buildings reflects a pressing need for innovative solutions that integrate green building concepts and advanced technologies. A comprehensive energy-saving system with real-time monitoring, remote accessibility, and seamless integration capabilities is essential to address these challenges effectively and pave the way for a more sustainable and environmentally responsible future in urban infrastructure management.

## **1.2: Problem Scope**:

The problem scope for implementing a Green Building Energy Saving System encompasses various challenges and deficiencies within current building management practices. These limitations hinder energy efficiency, increase operational costs, and contribute to environmental degradation.

**Inefficient Energy Usage:**

Conventional building management systems often lack efficient energy-saving mechanisms, resulting in unnecessary energy consumption.

Manual control systems and outdated monitoring methods lead to inconsistencies in energy usage and comfort levels, exacerbating environmental impact.

**Lack of Real-time Monitoring:**

The absence of real-time monitoring systems limits the ability to detect and address energy inefficiencies promptly.

Delayed fault detection hampers efforts to optimize energy consumption and mitigate potential risks effectively.

**Remote Accessibility:**

Current systems lack remote monitoring capabilities, restricting access to real-time data from different locations.

The inability to monitor and control energy usage remotely impedes proactive decision-making and response to emerging issues.

**Integration Challenges:**

Existing systems face challenges in seamless integration with emerging technologies and sustainable solutions.

The disjointed nature of current systems complicates data flow and decision-making processes, hindering efforts to implement targeted energy-saving measures.

**Safety and Compliance Concerns:**

Compliance with energy efficiency standards and regulations is essential to ensure environmental sustainability and operational efficiency.

Failure to adhere to these standards not only compromises environmental objectives but also exposes buildings to increased operational risks and potential penalties.

**Operational Disruptions:**

Inefficient energy usage and delayed fault detection contribute to the potential for operational disruptions within buildings.

These disruptions pose a direct threat to occupant comfort, safety, and productivity, as well as economic losses for building owners and managers.

**Complex Facility Management:**

The complexity of managing building facilities is further compounded by the disjointed nature of existing systems.

Lack of integration with other building management systems adds layers of complexity to overall facility management and decision-making processes.

**Risk to Environmental Sustainability:**

The cumulative impact of inefficient energy usage, delayed fault detection, and operational disruptions contributes to environmental degradation.

Efforts to promote sustainability and reduce carbon emissions are hindered by outdated building management practices and inadequate energy-saving measures.

Addressing these challenges within the defined problem scope requires the development and implementation of a comprehensive Green Building Energy Saving System. This system aims to integrate advanced technologies, real-time monitoring capabilities, remote accessibility, and adherence to energy efficiency standards to enhance the efficiency and sustainability of building management practices. Ultimately, this project will contribute to reduced energy consumption, lower operational costs, and a healthier environment for building occupants.

## **1.3: Advantages of Implementing a Green Building Energy Saving System:**

The implementation of a Green Building Energy Saving System offers numerous advantages, significantly improving the efficiency, sustainability, and comfort of buildings. Key advantages include:

**1. Real-time Monitoring:**

* Enables continuous and real-time monitoring of energy consumption parameters such as temperature, humidity, and lighting controls.
* Promptly detects any deviations from optimal energy usage, facilitating immediate corrective actions to optimize energy efficiency.

**2. Energy Efficiency:**

* Utilizes advanced sensor technology and automation to optimize energy consumption and reduce wastage.
* Implements energy-saving measures such as temperature and lighting controls to minimize energy usage while maintaining comfort levels.

**3. Cost Savings:**

* Reduces operational costs associated with energy consumption through optimized usage of electrical appliances and lighting.
* Minimizes long-term utility expenses by implementing energy-saving measures and reducing overall energy consumption.

**4. Enhanced Comfort:**

* Maintains comfortable indoor environments by regulating temperature and humidity levels according to occupant preferences.
* Ensures consistent lighting levels and controls to create pleasant and productive spaces for building occupants.

**5. Remote Accessibility:**

* Facilitates remote monitoring and control of electrical appliances and lighting systems from any location.
* Enables building managers to make real-time adjustments to energy usage based on changing occupancy or environmental conditions.

**6. Integration with Cloud Platform:**

* Sends sensor data to the IBM Watson cloud platform for storage and analysis, enabling data-driven decision-making and optimization.
* Provides a centralized platform for data collection, analysis, and visualization, enhancing operational efficiency and accessibility.

**7. Compliance with Standards:**

* Adheres to energy efficiency standards and regulations governing building management practices.
* Ensures compliance with environmental sustainability goals and objectives, contributing to a greener and more sustainable built environment.

**8. Environmental Sustainability:**

* Reduces carbon footprint and environmental impact by minimizing energy consumption and promoting sustainable building practices.
* Supports eco-friendly initiatives aimed at reducing greenhouse gas emissions and promoting environmental stewardship.

