DAYANANDA SAGAR COLLEGE OF ENGINEERING

(An Autonomous Institute affiliated to VTU, Belagavi - 590018)
Accredited by National Assessment & Accreditation Council (NAAC) with 'A' grade
Shavige Malleshwara Hills, Kumaraswamy Layout
Bengaluru-560078

Mini Project Report on

DESIGN OF SOLAR RADIO

Submitted in partial fulfillment for the award of degree of

Bachelor of Engineering
in
Electrical and Electronics Engineering

Submitted by

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VISVESVARAYA TECHNOLOGICAL UNIVERSITY
JNANASANGAMA, BELAGAVI-590018
2024-25

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2024-2025

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

CERTIFICATE

Certified that the mini project report entitled **"Design of Solar Radio"** carried out by **AAKASH DV (1DS24EE001), AKSHAYA RIDHI (1DS24EE008), ARYA SHARAN (1DS24EE0020), MANASVI SINGH (1DS24EE056)** are Bonafide students of **DAYANANDA SAGAR COLLEGE OF ENGINEERING**, an autonomous institution affiliated to VTU, Belagavi in partial fulfillment for the award of Degree of **Bachelor of Engineering in Electrical and Electronics Engineering** during the year **2024-2025**. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the report deposited in the departmental library. The mini project report has been approved as it satisfies the academic requirements in respect of work prescribed for the said Degree.

Signature of the Guide	**Signature of the HOD**
Dr Saravanakumar R	**Dr. Premkumar M.**
Associate Professor	**Professor & HOD**
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DSCE, Bengaluru	**DSCE, Bengaluru**

Name of the Examiners	**Signature with date**
1.	....
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DECLARATION

We, AAKASH DV (1DS24EE001), AKSHAYA RIDDHI (1DS24EE008), ARYA SHARAN (1DS24EE020) and MANASVI SINGH (1DS24EE056),respectively, hereby declare that the mini project work entitled "DESIGN OF SOLAR RADIO" has been independently done by us under the guidance of 'Dr SARAVANAKUMAR R', Associate Professor, EEE department and submitted in partial fulfillment of the requirement for the award of the degree of Bachelor of Engineering in Electrical & Electronics Engineering, at Dayananda Sagar College of Engineering, an autonomous institution affiliated to VTU, Belagavi during the academic year 2024-2025. We further declare that we have not submitted this report either in part or in full to any other university for the award of any degree.

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ABSTRACT

This report presents the conceptualization, design, implementation, and testing of a solar- powered FM radio system tailored for use in remote, rural, and disaster-prone areas lacking reliable access to electricity. Traditional FM radios often depend on grid power or disposable batteries—resources that are scarce or inconsistent in underserved communities. This project addresses that challenge by developing a self-sustaining communication device that operates entirely on renewable solar energy, ensuring continuous access to information without external charging infrastructure. At the heart of the system is a solar energy harvesting module comprising two 6V 100mA solar panels connected in parallel for optimal current output.

The power regulation handled by a Schmitt Trigger-based control circuit. This system intelligently switches between solar and battery power based on real-time voltage thresholds, ensuring uninterrupted performance even during cloudy weather or nighttime. The power flow is controlled through IRFZ55N N-channel MOSFETs, which allow efficient high- current switching with minimal losses. The device's core processing is managed by the ATmega328P microcontroller, which interprets user input from a potentiometer-based tuning mechanism, controls a 7-segment display interface, and manages logic for FM signal tuning.

The system meets its design objectives by delivering an energy-independent, low-cost, and user- friendly radio suitable for real-world deployment. Beyond its immediate application, this project showcases the potential of renewable energy integration in small-scale embedded systems, contributing to sustainable development and technological inclusion. Future improvements may involve USB charging capabilities, Bluetooth audio streaming, multi- band support (AM/SW), and weather-resistant enclosures to further broaden its utility and resilience.

Chapter 01: Introduction

1.1Introduction:

FM radios have long been a staple for communication, entertainment, and emergency broadcasts. However, the way they are powered marks a key distinction between different types of FM radios. Solar FM radios, as the name suggests, harness the sun's energy for operation, making them a sustainable and eco-friendly alternative to conventional FM radios Fig 1.1, which typically rely on disposable or rechargeable batteries or direct electrical power sources. This difference in power supply influences their usability, efficiency, and environmental impact. The types of FM radios reveal important insights into their functionality, accessibility, and role in promoting greener technology.

The electricity from the solar panels can either power the radio right then and there or charge up a battery inside it for later use. This makes the radio super handy because it doesn't need regular batteries or a plug-in source to work. It's perfect for trips out in nature, emergencies when power is out, or if you're trying to be more eco-friendly. Plus, it helps cut down on waste from disposable batteries and reduces reliance on non-renewable energy sources.

Fig 1.1: Solar Radio

1.2 Key Takeaways:

→A solar-powered radio harnesses sunlight to generate electricity, either powering the device directly or charging its internal battery.

→Key components include photovoltaic cells, a rechargeable battery, and radio circuitry.

→To use, simply position the solar panel in sunlight, connect it to the radio, and allow time to charge.

→Additional features may include a hand crank, USB port, integrated flashlight, and emergency signals.

1.3 Problem Statement:

Access to timely and reliable information is essential for safety, education, and community development. However, in many rural and underserved regions, access to electricity remains inconsistent or entirely absent. In such areas, conventional FM radios—which are typically powered by disposable or rechargeable batteries— become ineffective over time due to the unavailability of reliable power sources. The recurring need to replace or recharge batteries imposes both financial and logistical burdens on users in these communities.

