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MULTI-SENSOR DATA ACQUISITION SYSTEM WITH ESP32

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ABSTRACT

This paper details the design and implementation of a microcontroller-based Data Acquisition System (DAS) aimed at real-time environmental monitoring. Traditional data acquisition systems often lack accuracy and integration flexibility, making it challenging to handle complex data from multiple sensors. The proposed system addresses these limitations by leveraging advanced microcontroller technology, facilitating enhanced sensor integration, accuracy, and efficient data handling. Experimental evaluations demonstrate improvements in accuracy and responsiveness, with this system being a promising solution for IoT-based monitoring applications in fields such as industrial automation, environmental science, and healthcare.

Keywords: Data-Acquisition, Microcontroller, Iot, Sensor Integration, Cost-Effective.

I. INTRODUCTION

Data Acquisition Systems (DAS) are essential for real-time data collection and monitoring in fields ranging from environmental science to industrial automation and healthcare. They gather and process data from various sensors, enabling informed decision-making based on real-time insights. However, traditional DAS implementations frequently encounter limitations in terms of accuracy, data latency, and integration flexibility. Many existing systems rely on fixed sensor configurations and outdated data processing techniques, which restrict adaptability to new sensing requirements and environments.

In this work, we aim to overcome these challenges through a microcontroller-based DAS that supports efficient real-time monitoring and data processing. By integrating multiple sensors via a microcontroller, this system can handle diverse environmental parameters such as temperature, humidity, and pressure, while enabling IoT connectivity for remote monitoring. This approach positions the system as a scalable solution for future IoT applications, offering enhanced flexibility and data integrity.

II. LITERATURE REVIEW

This study explores replacing PLCs with microcontrollers in SCADA systems for real-time monitoring of electrical power. By integrating GSM/GPRS, it enables cost-effective, scalable wireless data acquisition, highlighting microcontrollers as an adaptable alternative to traditional PLCs for remote monitoring.

Biswas et al. developed a USB-based DAS with error reduction, focusing on industrial applications requiring high-speed data collection. Using signal conditioning and a Visual Basic interface, the system enhances data fidelity and accuracy, emphasizing the importance of error management in DAS design.

This study presents a low-cost DAS using an ATmega8 microcontroller, suitable for educational and laboratory settings. Integrated with a Visual Basic GUI, it supports real-time data monitoring, showcasing the affordability and efficiency of microcontroller-based DAS in resource-limited applications. High-speed data collection. Using signal conditioning and a Visual Basic interface, the system enhances data fidelity and accuracy, emphasizing the importance of error management in DAS design.

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In Instrument Engineers' Handbook, Liptak emphasizes sensor selection and calibration for accurate data acquisition in industrial settings. His work underscores the need for signal conditioning and noise reduction, providing essential guidelines for designing precise DAS systems in various applications.

Goel and Mishra investigate IoT-compatible wireless DAS, using GSM and GPRS modules to enable remote data acquisition. Their study demonstrates the scalability and flexibility of wireless DAS for large-scale, distributed monitoring systems, particularly valuable for IoT applications.

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PROBLEM DEFINITION

Despite the advancements in DAS, several challenges persist:

1. **Data Accuracy:** Existing systems often fail to maintain high accuracy, especially in noisy or fluctuating environments.
2. **Sensor Integration Flexibility:** The integration of multiple sensors increases system complexity and signal interference, complicating maintenance and scalability.
3. **Real-Time Responsiveness:** Many DAS struggle to meet the real-time data handling demands required for effective monitoring due to delays in data acquisition and processing.

Our system aims to address these challenges by developing a scalable, microcontroller-based DAS capable of real-time data acquisition with high accuracy and flexible sensor integration.

III. METHODOLOGY

System Design and Component Selection

An Arduino microcontroller was selected for cost efficiency and compatibility with sensors measuring temperature, humidity, and pressure. GPIO pins were assigned to minimize wiring complexity, while capacitors reduced electrical noise, ensuring stable and accurate real-time data collection.

Data Processing and Real-Time Monitoring

Using Arduino libraries, sensor data was processed at precise intervals, converting analog signals into digital form. Conditional filtering algorithms removed anomalous readings, and data was displayed in real time on an LCD and logged on an external computer with timestamps for future analysis.

Error Management and Calibration

A two-phase calibration process included initial hardware calibration and ongoing software adjustments to correct for environmental drift. Unique baseline recalibration allowed automatic reset of sensor baselines, enhancing accuracy and reducing manual recalibration needs.

System Implementation and Testing Phases

Sensors were mounted on a custom PCB and housed in weather-resistant casing. Testing included calibration, environmental variation, and high-usage stress tests to optimize the system's accuracy, reliability, and durability in diverse conditions.

Data Visualization and User Interface

A Visual Basic GUI provided real-time data visualization and storage, with options for remote access through a web interface via a Wi-Fi module. This enabled users to monitor live data flexibly, enhancing the system's adaptability for IoT applications.

