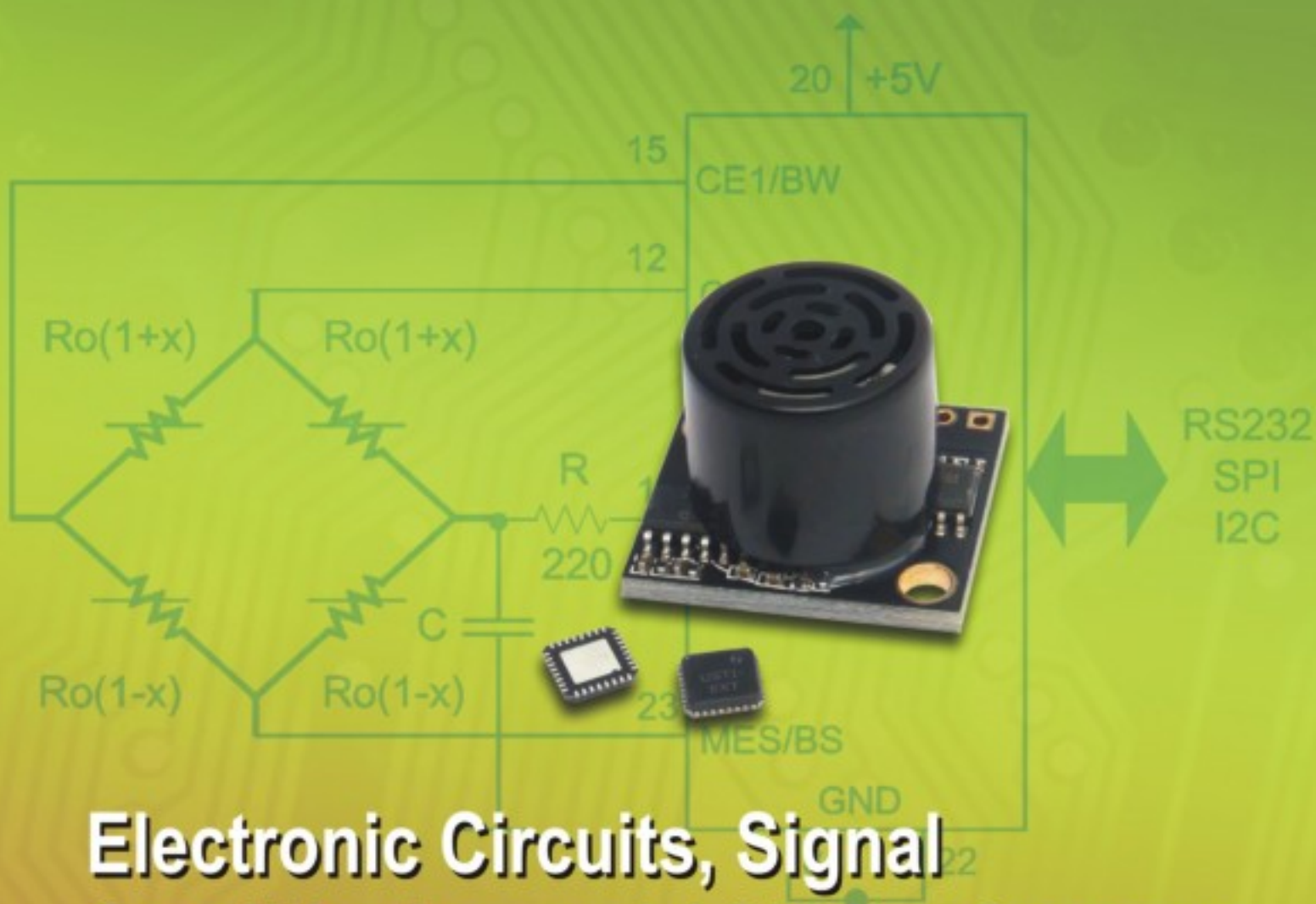


# SENSORS & TRANSDUCERS

6<sup>vol. 141</sup>  
/12



## Electronic Circuits, Signal Conditioning and ASIC for Sensors

**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  
**Djordjević, 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  
**Driljaca, 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 141  
Issue 6  
June 2012

