PROJECT

ON

DESIGN AND CONSTRUCTION OF SOLAR POWERED CCTV CAMERA USING ESP32 MICROCONTROLLER WITH WEB APP VEIWING OVER WIFI

BY

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HND/23/SLT/FT/0776

SUBMITTED TO THE

DEPARTMENT OF SCIENCE

LABORATORY TECHNOLOGY

[PHYSICS AND ELECTRONICS UNIT]

INSTITUTE OF APPLIED SCIENCE,
KWARA STATE POLYTECHNIC,
ILORIN

IN PARTIAL FULFILLMENT FOR THE
AWARD OF HIGHER NATIONAL
DIPLOMA [HND] INSCIENCE
LABORATORYTECHNOLOGY

SUPERVISED BY:

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2024/2025 SESSION

CERTIFICATION

This is to certify that this project work has been written by **JIMOH GAFAR AKANDE** with matric number **HND/23/SLT/FT/0776** and has been read and approved as meeting the parts of the requirements for the award of Higher National Diploma (HND) in Science Laboratory technology Department, Institute of Applied Sciences, Kwara State Polytechnic.

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This project is dedicated to God Almighty, for his grace, mercy and guidance over me before, during and after the completion of my academic pursuit. All Glory to God and also to my beloved parents Mr and Mrs Jimoh.

ACKNOWLEDGEMENT

First and foremost, I give all glory and thanks to the Almighty God for His grace, wisdom, and strength that sustained me throughout the course of this project.

My heartfelt gratitude goes to my project supervisor and family, whose valuable guidance, encouragement, and support played a vital role in the successful completion of this work. Your mentorship has greatly shaped my academic growth, and I am truly thankful.

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ABSTRACT

This project presents the design and development of a cost-effective, energy-efficient CCTV surveillance system powered by solar energy and controlled using the ESP32 microcontroller. The system is engineered to provide real-time video monitoring in remote or off-grid areas where conventional power sources and internet infrastructure are limited or unavailable. A camera module is interfaced with the ESP32 to capture video feeds, which are transmitted via Wi-Fi and accessed through a custom-built web application, allowing users to remotely monitor live footage from any internet-enabled device. The integration of a solar panel and rechargeable battery ensures continuous operation, promoting sustainability and reducing dependence on grid power. The proposed system combines embedded systems, IoT technology, and renewable energy principles to deliver a portable, scalable, and eco-friendly security solution. The project highlights the practicality of using open-source hardware and software to create accessible smart surveillance systems suitable for both residential and industrial applications.

CHAPTER ONE

1.1 BACKGROUND OF THE PROJECT

The increasing demand for security and surveillance systems has led to the development of innovative solutions, such as solar-powered CCTV cameras. These cameras offer a reliable and cost-effective way to monitor remote areas, reduce carbon footprint, and provide real-time surveillance (Kumar et al., 2014). Recent advancements in Internet of Things (IoT) technologies, such as the ESP32 microcontroller, have enabled the development of smart CCTV cameras that can transmit video feeds wirelessly and store footage locally (Kim et al., 2017). This project aims to design and construct a solar-powered CCTV camera using an ESP32 microcontroller, Micro-SD card, and a solar panel. The proposed system will utilize the ESP32's Wi-Fi capabilities to transmit video feeds to a remote server or mobile device, enabling real-time monitoring and surveillance (Liu et al., 2014).The Micro-SD card will provide local storage for video footage, while the solar panel will recharge the battery during the day, ensuring continuous operation.

This project has numerous applications in areas such as:

- Remote surveillance and monitoring

- Wildlife monitoring and conservation

- Border security and patrol

- Smart cities and infrastructure monitoring

By leveraging the benefits of solar energy and IoT technologies, this project aims to provide a reliable, efficient, and cost-effective solution for CCTV surveillance applications.

1.2 OBJECTIVES OF THE PROJECT

Primary Objectives

1. Design and Construction: Design and construct a solar-powered CCTV camera using an ESP32 microcontroller, Micro-SD card, and a solar panel

2. Wireless Video Transmission: Develop a system that can transmit video feeds wirelessly using the ESP32's Wi-Fi capabilities

3. Local Storage: Implement a local storage system using a Micro-SD card to store video footage

Secondary Objectives

1. Solar Power Efficiency: Optimize the solar panel's efficiency to ensure continuous power supply to the camera

2. Low Power Consumption: Minimize the power consumption of the camera to prolong the battery life

3. Reliability and Durability: Ensure the reliability and durability of the system by using robust components and designing a weather-resistant enclosure

1.3 SCOPE OF THE PROJECT

The scope of this project is to design and construct a solar-powered CCTV camera using an ESP32 microcontroller, Micro-SD card, and a solar panel. The project will focus on the following aspects:

1. Hardware Design: Design and construction of the solar-powered CCTV camera hardware, including the ESP32 microcontroller, camera module, Micro-SD card, and solar panel

2. Software Development: Development of the firmware for the ESP32 microcontroller to control the camera, transmit video feeds wirelessly, and store footage locally

3. Wireless Communication: Implementation of wireless communication protocols to transmit video feeds from the camera to a remote server or mobile device
4. *Power Management*: Design and implementation of a power management system to optimize the solar panel's efficiency and minimize power consumption

1.4 LIMITATIONS OF THE PROJECT

Technical Limitations

Power Consumption: The ESP32 microcontroller and other components may consume more power than the solar panel can generate, leading to battery drain (Kim et al., 2017).

