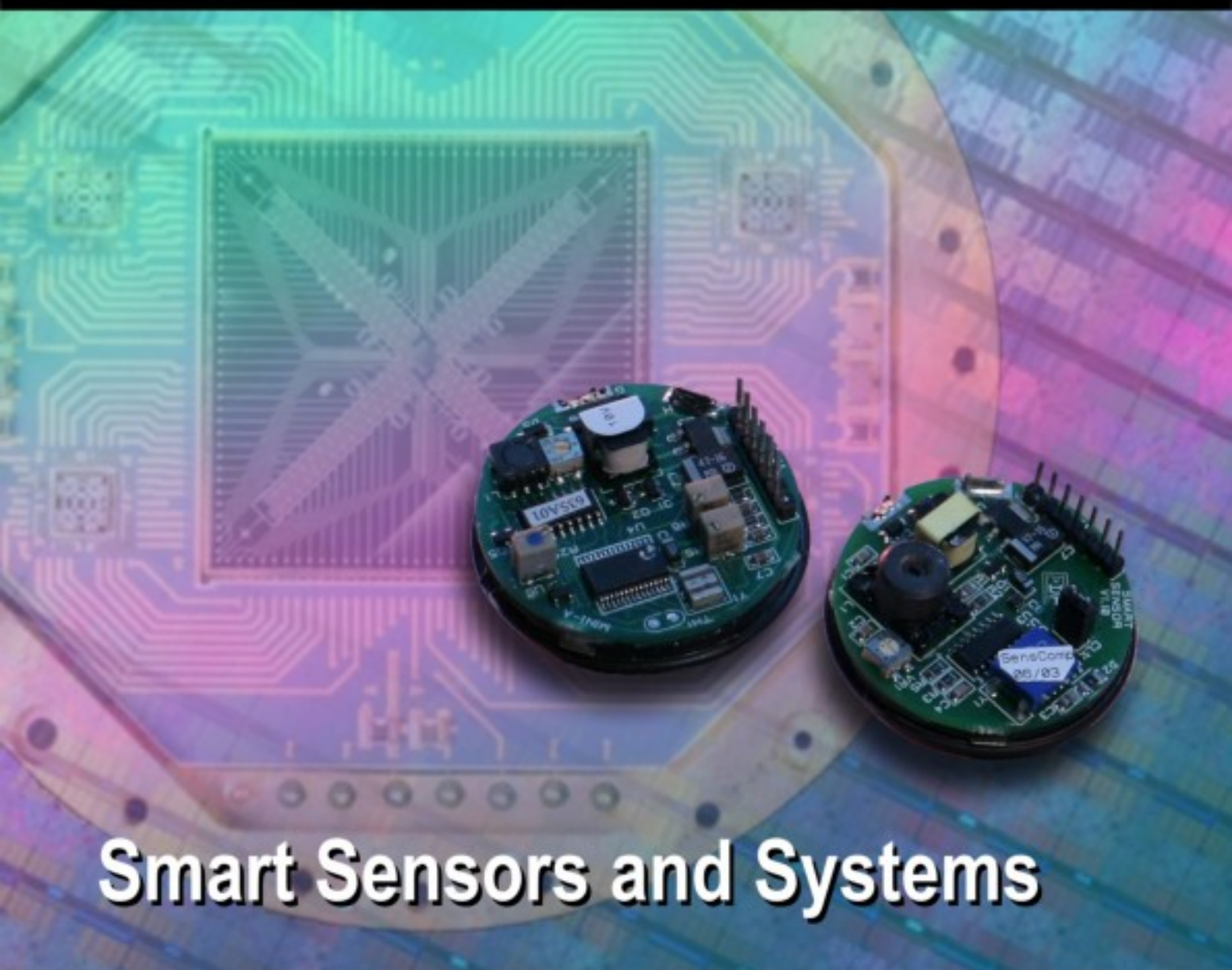


ISSN 1726-5479

# SENSORS & TRANSDUCERS

vol. 102  
**3**/09



## Smart Sensors and Systems

International Frequency Sensor Association Publishing



**Editor-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**, Nothern 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, Vyantas**, Kaunas University of Technology, Lithuania  
**Avachit, Patil Lalchand**, North Maharashtra University, India  
**Ayesh, Aladdin**, De Montfort University, UK  
**Bahreyni, Behraad**, University of Manitoba, Canada  
**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  
**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 Jian, Ning**, Jiangsu University, China  
**Djordjevic, 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  
**Drljaca, Predrag**, Intersema Sensoric SA, Switzerland  
**Dubey, Venketesh**, Bournemouth University, UK  
**Enderle, Stefan**, University 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  
**Grael, 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  
**Hashsham, Syed**, Michigan State University, USA  
**Hernandez, Alvaro**, University of Alcala, 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  
**Kim, Min Young**, Kyungpook National University, Korea South  
**Sandacci, Serghei**, Sensor Technology Ltd., UK

- 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, Saisune**, 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**, DIMET, 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 Seteбал, Portugal