www.sensorsportal.com

ISSN 1726-5479

## Editorial

### IFSA Publishing Starts to Publish Hardcover and Paperback Books

*Sergey Y. Yurish, Editor-in-Chief* ..... 1

## Research Articles

### Research in Nanothermometry Part 4. Amorphous Alloys of Thermo-resistive Thermometry

*Bohdan Stadnyk, Svyatoslav Yatsyshyn, Pylyp Skoropad*..... 1

### Research in Nanothermometry. Part 5. Noise Thermometry and Nature of Substance

*Svyatoslav Yatsyshyn, Bohdan Stadnyk, Zinoviy Kolodiy*..... 8

### Design of Linearized Thermistor Connection Circuit Using Modified 555 Timer

*Narayana K. V. L. and Bhujanga Rao A.*..... 17

### Design and Development of Microcontroller Based Photoacoustic Spectrometer

*P. Bhaskar, Immanuel J., and Bhagyajyoti*..... 26

### The Design of a New Instrument for Pen-contact Force Information Acquisition During Handwriting

*Jianfei Luo, Baoyuan Wu, Qiushi Lin, Zhongcheng Wu, Fei Shen* ..... 35

### ARM Cortex Processor Based Closed Loop Servo Motor Position Control System

*Madhusudhana Reddy Narayanareddygar, Nagabhushan Raju. K, Chandra Mouli. C., Chandrasekhar Reddy Devanna* ..... 45

### The Hardware Design Technique for Ultrasonic Process Tomography System

*Mohd Hafiz Fazalul Rahiman, Ruzairi Abdul Rahim, Herlina Abdul Rahim and Nor Muzakkir Nor Ayob* ..... 52

### Design, Development and Testing of a Semi Cylindrical Capacitive Sensor for Liquid Flow Rate Measurement in Process Industry

*Sagarika Pal, Sharmi Ganguly* ..... 62

### Synchronization Based SAW Sensor Using Delay Line Coupled Dual Oscillator Phase Dynamics

*Shashank S. Jha and R. D. S. Yadava* ..... 71

### Intelligent Robust Nonlinear Controller for MEMS Angular Rate Sensor

*Mohammad-Reza Moghanni-Bavil-Olyaei, Ahmad Ghanbari, Jafar Keighobadi* ..... 92


### Analysis of the Self-Calibration Process in a Displacement Sensor in Applications of Hip or Knee Implants

*Shiying Hao* ..... 106

<b>Acoustic Detector for Determining the Type and Concentration of a Solution</b> <i>Tariq Younes</i> .....	119
<b>Low Concentration Sodium Chloride Salinity Detection System</b> <i>Hee C. Lim, Hio Giap Ooi, Yew Fong Hor</i> .....	127
<b>ARM Processor Based Embedded System for Examination Question Paper Leakage Protection System</b> <i>Jyothi Pattipati, Chandra Mouli Chakala, Chaitanya Pavan Kanchisamudram, Nagaraja Chiyedu and Nagabhushan Raju Konduru</i> .....	134

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).



**Handbook  
of Laboratory Measurements  
and Instrumentation**


Maria Teresa Restivo  
Fernando Gomes de Almeida  
Maria de Fátima Chouzal  
Joaquim Gabriel Mendes  
António Mendes Lopes

## Handbook of Laboratory Measurements and Instrumentation

---

**Maria Teresa Restivo**  
**Fernando Gomes de Almeida**  
**Maria de Fátima Chouzal**  
**Joaquim Gabriel Mendes**  
**António Mendes Lopes**

The Handbook of Laboratory Measurements and Instrumentation presents experimental and laboratory activities with an approach as close as possible to reality, even offering remote access to experiments, providing to the reader an excellent tool for learning laboratory techniques and methodologies. Book includes dozens videos, animations and simulations following each of chapters. It makes the title very valued and different from existing books on measurements and instrumentation.



**International Frequency Sensor Association Publishing**

**Order online:**  
[http://www.sensorsportal.com/HTML/BOOKSTORE/Handbook\\_of\\_Measurements.htm](http://www.sensorsportal.com/HTML/BOOKSTORE/Handbook_of_Measurements.htm)

## The Design of a New Instrument for Pen-contact Force Information Acquisition During Handwriting

<sup>1, 2, 3</sup> Jianfei Luo, <sup>2</sup> Baoyuan Wu, <sup>3</sup> Qiushi Lin, <sup>3</sup> Zhongcheng Wu, <sup>3</sup> Fei Shen

<sup>1</sup> Department of Automation, University of Science and Technology of China, Anhui 230027, China

<sup>2</sup> Institute of Intelligent Machines, Chinese Academy of Sciences, Anhui 230031, China

<sup>3</sup> High Magnetic Field Laboratory, Chinese Academy of Sciences, Anhui 230031, China

E-mail: [jfluo@mail.ustc.edu.cn](mailto:jfluo@mail.ustc.edu.cn)

*Received: 17 May 2012 / Accepted: 25 June 2012 / Published: 30 June 2012*

---

**Abstract:** This paper describes a design and implementation of a new force-based instrument for the measurement of pen-contact force information. The instrument has the ability to detect 3-D forces and 2-D torques of writing force. Additionally, other handwriting information can be got through a special structure simultaneously. The condition design of the instrument is described for obtaining the force signals accurately, and the calibration is also discussed by applying a neural network algorithm. The experiments are carried out to validate the rationality and feasibility of the instrument to the potential applications. *Copyright © 2012 IFSA.*

**Keywords:** Pen-contact force, Handwriting, Visual feedback, Human computer interface.

---

### 1. Introduction

Pen-contact force information produced by pen movements while one is writing or signing provide useful information for handwriting research, particularly for applications like automatic signature verification[1-3]. Additionally, it is also important to improve the human computer interface in the field of haptic interaction and so on [4, 5].