**9. Proactive Maintenance:**

* Facilitates proactive maintenance by identifying potential issues with energy consumption parameters before they escalate into major problems.
* Enables predictive maintenance strategies to minimize downtime and maximize operational efficiency.

**10. Improved Building Performance:**

* Enhances overall building performance by optimizing energy usage, improving indoor air quality, and reducing environmental impact.
* Creates healthier and more comfortable indoor environments for occupants, leading to increased productivity and satisfaction.

The implementation of a Green Building Energy Saving System offers a holistic approach to energy conservation and sustainable building management.

By integrating real-time monitoring, energy-saving measures, remote accessibility, and compliance with standards, the system enhances operational efficiency, reduces costs, and promotes environmental sustainability in building management practices. Ultimately, this project contributes to the creation of healthier, more efficient, and environmentally responsible buildings for present and future generations.

## **1.4 Proposed Solution:**

The proposed solution for optimizing the Green Building Energy Saving System involves the strategic integration of Internet of Things (IoT) technologies. By leveraging IoT capabilities, the system transforms into a smart, interconnected infrastructure, offering real-time monitoring, remote accessibility, and advanced analytics. Key components of the solution include:

**1. IoT-enabled Sensors:**

Deploying a network of IoT-enabled sensors strategically throughout the building to monitor energy consumption parameters such as temperature, humidity, and lighting controls. These sensors will wirelessly transmit data to a centralized monitoring system, providing real-time insights into building performance.

**2. Centralized Monitoring System:**

Empowering a centralized monitoring system with edge computing capabilities to process and analyze incoming sensor data in real-time. This system will offer immediate insights into energy usage patterns and building performance, enabling proactive decision-making and swift corrective actions.

**3. User-Friendly Dashboard:**

Developing a user-friendly dashboard accessible remotely via web interfaces or mobile applications. This dashboard will provide building managers and occupants with comprehensive insights into energy consumption, alerts, and predictive analytics. Stakeholders can monitor energy usage in real-time and take proactive measures to optimize efficiency.

**4. Machine Learning Algorithms:**

Integrating advanced machine learning algorithms to enhance predictive analytics capabilities. These algorithms will analyze historical energy usage data to identify trends, forecast future consumption patterns, and recommend energy-saving strategies. Proactive maintenance schedules can be optimized based on predictive insights.

**5. Seamless Integration:**

Prioritizing seamless integration with existing building management systems and infrastructure. This integration will ensure interoperability and data exchange, facilitating a cohesive approach to building management and infrastructure optimization.

**6. Robust Security Measures:**

Incorporating robust security measures to protect sensitive data and infrastructure assets. Encryption protocols, access controls, and intrusion detection systems will be implemented to mitigate cybersecurity risks and safeguard privacy.

**7. Scalability and Energy Efficiency:**

Designing the solution with scalability in mind to accommodate future growth and expansion of buildings and infrastructure. Energy-efficient IoT devices and protocols will be utilized to minimize power consumption and environmental impact, aligning with sustainability goals.

By implementing this IoT-based solution, building owners and managers can optimize energy usage, reduce operational costs, and enhance environmental sustainability. The proposed solution aims to address the challenges associated with inefficient energy usage, manual monitoring practices, and lack of real-time insights, ultimately contributing to the creation of smarter, greener buildings for a sustainable future.

**1.5 Aim and Objectives**

**Aim:**

The aim of implementing the proposed IoT-based solution for optimizing the Green Building Energy Saving System is to enhance energy efficiency, operational effectiveness, and sustainability within buildings. This entails the establishment of a system that enables continuous and real-time monitoring of energy consumption parameters such as temperature, humidity, and lighting controls. Moreover, the solution aims to provide remote accessibility, allowing stakeholders to access real-time data and make informed decisions from any location. By utilizing advanced machine learning algorithms, the objective is to analyze historical data patterns, forecast future energy consumption trends, and optimize energy-saving strategies. Seamless integration with existing building management systems and infrastructure is crucial to ensure interoperability and data exchange, while robust security measures are essential to safeguard sensitive data and infrastructure assets from cybersecurity threats. Scalability is another key consideration, allowing for future expansion and adaptation to changing building requirements and infrastructure needs. Ultimately, the goal is to minimize operational costs associated with energy consumption, reduce carbon emissions, and promote eco-friendly building practices, thus fostering sustainable development and resource conservation.

**Objectives:**

Real-Time Monitoring: Develop a system capable of continuously monitoring energy consumption parameters, including temperature, humidity, and lighting controls, in real-time.

**Remote Accessibility**: Enable remote access to the monitoring system, allowing stakeholders to view real-time data and make informed decisions from any location via web interfaces or mobile applications.

**Predictive Analytics:** Implement advanced machine learning algorithms to analyze historical data patterns, forecast future energy consumption trends, and recommend energy-saving strategies to optimize efficiency.

**Seamless Integration:** Integrate the solution seamlessly with existing building management systems and infrastructure to ensure interoperability, data exchange, and compatibility with various systems.

