

ISSN 1726-5479

SENSORS & TRANSDUCERS

vol. 108
9/09



IEEE



TEDS Sensors, IEEE 1451 Standards

International Frequency Sensor Association Publishing





Editors-in-Chief: professor Sergey Y. Yurish,

Phone: +34 696067716, fax: +34 93 4011989, e-mail: editor@sensorsportal.com

Editors for Western Europe

Meijer, Gerard C.M., Delft University of Technology, The Netherlands
Ferrari, Vittorio, Università di Brescia, Italy

Editor South America

Costa-Felix, Rodrigo, Inmetro, Brazil

Editor for Eastern Europe

Sachenko, Anatoly, Ternopil State Economic University, Ukraine

Editors for North America

Datskos, Panos G., Oak Ridge National Laboratory, USA
Fabien, J. Josse, Marquette University, USA
Katz, Evgeny, Clarkson University, USA

Editor for Asia

Ohyama, Shinji, Tokyo Institute of Technology, Japan

Editor for Asia-Pacific

Mukhopadhyay, Subhas, Massey University, New Zealand

Editorial Advisory Board

- Abdul Rahim, Ruzairi**, Universiti Teknologi, Malaysia
Ahmad, Mohd Noor, Northern University of Engineering, Malaysia
Annamalai, Karthigeyan, National Institute of Advanced Industrial Science and Technology, Japan
Arcega, Francisco, University of Zaragoza, Spain
Arguel, Philippe, CNRS, France
Ahn, Jae-Pyoung, Korea Institute of Science and Technology, Korea
Arndt, Michael, Robert Bosch GmbH, Germany
Ascoli, Giorgio, George Mason University, USA
Atalay, Selcuk, Inonu University, Turkey
Atghiaee, Ahmad, University of Tehran, Iran
Augutis, Vygtantas, Kaunas University of Technology, Lithuania
Avachit, Patil Lalchand, North Maharashtra University, India
Ayesh, Aladdin, De Montfort University, UK
Bahreyni, Behraad, University of Manitoba, Canada
Baliga, Shankar, B., General Motors Transnational, USA
Baoxian, Ye, Zhengzhou University, China
Barford, Lee, Agilent Laboratories, USA
Barlingay, Ravindra, RF Arrays Systems, India
Basu, Sukumar, Jadavpur University, India
Beck, Stephen, University of Sheffield, UK
Ben Bouzid, Sihem, Institut National de Recherche Scientifique, Tunisia
Benachaiba, Chellali, Universitaire de Bechar, Algeria
Binnie, T. David, Napier University, UK
Bischoff, Gerlinde, Inst. Analytical Chemistry, Germany
Bodas, Dhananjay, IMTEK, Germany
Borges Carval, Nuno, Universidade de Aveiro, Portugal
Bousbia-Salah, Mounir, University of Annaba, Algeria
Bouvet, Marcel, CNRS – UPMC, France
Brudzewski, Kazimierz, Warsaw University of Technology, Poland
Cai, Chenxin, Nanjing Normal University, China
Cai, Qingyun, Hunan University, China
Campanella, Luigi, University La Sapienza, Italy
Carvalho, Vitor, Minho University, Portugal
Cecelja, Franjo, Brunel University, London, UK
Cerda Belmonte, Judith, Imperial College London, UK
Chakrabarty, Chandan Kumar, Universiti Tenaga Nasional, Malaysia
Chakravorty, Dipankar, Association for the Cultivation of Science, India
Changhai, Ru, Harbin Engineering University, China
Chaudhari, Gajanan, Shri Shivaji Science College, India
Chavali, Murthy, VIT University, Tamil Nadu, India
Chen, Jiming, Zhejiang University, China
Chen, Rongshun, National Tsing Hua University, Taiwan
Cheng, Kuo-Sheng, National Cheng Kung University, Taiwan
Chiang, Jeffrey (Cheng-Ta), Industrial Technol. Research Institute, Taiwan
Chiriac, Horia, National Institute of Research and Development, Romania
Chowdhuri, Arijit, University of Delhi, India
Chung, Wen-Yaw, Chung Yuan Christian University, Taiwan
Corres, Jesus, Universidad Publica de Navarra, Spain
Cortes, Camilo A., Universidad Nacional de Colombia, Colombia
Courtois, Christian, Universite de Valenciennes, France
Cusano, Andrea, University of Sannio, Italy
D'Amico, Arnaldo, Università di Tor Vergata, Italy
De Stefano, Luca, Institute for Microelectronics and Microsystem, Italy
Deshmukh, Kiran, Shri Shivaji Mahavidyalaya, Barshi, India
Dickert, Franz L., Vienna University, Austria
Dieguez, Angel, University of Barcelona, Spain
Dimitropoulos, Panos, University of Thessaly, Greece
Ding, Jianning, Jiangsu Polytechnic University, China
Djordjevich, Alexandar, City University of Hong Kong, Hong Kong
Donato, Nicola, University of Messina, Italy
Donato, Patricio, Universidad de Mar del Plata, Argentina
Dong, Feng, Tianjin University, China
Drljaca, Predrag, Instersema Sensoric SA, Switzerland
Dubey, Venketesh, Bournemouth University, UK
Enderle, Stefan, Univ. of Ulm and KTB Mechatronics GmbH, Germany
Erdem, Gursan K. Arzum, Ege University, Turkey
Erkmen, Aydan M., Middle East Technical University, Turkey
Estelle, Patrice, Insa Rennes, France
Estrada, Horacio, University of North Carolina, USA
Faiz, Adil, INSA Lyon, France
Fericean, Sorin, Balluff GmbH, Germany
Fernandes, Joana M., University of Porto, Portugal
Francioso, Luca, CNR-IMM Institute for Microelectronics and Microsystems, Italy
Francis, Laurent, University Catholique de Louvain, Belgium
Fu, Weiling, South-Western Hospital, Chongqing, China
Gaura, Elena, Coventry University, UK
Geng, Yanfeng, China University of Petroleum, China
Gole, James, Georgia Institute of Technology, USA
Gong, Hao, National University of Singapore, Singapore
Gonzalez de la Rosa, Juan Jose, University of Cadiz, Spain
Granel, Annette, Goteborg University, Sweden
Graff, Mason, The University of Texas at Arlington, USA
Guan, Shan, Eastman Kodak, USA
Guillet, Bruno, University of Caen, France
Guo, Zhen, New Jersey Institute of Technology, USA
Gupta, Narendra Kumar, Napier University, UK
Hadjiloucas, Sillas, The University of Reading, UK
Haider, Mohammad R., Sonoma State University, USA
Hashsham, Syed, Michigan State University, USA
Hasni, Abdelhafid, Bechar University, Algeria
Hernandez, Alvaro, University of Alcalá, Spain
Hernandez, Wilmar, Universidad Politecnica de Madrid, Spain
Homentcovschi, Dorel, SUNY Binghamton, USA
Horstman, Tom, U.S. Automation Group, LLC, USA
Hsiai, Tzung (John), University of Southern California, USA
Huang, Jeng-Sheng, Chung Yuan Christian University, Taiwan
Huang, Star, National Tsing Hua University, Taiwan
Huang, Wei, PSG Design Center, USA
Hui, David, University of New Orleans, USA
Jaffrezic-Renault, Nicole, Ecole Centrale de Lyon, France
Jaime Calvo-Galleg, Jaime, Universidad de Salamanca, Spain
James, Daniel, Griffith University, Australia
Janting, Jakob, DELTA Danish Electronics, Denmark
Jiang, Liudi, University of Southampton, UK
Jiang, Wei, University of Virginia, USA
Jiao, Zheng, Shanghai University, China
John, Joachim, IMEC, Belgium
Kalach, Andrew, Voronezh Institute of Ministry of Interior, Russia
Kang, Moonho, Sunmoon University, Korea South
Kaniusas, Eugenijus, Vienna University of Technology, Austria
Katake, Anup, Texas A&M University, USA
Kausel, Wilfried, University of Music, Vienna, Austria
Kavasoglu, Nese, Mugla University, Turkey
Ke, Cathy, Tyndall National Institute, Ireland
Khan, Asif, Aligarh Muslim University, Aligarh, India
Sapozhnikova, Ksenia, D.I.Mendeleyev Institute for Metrology, Russia