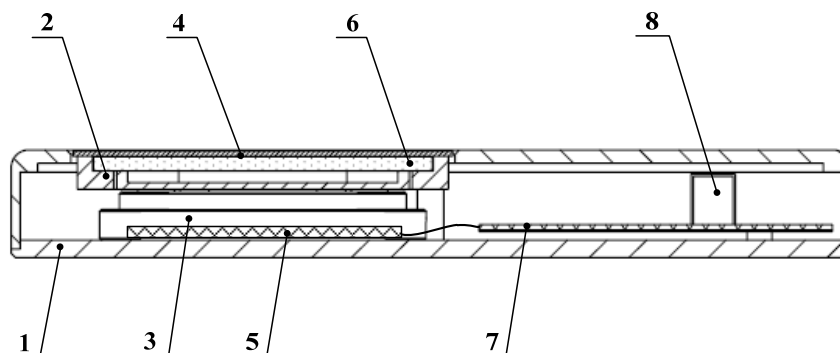
Measurement of pen-contact forces is usually done with different types of sensors integrated into a pen or a tablet. At present, various systems for detecting pen-contact forces, such as use of strain gauges[6] or magnetoelastic sensors[7] or angle sensor[8], and combination of 1-D force sensors[9, 10], have been developed. Although most designed devices based on the above methods can capture the 3-D handwriting forces, the structures of these devices are complicated. For example, the weakness of the

force-based pen [10] using a combination of five 1-D force sensors to detect the 3-D pen-contact force information, lies in the fact that the complex structure design speeds more time on computing which results in a poor real-time performance. On the other hand, most of these devices cannot work independently, but need external equipment to complete the pen-contact information acquisition.

In the present study, we propose a new instrument for pen-contact force information acquisition. The instrument can detect 3-D force and 2-D torque, and other pen-contact information such as trajectory, velocities, accelerations, and slants can be got simultaneously. Particularly, computing module and display module are added into the instrument to realize a stand-alone device and visual feedback for a natural human-computer interaction.

## 2. Instrumentation

The configuration of the F-Pad is shown by (Fig. 1). The instrument is based on the resultant force/torque balance method. A force sensor is countersunk into the cuboid box (1) to capture writing forces. A rigid adapter plate (2) is assembled between the sensor (3) and full-color liquid display (6) by four 5 mm-diameter nuts on the diagonal of the sensor, which ensure the consistency of the coordinate system. A pen-contact plate (4) is mounted on the top of the full-color liquid display. The conditioning circuit (5) and the digital processing circuit (7) are designed to complete analog sensor signals and digital sensor signals processing respectively. As a result, these attachments make the instrument simplified and more compact.



(a) Assembly photograph.



(b) Physical photograph.

**Fig. 1.** Internal view of the instrument.

The force sensor which can sense the five-dimension pen-contact forces is provided with a calibrated matrix calculated from a set of loading scenarios designed to cover the entire five-axis calibration range. The pen-contact forces are detected as follows: The forces resulting from handwriting on paper are transferred through the rigid adapter plate and captured in three perpendicular directions  $o-xyz$  by strain gauges which are placed to the cross beam of the sensor. We use metal strain gauges integrated in a full-bridge circuit. Their output signals are conditioned by a low pass filter and a single supply instrumentation amplifier providing signals in a dynamic voltage range of 4 V with sensitivity of about 0.2 V/Newton. The linear signals from the force sensor are digitized with a 14 bit A/D converter at a sampling frequency of 200 Hz.

### **3. Condition Design**

The signals conditioning design is responsible for performing any required conditioning of the analog input signals to achieve digitizing and computing. The output of the condition is a stream of digitized data that can then be processed numerically by the digital process module.

Results from our research shows that the maxim pen-contact force during handwriting is about 5 N, so the instrument is designed to measure forces between 0~25 N (50 N in Fz for the strongest signers), and the system resonance frequency is 160 Hz (for capturing the dynamic handwriting signal without distortion).

The purpose of the conditioning design is to provide digitized force signals which are representative of the handwriting produced by pen movements. To achieve this, the conditioning design has to extract useful signals from the force sensor output signals that correspond to hand-pen movements while ignoring irrelevant signals.