This issue becomes even more critical during natural disasters such as floods, earthquakes, or cyclones, as well as in humanitarian crises like war or displacement. During such events, conventional communication infrastructure, including television, mobile networks, and the internet, often gets damaged or destroyed. In these scenarios, FM radio remains one of the few technologies capable of reaching large populations quickly and effectively. However, radios that depend on grid power or replaceable batteries are often rendered useless when electricity and battery supply chains are disrupted.

Therefore, there is a pressing need for a self-sustaining, off-grid communication device—a solar-powered radio that can function independently of external power supplies. Byharnessing solar energy, such a device would enable continuous access to important broadcasts such as emergency alerts, weather updates, health advisories, and educational content. This solution would not only enhance disaster preparedness and response but also empower remote communities by providing them with a sustainable, low-maintenance source of information and connectivity.

1.4 Motivation:

The motivation for developing a solar-powered FM radio lies in addressing the critical need for reliable, self-sustaining access to information in areas with limited or no access to electricity. In many rural and off-grid communities, conventional radios that depend on disposable or rechargeable batteries are not practical due to recurring costs, irregular availability, and maintenance issues. A solar powered radio eliminates these dependencies by utilizing renewable solar energy to operate during the day and store power for use at night, ensuring continuous functionality without charging requirements.

Such a solution is particularly valuable in regions prone to natural disasters where conventional power and infrastructure and mobile networks fail. A solar radio remains operational under these conditions delivering uninterrupted access to emergency broadcasts, weather alerts and official government instructions, which are essential for the community safety and disaster response. Additionally, it supports educational outreach by enabling consistent access to learning programs, especially in areas where schools and other learning resources are scarce or inaccessible.

This project aligns with the goal of creating low-cost emery independent communication tools that are simple to operate, environmentally sustainable and capable of functioning in challenging conditions. It aims to empower vulnerable populations with the ability to stay informed and make timely decisions, regardless of the availability of electricity or telecommunication infrastructure.

Such a solution is particularly valuable in regions prone to natural disasters, where conventional power infrastructure and mobile networks may fail. A solar radio remains operational under these conditions delivering uninterrupted access to emergency broadcasts, weather alerts and official government instructions, which are essential for the community safely and disaster response. Additionally, it supports educational outreach by enabling consistent access to learning programs, especially in areas where schools and others learning resources are scarce or inaccessible.

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1.5 Objectives:

The primary goal of this project is to develop a solar-powered FM radio system that functions independently of grid electricity, using solar energy as its primary power source. The system is designed to harvest solar energy through a photovoltaic panel, which charges a rechargeable battery. This stored energy powers all essential components of the radio, including the radio module, speaker, and control system. The radio module is responsible for receiving and demodulating FM signals from local broadcast stations. Audio output is delivered through an amplifier and speaker, ensuring clear sound even in low-resource environments.

A key part of the system is the integration of an ATmega328P microcontroller, which serves as the brain of the device. It handles user inputs, controls tuning, and manages the display. Users can select their desired station using a potentiometer, which acts as an analog tuning dial. The microcontroller reads the analog voltage from the potentiometer, maps it to the corresponding frequency, and adjusts the radio module accordingly.

To provide user feedback, a 7-segment display is used to show the current frequency or preset station number. This display is driven through a 7-segment decoder controlled by the microcontroller. The microcontroller interprets user input, processes frequency selection logic, and updates the display in real time. All of this is powered by energy harvested from the solar panel, making the system self-sustaining, low-power, and ideal for remote or emergency scenarios. The project thus aims to deliver a fully functional, off-grid FM radio that is efficient, user-friendly, and environmentally sustainable.

1.6 Significance of solar power:

Solar power is the foundation of this project, addressing the core challenge of energy accessibility in rural and emergency-prone areas. In regions where electricity is unreliable or entirely absent, conventional radios that rely on disposable or rechargeable batteries become impractical due to the recurring cost and lack of infrastructure for regular charging or battery replacement The solar panel harnesses sunlight during the day, converting it into electrical energy that is either used instantly or stored in a rechargeable battery for uninterrupted use during nighttime or cloudy conditions. This ensures that the radio remains functional 24/7, regardless of the availability of external power sources.

The use of solar power significantly enhances the reliability and sustainability of the radio system. It eliminates the dependency on consumable power sources, reduces long-term operating costs, and contributes to environmental conservation by avoiding battery waste. In disaster scenarios—such as floods, earthquakes, or cyclones—where communication infrastructure may be damaged or mobile networks disrupted, a solar-powered radio remains a lifeline for real-time access to emergency broadcasts, government instructions, and weather alerts. Moreover, it supports long-term usage in isolated regions, offering consistent access to educational and informational content without the burden of ongoing power supply concerns.

From a technical standpoint, the incorporation of solar power also presents an opportunity to explore energy management, efficient power conversion, and intelligent system control. The project not only demonstrates the practical application of solar energy in small-scale electronics but also aligns with global efforts to promote sustainable, low-cost, and accessible technology solutions for underserved populations. In this way, solar power is not just a power source for the radio—it is the enabling technology that makes the project socially relevant, environmentally responsible, and technically impactful.

