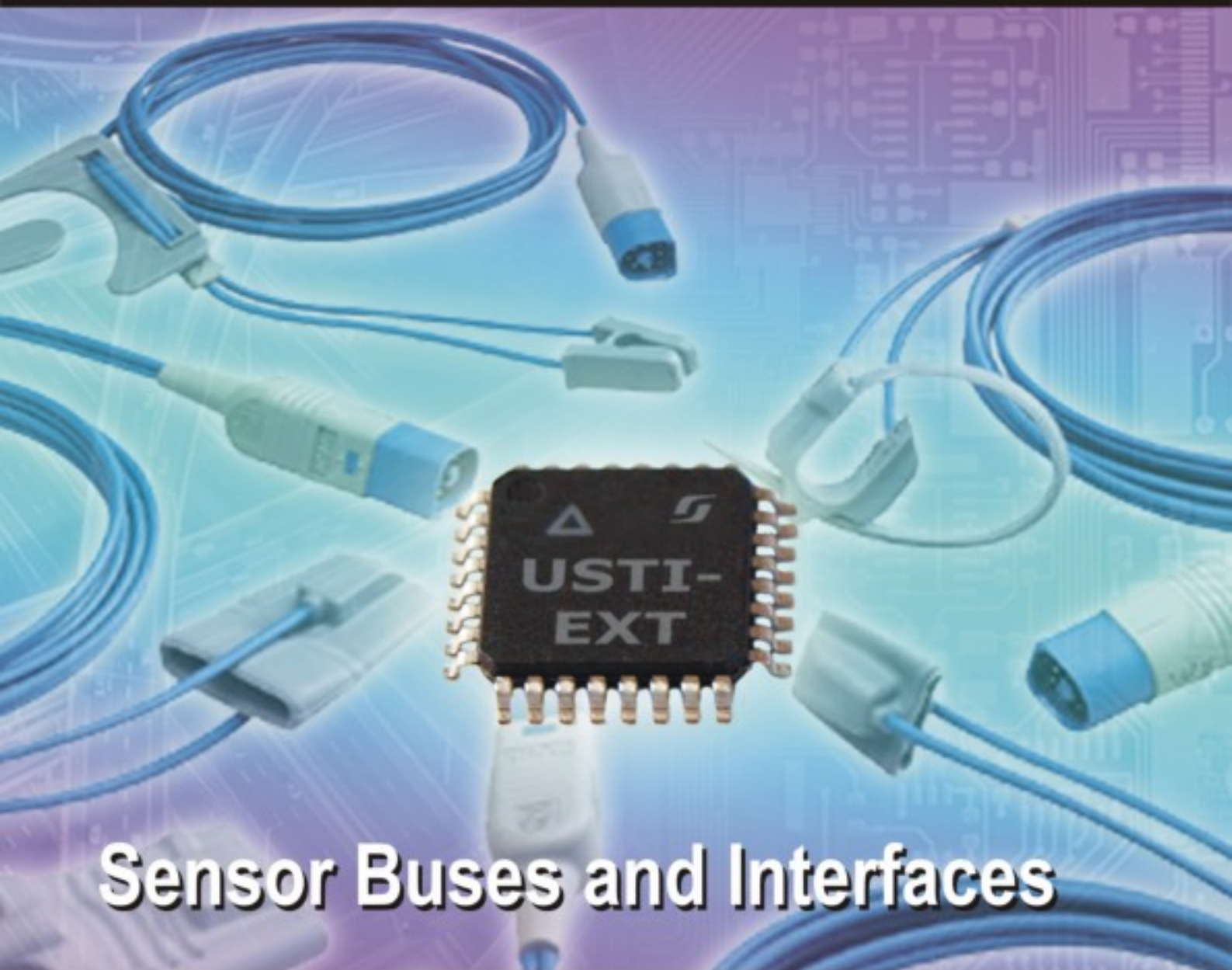


ISSN 1726-5479

SENSORS & TRANSDUCERS

vol. 140
5 / 12



Sensor Buses and Interfaces

International Frequency Sensor Association Publishing



Editors-in-Chief: professor Sergey Y. Yurish, tel.: +34 696067716, 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**Editors for North America**Datskos, Panos G., Oak Ridge National Laboratory, USA
Fabien, J. Josse, Marquette University, USA
Katz, Evgeny, Clarkson University, USA**Editor South America**

