

## LabWeb1451: Remotely Accessible Virtual Laboratory for Transducer Electronic Data Sheets Creation and Testing

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**Abstract** – In this paper the realization of a Virtual Remote Laboratory (LabWeb1451) for developing and testing electronic datasheets (TEDS.4) compliant with the recent standard IEEE1451.4 for plug and play sensors, is discussed. The Virtual Lab is a web-based resource for students and researchers working in the sensor field: it consists of a set of software components implemented to support the development of a TEDS.4 database for resistive sensors and to experiment new generation of sensors compliant with IEEE1451.4.

**Keywords** – IEEE1451, TEDS, gas sensors, Web-based Education, Virtual laboratory.

### I. INTRODUCTION

In the research field, it is well known the necessity of versatile measurement systems allowing the easy changing of sub-parts, like sensing devices, as well as measurement methods. The opportunity to test prototype transducers of different technologies is also highly desired and of great utility [1] since e.g. it would allow the exchanging of prototype transducers between research groups. The main barrier to this requirement is the vast difference in the transducers conditioning electronics as well as the interfaces for data transferring that bring to the requirement of a new interface, or front-end electronics and the re-writing of the software. A solution is envisaged in the acceptance of a standard to allow interoperability of different transducer technologies, portability of software, and expandability to further technical advances. Such solution will bring to the availability of sensors assembled in plug-and-play modules containing the conditioning electronics, the sensor information in electronic format and a standard bus for data communication in a standard format. As one would expect, plug-and-play modules would allow developing auto-configurable systems, provided with the chosen standard bus and managed by standard software. Other positive consequences will be also for companies that would count on the preservation of the user's investment. The family standard IEEE 1451 [1-6], recently approved in various parts, provides the tools for developing plug-and-play transducers and it can be exploited also for gas sensors [7-8]. The main advantage of the standard is to provide the necessary information and tools to let companies and researchers to develop their own standard transducers with minimum efforts. In particular, the

standard IEEE 1451.4 permits to turn traditional analog transducers into plug-and-play devices by means of the Transducer Electronic Data Sheet (TEDS.4) as explained afterward. Likely, TEDS.4 are going to become popular and vastly used in novel plug-and-play measurement systems; many companies are already providing their ones that can be downloaded by Internet (many can be found in the National Instruments website [9]). The creation of such electronic datasheets will be also of high didactical interest by students. TEDSs.4 can be deduced from traditional datasheets, encouraging their understanding. Since students are usually bond to the university laboratories where instruments and licensed software are present, it would be of great usefulness a software instrument available worldwide allowing TEDSs.4 creation from a home-station. In fact, education through Internet technologies is gradually taking place [10-11 and reference therein] showing its usefulness; among the advantages we can count the possibility of the usage of virtual remote laboratories that allow students to operate from any part of the world and by using free software. Such instruments would also be of great value for researchers who necessitate creating TEDSs.4 for new experimental sensors, such as e.g. gas sensors. In this paper, remotely accessible virtual instruments (VIs) to create and test various types of TEDS.4 for web-based education are presented. A detailed description of the IEEE 1451 and 1451.4 can be found in [7], but we'll report hereafter a brief overview for the reader convenience.

#### A. IEEE1451.4

The purpose of the IEEE 1451 Standards for Smart Transducer Interface for Sensors and Actuators, is to define a set of common interfaces for connecting transducers to microprocessor-based systems, instruments, and field networks in a network-independent fashion [1]. At present, the IEEE P1451 family standard is divided into seven parts named IEEE P1451.0, IEEE 1451.1, IEEE 1451.2, IEEE 1451.3, IEEE 1451.4, IEEE P1451.5 and IEEE P1451.6 where P stands for Proposal since some parts are not yet approved. Details of various parts can be found in [1-7] and references therein. Here we focus on the part of our interest, the IEEE1451.4 [5]. IEEE 1451.4 (dot 4 from now on) defines a mechanism for adding self-describing behavior to

traditional transducers with an analog signal interface. The dot 4 defines the concept of a transducer that supplies both analog and digital interface, namely, mixed-mode interface (Fig.1). The analog electrical interface provides a signal reflecting the physical phenomenon (such as temperature, pressure, and force) in the traditional manner. The digital interface allows communicating with an embedded memory device (EEPROM) within the transducer in order to read/write the Transducer Electronic Data Sheet (TEDS) containing all the relevant transducer information.

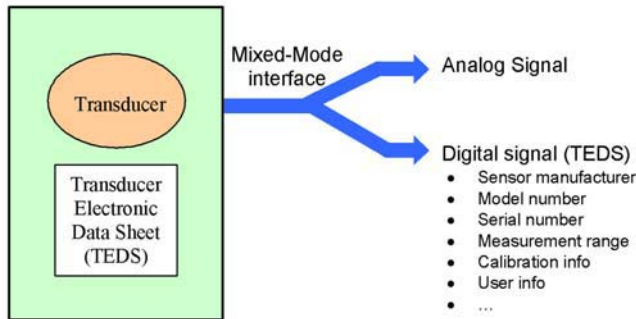


Fig. 1. - Smart Transducer Module with embedded TEDS.