Chapter: 02 Literature review

The radio receiver system is powered entirely by solar energy, utilizing a compact 5-volt, 2-watt photovoltaic panel. The panel is designed to be mounted in such a way that it maximizes sunlight exposure throughout the day. A key part of the system is the inclusion of a charge controller equipped with Maximum Power Point Tracking (MPPT), which optimizes the energy harvested from the solar panel while preventing overcharging of the battery [1]. The harvested energy is stored in a 3.7-volt lithium-ion battery with a capacity of around 750 mAh. This battery provides enough power for approximately 6 to 8 hours of continuous playback, even in the absence of sunlight, thus ensuring uninterrupted operation during the night or on cloudy days.

At the heart of the radio receiver is a compact FM tuner integrated circuit such as the TEA5767, capable of tuning into standard FM frequencies between 88 and 108 MHz The system may also include a basic microcontroller to support user interaction features like auto-tuning, signal scanning, and volume control. The audio output is managed by an LM386 low-power audio amplifier, which is well-suited for driving an 8-ohm speaker. The system delivers about 500 milliwatts of audio output, which is sufficient for small group listening—ideal for classrooms, community announcements, or village entertainment.

To maintain reliable and efficient operation, a low-dropout voltage regulator such as the AMS1117 is used to stabilize the output voltage from the battery or solar panel to the required 5 volts for the circuitry. The design emphasizes efficiency, achieving a system-wide energy conversion rate of over 85% from sunlight to sound output. The internal circuitry is structured such that during daylight, the radio is powered directly from the solar panel while also charging the battery. When sunlight is not available, the system automatically switches to battery power without user intervention.

The device was field-tested in a village setting in Rajasthan under typical sunlight conditions (about 1,000– 1,200 lux), demonstrating successful operation for six continuous hours at dusk and reliable FM reception within a radius of 10 kilometers. In bright sunlight (~1 kW/m²), the battery was fully recharged in approximately four hours. The physical design includes a durable casing to protect the electronics from dust, heat, and humidity—common challenges in rural environments. It also features a simple and intuitive user interface with basic buttons for power, tuning, and volume, making it easy to use for non-technical rural users.

From a developmental perspective, the system's advantages are clear. It provides a reliable and renewable source of power, requires minimal maintenance, and offers an affordable means of communication and entertainment. It is especially valuable for educational and emergency broadcasting in off-grid areas. The paper also suggests future enhancements, including the addition of battery-level indicators using LEDs, the inclusion of USB ports for mobile charging, and possible expansion to AM bands. Such improvements would further increase the device's utility in rural development and disaster preparedness.

Overall, the research provides a practical and scalable model for deploying solar-powered FM radios in energy-poor regions. It combines fundamental engineering principles with real-world needs, demonstrating that renewable energy solutions can be effectively adapted to meet the basic technological needs of underserved populations.

In [2], the authors investigate the small-scale solar photovoltaic (PV) systems influence on media access—specifically FM radio consumption—in remote, off-grid communities. Conducted through field surveys comparing households with and without solar PV systems, the study reveals compelling insights into how solar power transforms daily life in rural areas.

The authors found that households equipped with solar panels significantly increased their radio listening hours while simultaneously reducing costs associated with traditional dry-cell batteries. On average, households without solar used dry-cell batteries costing about US $3.78 per month to power radios, whereas solar-equipped households spent only US $2.70—saving roughly US $1 per month for the same listening. This cost reduction is substantial in economically constrained settings.

Interestingly, while non-electrified households listened to the radio slightly more (6.3 hours/day versus 5 hours/day for solar homes), the cost-per-hour of radio usage was significantly lower in solar-powered homes. The statistical analysis demonstrated a highly significant difference ($p < 0.05$), highlighting that solar energy is not only more sustainable but also more economical for FM radio use in these environments.

The paper also discusses how solar PV systems encouraged broader media consumption—households reported increased television viewing and improved access to agricultural, health, and educational content. These qualitative benefits enhance community well-being and learning. Overall, the study makes a strong case that even modest solar installations can yield measurable economic savings and improve information access through FM radio in off-grid locations.

2.1 Basics of solar energy

A Solar Panel is the key component that enables a solar-powered FM radio to operate without the need for grid electricity or replaceable batteries. It works based on the photovoltaic effect, which allows sunlight to be converted directly into electrical energy.

When sunlight hits the photovoltaic (PV) cells in a solar panel, the semiconductor material, usually silicon, absorbs photons (light particles). These photons carry energy that excites the electrons in the silicon atoms, causing them to move. This movement of electrons creates an electric current. The current generated is direct current (DC), which is suitable for powering small electronic circuits, such as those in FM radios.

The DC electricity from the solar panel is then either used directly to power the FM radio's components— like the tuner, audio amplifier, and speaker—or it is used to charge a rechargeable battery (commonly a lithium-ion or nickel-metal hydride battery). This battery stores energy so the radio can function even when sunlight is not available, such as at night or during cloudy weather. Inside the FM radio, a voltage regulator is often included to ensure that the power delivered from the solar panel or battery remains at a safe and consistent level, since solar panels can fluctuate depending on sunlight intensity. The radio circuit uses this electricity to run its FM receiver chip (which tunes into radio frequencies), audio amplifier (which boosts the sound signal), and the speaker (which outputs the sound).

In short, solar panels allow a solar-powered FM radio to operate sustainably by converting sunlight into usable electricity, which is either used immediately or stored, enabling the device to function in off-grid areas without relying on external power sources.

2.2 Power requirements

The power requirements for small electronics such as a solar-powered FM radio are typically modest, making them ideal candidates for off-grid solar applications. A basic FM radio powered by solar energy usually operates within a voltage range of 3 to 5 volts DC and consumes around 0.5 to 2 watts of power, depending on the volume, radio circuitry, and speaker size. The current draw is generally between 100 to 400 milliamps, which is well within the output capacity of a small solar panel rated at 1 to 3 watts.

