

IEEE SENSORS JOURNAL

The IEEE SENSORS JOURNAL is published by the IEEE Sensors Council, which is sponsored by 26 IEEE societies (see the inside back cover). For information please visit <http://www.ieee-sensors.org>. *Member copies of Transactions/Journals are for personal use only.*

Editor-in-Chief

SANDRO CARRARA
École Polytechnique Fédérale
de Lausanne (EPFL)
Lausanne, CH-1015 Switzerland

Past Editor-in-Chief (2012-2018)

KRIKOR B. OZANYAN
Professor
Phonic Sensors and Systems
Univ. of Manchester
Sch. Elect. & Electron. Eng.
Manchester, M13 9PL U.K.

Past Editor-in-Chief (2009-2011)

EVGENY KATZ
Milton Kerker Chair
in Colloid Science Chemistry
& Biomolecular Sci.
Clarkson Univ.
Potsdam, NY 13699 USA

Past Editor-in-Chief (2003-2009)

H. TROY NAGLE
Professor
Electrical & Computer Engineering
NC State Univ.
Raleigh, NC 27695-7115 USA

Founding

Editor-in-Chief (2001-2003)

VLADIMIR LUMELSKY
Univ. of Wisconsin
Madison, WI 53706 USA

Editorial Board

Associate Editors-in-Chief

GERALD GERLACH
Dresden Univ. of Technol.
Inst. for Solid-State Phys.
01062 Dresden, Germany

Radiation Sensors

Topical Editor

LORENZO LO MONTE
Telephonics
USA

Sensor Systems Integration

Topical Editor

MEHMET YUCE
Monash Univ.
Victoria, Australia

Sensor Applications

Topical Editor

SUBHAS C. MUKHOPADHYAY
Macquarie University
Australia

Mechanical & Magnetic Sensors

Topical Editor
PAUL C.-P. CHAO
National Chiao Tung Univ.
Hsinchu, Taiwan

Chemical & Biosensors

Sensor Materials

Topical Editor
MICHEL J. VELLEKOOP
Physics & Elec. Eng.
Univ. Bremen
Bremen, Germany

Sensor System Networks

Topical Editor
KISEON KIM
Gwangju Inst. Sci. Tech.
Gwangju, 500-712 Korea

Sensor Phenomena and Modelling

Topical Editor

ZEYNEP CELIK-BUTLER
Univ. of Texas at Arlington
USA

Fiber Optic Sensors

Topical Editor

CARLOS RUIZ
Public University Navarra, Spain

Sensor Data Processing

Topical Editor

MARCO DA SILVA
Universidade Tecnológica
Federal do Paraná
Brazil

Sensor Interface Electronics

Topical Editor

STOYAN NIHTIANOV
Delft Univ. of Technol.
The Netherlands

Topical Editor-at-Large

JOHN R. VIG
Consultant
33 Bucks Mill Rd.
Colts Neck, NJ 07722 USA

LAURA ANITORI
laura.anitori@tno.nl
CAMILLA BARATTO
camilla.baratto@ino.it
GIUSEPPE BARILLARO
giuseppe.barillaro@unipi.it
DIEGO RUBÉN BARRETTINO
diego.barrettino@epfl.ch
ARINDAM BASU
arindam.basu@ntu.edu.sg
VENKAT R. BHETHANABOTLA
venkat@eng.usf.edu
VERDAN BILAS
Vedran.Bilas@fer.hr
ALPER BOZKURT
alper.bozkurt@ncsu.edu
AMITAVA CHATTERJEE
cha.ami@yahoo.co.in
PAI-YEN CHEN
pychen@wayne.edu
SHOUSHUN CHEN
ecchenss@ntu.edu.sg
CHENG-TA CHIANG
ctchiang@mail.ncyu.edu.tw
BHASKAR CHOUHEY
Bhaskar.Chouhey@eng.ox.ac.uk
WAN-CHOUNG CHUNG
wychung@pku.ac.kr
RAVINDER DAHIYA
Ravinder.Dahiya@glasgow.ac.uk