Costa-Felix, Rodrigo, Inmetro, Brazil

Editor for Eastern Europe

Sachenko, Anatoly, Ternopil State Economic University, Ukraine

Editor for Asia

Ohyama, Shinji, Tokyo Institute of Technology, Japan

Editor for Africa

Maki K.Habib, American University in Cairo, Egypt

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
Azamimi, Azian binti Abdullah, Universiti Malaysia Perlis, Malaysia
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, Universitè 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
Bouchikhi, Benachir, University Moulay Ismail, Morocco
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
Calvo-Gallego, Jaime, Universidad de Salamanca, Spain
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, N.I. Center for Higher Education, (N.I. University), 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
Dighavkar, C. G., M.G. Vidyamandir's L. V.H. College, India
Dimitropoulos, Panos, University of Thessaly, Greece
Ding, Jianning, Jiangsu Polytechnic University, China
Djordjevich, Alexander, 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
Drlicja, 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
Granell, 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
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
Kaniasas, 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
Khelfaoui, Rachid, Université de Bechar, Algeria
Khan, Asif, Aligarh Muslim University, Aligarh, India
Kim, Min Young, Kyungpook National University, Korea South
Ko, Sang Choon, Electronics. and Telecom. Research Inst., Korea South
Kotulska, Malgorzata, Wroclaw University of Technology, Poland
Kockar, Hakan, Balikesir University, Turkey
Kong, Ing, RMIT University, Australia
Kratz, Henrik, Uppsala University, Sweden

Krishnamoorthy, Ganesh, University of Texas at Austin, USA
Kumar, Arun, University of Delaware, Newark, 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, Fengyuan (Thomas), Purdue University, USA
Li, Genxi, Nanjing University, China
Li, Hui, Shanghai Jiaotong University, China
Li, Sihua, Agiltron, Inc., USA
Li, Xian-Fang, Central South University, China
Li, Yuefa, Wayne State University, USA
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, University of Vigo, Spain
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
Malyshev, V.V., National Research Centre 'Kurchatov Institute', Russia
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
Mishra, Vivekanand, National Institute of Technology, India
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
Mrad, Nezhil, Defence R&D, Canada
Mulla, Imtiaz Sirajuddin, National Chemical Laboratory, Pune, India
Nabok, Aleksey, Sheffield Hallam University, UK
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
Passaro, Vittorio M. N., Politecnico di Bari, Italy
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
Pugno, Nicola M., Politecnico di Torino, Italy
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
Rastogi Shiva, K., University of Idaho, USA
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, Universitat Politècnica de Catalunya, Spain
Rothberg, Steve, Loughborough University, UK
Sadana, Ajit, University of Mississippi, USA
Sadeghian Marnani, Hamed, TU Delft, The Netherlands
Sapozhnikova, Ksenia, D.I.Mendeleyev Institute for Metrology, Russia
Sandacci, Serghei, Sensor Technology Ltd., UK
Saxena, Vibha, Bbhba Atomic Research Centre, Mumbai, India
Schneider, John K., Ultra-Scan Corporation, USA
Sengupta, Deepak, Advance Bio-Photonics, India
Seif, Selemani, Alabama A & M University, USA
Seifter, Achim, Los Alamos National Laboratory, USA
Shah, Kriyang, La Trobe University, Australia
Sankarraaj, Anand, Detector Electronics Corp., USA
Silva Giroa, Pedro, Technical University of Lisbon, Portugal
Singh, V. R., National Physical Laboratory, India
Slomovitz, Daniel, UTE, Uruguay
Smith, Martin, Open University, UK
Soleymanpour, Ahmad, University of Toledo, USA
Somani, Prakash R., Centre for Materials for Electronics Technol., India
Sridharan, M., Sastra University, India
Srinivas, Talabattula, Indian Institute of Science, Bangalore, India
Srivastava, Arvind K., NanoSonix Inc., USA
Stefan-van Staden, Raluca-Ioana, University of Pretoria, South Africa
Stefanescu, Dan Mihai, Romanian Measurement Society, Romania
Sumriddetchka, Sarun, National Electronics and Comp. Technol. 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
Syssoev, Victor, Saratov State Technical University, Russia
Szewczyk, Roman, Industr. 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
Thirunavukkarasu, I., Manipal University Karnataka, India
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
Vanga, Raghav Rao, Summit Technology Services, Inc., USA
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 Shiyong University, China
Wang, Kedong, Beihang University, China
Wang, Liang, Pacific Northwest National Laboratory, 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, Sen, Drexel University, USA
Xu, Tao, University of California, Irvine, USA
Yang, Dongfang, National Research Council, Canada
Yang, Shuang-Hua, Loughborough University, UK
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
Zakaria, Zulkarnay, University Malaysia Perlis, Malaysia
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, Qintao, 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 140
Issue 5
May 2012

www.sensorsportal.com

ISSN 1726-5479

Research Articles

Modern Sensors, Transducers and Sensor Networks

Editorial book review, IFSA 1

Research in Nanothermometry. Part 1: Temperature of Micro- and Nano- sized Objects

Bohdan Stadnyk, Svyatoslav Yatsyshyn, Yaroslav Lutsyk 1

Research in Nanothermometry. Part 2: Methodical Error Problem of Contact Thermometry

Bohdan Stadnyk, Svyatoslav Yatsyshyn, Oresta Kozak 8

Research in Nanothermometry. Part 3. Characteristics of the Thermometers with Liquid- and Solid-phase Sensitive Elements

Svyatoslav Yatsyshyn, Bohdan Stadnyk, Yaroslav Lutsyk 15

Film Cooling Technique Simulation

Bachir Bounegta, Rabah Dizene and Maamar Abdelkarim 24

Development of Parallel and Fan-Shaped Beam Mixed-Projection Optical Tomography

Siti Zarina Mohd. Muji, Ruzairi Abdul Rahim, Mohd Hafiz Fazalul Rahiman, Yusry Yunus, Zulkarnay Zakaria, Nor Muzakkir Nor Ayob 36