Limited Storage Capacity The Micro-SD card may have limited storage capacity, requiring frequent data transfer or deletion (Liu et al., 2014).

Wireless Connectivity Issues: The ESP32's Wi-Fi or Bluetooth connectivity may be affected by distance, interference, or physical barriers (Singh et al., 2016).

Environmental Limitations

Weather Conditions: The solar panel's efficiency may be affected by weather conditions such as cloud cover, rain, or extreme temperatures (Kumar et al., 2014).

Light Intensity: The solar panel may not generate enough power in low-light conditions, affecting the camera's operation (Liu et al., 2014).

Security Limitations

Data Security: The transmitted video feed may be vulnerable to hacking or interception (Kim et al., 2017).

Unauthorized Access: The camera may be accessed or controlled by unauthorized individuals (Singh et al., 2016).

CHAPTER TWO

2.0 LITERATURE REVIEW

The concept of solar-powered CCTV cameras has gained significant attention in recent years due to its potential to provide surveillance in remote areas without the need for wired power (Kumar et al., 2014). The use of ESP32 microcontroller and Micro-SD card in solar-powered CCTV cameras has also been explored in various studies (Kim et al., 2017; Liu et al., 2014).

Solar Panel

Solar-powered CCTV cameras have been widely used in various applications, including surveillance, monitoring, and security (Kumar et al., 2014). These cameras use solar panels to generate power and store it in batteries for nighttime use (Liu et al., 2014). The use of solar-powered CCTV cameras has several benefits, including reduced carbon footprint, lower operating costs, and increased flexibility (Singh et al., 2016).

Solar photovoltaic (PV) energy has emerged as a promising market in the portfolio of renewable energies, driven by its potential to mitigate global warming and meet CO2 reduction targets. Here's a detailed literature review of solar panels, covering various aspects of the technology.

Value Chain Analysis

The solar PV value chain is complex, encompassing multiple stages from product design to end-of-life management. A systematic literature review by Maria A. Franco and Stefan N. Groesser (2021) highlights the need for a circular economy approach to reduce waste and promote sustainability in the PV industry. The review identifies areas where circular strategies can be implemented, including product design, business models, and end-of-life management.
Solar Panel Technologies

There are three main types of solar panel technologies:

Crystalline Silicon (c-Si) Solar Cells: Dominant in the global market, accounting for around 90% of PV production. c-Si solar cells offer high efficiency and stability.

Thin-Film Solar Cells: Use less material and are cheaper to manufacture, but have lower efficiency rates. Cadmium telluride (CdTe) and copper indium gallium selenide (CIGS) are popular thin-film technologies.

Emerging PV Cell Technologies*: Multi-junction solar cells and organic PV cells offer potential for higher efficiency rates and lower costs.

2.2.ESP32 Microcontroller

The ESP32 microcontroller has been widely used in IoT applications due to its Wi-Fi and Bluetooth capabilities (Kim et al., 2017). It has also been used in various CCTV camera projects due to its ability to transmit video feeds wirelessly (Singh et al., 2016). The ESP32 microcontroller has several benefits, including low power consumption, high performance, and ease of use (Kim et al., 2017).

The ESP32-CAM is a popular microcontroller board with integrated Wi-Fi and Bluetooth capabilities, featuring a small camera module.

ESP32-CAM Module*: The ESP32-CAM development board includes an ESP32-S processor, OV2640 camera, microSD card slot, and various GPIOs for connecting peripherals. It supports Wi-Fi and Bluetooth communication protocols.

Camera Compatibility: The ESP32-CAM is compatible with various camera modules, including OV2640, OV3640, OV3660, OV5640, and more, offering different resolutions and lens sizes.

2.3 Micro-SD Card

Micro-SD cards have been widely used in various applications, including CCTV cameras, due to their small size and high storage capacity (Liu et al., 2014). They provide a convenient way to store video footage locally, which can then be transmitted wirelessly to a remote server or mobile device (Kim et al., 2017).

MicroSD cards have become a crucial component in various devices, including smartphones, cameras, drones and gaming consoles. Here's a detailed literature review of microSD cards, covering their types, performance, applications and future developments.