Kim, Min Young, Kyungpook National University, Korea South
Ko, Sang Choon, Electronics and Telecommunications Research Institute, Korea South
Kockar, Hakan, Balikesir University, Turkey
Kotulska, Malgorzata, Wroclaw University of Technology, Poland
Kratz, Henrik, Uppsala University, Sweden
Kumar, Arun, University of South Florida, USA
Kumar, Subodh, National Physical Laboratory, India
Kung, Chih-Hsien, Chang-Jung Christian University, Taiwan
Lacnjevac, Caslav, University of Belgrade, Serbia
Lay-Ekuakille, Aime, University of Lecce, Italy
Lee, Jang Myung, Pusan National University, Korea South
Lee, Jun Su, Amkor Technology, Inc. South Korea
Lei, Hua, National Starch and Chemical Company, USA
Li, Genxi, Nanjing University, China
Li, Hui, Shanghai Jiaotong University, China
Li, Xian-Fang, Central South University, China
Liang, Yuanchang, University of Washington, USA
Liawruangrath, Saisunee, Chiang Mai University, Thailand
Liew, Kim Meow, City University of Hong Kong, Hong Kong
Lin, Hermann, National Kaohsiung University, Taiwan
Lin, Paul, Cleveland State University, USA
Linderholm, Pontus, EPFL - Microsystems Laboratory, Switzerland
Liu, Aihua, University of Oklahoma, USA
Liu Changgeng, Louisiana State University, USA
Liu, Cheng-Hsien, National Tsing Hua University, Taiwan
Liu, Songqin, Southeast University, China
Lodeiro, Carlos, Universidade NOVA de Lisboa, Portugal
Lorenzo, Maria Encarnacio, Universidad Autonoma de Madrid, Spain
Lukaszewicz, Jerzy Pawel, Nicholas Copernicus University, Poland
Ma, Zhanfang, Northeast Normal University, China
Majstorovic, Vidosav, University of Belgrade, Serbia
Marquez, Alfredo, Centro de Investigacion en Materiales Avanzados, Mexico
Matay, Ladislav, Slovak Academy of Sciences, Slovakia
Mathur, Prafull, National Physical Laboratory, India
Maurya, D.K., Institute of Materials Research and Engineering, Singapore
Mekid, Samir, University of Manchester, UK
Melnyk, Ivan, Photon Control Inc., Canada
Mendes, Paulo, University of Minho, Portugal
Mennell, Julie, Northumbria University, UK
Mi, Bin, Boston Scientific Corporation, USA
Minas, Graca, University of Minho, Portugal
Moghavvemi, Mahmoud, University of Malaya, Malaysia
Mohammadi, Mohammad-Reza, University of Cambridge, UK
Molina Flores, Esteban, Benemérita Universidad Autónoma de Puebla, Mexico
Moradi, Majid, University of Kerman, Iran
Morello, Rosario, University "Mediterranea" of Reggio Calabria, Italy
Mounir, Ben Ali, University of Sousse, Tunisia
Mulla, Imtiaz Sirajuddin, National Chemical Laboratory, Pune, India
Neelamegam, Periasamy, Sastra Deemed University, India
Neshkova, Milka, Bulgarian Academy of Sciences, Bulgaria
Oberhammer, Joachim, Royal Institute of Technology, Sweden
Ould Lahoucine, Cherif, University of Guelma, Algeria
Pamidighanta, Sayanu, Bharat Electronics Limited (BEL), India
Pan, Jisheng, Institute of Materials Research & Engineering, Singapore
Park, Joon-Shik, Korea Electronics Technology Institute, Korea South
Penza, Michele, ENEA C.R., Italy
Pereira, Jose Miguel, Instituto Politecnico de Setebal, Portugal
Petsev, Dimiter, University of New Mexico, USA
Pogacnik, Lea, University of Ljubljana, Slovenia
Post, Michael, National Research Council, Canada
Prance, Robert, University of Sussex, UK
Prasad, Ambika, Gulbarga University, India
Prateepasen, Asa, Kingmoungut's University of Technology, Thailand
Pullini, Daniele, Centro Ricerche FIAT, Italy
Pumera, Martin, National Institute for Materials Science, Japan
Radhakrishnan, S., National Chemical Laboratory, Pune, India
Rajanna, K., Indian Institute of Science, India
Ramadan, Qasem, Institute of Microelectronics, Singapore
Rao, Basuthkar, Tata Inst. of Fundamental Research, India
Raouf, Kosai, Joseph Fourier University of Grenoble, France
Reig, Candid, University of Valencia, Spain
Restivo, Maria Teresa, University of Porto, Portugal
Robert, Michel, University Henri Poincare, France
Rezazadeh, Ghader, Urmia University, Iran
Royo, Santiago, Universitat Politècnica de Catalunya, Spain
Rodriguez, Angel, Universidad Politécnica de Catalunya, Spain
Rothberg, Steve, Loughborough University, UK
Sadana, Ajit, University of Mississippi, USA
Sadeghian Marnani, Hamed, TU Delft, The Netherlands
