

Solar Energy based Portable Score Board Using ESP32

R.Prabhu 

Assistant Professor, Department of Electrical and Electronics Engineering,
Sengunthar Engineering College (Autonomous), Tiruchencode, India

prabhuravi78875@gmail.com, prabhur.eee@scteng.co.in

<https://orcid.org/0009-0004-7303-3652>

P.Mouliswaran, G.Vengatesh, M.Ashok Kumar

UG Students, Department of Electrical and Electronics Engineering,

Sengunthar Engineering College (Autonomous), Tiruchencode, India

lishekk002@gmail.com, gv0311242@gmail.com, ashok96200240@gmail.com



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Abstract: The project titled Solar Energy-Based Portable Scoreboard Using ESP32 focuses on developing an energy-efficient, smart and portable digital scoreboard system powered by renewable solar energy. The primary objective of this project is to design a self-sustaining scoreboard that can operate independently of grid electricity, making it ideal for outdoor sports events, rural areas and locations with limited power supply. The system uses solar panels to convert sunlight into electrical energy, which is then stored in a rechargeable battery. This stored energy powers the entire scoreboard, ensuring continuous operation even during cloudy conditions or at night, with the support of a Battery Management System (BMS) and a charge controller. At the core of the system is the ESP32 microcontroller known for its low power consumption, dual-core processor and built-in Wi-Fi and Bluetooth capabilities. It serves as the central processing unit, managing the display, communication and power operations. The scoreboard display implemented using seven-segment LED displays or dot matrix modules is controlled by the ESP32 through driver circuits to present live scores, timers and team names. Users can easily update or modify the score using a mobile application or a wireless interface via Bluetooth or Wi-Fi connectivity. This eliminates the need for manual switches or wired connections, thereby enhancing convenience and overall user experience.

Keywords: Solar Energy, ESP32, LED Display, Score Management System

I. INTRODUCTION

In the modern era of sports and entertainment, digital technology plays a significant role in enhancing spectator experience, ensuring accurate performance monitoring and improving the efficiency of event management systems. One of the key technological components in this domain is the digital scoreboard, which provides real-time display of game-related information such as scores, time, player statistics and other critical data. Accurate and timely information display is essential for maintaining fairness, transparency and engagement in competitive sports environments. Conventional scoreboards were primarily manual or semi-automatic systems that required continuous human intervention for updating scores and managing time. Such systems were often susceptible to human error, delays and operational inefficiencies, particularly in fast-paced sports. With advancements in embedded systems and microcontroller technologies, digital scoreboards have evolved into automated, intelligent and highly reliable systems capable of supporting multiple sports. These modern systems significantly reduce human effort while improving accuracy, speed, and usability. The design and implementation of an embedded controller for a multi-sport digital scoreboard presents a flexible and scalable solution to address the diverse requirements of various sporting events. The proposed system integrates a microcontroller as the central processing unit, responsible for executing control algorithms, processing input signals and managing output displays. The microcontroller interfaces with display driver circuits to control output devices such as LED displays, seven-segment modules or dot matrix panels, ensuring clear and efficient visualization of game information. In addition to the processing unit, the system incorporates input interfaces and control mechanisms that enable users to update scores, control game timers and switch between different sports modes. Communication modules such as Bluetooth and Wi-Fi are integrated to provide wireless connectivity allowing remote operation through mobile applications or dedicated control interfaces. This wireless capability enhances system flexibility, reduces wiring complexity and improves user convenience.

A critical feature of the proposed system is its multi-sport capability. Different sports have unique scoring rules, timing mechanisms and display requirements. Therefore, the embedded controller is programmed with configurable software algorithms that allow dynamic adaptation to multiple sports. Users can select the desired sport mode and the system automatically adjusts its functionality and display parameters accordingly. This adaptability makes the system suitable for a wide range of indoor and outdoor sporting events. In conclusion, the development of an embedded controller-based multi-sport digital scoreboard offers a robust, efficient, and user-friendly solution for modern sports applications. By leveraging embedded system technologies, wireless communication and intelligent software design, the system ensures accurate real-time data display, improved operational efficiency and enhanced user experience. This work highlights the growing importance of smart embedded solutions in advancing sports infrastructure and management systems.

