A Case Study: Application of the IEEE 1451.2 Smart Transducer Interface Standard to a Set of Product Requirements

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Introduction

In this paper, an application of the IEEE 1451.2 standard is described and key features from this standard are explained in terms of the application requirements and the standard's guidelines. Other papers in these proceedings summarize the IEEE 1451 family of interface standards and discuss the motivations behind developing smart transducer interface standards; this paper will focus on the IEEE 1451.2 standard [1].

An Application of IEEE-1451.2 – Network Enabled Equipment Monitor

For the application described here, a request was made to provide a networked monitor that could indicate the status of certain high-valued assets. Unfortunately, there were multiple categories of assets that provided different indicators of equipment status. The customer requested a single unit that could be used with six different types of sensors but all types of sensors should be processed to provide the same type of output – a utilization percentage. This percent utilization would indicate to the customer approximately what percentage of the workday this relatively high value asset (equipment) was in use. The requested output was to be provided as a unitless percentage indicating the asset utilization during the workday. Once the equipment monitor was attached to a specific target piece of equipment, the type of sensor used to indicate the "in-use" condition would be selected. A threshold setting for the selected "in-use" sensor would then be set-up for this target piece of equipment. The "Asset Utilization" value was then defined as the condition that occurs when the selected "in-use" indicating sensor exceeds the defined threshold value.

To Know TEDS is to Love TEDS

Part of the advantage of using the IEEE 1451.2 standard for this application is that the standard provides a uniform "Transducer Electronic Data Sheet" (TEDS) suitable for all six types of sensors specified for this application. The TEDS provides a mechanism to create a common data and sensor configuration structure for these six different types of sensors. The common structure helped us transform the sensor signal outputs from each sensor into the required "Asset Utilization" parameter. The TEDS also creates a uniform approach to accommodate timing differences, trigger differences, and other fundamental differences between the various sensors. By adhering to the data structures outlined in the IEEE 1451.2 standard, we were able to configure each sensor appropriately, and make changes as needed to the contents of the TEDS fields. The completeness of the TEDS definitions and TEDS data structures greatly assisted our efforts.

The Channel Transducer Electronic Data Sheet – Channel-TEDS – provides an opportunity to specify details about each of the six sensors including calibration coefficients, the details of the data format emitted from each sensor channel, physical units, valid data range, timing issues, and type of sensor. The meta-TEDS and meta-ID TEDS provides the ability to include global information about the entire unit including text descriptions, serial numbers, date of manufacture, timing issues and a substantial amount of other information.

The standard includes accommodations for various trigger modes and status bytes for reporting operational errors. In addition, if sensor data correction is needed, general-purpose, sensor-data, correction algorithms are specified in detail in this standard. The Calibration TEDS describes the details of the correction engine and how this can be applied.

The IEEE 1451.2 standard also includes a Smart Transducer Interface Module (STIM) description that, among other things, provides a set of "functional addresses" for software interfaces to the TEDS. These functional addresses provided a common, well-defined command interface for acquiring data and setting parameters.

Know When to Say Zero

Since the writers of this standard, tried to make a widely useful standard to cover many types of sensors, actuators, applications, networks, and processors, many of the TEDS fields will be zero for any given implementation. The "trick" for using these TEDS is to understand which fields are relevant for your application and which fields can be "zeroed". Of course, for different applications, different transducers fields will be utilized and therefore different fields will be zeroed. In fact, of the eight TEDS data structures defined in the IEEE 1451.2 standard, only two of these structures - the channel TEDS and the Meta TEDS - are required. The other six TEDS are essentially optional. The application of the smart transducer will determine the need to add any of the other TEDS or to leave them zeroed.

It's All in the Timing

The next most valuable aspect of this standard, is the description of how these commands, signals and digital communications all work together. IEEE 1451.2 contains several examples illustrating the interactions between the commands from the Network Capable Application Process (a generalized network interface unit) and the STIM. In developing a "real world" application, it is important to understand these timing requirements, but even more important to understand how different elements in the smart transducer respond when something go wrong. The IEEE 1451.2 standard contains several status registers that indicate various error conditions and are used to indicate a need to service (software or hardware) the smart transducer.