Types of MicroSD Cards

UHS-I Cards: These cards offer high-speed performance, with read and write speeds up to 104 MB/s. Examples include the Lexar Professional Silver Plus and Samsung Pro Plus.

UHS-II Cards: These cards provide even faster performance, with speeds up to 312 MB/s. However, they are more expensive and require compatible devices.

SD Express Cards: These cards utilize the SD Express bus interface, offering speeds up to 880 MB/s. Examples include the SanDisk microSD Express Card.[1] [2]

Performance and Applications

Read and Write Speeds: MicroSD cards are judged on their read and write speeds, which are crucial for applications like video recording and gaming.

Capacity: MicroSD cards come in various capacities, ranging from 128GB to 2TB. Higher capacities are suitable for storing large files and applications.

Applications: MicroSD cards are used in various devices, including smartphones, cameras, drones, dashcams and gaming consoles like the Nintendo Switch.

2.4 CCTV Camera Systems

CCTV (Closed-Circuit Television) camera systems have been extensively studied for their effectiveness in crime prevention and investigation. Here's a detailed literature review of CCTV camera systems, covering their applications, benefits and limitations. ### Applications of CCTV Camera Systems

Crime Prevention: CCTV cameras are widely used in public spaces, such as streets, parks and transportation hubs, to deter crime and improve safety.

Investigative Tool: CCTV footage is used as evidence in criminal investigations, helping law enforcement agencies identify suspects and track their movements.

Traffic Monitoring: CCTV cameras are used to monitor traffic flow, detect incidents and manage traffic signals.

Benefits of CCTV Camera Systems

Crime Reduction: Studies have shown that CCTV cameras can reduce crime rates in public spaces, particularly in areas with high crime rates.

Improved Safety: CCTV cameras can enhance safety in public spaces, such as parks and transportation hubs, by providing a visible security presence.

Investigative Aid: CCTV footage can aid investigators in identifying suspects, tracking their movements and reconstructing crimes.

2.5 Web App development

Web App Development Literature Review

Web app development has become a crucial aspect of modern software development, with a growing demand for web applications that provide seamless user experiences. Here's a detailed literature review of web app development, covering its trends, challenges and best practices.

Trends in Web App Development

Progressive Web Apps (PWAs): PWAs have gained popularity in recent years, offering a native app-like experience to users. According to a study by Google, PWAs can increase user engagement and conversion rates.

Single-Page Applications (SPAs): SPAs have become increasingly popular, providing a seamless user experience by dynamically updating content without requiring full page reloads.

Microservices Architecture: Microservices architecture has emerged as a popular approach to web app development, allowing for greater scalability and flexibility.

Challenges in Web App Development

Security: Web app security is a major concern, with threats such as SQL injection and cross-site scripting (XSS) posing significant risks. According to a study by OWASP, injection attacks are among the most common web app security threats.

Performance: Web app performance is critical, with slow load times and poor responsiveness negatively impacting user experience. A study by Google found that a 1-second delay in page load time can result in a 7% reduction in conversions.

Scalability: Web apps need to be scalable to handle increasing traffic and user demand, with cloud computing and containerization emerging as popular solutions.

Best Practices in Web App Development

Agile Development: Agile development methodologies, such as Scrum and Kanban, have become widely adopted in web app development, allowing for iterative and incremental development.

Test-Driven Development (TDD): TDD is a best practice in web app development, ensuring that code is testable and meets requirements.

Continuous Integration and Continuous Deployment (CI/CD): CI/CD pipelines have become essential in web app development, allowing for automated testing, building and deployment of code changes.

2.2.6 Wireless Communication and Power Management

Wireless communication protocols, such as Wi-Fi and Bluetooth, have been widely used in CCTV camera projects due to their ability to transmit video feeds wirelessly (Singh et al., 2016). These protocols provide a convenient way to transmit video feeds to a remote server or mobile device, enabling real-time monitoring and surveillance (Kumar et al., 2014).

Power management is a critical aspect of solar-powered CCTV cameras, as it ensures that the camera operates continuously without interruption (Liu et al., 2014). Various power management techniques have been used in solar-powered CCTV cameras, including the use of batteries, supercapacitors, and power management ICs (Kim et al., 2017).

CHAPTER THREE

3.0 METHODOLOGY

The selection of materials and components is critical to the successful implementation of a solar-powered, WiFi-enabled CCTV surveillance system. The components chosen ensure energyefficiency, real-time wireless communication, environmental sustainability, and reliable performance in off-grid or remote areas. Each material is selected based on functionality, availability, cost-effectiveness, and compatibility with the ESP32-CAM platform. Hardware materials and software materials are used in the project.