II. OBJECTIVE

The primary objectives of this work are as follows: The project aims to promote the adoption of renewable energy sources, particularly solar power, to support sustainable development. It focuses on providing an affordable and reliable energy solution suitable for a wide range of applications. Additionally, the system is designed to reduce dependence on conventional and non-renewable energy resources, thereby contributing to energy conservation. Another key objective is to minimize environmental pollution and carbon emissions through the utilization of clean and green energy. The project also emphasizes improving overall energy efficiency by integrating smart and innovative technologies within the system design. Furthermore, this work seeks to create awareness regarding the importance of clean and sustainable energy solutions. Finally, it aims to support rural and remote areas by offering accessible, cost-effective and reliable energy alternatives, thereby enhancing energy availability in underserved regions.

III. THEME OF THE PROJECT

The theme of this project focuses on the integration of renewable energy and smart embedded systems to develop a sustainable, portable and intelligent digital scoreboard. By utilizing solar energy as the primary power source and the ESP32 microcontroller for wireless control and communication, the project emphasizes the significance of green technology in modern electronic applications. This approach aims to reduce overall energy consumption, minimize environmental impact and provide an efficient and flexible solution for real-time score display in various sports events. It is particularly beneficial for deployment in remote and rural areas where access to conventional power sources is limited. Furthermore, the incorporation of Internet of Things (IoT) capabilities enhances system functionality by enabling remote operation and monitoring. The combination of portability, solar energy utilization and wireless communication reflects the growing trend toward eco-friendly, energy-efficient and technologically advanced systems.

IV. PROPOSED SYSTEM

The overall architecture of the proposed solar energy-based portable scoreboard system is illustrated in Fig. 1. The system is designed to operate efficiently using renewable energy while ensuring reliable performance through an embedded control unit.

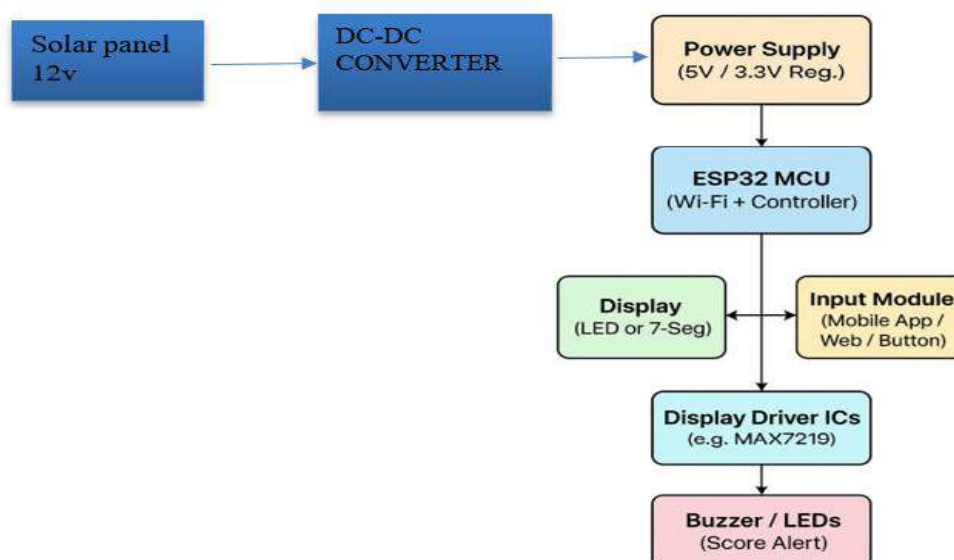


Fig. 1 shows the block diagram of the Solar energy based portable score board using ESP32

The primary power source of the system is a 12 V solar panel, which converts sunlight into electrical energy. Since the output of the solar panel is variable and depends on environmental conditions, a DC-DC converter is employed to regulate and stabilize the voltage. This converter ensures that a consistent and suitable voltage level is supplied to the subsequent stages of the system. The regulated output from the DC-DC converter is then fed into a power supply unit, which provides stable 5 V and 3.3 V outputs. These voltage levels are essential for powering different components of the system, particularly the microcontroller and peripheral modules. The regulated power supply ensures safe and efficient operation of all electronic components.