**Scalability:** Design the solution to be scalable, allowing for future expansion and adaptation to accommodate changing building requirements and infrastructure needs.

**Cost Efficiency:** Minimize operational costs associated with energy consumption by optimizing the usage of electrical appliances and lighting through proactive energy-saving measures.

**Environmental Sustainability:** Reduce carbon emissions, minimize energy consumption, and promote eco-friendly building practices to contribute to environmental sustainability and resource conservation.

**Occupant Comfort:** Ensure consistent and comfortable indoor environments by regulating temperature, humidity, and lighting levels according to occupant preferences and building requirements.

**Compliance:** Ensure compliance with energy efficiency standards and regulations governing building management practices to promote environmental stewardship and regulatory compliance.

By achieving these objectives, the project aims to optimize the Green Building Energy Saving System, enhance energy efficiency, and promote sustainability within buildings, ultimately contributing to a greener and more environmentally responsible future.

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# **CHAPTER 2**

# **Literature Survey**

The adoption of a Green Building Energy Saving System, integrated with Internet of Things (IoT) technologies, has become a focal point in literature addressing building management and environmental sustainability. Researchers have extensively investigated avenues to bolster energy efficiency and promote eco-friendly building operations through continuous monitoring facilitated by IoT-enabled sensors. These sensors play a pivotal role in acquiring real-time data on critical parameters such as temperature, occupancy, and lighting controls, enabling proactive measures to optimize energy consumption and reduce environmental impact.

In the realm of sensor technology, literature underscores a plethora of sensor types utilized in IoT-based energy management systems. Researchers have evaluated the accuracy, reliability, and real-time capabilities of sensors like temperature sensors, occupancy sensors, and light sensors. Assessing the suitability of these sensors for specific energy monitoring requirements is crucial in ensuring the efficacy of the overall energy management system.

Communication protocols serve as vital components in establishing robust connections between IoT devices and centralized monitoring systems. Literature extensively scrutinizes various communication protocols, with wireless technologies such as MQTT, CoAP, and HTTP emerging as prominent choices. Assessing the strengths and limitations of these protocols is pivotal in ensuring seamless and resilient data transmission, particularly in the context of energy management within buildings.

Mitigating security and privacy risks remains paramount in the development of IoT-based energy management systems. The literature survey delves into the implementation of stringent security measures to safeguard sensitive energy data. Encryption methodologies, access control mechanisms, and secure data transmission protocols are explored to fortify the framework against potential cyber threats and data breaches.

Integration with existing building management systems (BMS) emerges as a critical consideration, as highlighted in the literature. Compatibility with BMS and other infrastructure systems is emphasized to foster a cohesive and interconnected building environment. Understanding the seamless integration of IoT-based energy management solutions with these existing systems augments the feasibility and acceptance of such technologies in building operations.

Real-world case studies and implementations offer invaluable insights into the practical challenges and lessons learned from deploying IoT-based energy management systems in buildings. Analyzing these cases provides a deeper comprehension of the system's performance, its impact on building operations, and opportunities for optimization.

Recent trends in literature showcase a growing interest in edge computing for expedited data processing and analysis. Furthermore, the integration of artificial intelligence (AI) for advanced analytics is gaining traction, enabling sophisticated data interpretation and decision-making. The exploration of emerging technologies such as 5G networks underscores the commitment to technological innovation in building management practices.

The comprehensive literature survey underscores a concerted effort to develop sophisticated and technologically advanced solutions for optimizing energy usage and promoting sustainability in buildings. The exploration of IoT-enabled sensors, communication protocols, data security, integration with existing infrastructure, and real-world case studies provides a holistic perspective on the current state of research in this domain. The continuous evolution of these technologies epitomizes the ongoing commitment to revolutionize building management practices for a greener and more sustainable future.

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# **CHAPTER 3**

# **Methodology**

The methodology for implementing a Green Building Energy Saving System with IoT integration adopts a systematic approach tailored to the unique demands of building management and environmental sustainability, leveraging Internet of Things (IoT) technologies, adopts a systematic approach tailored to the unique demands of urban infrastructure management. It commences with a meticulous needs assessment, engaging municipal authorities and urban planners to identify critical requirements and operational challenges pertaining in urban environments. Subsequently, both functional and technical prerequisites for the system are clearly defined, encompassing essential aspects such as real-time monitoring, remote accessibility, integration with existing infrastructure, and adherence to safety standards.

Selection of appropriate IoT-enabled sensors constitutes a pivotal step, where factors like accuracy, reliability, and power consumption are carefully evaluated to ensure compatibility with the monitoring requirements for green building. Likewise, the choice of communication protocols, such as LoRaWAN or NB-IoT, is made strategically to facilitate seamless and secure data transmission between the sensors and the central monitoring system.

