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Design of a Low Cost Smart Dryer Temperature Measurement System for Tea Factories

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Abstract: This paper presents the design of a low cost smart dryer temperature measurement system for Tea Factories using K-type Thermocouple implementing linearization polynomial. The thermo emf is amplified by an instrumentation amplifier having high CMRR (106 dB) and high input impedance (10^{12} Ohm). The analog signal is converted to digital form with the help of an SPI compatible 12-bit ADC. Data acquisition and transmission is done with an 8- bit microcontroller. As the dependence of thermo emf on temperature is not linear hence it is fitted with a polynomial. NIST data for K-type TC is taken as a standard for this fitting. The error with linear fit and polynomial fit is also presented. The digital data is corrected according to the polynomial and sent to a PC located at a remote control room for monitoring and data logging via RS232C communication. The performance of the entire system is discussed in the paper. *Copyright © 2009 IFSA.*

Keywords: Sensor network, Serial communication, Thermocouple linearization, Tea factory, Microcontroller

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1. Introduction

Tea is the major agricultural resource which plays an important role to the economic growth of India in general and Assam in particular. Almost 2500 numbers of tea gardens are there in Assam producing almost 25 % of total tea production of India [12]. But advanced process control and monitoring systems are not yet introduced in most of the tea factories. To enhance quality of tea precise monitoring and control of different physical parameters like humidity, temperature, moisture content of tea leaves etc. are very much essential.

In tea processing fermented tea leaves are dried in a dryer. Hot air with temperature 104 ^{0}C is allowed to enter the dryer. Precise measurement of hot air temperature at the inlet of a dryer is a crucial factor for tea quality [1]. Apart from it data storage is also essential such that the supervisor can analyze the past status of the dryer. Field experience reveals that most of the factories use conventional instrumentation for measurement of temperature. These instruments have limited precision with no data storage feature. One of the solutions to it is the use of sophisticated data acquisition cards, but these are not popular because of their high cost and necessity of skilled manpower.

Thermocouples (TC) are one of the most popular and reliable sensors, which have a very wide range of operation and can be applied to many different industrial environments [9, 10, 11]. The first complexity with TC for high accuracy measurement is that there is no fixed relationship for temperature and thermo emf produced [6]. So look-up table [3, 4, 7] is one of the options. Look-up tables require many calibration points, whose number can be reduced by interpolating between them. Calculating the inverse of the function (polynomial fit) that relates the input and the output requires us first to determine that function; which needs many reference inputs again. Storage need is smaller than that for the look-up table method [7]. In smart sensor application, this polynomial [9] fit can be done within STIM (Smart Transducer Interface module) [5, 8] or by the host PC.

The required relation between this conditioned emf and temperature is derived applying the polynomial-fitting algorithm to the amplified thermo emf. The increase in accuracy thus obtained is observed. The polynomial for temperature is calculated for the range of 0-200 ^{0}C such that it is compatible with 12-bit resolution ADC (ADS1286, *Texas Instruments*) that runs with 5V dc source. We have used NIST-90 data for K-type thermocouple for this purpose.

The data is sent to a central control room via RS232C where display of this data and storing is done using a PC. The linearization, system description and software developed for this purpose is in the following sections.

2. Linearization of Thermocouple

The thermo emf is amplified using an instrumentation amplifier (INA110, Texas Instruments) with a gain 500. The amplified thermo emf is used to fit a 9th order polynomial using least square polynomial fitting [2] algorithm for the corresponding temperature. The coefficients of the polynomial are shown in Table 1.

Table 1. Coefficients of the polynomial.

Parameter	Value
A	0.00269
B_1	0.05063
B_2	-1.24656E-6
B_3	-4.34493E-10
B_4	9.39481E-13
B_5	-6.8794E-16
B_6	3.02726E-19
B_7	-7.72974E-23
B_8	1.04247E-26
B_9	-5.76086E-31

Polynomial:

$$Y = A + B_1 \cdot X + B_2 \cdot X^2 + B_3 \cdot X^3 + B_4 \cdot X^4 + B_5 \cdot X^5 + B_6 \cdot X^6 + B_7 \cdot X^7 + B_8 \cdot X^8 + B_9 \cdot X^9,$$

where Y is the temperature in ^{0}C; A, B's are constant coefficients and X is the amplified thermo emf.

From the theoretical data error curves are drawn for different temperatures from 0 to 200 ^{0}C using both polynomial (Fig. 1) and linear regression (Fig. 2) i.e. assuming 40 microvolt per degree Celsius. The error calculated using polynomial is found to be +0.02 ^{0}C to –0.01 ^{0}C. But for linear regression it is found to be +0.83 ^{0}C to – 0.5 ^{0}C, which is much higher than the error calculated from polynomial.

