Real Time monitoring of high temperature of remote places using Wireless Sensor Network without use of any peripheral hardware

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***Abstract*— This paper is about the use of thermocouples in wireless sensor networks using Java. Thermocouples are able to measure temperatures as high as 1200 degree Celsius. Standard implementation of thermocouples requires the use of peripheral hardware to measure temperature. Through this paper, it has been shown how Java can be used to interface the thermocouple directly with the Xbee radio modules using customized API, without using any peripheral hardware or microcontrollers. Real time data are stored and analyzed through graph.**

Keywords— ***Thermocouples, Java, Xbee Radios, Wireless Sensor Networks***

I. INTRODUCTION

Wireless sensor networks are often seen as an alternative to their wired counterparts in the modern era. Xbee radios are a market standard in creating wireless sensor networks. The Xbee radios are scalable, flexible and easy to use. Extensive research in this field has shown that to measure the parameters of remote locations, the traditional wired systems fail [1]. Wireless sensor networks have a number of advantages such as self-organization, flexibility and ease of deployment over wired systems [2]. Wireless sensor networks can be used for remote sensing, industrial and domestic automation, control applications [3] with their proven reliability. Wireless Sensor Networks consist of a central control node and many remote nodes which are connected to the central node. These remote nodes can sense data, provide actuating output or act as repeaters [4-5].They contain power units, data processors, memory, telemetry and sensing-actuating capabilities [6-8]. They are independent devices that are able to collect sensor data and send that to the 'controller' device wirelessly. The 'controller' device in a wireless sensor network is often called a coordinator. The coordinator is concerned with gathering the data from all the remote devices on the network. Thermocouples can sense temperatures ranging from −270ºC to 3000°C, giving them a very large operating range [9]. Margaret Richardson Ansah, Yan Shu, Cao Qing Hua [10], Ricardo Mayo Bayón et al [11] have extensively researched on the theme of using thermocouples in wireless sensor networks. They have shown areas of practical application where such systems can be implemented. These include data monitoring in tunnel ovens, monitoring systems for coalmine fires, and temperature monitoring systems for industrial and research applications. They can withstand high temperatures which other temperature sensors cannot. Thermocouples excel at their role of measuring such high temperatures because they are rugged and durable. Sensors and hardware used in wireless network is different from the ones used in wired networks. Characteristics such as low power consumption, active sensors take precedence in wireless sensor networks. Thermocouples are active sensors. They do not require additional power to sense temperature. However thermocouples require additional interfacing hardware, namely amplifiers, to connect to wireless sensor networks. The remote node has to provide power to the 'amplifier circuit'. This hampers the overall network performance. It also makes it hard to scale the network and inflexible. In this paper a new design paradigm has been presented for using thermocouples in remote wireless sensor networks. The design does not require an amplifier circuit or interfacing hardware. Proposed approach is hardware independent and can be used with any type of thermocouple. It has also been shown how one can perform dynamic reference junction temperature compensation for achieving more accurate readings.

In this paper, it has been discussed how one can use Java to sense temperature data directly from a thermocouple connected to a Xbee radio using software. This approach is vastly superior to the traditional method. This has been discussed in the paper. It has also been demonstrated how to carry out real-time data logging and visualization for future analysis by data scientists. The paper is divided into six sections. Section I describes the paper. Section II elaborates the system design and experimental setup. Section III shows the Flow Chart for the complete operation using Java software. Section IV demonstrates how the software can process the raw sensor data from the thermocouple into temperature. It also sheds light on how reference junction temperature is calculated. Result and Conclusion are discussed in Sections V and VI respectively.

