

ISSN 1726-5479

# SENSORS & TRANSDUCERS

vol. 100  
**1** /09

vol.  
**100**



## Sensor Instrumentation, DAQ and Virtual Instruments

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

**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

## 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, Vyngantas**, 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  
**Djordjevich, Alexander**, City University of Hong Kong, Hong Kong  
**Ko, Sang Choon**, Electronics and Telecommunications Research Institute,  
**Donato, Nicola**, University of Messina, Italy  
**Donato, Patricio**, Universidad de Mar del Plata, Argentina  
**Dong, Feng**, Tianjin University, China  
**Drljaca, Predrag**, Instersema Sensoric SA, Switzerland  
**Dubey, Venketesh**, Bournemouth University, UK  
**Enderle, Stefan**, 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  
**Granel, Annette**, Goteborg University, Sweden  
**Graff, Mason**, The University of Texas at Arlington, USA  
**Guan, Shan**, Eastman Kodak, USA  
**Guillet, Bruno**, University of Caen, France  
**Guo, Zhen**, New Jersey Institute of Technology, USA  
**Gupta, Narendra Kumar**, Napier University, UK  
**Hadjiloucas, Sillas**, The University of Reading, UK  
**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**, Koh Young Technology, Inc., Korea South  
**Sandacci, Serghei**, Sensor Technology Ltd., UK  
**Sapozhnikova, Ksenia**, D.I.Mendeleyev Institute for Metrology, Russia