Network Details Go Away

One of the goals of the IEEE 1451.2 was to make the standard independent of the specific network to be used in the application. Although there are many great technical arguments for selecting any one of tens of different network standards, the goal of this standard is to abstract the details of the network into a separate functional block. This block, referred to as the Network Capable Application Processor – NCAP, is described only with respect to the hardware and software interactions with the STIM. No network interaction details are specified so that any device, compliant with any network, is allowed to function as a 1451.2 NCAP as long as the device behaves according to the standard regarding the STIM-NCAP interactions. Figure 1 shows a block diagram structure of the IEEE 1451.2 interface. Note that the objects to the left of the left side vertical dashed line and the objects to the right of the right side vertical dashed lines are not included in the standard.

A Network Enabled Equipment Monitor

Using the IEEE 1451.2 technology in a data acquisition and transducer characterization "engine", a network enabled equipment monitor was developed. This unit is schematically shown in Figure 2 followed by a photograph of the actual 6.75" x 2.5" x 8"(W x H x D) unit in Figure 3. This Network Enabled Equipment Monitor has some interesting features and can support several classes of applications. When analyzing this unit's features, it is apparent that the use of the IEEE-1451.2 is an underlying enabling technology.

For example, since text attributes for each sensor are stored in a modifiable Channel ID TEDS field, information can be customized as indicated by the user for each application. In addition, a unique threshold value to indicate the "in-use" condition can be associated with each sensor selected.

For this implementation, the Network Capable Application Processor was selected to be a micro-web server that includes a TCP/IP (Transmission Control Protocol/ Internet Protocol) stack and support for HTTP (HyperText Transaction Protocol) requests. This results in compatibility with HTML (HyperText Markup Language) type "web" pages to display data from this unit on the (essentially) universally available "Web Browser" software.

By providing an Ethernet type NCAP, the number of possible applications for this monitor is greatly enhanced compared with most other industrial network hardware/software solutions. To support this, the January 2001 issue of the IEEE Spectrum magazine had a section dedicated to industrial network connectivity [2]. One editorial predicted that by the year 2005, the "manufacturing and process control markets would be nearly 100 percent Ethernet …" Since the IEEE 1451.2 smart transducer technology does not care which outside world network is selected, Ethernet was initially selected for the NCAP for compatibility with the Internet. However, this selection did not exclude the possibility of later applying this same technology to other proprietary industrial control buses, should this prediction be in error.

By adhering to the standard representation for the IEEE 1451.2 TEDS, the resulting product includes "plug and play" like characteristics allowing the end-user to easily customize the product with end-user specific names, "in-use" sensor selection, and output screen display.

Due to the flexibility provided by the IEEE 1451.2 TEDS data structures and STIM command structures, the goals of this project were achieved. The initial product specifications requested that one of several different types of sensors should be able to be used to indicate the equipment "in-use" condition; the final product design fulfilled this requirement. This implementation of the IEEE 1451.2 technology accommodates a broad range of sensor inputs. The compatible types of sensors include the following: 1) 0-5 volt analog signal, 2) 0 –5 volt digital logic signal, 3) switch closure, 4) 4-20 milliamp analog signal, 5) a series of 0-5 volt pulses for event counting or frequency measurement, and 6) a type K thermocouple signal.

This allows the same monitoring unit to be applied to a broad range of equipment types and application categories and still provide essentially the same type of output – percent utilization. The applications for this type of unit can include the following: 1) up-time monitoring, 2) capital equipment resource allocation optimization, 3) supervisory "in-use" monitoring, 4) production output quantity monitoring, 5) preventive maintenance monitoring and more.

Conclusions

We have described an example of smart sensor device technologies applied to a real world problem – keeping track of the utilization of high-valued, capital assets. The design and development of the Network Enabled Equipment Monitor example described here utilized the key features of the IEEE 1451.2 smart sensor standard. These features include a set of sensor-specific electronic datasheet (TEDS), a set of smart transducer interface module (STIM) commands, and a NCAP compliant with several STIM-network interface functions. For the example described here, the selected NCAP served as a micro-web server and provided Ethernet-based, hypertext transaction protocol for Internet compatibility.

References

[1] IEEE Std 1451.2-1997, "IEEE Standard for a Smart Transducer Interface for Sensors and Actuators – Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats", IEEE Instrumentation and Measurement Society, TC-9 Committee on Sensor Technology, Institute of Electrical and Electronics Engineers, New York, N.Y., Sept. 1998.