- Petsev, Dimitar**, 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 Cataluña, 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
- Saxena, Vibha**, Bhabha Atomic Research Centre, Mumbai, India
- Schneider, John K.**, Ultra-Scan Corporation, USA
- Seif, Selemeni**, Alabama A & M University, USA
- Seifter, Achim**, Los Alamos National Laboratory, USA
- Sengupta, Deepak**, Advance Bio-Photonics, India
- Shankar, B. Baliga**, General Monitors Transnational, USA
- Shearwood, Christopher**, Nanyang Technological University, Singapore
- Shin, Kyuho**, Samsung Advanced Institute of Technology, Korea
- Shmaliy, Yuriy**, Kharkiv National University 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
- Sumriddetchka, 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 Institute 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 University 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
- Ymeti, Aurel**, University of Twente, Netherlands
- Yong Zhao**, Northeastern University, China
- Yu, Haihu**, Wuhan University of Technology, China
- Yuan, Yong**, Massey University, New Zealand
- Yufra Garcia, Alberto**, Seville University, Spain
- Zagnoni, Michele**, University of Southampton, UK
- Zeni, Luigi**, Second University of Naples, Italy
- Zhong, Haoxiang**, Henan Normal University, China
- 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
- Zhou, Zhi-Gang**, Tsinghua University, China
- Zorzano, Luis**, Universidad de La Rioja, Spain
- Zourob, Mohammed**, University of Cambridge, UK



# Contents

Volume 102  
Issue 3  
March 2009

[www.sensorsportal.com](http://www.sensorsportal.com)