HARDWARE MATERIALS - They are the physical components of our Camera System. These hardware materials include:

i,Pv (solar panel)

ii. Dc bulk converter

iii ESP32CAM

iv. Microcontroller

V Printed Circuit Board

vi. Ic Socket

vii Capacitor (Electrolytic)

viii Non Electrolytic Capacitor

viii Electric motor (Servo Motor)

ix. BMS

x. Microprocessor

xi. Voltage regulator

Xii. Battery

SOFTWARE MATERIALS: These are referred to the program, algorithm and firmware that enables the camera to function and provide various features. The software materials include:

1. Arduino IDE

2. Web App

3.1 HARDWARE MATERIALS

i. MICROPROCESSOR AND MICRO CONTROLLER

MICROPROCESSOR: Microprocessor in our CCTV camera refers to a small chip that acts as the brain of the camera. It executes instructions, manages video processing.

The microprocessor act as the camera brain, enabling it to capture,process and transmit video signals. It's a crucial components that determine the camera performance, feature and functionality.

For our CCTV camera project work, we are provided with 8085. The image below shows a Microprocessor PIN Configuration.

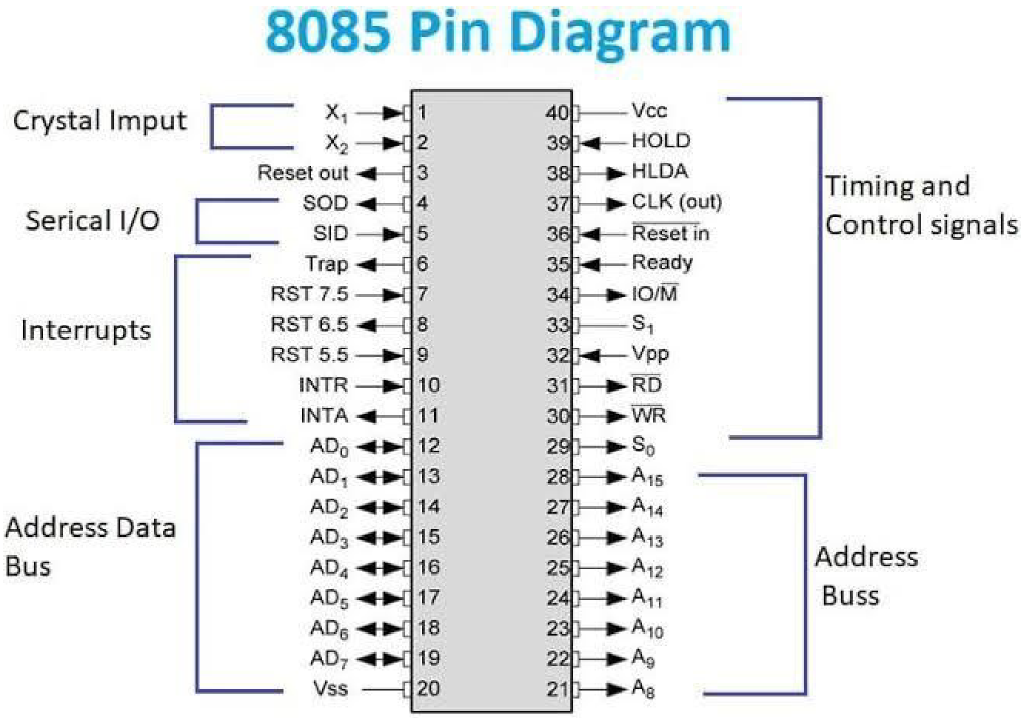


Figure 3.1: *IMAGE OF A MICRO CONTROLLER*

https://electronicsdesk.com/Roshni Y

MICROCONTROLLER: In CCTV Camera, a microcontroller is a small computer chip that controls camera functions (emg exposure, focus etc), interface with sensors(handles data from sensor like motion detector and manage communication).

ii. ESP32-CAM

ESP32-CAM is a small development board that combines the ESP32 microcontroller with a camera module, enabling Wi-Fi and Bluetooth connectivity along with image capture and video streaming capabilities. Here's a breakdown of the term:

ESP32: A powerful microcontroller developed by Espressif Systems with built-in Wi-Fi and Bluetooth. It has dual-core processing capabilities, various GPIOs, and supports IoT applications.

CAM: Short for "camera", indicating that the board includes a camera module (usually the OV2640 sensor).

ESP32-CAM features typically include:

ESP32-S chip

OV2640 camera

MicroSD card slot (for storage)

GPIO pins (limited, as many are used by the camera)

Support for video streaming over Wi-Fi

Low cost and compact design

Remote monitoring devicesThe ESP32-CAM is a compact camera module that integrates a camera with Wi-Fi and Bluetooth capabilities.

It is used in various projects such as:

• Security Cameras: For remote monitoring and motion detection.

• Home Automation: Integrating cameras with smart home systems.

• Surveillance: Continuous observation in sensitive or vulnerable locations.

