Multi -Sensor Integration and Bluetooth Data Transmission for Tiva Board using MATLAB for Real-Time Analysis

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***Abstract*—This paper outlines the integration of ultrasonic, accelerometer, temperature, switch, and potentiometer sensors with the Tiva board. The system successfully gathers real-time data from these sensors and presents it in MATLAB for immediate display and observation. Utilizing Bluetooth, the Tiva board wirelessly transmits sensor data to enable real-time monitoring and analysis. The project showcases a multi-sensor data acquisition setup tailored for diverse environmental parameter monitoring and immediate observation in MATLAB for various applications.**

Keywords—Tiva Board, Sensor Integration, Ultrasonic Sensor

Accelerometer, Temperature Sensor, Switch, Potentiometer

Bluetooth Communication, Real-Time Data Transmission, Multi-Sensor Data Fusion

I. INTRODUCTION

A. Problem Statement

The integration of sensors with microcontrollers has become pivotal in modern engineering applications, enabling real-time monitoring and control in various fields. The combination of diverse sensors, such as ultrasonic, accelerometer, temperature, switch, and potentiometer, offers a comprehensive approach to environmental data acquisition. This project aims to integrate these sensors with the Tiva board, a versatile microcontroller platform, to create a robust data collection system.

B. Objective

The primary objective of this project is to interface five different sensors with a Tiva board, leveraging its capabilities as an ARM Cortex-M based microcontroller. The data acquired from these sensors is processed within the Tiva board and wirelessly transmitted via a Bluetooth module. The transmitted real-time sensor data is directly displayed and observed in MATLAB, allowing immediate visibility into the sensor readings and their variations.

C. Scope of the Project

This project primarily focuses on hardware-software interfacing, configuring the Tiva board to interface with various sensors. It entails implementing sensor-specific algorithms for data collection and processing, culminating in the real-time display of sensor values using MATLAB. The project aims to demonstrate a functional system capable of gathering, transmitting, and showcasing real-time multi-sensor data for immediate analysis and applications.

II. SENSOR SELECTION AND OVERVIEW

A. Ultrasonic Sensor

The ultrasonic sensor selected for this project is the HC-SR04. It operates on the principle of emitting ultrasonic waves and measuring the time taken for the waves to return after hitting an object. With a range of 2cm-400cm, operating at a frequency of 40KHz, it enables distance measurement in real-time applications. The sensor's accuracy and reliability make it suitable for proximity sensing and object detection.

Fig. 1. Ultrasonic Sensor HC-SR04

B. Accelerometer

Utilizing an ADXL345, this sensor detects acceleration along the X, Y, and Z axes, providing readings in the range of ±[2, 4, 8 or 16] g. It's ideal for capturing dynamic motion and tilt sensing. The high sensitivity and low power consumption of this sensor make it suitable for applications requiring precise motion detection.

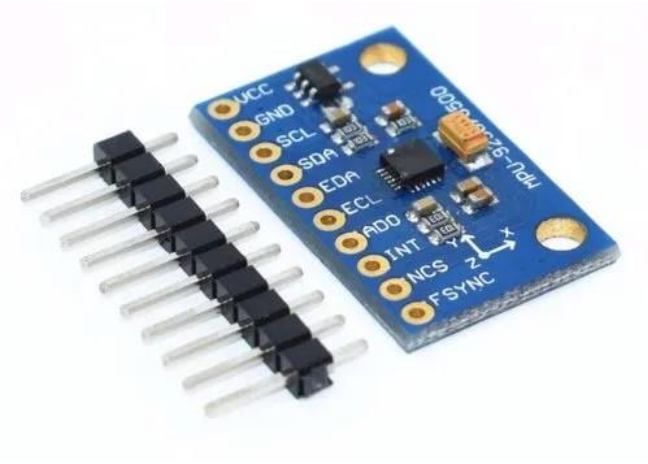

Fig.2. Accelerometer Sensor ADXL345

C. Temperature Sensor

The [Temperature Sensor Model] employed in this setup offers a temperature range of −55°C to 150°C, with an accuracy of −40°C to 110°C range (−10° with improved accuracy). The LM35 sensor operates based on the principle of generating a voltage output that is linearly proportional to the temperature being measured. This principle enables accurate temperature measurement for various environmental monitoring and control applications.