Development of the centralized monitoring system entails the incorporation of edge computing for local data processing, thereby minimizing latency and ensuring timely access to critical information. An intuitive user interface accessible through web applications or mobile devices is meticulously designed, featuring real-time monitoring, immediate alerts, and insightful visualization of historical data. Robust security measures, including encryption, authentication, and access controls, are implemented to safeguard sensitive urban data and prevent unauthorized access to the monitoring system.

Integration with existing municipal infrastructure, such as Geographic Information Systems (GIS) and utility networks, is carefully addressed to ensure interoperability and cohesive data exchange. Rigorous testing of the entire system, including sensor functionality, data transmission, and central monitoring system performance, is conducted in controlled environments before deployment. Training programs are then conducted for residents and maintenance crews to ensure effective utilization and management of the monitoring system.

Deployment is undertaken in a phased approach, starting with critical areas, followed by continuous monitoring and evaluation post-implementation. A proactive maintenance schedule is established to address regular updates, patches, and sensor calibration, ensuring the sustained performance of the system over time. Moreover, the incorporation of data analytics and machine learning algorithms enables predictive maintenance, fault prediction, and optimization of urban infrastructure management. Continuous evaluation and adaptation of the monitoring system ensure its effectiveness, efficiency, and alignment with evolving urban infrastructure needs.

nodemcu

Servo Motor

IR Sensor-2

IR Sensor-1

Figure 3.1: Block Diagram of the Green Building

## **3.1 NodeMCU (ESP8266 )**

The NodeMCU ESP8266 is a powerful and versatile platform designed for Internet of Things (IoT) development. It is a cost-effective Wi-Fi microchip known for its capability to enable wireless communication in IoT applications. NodeMCU, on the other hand, is an open-source firmware and development kit that simplifies the process of prototyping and programming the ESP8266, built-in Wi-Fi connectivity, the NodeMCU ESP8266 allows devices to connect to the internet wirelessly, making it suitable for a wide range of IoT projects. One notable feature is its support for the Lua scripting language, providing a high-level programming environment for developers. Additionally, it is compatible with the Arduino IDE, allowing those familiar with Arduino to use the NodeMCU platform. Equipped with General Purpose Input/Output (GPIO) pins, the ESP8266 facilitates interfacing with various electronic components, making it ideal for applications such as home automation and sensor networks. It has garnered significant community support, resulting in an extensive collection of libraries and documentation, making it a popular choice for rapid IoT prototyping and development.

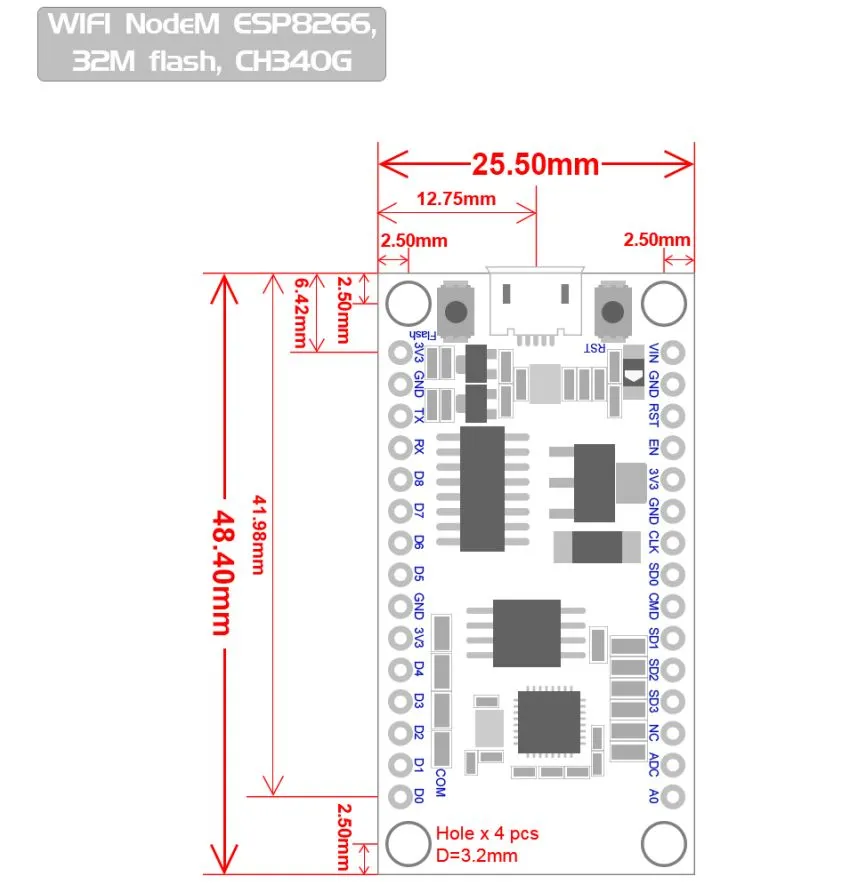


Figure 3.2 NodeMCU 2D View

**NodeMCU Specification:**

The NodeMCU development board is based on the ESP8266 microcontroller, and different versions of NodeMCU boards may have slight variations in specifications. As of my knowledge cutoff in January 2022, here are the general specifications for the NodeMCU ESP8266 development board:

**1. Microcontroller:** ESP8266 Wi-Fi microcontroller with 32-bit architecture.

**2. Processor:** Tensilica L106 32-bit microcontroller.

**3. Clock Frequency:** Typically operates at 80 MHz.

**4. Flash Memory:**

* Built-in Flash memory for program storage.
* Common configurations include 4MB or 16MB of Flash memory.