A Study on Optical Sensors Orientation for Tomography System Development

M. Fadzli B Abdul Shaib, Ruzairi Abdul Rahim, Siti Zarina M. Muji, Leow Pei Ling, M. Mahadi Abdul Jamil 45

Optimizing the Frequency of Ultrasonic Tomography System with a Metal Pipeline

Javad Abbaszadeh, Herlina Abdul Rahim, and Ruzairi Abdul Rahim 53

A Line Detection Algorithm for Road Remarkings

Mark Cameron and Ibrahim Al-Bahadly 65

Identification of Faces by Multimodal Information Fusion of Depth and Color

Abdelmalik Ouamane, Mébarka Belahcene, Abdelhamid Benakcha, Mohamed Boumehrez, Abdelmalik Taleb Ahmed 74

Implementation of PID Controller in MATLAB for Real-time Position Control of Faulhaber DC Micromotor

Manjunatha Reddy H. K., Immanuel J., Shrimanth Sudheer L., Parvathi C. S., and Bhaskar P. 88

PMMA (Polymethyl Methacrylate) Fibre Optic Probe for Sensing Acceleration

Binu Sukumaran 96

Applications of Electronic Nose Based on MOX and QMB Sensors

Valeria Messina and Noemi Walsõe de Reca 106

Design of Optoelectronic System Using Multi Wavelength Illuminator for the Analysis of Sodium Ion in Blood Serum

K. Muruganathan, R. Raghoonathan, K. Chakrapani and P. Neelamegam 115

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>

International Frequency Sensor Association (IFSA).

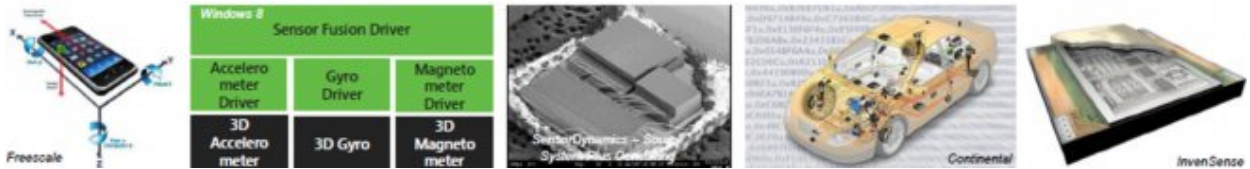
Inertial Combo Sensors for Consumer & Automotive

Technology, Applications, Industry & Market Report to 2016



This report is focused on the analysis of the opportunities and the challenges for inertial combo sensors in those high-volume market areas.

http://www.sensorsportal.com/HTML/Inertial_Combo_Sensors_Market.htm



Uncooled Infrared Imaging Market: Commercial & Military applications

Market & Technology Report to 2016



This new 2011 IR report, is an updated and in depth analysis of commercial markets covered in the 2010 report in addition we have included a new analysis of the military markets.

http://www.sensorsportal.com/HTML/Detectors_for_Thermography.htm



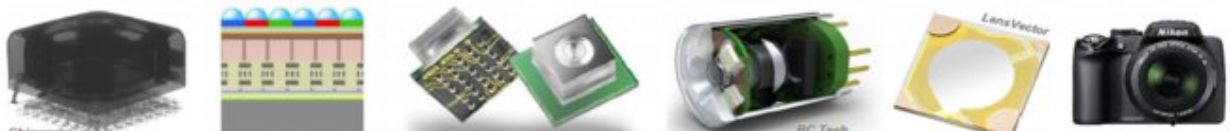
CMOS Image Sensors Technologies & Markets - 2010 Report

Disruptive technologies are paving the way to the future of digital imaging industry !



Image sensors have come a long way since the first introduction of CCD sensor technology in the 1990's. They made a big jump in the 2000's with the introduction of CMOS sensor technology which gave birth to the low-cost, high volume camera phone market. Image sensors are now part of our everyday life: from cell-phone cameras, to notebook webcams, digital cameras, video camcorders to security & surveillance systems. In the future, new markets are also emerging such as sensors for medical applications, automotive security features, but also gaming and home TV webcams ... The reason why we are now releasing our first report on the CMOS image sensor industry is that we feel that we are at an historic turning point for this young, but still maturing industry.

http://www.sensorsportal.com/HTML/CMOS_Image_Sensors.htm



Research in Nanothermometry. Part 2: Methodical Error Problem of Contact Thermometry

Bohdan STADNYK, Svyatoslav YATSYSHYN, Oresta KOZAK

Lviv Polytechnic National University,
Institute of Computer Technologies, Automation and Metrology,
Bandera str. 12, Lviv, 79013, Ukraine
Tel.: +38-0322-37-50-89
E-mail: slav.yat@gmail.com

Received: 27 March 2012 /Accepted: 21 May 2012 /Published: 31 May 2012

Abstract: The evaluation of temperature distortions of controlled object caused by a temperature measurement has to solve on the way of providing further nanotechnology progress. To reduce the consequences of measuring intervention to the heat balance of controlled objects, it is necessary to develop the sensitive methods of energy-measuring action. *Copyright © 2012 IFSA.*

Keywords: Temperature measurement, Micro- and nanosized objects, Related methodical error, Temperature wave.