II. DESIGN & EXPERIMENTAL SET UP

The system is designed to remotely carry out remote sensing of temperature using a thermocouple which is connected to one of the nodes of a wireless sensor network, made up of Xbee S2B radios. The proposed system consists of 2 Xbee S2B radios. One of them is configured to be the coordinator node, where as the other is configured to be the remote sensor node. The coordinator node is connected to the PC through a COM port. The remote node is connected wirelessly to the coordinator node through the Xbee protocol. The thermocouple is connected to one of the analog IO pins of the remote node. The Java software is able to read the thermocouple data from the coordinator node. The coordinator node is configured to operate in API mode, whereas the remote node is configured to operate in the AT mode. As stated before, the radios are configured as coordinator and router nodes respectively. The Xbee radios are configured for initial use through Digi's XCTU software. The Java program runs on the PC and is connected to the coordinator node through the USB-COM port. The program is able to read Xbee frames, extract thermocouple sensor data, convert it into temperature, and log and visualize the data in real-time.

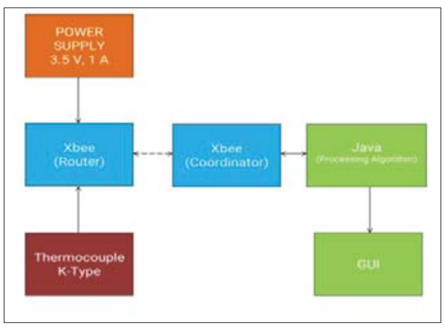


Fig.1. Block Diagram for Wireless Sensor Network Using Xbee, K-type Thermocouple and Java

III. FLOW CHART

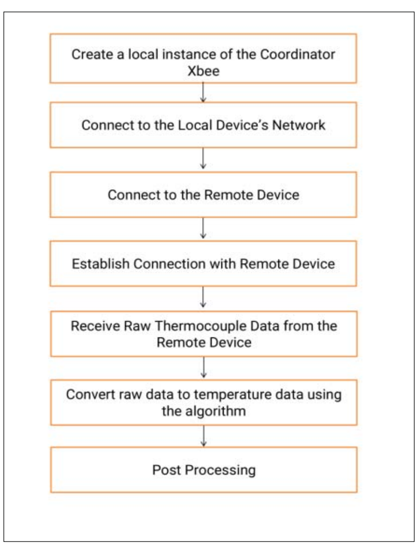


Fig.2. Flow Chart for operation of the Java program

IV. THERMOCOUPLE DATA PROCESSING USING JAVA

Thermocouples use the thermoelectric effect (Seebeck's effect) to sense temperature. The Seebeck effect is concerned with the conversion of thermal energy into electrical energy. The Seebeck emf (electromotive force) is any electric potential difference that results from non-uniform temperature distribution in conducting materials which is not subject to a magnetic field. A thermocouple is made up of two wires - usually alloys which are welded at one end. The wires are then coiled with an electric insulator and enclosed in a metal jacket. Thermocouple sensors have a simple construction. Thermocouples have good repeatability. They are durable and reliable. They generate an active signal voltage with low impedance. This means that they are able to function without a power supply. This makes them uniquely attractive for wireless sensor network applications. The thermocouple requires two different inputs to accurately measure data. These inputs are the measurement of reference temperature and the measurement of thermoelectric voltage. The active voltage is measured by the wireless sensor network node. The active voltage never exceeds the value of 2 Volts which is well within the Xbee's ADC (Analog to Digital Convertor) pin's measurement range. This makes it possible to use thermocouples without any extra circuitry or hardware. The measurement of the reference junction temperature can be done manually. The measured temperature can be entered directly into the software's graphic user interface (GUI). The active voltage measurement is then converted into the equivalent temperature reading using the thermocouple's voltage to temperature conversion algorithm. The coefficient values for the algorithm are dynamically taken by the software. The reference junction temperature is used to calculate reference junction voltage. This voltage is added to the calculated thermocouple temperature to get the total junction temperature.

V. RESULT

A. Converting raw thermocouple data into temperature

The raw sensor output voltage is converted into temperature data in real-time using our software.