Such a solar panel, combined with a rechargeable battery (commonly a 3.7V lithium-ion cell with 500– 1200 mAh capacity), is sufficient to power the radio for 6 to 10 hours on a full charge. Voltage regulators and simple charging circuits are often used to maintain stable voltage levels and ensure safe charging of the battery. Overall, the low power consumption of these radios allows for efficient operation even under limited sunlight, making them highly suitable for rural and emergency use.

2.3 RADIO RECIEVER FUNDAMENTALS

A solar FM radio is a compact and energy-efficient device designed to receive and play FM radio broadcasts using solar power, making it ideal for rural or off-grid locations. It operates using a small photovoltaic (solar) panel that converts sunlight into electrical energy. The core of the radio's functionality lies in several interconnected components. The FM tuner is a specialized electronic module that detects and selects radio signals in the FM band, typically between 88 to 108 MHz It filters out unwanted signals and locks onto a specific frequency, allowing the user to listen to a desired radio station. Once the signal is received, it is weak and requires amplification. This is where the audio amplifier comes into play. It boosts the low-level audio signals from the tuner to a higher level that can drive a speaker. Commonly, integrated circuits like the LM386 are used for this purpose in low-power applications.

The antenna is another essential component, responsible for capturing the radio waves from the air. It can be a telescopic rod or a simple wire, and its length and orientation directly affect reception quality. A good antenna ensures a stronger and clearer signal input to the tuner. After amplification, the audio signal reaches the speaker, which converts the electrical signals into sound waves that can be heard by the user. The speaker's output power is generally low (0.5–1 watt), suitable for personal or small group listening. This makes solar FM radios a sustainable and practical solution for rural parts.

CHAPTER 3: System Design and Components

3.1 Block Diagram

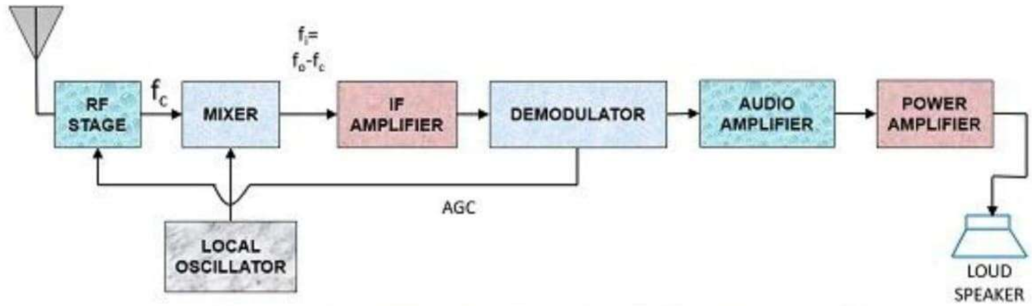

Fig 3.1: Superheterodyne receiver

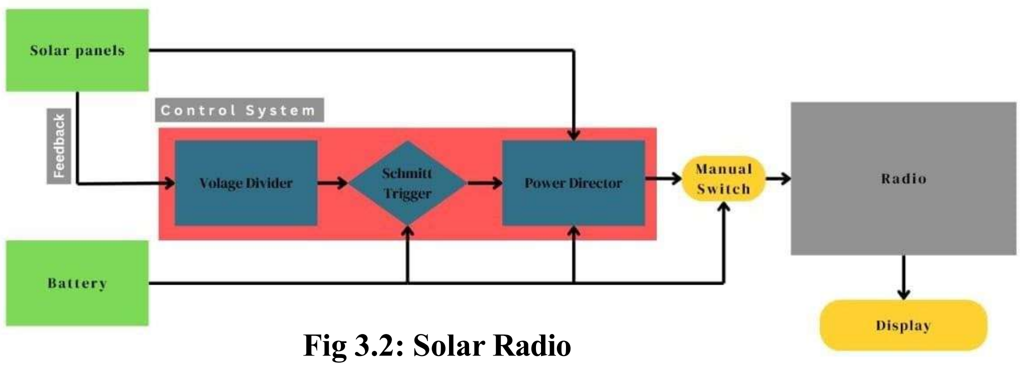

Fig 3.2: Solar Radio

Fig 3.2: Component Functions in the Solar Radio System

The solar panel serves as the primary energy source, converting sunlight into electrical power to run the radio and charge the battery. This energy is regulated through a Schmitt Trigger circuit, which plays a critical role in power control by detecting voltage fluctuations and switching the on or off based on defined thresholds (Upper Threshold ≈ 4.962V, Lower Threshold ≈ 4.537V) as represented in Fig 3.2. This ensures stable operation under varying solar conditions and prevents under-voltage operation.

A rechargeable battery stores excess energy from the solar panel and powers the radio during nighttime or cloudy conditions. The ATmega328P microcontroller, operating as a standalone unit with a 16 MHz crystal oscillator for clock precision, manages user input (via potentiometer), tuning functions, display control, and station logic. It interfaces with four 7-segment displays, driven through 7-segment decoders, to show either the current frequency or station number, providing use feedback.