[2] Kaplan, G., "Ethernet's Winning Ways", IEEE Spectrum, January 2001 vol. 38, #1, page 113 – 115

Brief Biography for James Wiczer

James Wiczer is the President of Sensor Synergy, Inc in Buffalo Grove, IL. Sensor Synergy develops custom and semi-custom software and hardware interfaces for sensors and actuators used in industrial automation and control applications. Prior to Sensor Synergy, Wiczer was the manager of the Microsensors R&D Dept. and before that he was manager of the Robotics and Automation Dept. - both at Sandia National Laboratories in Albuquerque, New Mexico. James received his PhD in Electrical Engineering from the University of Illinois in 1977 and has worked at Sandia National Labs between 1977 - 1994. Wiczer's activities at Sandia have included: sensor program development; research and development of sensors for automation and process control applications using ultrasonic, optical and capacitance phenomena; and the design and development of specialized optical detectors for adverse environments. Wiczer has published over 40 articles on his research and development work and has been awarded five patents on microimpedance imaging sensors and fluid quality sensors. Additional patents on networking sensors are pending. He is a member of the IEEE, Tau Beta Pi, and HKN.

Figure 1. Block Diagram of IEEE 1451.2 Smart Sensor Interface

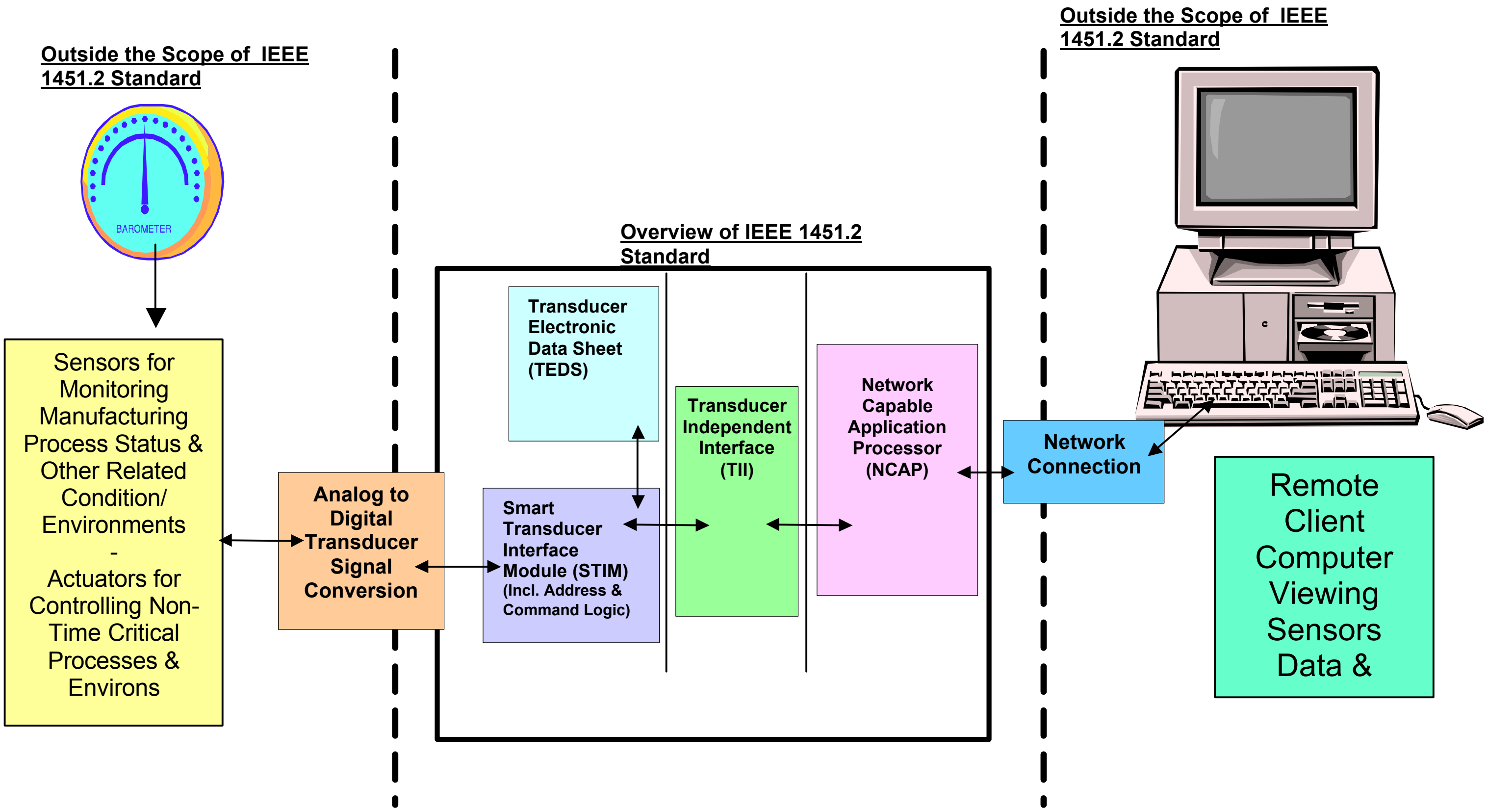

Figure 2. A Network Enabled Equipment Monitor Using IEEE 1451.2 technology to accommodate multiple types of “equipment-status indicating” transducers

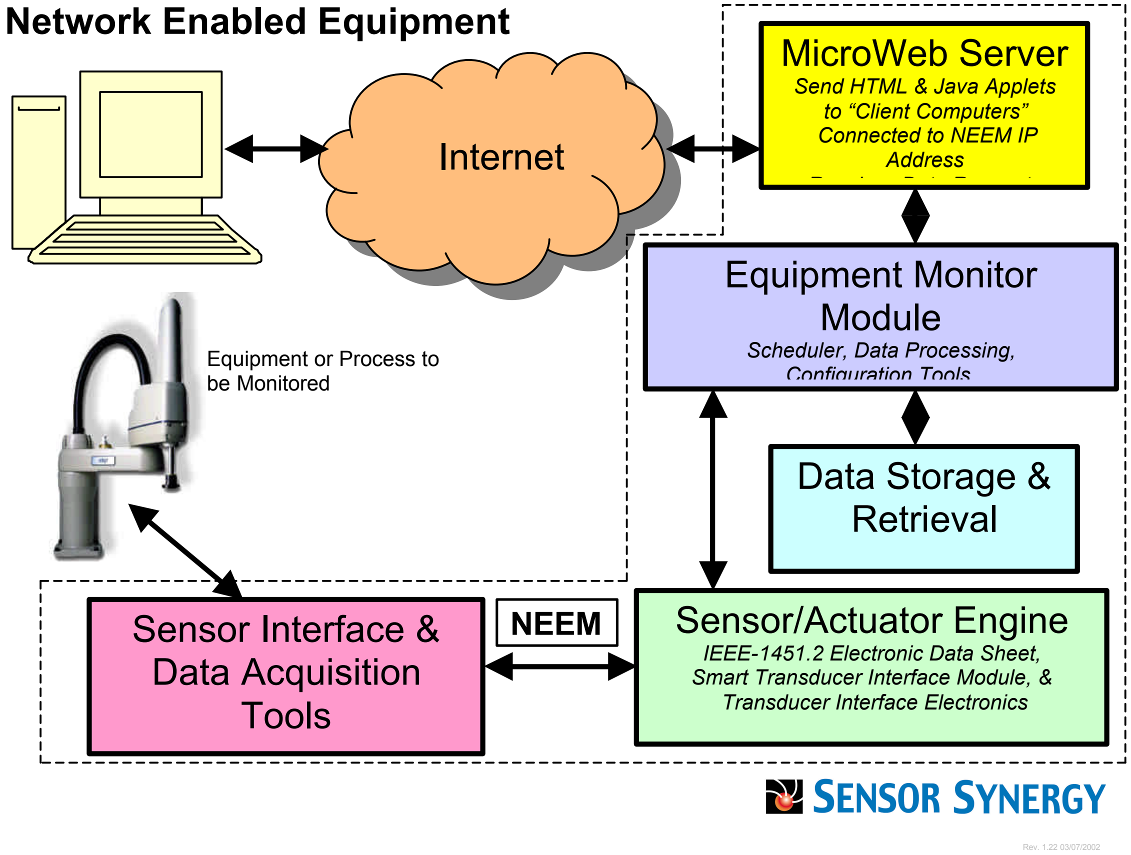

Figure 3. A photograph of the Network Enabled Equipment Monitor which internally uses the IEEE 1451.2 technology.