Hereafter, we'll refer to TEDS as TEDS.4 to distinguish it from the TEDS defined by the sub-project IEEE1451.2 that is considerably different. Using the dot 4 directions, it is possible to implement TEDS.4 for virtually any type of amplified or unamplified sensor or actuator (thermocouples, RTDs, thermistors, bridge sensors, electrolytic chemical cells, 4-20 mA current loop sensors, etc.). In the cases where an EEPROM cannot be embedded within the transducer module, it is possible to store the TEDS.4 in a file, (*virtual TEDS*). The TEDS.4 structure is flexible and extensible to handle a wide range of sensor types and requirements and it is very compact allowing the saving of memory (less than 256 bits). The TEDS.4 is divided into four key sections: Basic TEDS, Template TEDS, Calibration TEDS and User Data. The first section is obligatory and the last three ones are optional. The main innovation of the TEDS.4 is related to the definition of a collection of standard Templates that are specific for each class of transducers. The templates provide the means for the measurement system to convert the TEDS binary data stored on a EEPROM or on a file into meaningful specifications for that sensor. Each template has a specific ID. Templates 25 through 39 are transducer-type templates that contain properties that are needed for the specific types of transducers. Example of template fields are: "maximum electrical output", "response time", "excitation level", "calibration date", "measurement location". Some fields are read only, while others can be written by the user. Standard templates allow specifying both the physical measurand and electrical value full scale precision with respective standard units. In some cases, it is possible to indicate the coefficients' resolution in order to reduce the TEDS.4 size. Templates 30, 31, and 32 are general purpose templates for voltage, current

and resistive output sensors respectively. Templates 40, 41, and 42 are calibration templates and can be used with one of the transducer-type templates. The Calibration Table Template (ID = 40) allows the inclusion of multiple data pairs to specify the input-output function of the sensor. The Calibration Curve Template (ID = 41) allows the specification of the input-output function of the sensor as a multi-segment, multi-polynomial curve. Finally, the calibration templates 42 (Frequency Response Table Template) allows the specification of the frequency response function of a sensor as a set of amplitude-frequency data pairs. Calibration templates 40 and 41 permit to apply data correction to physical measurand or to the electrical value. This allows the user to represent the acquired data with the correct units. For instance, by applying calibration to physical measure it is possible to convert the measured voltage sensor output to gas concentration.

## II. PROPOSED APPROACH

The choice of the programming language to create the remote laboratory was fallen in LabVIEW®, a graphical programming language by National Instruments [9], because

- the easiness of publishing interactive web-pages with virtual instruments that can be accessed with a browser such as Explorer;
- the availability of graphical tools;
- and the possibility to interact with such VIs at the only condition to install the Labview RunTime Engine 7.1 which is free and downloadable from National Instruments website [9] or from the virtual lab presented hereafter.

The last point can be seen as the only drawback of this approach since it forces the user to download a 23MB file (the RunTime Engine) and install it.

### A. LabWeb1451

The developed virtual laboratory to manage TEDSs defined by IEEE451.4 was named LabWeb1451 [[http://www.dii.unisi.it/~electron/lab/Tele\\_Lab/labweb1451index.htm](http://www.dii.unisi.it/~electron/lab/Tele_Lab/labweb1451index.htm)] and its index page is shown in Figure 2-top. From the index page, the user has the possibility to reach the instruction page on the functionality of the LabWeb1451, to read fundamental information of the standard IEEE1451.4 or, finally, to directly enter the page for the activities choice (Figure 2-bottom). The latter page lets the user to access to the proposed exercises and to run the TEDS builder VI or the LabWeb1451 to test the developed TEDS.4.

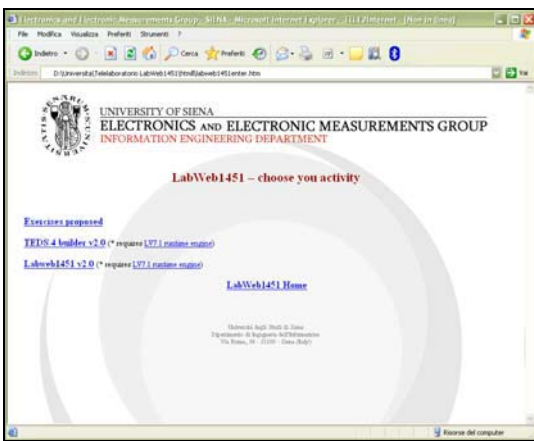


Fig. 2. – (top) Index page of the LabWeb1451; (bottom) Page for activity choice.

### III. RESULTS

As a result of this project we consider the implemented tools and the way they are used by students or other users interested in developing TEDS.4. In the website, various exercises are proposed for creation and test of TEDS.4, e.g. Resistive Temperature Detectors (RTD), bridge sensors and gas sensors. In particular, traditional datasheets are available by links, that can be used to fill the TEDS.4. In case of need, the solution of exercises is provided as a guide to use the VIs. Once the problem is comprehended, one can use the TEDS builder (Figure 3-top) to create the TEDS. All the templates for resistive sensors are implemented and each field of every template can be edited. Also data correction by using Calibration Template 41 for polynomial correction is available and selectable by a switch.