DANILO DEMARCHI
danilo.demarchi@polito.it
WEILEUN FANG
fang@pme.nthu.edu.tw
ALEXANDER FISH
afish@ce.bgu.ac.il
GIANCARLO FORTINO
g.fortino@unica.it
ELENA GAURA
e.gaura@coventry.ac.uk
BOBY GEORGE
boby@ce.iitm.ac.in
PANTELIS GEORGIU
pantelis@imperial.ac.uk
PROSANTA GOPE
prosanta.nitdgp@gmail.com
SILLAS HADJILOUCAS
s.hadjiloucas@reading.ac.uk
DONGSOO HAR
dshar@kaist.ac.kr
SHYQYRI HAXHA
shyqyri.haxha@beds.ac.uk
FRANK HINDLE
francis.hindle@univ-littoral.fr
AGOSTINO IADICICCO
iadicicco@uniparthenope.it
ZELJKO IGNJATOVIC
zeljko.ignjatovic@rochester.edu
TARIKUL ISLAM
tislam@jmi.ac.in

BERNHARD JAKOBY
bernhard.jakoby@jku.at
MEHDI JAVANMARD
mehdi.javanmard@rutgers.edu
OKYAY KAYNAK
okyay.kaynak@boun.edu.tr
TAN YEN KHENG
tanyenkheng@ieee.org
CHANG-SOO KIM
ckim@mst.edu
JURGEN KOSEL
jurgens.kosel@kaust.edu.sa
RICHARD T. KOUZES
richard.kouzes@pnl.gov
GIJS KRIJNEN
gijs.krijnen@utwente.nl
AIME LAY-EKUAKILLE
aime.lay.ekuakille@unisalento.it
SANG-SEOK LEE
sslee@ele.tottori-u.ac.jp
HUANG CHEN LEE
huclee@ccu.edu.tw
SHENG-SHAN LI
ssli@mx.nthu.edu.tw
YU-TE LIAO
yudoliao@nctu.edu.tw
JANICE LIMSON
j.limson@ru.ac.za
YU-CHENG LIN
yuclin@mail.nctu.edu.tw
NITAIGOUR MAHALIK
nmahalik@csufresno.edu

CARLOS MARQUES
carlos.marques@ua.pt
MAHMOUD MERIBOUT
mmeribout@pi.ac.ac
ROSARIO MORELLO
rosario.morello@unirc.it
RAVIBABU MULAVEESALA
ravi@iitpr.ac.in
ASHISH PANDHARIPANDE
pashish@gmail.com
MARCO PETROVICH
mnp@son.ac.uk
OCTAVIAN POSTOLACHE
octavian.postolache@gmail.com
IOANIOS RAPTIS
i.raptis@inn.demokritos.gr
FERRAN REVERTER
ferran.reverter@upc.edu
CHIRASREE ROYCHAUDHURI
chiroseepram@gmail.com
STEFAN RUPITSCH
stefan.rupitsch@lse.eui-eri-erlangen.de
PIOTR SAMCZYNSKI
psamczyn@elka.pw.edu.pl
THILO SAUTER
sauter@ict.tuwien.ac.at
KAZUAKI SAWADA
sawada@ce.tut.ac.jp
EDWARD SAZONOV
esazonov@eng.ua.edu