Korea South  
**Kockar, Hakan**, Balikesir University, Turkey  
**Kotulska, Malgorzata**, Wroclaw University of Technology, Poland  
**Kratz, Henrik**, Uppsala University, Sweden  
**Kumar, Arun**, University of South Florida, USA  
**Kumar, Subodh**, National Physical Laboratory, India  
**Kung, Chih-Hsien**, Chang-Jung Christian University, Taiwan  
**Lacnjevac, Caslav**, University of Belgrade, Serbia  
**Lay-Ekuakille, Aime**, University of Lecce, Italy  
**Lee, Jang Myung**, Pusan National University, Korea South  
**Lee, Jun Su**, Amkor Technology, Inc. South Korea  
**Lei, Hua**, National Starch and Chemical Company, USA  
**Li, Genxi**, Nanjing University, China  
**Li, Hui**, Shanghai Jiaotong University, China  
**Li, Xian-Fang**, Central South University, China  
**Liang, Yuanchang**, University of Washington, USA  
**Liawruangrath, Saisunee**, Chiang Mai University, Thailand  
**Liew, Kim Meow**, City University of Hong Kong, Hong Kong  
**Lin, Hermann**, National Kaohsiung University, Taiwan  
**Lin, Paul**, Cleveland State University, USA  
**Linderholm, Pontus**, EPFL - Microsystems Laboratory, Switzerland  
**Liu, Aihua**, University of Oklahoma, USA  
**Liu Changgeng**, Louisiana State University, USA  
**Liu, Cheng-Hsien**, National Tsing Hua University, Taiwan  
**Liu, Songqin**, Southeast University, China  
**Lodeiro, Carlos**, Universidade NOVA de Lisboa, Portugal  
**Lorenzo, Maria Encarnacio**, Universidad Autonoma de Madrid, Spain  
**Lukaszewicz, Jerzy Pawel**, Nicholas Copernicus University, Poland  
**Ma, Zhanfang**, Northeast Normal University, China  
**Majstorovic, Vidosav**, University of Belgrade, Serbia  
**Marquez, Alfredo**, Centro de Investigacion en Materiales Avanzados, Mexico  
**Matay, Ladislav**, Slovak Academy of Sciences, Slovakia  
**Mathur, Prafull**, National Physical Laboratory, India  
**Maurya, D.K.**, Institute of Materials Research and Engineering, Singapore  
**Mekid, Samir**, University of Manchester, UK  
**Melnyk, Ivan**, Photon Control Inc., Canada  
**Mendes, Paulo**, University of Minho, Portugal  
**Mennell, Julie**, Northumbria University, UK  
**Mi, Bin**, Boston Scientific Corporation, USA  
**Minas, Graca**, University of Minho, Portugal  
**Moghavvemi, Mahmoud**, University of Malaya, Malaysia  
**Mohammadi, Mohammad-Reza**, University of Cambridge, UK  
**Molina Flores, Esteban**, Benemérita Universidad Autónoma de Puebla, Mexico  
**Moradi, Majid**, University of Kerman, Iran  
**Morello, Rosario**, DIMET, University "Mediterranea" of Reggio Calabria, Italy  
**Mounir, Ben Ali**, University of Sousse, Tunisia  
**Mukhopadhyay, Subhas**, Massey University, New Zealand  
**Neelamegam, Periasamy**, Sastra Deemed University, India  
**Neshkova, Milka**, Bulgarian Academy of Sciences, Bulgaria  
**Oberhammer, Joachim**, Royal Institute of Technology, Sweden  
**Ould Lahoucine, Cherif**, University of Guelma, Algeria  
**Pamidighanta, Sayanu**, Bharat Electronics Limited (BEL), India  
**Pan, Jisheng**, Institute of Materials Research & Engineering, Singapore  
**Park, Joon-Shik**, Korea Electronics Technology Institute, Korea South  
**Penza, Michele**, ENEA C.R., Italy  
**Pereira, Jose Miguel**, Instituto Politecnico de Setebal, Portugal  
**Petsev, Dimiter**, University of New Mexico, USA  
**Pogacnik, Lea**, University of Ljubljana, Slovenia  
**Post, Michael**, National Research Council, Canada  
**Prance, Robert**, University of Sussex, UK  
**Prasad, Ambika**, Gulbarga University, India  
**Prateepasen, Asa**, Kingmoungut's University of Technology, Thailand  
**Pullini, Daniele**, Centro Ricerche FIAT, Italy  
**Pumera, Martin**, National Institute for Materials Science, Japan  
**Radhakrishnan, S.** National Chemical Laboratory, Pune, India  
**Rajanna, K.**, Indian Institute of Science, India  
**Ramadan, Qasem**, Institute of Microelectronics, Singapore  
**Rao, Basuthkar**, Tata Inst. of Fundamental Research, India  
**Raouf, Kosai**, Joseph Fourier University of Grenoble, France  
**Reig, Candid**, University of Valencia, Spain  
**Restivo, Maria Teresa**, University of Porto, Portugal  
**Robert, Michel**, University Henri Poincare, France  
**Rezazadeh, Ghader**, Urmia University, Iran  
**Royo, Santiago**, Universitat Politècnica de Catalunya, Spain  
**Rodriguez, Angel**, Universidad Politécnica de Catalunya, Spain  
**Rothberg, Steve**, Loughborough University, UK  
**Sadana, Ajit**, University of Mississippi, USA  
**Sadeghian Marnani, Hamed**, TU Delft, The Netherlands  
**Saxena, Vibha**, Bhabha Atomic Research Centre, Mumbai, India  
**Schneider, John K.**, Ultra-Scan Corporation, USA  
**Seif, Selemani**, Alabama A & M University, USA  
**Seifter, Achim**, Los Alamos National Laboratory, USA  
**Sengupta, Deepak**, Advance Bio-Photonics, India  
**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  
**Soleymanpour, 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  
**Teher, 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 Shiyong 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, Netherland  
**Yong Zhao**, Northeastern University, China  
**Yu, Haihu**, Wuhan University of Technology, China  
**Yuan, Yong**, Massey University, New Zealand  
**Yufera Garcia, Alberto**, Seville University, Spain  
**Zagnoni, Michele**, University of Southampton, UK  
**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  
**Zourab, Mohammed**, University of Cambridge, UK

# Contents

Volume 100  
Issue 1  
January 2009

www.sensorsportal.com

ISSN 1726-5479

## Editorial

- International Frequency Sensor Association (IFSA) Celebrates the 10<sup>th</sup> Anniversary** ..... 1  
*Sergey Y. Yurish*