#### A. Example of creation and test of a gas sensor TEDS.4

In the example reported hereafter, related to a gas sensor, correction is applied to convert gas sensor resistance in butane concentration. The coefficients for the polynomial correction were extrapolated from the datasheet of a

commercially available gas sensor for butane detection (SB-15 by FIS Inc., Japan) and a second order polynomial curve was used to fit the data. A button allows the automatic creation of the TEDS that is printed on the bottom-right side window as a string of bits. That string can be copied and saved in a text file for subsequent use in LabWeb1451. The choice of printing the TEDS in a window as a string was due to the fact that LabVIEW doesn't allow to save files in a client PC but only on the server. The adopted solution overcomes this restriction by using the commonly used "copy and paste" approach. Once the TEDS is created, users could generate (e.g. with PSpice Student Edition) a simulated signal that is supposed to be generated by the sensor under study, mounted in a configuration proposed by the Standard. A raw data signal is also available on the proposed exercise page. The simulated signal, copied in a text file, can be pasted in the apposite window of LabWeb1451 while the TEDS is pasted in another one on the upper-left side of the window.

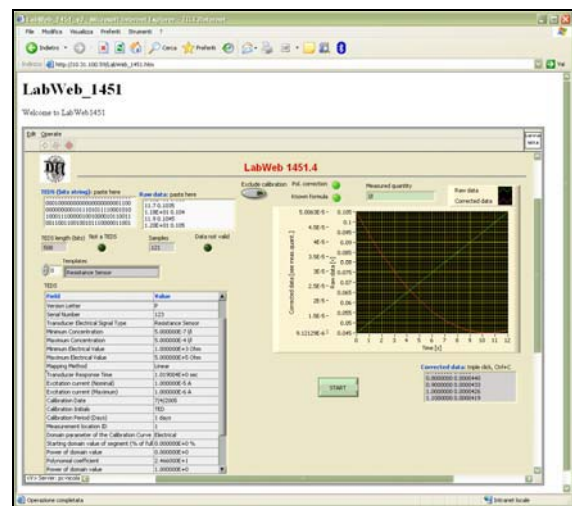
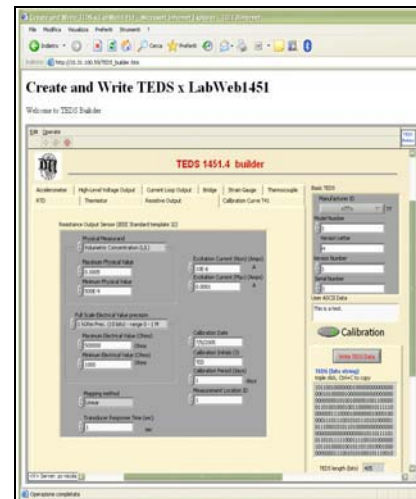


Fig. 3. – (top) webpage of the TEDS builder; (bottom) webpage of the LabWeb1451.

At this phase of the exercise, by pushing the Start button, it is possible to observe if the TEDS.4 is correctly recognized; in this case every sensor characteristic is shown in bottom-left side table. Above, the type of template is shown.

The graph shows both the raw and the correct data (concentration in the example in Figure 3-bottom) that is automatically evaluated from parameters from TEDS. Two Y axes with separated scales are associated to the two data. Above the graph, two leds indicate that LabWeb1451 knows how to evaluate data ('known formula') and when a polynomial correction is applied. In the example in Figure 3, the Template 32 for generic resistive output sensor is used; the 'known formula' to evaluate the sensor resistance is  $V_o/I_{nom}$  for this template, where  $V_o$  is the acquired voltage from a standard module (simulated data in his virtual lab) and  $I_{nom}$  is read from the TEDS and indicates the current that supplies the resistive sensor (gas sensor in this example).

The calibration is applied in this example to convert the electrical value in a physical quantity; the sensor resistance value is converted automatically in a gas concentration with unit l/l, that can be read on a text label next to the leds. It can be noted that the relationship between the acquired voltage and the gas concentration is not linear. Correction can be excluded by a switch, in order to observe the electrical values (sensor resistance in the reported example). Finally, on the bottom-right side, a text window allows to copy the corrected data for saving and successive elaboration.

#### IV. CONCLUSIONS AND FUTURE WORKS

The developed LabWeb1451 places the basis for a useful and versatile instrumentation to be used from students as well as researchers who experiments with new sensors. Exercises that will be developed during university courses will be inserted in the lab and they will contribute to the creation of a vast database of TEDS.4 for resistive sensors that will be available worldwide together with the LabWeb1451 for their managing. Since the possibility to easily modification of programs written in the LabVIEW environments, future works will be devoted to the addition of real sensors provided with EEPROM for real TEDS.4 storing and data acquisition. Anyhow, at this phase of the project, the LabWeb1451 as a tool for understanding and managing TEDS.4 is presented as the relevant part.

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