1. Introduction

Nanotechnology has appeared due to the scientific research directed inside substance. Micro-, nanoscaled and structured materials demonstrate new set of properties and functions as compared with volumetric analogues. Their reproducible research and production are ensured by the development of nanometrology and especially by the methods and devices of temperature measurement, because each physical property has a meaning at the certain temperature. Therefore temperature control constitutes a basis for all types of measurements, and temperature measurements themselves make ~ 50 % of all measurements [1].

There are a lot of problems, which nanometrology, and especially nanothermometry, has to solve on the way of providing further progress and development of industrial production as well as applications of nanoobjects. The first of them is the elaboration of the grounds for applying concept "temperature"

to nanoobjects in a similar way as to macro-objects. Enough attention has been paid to this problem recently [2-4]. The next and quite obvious problem is the evaluation of temperature distortions of the controlled object caused by a temperature measurement process, regardless of whether contact [5] or contactless [6] methods are used. Practically there are no developed methodologies and methods that could minimize the influence of a temperature measuring process of nanoobjects.

2. Aim of the Work

The aim lies in grounding a possibility to apply methods of researching temperature of micro- and nanoobjects by developing and changing methodological concepts about temperature measurements with decreasing linear dimensions of the controlled objects, and, therefore, of measuring instruments (probes) to micro- and nanoscale.

3. Metrological Model and Methodical Error of Temperature Measuring

Further evolution of nanotechnology is impossible without improving the methods and measuring devices (nanometrology) based on the development of temperature background. Every year the particles researched by scientists when approaching atoms are becoming smaller. It is accepted a priori that we do not influence the temperature field of the controlling object. This mostly happens in the case of a macroobject; since a measurement instrument is tend to be made so that its linear dimensions were one order smaller than an object. Then in case of convergence of thermo physical properties both of object and instrument, the temperature measurement with the relative methodical error $\sim 10^{-3}$ could be guaranteed. Evidently, with gradual decreasing the linear dimensions of the controlled object a point comes when further minimization of measuring instrument dimensions seems to be unreal. Usually this happens in the case of microobjects, when a measuring instrument must be 3 orders smaller in volume.

Contact methods of temperature measurement suggest that information on the status of the controlled object enters to the thermocouple sensor as a result of setting of heat exchange between them. Moreover, in the standby of thermodynamic equilibrium (with their prolonged thermal contact) the measurements are stationary, and provided short-term contact - non-stationary. In this manner we consider the conditions of the heat exchange and methodical error of temperature measurement.

As a result of prolonged thermal contact of a warm sensor and a cold controlled object, the latter is heated and the sensor is cooled, fixing the situation of a heat exchange (Fig. 1):

$$c_{ob} m_{ob} (T_x - T_0) = c_{sen} m_{sen} (T_{sen} - T_x), \quad (1)$$

where, T_0 is the temperature of controlled object until the measurement; T_x is the temperature of controlled object, which has established due to thermal contact with the sensor; T_{sen} is the initial temperature of sensor; $c_{ob}; m_{ob}$; $c_{sen}; m_{sen}$ are the specific heat and mass of the object and the sensor respectively. In this case, the sensor measures the averaged temperature of "controlled object – sensor" in excess of $\Delta T_{met} = T_x - T_0$ the initial temperature of the first one. Expressing mass via specific density of matter w and its volume V and taking the object and the sensor uniform discoid shape (diameter $D; d$ and height $H; h$, respectively), we obtain the equation of energy balance during prolonged contact of sensor and controlled object:

$$c_{ob} w_{ob} D^2 H \Delta T_{met} = c_{sen} w_{sen} d^2 h (T_{sen} - T_x) \quad (2)$$

Dividing the left and right sides of (2) and converting it we receive a relative methodical error of measurement:

$$\delta T_{met} = \frac{c_{sen} w_{sen} V_{sen}}{c_{ob} w_{ob} V_{ob}} \left(\frac{T_{sen}}{T_x} - 1 \right) = \frac{c_{sen} w_{sen} d^2 h}{c_{ob} w_{ob} D^2 H} \left(\frac{T_{sen}}{T_x} - 1 \right), \quad (3)$$

It depends on the ratio of volume or linear dimensions of the sensor and the controlled object. Let us consider that at comparable thermal characteristics of the object and the sensor ratio of the volumes will be 1:1 (Fig. 1 a), 10:1 (Fig. 1 b) and 1:10 (Fig. 1 c). Thus, the sensor changes smoothly over time its own temperature from T_{sens} to T_x measuring the temperature of the object with a certain error.