## Research Articles

- A Log Amplifier Based Linearization Scheme for Thermocouples**  
*Nikhil Mondal, A. Abudhahir, Sourav Kanti Jana, Sugata Munshi and D. P. Bhattacharya* ..... 1
- Uncertainty Analysis of Thermocouple Circuits**  
*B. Vasuki, M. Umapathy, S. K. Velumani* ..... 11
- Calibration System for Thermocouple Testing**  
*Dragan R. Milivojevic, Visa Tasic, Marijana Pavlov, Zoran Andjelkovic* ..... 16
- Embedded Processor Based Automatic Temperature Control of VLSI Chips**  
*Narasimha Murthy Yayavaram, Saritha Chappidi, Sukanya Velamakuri* ..... 27
- Field of Temperature Measurement by Virtual Instrumentation**  
*Libor Hargaš, Dušan Koniar, Miroslav Hrianka, Jozef Čuntala* ..... 45
- Analyzing Electroencephalogram Signal Using EEG Lab**  
*Mukesh Bhardwaj and Avtar. K. Nadir* ..... 51
- New Aspects in Respiratory Epithelium Diagnostics Using Virtual Instrumentation**  
*Dušan Koniar, Libor Hargaš, Miroslav Hrianka, Peter Bánovčín* ..... 58
- A PC-based Technique to Measure the Thermal Conductivity of Solid Materials**  
*Alety Sridevireddy, K. Raghavendra Rao* ..... 65
- A New Wide Frequency Band Capacitance Transducer with Application to Measuring Metal Fill Time**  
*Wael Deabes, Mohamed Abdelrahman, and Periasamy K. Rajan* ..... 72
- A Novel Hall Effect Sensor Using Elaborate Offset Cancellation Method**  
*Vlassis N. Petoussis, Panos D. Dimitropoulos and George Stamoulis* ..... 85
- A Review of Material Properties Estimation Using Eddy Current Testing and Capacitor Imaging**  
*Mohd. Amri Yunus, S. C. Mukhopadhyay and G. Sen Gupta* ..... 92
- Surface Plasmon Resonance Based Fiber Optic Sensor with Symmetric and Asymmetric Metallic Coatings: a Comparative Study**  
*Smita Singh, Rajneesh K. Verma and B. D. Gupta* ..... 116

<b>Increasing of Excursion Range of Absolute Optical Sensors Intended for Positioners</b> <i>Igor Friedland, Ioseph Gurwich, Amit Brandes</i> .....	125
<b>Field-Effect-Transistor Behavior of a Multiwall Carbon Nano Fiber Directly Grown on Nickel Electrodes</b> <i>L. W. Chang, P. S. Wu, J. T. Lue and Z. P. Chen</i> .....	137
<b>Classification of Fiber-Optic Pressure Sensors with Amplitude Modulation of Optical Signal</b> <i>Vladyslav Kondratov, Vitalii Redko</i> .....	146
 <b>New e-Book</b>	
<b>Laboratories of Instrumentation for Measurement</b> Maria Teresa Restivo, Fernando Gomes de Almeida, Maria de Fátima Chouzal, Joaquim Gabriel Mendes, António Mendes Lopes.....	161

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>



## Analyzing Electroencephalogram Signal Using EEG Lab

**Mukesh BHARDWAJ and Avtar. K. NADIR**

Lingaya's Institute of Management & Technology

Nachauli, Old Faridabad- 121002, India

Tel.: 91-129-2201008, 2201009, fax: +2202615

E-mail: mukeshbhardwaj4@gmail.com, avtarnadir@rediffmail.com

*Received: 14 October 2008 /Accepted: 19 January 2009 /Published: 26 January 2009*

---

**Abstract:** The EEG is composed of electrical potentials arising from several sources. Each source (including separate neural clusters, blink artifact or pulse artifact) forms a unique topography onto the scalp – ‘scalp map’. Scalp map may be 2-D or 3-D. These maps are mixed according to the principle of linear superposition. Independent component analysis (ICA) attempts to reverse the superposition by separating the EEG into mutually independent scalp maps, or components. MATLAB toolbox and graphic user interface, EEGLAB is used for processing EEG data of any number of channels. Wavelet toolbox has been used for 2-D signal analysis. *Copyright © 2009 IFSA.*

**Keywords:** Electro-encephalogram, Independent component analysis, ERP, EEG

---

### 1. Introduction

The paper is related to the study of EEG signal using EEG lab and wavelet toolbox. The EEG signal contains along with useful information showing cerebral activity, redundant or noise information. In order to conclude that something is wrong or the patients have a disease further processing is necessary.

EEG obtained from the scalp electrodes is a sum of the large number of neuron potentials. The interest is in studying the potentials in the sources inside the brain and not only the potentials on the scalp, which describe the brain activity. Direct measurements from the different centers in the brain require placing electrodes inside the head, which means surgery. This is not acceptable because of the risk of the subject. Signals of interest are calculated using EEG obtained on the scalp. These signals are weighted sums of the neuron activity, the weights depending on the signal path from the brain cell to

the electrodes. Because the same potential is recorded from more than one electrode signals, the signals from the electrodes are supposed to be highly correlated. Independent component analysis (ICA), sometimes referred to as blind signal separation or blind source separation, is a mathematical tool that can help in solving the problem. This is an extension of principal component analysis (PCA), which had been used in EEG research for years.

## **2. EEG Signal Pre - Processing**

One of the main problems in the automated EEG analysis is the detection of the different kinds of interference waveforms (artifacts) added to the EEG signal during the recording sessions. These interference waveforms, the artifacts, are any recorded electrical potentials not originated in brain. There are four main sources of artifacts emission:

1. EEG equipment.
2. Electrical interference external to the subject and recording system.
3. The leads and the electrodes.
4. The subject her/himself: normal electrical activity from the heart, eye blinking, eyes movement, and muscles in general.