ISSN 1726-5479

## Research Articles

<b>Smart Sensor Systems: Book Review</b> .....	I
<b>Design of a Smart and High Precision Industrial Temperature Measurement and Monitoring System Using K-type Thermocouple and SPI-compatible Temperature Sensor</b> <i>Utpal Sarma, Digbijoy Chakraborty, P. K. Boruah</i> .....	1
<b>IEEE 1451.0-2007 Compatible Smart Sensor Readout with Error Compensation Using FPGA</b> <i>J. Kamala and B. Umamaheswari</i> .....	10
<b>Predicting the Deflections of Micromachined Electrostatic Actuators Using Artificial Neural Network (ANN)</b> <i>Hing Wah Lee, Mohd. Ismahadi Syono and Ishak Hj. Abd. Azid</i> .....	22
<b>Conception and Development of a Portable Electronic Nose System for Classification of Raw Milk Using Principal Component Analysis Approach</b> <i>Hing Wah Lee, Mohd. Ismahadi Syono and Ishak Hj. Abd. Azid</i> .....	33
<b>Viscosity Measurement Using Microcontroller to Study the Thermal Degradation of Edible Oil</b> <i>Neelameagam Periyasamy, Rubalya Valantina Sathianathan and Murugananthan Krishnamoorthy</i> .....	45
<b>Problems of Terminology in the Field of Measuring Instruments with Elements of Artificial Intelligence</b> <i>Roald Taymanov, Ksenia Sapozhnikova</i> .....	51
<b>Microcontroller Based Closed Loop PMDC Motor Position Control System</b> <i>Subrata Chattopadhyay, Utpal Chakraborty, Arindam Bhakta and Sagarika Pal</i> .....	62
<b>Discrete Time Sliding Mode Control Using Fast Output Sampling Feedback for Piezoelectric Actuated Structures</b> <i>L. R. Karl Marx, M. Umapathy, A. Girija, D. Ezhilarasi</i> .....	71
<b>A Particle Swarm Optimization of Natural Ventilation Parameters in a Greenhouse with Continuous Roof Vents</b> <i>Abdelhafid Hasni, Belkacem Draoui, Thierry Boulard, Rachid Taibi and Brahim Dennai</i> .....	84
<b>Experimental and Computational Study of Two-phase (Air–Palm Oil) Flow through Pipe and Control Valve in Series</b> <i>Arivazhagan M., Pugalenth, Krishna Karthik K., Rani Hemamalini, Sundaram S.</i> .....	94
<b>The Effect on Pressure Drop across Control Valve for Two Phase Flow (Air-Water)</b> <i>Arivazhagan M, Krishna Karthik K, Sundaram S</i> .....	105
<b>RBIC-Lite – a Family of Signal Conditioning ICs of ZMD</b> <i>Krauss Gudrun, Krauss Mathias</i> .....	115

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

## RBIC-Lite – a Family of Signal Conditioning ICs of ZMD

**Krauss GUDRUN, Krauss MATHIAS**

ZMD America, Inc. 201 Old Country Road, Melville, NY, 11747, USA

Tel.: 631 549 2666, fax: 631 549 2882

E-mail: [gkrauss@zmda.com](mailto:gkrauss@zmda.com), [mkrauss@zmda.com](mailto:mkrauss@zmda.com)

*Received: 18 February 2009 /Accepted: 24 March 2009 /Published: 31 March 2009*

---

**Abstract:** A family of low-cost signal conditioners for bridge type sensors is described, which has state-the-art features like chopper stabilized analog front end, high resolution A to D conversion, digital calibration math based with EEPROM stored coefficients and a variety of digital and analog outputs. Besides that, useful features like power safe mode, internal regulator and diagnostic functions are also available. The paper focuses in particular on end-of-line calibration which is supported by ZMD's proprietary one wire protocol. *Copyright © 2009 IFSA.*

**Keywords:** Sensor signal conditioner, End-of-line calibration, Bridgetype sensor conditioning

---

### 1. Introduction

The increasing need to measure the analog world and connect it with digital signal processing results in a rapid development of the sensor technology. The transformation of the analog electrical sensor raw signal into a standardized digital/analog output signal with the tasks of signal amplification, error correction and removal of unwanted environmental influences (for example, temperature dependence), are summarized as sensor signal conditioning. With the ability of integrating analog and digital functions on a chip, this functionality suggests the development of a standard sensor signal conditioner (SSC), especially for conditioning of Wheatstone bridge sensors. This sensor type is widely used for pressure measurement, force measurement as well as magneto-resistive bridges in the linear and angular position measurement. The differential output signal and the ratiometricity, i.e. the strict proportionality of signal and supply voltage, connected with this sensor principle, offer ideal conditions for a very robust but precise signal processing in relation to disturbances of any kind. A substantial advantage of ZMD's standard SSC is the method of the calibration procedure as one of the cost-determining factors in the sensor module production. The conventional calibration method with potentiometers and laser-trimmed correction resistors is characterized by a complex, usually iterative