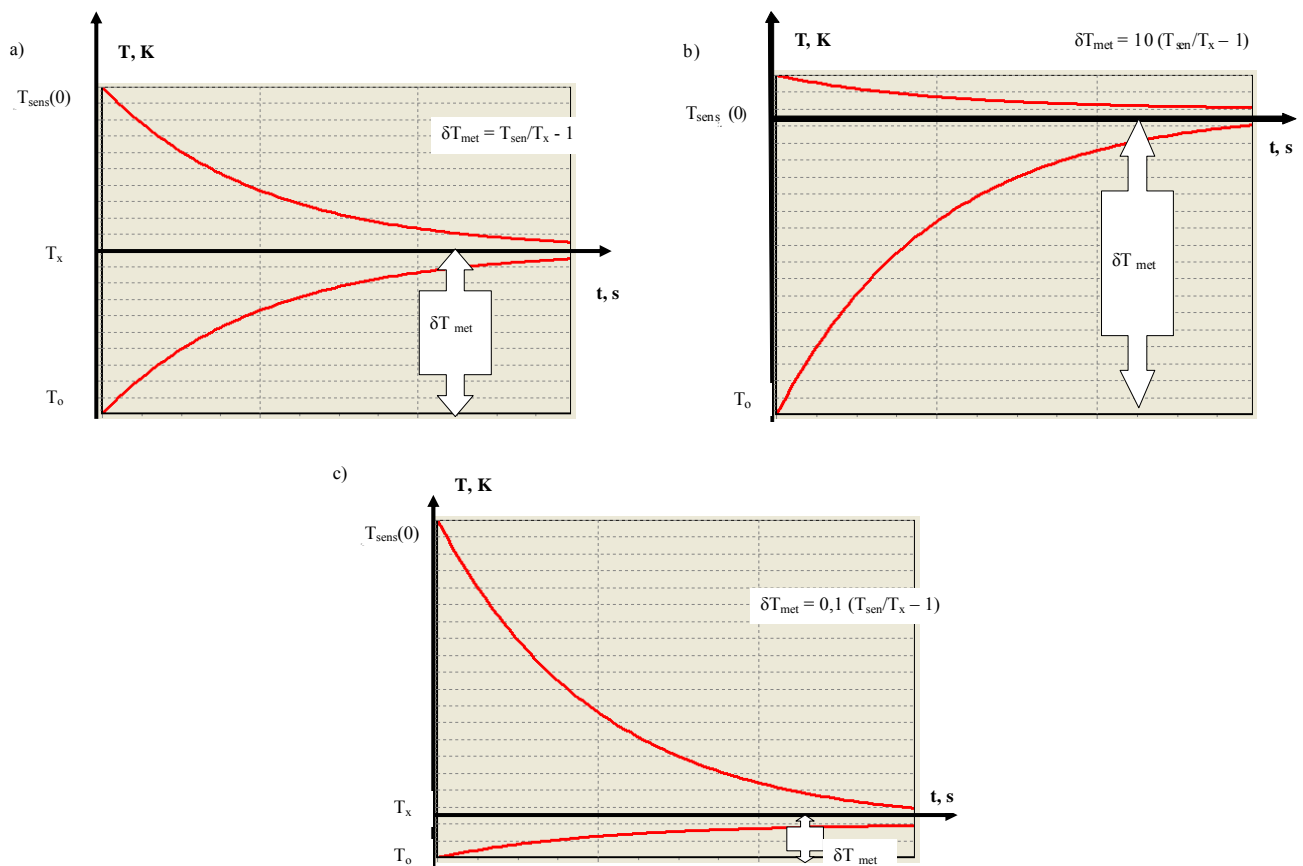


Fig. 1. Temperature vs. time changes of sensor cooling and object heating during their prolonged thermal contact:

- a) $c_{ob} w_{ob} V_{ob} = c_{sen} w_{sen} V_{sen}$;
- b) $10 c_{ob} w_{ob} V_{ob} = c_{sen} w_{sen} V_{sen}$;
- c) $c_{ob} w_{ob} V_{ob} = 10 c_{sen} w_{sen} V_{sen}$

In the macroworld by default assume that a linear sensor size does not exceed 0.1 linear size of the controlled object, and the ratio of their volumes – 0.001. That defines a relative methodical error of measurement no higher than 0.1 %. This value loses in total other components of the measurement error, including the instrumental one. So there are grounds not to consider and not take into account

the methodical error of temperature measurement.

For micro- and nano- sized sensors and controlled objects with comparable thermophysical properties (Fig. 1 b) a relative methodical error is:

$$\delta T_{met} = \frac{T_{sen}}{T_x} - 1 \quad (4)$$

For example, the temperature controlling of microobject with 270 K by means commensurate-sized sensor of initial temperature 300 K it receives $\delta T_{met} = 0,11 = 11\%$. This concerns methodical errors in a temperature measurement of nanoobjects with the help of nanoscaled sensors.

The temperature measuring of nanoobjects with the help of microsensors generally is not considered, as this will have methodical error of $\sim 10^5\%$. So, trying to use contactless the optic techniques for instance, where the beams bundle serves as a measuring probe [7]. As a consequence, there is a modified methodical error [6] due to the transfer laser bundle energy to nanoobject. The laser should work in continuous mode to ensure intensity of reflected bundle that contains temperature information. The use of biological methods [2] of temperature control brings its own restrictions and disadvantages with considerable inertia.