Previous works have shown that the most severe of the artifacts are due to eye blinks and eyeball movements. A movement of the eyeball and the eyelids causes a change in the potential field because of the existing potential difference of about 100 mV between the cornea and the retina.

## **3. ICA of EEG Data**

Some simple neural network algorithms can blindly separate mixtures, of independent sources. On maximizing the joint entropy( $y$ ), of the output of neural processor minimizes the mutual information among the output components,  $y_i = g(u_i)$ , where  $g(u_i)$  is an invertible bounded nonlinearity and  $u=W_x$ , a version of the original sources.

ICA is suitable for performing blind source separation on EEG data because: (1) it is possible that EEG data recorded at multiple scalp sensors are linear sums of temporally independent components arising from spatially fixed, distinct brain or extra-brain networks, and, (2) EEG data by volume conduction does not involve significant time delays. In EEG analysis, the rows of the input matrix  $x$  are the EEG signals recorded at different electrodes, while the columns are measurements recorded at different time points.

### **3.1. Requirement of ICA**

EEG activity at different electrodes is highly correlated and thus contains redundant information. Also, several artifacts might be represented at the same set of electrodes and it would be useful if we could isolate and measure these artifacts. This is what ICA does.

## **4. Event Related Potentials (ERPs)**

Scalp-recorded event-related potentials (ERPs) are voltage changes in the ongoing electroencephalogram (EEG). These potentials are usually averaged to increase their signal/noise ratio relative to artifacts. Fig. 1 shows Artifact-laden EEG signal and yellow part indicates the portion which can be manually rejected. Fig. 2 shows an ERP image.

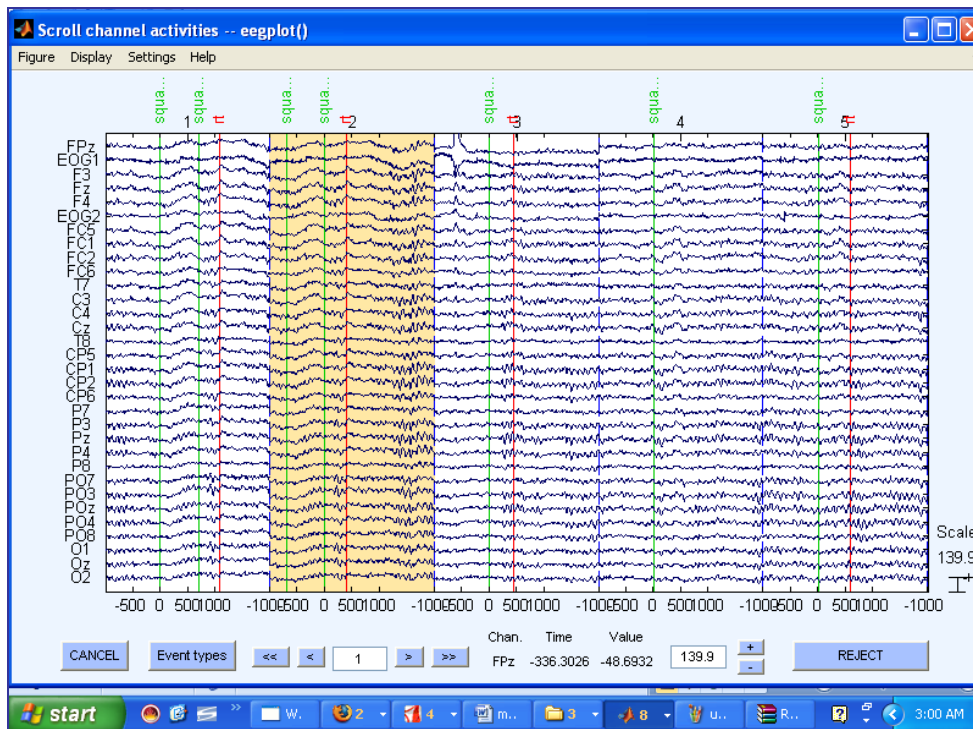


Fig. 1. Artifact-laden EEG signal. The yellow part indicates the portion which can be manually rejected.