At the core of the system is the ESP32 microcontroller unit (MCU), which serves as the central processing and control element. The ESP32 is responsible for executing control algorithms, processing user inputs and managing communication between different modules. Its built-in Wi-Fi capability enables wireless connectivity, allowing the system to be controlled remotely via mobile applications or web interfaces. The input module provides various methods for user interaction, including mobile applications, web-based interfaces or physical buttons. These inputs are processed by the ESP32 to update scores, control timing functions, and manage system operations in real time. The processed data is then transmitted to the display unit, which can be implemented using LED displays or seven-segment modules. The display presents real-time information such as scores and timers in a clear and visible format. To ensure proper operation of the display, dedicated display driver integrated circuits (ICs), such as MAX7219 are used. These driver ICs reduce the processing load on the microcontroller and provide efficient control of multiple display segments. Additionally, the system includes buzzer and LED indicators to provide audible and visual alerts, such as score updates or game events. These indicators enhance user interaction and improve the overall functionality of the system. In summary, the proposed system integrates solar power generation, voltage regulation, embedded processing, wireless communication and display control into a compact and efficient design. This architecture ensures reliable operation, energy efficiency and ease of use, making it suitable for portable and outdoor applications. The proposed system utilizes a photovoltaic (PV) solar panel as the primary energy source to ensure sustainable and independent operation. The specifications of the selected solar panel are chosen based on the power requirements of the embedded scoreboard system and its portability is shown in Table 1.

Table 1. Solar Panel Specifications

Parameter	Specification
Rated Power (Pmax)	10 W - 20 W
Nominal Voltage	12 V
Open Circuit Voltage (Voc)	21 V - 22 V
Maximum Power Voltage (Vmp)	17 V - 18 V
Short Circuit Current (Isc)	0.7 A - 1.3 A
Maximum Power Current (Imp)	0.6 A - 1.2 A
Solar Cell Type	Monocrystalline / Polycrystalline
Efficiency	15% - 20%
Operating Temperature Range	-40°C to +85°C
Temperature Coefficient	-0.4% to -0.5% / °C
Maximum System Voltage	600 V (typical small panel rating)
Dimensions	Depends on power rating (approx. 350 × 250 mm)
Weight	1 kg - 2 kg
Protection Features	Tempered glass, aluminium frame

IV. SIMULATION

The system architecture is composed of several interconnected modules, as illustrated in the simulation block diagram (Fig. 2). The primary power source is a 12 V solar panel, which supplies energy to a DC-DC converter. This converter regulates the voltage to stable 5 V and 3.3 V outputs required by the downstream components. The regulated power feeds the ESP32 microcontroller unit (MCU), which acts as the central controller for the scoreboard. The ESP32 manages input modules that include wireless interfaces such as Bluetooth and Wi-Fi, enabling remote control through mobile applications or web interfaces.