#### **3.1. Amplify**

The raw analog signals from the force sensor are weak. The amplitude of the output voltage from the Wheatstone bridges is approximately 0.8~1.2 mV under full loading, which will be prone to be interfered by noise signals. Therefore, conditioning circuit is designed to amplify the weak signals so that the valuable signals are able to be extracted and processed subsequently.

Noise signals always generate in common-mode signals. In order to reduce the noise interference, the differential-mode signals are adopted as shown in Fig. 2. When the bridge circuit is out of balance, the differential value between  $IN+$  and  $IN-$  respects the pen-contact force amplitude. A1 and A2 together constitute the differential amplifier for amplifying the differential value. The output of the amplified values can be expressed as:

$$V_o = (V_{IN+} - V_{IN-}) * G + V_{ref}, \quad (1)$$

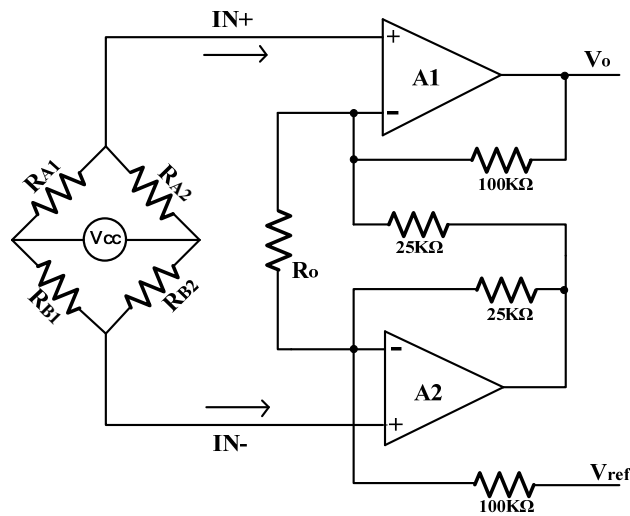
where  $V_{ref}$  is the reference voltage of the differential amplifier. And  $G$  is the gain which can be calculated as following:

$$G = \left(5 + \frac{200K\Omega}{R_o}\right), \quad (2)$$

where  $R_o$  is the external gain resistance value with range of 20  $\Omega$ ~ 40 k $\Omega$ . In order to guarantee the linearity of amplification, the selection value of  $R_o$  should make  $G$  value range from 1000 to 4000. In



addition, the resistance accuracy and temperature drift coefficient of  $R_O$  itself will affect the stability of  $G$ . It is necessary to determine the  $R_O$  value selection according to the actual accuracy requirement of the system application.

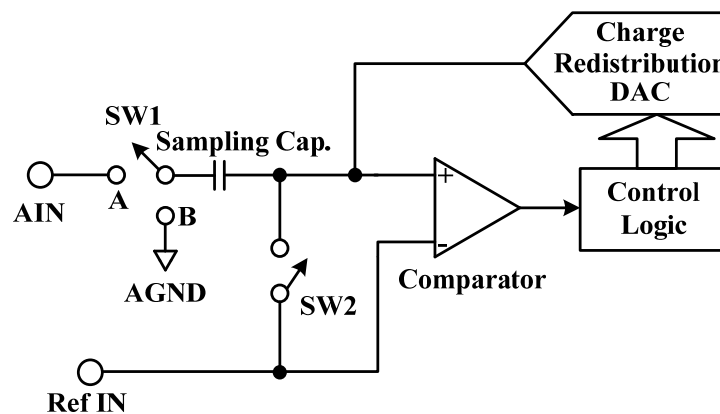


**Fig. 2.** Schematic of amplify circuit

### 3.2. Digital

The main task of the digital processing is to convert analog signals to digital signals so as to achieve digital transmission after amplifying. Therefore, an ADC component is adopted to ensure the accuracy of signal conversion. A 14-bit converter is required to gain a high resolution (0.125 mV LSB) to meet the quantization requirement for all signers with the instrument.