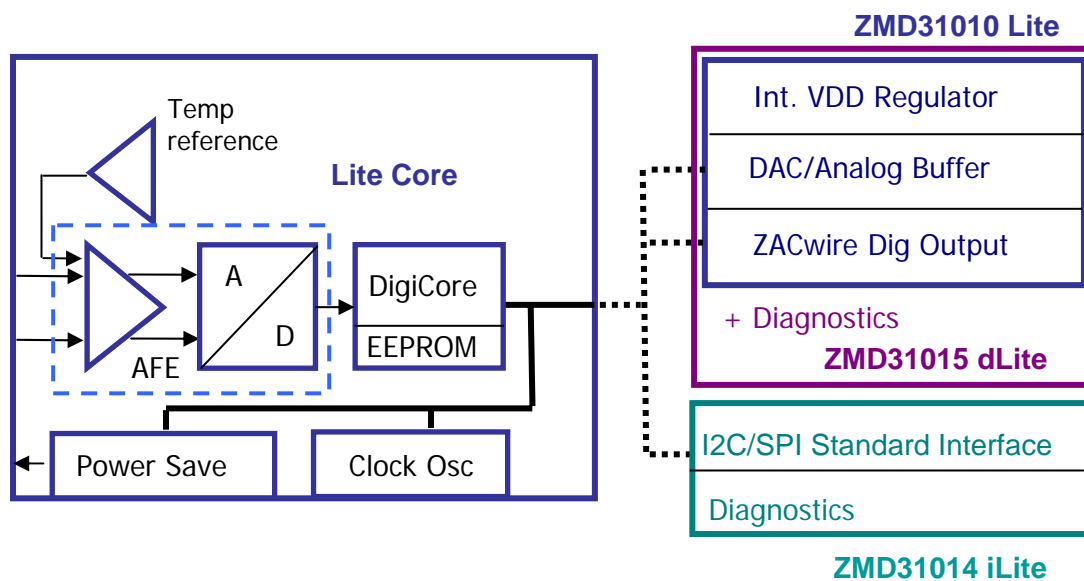
calibration process, insufficient calibration accuracy (only gain and offset) as well as insufficient stability. The "END OF LINE" calibration, implemented in ZMD SSC for several product generations, eliminates multiple iterations.

Ideally, a universal SSC IC, offering all feasible features to interface with the wide variety of resistive bridge sensors and supporting a variety of different analog and digital standard outputs is one reasonable approach for a standard product. To address this, ZMD has developed the ZMD31050 RB<sup>IC™</sup> to cover the many different applications.

While very attractive to many custom transducer manufacturers, such solutions do not apply to requirements aligned with a single application requiring:

- Low power
- High degree of miniaturization
- Optimized cost

The following product outline describes the RB<sup>IC™</sup> family of "Lite" products developed by ZMD based upon the modular concept of the ZMD31050 that addresses these requirements. The core blocks and the associated features of the Lite IC family are explained in detail (Fig. 1).



**Fig. 1.** Block diagram with core blocks and optional blocks.

## 2. Analog Front End (AFE)

The analog front end is characterized by the following blocks:

