IEEE Standard for a Smart Transducer Interface for Sensors and Actuators—Common Functions, Communication Protocols, and Transducer Electronic Data Sheet (TEDS) Formats

IEEE Instrumentation and Measurement Society

Sponsored by the
Technical Committee on Sensor Technology (TC-9)

IEEE
3 Park Avenue
New York, NY 10016-5997, USA

21 September 2007

IEEE Std 1451.0™-2007

Recognized as an
American National Standard (ANSI)

IEEE Std 1451.0™-2007

IEEE Standard for a Smart Transducer Interface for Sensors and Actuators—Common Functions, Communication Protocols, and Transducer Electronic Data Sheet (TEDS) Formats

Sponsor

Technical Committee on Sensor Technology (TC-9)
of the
IEEE Instrumentation and Measurement Society

Approved 9 August 2007

American National Standards Institute

Approved 22 March 2007

IEEE-SA Standards Board

Abstract: This standard provides a common basis for members of the IEEE 1451 family of standards to be interoperable. It defines the functions that are to be performed by a transducer interface module (TIM) and the common characteristics for all devices that implement the TIM. It specifies the formats for Transducer Electronic Data Sheets (TEDS). It defines a set of commands to facilitate the setup and control of the TIM as well as reading and writing the data used by the system. Application programming interfaces (APIs) are defined to facilitate communications with the TIM and with applications.

Keywords: actuator, application programming interface, communication protocol, network-capable application processor, sensor, smart transducer, transducer electronic data sheet, transducer interface module

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

2nd Printing 2 November 2007. A printing error for Equation (15) has been corrected.

Print: ISBN 0-7381-5597-7 SH95684
PDF: ISBN 0-7381-5598-5 SS95684

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. The IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. While the IEEE administers the process and establishes rules to promote fairness in the consensus development process, the IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards.

Use of an IEEE Standard is wholly voluntary. The IEEE disclaims liability for any personal injury, property or other damage, of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance upon this, or any other IEEE Standard document.

The IEEE does not warrant or represent the accuracy or content of the material contained herein, and expressly disclaims any express or implied warranty, including any implied warranty of merchantability or fitness for a specific purpose, or that the use of the material contained herein is free from patent infringement. IEEE Standards documents are supplied "**AS IS**."

The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation. When a document is more than five years old and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

In publishing and making this document available, the IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity. Nor is the IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing this, and any other IEEE Standards document, should rely upon the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position, explanation, or interpretation of the IEEE.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Comments on standards and requests for interpretations should be addressed to:

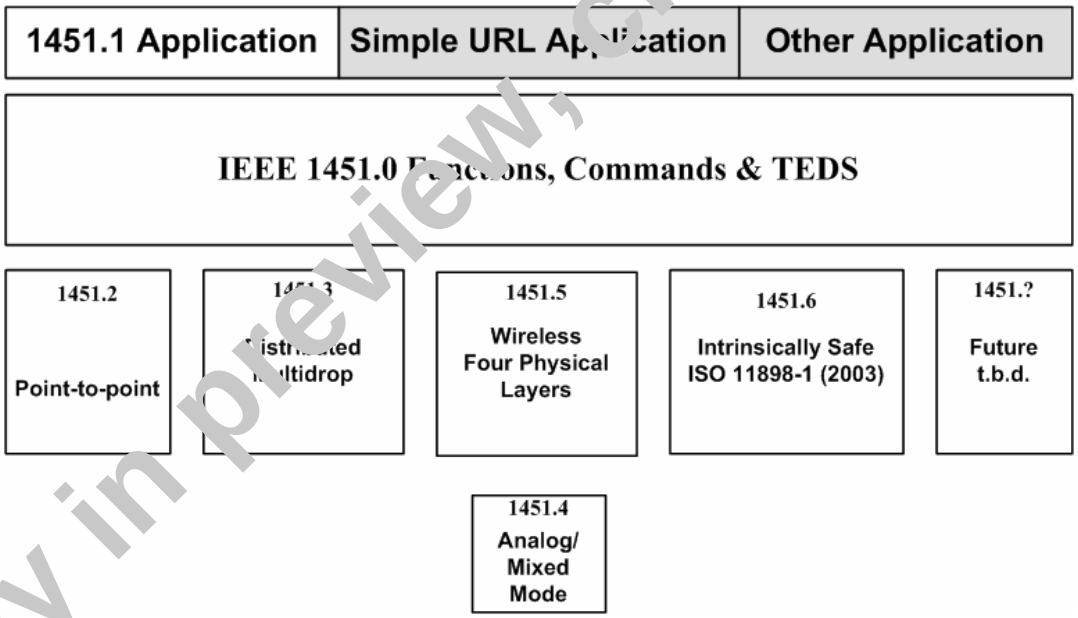
Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854
USA

Introduction

This introduction is not part of IEEE Std 1451.0-2007, IEEE Standard for a Smart Transducer Interface for Sensors and Actuators—Common Functions, Communication Protocols, and Transducer Electronic Data Sheet (TEDS) Formats.