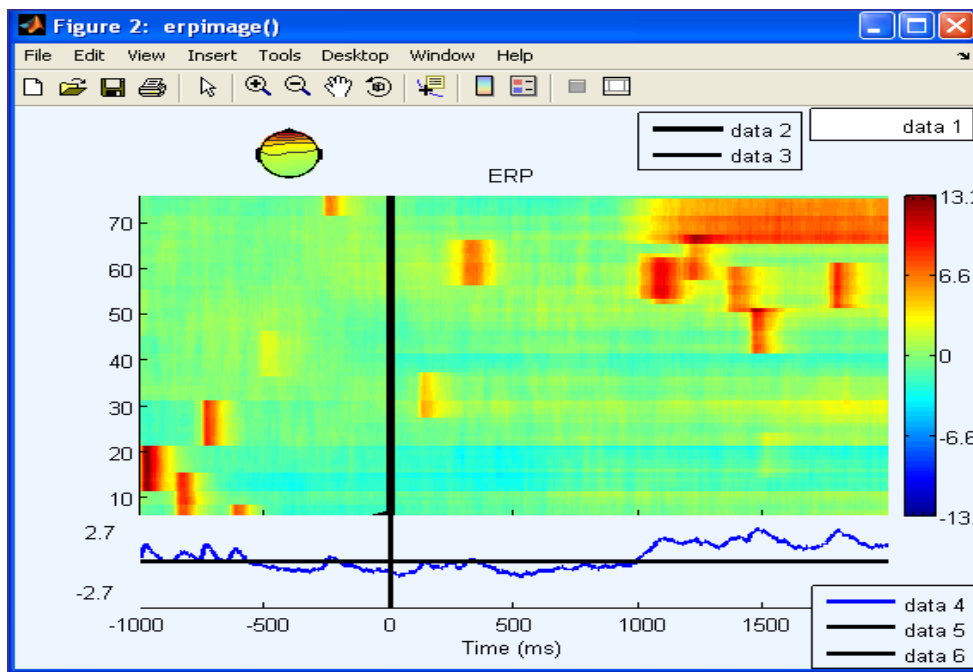


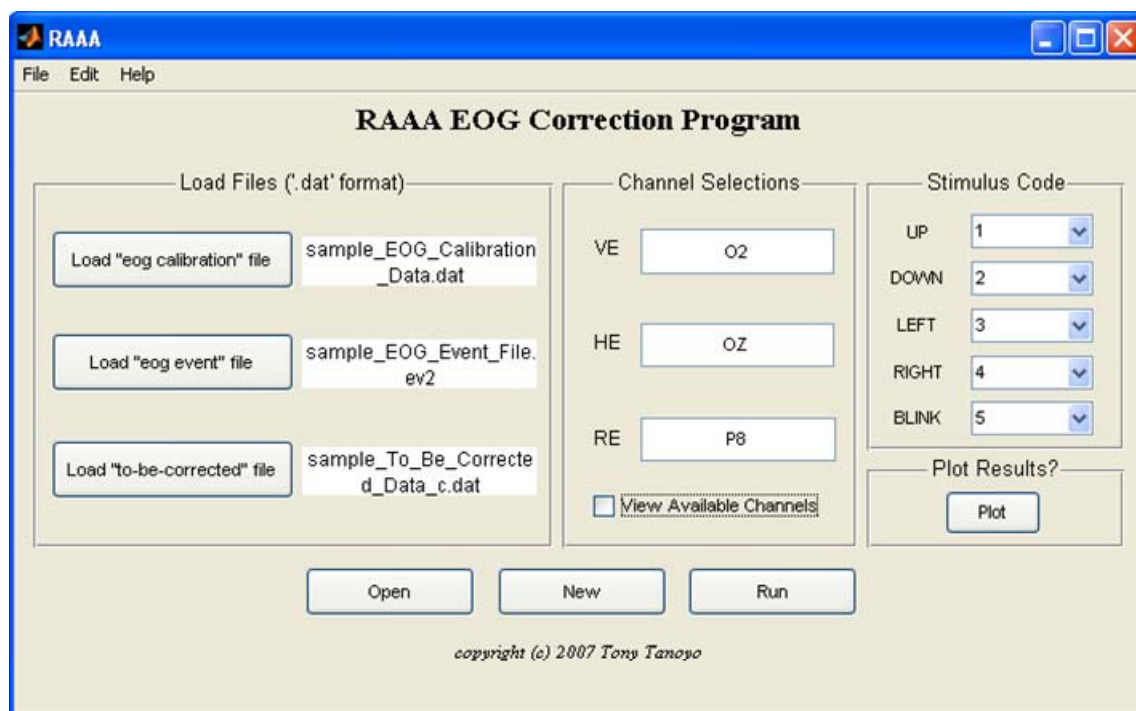
Fig. 2. ERP image.