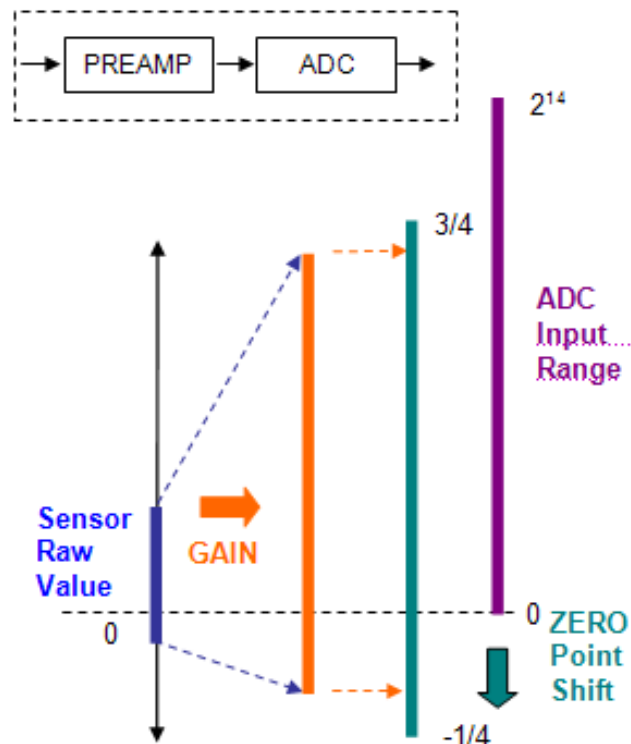
- Chopper stabilize pre-amplifier
- Second-order Charge Balancing A/D Converter
- Input multiplexer with Auto-zero function.

To reach the required output resolution of 10 to 12 bits to, the AFE must be configured in its pre-amplification (GAIN parameter) and by an adjustable zero point shift (ZERO parameter) roughly to the actual output voltage range of the sensor (see Fig. 2).

In greater time steps the temperature signal and the offset (Autozero) are sampled by the AFE.

The simplification of the AFE of the Lite product family compared to the universal SSC consists in the following:

- Applicable only for bridges with voltage excitation;
- Optimized, two-stage pre-amplifier with only 2 to 6 configurable GAIN values and without analog pre-compensation of higher bridge offset voltages;
- The 14 bit A/D converter compensates the resolution loss due to the less exact adjustment of the AFE to the sensor signal range.



**Fig. 2.** AFE Configuration.

### 3. Digitally Core

In principle, a micro controller can provide functions like clock control of the analog circuitry, the correction calculation and the implementation of the serial communication interface. Considering less complex calculations, further chip size reduction can be achieved by using a state machine concept as is realized in the ZMD Lite product family. The retention of 16 bits processing and data width of the EEPROM coefficients together with the 14 bit A/D conversion guarantees the required computational accuracy and overflow security in the fixed-point arithmetic. Basing on a polynomial approach the implemented mathematics calculates the corrected output signals using the stored calibration coefficients and the already auto-zero compensated ADC raw values of the bridge signal and the temperature signal. For low power applications, which require only a few measurements per second, the so-called update mode is available. Between the single measurements, the IC is in standby mode and the bridge is deactivated.

## 4. Back End

The I<sup>2</sup>C and SPI protocols are the most common digital interfaces for the sensor signal readout. The ZMD31014 supports at the output only these two protocols. Giving up the analog output an average current consumption can be achieved as low as some 10µA in the update mode. The digital interface serves also the so-called "END OF LINE" calibration, which prevents that possible changes of sensor parameters during the module manufacturing process due to mechanical or thermal stress can influence the calibration. There appears a time window of some ms after power ON, in which the IC must receive a certain command in order to enter the communication mode. Otherwise the IC continues in the normal operation mode.

## 5. Diagnostic Functions

Detectable error states with the Lite product family include sensor errors (loss or short-circuit of bridge connections), data errors in the EEPROM of the SSC IC (check sum error) and power and ground loss as well.

Additional to the diagnostic functions part traceability of failed units is required for today's quality standards. This is supported by space for customer data reserved in the EEPROM. An EEPROM LOCK function with the ZMD31014 prevents from changing of the EEPROM data after distribution of a sensor module.

## 6. One Shot "End of Line" Calibration

A very cost-sensitive part of the sensor module mass production is the calibration procedure, in which different pressure and temperature values (especially time intensive) must be applied to each module several times. To reach a flexible and effective calibration process, the following has to be made sure:

- Calibration without iterative steps
- Raw data collection in arbitrary order
- Raw data collection, determination of the correction coefficients and programming as separable processes
- The quality of the calibration result must be independent of whether the values were intended for pressure and temperature by accurate reproduction of the operating points or by accurate back measurement in the respective operating point.