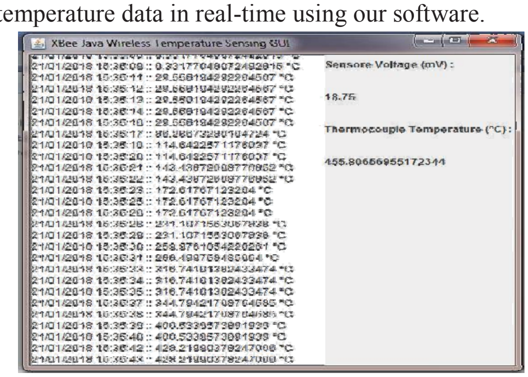


Fig.3.Converting raw thermocouple data into temperature

B. Performing cold junction compensation in real time

The cold junction temperature compensation is set in real-time that allows for more accurate data.

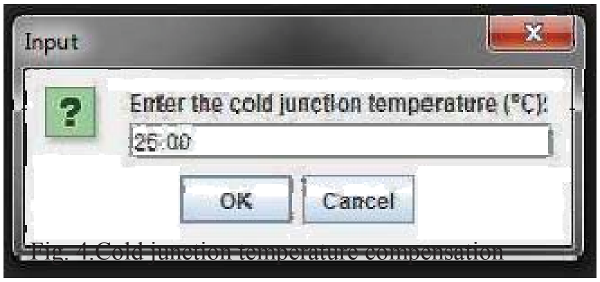


Fig. 4.Cold junction temperature compensation

C. Representing the thermocouple data as a graph in real time

The temperature - time graph for the thermocouple is plotted in real- time.

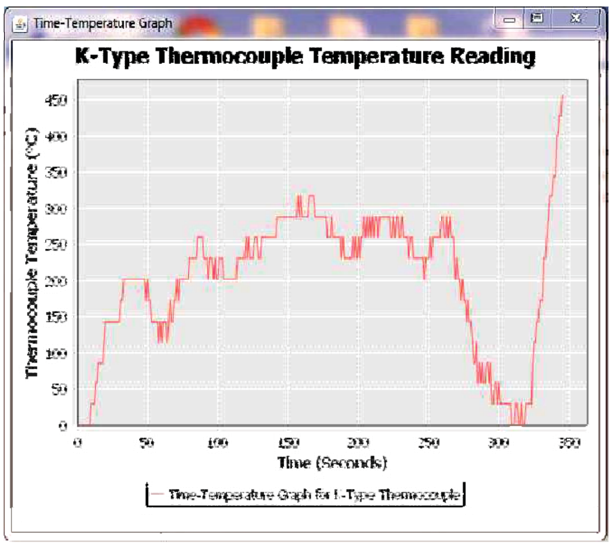
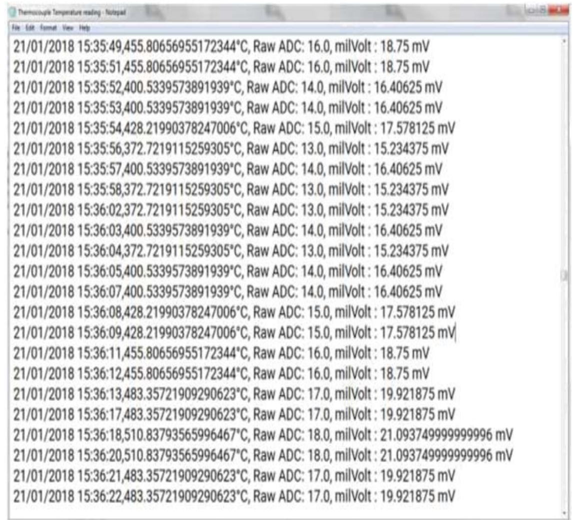


Fig.5. Graphical representation of Thermocouple data

D. Saving the processed processed information to disk

The thermocouple temperature calculated by the software is written to a .txt file in real-time.