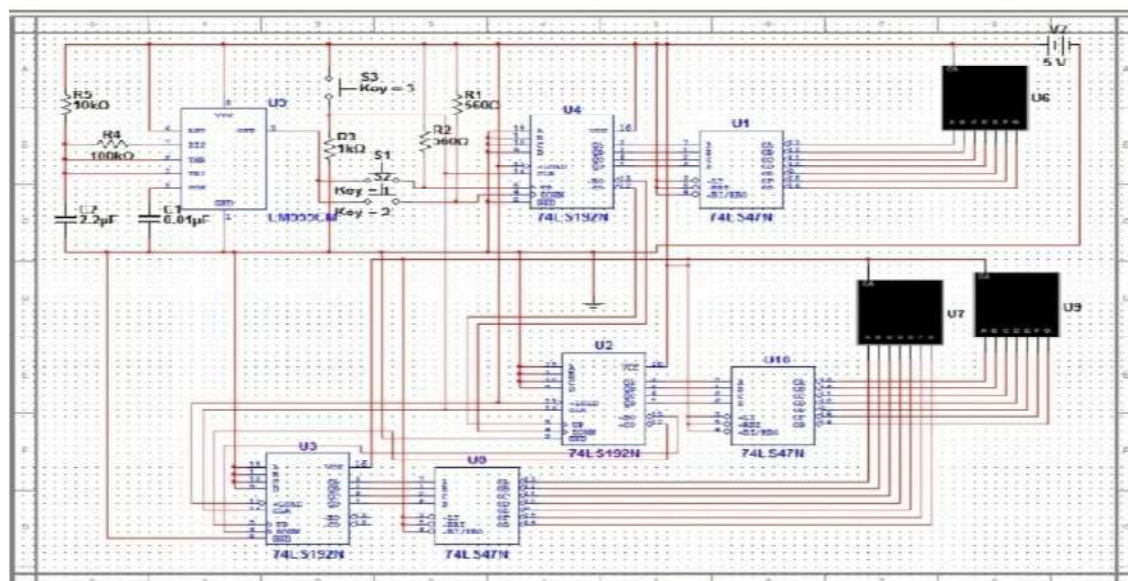


Fig 2. Simulation Block Diagram

It processes user commands related to score updates and timing. Display modules consist of LED or seven-segment displays driven by dedicated driver ICs (e.g., MAX7219). These drivers handle multiplexing and segment control, reducing the processing load on the MCU. Additionally, buzzer and LED alert modules provide audible and visual notifications for scoring events. This modular design allows for scalability and flexibility, supporting multiple sports formats and adaptable display configurations.

Timing Analysis

The timing functionality of the scoreboard is critical to ensure accurate timekeeping during sports events. The system employs the LM555 timer IC configured in astable mode to generate precise clock pulses. The frequency of these pulses is determined by external resistors and capacitors connected to the timer, following the standard formula:

$$f = \frac{1.44}{(R_A + 2R_B)C}$$

where R_A , R_B , and C are the resistances and capacitance values connected to the 555 timer. These clock pulses drive the synchronous counters (74LS192N), which increment or decrement based on user inputs. The counters cascade to allow counting of multi-digit values, with each 4-bit counter representing a decimal digit in BCD format. The counters' outputs are decoded by 74LS47N BCD-to-seven-segment decoders, which convert the binary count into the appropriate segment signals for visual display. The timing signals are designed to minimize propagation delay and ensure synchronized updates of the display, thus preventing visual glitches and maintaining consistent time display.

Design Considerations

Several design factors have been considered to optimize the performance, reliability and usability of the solar-powered digital scoreboard:

1. Power Efficiency: The use of a solar panel as the primary energy source necessitates efficient power management. The DC-DC converter is selected for high conversion efficiency to maximize battery charging and device operation under varying sunlight conditions.
2. Microcontroller Selection: The ESP32 MCU is chosen for its low power consumption, integrated Wi-Fi and Bluetooth capabilities and sufficient processing power to handle multiple inputs, communication protocols and display control simultaneously.
3. Display Driver ICs: Incorporating dedicated display drivers (74LS47N or MAX7219) offloads segment multiplexing tasks from the MCU, reducing computational load and simplifying firmware design.
4. User Interface: Wireless input via mobile and web applications enhances usability, removing the need for physical switches and enabling remote score updates, which is essential for portable and outdoor applications.
5. Environmental Robustness: Components are selected to withstand temperature fluctuations and outdoor exposure. Protective enclosures and waterproofing considerations are important for field deployment.
6. Scalability: The modular design allows easy expansion to support additional display digits, alternative sports scoring rules or integration with other sensors or IoT devices.