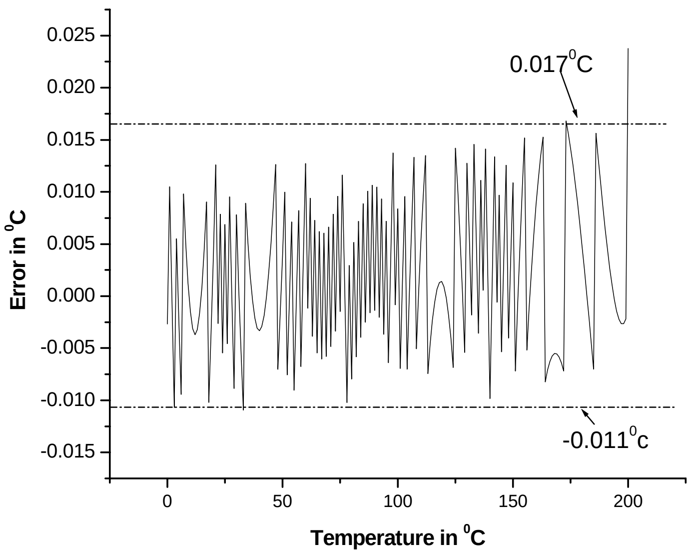

Fig. 1. Error calculated using polynomial.

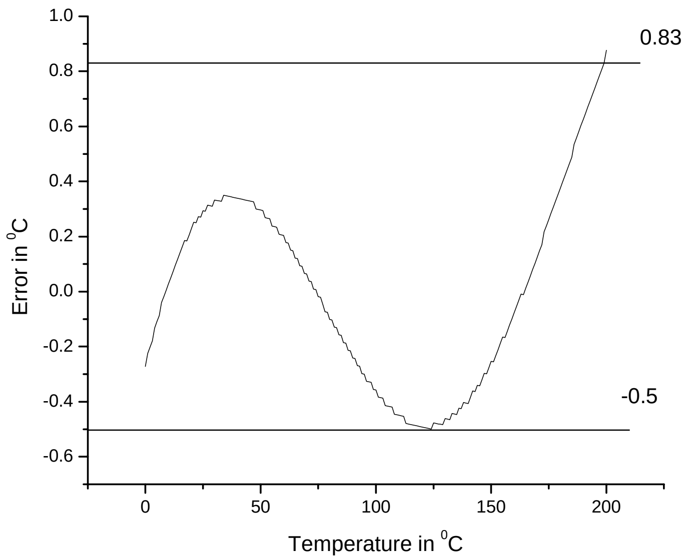

Fig. 2. Error calculated using linear regression.

3. System Description

The block diagram of the system is shown in Fig. 3. The thermo emf is amplified by an instrumentation amplifier having high CMRR (106 dB) and high input impedance (10^{12} Ohm). This part is put in metallic shielding to avoid radio frequency (RF) and electromagnetic (EM) interferences. The noises picked up by the TC are filtered out using a low pass filter (LPF). The analog signal is converted to digital form with the help of a serial synchronous interface (SSI) compatible 12-bit ADC.

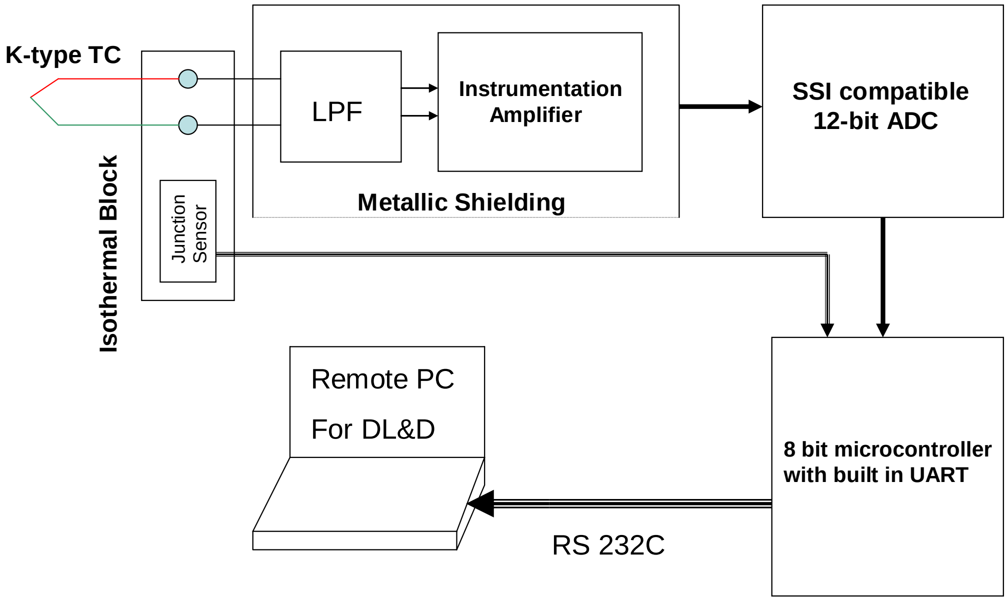

Fig. 3. Block diagram of the system.