Sandacci, Serghei, Sensor Technology Ltd., UK
Saxena, Vibha, Bhabha Atomic Research Centre, Mumbai, India
Schneider, John K., Ultra-Scan Corporation, USA
Seif, Selemani, Alabama A & M University, USA
Seifter, Achim, Los Alamos National Laboratory, USA
Sengupta, Deepak, Advance Bio-Photonics, India
Shearwood, Christopher, Nanyang Technological University, Singapore
Shin, Kyuho, Samsung Advanced Institute of Technology, Korea
Shmaliy, Yuriy, Kharkiv National Univ. of Radio Electronics, Ukraine
Silva Girao, Pedro, Technical University of Lisbon, Portugal
Singh, V. R., National Physical Laboratory, India
Slomovitz, Daniel, UTE, Uruguay
Smith, Martin, Open University, UK
Soleymannpour, Ahmad, Damghan Basic Science University, Iran
Somani, Prakash R., Centre for Materials for Electronics Technol., India
Srinivas, Talabattula, Indian Institute of Science, Bangalore, India
Srivastava, Arvind K., Northwestern University, USA
Stefan-van Staden, Raluca-Ioana, University of Pretoria, South Africa
Sunriddetchka, Sarun, National Electronics and Computer Technology Center, Thailand
Sun, Chengliang, Polytechnic University, Hong-Kong
Sun, Dongming, Jilin University, China
Sun, Junhua, Beijing University of Aeronautics and Astronautics, China
Sun, Zhiqiang, Central South University, China
Suri, C. Raman, Institute of Microbial Technology, India
Sysoev, Victor, Saratov State Technical University, Russia
Szewczyk, Roman, Industrial Research Inst. for Automation and Measurement, Poland
Tan, Ooi Kiang, Nanyang Technological University, Singapore,
Tang, Dianping, Southwest University, China
Tang, Jaw-Luen, National Chung Cheng University, Taiwan
Teker, Kasif, Frostburg State University, USA
Thumbavanam Pad, Kartik, Carnegie Mellon University, USA
Tian, Gui Yun, University of Newcastle, UK
Tsiantos, Vassilios, Technological Educational Institute of Kaval, Greece
Tsigara, Anna, National Hellenic Research Foundation, Greece
Twomey, Karen, University College Cork, Ireland
Valente, Antonio, University, Vila Real, - U.T.A.D., Portugal
Vaseashta, Ashok, Marshall University, USA
Vazquez, Carmen, Carlos III University in Madrid, Spain
Vieira, Manuela, Instituto Superior de Engenharia de Lisboa, Portugal
Vigna, Benedetto, STMicroelectronics, Italy
Vrba, Radimir, Brno University of Technology, Czech Republic
Wandelt, Barbara, Technical University of Lodz, Poland
Wang, Jiangping, Xi'an Shiyou University, China
Wang, Kedong, Beihang University, China
Wang, Liang, Advanced Micro Devices, USA
Wang, Mi, University of Leeds, UK
Wang, Shinn-Fwu, Ching Yun University, Taiwan
Wang, Wei-Chih, University of Washington, USA
Wang, Wensheng, University of Pennsylvania, USA
Watson, Steven, Center for NanoSpace Technologies Inc., USA
Weiping, Yan, Dalian University of Technology, China
Wells, Stephen, Southern Company Services, USA
Wolkenberg, Andrzej, Institute of Electron Technology, Poland
Woods, R. Clive, Louisiana State University, USA
Wu, DerHo, National Pingtung Univ. of Science and Technology, Taiwan
Wu, Zhaoyang, Hunan University, China
Xiu Tao, Ge, Chuzhou University, China
Xu, Lisheng, The Chinese University of Hong Kong, Hong Kong
Xu, Tao, University of California, Irvine, USA
Yang, Dongfang, National Research Council, Canada
Yang, Wuqiang, The University of Manchester, UK
Yang, Xiaoling, University of Georgia, Athens, GA, USA
Yaping Dan, Harvard University, USA
Ymeti, Aurel, University of Twente, Netherland
Yong Zhao, Northeastern University, China
Yu, Haihu, Wuhan University of Technology, China
Yuan, Yong, Massey University, New Zealand
Yufera Garcia, Alberto, Seville University, Spain
Zagnoni, Michele, University of Southampton, UK
Zamani, Cyrus, Universitat de Barcelona, Spain
Zeni, Luigi, Second University of Naples, Italy
Zhang, Minglong, Shanghai University, China
Zhang, Quintao, University of California at Berkeley, USA
Zhang, Weiping, Shanghai Jiao Tong University, China
Zhang, Wenming, Shanghai Jiao Tong University, China
Zhang, Xueji, World Precision Instruments, Inc., USA
Zhong, Haoxiang, Henan Normal University, China
Zhu, Qing, Fujifilm Dimatix, Inc., USA
Zorzano, Luis, Universidad de La Rioja, Spain
Zourob, Mohammed, University of Cambridge, UK