## 5. Removing EOG Artifact from EEG Signal

RAAA EOG correction program has been used for EOG artifact removal from EEG signal. The purpose of this program is to work out the amount of ocular potential recorded by the electroencephalogram(EEG) and to subtract this from EEG. By doing this we are able to reduce the



effect of ocular potentials on the EEG, and this in turn increase the amount of usable data. RAAA EOG program window looks like as shown in Fig. 3.



**Fig. 3.** RAAA EOG program window.

For this program files required are:

- A. An 'EOG Calibration file
- B. An 'EOG Calibration Event' file
- C. A 'To-BE-Corrected' file

### 5.1. EOG Channels

In order to use this correction procedure, we need to have an EOG channel above (E1) and another below (E3) one of the eyes (these will be used to create vertical and radial EOG channels), and a horizontal EOG channel (which is the difference between 2 electrodes placed on the outer canthi of the eyes; HE). For the HEOG channel, this can be either the difference of the 2 electrodes, or else you can record the left (E5) and right (E6) channels separately and let the correction program do the subtracting. The reference for E1, E3, E5 and E6 should be the same as that used as the scalp reference (and if you generate an HE channel directly, rather than recording E5 and E6 separately, then the reference is irrelevant as this 'bipolar' montage is already referencing one electrode to the other). (Fig. 4). RAAA EOG program gives EOG corrected data at P4 electrode (Fig. 5).

## 6. EEG Lab

It is a toolbox and graphic user interface running under the cross-platform MATLAB environment for processing of EEG data of any number of channels. It can be used for EEG analysis through various plots as shown in Fig.6.

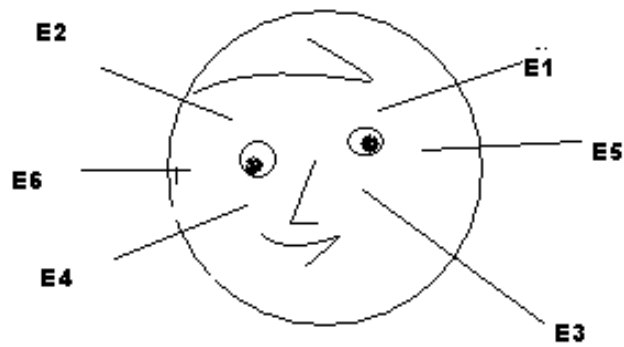


Fig. 4. EOG Channels.

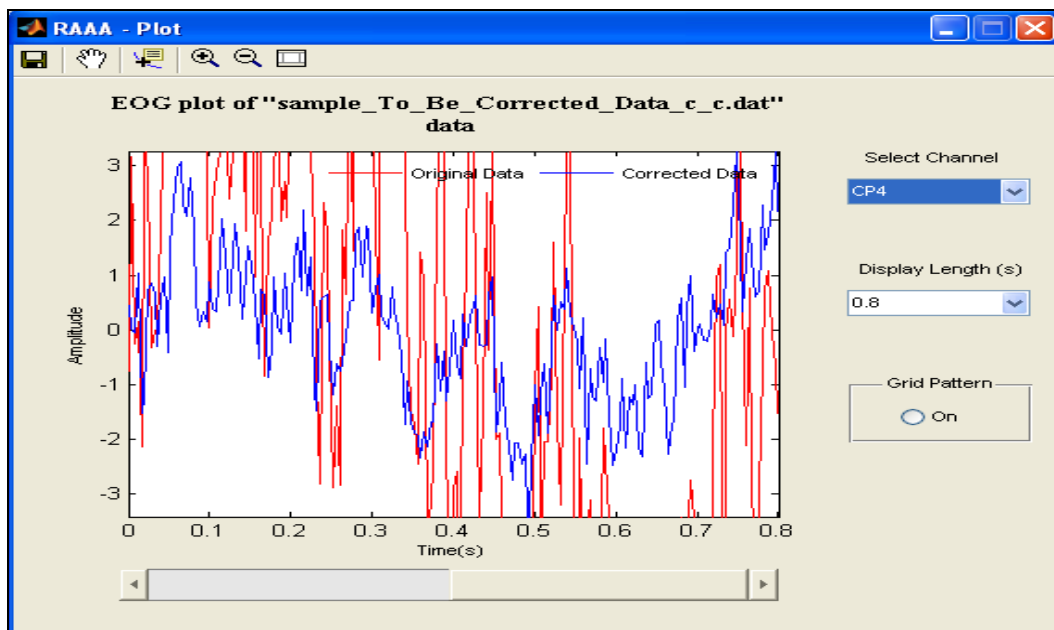


Fig. 5. Plot of EOG corrected data at CP4 electrode.