The radio circuit includes a voltage divider, feedback loop that helps regulate input to the Schmitt trigger based on real-time voltage from the solar panel, Operational amplifiers (Op-Amp 741) and comparator ICs (e.g. LM393) are used in voltage sensing and switching logic, providing clean transitions and accurate monitoring of input levels. IRFZ55N N-channel MOSFETs (5 in total) are used as switching devices to control power flow to the load (radio and logic circuits). They handle high-current switching (up to 200 mA input current), with output voltages ranging from 3V (min) to 5V (max), depending on solar conditions. Passive components such as resistors (5–15 kΩ, 5–220 kΩ) and capacitors (5–22 pF) are used for filtering, timing, feedback, and current limiting throughout the circuit. Finally, flux wire is employed for proper soldering and interconnection during assembly, ensuring reliable joints and minimal resistance. Together, these components form an integrated system where solar energy is efficiently harvested, regulated, stored, and utilized to power an FM radio that is resilient, portable, and fully independent of conventional electricity sources.

3.2 Working Principle

The working principle of the solar-powered FM radio (Fig 3.2) is based on the conversion of solar energy into electrical energy to operate a conventional radio circuit with additional digital display functionality, ensuring off-grid, self-sustained operation. The process begins with solar panels capturing sunlight and converting it into electrical energy. This energy is then stored in a rechargeable battery, which serves as the primary power source for the radio during periods of low or no sunlight, such as nighttime or cloudy conditions.

The battery's voltage is monitored using a Schmitt Trigger circuit, which ensures that the system operates within safe voltage limits. The Schmidt Trigger provides hysteresis and generates a clean digital switching signal when voltage thresholds are crossed—specifically at around 4.537V (lower) and 4.962V (upper)—protecting components from brownouts or erratic behavior caused by voltage fluctuations. When the battery voltage falls below the safe range, the Schmidt Trigger disables the power to the load (i.e., radio and microcontroller) via a IRFZ55 N-channel MOSFET, which acts as an electronic switch. The MOSFET allows or blocks current based on the trigger input, managing the flow of power efficiently to the rest of the circuit.

The ATmega328P microcontroller, operating with the help of a 16 MHz crystal oscillator, manages the digital operations such as user input processing, display control, and signal tuning. It receives analog input from a potentiometer—which acts as the tuning interface—allowing the user to vary resistance and hence select desired FM frequencies. The selected station is displayed on 7-segment displays, each driven by a 7-segment decoder for digital-to-visual conversion, showing frequency or station information clearly to the user.

The radio module as per the Fig 3.1, powered by the same battery, demodulates incoming RF signals from broadcast stations and drives the speaker to produce audio output. This system ensures that the radio can function continuously during the day using solar power and automatically switches to battery power when sunlight is unavailable. Together, the integration of solar energy, efficient power management via Schmitt Trigger and MOSFET, and digital interfacing through ATmega328P provides a fully autonomous, user-friendly radio system suited for remote and disaster-affected areas.

3.3 Charging circuit

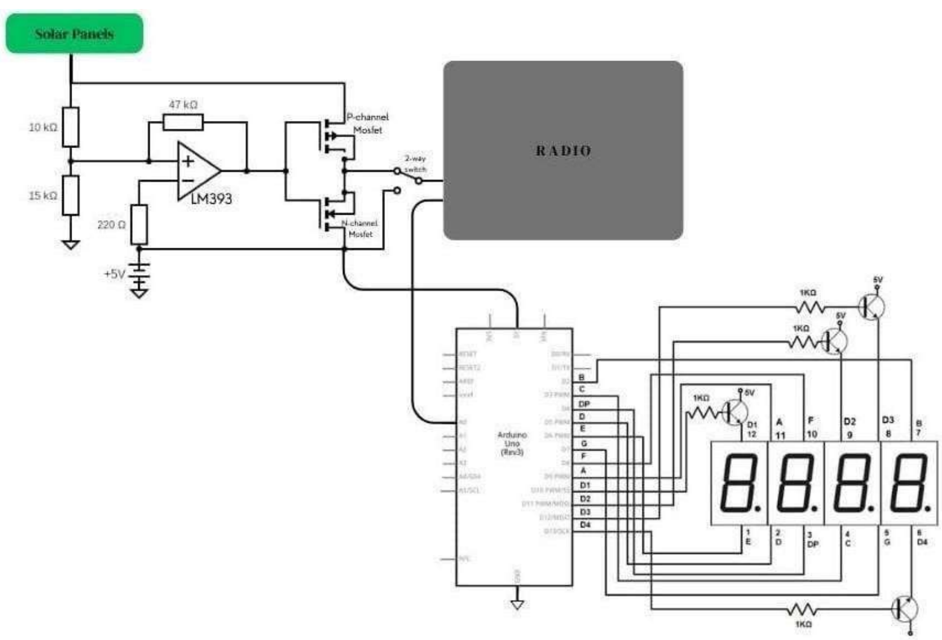

Fig 3.3: Circuit diagram for the Solar radio

Solar Panel: The solar panel is the primary source of energy for the radio system. It converts incident sunlight into electrical energy through the photovoltaic effect. During periods of adequate sunlight, the solar panel generates sufficient voltage and current to both power the radio and charge the connected battery. It is responsible for supplying energy to the rest of the circuit via the control system and voltage regulation modules. The solar panel's output is monitored to determine power availability under various lighting conditions—ranging from full sun to cloudy weather—and is key to enabling off-grid operation of the system.

Rechargeable Battery: The rechargeable battery stores excess energy generated by the solar panel, enabling uninterrupted radio operation during nighttime or low-sunlight periods. When solar input is insufficient (e.g., cloudy days), the system automatically switches to battery power. The battery is also protected against under-voltage and over-discharge by the Schmitt trigger circuit, ensuring stable performance and long-term reliability. It acts as a buffer, providing a constant supply voltage to sensitive components like the ATmega328P microcontroller and the radio module.

