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Wireless Bluetooth Low Energy (BLE) Voltmeter: A Modern Solution for Remote Voltage Monitoring

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Abstract

The increasing need for wireless communication in measurement systems has sparked the development of innovative tools that provide enhanced flexibility, convenience, and portability. This research paper introduces the concept of a Wireless Bluetooth Low Energy (BLE) Voltmeter, a system designed to measure and transmit voltage values remotely via Bluetooth technology. Using Arduino Nano and a BLE module, this voltmeter wirelessly transmits real-time voltage data to a mobile device, eliminating the need for traditional wired connections. The paper explores the working principle, components, and system design, demonstrating how Bluetooth Low Energy can be leveraged to create a low-power, cost-effective solution for voltage measurement. Applications of this system are discussed in various fields such as electronics, automotive diagnostics, and industrial monitoring, highlighting the advantages of portability, ease of use, and efficiency.

Introduction

In the world of electronics and electrical engineering, voltage measurement is a fundamental task that often requires precision and efficiency. Traditionally, voltmeters have been wired instruments that physically connect to the circuit whose voltage is being measured. While these systems are effective, they come with limitations such as cumbersome setups, restricted mobility, and the inconvenience of constant reconnection during measurements.

With the rapid advancements in wireless communication technologies, especially in the domain of Bluetooth Low Energy (BLE), it is now possible to eliminate these constraints. BLE technology, designed for low-power, short-range communication, enables devices to transfer data wirelessly with minimal energy consumption. This project explores the development of a Wireless BLE Voltmeter that makes use of an Arduino Nano and a BLE module to wirelessly measure and display voltage data on a mobile application.

The core objective of this project is to eliminate the need for direct physical connections, making it easier for users to measure voltages remotely. The system is not only portable but also offers the

flexibility of monitoring voltage data in real-time without the complexities associated with traditional voltmeter setups. This opens up new possibilities in various industries, ranging from electronics to automotive diagnostics and industrial monitoring.

OBJECTIVES

The primary objective of this project is to design and implement a system that facilitates remote voltage measurement using wireless Bluetooth communication. To achieve this goal, the project involves the development of a system that meets the following specific objectives:

- Voltage Measurement: The system will be capable of measuring the input voltage through an analog-to-digital converter (ADC) on an Arduino Nano. The voltage readings will be scaled down using a voltage divider circuit to fit within the measurement range of the ADC.
- Wireless Communication: The system will transmit the processed voltage data wirelessly to a mobile device via Bluetooth Low Energy (BLE). This eliminates the need for direct wired connections.
- Mobile Application Development: A mobile application will be developed to receive the voltage readings transmitted by the BLE module and display the values in real-time. The app will allow users to monitor voltage remotely.
- Low-Power Operation: The design will prioritize low-power consumption to ensure that the system is energy-efficient and can operate for extended periods on battery power.
- User-Friendliness: The system should be easy to set up and use, with a simple interface for monitoring voltage on a mobile device.

By meeting these objectives, the Wireless BLE Voltmeter aims to provide an efficient, cost-effective, and portable solution for voltage measurement, applicable in various domains.

SYSTEM BLOCK DIAGRAM

The system consists of the following key components:

- Voltage Divider: Scales down the input voltage to a measurable range (0-5V).
- Arduino Nano: The central controller responsible for processing the voltage readings.
- BLE Module (HM-10): Enables wireless communication by transmitting the processed data to the mobile device.
- Mobile Application: The interface on the mobile device that receives and displays the voltage reading in real-time.

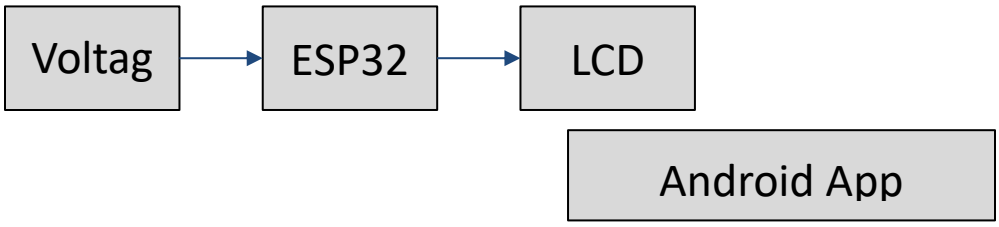

Fig. 1 Block Diagram of Wireless Bluetooth Low Energy (BLE) Voltmeter

WORKING OF THE WIRELESS BLE VOLTMETER

The working of the Wireless BLE Voltmeter can be broken down into several key stages: voltage measurement, analog-to-digital conversion, Bluetooth communication, and mobile application interaction. Each stage plays a critical role in ensuring that voltage readings are accurately captured and transmitted to the user.

Voltage Measurement

The first step in the process involves measuring the voltage applied to the system. To ensure that the voltage is within the measurable range of the Arduino Nano, which operates on a 5V reference voltage, the input voltage must be scaled down appropriately. This is achieved using a voltage divider circuit.