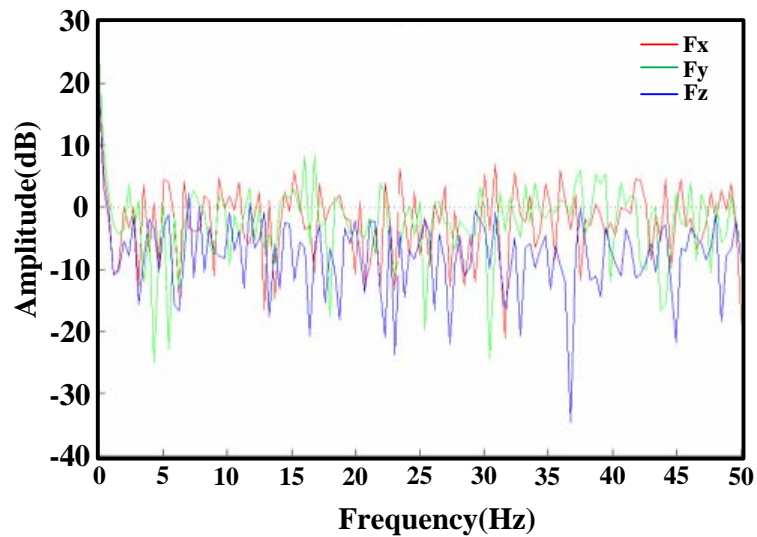
The structure of digital processing circuit is shown in Fig. 3. When SW2 is closed and SW1 is in Position A, the ADC starts an acquisition phase and the comparator is held in a balanced condition and the sampling capacitor acquires the signal on AIN. When the ADC starts a conversion, SW2 will open and SW1 will move to Position B causing the comparator to become unbalanced. The control logic and the charge redistribution DAC are used to add and subtract fixed amounts of charge from the sampling capacitor to bring the comparator back into a balanced condition. When the comparator is rebalanced, the conversion is complete. The control logic generates the ADC output code.



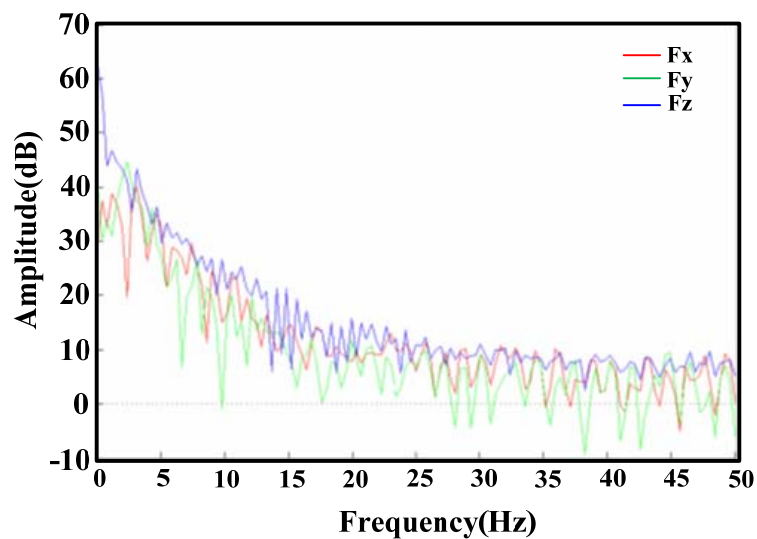
**Fig. 3.** Schematic of digital processing.

### 3.3. Filter

Upper frequency limit of human handwriting is 20 Hz [11], so the captured signals should be filtered out larger than 20 Hz. Due to the digital quantization error, there may have a deviation between the actual signal value and the theoretical value. As a result, the spectrum analysis is done on force signals and noise signals which are shown in Fig. 4.



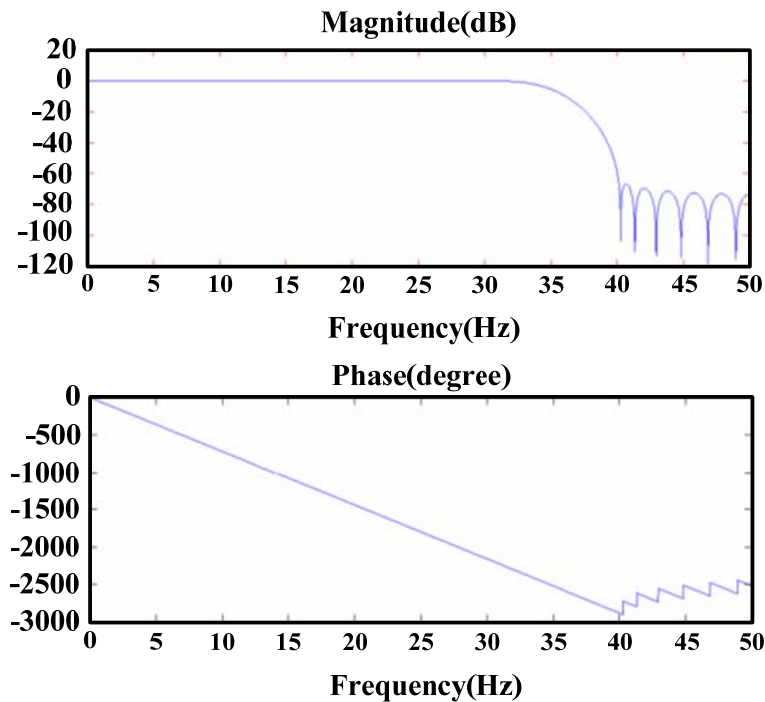
(a) Noise signals spectrum.