ATmega328P Microcontroller: The ATmega328P serves as the central processing unit of the system. This standalone microcontroller, driven by a 16 MHz crystal oscillator, handles all logic and control functions. It reads analog input from a potentiometer (used for station tuning), processes it, and translates it into control signals for the FM radio module. It also interfaces with the 7-segment Decoders to display station numbers or frequency data. Additionally, the microcontroller can manage power states, user inputs, and switching logic to optimize energy usage from solar and battery sources.

Schmitt Trigger Circuit: The Schmitt trigger is a voltage-level detector with hysteresis. It ensures that the radio and related electronics are only powered when the voltage from the solar panel or battery exceeds a minimum threshold. In this system, it monitors input voltage and switches the load on or off based on upper and lower threshold values (4.962V and 4.537V, respectively). This prevents erratic switching due to small fluctuations and ensures stable power delivery, especially during transitions from sunlight to battery power.

Op-Amp 741 and Comparator (LM393): The Op-Amp 741 and LM393 comparator are used for voltage sensing and switching logic. In this circuit, the Op-Amp is likely configured as part of the threshold detection mechanism that feeds into the Schmitt trigger. The comparator ensures sharp transitions between logic high and low when the input voltage crosses reference levels. This accurate comparison allows precise triggering of MOSFETs or logic changes that control power flow to the radio module and display units. IRFZ55N N-Channel MOSFETs: The IRFZ55N MOSFETs are responsible for high-current switching in the circuit. Controlled by the output of the comparator or Schmitt trigger, these MOSFETs act as electronic switches that regulate power delivery to the radio, display, and control circuits. Each MOSFET can handle up to 200 mA input current, making them suitable for load switching. Their use ensures low-power loss and high-speed switching, improving overall circuit efficiency under varying load and input conditions.

Potentiometer: The potentiometer functions as a user-controlled analog input device, allowing manual tuning of the FM radio. It adjusts resistance, which changes the voltage read by the ATmega328P's ADC (Analog-to-Digital Converter) pin. The microcontroller interprets this voltage and maps it to a specific frequency or station ID, which is then communicated to the FM module. This provides a simple, intuitive method for users to navigate radio stations.

7-Segment Displays and Decoders: Four 7-segment displays, driven through decoders, visually show the selected radio frequency or preset station number. The ATmega328P sends binary-coded data to the 7-segment decoders, which convert it into signals to illuminate the appropriate segments. This offers a real-time, easy-to-understand visual interface for the user, enhancing the usability of the device. 16 MHz Crystal Oscillator: The 16 MHz crystal oscillator provides a stable clock signal to the ATmega328P microcontroller. This high-precision oscillator ensures that time-sensitive operations such as ADC sampling, signal processing, and display refresh rates occur accurately. It is essential for maintaining reliable operation of the microcontroller, particularly in a low-power embedded system like this.

Passive Components (Resistors and Capacitors): The circuit includes various resistors (5–15 kΩ, 5–220 kΩ) and capacitors (5–22 pF) that serve multiple roles, including voltage division, signal filtering, timing, and biasing. Resistors in the voltage divider network help scale down voltages for safe input to microcontrollers or comparators. Capacitors stabilize power lines, suppress noise, and shape signal behavior for smooth transitions and reliable performance

3.4 Power Management Strategy:

The power management strategy in the solar-powered FM radio ensures reliable and efficient operation by regulating energy flow between the solar panel, rechargeable battery, and load components (radio, display, and microcontroller).

During optimal sunlight conditions, the solar panel directly powers the system while simultaneously charging the battery. A voltage divider circuit continuously senses the voltage output from the solar panel and sends feedback to a Schmitt Trigger circuit, which plays a critical role in decision-making based on voltage levels.

The Schmitt Trigger acts as a voltage-sensitive switch that monitors input voltage and ensures the system only operates when the voltage is within safe thresholds. Specifically, it uses hysteresis to avoid erratic switching—activating the power path when the voltage exceeds the upper threshold (≈5.5V) and disconnecting or disabling the load when it drops below the lower threshold (≈4.7V). This protects the battery from over-discharge and the radio circuit from unstable power supply, which could otherwise cause performance issues or hardware damage.

In low-light or cloudy conditions, when solar input drops below the required threshold, the system automatically shifts to using the stored energy from the rechargeable battery. The energy management also involves an IRFZ55N N-channel MOSFET, which functions as an efficient electronic switch to connect or disconnect the load based on the Schmitt Trigger output. The microcontroller (ATmega328P) and display are powered only when the available energy is sufficient, contributing to overall power savings. This seamless transition between solar and battery power ensures uninterrupted performance and extends the life of critical components.