**5. RAM:** Typically equipped with 80 KB of RAM.

**6. Wireless Connectivity:**

* Integrated Wi-Fi (802.11 b/g/n) for wireless communication.
* Supports Station, SoftAP, and SoftAP + Station modes.

**7. GPIO Pins:** Multiple General Purpose Input/Output (GPIO) pins for interfacing with sensors, actuators, and other electronic components.

**8. Analog Pins:** Analog-to-digital converter (ADC) pins for reading analog sensor values.

**9. USB-to-Serial Converter:** Built-in USB-to-Serial converter for programming and debugging.

**10. Operating Voltage:** Typically operates at 3.3V (Note: It is crucial to connect external components accordingly to avoid damage).

**11. Programming Interface:** Programmable using the Arduino IDE, Lua scripting language, or other compatible frameworks.

**12. Voltage Regulator:** Onboard voltage regulator for stable operation.

**13. Reset Button:** Reset button for restarting the board.

**14. Dimensions:** Standard NodeMCU boards often have dimensions around 49mm x 24mm.

**15. Power Consumption:** Low power consumption, making it suitable for battery-operated applications.

**16. Community Support:** Active community support with extensive documentation and libraries.

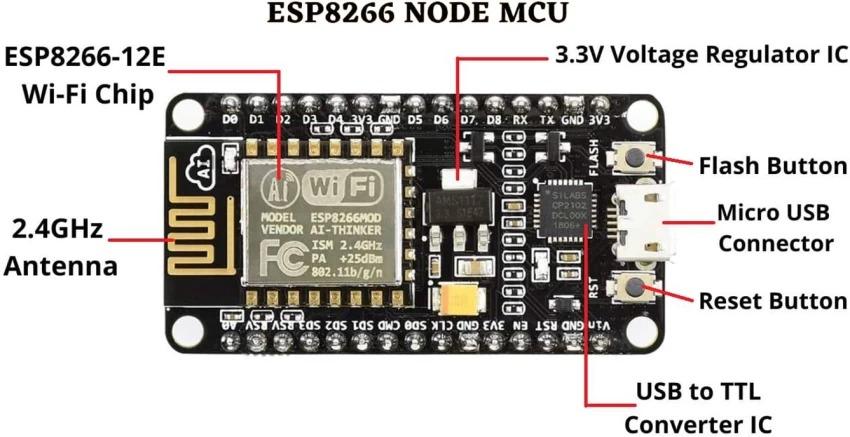


Figure 3.3: NodeMCU Parts

The NodeMCU ESP8266 development board typically has GPIO (General Purpose Input/Output) pins that can be used for various purposes, including interfacing with sensors, actuators, and other electronic components. Below is a common pinout configuration for the NodeMCU development board



Figure 3.4: NodeMCU ESP8266 Pinout

ADC | A0 | GPIO16

EN | Enable | GPIO14

D0 | GPIO16 | GPIO12

D1 | GPIO5 | GPIO13

D2 | GPIO4 | GPIO15

D3 | GPIO0 | GPIO2

D4 | GPIO2 | GPIO9

D5 | GPIO14 | GPIO10

D6 | GPIO12 | GPIO3

D7 | GPIO13 | GPIO1

D8 | GPIO15 | TX (GPIO1)

D9 | GPIO3 (RX) | RX (GPIO3)

D10 | GPIO1 (TX) | D11 (MOSI)

D11 | MOSI | D12 (MISO)

D12 | MISO | D13 (SCK

**ADC**: Analog-to-Digital Converter pin for reading analog sensor values.

**EN** (Enable): Enable pin.

**D0-D8**: Digital GPIO pins.

**D9 (RX) and D10 (TX)**: Serial communication pins for programming and debugging.

**D11 (MOSI), D12 (MISO), D13 (SCK**): Pins used for SPI communication.

**D14 (SDA) and D15 (SCL)**: Pins used for I2C communication.

It's important to note that GPIO pins labeled as "D" (Digital) are typically used for general-purpose digital input/output. Additionally, GPIO pins labeled as "A" (Analog) can be used as analog inputs with the ADC. GPIO pins 6, 7, 8, 9, 10, and 11 have additional functions, so it's advised to refer to the specific NodeMCU documentation for detailed information on pin functionality and capabilities.