Figure 3.2 *ESP 32CAM* *IMAGE*

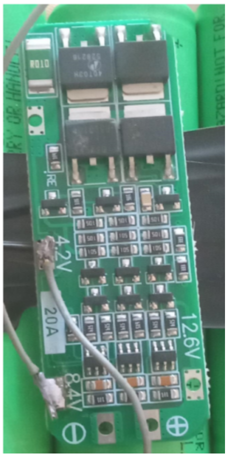
iii. BATTERY MANAGEMENT SYSTEM (BMS)

A battery management system (BMS) as used in our CCTV camera is an electronic system that monitor battery health (Tracks battery state of charge, voltage and temperature), controls charging (Regulates charging process to prevent overcharging or undercharging) and also provides power management. BMS in CCTV camera ensure:

1. Reliable operation

2. Extended battery life

3. Safe operation



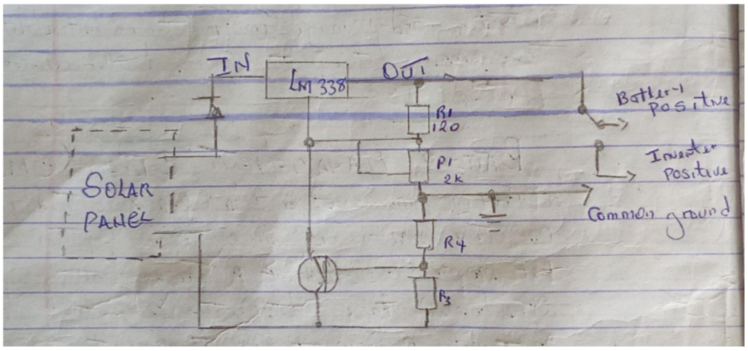


Figure 3.3 *BMS CIRCUIT DIAGRAM AND IMAGE*

iv. PRINTED CIRCUIT BOARD (PCB)

Printed Circuit Board (PCB) is a flat board that connects and support electronic components such as chips resistor and capacitor using a conducive pathway printed omto the board.

In our CCTV camera, the Printed Circuit Board (PCB) is a crucial components that is:

1. Connect and supports various electronic components such as image sensors, amplifier and video processing chips.

2. Enable functionality: The PCB allow the camera to capture, process and transmit video signals.

Figure 3.4 *IMAGE OF A PRINTED CIRCUIT BOARD*

v. IC SOCKET

IC Socket is an electronic components attached or place on our printed Circuit Board to serve or aid the plugging and unplugging our microcontroller.

The micro-controller can be plug on the IC Socket and be unplug also from the IC Socket attached to our PCB Board.

Figure 3.5 *IMAGE OF AN IC SOCKET*

Vi. ELECTRIC MOTOR

ELECTRIC MOTOR

Ac motor
- Single phase.
- 3 - phase motor

DC motor
- Brush motor
- brushless motor
- Servo motor
- Stepper motor

In our solar CCTV camera, the type of motor we will be needing a SERVO MOTOR to rotate the camera.

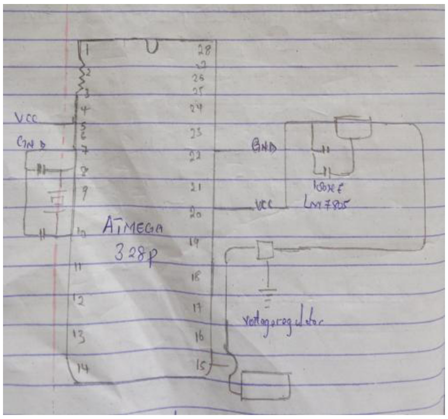


Figure 3.6 circuit diagram of a servo motor

Servo Motor is a type of motor that precisely control movement allowing for accurate positioning, rotation or movement. It uses feedback to adjust it's position or speed ensuring precise control. In our CCTV camera, the servo motor help to rotate the camera and change the position of the camera in other to have the streaming at one particular angle for sometime and streaming in another particular angle for sometimes.

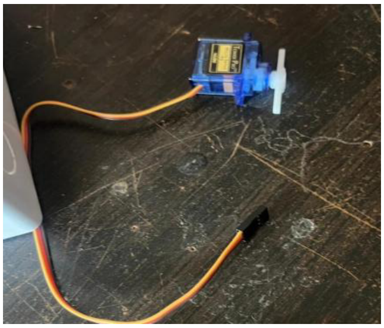


Figure 3.7 *IMAGE OF A SERVO MOTOR*

Our servo motor will come with 3- wires, which are:

1. Signal wire: which provides direction

2. Vcc wire : The VCC wires refers to our positive power supply to power the motor

3. The GND wires: refers to the negative power supply to power the motor.

From the circuit diagram, the microcontroller will control the signal of the SERVO MOTOR and voltage regulator to regulate voltage from 12v to 5v.

vii. VOLTAGE REGULATOR

In the CCTV camera, the voltage regulator helps to regulate the voltage coming from the battery in the project. Two voltage regulator was used. The first voltage regulator helps to regulate voltage from the battery to the servo motor and the second voltage regulator regulates voltage from the battery to the microcontroller and the microcontroller only needs 5v.