The voltage divider consists of two resistors arranged in series. The input voltage is applied across the series resistors, and the voltage at the junction between the two resistors is the output. The value of the output voltage is determined by the ratio of the resistors, as described by the voltage divider equation:

Vout=Vin×R2R1+R2V_{\text{out}} = V_{\text{in}} \times \frac{R_2}{R_1 + R_2}Vout=Vin×R1+R2R2
Where:
VoutV_{\text{out}}Vout is the scaled voltage,
VinV_{\text{in}}Vin is the input voltage,
R1R_1R1 and R2R_2R2 are the resistors in the voltage divider circuit.
By selecting appropriate values for R1R_1R1 and R2R_2R2, the output voltage is scaled to a range between 0V and 5V, which can be safely read by the Arduino Nano.

Analog-to-Digital Conversion (ADC)

Once the voltage has been scaled to the appropriate level, it is fed into one of the analog input pins of the Arduino Nano. The Arduino Nano is equipped with a 10-bit ADC, which converts the analog voltage into a corresponding digital value. The ADC produces a digital value in the range of 0 to 1023, where 0 corresponds to 0V and 1023 corresponds to 5V.
The digital value can be mapped back to the corresponding voltage using the following formula:
Voltage=(ADC Value1023)×5.0\text{Voltage} = \left(\frac{\text{ADC Value}}{1023} \right) \times 5.0Voltage=(1023ADC Value)×5.0
This allows the Arduino Nano to calculate the input voltage based on the digital output from the ADC.

Bluetooth Communication

Once the voltage has been measured and converted into a digital value, the Arduino Nano communicates this value to a mobile device via Bluetooth Low Energy (BLE). The Arduino uses Serial Communication (UART) to send the data to the BLE module (commonly the HM-10 module).
The HM-10 BLE module uses Bluetooth 4.0 technology, designed for short-range, low-power communication. The module establishes a connection with the mobile device, transmitting the voltage data over Bluetooth. This eliminates the need for physical wiring, allowing for remote voltage monitoring.

Mobile Application Interaction

On the mobile side, a dedicated application receives the voltage data sent by the BLE module. The application communicates with the BLE module, retrieves the data, and displays it on the mobile device screen. The app allows users to monitor voltage readings in real-time, providing a convenient, portable method for voltage measurement.

The mobile application can be developed using various platforms, such as MIT App Inventor, Flutter, or Android Studio. The application is designed to be user-friendly, with an intuitive interface for displaying voltage values, updating readings in real-time, and providing notifications if the voltage exceeds preset thresholds.

SYSTEM DESIGN AND COMPONENTS

The system comprises several essential components, each of which plays a specific role in enabling the wireless voltage measurement and monitoring:

- Arduino Nano: The central controller responsible for measuring and processing the voltage values. It also handles the communication with the BLE module.
- Voltage Divider Circuit: A resistor-based circuit that scales down the input voltage to fit within the Arduino's ADC range.
- BLE Module (HM-10): The Bluetooth Low Energy module responsible for wirelessly transmitting the voltage data to the mobile device.
- Mobile Application: The application installed on the mobile device that receives and displays the voltage readings transmitted via BLE.

Each component is chosen based on its compatibility, low power consumption, and ease of integration into the overall system design.

RESULTS AND DISCUSSION

The Wireless BLE Voltmeter provides several advantages over traditional wired voltmeter systems:

Convenience

By utilizing Bluetooth technology, this system eliminates the need for physical connections between the voltmeter and the measured circuit. Users can remotely monitor voltage values from a distance, providing greater flexibility and convenience.

Portability

The system's wireless nature makes it highly portable. The compact size of the Arduino Nano and the BLE module ensures that the system can be used in a variety of environments without the limitations of traditional wired instruments.

Low Power Consumption

The use of Bluetooth Low Energy (BLE) ensures that the system consumes minimal power, making it suitable for battery-operated applications. This is particularly useful for remote monitoring where a power supply may not be readily available.

Real-time Monitoring

The real-time transmission of data to a mobile application allows users to observe voltage fluctuations as they happen. This is particularly valuable in applications where voltage stability is critical, such as in industrial machinery or automotive diagnostics.

CONCLUSION

The Wireless Bluetooth Low Energy Voltmeter is an innovative and effective solution for voltage measurement, offering several benefits such as convenience, portability, low power consumption, and real-time monitoring. By integrating Arduino Nano with Bluetooth Low Energy (BLE), the system provides a cost-effective and user-friendly alternative to traditional voltmeters. This project demonstrates how wireless technologies can be used to improve the efficiency and flexibility of measurement systems.

Future work could focus on improving the accuracy of the system, expanding its measurement capabilities to higher voltage ranges, and enhancing the mobile application with additional features such as data logging, voltage trend analysis, and alert systems for abnormal voltage levels.

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