Contents

Volume 108
Issue 9
September 2009

www.sensorsportal.com

ISSN 1726-5479

Research Articles

| | |
|--|-----|
| Smart Sensor for Analyzing Train Vibration in WCR Zone <i>Alka Dubey and Ashish Verma</i> | 1 |
| Design of a Low Cost Smart Dryer Temperature Measurement System for Tea Factories <i>Utpal Sarma, Digbijoy Chakraborty, Pradip Kr. Boruah</i> | 8 |
| Design of a MEMS Capacitive Comb-drive Micro-accelerometer with Sag Optimization <i>B. D. Pant, Lokesh Dhakar, P. J. George and S. Ahmad</i> | 15 |
| Dynamic Characterization of MEMS Scanners <i>Çağlar Ataman, Hüseyin R. Seren, Harald Schenk, Hakan Ürey</i> | 31 |
| Electromagnetic Investigation of a CMOS MEMS Inductive Microphone <i>Farès Tounsi, Brahim Mezghani, Libor Rufer, Mohamed Masmoudi and Salvador Mir</i> | 40 |
| Study of Thermoelastic Damping in Capacitive Micro-beam Resonators Using Hyperbolic Heat Conduction Model <i>Ghader Rezazadeh, Armin Saeedi vahdat, Seyed-Mehdi Pestei, Bahman Farzi</i> | 54 |
| Development of Planter Foot Pressure Distribution System Using Flexi Force Sensors <i>S. L. Patil, Madhuri A. Thatte, U. M. Chaskar</i> | 73 |
| Fiber Optic Displacement and Liquid Refractive Index Sensors with Two Asymmetrical Inclined Fibers <i>H. Z. Yang, S. W. Harun and H. Ahmad</i> | 80 |
| Controlling a pH Process Using Feedback & Double Controller Scheme <i>S. Shobana, A. Srinivasan and Rames C. Panda</i> | 89 |
| Time Domain Analysis of Ultrasonic Wave Propagation using an Electromagnetic Acoustic Transducer <i>Sadiq Thomas, Salah Obayya, Domenico Pinto, D. Dulay, W. Balachandran, Mostafa Darwish</i> | 102 |
| Design of a PC Based Mass Flow Indicator of an Electrical Motor Driven Water Lift Pump using Motor Load Current as the Flow Sensing Parameter <i>S. C. Bera, N. Mandal and R. Sarkar</i> | 116 |
| A Bimorph Moment/Force Actuator for Dynamic Testing <i>Hou Xiaoyan</i> | 128 |
| Instrumentation to Measure the Capacitance of Biosensors by Sinusoidal Wave Method <i>Pavan Kumar Kathuroju and Nagaraju Jampana</i> | 139 |
| Humidity and Electrical Sensing Properties of CoCr₂O₄-ZnO-MnO₂ Composites <i>Regina Mary L., Jeyaraj B. and Nagaraja K. S.</i> | 147 |