Fig. 3. Temperature Sensor LM35

D. Switch

For discrete input detection, switch is incorporated. It serves as an on/off indicator for specific conditions or events within the system.

Fig. 4. Switch

E. Potentiometer

The chosen potentiometer, POT Sensor, offers a resistance range of 0 to 20 K ohms. It facilitates analog input control and serves as a variable voltage divider, enabling analog signal manipulation within the circuit.

Fig. 5. Potentiometer

Sensors	Range
Ultrasonic Sensor (HC-SR04)	2cm-400cm
Accelerometer (ADXL345)	±[2, 4, 8 or 16] g
Temperature Sensor (LM35)	−55°C to 150°C
Potentiometer (POT Sensor)	0 to 20 K ohms

TABLE 1: SENSOR SPECIFICATIONS AND RANGES

III. HARDWARE SETUP

A. Tiva Board Configuration

The core component of the system is the Tiva board,

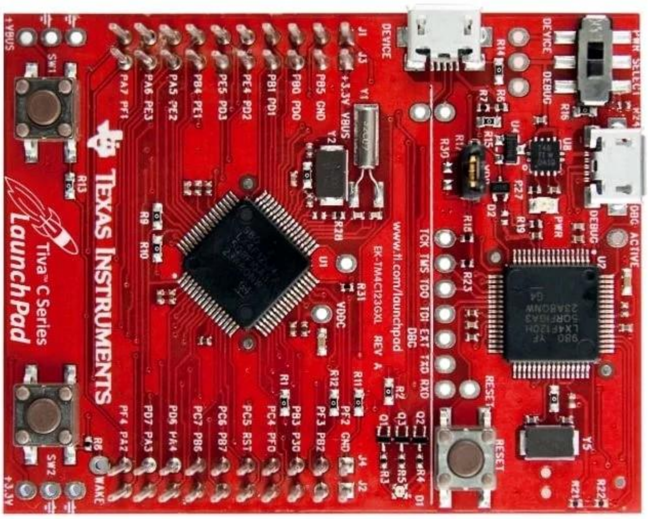

Fig. 6. Tiva TM4C123GH6PM LaunchPad

TM4C123GH6PM, utilized as the central processing unit. The board is configured to interface with the selected sensors through GPIO pins and analog input ports. Power supply connections, clock settings, and pin configurations are established as per the datasheet specifications to ensure proper functionality.

B. Sensor Interfacing

1) *Ultrasonic Sensor:* Connected to GPIO pins for trigger and echo signals. The trigger pin initiates the ultrasonic pulse, while the echo pin receives the reflected signal for distance calculations.

2) *Accelerometer:* Interfaced via I2C/SPI protocol for digital communication. The X, Y, and Z axis outputs are read using the appropriate communication protocol for real-time motion sensing.

3) *Temperature Sensor:* Analog output linked to an analog input pin for temperature readings. Analog-to-digital conversion is performed to obtain digital temperature data.

4) *Switch:* Connected to a digital input pin to detect the state change for event detection within the system.

5) *Potentiometer:* Utilizes an analog input pin to measure the variable resistance and generate an analog signal for control applications.

C. Bluetooth Module Integration

A Bluetooth module, [Bluetooth Module Model], is incorporated into the setup to enable wireless data transmission. The module interfaces with the Tiva board through UART communication. Configuration settings are established to establish a Bluetooth connection and facilitate data streaming to external devices.

IV. Software Implementation

A. Data Acquisition and Processing

1) *Sensor Data Collection:* Dedicated software routines are developed to interface with each sensor connected to the Tiva board. These routines enable the acquisition of real-time data from the sensors, ensuring accuracy and reliability in data collection.