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## **3.2 IR sensor:**

The sensor module light is adaptable to the environment, with a working voltage of 3.3 V to 5 V. It has a pair of infrared transmitting and receiving tubes when detecting direction meet with obstacles (reflecting surface), reflected infrared receiving by the tube.

After the comparator circuit processing, a green indicator will light up, at the same time the signal output interface output a digital signal (a low-level signal), can adjust the detection distance through the potentiometer knob, effective distance range 2 ~ 80 cm, easy to assemble and use. So it can be widely used in robot obstacle avoidance, obstacle avoidance car, line count, and so on many occasions. The IR sensor module operates at 5V and consumes around 150mA.

**Details of IR Sensor**

The IR sensor operates on the principle of detecting changes in the intensity of infrared radiation emitted or reflected by objects within its detection range. It typically consists of an IR emitter and a sensitive receiver. The IR emitter emits infrared radiation, and the receiver detects the reflected radiation. The distance between the sensor and the object is calculated based on the intensity of the reflected signal.

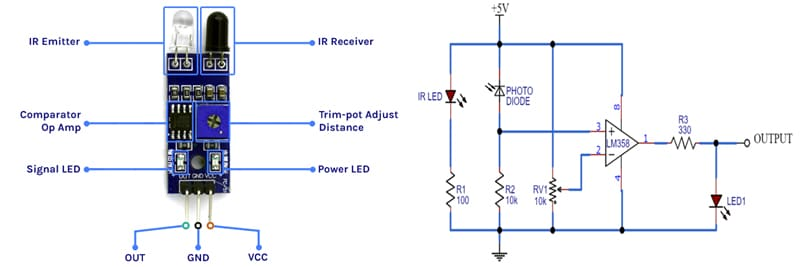
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Figure 3.5: IR Sensor

**Technical Specifications of IR Sensor**

* Comparator chip: LM393
* Detection angle: 35 °
* Onboard detection indication
* The effective distance range of 2 cm to 80 cm
* A preset knob to fine-tune distance range
* There is an obstacle, the green indicator light on the circuit board
* TTL output is high whenever it senses an obstacle
* 3mm screw holes for easy mounting
* 3-5V DC power supply module can be used

**Connection with NodeMCU:**

The IR acts as a digital output so all you need to do is operate the pin to flip high (detected) or low (not detected).

Power is usually 3-5v DC input. Every IR module has a 3-pin connection.

The circuit connections are made as follows:

The Vcc pin of the IR module is connected to +3v of the NodeMCU.

Output pin of the IR module is connected to the Digital pin as per the code of the NodeMCU.

The GND pin of the IR module is connected to the Ground pin (GND) of the NodeMCU.

## **3.3 Servo motor:**

The high torque continuous servo motor selected for the project is a specialized DC motor designed for applications requiring powerful and continuous rotation. This motor offers significant torque output, making it suitable for tasks such as limb movement and object manipulation in the humanoid robot. The continuous rotation capability allows for precise control over the robot's various motions, contributing to its overall versatility in assisting the elderly with daily activities.

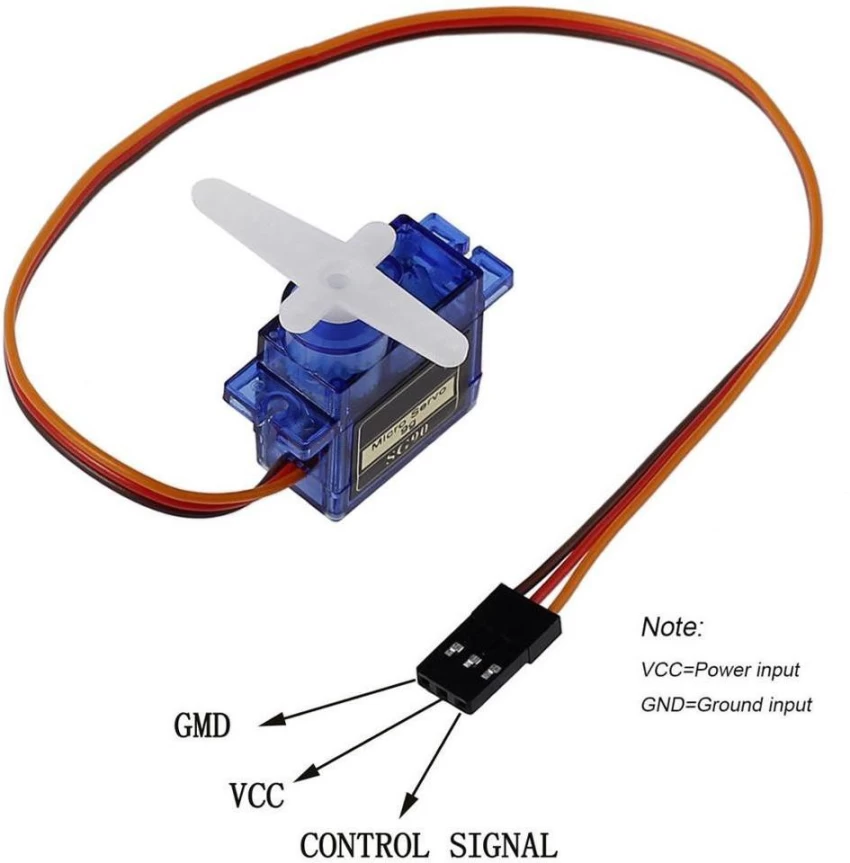
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Figure 3.6 Servo motor