| | |
|---|-----|
| AC Response to Humidity and Propane of Sprayed Fe-Zn Oxide Films <i>Alejandro Avila-García, Manuel García-Hipólito and Yasuhiro Matsumoto-Kuwabara</i> | 156 |
| Sn-doped Zinc Oxide Thin Films for Methanol <i>Rajarshi Krishna Nath and Siddhartha Sankar Nath</i> | 168 |
| Spray Deposited Pure and CuO Doped ZnO Thin Films for NH₃ Sensing <i>L. A. Patil, I. G. Pathan</i> | 180 |
| Formulation and Characterization of Cr₂O₃ Doped ZnO Thick Films as H₂S Gas Sensor <i>A. V. Patil, C. G. Dighavkar, S. K. Sonawane, S. J. Patil and R. Y. Borse</i> | 189 |

Authors are encouraged to submit article in MS Word (doc) and Acrobat (pdf) formats by e-mail: editor@sensorsportal.com
Please visit journal's webpage with preparation instructions: <http://www.sensorsportal.com/HTML/DIGEST/Submission.htm>



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

Utpal SARMA, Digbijoy CHAKRABORTY, Pradip Kr. BORUAH

Department of Instrumentation and USIC, Gauhati University
GNB Nagar- 781014, India

Received: 11 June 2009 /Accepted: 21 September 2009 /Published: 28 September 2009

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

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 °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 °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 $^{\circ}\text{C}$; 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 $^{\circ}\text{C}$ 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 $^{\circ}\text{C}$ to -0.01 $^{\circ}\text{C}$. But for linear regression it is found to be +0.83 $^{\circ}\text{C}$ to -0.5 $^{\circ}\text{C}$, which is much higher than the error calculated from polynomial.

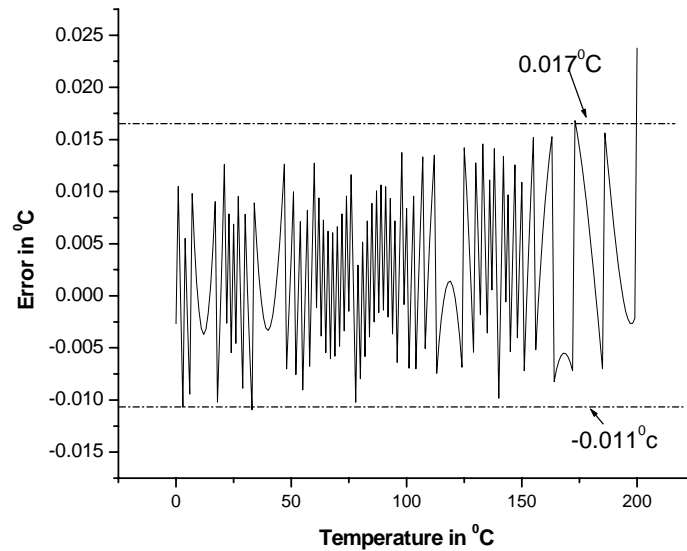


Fig. 1. Error calculated using polynomial.

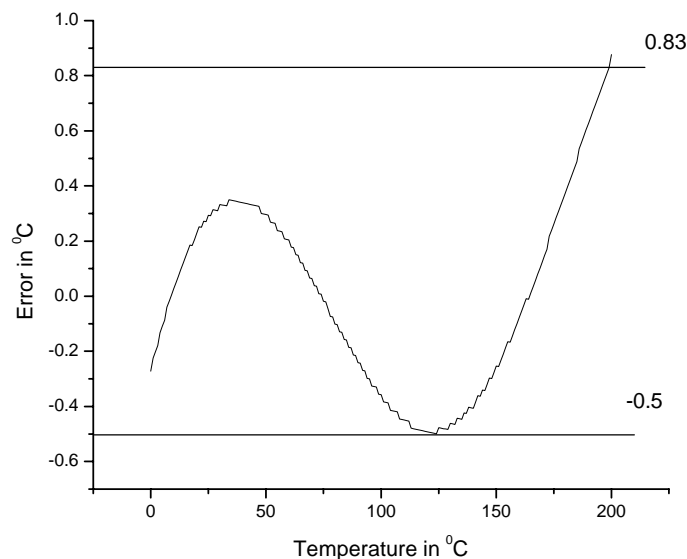


Fig. 2. Error calculated using linear regression.