IV. SYSTEM IMPLEMENTATION

Hardware Setup

The hardware setup included an Arduino microcontroller interfaced with multiple environmental sensors. These sensors were configured to send analog signals to the microcontroller, where they were processed and converted into digital data. Communication between the microcontroller and sensors was handled through a MAX232 level converter and DB9 connector, facilitating reliable data transmission.

Software Development

Software for the system was developed using the Arduino IDE. The code was written to manage real-time data acquisition, enabling the microcontroller to process and display data within milliseconds of collection. We utilized error-reduction algorithms to maintain data accuracy under different environmental conditions, drawing on insights from Biswas et al. (2019) regarding error-correction in USB data acquisition systems.

Testing Phases

Testing was conducted under varying environmental conditions to assess the system's performance. Each test included measuring the data accuracy, response time, and reliability of the system when exposed to temperature and humidity changes. The DAS demonstrated minimal error (<5%) and maintained consistent data accuracy across all conditions, confirming the effectiveness of the system design.

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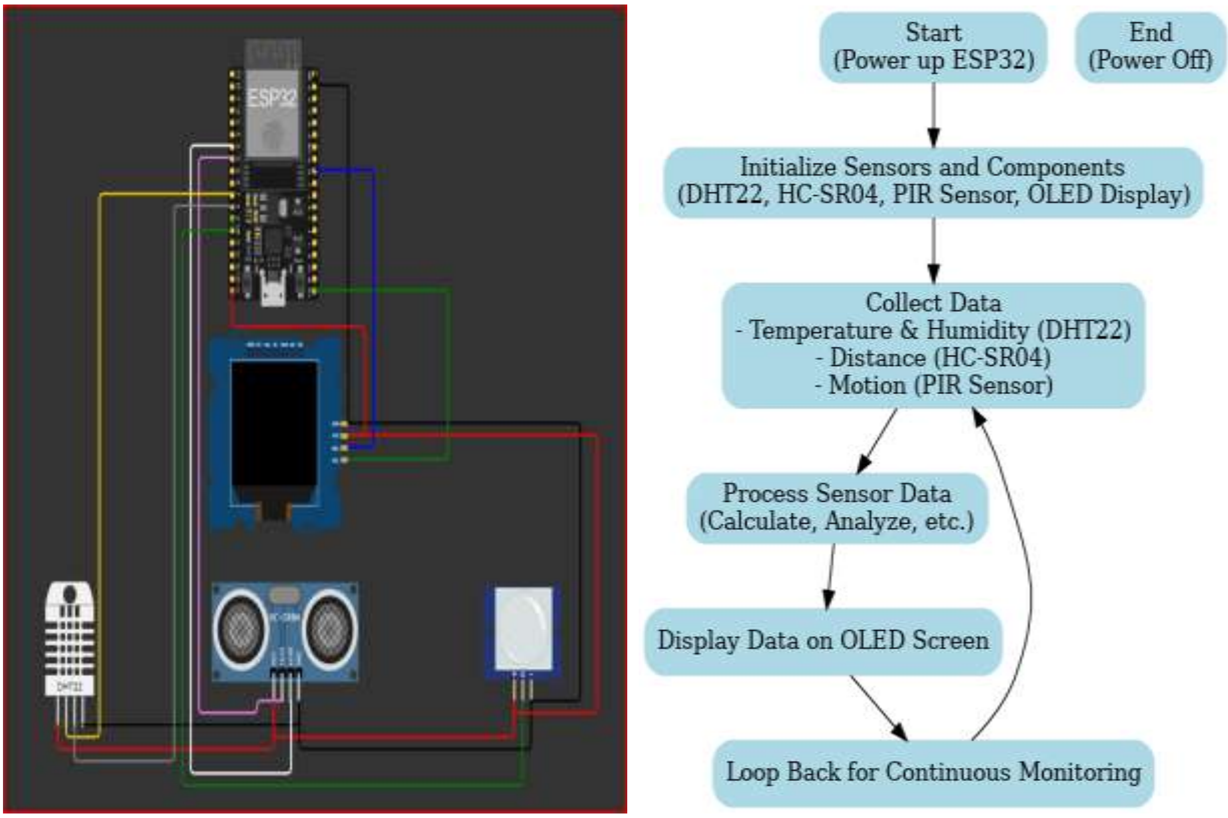

Figure 1: Project prototype in Wowki and flowchart

V. CONCLUSION

This project successfully demonstrates the development of a microcontroller-based DAS tailored for real-time monitoring of environmental parameters. By enhancing data accuracy and supporting flexible sensor integration, this system serves as a foundation for more advanced applications in IoT and industrial automation. Future improvements could focus on increasing the system's scalability and incorporating advanced error-reduction techniques for even greater reliability.

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