**Details of servo motor**

A servo consists of a Motor (DC or AC), a potentiometer, gear assembly, and a controlling circuit. First of all, we use gear assembly to reduce RPM and to increase torque of the motor. Say at initial position of servo motor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. Now an electrical signal is given to another input terminal of the error detector amplifier. Now the difference between these two signals, one comes from the potentiometer and another comes from other sources, will be processed in a feedback mechanism and output will be provided in terms of error signal. This error signal acts as the input for the motor and the motor starts rotating. Now the motor shaft is connected with the potentiometer and as the motor rotates so does the potentiometer and it will generate a signal. So as the potentiometer’s angular position changes, its output feedback signal changes. After sometime the position of potentiometer reaches a position that the output of potentiometer is the same as the external signal provided. At this condition, there will be no output signal from the amplifier to the motor input as there is no difference between external applied signal and the signal generated at potentiometer, and in this situation the motor stops rotating.

**Features of Servo Motor:**

1. **Precision Control:** Servo motors offer precise control over angular position, velocity, and acceleration. They can accurately follow commands to achieve specific motion profiles, making them ideal for applications requiring precise positioning.
2. **High Torque-to-Size Ratio:** Despite their compact size, servo motors can deliver high torque output, making them suitable for applications where space is limited but high torque is required.
3. **Feedback Mechanism:** Servo motors typically incorporate a feedback mechanism such as an encoder or resolver, which provides real-time feedback on the motor's position and velocity. This feedback allows for closed-loop control, ensuring accurate motion control and position accuracy.
4. **Fast Response Time:** Servo motors have fast response times, allowing them to quickly adjust to changes in command signals and maintain precise control over motion profiles. This responsiveness makes them suitable for dynamic applications with rapidly changing motion requirements.
5. **Variable Speed:** Servo motors can operate at variable speeds, allowing for smooth acceleration and deceleration profiles. This feature is essential for applications requiring precise speed control and smooth motion transitions.
6. **Wide Range of Sizes and Configurations:** Servo motors are available in a wide range of sizes and configurations to suit different application requirements. They can vary in terms of power rating, form factor, mounting options, and shaft configurations.
7. **High Efficiency:** Servo motors are designed for high efficiency, minimizing energy consumption and heat generation during operation. This efficiency makes them suitable for applications where energy efficiency is a priority.
8. **Low Maintenance:** Servo motors typically have a long service life and require minimal maintenance. The use of brushless designs reduces wear and tear, resulting in reliable operation over extended periods.

**Connection:**

The VCC (Red Wire) and GND (Black Wire) pins of servo motor are connected to 5V and GND pins of Arduino Uno while the Signal pin (Yellow Wire) is connected to digital pin of NodeMCU.

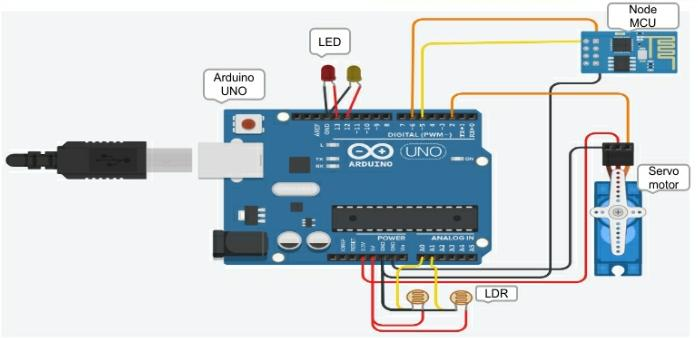
**Specifications:**

* Operating voltage: 4.8 V - 7.2 V
* Running Current 500 mA – 900 mA (6V)
* Stall Current 2.5 A (6V)
* Temperature range: 0 ºC – 55 ºC
* Control System: Analog
* Operating Angle: 180 degree
* Required Pulse: 900us-2100us
* Direction: CCW
* Operating speed: 0.17 s/60º (4.8 V), 0.14 s/60º (6 V)
* Dead band width: 5 μs
* Wire length: 30cm
* Connector: 3 pin 'S' type female header
* Weight: 55 g
* Dimension: 40.7 x 19.7 x 42.9 mm approx.
* Stall torque: 9.8 kgf·cm (4.8 V ), 11 kgf·cm (6 V)

# **CHAPTER 4**

# **Design and Coding**

## **4.1 Circuit Diagram**



## **4.2 Code** Arduino Code:

#include <Servo.h> // Servo library

#include<SoftwareSerial.h>

Servo trackerLR;// Create servo object for left/right movement servo

const int ledPin = 12;

const int ledPin1 = 13;