This standard is intended to provide a basis for all future members of the IEEE 1451 family of standards that use digital interfaces. It should also be adopted by the existing members of the IEEE 1451 family of standards as they are revised in the future in order to provide the highest degree of compatibility among the members of the family. This standard does not apply to IEEE Std 1451.4™-2004, which only provides size-constrained TEDS and an analog interface.

The relationships between this standard and the other members of the family are shown in the following diagram. Three of these standards were complete before this standard was started and do not comply with this standard but will in the future as they are revised. They are IEEE Std 1451.1™-1999, IEEE Std 1451.2™-1997, and IEEE Std 1451.3™-2003. IEEE Std 1451.1 is an application that, in the future, will fit between the user's network and this standard. IEEE Std 1451.2 and IEEE Std 1451.3 will also be modified to interface with this standard. When these changes are made, the functions of an IEEE 1451 transducer will be as defined in this standard as will be the commands and TEDS. IEEE 1451.5™-2007, which uses any of several different wireless communications media, and IEEE P1451.6™ have been written around the functions, commands, and TEDS as described in this standard. IEEE Std 1451.4 uses an analog signal interface and a TEDS that is not the same as that used by the other members of the family. It may be used as the input to any of the other standards in the family but does not comply with the functions, commands, and TEDS defined in this standard. Items shown with a gray background are items that are not covered by any of the IEEE 1451 family of standards but that may be used.



The underlying purpose of this family of standards is to allow manufacturers to build elements of a system that are interoperable. To accomplish this goal, the IEEE 1451 family of standards divides the parts of a system into two general categories of devices. One is the network capable application processor (NCAP) that functions as a gateway between the users' network and the transducer interface modules (TIMs). The NCAP is a processor-based device that has two interfaces. The physical interface to the users' network is not specified in any of this family of standards. IEEE Std 1451.1 provides a logical object model for this

interface. Other applications may also be used at the manufacturer's discretion. The communications interface between the NCAP and the TIMs is defined in the remaining members of the family of standards. Different manufacturers may build the NCAPs and TIMs, and if both comply with this standard, they should be interoperable.

This standard provides a description of the functions that are to be performed by a transducer interface module or TIM. Provisions are made for a high level of addressing that is independent of the physical medium-level and low-level protocols that are used to implement the communications. It defines the common characteristics for all devices that implement the transducer modules. The timing of the acquiring or processing of the data samples is described. Methods of grouping the outputs from multiple transducers within one TIM are defined. Common status words are also defined.

A standard set of commands are defined to facilitate the setup and control of the transducer modules as well as to read and write the data used by the system. Commands are also provided for reading and writing the TEDS that supply the system with the operating characteristics that are needed to use the transducer modules. A method of adding manufacturer unique commands is included.

In addition, this standard provides formats for the TEDS. Several TEDS are defined in the standard. Four of these TEDS are required, and the remaining TEDS are optional. Some TEDS are provided to allow the user to define information and to store it in the TEDS.

This standard provides areas that are "open to manufacturers." It should be noted that any use of these areas may compromise the "plug-and-play" potential of controllers and TIMs.

Notice to users

Errata

Errata, if any, for this and all other standards can be accessed at the following URL: http://standards.ieee.org/reading/ieee/updates/errata/index.html. Users are encouraged to check this URL for errata periodically.

Interpretations

Current interpretations can be accessed at the following URL: http://standards.ieee.org/reading/ieee/interp/index.html.

Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims or determining whether any licensing terms or conditions are reasonable or non-discriminatory. Further information may be obtained from the IEEE Standards Association.