## 1. Basic functions

The ICA/EEG toolbox includes a collection of Matlab functions for signal processing and visualization of EEG data. ERP-image plotting, visualizing potential variations and time-frequency decomposition.

## 2. Data preprocessing

EEGLAB allows reading of data, event information, and channel location files in several different formats. EEGLAB is a completely interactive environment for processing EEG data under *Matlab*.

## 7. EEG Signal Classification

Traditional spectral analysis tools are not the best options to quantify the different oscillatory activities in the EEG, since the neural processes that generate the EEG are intrinsically dynamic. Indeed, there are transient changes in the power or peak frequency of EEG waves which can provide information of primary interest. The non-stationary nature of the EEG signals makes it necessary to use methods which are able to quantify their spectral content as a function of time. Time-frequency representation (TFR) methods are well suited as tools for the study of spontaneous and induced changes in oscillatory states.

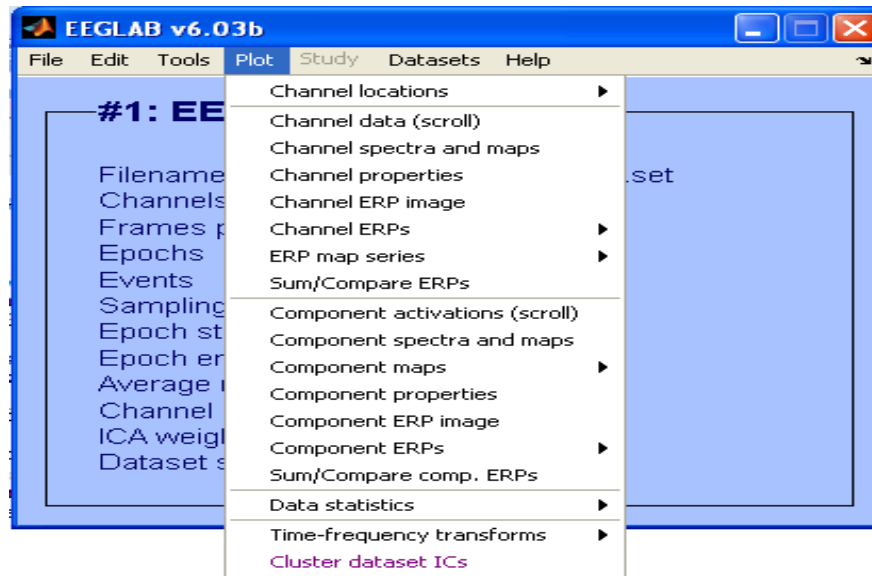


Fig. 6. Various plots which can be used for EEG signal analysis are shown in the menu.

## 8. Feature Extraction through Time – Frequency Analysis

### 8.1. Short-Time Fourier Analysis: The Spectrogram

The spectrogram is the squared magnitude of the windowed short-time Fourier transform. It considers the squared modulus of the STFT to obtain a spectral energy density of the locally windowed signal  $x(u)h^*(u - t)$ .

Thus, we can interpret the spectrogram as a measure of the energy of the signal contained in the time-frequency domain centered on the point  $(t, f)$ . In the image below (Fig. 7), the spectrograms of the five mental tasks are represented for the electrode P4, in order to see if there is an interclass variation big enough to classify them through this procedure.

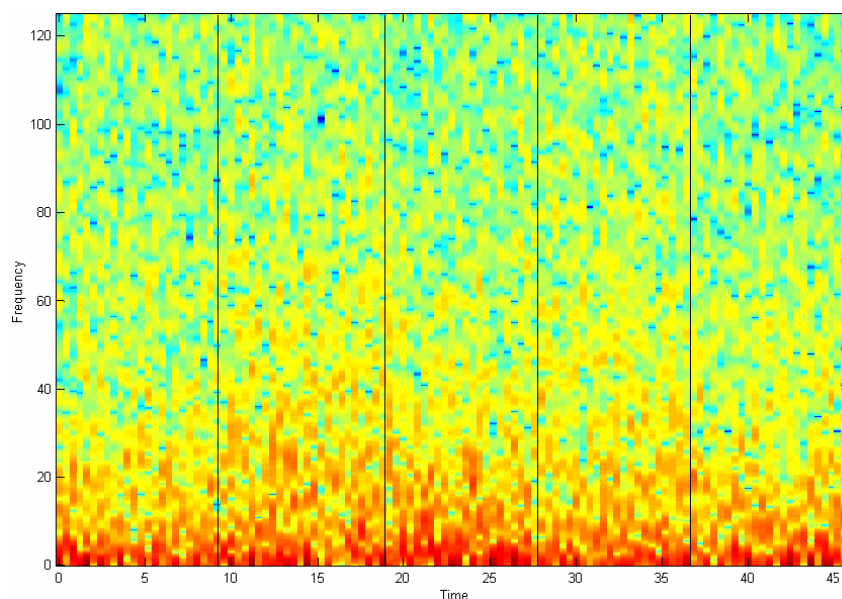


Fig. 7. Spectrogram for the different tasks P4 electrode is considered.