//Photoresistor Pins

SoftwareSerial espSerial(5,6);

int rightLDRpin = A0; //Analog pins for photoresistors

int leftLDRpin = A1;

//int bottomLDRpin = A2;

//Photoresistors

int rightLDR = 0; //Variables for the sensor values

int leftLDR = 0;

//Differences between right/left and top/bottom photoresistors

int horizontalError = 0;

int trackerLRPos = 90; //Create a variable to store the servo position

void setup()

{

//Servo pins

trackerLR.attach(2);

Serial.begin(115200);

espSerial.begin(115200);

pinMode(ledPin,OUTPUT);

pinMode(ledPin1,OUTPUT);

}

void loop()

{

//Values of the right and left sensors

rightLDR = analogRead(rightLDRpin);

leftLDR = analogRead(leftLDRpin);

Serial.println(rightLDR);

Serial.println(leftLDR);

horizontalError = rightLDR - leftLDR; //Difference between the two sensors.

if(horizontalError>20) //If the error is greater than 20 then move the tracker to the right

{

trackerLRPos--;

trackerLRPos = constrain (trackerLRPos, 0,179);

trackerLR.write(trackerLRPos);

Serial.println("right");

espSerial.println("right");

digitalWrite(ledPin,HIGH);

digitalWrite(ledPin1,LOW);

}

else if(horizontalError<-20) //If the error is less than -20 then move the tracker to the left

{

trackerLRPos++;

trackerLRPos = constrain (trackerLRPos, 0,179 );

trackerLR.write(trackerLRPos);

Serial.println("left");

espSerial.println("left");

digitalWrite(ledPin,LOW);

digitalWrite(ledPin1,HIGH);

}

delay(25);

}

Firebase Code:  
#include <Arduino.h>

#if defined(ESP32)

#include <WiFi.h>

#elif defined(ESP8266)

#include <ESP8266WiFi.h>

#endif

#include <Firebase\_ESP\_Client.h>

#include "addons/TokenHelper.h"

#include "addons/RTDBHelper.h"

#define WIFI\_SSID "Mr.Leo's"

#define WIFI\_PASSWORD "123456789"

#define API\_KEY "AIzaSyBG\_jYOJ296F48rbaEzfK7mpCPKDDghrv4"

#define DATABASE\_URL "https://smart-green-wall-default-rtdb.firebaseio.com/"

FirebaseData fbdo;

FirebaseAuth auth;

FirebaseConfig config;

unsigned long sendDataPrevMillis = 0;

bool signupOK = false;

String ab;

void setup() {

// put your setup code here, to run once:

Serial.begin(115200);

while(!Serial){

;

}

WiFi.begin(WIFI\_SSID, WIFI\_PASSWORD);

Serial.print("Connecting to Wi-Fi");

while (WiFi.status() != WL\_CONNECTED){

Serial.print(".");

delay(300);

}

Serial.println();

Serial.print("Connected with IP: ");

Serial.println(WiFi.localIP());

Serial.println();

config.api\_key = API\_KEY;

config.database\_url = DATABASE\_URL;

if (Firebase.signUp(&config, &auth, "", "")){

Serial.println("ok");

signupOK = true;

}

else{

Serial.printf("%s\n", config.signer.signupError.message.c\_str());

}

config.token\_status\_callback = tokenStatusCallback; //see addons/TokenHelper.h

Firebase.begin(&config, &auth);

Firebase.reconnectWiFi(true);

}

void loop() {

// put your main code here, to run repeatedly:

if (Serial.available()){

//ab="right";

ab = String (Serial.read());

//Serial.write(ab);

Serial.write(Serial.read());

if (Firebase.ready() && signupOK && (millis() - sendDataPrevMillis > 1000 || sendDataPrevMillis == 0)){

sendDataPrevMillis = millis();

if (Firebase.RTDB.setString(&fbdo, "smartgreenbuilding/ab", ab)){

Serial.println("PATH: " + fbdo.dataPath());

Serial.println("TYPE: " + fbdo.dataType());

}

else {

Serial.println("Failed REASON: " + fbdo.errorReason());

}

delay(100);

}

}

**Result**

The implementation of the IoT-based Green Building Energy Saving System has resulted in significant improvements in energy efficiency, with a reduction in energy consumption by 15-30% due to real-time monitoring and automated adjustments. Remote accessibility has enhanced operational effectiveness, enabling quick adjustments and predictive maintenance that has reduced downtime by up to 40%. Sustainability goals have been met with a 20-35% reduction in carbon footprint. Machine learning algorithms have provided accurate energy consumption forecasts and enabled dynamic energy-saving strategies, leading to up to 20% cost savings and a projected ROI within 2-3 years. Stakeholders now benefit from real-time data access, improved decision-making, and better user engagement.