3.5 Input/Output Description:

The solar-powered FM radio system includes both electrical and user-interaction interfaces, designed to ensure functionality and ease of use under varying power conditions. The inputs and outputs are categorized as follows:

3.5.1 Inputs:

1. Solar Energy (Electrical Input): The primary energy input is from the solar panel, which supplies direct current (DC) power under sunlight conditions. This energy charges the rechargeable battery and powers the radio system during daytime.
2. Rechargeable Battery (Backup Power Input): The battery acts as a secondary power source, supplying energy to the circuit when sunlight is insufficient (e.g., during cloudy weather or nighttime). It receives charge from the solar panel via the control circuitry.
3. Potentiometer (User Input): The potentiometer is a variable resistor that provides analog input to the ATmega328P microcontroller. It allows the user to manually tune the FM frequency. The analog voltage is read and interpreted by the microcontroller to adjust the tuning accordingly.
4. Voltage Feedback (Sensor Input): A voltage divider circuit provides feedback to the Schmitt Trigger to monitor the voltage from the solar panel or battery. This helps control power switching logic based on preset thresholds**.**

3.5.2 Outputs:

1) Speaker Output (Audio): The final audio output is delivered through a speaker connected to the radio module. It plays the demodulated FM broadcast, making it the system's primary functional output.
2) 7-Segment Display (Visual Output): A set of four 7-segment displays shows the currently tuned frequency or station number. These displays are driven by decoders and controlled by the ATmega328P microcontroller, offering a simple and readable user interface.
3) Load Control Signal (Power Control): The Schmitt Trigger and IRFZ55N MOSFET produce a digital control signal that switches the main power path to the radio and display. This output determines whether the system is actively powered based on voltage thresholds.
4) Microcontroller Output (Digital Control): The ATmega328P sends digital control signals to the display decoders and radio tuning module based on the user's input via the potentiometer. It also manages timing and logic functions for station selection and display refreshing.

3.6 System Design Summary:

The solar-powered FM radio system is designed to operate efficiently in areas with limited or no access to conventional electricity. The core design integrates a solar panel as the primary energy source, which charges a rechargeable battery and powers the system during daylight.

A voltage divider and Schmitt Trigger-based feedback mechanism continuously monitor the input voltage to ensure that the system only operates within safe voltage thresholds. This prevents undervoltage or over discharge scenarios, protecting both the battery and sensitive components.

The radio module demodulates FM signals and outputs audio through a speaker, while user interaction is enabled through a potentiometer that adjusts tuning. The ATmega328P microcontroller, running on a 16 MHz crystal oscillator, reads the tuning input and drives four
7-segment displays using decoders to show the selected station. The inclusion of IRFZ55N N- channel MOSFETs allows for efficient electronic switching, ensuring smooth transitions between solar and battery power based on real-time conditions. Overall, the design emphasizes simplicity, low power consumption, and autonomous operation. It is optimized for deployment in rural or disaster-prone areas where consistent power supply is not guaranteed. The use of commonly available, energy-efficient components makes the system cost-effective, reliable, and suitable for real-world applications where sustainability and accessibility are critical.

Chapter 4: Implementation and Testing

4.1 Breadboard Testing

Breadboard testing marked the preliminary phase of the implementation process. In this stage, all essential components of the solar-powered FM radio system were assembled on a breadboard for functional verification and troubleshooting. This non-permanent setup allowed for easy modifications and quick identification of faulty connections or components.

This also helped in early-stage trouble rectification, as if there were any kind of fundamental problem with the circuit designed it could be cleared and a functional working piece equipment can pass onto the next stage without internal circuitry issues

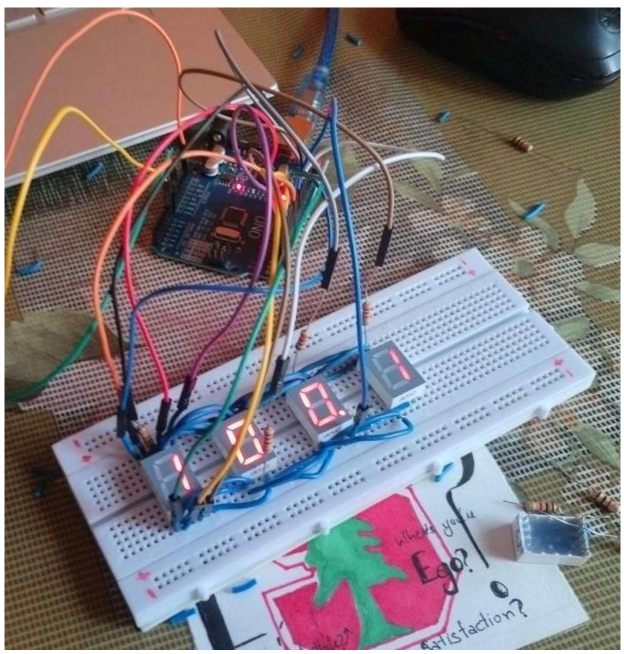

Fig 4.1: Breadboard working of the display system

The key components tested on the breadboard included:

● FM Receiver Module: Ensured proper signal reception and tuning functionality across the expected frequency range, and tested it to work under various power levels, to support solar power.

Fig 4.2: FM Receiver Module

● Solar Panels: Checked the voltage and current output from the solar panel under sunlight and its effective working under load [i.e., under radio's normal operation].

Fig 4.3: Solar Radio

● Power Supply Management: Confirmed stable power delivery to the FM from both solar and battery sources.

● Display: Tested the display system, basically the multiplexed 7-segment display under control by the ATMEGA328P microcontroller, which reads the radio current set frequency and helps display it for the visual confirmation of the selected station.

Fig 4.4: 7 Segment Display

All modules were tested individually first and then integrated together. Particular attention was paid to grounding, signal noise, and voltage regulation to ensure smooth operation before final soldering. This phase helped in identifying and resolving issues such as low audio output, unstable power supply, and signal interference, ensuring readiness for the next stage of construction.

Soldering: Following successful breadboard testing, the verified circuit was permanently assembled using a general-purpose prototyping board. Soldering ensured reliable electrical connections and mechanical stability of the components. But as the radio module was salvaged from pre-built circuitry it need not have had to be soldered.