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.

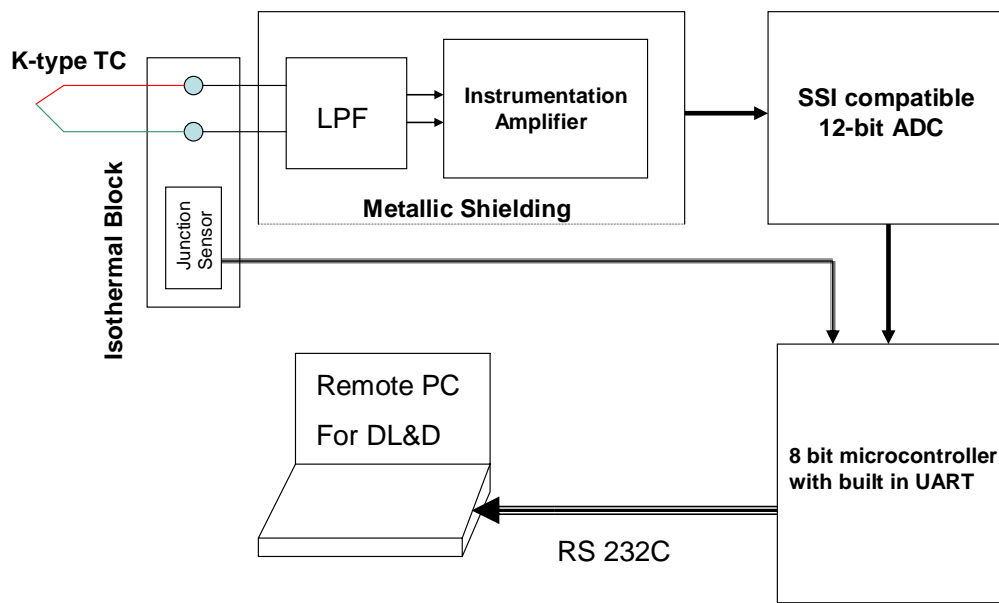


Fig. 3. Block diagram of the system.

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 in 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.

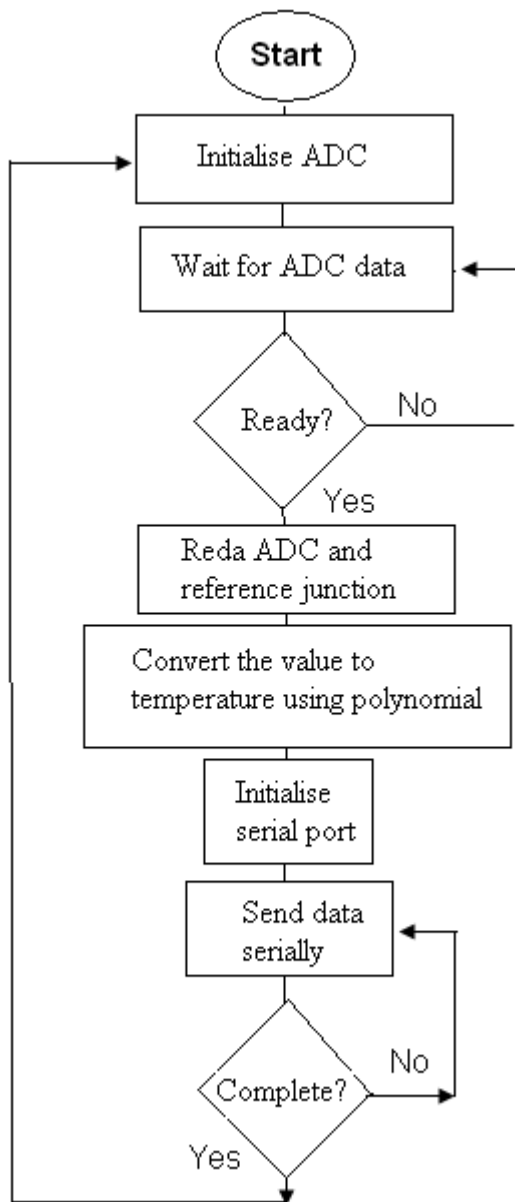


Fig. 4. Firmware.