We can then recommend the development of non-stationary method of temperature measuring, implemented by a brief contact the sensor and the object. Thus, the equation of energy balance allows determining a relative methodical error of temperature measuring:

$$\delta T_{met} = \frac{c_{sen} w_{sen} V_{sen}}{c_{ob} w_{ob} V_{ob}} \int \frac{\partial(\Delta T_{met} / T_x)}{\partial t} dt \quad (5)$$

The short contact duration of sensor and object are determined by the structure of piezoelectric pin unit that set a duty cycle D . At short term contact of 10^{-3} s. ($f = 1$ Hz; $D = 10^{-3}$) the methodical error is corrected to the minimum comparatively the error in a stationary mode. When duration of the last is about 1 s for microobjects, the relative methodical error in non-stationary mode is $\sim 10^3$ less than that of stationary mode:

$$\delta T_{met.non-stat.} = D \delta T_{met.stat.} \quad (6)$$

4. Basic Theoretical Principles

The basis of mentioned non-stationary method is described below. Distribution of heat flux in an infinite thin rod is described by Fourier equation with the appropriate correction:

$$\frac{\partial T}{\partial t} = a \frac{\partial^2 T}{\partial x^2} - b^2 T, \quad (7)$$

where t is the time; b is the constant related to boundary conditions (for its reduction the lateral thermal insulation of a rod should be applied; it is partially implemented in the designed by us equipment); a is the temperature conductivity of the material, in the concrete case, of a measurement instrument sensor. In non-stationary case, velocity of a thermal process is defined by the temperature conductivity $a = \lambda / c\rho$ (c is the heat capacity at the constant pressure; ρ is the specific density of the material), which here takes the same signification as the λ - the thermal conductivity in stationary

case.

The solution of this equation that describes temperature in any moment of time and at any distance x from the contact surface is:

$$T = T_0 \exp\left(-x\sqrt{\omega/a}\right) \sin\left(\omega t - x\sqrt{\omega/a}\right), \quad (8)$$

where T_0 is the temperature of the controlled object surface; $\exp\left(-x\sqrt{\omega/a}\right)$ is the multiplier that reflects temperature reduction of sensor material with increasing distance from the contact surface; ω is the circular frequency of repeated temperature fluctuations.

By periodic contact between the surface of a rod cylindrical sensor and the flat surface of the controlled object, one-dimensional heat flux which is exposed to simple periodic temperature changes spreads in a cylinder. In the simplest case, when the controlled object is much bigger than a sensor, quite a trivial case [8] takes place, which is considered below.

Time for which the temperature reaches its maximum or minimum at any point of a sensor is determined from the equation:

$$\omega t - x\sqrt{\omega/a} = (2n+1)\frac{\pi}{2}, \quad (9)$$

Here odd values n give minimums and even maximums of a temperature wave that spreads along the normal directed from the contact surface with the certain velocity. We are interested in the case that leads to micro- and nanothermometry that takes place when thermal parameters and mass of the controlled object and sensor are commensurate. Therefore to ensure the minimal distortion of a temperature field of the controlled object, a sensor should be managed to perform only one short touch. Basing on the mentioned above, we can determine a period of time during which temperature reaches maximum at the first touch to the controlled object when $n = 2$:

$$t|_{n=2} = \frac{x\sqrt{\omega/a} + \frac{5\pi}{2}}{\omega}, \quad (10)$$

Through the use of a piezoelectric contact mechanism we are able to provide a repetition factor of sensor touch with the circular frequency - 20π (frequency – 10 Hz) with different discreteness. Taking a value of temperature conductivity of metal equal to 10^{-5} m²/s, height of a sensor 2 μ m and using (10), we can determine the time of temperature maximum as ~ 1 s.

The duration of a direct contact between sensor and object become shorter down to 10^{-3} s. using a piezoelectric unit with its duty cycle D . Then temperature distortion of the controlled object does not exceed 10^{-2} %, and on the other hand, an analog-digital converter (hereinafter - ADC) that is mounted on the output of a microthermometer has enough time to convert, and then to record information about the state of the object. This time value allows recording the process of passing the temperature wave through a cylindrical sensor using ADC with discreteness 10^{-5} s.

Thus, we work with the first wave of the temperature maximum in the material of a sensor, employing the above mentioned parameters, regardless of whether a sensor will or will not contact with the object. Every subsequent contact will add the following portion of heat, which spreads into the sensor substance after the first temperature wave. For the duty cycle of piezoelectric mechanism and the

above mentioned dimensions of a sensor every subsequent contact occurs when the previous temperature wave has already passed through a sensor and is recorded by the ADC. Additionally it prevents us from working in an initial transition temperature mode, providing the mode of the repeated heat flux with the formed temperature wave.