Participants

At the time this standard was submitted to the IEEE-SA Standards Board for approval, the Common Functionality and TEDS Working Group had the following membership:

Kang Lee, *Chair*
Victoria K. Sweetser, *Vice Chair*
Jay J. Nemeth-Johannes, *Secretary*
Lee H. Eccles, *Editor*
Jefferson B. Burch, *API Architect*

Pat Blakely
Murat Bog
Charles H. Jones
Edward Koch
Dan Maxwell
David B. Perrussel
Andrew Segal
Mallikarjun Shankar
Robert Sinclair
Eugene Song
Rich Valde
Larry Whipple
James J. Wiczer
Darold Wobschall

Other individuals who have contributed to this standard are as follows:

Thurston Brooks
Wayne Catlin
Baozhi Chen
Stephen Chen
Ryan Coleman
Ken Cornett
Phil Ellerbrock
Peter Flitner
Fernando GenKuong
Robert N. Johnson
Alice Law
Myung Lee
Larry Marshodi
Oren Mittle
Jay Warrior
Stan Woods

The following members of the individual balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

William J. Ackerman
Chris B. Bagge
Jefferson B. Burch
Juan C. Carreon
Danila Chernetsov
Keith Chow
Tommy P. Cooper
Matthew T. Davis
David B. Droste
Lee H. Eccles
Michael D. Geipel
Fernando Genkuong
Sergiu R. Goma
Patrick S. Gonia
Randall C. Groves
Ryusuke Hasegawa
Werner Hoelzl
Dennis Horwitz
Jens Hult
Robert N. Johnson
Charles H. Jones
Innocent Kamwa
Piotr Karocki
James G. Kinnerling
Edward Koch
Charles A. Lennon, Jr.
William Lumpkins
G. L. Luri
Joseph R. Marshall, Jr.
Gary L. Michel
Yinghua Min
Georges F. Montillet
Jerry R. Murphy
Jay J. Nemeth-Johannes
Michael S. Newman
Chris L. Osterloh
Howard W. Penrose
David B. Perrussel
Vikram Punj
Bogdan Seliger
Mallikarjun Shankar
Thomas M. Siep
Matthew L. Smith
Victoria K. Sweetser
Leroy O. Thielman
Stephen C. Webb
James J. Wiczer
Ernesto Jorge Wiedenbrug
Darold Wobschall
Derek T. Woo
Eric V. Woods
Oren Yuen
Janusz Zalewski

When the IEEE-SA Standards Board approved this standard on 22 March 2007, it had the following membership:

Steve M. Mills, *Chair*
Robert M. Grow, *Vice Chair*
Donald F. Wright, *Past Chair*
Judith Gorman, *Secretary*

Richard DeBlasio
Alex Gelman
William R. Goldbach
Arnold M. Greenspan
Joanna N. Guenin
Julian Forster*
Kenneth S. Hanus
William B. Hopf
Richard H. Hulett
Hermann Koch
Joseph L. Koepfinger*
John D. Kulick
David J. Law
Glenn Parsons
Ronald C. Petersen
Tom A. Prevost
Narayanan Ramachandran
Greg Ratta
Robby Robson
Anne-Marie Sahazizian
Virginia C. Sulzberger
Malcolm V. Thaden
Richard L. Townsend
Howard L. Wolfman

*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Satish K. Aggarwal, *NRC Representative*
Alan H. Cookson, *NIST Representative*

Jennie M. Steinhagen
IEEE Standards Program Manager, Document Development

Norma B. Davis
IEEE Standards Program Manager, Technical Program Development

Contents

IEEE Standard for a Smart Transducer Interface for Sensors and Actuators—Common Functions, Communication Protocols, and Transducer Electronic Data Sheet (TEDS) Formats

1. Overview

This standard introduces the concept of a transducer interface module (TIM) and a network capable application processor (NCAP) connected by a media specified by another member of the IEEE 1451 family of standards. A TIM is a module that contains the interface, signal conditioning, analog-to-digital and/or digital-to-analog conversion and, in many cases, the transducer. A TIM may range in complexity from a single sensor or actuator to units containing many transducers (sensors and actuators). An NCAP is the hardware and software that provides the gateway function between the TIMs and the user network or host processor. Another member of the standards family provides the communications interface between an NCAP or host processor and one or more TIMs. Three types of transducers are recognized by this standard. They are sensors, event sensors, and actuators.

A transducer is denoted "smart" in this context because of three features:

— It is described by a machine-readable Transducer Electronic Data Sheet (TEDS).

— The control and data associated with the transducer are digital.

— Triggering, status, and control are provided to support the proper functioning of the transducer.

An NCAP or a host processor controls a TIM by means of a digital interface medium. The NCAP mediates between the TIM and a higher level digital network and may provide local intelligence.

This standard defines an application program interface (API) for applications that provide communications between the users' network and the IEEE 1451.0 layer. An API is also provided between the IEEE 1451.0 layer and the underlying physical communications layers usually referred to in this standard as IEEE 1451.X. These API definitions are provided for systems that have visible interfaces. For TIMs and