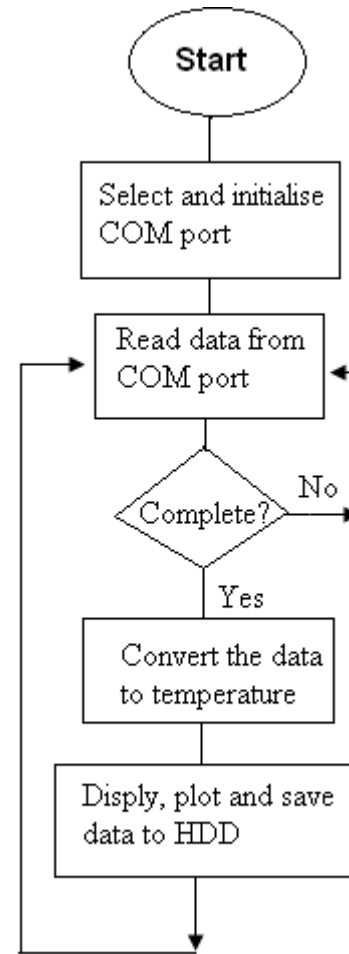


Fig. 5. Software.

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.

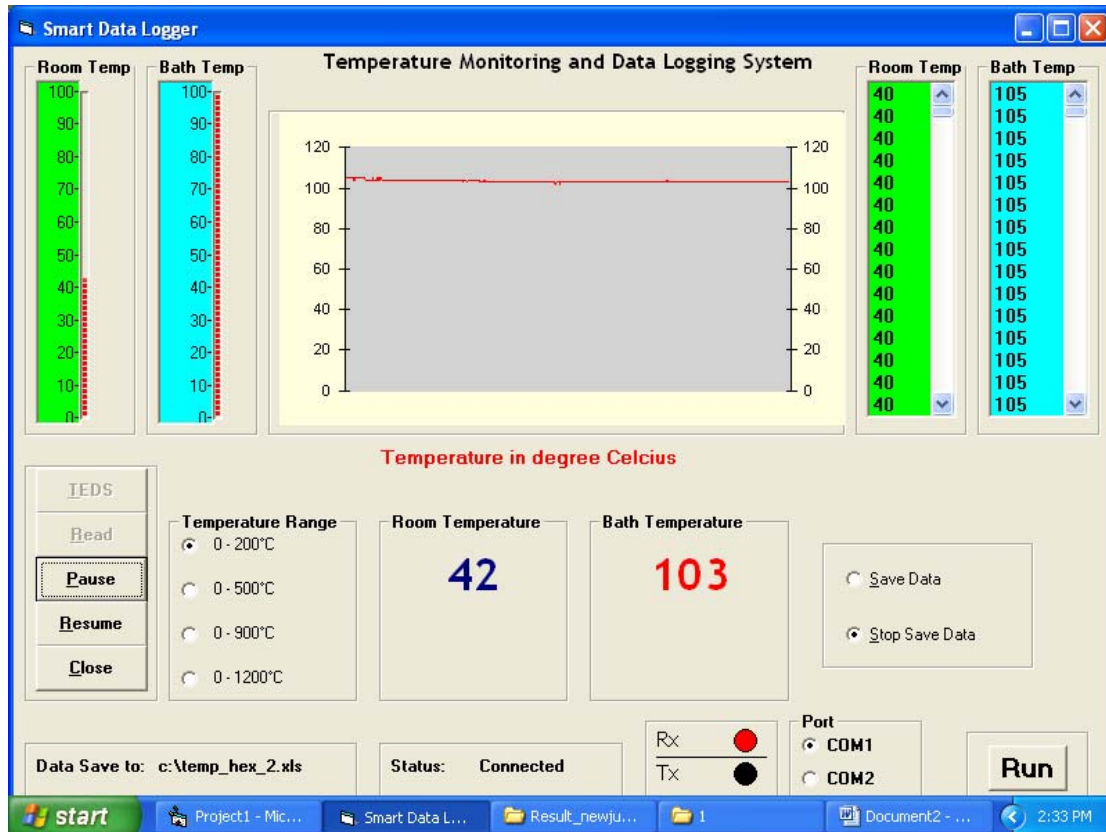


Fig. 6. Screen shot.

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.

Acknowledgement

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.

References

- [1]. S. L. Sarnot, Need of Electronic Instrumentation in Tea Industries, *Technical Report*.
- [2]. L. A. Pipes and R. Harvill, Applied Mathematics for Engineers and Physicist, 3rd Edition, *McGraw- Hill International Editions*, pp. 562-565.
- [3]. Utpal Sarma, Digbijoy Chakraborty, P. K. Boruah, Design of a Smart and High Precision Industrial Temperature Measurement and Monitoring System using K-type Thermocouple and SPI-compatible Temperature Sensor, *Sensors. and Transducers*, Vol.102, Issue 3, March 2009, pp.1-9.
- [4]. Sandip Pal, A. Rakshit, *Sensors and Actuators A*, 112, 2004, pp. 381–387.
- [5]. K. Lee, *Proceedings of the Technology Conference on IEEE Instrumentation and Measurement*, Baltimore, MD, USA, 1–4 May 2000.
- [6]. Mark W. Zemansky and R. H. Dittman, Heat and Thermodynamics, 6th edition, *McGraw Hill International Book Company*, pp. 21.
- [7]. Josep Jordana and Ramon Pallas-Areny, *IMTC 2M4 - Instrumentation and Measurement Technology Conference*, Coma, Italy, 18-20 May 2004.
- [8]. IEEE Standard for a Smart Transducer Interface for Sensors and Actuators—Network Capable Application Processor (NCAP) Information Model, Sponsor: - TC-9 Committee on Sensor Technology of the: - IEEE Instrumentation and Measurement Society; Approved 26 June 1999 IEEE-SA Standards Board
- [9]. M. S. Wantable, et al., Micro-thermocouple Probe for Measurement of Cellular Thermal Responses, in *Proc. of IEEE Engineering in Medicine and Biology 27th Annual Conf.*, 2005, pp. 4858-4861.
- [10]. M. Marinov, et al, An Adaptive Approach for Linearization of Temperature Sensor Characteristics, *IEEE 27th Int'l Spring Seminar on Electronics Technology*, 2004, pp. 417-420.
- [11]. J. P. Bentley, Temperature Sensor Characteristics and Measurement System Design, *J. Phys, E: Sci. Instrum.*, 17, 1984, pp. 430-439.
- [12]. <http://www.assamteaxchange.com/directory/gardens.asp?id=556>