JOSEPH SHOR
joseph.shor@biu.ac.il
GYMAMA SLAUGHTER
gslaught@umbc.edu
PAUL SORTIADIS
pps@ieee.org
CHAO TAN
tanchao@tju.edu.cn
ZHICHAO TAN
zhichao.tan@analog.com
GUI YUN TIAN
g.y.tian@ncl.ac.uk
TAKASHI TOKUDA
tokuda@ms.naist.jp
KAGAN TOPALLI
kagan.topalli@gmail.com
DANIELE TOSI
daniele.tosi@nu.edu.kz
MARKO VAUHKONEN
marko.vauhkonen@uef.fi
CHANG-HEE WON
cwon@temple.edu
QIANG WU
qiang.wu@northumbria.ac.uk
SHANHONG XIA
shxia@mail.ie.ac.cn
EUI-HYEOK YANG
ehyang@stevens.edu
MINGHONG YANG
minghong.yang@whut.edu.cn
YING ZHANG
yzhang@gatech.edu

2018 IEEE Officers

JAMES A. JEFFERIES, *President*
JOSÉ M. F. MOURA, *President-Elect*
WILLIAM P. WALSH, *Secretary*
JOSEPH V. LILLIE, *Treasurer*
KAREN BARTLESON, *Past President*

WITOLD M. KINSNER, *Vice President, Educational Activities*
SAMIR M. EL-GHAZALY, *Vice President, Publication Services and Products*
MARTIN J. BASTIAANS, *Vice President, Member and Geographic Activities*
FORREST D. WRIGHT, *President, Standards Association*
SUSAN "KATHY" LAND, *Vice President, Technical Activities*
SANDRA "CANDY" ROBINSON, *President, IEEE-USA*

RENUKA P. JINDAL, *Director, Division I*

IEEE Executive Staff

STEPHEN P. WELBY, *Executive Director & Chief Operating Officer*

THOMAS SIEGERT, *Business Administration*
JULIE EVE COZIN, *Corporate Governance*
DONNA HOURLICAN, *Corporate Strategy*
JAMIE MOESCH, *Educational Activities*
JACK BAILEY, *General Counsel & Corporate Compliance Officer*
VACANT, *Human Resources*
CHRIS BRANTLEY, *IEEE-USA*

CHERIF AMIRAT, *Information Technology*
KAREN HAWKINS, *Marketing*
CECELIA JANKOWSKI, *Member and Geographic Activities*
MICHAEL FORSTER, *Publications*
KONSTANTINOS KARACHALIOS, *Standards Association*
MARY WARD-CALLAN, *Technical Activities*

IEEE Periodicals

Transactions/Journals Department

Senior Director, Publishing Operations: DAWN MELLEY

Director, Editorial Services: KEVIN LISANKIE Director, Production Services: PETER M. TUOHY

Associate Director, Editorial Services: JEFFREY E. CIOCHOCKI Associate Director, Information Conversion and Editorial Support: NEELAM KHINVASARA

Managing Editor: CHRISTOPHER PERRY Journals Coordinator: PATRICIA M. PENA

IEEE SENSORS JOURNAL (ISSN 1530-437X) is published semimonthly by The Institute of Electrical and Electronics Engineers, Inc. Responsibility for the contents rests upon the authors and not upon the IEEE, the Society/Council, or its members. **IEEE Corporate Office:** 3 Park Avenue, 17th Floor, New York, NY 10016-5997. **IEEE Operations Center:** 445 Hoes Lane, Piscataway, NJ 08854-4141. **NJ Telephone:** +1 732 981 0060. **Price/Publication Information:** Individual copies: IEEE Members \$20.00 (first copy only), nonmembers \$71.00 per copy. (Note: Postage and handling charge not included.) Member and nonmember subscription prices available upon request. **Copyright and Reprint Permissions:** Abstracting is permitted with credit to the source. Libraries are permitted to photocopy for private use of patrons, provided the per-copy fee of \$31.00 is paid through the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923. For all other copying, reprint, or republication permission, write to Copyrights and Permissions Department, IEEE Publications Administration, 445 Hoes Lane, Piscataway, NJ 08854-4141. Copyright © 2018 by The Institute of Electrical and Electronics Engineers, Inc. All rights reserved. IEEE prohibits discrimination, harassment and bullying. For more information visit <http://www.ieee.org/ nondiscrimination>. Printed in U.S.A.