## 9. Discussions and Conclusions

The study proves that ICA/EEG lab is a powerful tool when the biomedical analysis involved more channels and EEGLAB toolbox can help in analysis and diagnosis of brain related disorders. Biomedical signals are non-stationary in nature so spectral analysis is not sufficient for modeling and analyzing biomedical (ECG, EEG, EOG or EMG) signal. Time-scale methods using wavelets can be better option for analysis. The wavelet toolbox of MATLAB software of Mathworks Inc. can decompose signal in better manner. Short-Time Fourier Transform (STFT) can also be better option. Spectrogram also gives good explanation.

## References

- [1]. M. Ungureanu, C. Bigan, R. Strungaru, V. Lazarescu, Independent Component Analysis Applied in Biomedical Signal Processing, *Measurement Science Review*, Vol. 4, Section 2, 2004.
- [2]. Arnaud Delorme, Scott Makeig, EEGLAB: An open source toolbox for analysis of single-trial EEG dynamics including independent component analysis, *Journal of Neuroscience Methods*, 134, 2004, pp. 9-21.
- [3]. A. Delorme, S. Makeig, T. Sejnowski, Automatic Artifact Rejection for EEG Data using high-order Statistics and Independent Component Analysis, <http://citeseer.ist.psu.edu/556350.html>
- [4]. RAAA EOG Correction help file.
- [5]. Jorge Baztarrica Ochoa, Gary Garcia, Molina., Touradj Ebrahimi, EEG Signal Classification for Brain. Computer Interface Applications, *Project Report*, Ecole Polytechnique Federale de Lausanne, 28 March 2002.

---

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

Two day IntertechPira conference plus expert pre-conference workshop

24 - 26 MARCH 2009  
COPTHORNE TARA HOTEL, KENSINGTON, LONDON, UK

# IMAGE SENSORS EUROPE 2009

NEW APPLICATIONS AND TECHNOLOGY INNOVATIONS

DON'T MISS THIS UNRIVALLED OPPORTUNITY TO FIND OUT ABOUT THE LATEST DEVELOPMENTS IN TECHNOLOGY AND APPLICATIONS ACROSS THE INDUSTRY!

THIS YEAR'S CONFERENCE WILL FEATURE OVER 20 NEW PRESENTATIONS FROM EXPERT ANALYSTS AND LEADING INTEGRATORS FROM ACROSS THE SUPPLY CHAIN.

IMAGE SENSORS EUROPE 2009 WILL GIVE YOU AN OPPORTUNITY TO EXPAND YOUR BUSINESS NETWORK AS WELL AS LEARN ABOUT TRENDS THAT MATTER TO YOUR BUSINESS.

TO BOOK NOW VISIT [WWW.IMAGE-SENSORS.COM](http://WWW.IMAGE-SENSORS.COM) OR CONTACT PAUL SQUIRES ON +44 (0)1372 802051 OR AT [PAUL.SQUIRES@PIRA-INTERNATIONAL.COM](mailto:PAUL.SQUIRES@PIRA-INTERNATIONAL.COM)

SUPPORTED BY

- PHOTONICS
- ADVANCED IMAGING
- sensors
- EUROPHOTONICS
- E-EDN
- IFSA

GET YOUR 20% DISCOUNT BEFORE 2 DECEMBER 2008!  
[WWW.IMAGE-SENSORS.COM](http://WWW.IMAGE-SENSORS.COM)

## 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)



**e-Impact Factor 2008:  
205.767**



## **Subscription 2009**

*Sensors & Transducers Journal (ISSN 1726-5479)  
for scientists and engineers who need to be  
at cutting-edge of sensor and measuring  
technologies and their applications.*

*Keep up-to-date with the latest, most significant  
advances in all areas of sensors and transducers.*

**Take an advantage of IFSA membership  
and save **40 %** of subscription cost.**

Subscribe online:

[http://www.sensorsportal.com/HTML/DIGEST/Journal\\_Subscription\\_2009.htm](http://www.sensorsportal.com/HTML/DIGEST/Journal_Subscription_2009.htm)

e-mail: [editor@sensorsportal.com](mailto:editor@sensorsportal.com)

tel. +34 696 06 77 16

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