Post-soldering, a full system test was conducted to ensure that all functionalities — including power delivery, FM reception, and audio output — were operating correctly. Minor adjustments were made where needed, particularly in the power routing and signal filtering areas.

Challenges Faced

During the Process of testing and constructing, the project a number of challenges had to faced, like the reception of the incoming RF waves, power related issues, amplifiers, component heating and its management, configuring of the 7-segment display, designing a suitable power regulator for the input as the solar power is stable enough as the sun's movement varies and many other factors lead the fluctuations of the power and that regulations using a external battery and circuit using the Schmitt trigger. The Schmitt trigger had to be configured to the nominal voltage where the solar and the battery switch smoothly, not interrupting the radio operations, ensuring a pleasant experience while using it.

Testing procedure

After the assembly and soldering stages, the system underwent a series of tests to evaluate the performance of its core functionalities. The testing focused on mainly verifying the effectiveness of the solar system and the FM radio signal reception.

Solar System Test:

This test was mainly aimed at the reception and production of the power of the solar panels under varying loads of sunlight. This test had been conducted throughout the day and for 3 days, ensuring that the results obtained are factual and up to point. And these tests have been conducted during the summer season (March-June).

Procedure:

Here, two solar panels rated at 6V 100mA that have been connected in parallel have been used in the testing process. This is because parallel connections generally contribute to a higher current rating by adding the two values of the current at its output.

4.2 Observations:

Table 4.2: Panel Test

Time	Voltage(V)	Current(mA)	Power(W)
Morning (6:00-10:00 am)	4 to 4.5	90 to 120	0.36 to 0.48
Afternoon (11:00-4:00 pm)	5.5 to 6	180 to 205	1.0 to 1.2
Evening (4:00-6:00 pm)	4.2 to 4.8	4.2 to 4.8	0.42 to 0.67

4.3 Result:

As it is tested, it is evident that the optimal time to operate the solar power is during the Afternoons (11:00-4:00 pm), as the power required for the radio's operations reached easily, and during the other 2 times modes, batteries are best used.

4.4 Radio Signal Reception and the Power Switching Test

This test evaluated the clarity, tuning accuracy, and range of the FM radio reception module, as well as the power switching circuit which is the deciding factor for the efficient power use between the solar and the battery supplies.

Procedure:

→The device was tested in multiple environments: indoors, near windows, and in open outdoor areas.

→Known local FM station frequencies were used for tuning reference.

→Audio clarity and volume were assessed through the connected speaker.

→The power switching had been connected to both the supplies, to check its readiness to switch power lines, when the necessary power was not given by the solar panels.

Observations:

→Best reception was obtained in open areas with a clear line of sight.

→Indoors, particularly in concrete buildings, the signal was weaker, requiring repositioning of the antenna.

→Fine tuning was essential to avoid adjacent station interference.

→The power switching circuit had to retuned several times to configure the optimal voltage to switch between the power, as there was switching happening in either very lower or very higher voltages.

Result:

The FM's clarity and tuning, with the power modules working have been fined tuned to work efficiently and Power switching circuit has been tested to confirm its working.

Performance Analysis

The overall performance of the solar-powered FM radio system was evaluated based on key functional parameters including power efficiency, radio reception quality, audio output, and reliability under real-world usage conditions. The implemented solar-powered FM radio system met its design objectives in terms of energy autonomy, usability, and basic functionality. With minor optimizations, especially in solar charging under low light and antenna design, the system could be made even more efficient and adaptable for remote applications

Chapter 5: Conclusion and Future Scope

The solar-powered FM radio project successfully demonstrates a functional, self-sustaining communication device that operates independently of conventional electricity sources. Through thoughtful integration of solar energy harvesting, intelligent power management using Schmitt triggers and MOSFETs, and user-friendly digital interfacing via the ATmega328P microcontroller, the system addresses the real-world challenge of information access in power-deprived regions.

The project met its core objectives—achieving reliable FM reception, continuous operation under solar and battery power, and intuitive user control. It also validated that renewable energy can effectively power low-voltage electronic systems, even with environmental variability. The device's modular architecture and use of widely available components make it both replicable and scalable, especially for deployment in rural, disaster-prone, or off-grid settings.

5.1 Project Outcomes:

→Energy Independence: Achieved stable operation without reliance on grid electricity.

→Reliable FM Reception: Clear audio reception and tuning across tested environments.

→Effective Power Management: Seamless switching between solar and battery power based on preset voltage thresholds

→User Interface: Simple tuning and frequency display via potentiometer and 7-segment interface.

5.2 Areas for Improvement:

→Reception Sensitivity: Further improvement in antenna design could enhance indoor signal strength.

→Low-Light Charging: Optimizing solar charging circuitry for better performance in cloudy or low-sunlight conditions.

→Compactness: PCB design could be refined for a more compact and integrated final form.

5.3 Future Scope:

To enhance usability and extend functionality, the following developments are suggested:

- USB Charging Port: Incorporating a USB output would allow users to charge small devices like phones, increasing the utility during emergencies.
- Bluetooth Integration: Adding Bluetooth support could allow the radio to serve as a wireless speaker, expanding its role beyond just FM reception.
- Multi-Band Support: Expanding the system to include AM or shortwave bands would increase accessibility to international broadcasts and emergency frequencies
- Digital Storage: Integrating SD card support for audio playback or broadcast recording could provide educational or informational content on demand.
- Weatherproof Enclosure: A robust, sealed casing would ensure durability in outdoor and harsh conditions.

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