The heart of the system is an 8 bit microcontroller (AT89C2051) with built in UART. The ADC is interfaced with it. The digital data is converted to temperature with the polynomial mentioned above by this microcontroller. The converted value is sent to a PC situated at a remote control room is transmitted using RS232C communication. The Firmware is developed for this purpose using KEIL IDE. The software for the host PC is also developed. PC is used for data logging and display (DL&D).

4. Software Description

The required firmware for data conversion, correction and transmission to the remote PC is done with the help KEIL integrated development environment (IDE). Flowchart of the firmware is shown if Fig. 4.

The software required at PC to receive data serially is developed using Visual Basic. It receives data serially through COM port. Digital data is then converted to temperature. The temperature is displayed on the PC. Simultaneously the data is also stored in the HDD of the PC for future use. The flow chart is shown in the Fig. 5.

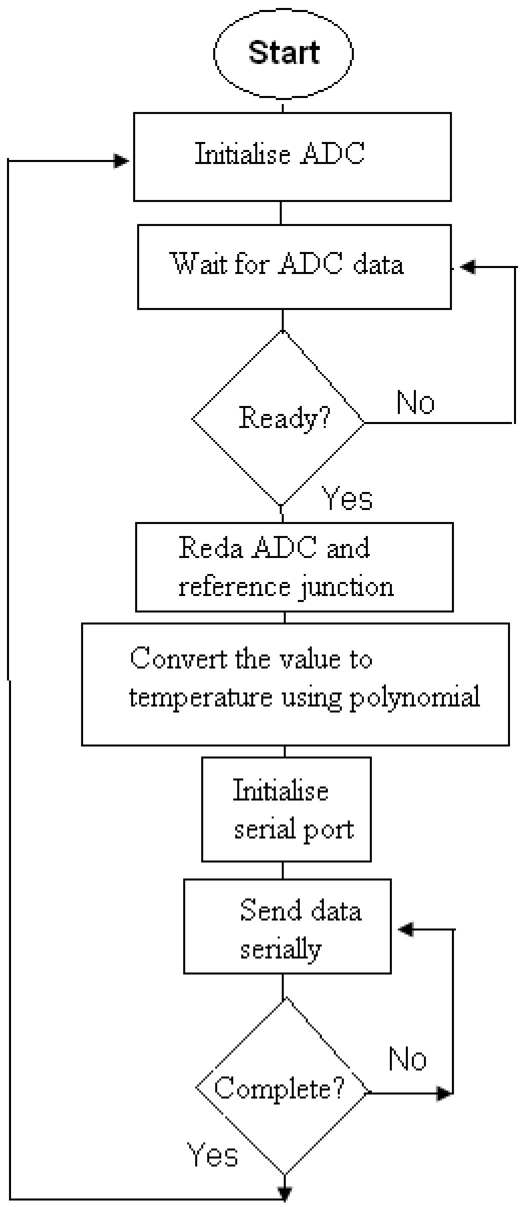

Fig. 4. Firmware.

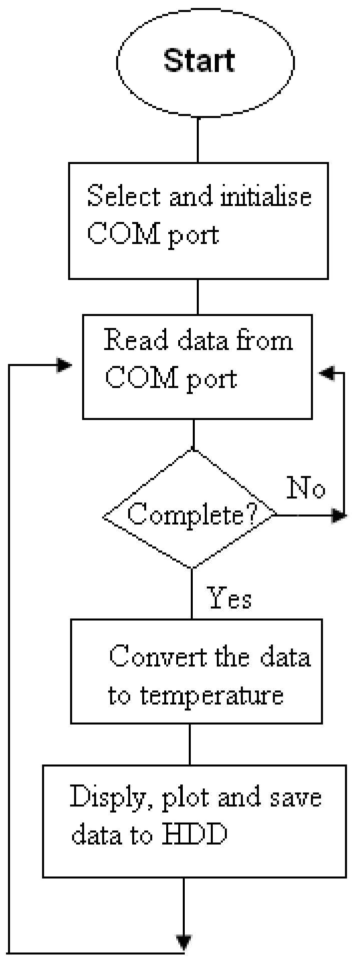

Fig. 5. Software.