5. Experimental Research

Particular attention is given to the determination of output parameters of a temperature control device, which is a part of equipment with a piezoelectric contact mechanism. The measuring instrument incorporating a sensor in the form of a tablet is mounted using the specified mechanism that allows periodically pressing a sensor to the surface of the controlled object.

At the first stage the set incorporating the thermistor in the form of a tablet with the diameter 0.2 mm and the height 2 μm is being calibrated. For this purpose we preset the value of temperature of the flat surface equal to 313 K with an error ± 0.1 K. Since the temperature conductivity of sensor material is known approximately, it is possible to define it more exactly. For this purpose we should previously calculate the average temperature of sensor material during spreading a temperature wave.

At the second stage, considering the known temperature conductivity of sensor material, it is possible to determine a temperature wave through alteration the readings of a measurement instrument in time, and thus, using (8), to calculate the temperature of the controlled object surface.

Device for measuring temperature by a brief touch of microsensors to microobject provides the temporal monitoring of temperature. In order to reduce possible damage of microobject and minimize methodical error it is purposefully limited the duration of sensor contact with object and the sensor is assigned from an object using the piezoelectric unit. Moment of feeding an electrical signal to actuator is defined as follows. According to considerable temporal discreteness of recording sensor information determine the fixed sensor data in each moment. At the same time drew from the information bank the value of probability function, tied with sensor thermal and dimensional properties [8]. Using a programmed microcontroller with the installed software of solution of two equations system with 2 temperatures for 2 temporal points of measurement, determine the microobject temperature preceding the moment of measurement.

To ensure qualitative measurements, the duty cycle of piezoelectric mechanism of measuring rod transposition is chosen so that the passing of temperature waves is fixed using ADC (the work frequency 512 kHz). As a result, the relative methodical error of temperature measurement reduces ($\sim 10^3$) concerning the relative methodical error at the prolonged contact (duration ~ 1 s.) between sensor and object, proportionally to the reducing of contact duration.

5. Conclusions

1. Further development of nanotechnology is impossible without the estimation of values of surface temperature of micro- and nanosized objects which requires additional energy intervention in a life cycle of nanoparticles. To reduce the consequences of intervention, it is necessary to develop the sensitive methods of energy-measuring action, comparing a factor of intervention with a factor of measurement accuracy on the basis of evolving the methods of temperature field analysis in the case of micro- and nanosized controlled objects and measuring instruments.
2. During the prolonged contact between sensor and controlled object, the significance of dimensions and correspondingly the estimation of controlled object temperature using a measuring instrument are related due to the ratio of their volumes (with commensurate values of their thermal conductivities)

which corresponds to the related methodical error of temperature measurements, caused by a heat transfer between object and measuring instrument. Hence, the smaller sensor of measuring instrument, the smaller relative methodical error of temperature measuring.

3. During a short (the order of milliseconds) contact between a measuring instrument and the controlled object of commensurate dimensions, the relationship between dimensions of construction parameters, including sensor thickness and its temperature conductivity, and contact duration is grounded. The reason is rooting in providing the passage of a temperature wave through the thickness of a sensor that is estimated theoretically and experimentally determined on a stage of calibrating the equipment.

References

- [1]. Ya. Lutsyk, O. Huk, O. Lach, B. Stadnyk, Temperature Measurements: theory and practice, *Beskyd Bit*, Lviv, Ukraine, 2006 (in Ukrainian).
- [2]. A precise nanothermometer for intracellular temperature mapping. *Nanowerk Nanotechnology Spotlight*, March 19, 2012.
- [3]. V. Khanna, Frontiers of Nanosensor Technology, *Sensors and Transducers*, Vol. 103, Issue 4, 2009, pp. 1-16.
- [4]. G. Gouadec, Ph. Colomban. Raman Spectroscopy of Nanomaterials: How Spectra Relate to Disorder, Particle Size and Mechanical Properties, *Progress in Crystal Growth and Characterization of Materials*, Vol. 53, Issue 1, 2007, pp. 1-56.
- [5]. B. Stadnyk, S. Yatsyshyn, Thermoelectric Transducers. Investigation of Instrumental Error, *Information processing systems*, V. 79, Issue 5, 2009, pp. 106-109 (in Ukrainian).
- [6]. B. Stadnyk, S. Yatsyshyn, O. Seheda. Metrology of Temperature Transducer based on Raman Effect, *Sensors and Transducers*, V. 117, Issue 6, 2010, pp. 78-84.
- [7]. A. N. Magunov, Laser Thermometry of Solids, *Fizmatlit*, Moscow, 2001 (in Russian).
- [8]. L. Ingersoll, O. Zobel, A. Ingersoll, Heat conduction with engineering, geological and other applications, *McGraw-Hill*, New York, 1954.