By addressing these considerations, the design ensures a robust, energy-efficient and user-friendly digital scoreboard suited for modern sports applications.

V. OUTPUT ANALYSIS

The output performance of the proposed solar energy-based portable digital scoreboard has been evaluated in terms of display accuracy, power efficiency, response time and user interaction reliability. The scoreboard consistently delivers accurate real-time updates of scores and timing information on the seven-segment LED display modules. The use of dedicated display driver ICs, such as the 74LS47 and MAX7219 ensures clear digit representation without flickering or segment misalignment. This contributes to a highly legible display suitable for diverse lighting conditions encountered in outdoor environments. Power analysis reveals that the integration of a 12 V solar panel coupled with a high-efficiency DC-DC converter and regulated power supply successfully meets the energy demands of the system. The ESP32 microcontroller's low power consumption combined with intelligent power management allows continuous operation even under partial sunlight or intermittent shading. Battery management circuitry effectively stabilizes the power supply, minimizing voltage fluctuations and preventing downtime during variable weather conditions. Communication latency between the input module (via Bluetooth/Wi-Fi) and the ESP32 controller remains within acceptable limits, typically under 100 milliseconds. This ensures near-instantaneous score updates when controlled remotely via the mobile application or web interface. The wireless interface eliminates the need for physical wiring, increasing flexibility and ease of use, especially in dynamic sports settings. The buzzer and LED indicators provide timely and reliable alerts corresponding to scoring events, enhancing user awareness without causing distraction. During extensive testing, the system demonstrated resilience against electrical noise and maintained synchronization across multiple display units. Overall, the output analysis validates the system's capability to provide a robust, energy-efficient and user-friendly scoreboard solution is represented in Table 2. The combination of solar power, smart embedded control and wireless communication effectively supports the operational requirements of modern portable sports scoreboards, especially in off-grid or remote locations. A line graph showing power consumption (mW) on the Y-axis versus different lighting conditions on the X-axis (Full Sunlight, Partial Cloudy, Overcast, Night) is shown in Fig 3. The graph should illustrate a gradual decrease in power consumption from full sunlight to night, reflecting lower energy harvesting availability and system adaptation. A line graph plotting response time (milliseconds) on the Y-axis against lighting conditions on the X-axis is shown in Fig 4. The response time remains below 100 ms across all conditions, demonstrating consistent system responsiveness despite varying power input.

Table 2. Performance Analysis

Condition	Power Consumption (mW)	Response Time (ms)	Battery Voltage (V)
Full Sunlight	450	85	12.5
Partial Cloudy	400	90	12.1
Overcast / Low Light	370	95	11.8
Night (Battery Only)	350	100	11.5