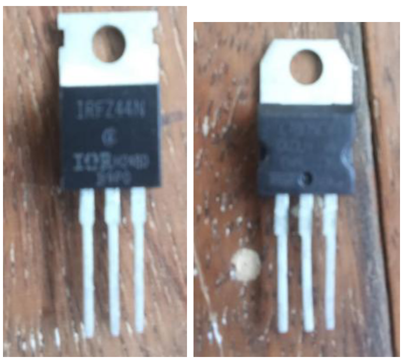


Figure 3.8 *IMAGE OF A VOLTAGE REGULATOR*

ix. SOLAR PANEL

A photovoltaic (PV) solar panel is a device that converts sunlight into electricity using semiconducting materials and it's used to generate electrical energy from sunlight, making the system energy-independent. A 6V or 12V, 3W to 10W panel is typically used depending on the power consumption profile and expected solar irradiance in the region.

Considerations for Selection:

Output voltage range: 6V to 18V

Power output: minimum 3W for daylight operation

In our CCTV camera setup, the solar cell is vital to:

- Power the Camera: Harnesses sunlight to generate electricity, reducing reliance on wired power or replaceable batteries.

- Enable Wireless, Battery-Free Operation: Ideal for remote or hard-to-reach locations without access to a stable power grid.

- This makes solar-powered CCTV cameras suitable for:

- Outdoor Surveillance: Monitoring parking lots, building perimeters, or public spaces.

- Remote Areas: Securing locations where conventional electrical infrastructure is unavailable.

1. Solar CCTV Camera

CCTV → "CCTV" meaning Closed Circuit Television Camera also known as Video Surveillance. It’s a system using cameras to transmit signals to specific monitors, often for security and surveillance purposes.

Types of IC Used in CCTV

1) Analogue IC: Analogue IC is known as Analogue Integrated Circuit. ICs are electronic components that process continuous signals such as voltage or current to perform various functions such as amplification, filtering, conversion etc.

“CCTV” cameras operating in analogue mode of signal transmit video signal using composite video cable (e.g. BNC connections). Examples of analogue ICs include:

I. Operational Amplifier (Op-Amps)

Ii. Voltage Regulators

Iii.Analogue-to-Digital Converters (ADC)

Iv.Digital-to-Analogue Converters (DAC)

(A circuit diagram is shown here, labeled with Inputs, Output, resistors, and an op-amp symbol)

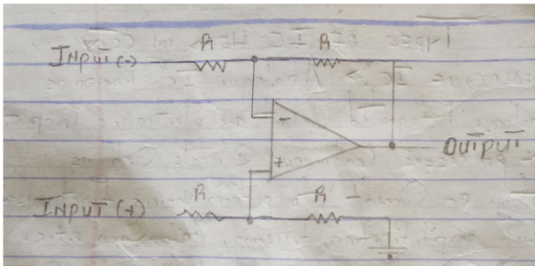


Figure 3.9 *A simple analogue circuit diagram*

DIGITAL IC: A Digital Integrated Circuit (Digital IC) is an electronic chip that processes digital signals—signals that use only two states: ON (1) and OFF (0). Unlike analog ICs that work with continuous signals (like varying voltages), digital ICs work with binary logic. Digital IC was used in the project.

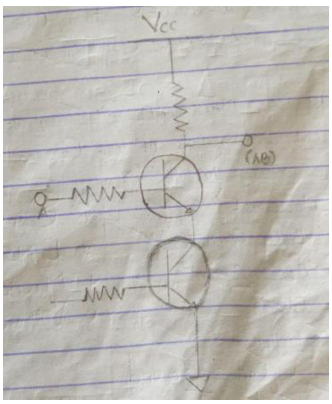


Figure 3.1.1 *A simple digital circuit diagram is shown above*

Role of Digital ICs in CCTV Cameras:

I. Video Processing:

Ii. The raw signal from the camera sensor is often in analog form.

Iii. A Digital Signal Processor (DSP) converts it into a digital format.

Iv. It enhances image quality,reduces noise, and applies corrections (like brightness/contrast adjustment). v. Image Processing:

Vi. Motion detection

These functions help in smart surveillance

Camera Settings Control

Digital ICs manage

Exposure control

Zoom/focus

They also handle automation based on lighting and scene detection.

Common Digital ICs Used in CCTV:

Microcontrollers / Microprocessors – Control camera functions.

FPGA (Field Programmable Gate Array) – For high-speed parallel processing.

DSP (Digital Signal Processor) – Handles video encoding/decoding.