2) *Data Processing Algorithms :*Specific algorithms are implemented to process the raw data obtained from sensors. For instance*:*

a) *Ultrasonic Sensor:* Distance calculation based on the time difference between transmitted and received signals.

b) *Accelerometer:* Conversion of raw accelerometer readings into meaningful motion data (e.g., acceleration, tilt angles).

c) *Temperature Sensor:* Conversion of analog temperature data into human-readable temperature values.

B. Bluetooth Communication Setup

A Bluetooth module, HC-05 is incorporated into the setup to enable wireless data transmission. The module interfaces with the Tiva board through UART communication. Configuration settings are established to establish a Bluetooth connection and facilitate data streaming to external devices.

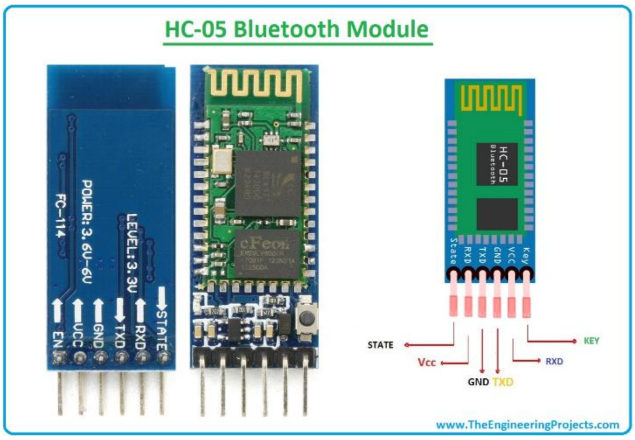

Fig. 7. Bluetooth Module HC-05

1) *UART Communication Configuration:* Software protocols are established to enable UART communication between the Tiva board and the Bluetooth module.

2) *Data Transmission Protocol:* A communication protocol is implemented to format and transmit sensor data via Bluetooth. Packet structures are defined for efficient data transmission, ensuring synchronization and error handling.

C. Real-Time Sensor Data Display in MATLAB

1) *Real-Time Data Display:* MATLAB is utilized to receive and display real-time data transmitted via Bluetooth from the Tiva board. MATLAB functions and scripts are employed to interpret incoming data packets and directly showcase the live sensor values in a textual format.

2) *Immediate Sensor Value Representation:* Within MATLAB, the received sensor data is dynamically displayed, allowing immediate observation of real-time values without Simulink's involvement. The values are observed and analyzed within MATLAB's environment for real-time assessment and monitoring.

V. System Integration and Testing

A. Calibration and Validation

1) *Sensor Calibration:* Each sensor undergoes calibration to ensure accurate and consistent readings. Calibration parameters are determined and applied to the sensor data processing algorithms.

2) *Validation of Sensor Outputs:* The acquired sensor data is compared against known reference values or standards to validate the accuracy and reliability of the sensor outputs. This step ensures that the sensors provide consistent and expected results.

B. Real-Time Data Transmission

1) Bluetooth Connectivity Testing: The Bluetooth module's functionality is tested for establishing connections, data transmission, and maintaining stability over varying distances and environmental conditions.

2) Data Integrity Checks: Robustness of the data transmission protocol is evaluated through stress testing and data integrity checks to ensure that transmitted data is received accurately and without loss.

C. System Performance Evaluation

1) Real-Time Analysis in MATLAB: The system's performance for real-time analysis is evaluated based on the capability to display and process sensor data in MATLAB. The effectiveness of MATLAB in presenting real-time sensor values and its ability to handle and showcase data accurately are assessed.

2) Response Time and Accuracy: The system's response time to sensor inputs and the accuracy of the processed data are analyzed under various scenarios and environmental conditions.