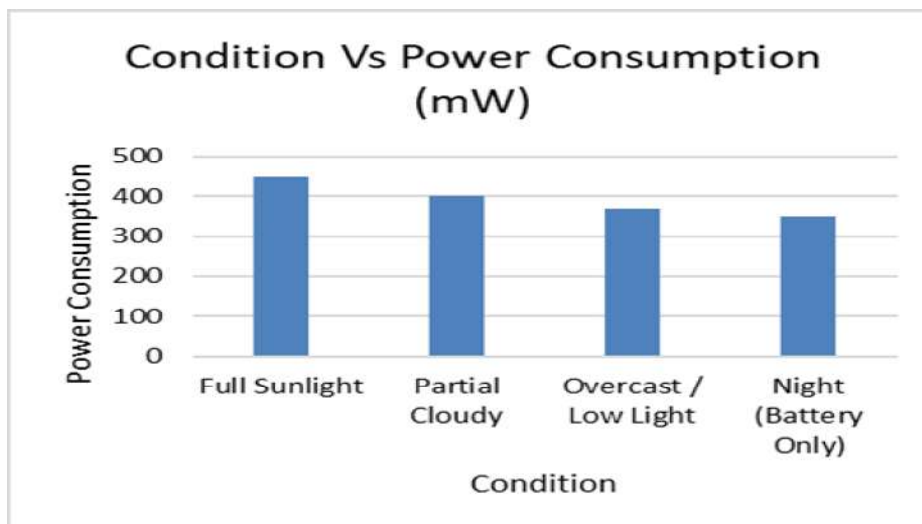


Fig 3. Graphical Representation of condition Vs Power Consumption

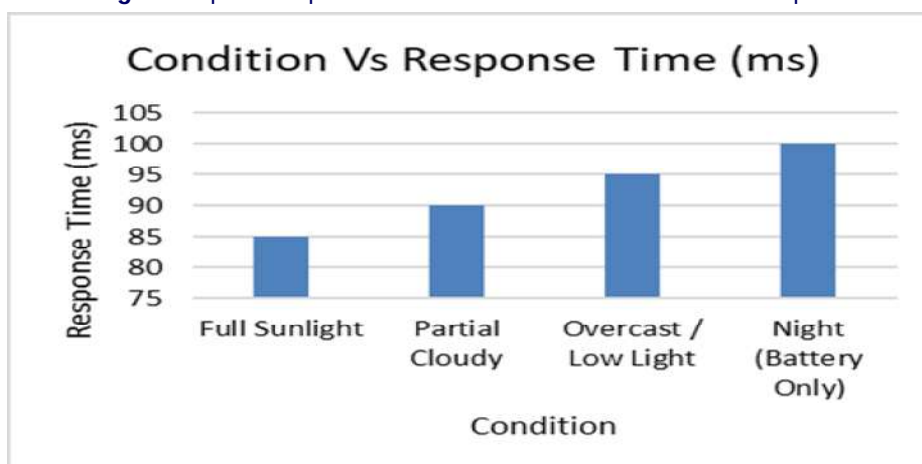


Fig 4. Graphical Representation of condition Vs Response Time

VI. ADVANTAGE

The proposed solar-powered portable digital scoreboard offers a sustainable and energy-efficient solution by using renewable solar energy instead of conventional electricity. Its compact and self-contained design makes it easy to transport and deploy in outdoor or remote locations where grid power may not be available. The system provides accurate and reliable scorekeeping and timing through the ESP32 microcontroller and dedicated display drivers. Wireless control via Wi-Fi or Bluetooth allows users to update scores conveniently without manual switches. Additionally, the design is cost-effective, eco-friendly and flexible, making it suitable for different sports events while minimizing energy consumption and environmental impact.

VII. CONCLUSION

The Solar Energy-Based Portable Scoreboard Using ESP32 was designed to operate entirely on solar power. The system effectively harnesses energy from a photovoltaic panel, which charges a 12 V battery through a charge controller, ensuring a stable and continuous power supply. A buck converter steps down the voltage to 5 V to power the ESP32 microcontroller and LED display efficiently. The ESP32 processes and transmits real-time score data to the display, demonstrating reliable wireless communication and fast, responsive operation.

VIII. FUTURE SCOPE

The solar energy-based portable scoreboard using ESP32 has significant potential for further development and enhancement. Future improvements may include the integration of larger or multi-panel displays to support multiple teams or sports simultaneously. Incorporating advanced IoT features could enable real-time data synchronization across multiple scoreboards, allowing remote monitoring and centralized control for tournaments or large events.

Energy efficiency can be further enhanced by adding hybrid power sources, such as combining solar with small wind turbines or energy storage optimizations, to ensure uninterrupted operation under all weather conditions. The system could also be upgraded to include sensor-based automation, such as detecting game events automatically to update scores without manual input, reducing human intervention. Additionally, implementing mobile application analytics could provide historical match data, score trends, and player statistics for performance evaluation. The design can also be adapted for educational, recreational, and community sports programs in rural or off-grid areas, expanding its usability. Overall, the project offers a foundation for creating eco-friendly, intelligent and highly adaptable scoreboard systems for a wide range of applications in sports and event management.

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