Memory ICs – Store firmware or captured images/videos.
Simple Digital Circuit Diagram (from image):

X. BULK CONVERTER: The Buck converter is a type of a DC-DC converter that steps down the voltage from a higher level to a lower level while maintaining the efficiency.

Xi. BATTERY:The battery helps to store electricity generated by the solar panel during the day,provide power at night and also ensure continous operation even without sunlight when charged.

3.2 SOFTWARE MATERIALS

Software Materials for Programming ESP32-CAM and Web Application Development

This project involves the development of a wireless surveillance system using the ESP32-CAM module, which is capable of capturing and streaming real-time video over Wi-Fi. A web application is also developed to view and control the live video feed from a browser on any connected device. Programming the Microcontroller

To operate our ESP32-CAM, we use embedded system programming. This includes:

Software: Instructions programmed into the microcontroller using a low-level software system called firmware.

LED Indicators: Light Emitting Diodes (LEDs) are used for feedback, responding to signals from the microcontroller.

Microcontroller & LED Functionality:

The microcontroller sends instructions to the LED to:

Blink

Stay on or off for a specific time

Respond to programmed sequences

The instructions are written using environments such as the Arduino IDE, which supports ESP32-CAM development.

1. **Programming Environment for ESP32-CAM**

1.1 Arduino Integrated Development Environment (IDE)

The Arduino IDE is used as the primary programming environment for the ESP32-CAM module. It supports the C/C++ language and provides access to essential hardware abstraction libraries.

Setup Steps:

Install the Arduino IDE from https://www.arduino.cc/en/software.

Add ESP32 board support using the URL:

https://raw.githubusercontent.com/espressif/arduino-esp32/ghpages/package_esp32_index.json

Use the Board Manager to install the ESP32 package.

Select AI Thinker ESP32-CAM

Write and upload the code using a USB-to-Serial converter (CP2102 or CH340G).

1.2 Required Libraries

The following libraries are included in the sketch to enable core functionalities:

WiFi.h – Manages wireless connections.
WebServer.h – Handles HTTP communication.

esp_camera.h – Provides camera initialization and frame capture.

FS.h and SD.h – For microSD card access (optional).

ESPAsyncWebServer.h – Optional for asynchronous web server performance.

2. USB-to-Serial Driver Installation

To upload code, a USB-to-Serial converter is required. Proper drivers must be installed for communication:

CP2102 Driver: https://www.silabs.com/developers/usb-to-uart-bridge-vcp-drivers

CH340G Driver: http://www.wch.cn/download/CH341SER_EXE.html

3. Web Application for Video Streaming

A lightweight web application is embedded directly within the ESP32-CAM firmware. Once the ESP32-CAM connects to a Wi-Fi network, it hosts a web server that streams live video and optionally provides control buttons (e.g., for switching on/off LEDs or triggering image capture).

3.1 Features of the Web Application

Live video feed from the ESP32-CAM (JPEG or MJPEG stream)

User interface accessible from any device on the same network

Optional controls for GPIO functions (e.g., flash control)

HTML and JavaScript-based front end served from ESP32's onboard storage

The camera stream is served from the /stream endpoint, while other endpoints (e.g., /flash)

can be used for control.

3.6 CONSTRUCTION AND MODE OF OPERATION OF SOLAR POWERED CCTV

The system operates as an autonomous, solar-powered surveillance unit. It integrates a camera module, solar power system, ESP32 microcontroller, and a web-based viewing platform. The mode of operation is explained in sequential stages:

1. Power Supply via Solar Energy

A solar panel charges a rechargeable battery (e.g., 12V or 7.4V Li-ion) during daylight.

The battery powers the system through a voltage regulation circuit (e.g., buck converter or LM7805 for 5V).

This ensures uninterrupted operation even at night or during cloudy weather.

2. Image and Video Capture

The ESP32-CAM module has an onboard camera (OV2640) that captures real-time video or still images.

It is programmed using Arduino IDE or ESP-IDF to operate in web server mode.

3. WiFi Connectivity and Web Server

The ESP32-CAM connects to a WiFi network (e.g., home router or mobile hotspot).

It sets up an HTTP web server and hosts a local webpage containing the camera feed.

The web page can be accessed on any device (PC/smartphone) connected to the same network using the ESP32's IP address.

4. Web App Viewing Interface

The web interface displays

Live video stream

Optional controls (e.g., LED flash ON/OFF, camera resolution)

The user accesses the feed by entering the ESP32's IP address in a browser.