21/01/2018 15:35:49,455.80656955172344°C, Raw ADC: 16.0, milVolt : 18.75 mV
21/01/2018 15:35:51,455.80656955172344°C, Raw ADC: 16.0, milVolt : 18.75 mV
21/01/2018 15:35:52,400.5339573891939°C, Raw ADC: 14.0, milVolt : 16.40625 mV
21/01/2018 15:35:53,400.5339573891939°C, Raw ADC: 14.0, milVolt : 16.40625 mV
21/01/2018 15:35:54,428.21990378247006°C, Raw ADC: 15.0, milVolt : 17.578125 mV
21/01/2018 15:35:56,372.7219115259305°C, Raw ADC: 13.0, milVolt : 15.234375 mV
21/01/2018 15:35:57,400.5339573891939°C, Raw ADC: 14.0, milVolt : 16.40625 mV
21/01/2018 15:35:58,372.7219115259305°C, Raw ADC: 13.0, milVolt : 15.234375 mV
21/01/2018 15:36:02,372.7219115259305°C, Raw ADC: 13.0, milVolt : 15.234375 mV
21/01/2018 15:36:03,400.5339573891939°C, Raw ADC: 14.0, milVolt : 16.40625 mV
21/01/2018 15:36:04,372.7219115259305°C, Raw ADC: 13.0, milVolt : 15.234375 mV
21/01/2018 15:36:05,400.5339573891939°C, Raw ADC: 14.0, milVolt : 16.40625 mV
21/01/2018 15:36:07,400.5339573891939°C, Raw ADC: 14.0, milVolt : 16.40625 mV
21/01/2018 15:36:08,428.21990378247006°C, Raw ADC: 15.0, milVolt : 17.578125 mV
21/01/2018 15:36:09,428.21990378247006°C, Raw ADC: 15.0, milVolt : 17.578125 mV
21/01/2018 15:36:11,455.80656955172344°C, Raw ADC: 16.0, milVolt : 18.75 mV
21/01/2018 15:36:12,455.80656955172344°C, Raw ADC: 16.0, milVolt : 18.75 mV
21/01/2018 15:36:13,483.3572190929062З°C, Raw ADC: 17.0, milVolt : 19.921875 mV
21/01/2018 15:36:17,483.35721909290623°C, Raw ADC: 17.0, milVolt : 19.921875 mV
21/01/2018 15:36:18,510.83793565996467°C, Raw ADC: 18.0, milVolt : 21.093749999999996 mV
21/01/2018 15:36:20,510.83793565996467°C, Raw ADC: 18.0, milVolt : 21.093749999999996 mV
21/01/2018 15:36:21,483.35721909290623°C, Raw ADC: 17.0, milVolt : 19.921875 mV
21/01/2018 15:36:22,483.35721909290623°C, Raw ADC: 17.0, milVolt : 19.921875 mV

Fig. 6. Saving the processed data in file

VI. CONCLUSION

Through this paper, it has been demonstrated the following:

1. Performing remote temperature sensing using a thermocouple and a wireless sensor network.
2. Interfacing the Xbee with a K-Type thermocouple without requiring any additional interfacing hardware.
3. Performed thermocouple voltage conversion into temperature using software for interfacing with K-Type thermocouples. The software was written in Java.
4. Performed reference junction temperature compensation in real time for calculating accurate thermocouple temperature.
5. Logging and visualizing the remote thermocouple temperature in real-time.

Proposed setup has many advantages over the conventional approach of using peripheral hardware. It is immune to variations due to change in temperature, hardware drift & ageing. Proposed setup allows for real-time cold junction compensation. No peripheral device has the ability to perform real time cold junction compensation. No peripheral or interfacing hardware is required in proposed design. The software is modular and can be used with any type of thermocouple without requiring any additional hardware. However, certain limitations of the setup were found. For the system to function properly, calibration of the thermocouple is required. Failure to do so may result in incorrect temperature readings. Incorrect measurement of the cold-junction temperature may lead to inaccuracies in the final temperature readings.

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