(b) Force signals spectrum.

**Fig. 4.** The captured signals spectrum.

The noise signals shown in Fig. 4 (a) is a kind of white noise and distributes evenly in the whole frequency domain, while the force signals shown in Fig. 4 (b) is a low frequency and distributes between 0 Hz up to 40 Hz approximately. So, it is apparent that we should filter out the signals frequency larger than 40 Hz. A FIR low-pass digital filter is applied to achieve the above function, which the amplitude-frequency characteristics and phase-frequency characteristic curves are shown in Fig. 5.



**Fig. 5.** The characteristic curves of the designed FIR.

## 4. Calibration

The force sensor integrated in the instrument can detect the 3-D forces and 2-D torques of pen-contact force information, which is developed using piezoresistive strain method. In order to acquire the force information accurately, the outputs of the force sensor must be calibrated.

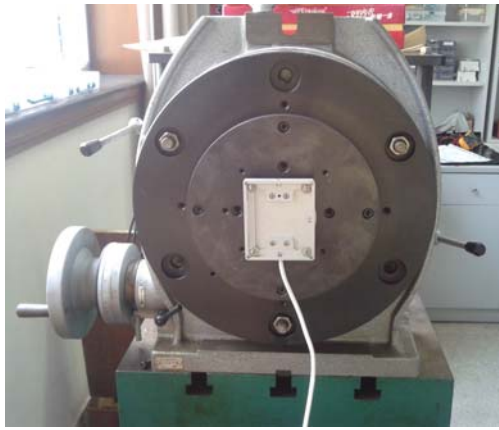
### 4.1. Calibration Platform

The calibration platform for the sensor presented above is designed. It consists of five parts: sensor platform, rotary surface, loading cap, high-precision weights and angle regulator (Fig. 6).

In the calibration process, the force sensor is fixed on the sensor platform and the sensor platform is then mounted on the rotary surface. The loading caps are assembled to the force sensor rigidly, and the high-precision weights as the reference loading material are exerted to the force sensor via the loading caps. The *XY*-directional calibration of the force sensor is processed by adjusting the angle of the rotary surface through the angle regulator.

### 4.2. Calibration Method

Recently, many researchers realize sensor's calibration and nonlinear error's emendation using Neural Network [12]. In this paper, A kind of common multilayer feedforward ANN-backpropagation network (BP) is adopted to estimate measurement errors. Two BP networks were trained for estimating error. The networks have one hidden layer. Levenberg-Marquardt algorithm is used to calculate weight and offset, while sigmoid function and pureline function are chosen as transfer function of the hidden layer and transfer function of output layer respectively.



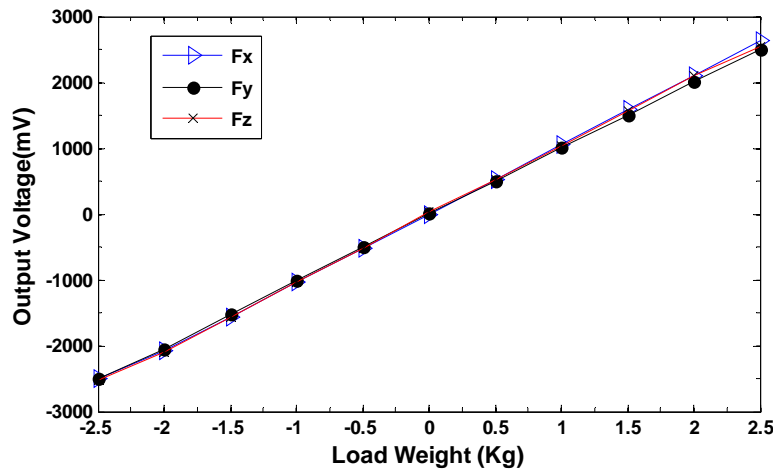
**Fig. 6.** Calibration platform.

## 5. Experiments

In order to critically evaluate the instrument features, several experiments are carried out in the lab.

### 5.1. Characteristic Test

Firstly, a verification experiment is done after calibration of the force sensor, which can determine the effectiveness of the calibration method. Fig. 7 shows the test result, and Table 1 gives the characteristic indexes of the instrument on the measurement of pen-contact force information after the experiment.



