

# Preface

Sensors play a key role in almost all the scientific advancements in the world. Successful operation of the engineering systems, from automotive engines to International space stations, is almost impossible to imagine without efficient and reliable sensors. Sensors are inevitable, for the operation and maintenance of various industries including automation, automotive, shipping, transportation, power, manufacturing, wood, and paper. With the advanced sensing techniques and processing/manufacturing technologies available today, the variety of sensors that are/can be realized and manufactured to sense vital parameters of any system which are of tremendous interest are plenty compared to the situation prevailed a decade back.

Output from any sensor or sensing element is converted into a usable and standardized form using a unit, typically, called as signal conditioning unit. In some cases, these are referred as interfacing or read-out circuits. This unit is present immediately after the sensing element, in a measurement system. In most of the cases, the raw signal from the sensing element can be as bad as noise signal. Unless processed correctly by a suitable interfacing unit, the sensor system will fail to work or perform unsatisfactorily. In addition, the interfacing unit plays an important role in exploiting the full capabilities of the sensing element. Thus, in general, the interfacing instrumentation is an integral part of any sensor system and a deep understanding of those schemes is a requirement for a scientist or instrumentation engineer who selects the appropriate interfacing circuit for a sensor that is of interest. This understanding will also help the reader to develop his/her own interfacing schemes with more useful features for an existing sensor or a new interfacing scheme that may be required for a new or an existing sensor.

The interfacing scheme can be an analogue electronics solution, a digital-based solution, or a mixed signal solution. Certain operations can be achieved effectively using analogue systems while a mixed signal approach is preferred in some other applications. There are interfacing schemes available, purely, using digital schemes/systems. Each one has its own advantages and disadvantages. This book will help the reader to acquire basics as well as advanced knowledge about the interfacing schemes for various sensors that are widely used. The book will also discuss the important signal processing techniques, certain sensing

applications, future trends that are worth to understand and follow for a sensing and instrumentation scientist. The book contains invited chapters from experts working in the field of sensors and instrumentation domain, presenting various aspects of sensors, advanced interfacing techniques for sensors and interesting applications. The book is organized as discussed below.

The book begins with a chapter that deals with the fundamentals of the measuring/sensing systems. This includes types of sensor systems, important performance characteristics, propagation of errors, statistical analysis of random error and transient and steady-state response of sensors. The above-mentioned topics presented in Chapter “[Sensors and Their Characteristics](#)” provide the necessary background information for those who are relatively new to the field. It helps others in clearing most of the possible ambiguity or doubts that may come out, in relation to some of the fundamentals of the measurement, while reading other chapters of the book.

Chapters “[Advanced Interfacing Techniques for the Capacitive Sensors](#)” and “[A Simple Embedded Sensor: Excitation and Interfacing](#)” deal with impedance sensors and interfacing circuits. Chapter “[Advanced Interfacing Techniques for the Capacitive Sensors](#)” introduces a few important sensors. Later, the advantages of the impedance sensors such as capacitive or inductive sensors over the resistive sensors are presented. The chapter also presents the design and development of a low-cost portable sensing system, which measures impedance of a capacitive sensor. In addition, some of the possible applications of the capacitive sensors are presented in Chapter “[Advanced Interfacing Techniques for the Capacitive Sensors](#)”. Chapter “[A Simple Embedded Sensor: Excitation and Interfacing](#)” concentrates more on different types of capacitive sensors and the interface electronics for instrumentation applications. Some of the advanced electronic circuits that combines the well-established bridge methods of measurement together with certain oscillator configuration for accurate interfacing of the perfect and the lossy capacitive sensors are discussed in Chapter “[A Simple Embedded Sensor: Excitation and Interfacing](#)”.

An interesting way to design low-cost but efficient digital measurement systems, for interfacing resistive sensors is presented in Chapter “[Advanced Techniques for Directly Interfacing Resistive Sensors to Digital Systems](#)”. The technique involves the use of relatively advanced techniques for direct connection of resistive sensors to the digital systems. The digital system measures the resistance with the help of an embedded digital timer that digitizes the charging/discharging time of an RC circuit formed by the resistive sensor and a known capacitor. The uncertainty sources involved in measurement and the performance, in some applications are discussed. Next, the chapter deals with the direct connection of resistive sensor arrays to field-programmable gate arrays, where different resistors of the array are measured in parallel through a set of timers that are running simultaneously.

Combination of sensors and IoT can provide very efficient sensing solutions that we, otherwise, would not have imagined. While the techniques for wireless internet connectivity for the sensor unit is relatively a solved problem, powering the node

and keeping the power requirement to ultra-low values remain challenging in many applications. Chapter “[Interfaces for Autarkic Wireless Sensors and Actuators in the Internet of Things](#)” presents various aspects of those challenges and possible solutions through ISO/IEC/IEEE 21450-2010 smart transducer standard.

Output from some of the sensors are very low and many times special techniques are required to improve the SNR at the final output. Chapter “[Lock-In Amplifier Architectures for Sub-ppm Resolution Measurements](#)” presents some of the effective schemes to recover sensor signals from noise. The fundamental limitations of the widely used lock-in amplifier technique are discussed in this chapter, followed by possible ways to enhance the performance to achieve high resolution measurements.

From here onwards, the reader will find the application-oriented chapters of the book. Chapters “[Biomedical Sensors and Their Interfacing](#)” and “[Interfacing and Pre-processing Techniques with Olfactory and Taste Sensors](#)” discuss some of the requirements in the healthcare domain and possible approaches to support or help the caregiver, to realize un-obstructive monitoring, etc. Chapter “[Biomedical Sensors and Their Interfacing](#)” presents schemes for continuous monitoring of patients in their normal activity. This includes real-time recognition of abnormal ‘events’ such as fall and unconsciousness. This is achieved with the help of autonomous sensor systems with necessary processors having the required computational capability. Chapter “[Interfacing and Pre-processing Techniques with Olfactory and Taste Sensors](#)”, in the similar lines, presents the challenges in un-obstructive monitoring of important parameters and possible solution through smart sensing systems. The sensor system discussed is compatible with IEEE1451 standard.

In Chapters “[Harnessing Vision and Touch for Compliant Robotic Interaction with Soft or Rigid Objects](#)” and “[IEEE1451 Smart Sensors Architectures for Vital Signs and Motor Activity Monitoring](#)”, interfacing challenges and solutions of couple of industrial applications are presented. Chapter “[Harnessing Vision and Touch for Compliant Robotic Interaction with Soft or Rigid Objects](#)” concentrates on the details of electronic nose and tongue. Basic principle, sensing mechanism, interfacing and pre-processing techniques, etc. employed for typical electronic nose and tongue are presented. Number of groups across the world are working in this domain. Chapter “[IEEE1451 Smart Sensors Architectures for Vital Signs and Motor Activity Monitoring](#)” presents the sensing issues and interfacing techniques to enable safe interaction of commercial-grade robot manipulators with objects exhibiting rigid or soft surfaces. The solution involves combination of vision and touch sensing techniques. Details of the proposed solutions and results of the experimental studies validating the usefulness are presented in the chapter.

We would like to express our deep appreciation to the distinguished authors of the chapters. The book has taken an interesting shape with valuable content, due to the expertise, professionalism and kindness of the contributed authors of this book. We are expecting that the readers will find the book very interesting, informative and enriching.

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Advanced Interfacing Techniques for Sensors  
Measurement Circuits and Systems for Intelligent  
Sensors

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(Eds.)

2017, XIV, 314 p. 193 illus., 121 illus. in color.,  
Hardcover

ISBN: 978-3-319-55368-9