2012 Copyright ©, International Frequency Sensor Association (IFSA). All rights reserved.
(<http://www.sensorsportal.com>)



UFDC-1

Universal Frequency-to-Digital Converter (UFDC-1)

- 16 measuring modes: frequency, period, its difference and ratio, duty-cycle, duty-off factor, time interval, pulse width and space, phase shift, events counting, rotation speed
- 2 channels
- Programmable accuracy up to 0.001 %
- Wide frequency range: 0.05 Hz ... 7.5 MHz (120 MHz with prescaling)
- Non-redundant conversion time
- RS-232, SPI and I²C interfaces
- Operating temperature range -40 °C... +85 °C

www.sensorsportal.com info@sensorsportal.com SWP, Inc., Canada

The 3rd International Conference on Sensor Device Technologies and Applications



SENSORDEVICES 2012

19 - 24 August 2012 - Rome, Italy

Deadline for papers: 5 April 2012



Tracks: Sensor devices - Ultrasonic and Piezosensors - Photonics - Infrared - Geosensors - Sensor device technologies - Sensors signal conditioning and interfacing circuits - Medical devices and sensors applications - Sensors domain-oriented devices, technologies, and applications - Sensor-based localization and tracking technologies

<http://www.aria.org/conferences2012/SENSORDEVICES12.html>

The 6th International Conference on Sensor Technologies and Applications



SENSORCOMM 2012

19 - 24 August 2012 - Rome, Italy

Deadline for papers: 5 April 2012



Tracks: Architectures, protocols and algorithms of sensor networks - Energy, management and control of sensor networks - Resource allocation, services, QoS and fault tolerance in sensor networks - Performance, simulation and modelling of sensor networks - Security and monitoring of sensor networks - Sensor circuits and sensor devices - Radio issues in wireless sensor networks - Software, applications and programming of sensor networks - Data allocation and information in sensor networks - Deployments and implementations of sensor networks - Under water sensors and systems - Energy optimization in wireless sensor networks

<http://www.aria.org/conferences2012/SENSORCOMM12.html>

The 5th International Conference on Advances in Circuits, Electronics and Micro-electronics



CENICS 2012

19 - 24 August 2012 - Rome, Italy

Deadline for papers: 5 April 2012



Tracks: Semiconductors and applications - Design, models and languages - Signal processing circuits - Arithmetic computational circuits - Microelectronics - Electronics technologies - Special circuits - Consumer electronics - Application-oriented electronics

<http://www.aria.org/conferences2012/CENICS12.html>

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 of it is a peer reviewed international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per year by International Frequency Sensor 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. Since 2011 the journal is covered and indexed (including a Scopus, Embase, Engineering Village and Reaxys) in Elsevier products.

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.

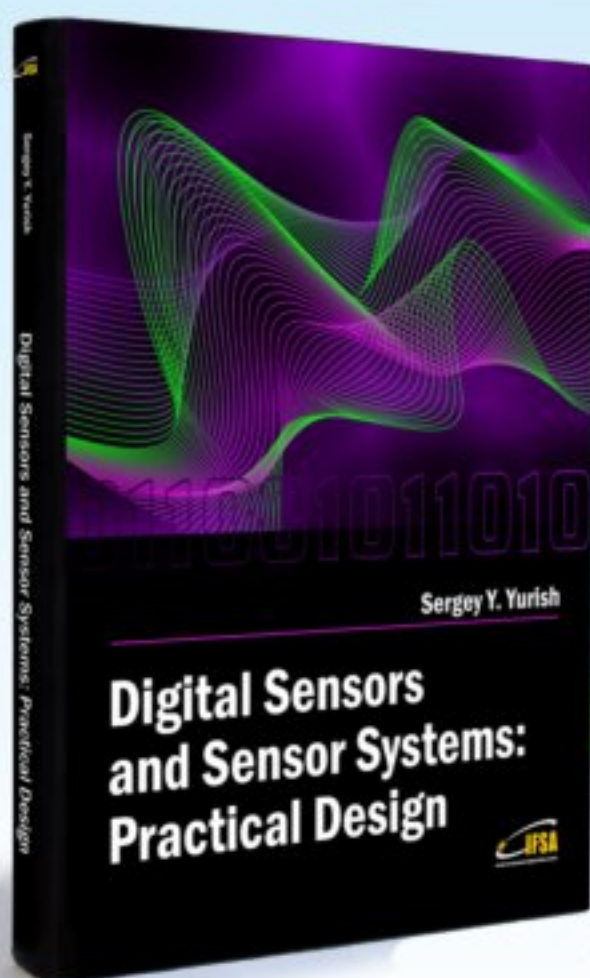
Submission of papers

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_2012.pdf

Digital Sensors and Sensor Systems: Practical Design will greatly benefit undergraduate and at PhD students, engineers, scientists and researchers in both industry and academia. It is especially suited as a reference guide for practitioners, working for Original Equipment Manufacturers (OEM) electronics market (electronics/hardware), sensor industry, and using commercial-off-the-shelf components, as well as anyone facing new challenges in technologies, and those involved in the design and creation of new digital sensors and sensor systems, including smart and/or intelligent sensors for physical or chemical, electrical or non-electrical quantities.



"It is an outstanding and most completed practical guide about how to deal with frequency, period, duty-cycle, time interval, pulse width modulated, phase-shift and pulse number output sensors and transducers and quickly create various low-cost digital sensors and sensor systems ..." (from a review)

Order online:

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



www.sensorsportal.com