VI. RESULTS AND ANALYSIS

A. Real-Time Sensor Values Display in MATLAB

1) Real-Time Values Presentation: The sensor data acquired and transmitted to MATLAB is showcased through real-time numerical displays or text outputs. MATLAB functions are utilized to present the instantaneous readings of each sensor in a textual format, providing direct visibility into the current values.

main.m

```
clear all
s=Bluetooth('IoT4',1);
% Open the serial port
fopen(s);

% Read values from the serial port and display them
while true
    if s.BytesAvailable > 0
        data = fscanf(s);
        disp(data);
    end
end

% Remember to close the serial port when finished
fclose(s);
```

Fig. 8.Code snippet for real time data transmission in MATLAB

2) Observational Analysis: The direct observation and analysis of real-time sensor values are conducted within MATLAB. The values displayed in MATLAB are observed and studied for trends, variations, or instantaneous changes among different sensors.

B. Comparative Analysis of Sensor Data

1) Sensor Comparison: The direct display of real-time sensor values allows for a qualitative comparison between

```
Potentiometer Value (Voltage) = 2.568 Volts

Ultrasonic Value (Distance) = 33 cm

Temperature Sensor Value =  25.4 C

Potentiometer Value (Voltage) = 2.566 Volts

Ultrasonic Value (Distance) = 42 cm

Temperature Sensor Value =  25.4 C

Potentiometer Value (Voltage) = 2.567 Volts

Ultrasonic Value (Distance) = 8 cm

Temperature Sensor Value =  25.4 C
```

different sensors. Observations regarding simultaneous changes or variations in readings from various sensors are noted for qualitative analysis.

Fig. 9.Output snippet for real time data transmission in MATLAB

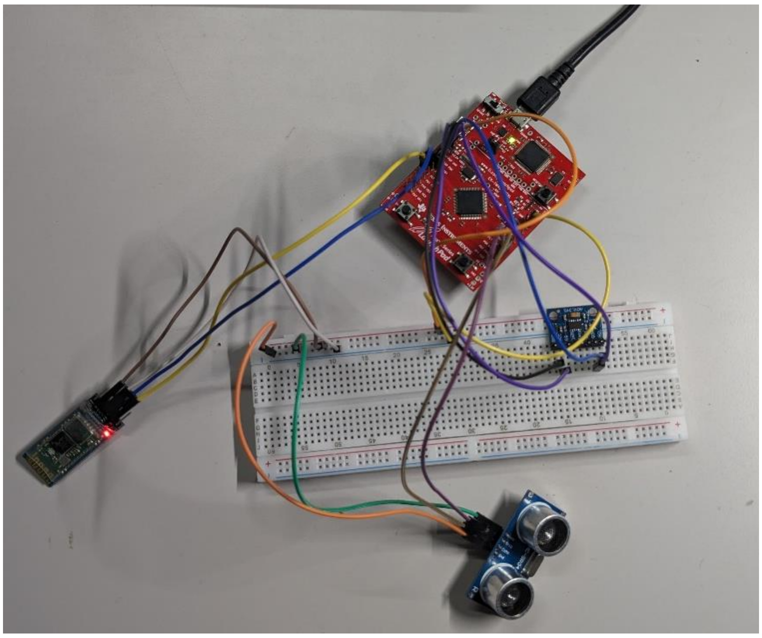

Fig. 10.This connection shows ultrasonic sensor, accelerometer and Bluetooth being connected with Tiva Board

2) Correlation Studies: Statistical methods are employed to identify correlations or relationships between sensor outputs. For instance, correlating temperature variations with accelerometer readings or ultrasonic sensor distance measurements.