2009 Copyright ©, International Frequency Sensor Association (IFSA). All rights reserved.
(<http://www.sensorsportal.com>)



**Universal Frequency-to-Digital Converter
(UFDC-1 and UFDC-1M-16)
in MLF (5 x 5 x 1 mm) package**

**SMALL WORLD -
BIG FEATURES**

SWP, Inc., Toronto, Ontario, Canada,
Tel. +34 696067716, fax: +34 93 4011989, e-mail: sales@sensorsportal.com
http://www.sensorsportal.com/HTML/E-SHOP/PRODUCTS_4/UFDC_1.htm

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 addition, 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.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

Submission of papers

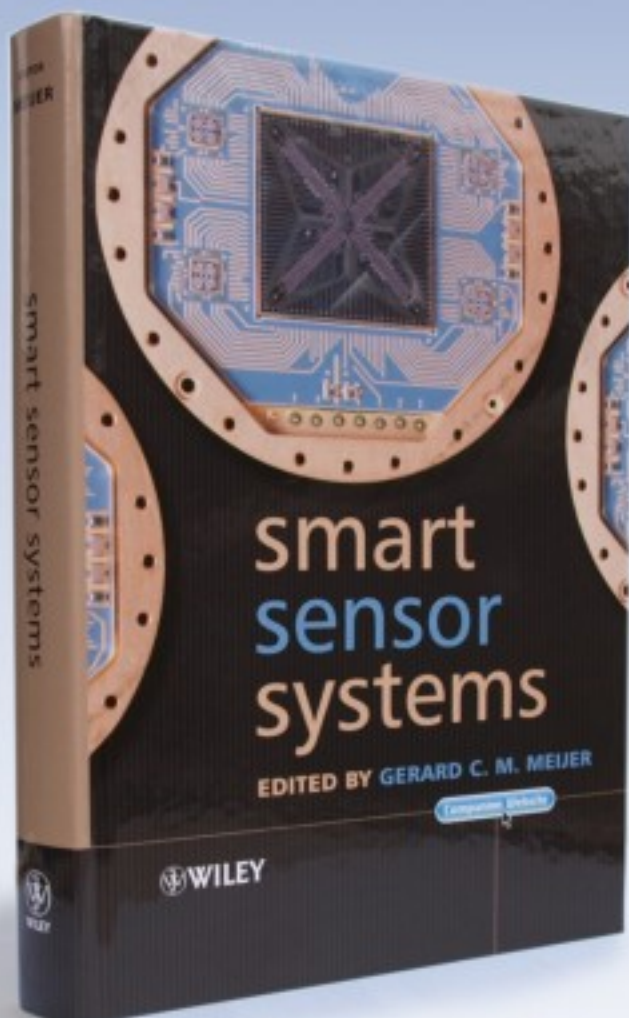
Articles should be written in English. Authors are invited to submit by e-mail editor@sensorsportal.com 8-14 pages article (including abstract, illustrations (color or grayscale), photos and references) in both: MS Word (doc) and Acrobat (pdf) formats. Detailed preparation instructions, paper example and template of manuscript are available from the journal's webpage: <http://www.sensorsportal.com/HTML/DIGEST/Submission.htm> Authors must follow the instructions strictly when submitting their manuscripts.

Advertising Information

Advertising orders and enquires may be sent to sales@sensorsportal.com Please download also our media kit: http://www.sensorsportal.com/DOWNLOADS/Media_Kit_2009.pdf

 **WILEY**
1807-2007

KNOWLEDGE FOR GENERATIONS



'Written by an internationally-recognized team of experts, this book reviews recent developments in the field of smart sensors systems, providing complete coverage of all important systems aspects. It takes a multidisciplinary approach to the understanding, design and use of smart sensor systems, their building blocks and methods of signal processing.'



Order online:

http://www.sensorsportal.com/HTML/BOOKSTORE/Smart_Sensor_Systems.htm

www.sensorsportal.com