An example for the calibration procedure will be explained for the sensor characteristics represented in Fig. 3.

In this case all 7 of the coefficients possible with the ZMD31014 are used for the bridge correction. After acquiring the raw data in 7 calibration points the 7 coefficients can be computed. In order to minimize the random measurement and rounding errors those points should lie close to the respective limits as well as in the center of pressure and temperature range.

$$RB = O * (1 + TCO1 * ZT + TCO2 * ZT^2) + G * (1 + TCG1 * ZT + TCG2 * ZT^2) * ZB + SOT * ZB^2, \quad (1)$$

where G is the Gain correction factor ("digitally zoom " up to x64); O is the Offset correction; SOT is the second order term for the correction of the nonlinearity by a polynomial of second order; TCO1 and TCO2 are terms for the compensation of the Offset TC (first and second order); TCG1 and TCG2 are terms for the compensation of the Gain TC (first and second order).



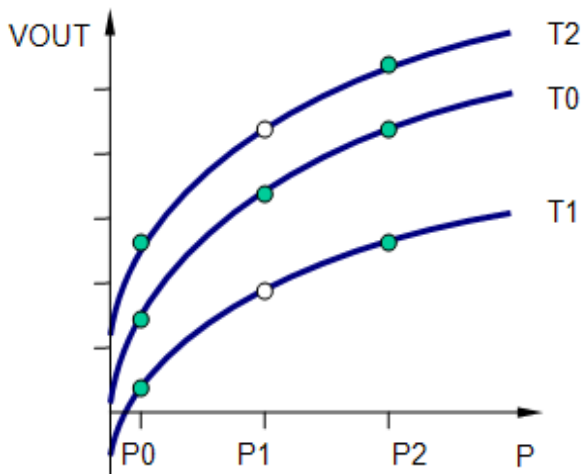


Fig.3. Measuring Point Order.

The errors at the calibration points become zero, though, the error in the ranges between them will be the smaller, the better equation (1) describes the real, physically caused sensor behavior. The solution of the polynomial equation set, in particular if the operating points are not strictly fixed (back-measured values), can be calculated by a nonlinear optimization method (curve fitting). For that reason in the ZMD development software offered for the Lite products the Excel Solver is merged into the DLL for the step of the coefficient calculation. With the process steps of digital raw data acquiring, coefficient calculation by curve fitting and programming of all coefficients (One Shot), the Lite product family fulfills all conditions for an effective calibration procedure mentioned above.

## 7. Summary

With the addition of the ZMD31014 iLite™ signal conditioner with digital I<sup>2</sup>C or SPI interface, ZMD addresses high functionality, low power and low cost as required in certain high volume applications. The Rbic “Lite” SSC name is synonymous in this family of products, with iLite being the latest part in this series. Following our slogan “In a World of Complexity, Simplicity is Key”, overkill features have not been implemented in these products. Functionality, which extends the field of application without high auxiliary costs, is clearly the consideration in the concept behind the ZMD31014 RB<sup>IC</sup> iLite™. Optimization for low power and easy micro-controller interface are its key attributes.

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

### 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 I<sup>2</sup>C interfaces
- Operating temperature range -40 °C...+85 °C



Celebrating 125 Years  
of Engineering the Future

# IEEE SENSORS 2009 CONFERENCE SENSORS 2009 NEW ZEALAND

OCTOBER 25-28, 2009 • CHRISTCHURCH, NEW ZEALAND

## Announcement and CALL FOR PAPERS

IEEE Sensors Conference 2009 is intended to provide a common forum for researchers, scientists, engineers and practitioners throughout the world to present their latest research findings, ideas, developments and applications in the area of sensors and sensing technology. IEEE Sensors Conference 2009 will include keynote addresses by eminent scientists as well as special, regular and poster sessions.