**Fig. 7.** Verification results.

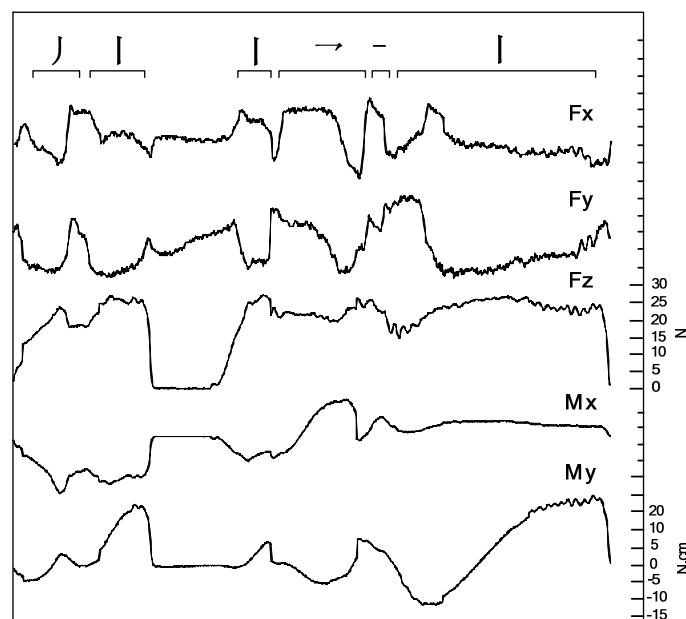
**Table 1.** The characteristic indexes of the instrument.

Indexes	Fx	Fy	Fz	Mx	My
Sensitivity (N, N*m)	0.1	0.1	0.1	0.003	0.003
Nonlinearity (FS %)	0.07	0.06	0.05	0.13	0.21
Precision (FS %)	0.01	0.01	0.01	0.02	0.02
Stability errors (FS %)	0.05	0.05	0.05	0.05	0.05
Non-repeatability errors (FS %)	0.02	0.02	0.02	0.03	0.03

Fig. 7 shows the verification results for the 3-D forces (labeled as  $F_x$ ,  $F_y$ ,  $F_z$ ) respectively. The horizontal axes of the graphs show the loading reference forces, while the vertical axes show the detected writing forces. The negative values indicate the case in which the force is applied in the negative direction. As we can see, the curves are almost linear which also illustrates the adopted BP method is feasible. Additionally, the characteristic indexed of the instrument is shown in Table 1 under repeated loading test experiments.

## 5.2. Forces Measurement

The primary feature of the instrument is that it can detect the pen-contact force information, including 3-D forces and 2-D torques. An experiment in which Chinese characters are written is performed. Any pen-like object can be used to writing and Fig. 8 shows an example of the obtained pen-contact force pattern when writing Chinese character “仲”.



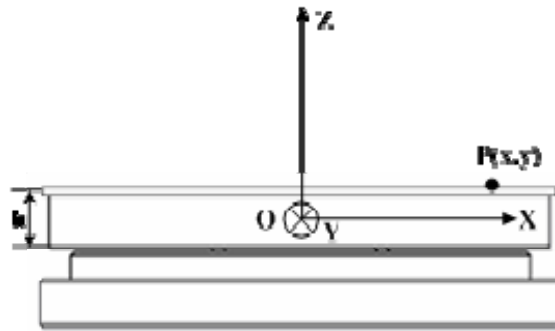
**Fig. 8.** Force outputs when writing the Chinese character “仲”

According to the Fig. 8, we can see that the instrument can get all pen-contact force information ( $F_x$ ,  $F_y$ ,  $F_z$ ,  $M_x$ ,  $M_y$ ).

## 5.3. Other Information Measurements

Besides the obtained force information, the instrument can also get other further information during handwriting such as trajectories, velocities, accelerations and so on. Particularly, all these information are calculated and the writing results are displayed directly.

The coordinate of the instrument is illustrated in (Fig. 9). Suppose that a pen is writing at point  $P(x, y)$ , the forces (i.e.  $F_x(t_i)$ ,  $F_y(t_i)$ ,  $F_z(t_i)$ ,  $M_x(t_i)$ ,  $M_y(t_i)$ ) is measured directly which are all functions of time  $t_i$ . Then, the coordinates of the point  $P$  can be calculated as follows.