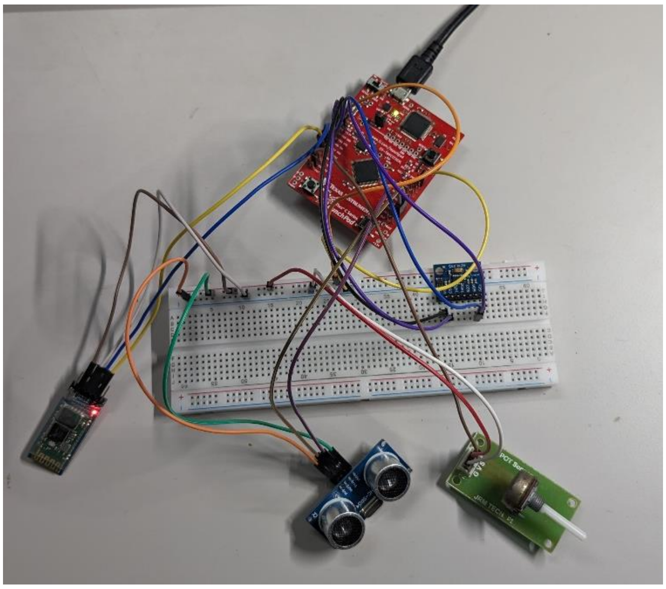

Fig. 11.This connection shows ultrasonic sensor, accelerometer ,POT sensor and Bluetooth being connected with Tiva Board

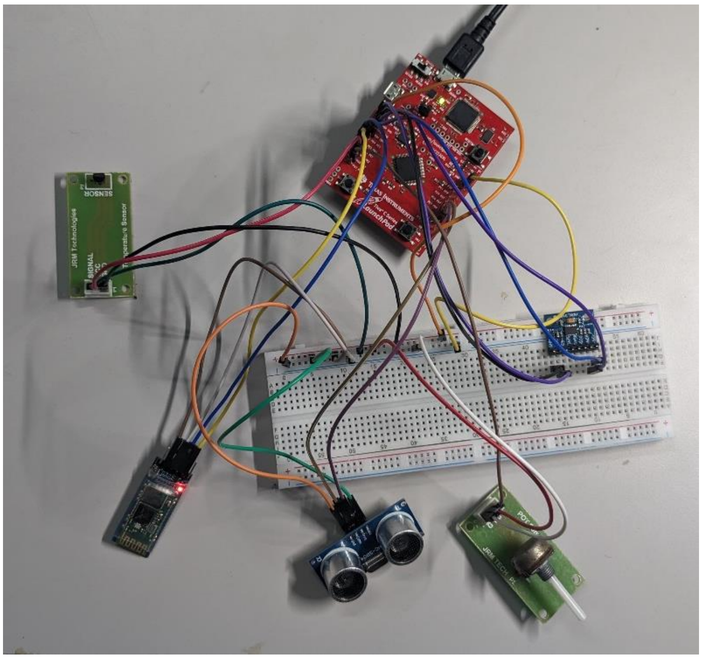

Fig. 12.This image shows the complete circuit connection of the project where all the sensors are being connected(LM35, HC-05, HC-SR04,POT sensor, ADXL345)

C. System Reliability and Accuracy

1) Accuracy Assessment: The accuracy of sensor readings and their consistency over multiple trials are assessed against known benchmarks or expected values.

2) Reliability Testing: The system's reliability under different environmental conditions, such as temperature variations or changes in sensor orientations, is evaluated to determine its robustness.

VII. Conclusion

A. Summary of Findings

The project successfully accomplished the integration of multiple sensors with the Tiva board, enabling real-time display of sensor values in MATLAB. The effective interfacing of diverse sensors, including ultrasonic, accelerometer, temperature, switch, and potentiometer, facilitated the collection of data from various environmental parameters.

B. Achievements

1) Functional Multi-Sensor Setup: A functional system capable of collecting data from various environmental parameters.

2) Reliable Sensor Data Display: Implementation of reliable sensor data display in MATLAB facilitated seamless and immediate observation of real-time sensor values

C. Insights and Future Enhancements

1) Insights Gained: Implementation of reliable sensor data display in MATLAB facilitated seamless and immediate observation of real-time sensor values

2) Future Scope: Potential enhancements include refining algorithms for improved data processing, expanding sensor capabilities, and integrating additional functionalities for more comprehensive analysis.

D. Conclusion Remarks

In conclusion, the project successfully achieved the integration of multiple sensors with the Tiva board, enabling real-time display of sensor values in MATLAB. The establishment of a reliable system for acquiring and showcasing real-time sensor data lays the groundwork for future advancements in multi-sensor data acquisition and analysis across various applications.

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