Authentication or password protection can be implemented for security

SOLAR CCTV BLOCK DIAGRAM

Solar panel

│

▼

[Battery]

(12V DC)

│

▼

[BUCK CONVERTER MODULE]

(Step-down to 5V + USB Output)

│

▼

[MICROCONTROLLER UNIT]

│ │

▼ ▼

[POTENTIOMETER] [SERVO MOTOR]

(Input Control) (Mechanical Output)

│

▼

(Camera)

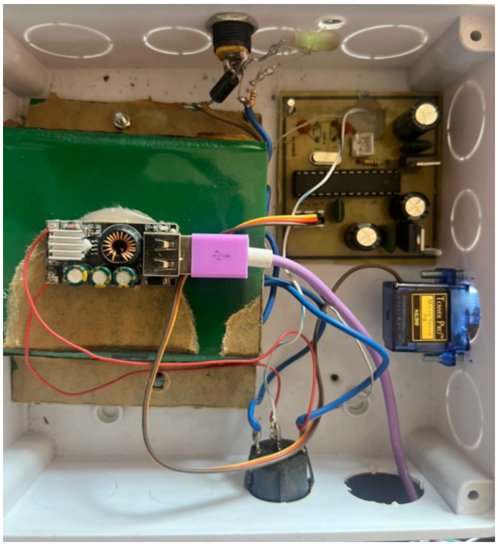


Figure 3.1.2 IMAGE OF THE OVERALL COMPONENTS

CHAPTER FOUR

4.0 TESTING AND EVALUATION

4.1 Power System Test

- The solar panel was tested under different sunlight conditions.
- The TP4056 charger correctly charged the 18650 battery during daytime.
- Voltage output remained stable at ~3.3V (regulated) for the ESP32-CAM.

4.2 Camera and Streaming Test

- The camera delivered a video feed of 15–20 fps at VGA resolution (depending on WiFi strength).
- Image quality was acceptable for surveillance purposes.
- Live streaming over WiFi was successful at a distance of up to 30 meters.

4.3 Web Interface Test

- Users could connect to the ESP32 IP and view live feed using smartphones or laptops.
- Response time was minimal, with less than 1-second delay on average.
- Interface remained stable for extended periods.

4.4 RESULTS

- The system successfully achieved solar-powered surveillance with real-time streaming.
- ESP32-CAM maintained connectivity and performance under standard operation.
- The battery lasted through the night on a full charge, supporting 24/7 surveillance.

Test Parameter	Result
Streaming Range	Up to 30 meters (WiFi)

Battery Duration	8 – 12 hours (overnight)
Charging Time (Full Sun)	3 – 4 hours
Web App Access Delay	Less than 1 second
Resolution	VGA (640x480) to SVGA (800x600)

4.5 CHALLENGES ENCOUNTERED

- Limited Night Vision: The ESP32-CAM lacks built-in IR; additional IR LEDs may be required.
- WiFi Coverage Limitations: Coverage was restricted to local network range.
- Power Regulation: Needed efficient regulation to avoid under-voltage issues.
- Overheating: Prolonged use in direct sun required additional cooling considerations.

CHAPTER FIVE

Summary

This project focuses on the design and implementation of a solar-powered CCTV surveillance system using the ESP32 microcontroller. The goal was to create an energy-efficient, low-cost, and wireless security solution suitable for remote or off-grid locations. The system integrates a solar panel for renewable power generation, a rechargeable battery for energy storage, and an ESP32 microcontroller for processing and wireless connectivity. A camera module is interfaced with the ESP32 to capture real-time video, which is then streamed through a custom web application accessible over Wi-Fi. The system allows remote monitoring via any device with internet access, eliminating the need for physical DVR systems and extensive cabling. Through this project, key principles in embedded systems, IoT, solar energy, and web development were combined to build a functional prototype with practical real-world applications.

CONCLUSION

The successful implementation of the solar-powered CCTV system demonstrates the feasibility and effectiveness of using ESP32 microcontrollers for low-power surveillance applications. By leveraging solar energy, the design ensures sustainability and cost efficiency, particularly in areas without reliable electricity. The integration of real-time web-based video streaming further enhances the usability of the system, offering remote access and surveillance capabilities through Wi-Fi. Overall, the project achieved its objectives, showcasing a scalable and eco-friendly alternative to traditional surveillance systems.

CHAPTER SIX

Recommendation

1. Enhance Storage Capabilities: Integrate cloud storage or local SD card backup to store footage for later review, especially in cases of connectivity issues.

2. Implement Motion Detection: Add motion detection algorithms to reduce bandwidth and power usage by streaming video only when movement is detected.

3. Improve Solar Power Efficiency: Use Maximum Power Point Tracking (MPPT) charge controllers to optimize solar energy harvesting and prolong battery life.

4. Night Vision Integration: Equip the system with infrared (IR) LEDs or low-light camera modules to enable night-time surveillance.

5. Expand to Mesh Networking: For wider coverage in large areas, consider deploying multiple units with ESP-NOW or mesh networking capabilities for better communication.

6. Security Enhancements: Implement authentication and encryption for the web app to prevent unauthorized access to video feeds.

7. Mobile App Development: Complement the web app with a mobile application for enhanced accessibility and user experience

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