5. Field Experience

The system was installed for testing at Sonapur Tea Estate, Sonapur, Kamrup, Assam (India). The system was used to monitor the inlet temperature of one dryer. The screenshot of the display is shown in Fig. 6 below. In the industrial environment the performance of the system is found to be satisfactory.

The dryer is situated at a distance of 20 meters from the control room. So RS232C communication works properly.

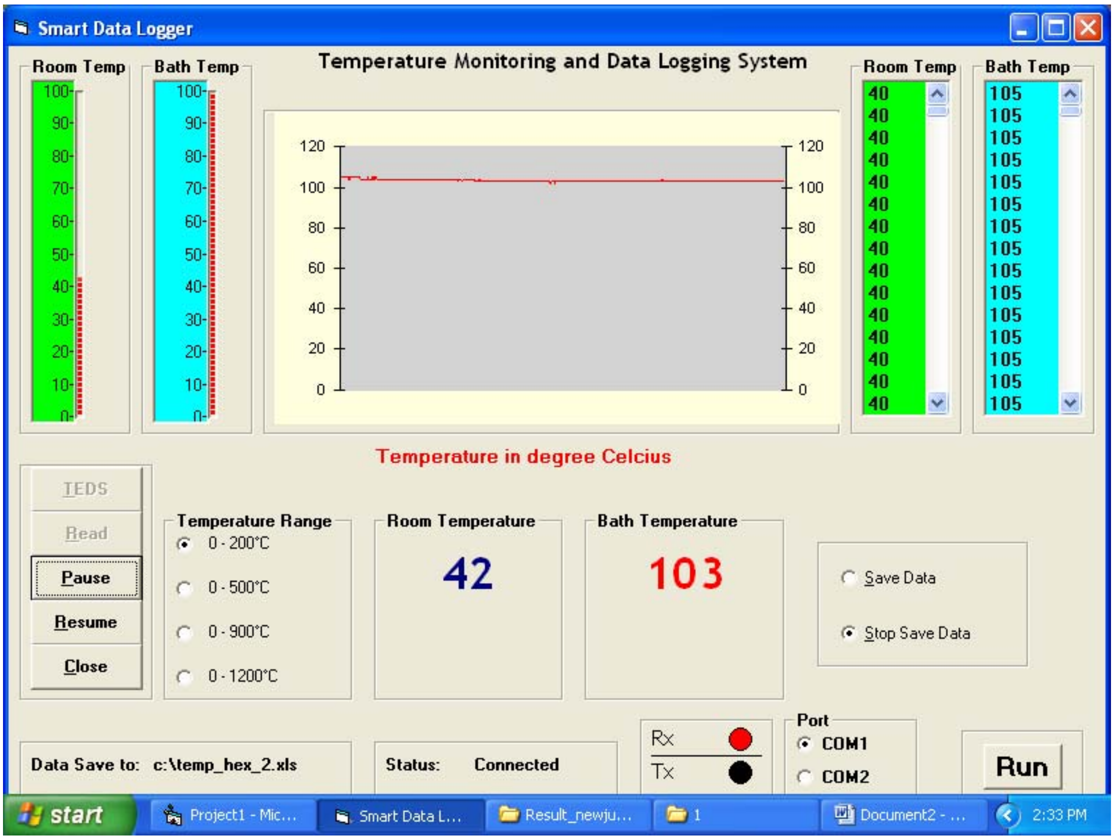

Fig. 6. Screen shot.

6. Conclusion and Discussion

The system has been constructed and successfully installed and operated in Sonapur Tea Factory near Guwahati, India. Automatic alarming after reaching set point is also incorporated with this system.

This system is used for both inlet and outlet temperature measurement of the dryer. The communication through RS232C is a low cost one and compatible with such industrial environment. The monitoring and data logging by a PC will help future analysis. No skilled manpower is required for the operation of the system.

The system can accommodate more number of dryers without major modification at a very nominal cost.

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The authors of the paper acknowledge University Grant Commission, New Delhi, India for their support under Minor Research Project (No. 34-570/2008 (SR)). Support from Texas instruments (Texas, USA) for supplying few components under their sample program is also acknowledged. The manager of Sonapur Tea estate (Sonapur, Guwahati, Assam, India) and the staff freely provided their cordial co-operation in installing the device and testing at their factory site.

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Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc.

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- Sensor instrumentation;
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