### TOPICS:

- Phenomena, Modeling and Evaluation
- Biosensors
- Mechanical Sensors
- Sensor/Actuator Systems
- Applications
- Chemical and Gas Sensors
- Optical Sensors
- Physical Sensors
- Sensor Networks
- Special "Focus" Sessions

*Authors are invited to submit a 2-page abstract in one or more of the areas identified above.*

### DATES:

Special Session Proposals Deadline: **JAN 30, 2009**

Abstract Submission Deadline: **MAR 31, 2009**

Author Notification: **MAY 31, 2009**

Final Full Paper Submission (4 Pages): **JUL 11, 2009**

Presenting Author Conference Registration: **JUL 11, 2009**

Early Registration: **On or Before JUL 31, 2009**

Advance Registration: **AUG 1, 2009 to SEP 15, 2009**

For additional Conference information  
please visit the website at:

**IEEE-SENSORS2009.org**

#### GENERAL CHAIR:

Subhas Mukhopadhyay, Massey University

#### TECHNICAL PROGRAMME CHAIR:

Paddy French, Delft University of Technology



**SPONSORED BY:**

IEEE SENSORS Council



## 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.

### 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:

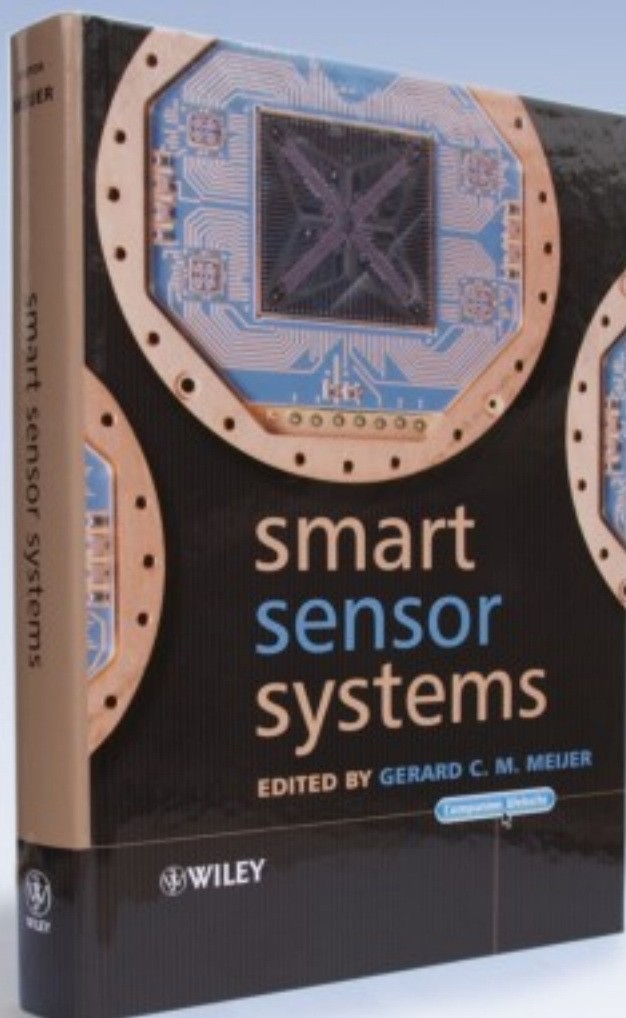
- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors 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](mailto:editor@sensorsportal.com) 6-14 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](mailto:sales@sensorsportal.com) Please download also our media kit: [http://www.sensorsportal.com/DOWNLOADS/Media\\_Kit\\_2008.pdf](http://www.sensorsportal.com/DOWNLOADS/Media_Kit_2008.pdf)



**'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](http://www.sensorsportal.com/HTML/BOOKSTORE/Smart_Sensor_Systems.htm)

**[www.sensorsportal.com](http://www.sensorsportal.com)**