**Fig. 9.** the Coordinate system of the instrument.

$$\begin{aligned} x_p(t_i) &= \frac{M_y(t_i) - F_x(t_i) * h}{F_z(t_i)} \\ y_p(t_i) &= \frac{M_x(t_i) - F_y(t_i) * h}{F_z(t_i)} \end{aligned} \quad (3)$$

where h denotes the distance between the pen-contacting plate and the origin of the coordinate of the force sensor. The velocities and accelerations are the derivative of the two coordinates, which can be expressed as (4) and (5).

$$\begin{aligned} v_x(t_j) &= \frac{x(t_j) - x(t_{j-1})}{\Delta t} \\ v_y(t_j) &= \frac{y(t_j) - y(t_{j-1})}{\Delta t} \end{aligned} \quad (4)$$

$$\begin{aligned} a_x(t_k) &= \frac{v_x(t_k) - v_x(t_{k-1})}{\Delta t} \\ a_y(t_k) &= \frac{v_y(t_k) - v_y(t_{k-1})}{\Delta t} \end{aligned} \quad (5)$$

According to (3) and (5), the instrument draws the writing trajectories and drives the data to the memory to complete the handwriting display. Fig. 10 shows a sample of handwriting with the instrument. Note that it is a real time process between the display and handwriting without disturbing users' attention.



**Fig. 10.** Sample of the handwriting with the instrument.

## 6. Conclusion

In this paper, we presented a new instrument for pen-contact force information acquisition during handwriting. With a force sensor and other modules integrated, the instrument can directly detect 3-D forces and 2-D torques during pen movements, and other pen-contact information such as trajectories, velocities, accelerations, and so on can be got simultaneously. In order to get a nature interaction and be a stand-alone device, in-system computing and visual feedback are applied to achieve the requirements when using in practice.

As all force information and other pen-contact information about the writers' handwriting can be got by the instrument, it may be a remarkable potential of the instrument for biomechanical application or person verification and identification.

## Acknowledgments

The authors would like to thank the financial supports from the National Natural Science Foundation funded project No: 60975057.

## References

- [1]. R. Plamondon, and S. N. Srihari, On-line and off-line handwriting recognition: a comprehensive survey, *IEEE Trans. on Pattern Analysis and Machine Intelligence*, 2000, 22, pp. 63-85.
- [2]. Monji Kherallah, Lobna Haddad, Adel M. Alimi, Amar Mitiche, On-line handwritten digit recognition based on trajectory and velocity modeling, *Pattern Recognition Letters*, 2008, 29, pp. 580-594.
- [3]. Alisher Kholmatov and Berrin Yanikoglu, SUSIG: An On-line Handwritten Signature Database, Associated Protocols and Benchmark Results, *Pattern Analysis & Applications*, 2009, 12, pp. 227-236.
- [4]. El Saddik, M. Orozco, Y. Asfaw, S. Shirmohammadi, and A. Adler, A novel biometric system for identification and verification of haptic users, *IEEE Trans. Instrum. Meas.*, 56, 3, 2007, pp. 895-906.
- [5]. Greg R. Luecke, Haptic interactions using virtual manipulator coupling with applications to underactuated systems, *IEEE Transactions on Robotics*, 2011, Vol. 27, No. 4, pp. 730-740.
- [6]. H. D. Crane, J. S. Ostrem, Automatic signature verification using a three-axis force-sensitive pen, *IEEE Trans. Syst. Man Cybernetics SMC-13*, 1983, 3, pp. 329-337.
- [7]. A. Zhukov, M. Vaququez, Garcia-Beneytez, Magnetoelastic sensor for signature identification based on mechanomagnetic effect in amorphous wires, *J. Phys.*, IV, 8, 1998, pp. 763-766.
- [8]. H. Shimizu, S. Kiyono, T. Motoki, and W. Gao, An electrical pen for signature verification using a two-dimensional optical angle sensor, *Sensors and Actuators*, 2004, 111, pp. 216-221.
- [9]. Alexander W. Hooke, Jaebum Park, Jae Kun Shim: The forces behind the words: Development of the Kinetic Pen, *J. Biomechan.*, 2008, Vol. 41, No. 6, pp. 2060-2064.
- [10]. D. Wang, Y. Zhang, C. Yao, J. Wu, H. Jiao and M. Liu, Toward Force-Based Signature Verification: A Pen-Type Sensor and Preliminary Validation, *IEEE Trans. Instrum. Meas.*, 2011, Vol. 59, No. 4, pp. 752-762.
- [11]. Z. Wu, P. Fang, M. Meng and F. Shen, A Novel Force Sensitive Tablet for Handwriting Information Acquisition, *Sinobiometrics*, LNCS 3338, 2004, pp. 654-662.
- [12]. F. Xu, Y. Ge, Y. Yu, J. Ding, T. Ju and S. Li, The Design of a Novel Flexible Tactile Sensor Based on Pressure-conductive Rubber, *Sensors & Transducers*, 124, 1, 2011, pp. 19-29.

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](mailto: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](mailto:sales@sensorsportal.com) Please download also our media kit: [http://www.sensorsportal.com/DOWNLOADS/Media\\_Kit\\_2012.pdf](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](http://www.sensorsportal.com/HTML/BOOKSTORE/Digital_Sensors.htm)



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