IEEE1451.2 Correction Engine Applications

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The recently approved standard, IEEE1451.2 [IEEE], defines an interface between transducers and microprocessors useful in industrial automation and other fields.

The standard defines a physical interface consisting of a data transport serial link, in addition to triggering, interrupt and hot swap signaling. The standard also defines a transducer electronic data sheet, TEDS, that describes the functionality of the transducer in machine-readable form. The interface supports as many as 255 independent transducer channels. These may be accessed individually or as a unit.

This report describes the use of the correction and calibration features of this standard to implement a variety of measurement functions.

1 Introduction

The recently approved standard, IEEE1451.2 [IEEE], defines an interface between transducers and microprocessors useful in industrial automation and other fields.

The standard defines a physical interface consisting of a data transport serial link, in addition to triggering, interrupt and hot swap signaling. The standard also defines a transducer electronic data sheet, TEDS, that describes the functionality of the transducer in machine-readable form. The interface supports as many as 255 independent transducer channels. These may be accessed individually or as a unit.

One portion of the TEDS defines correction coefficients to be used in converting the raw readings of the transducer into the appropriate form and units for engineering computations. This report describes this correction method and indicates how the mechanism may be used to accomplish a number of useful functions.

2 Brief description of a 1451.2 device

Figure 1 illustrates a typical device using the 1451.2 standard. The 1451.2 transducer, called a STIM, consists of the TEDS, the actual transducers, data converters, and addressing and control logic. (STIM is an IEEE1451.2 acronym for Smart Transducer Interface Module). The STIM works in conjunction with a microprocessor based interface to a communication network. This module, termed an NCAP in the standard, implements network access, the correction of raw data from the STIM and may include application specific data processing and control functionality. (NCAP is an IEEE1451.2 acronym for Network Capable Application Processor.)

The STIM may include as many as 255 independent transducers. The transducers may include a mixture of sensors and actuators. Each transducer channel is described in the TEDS. The TEDS description of each channel includes a set of correction coefficients. Corrections based on these coefficients may be applied to the raw transducer data either in the STIM itself or in the correction engine of the NCAP.

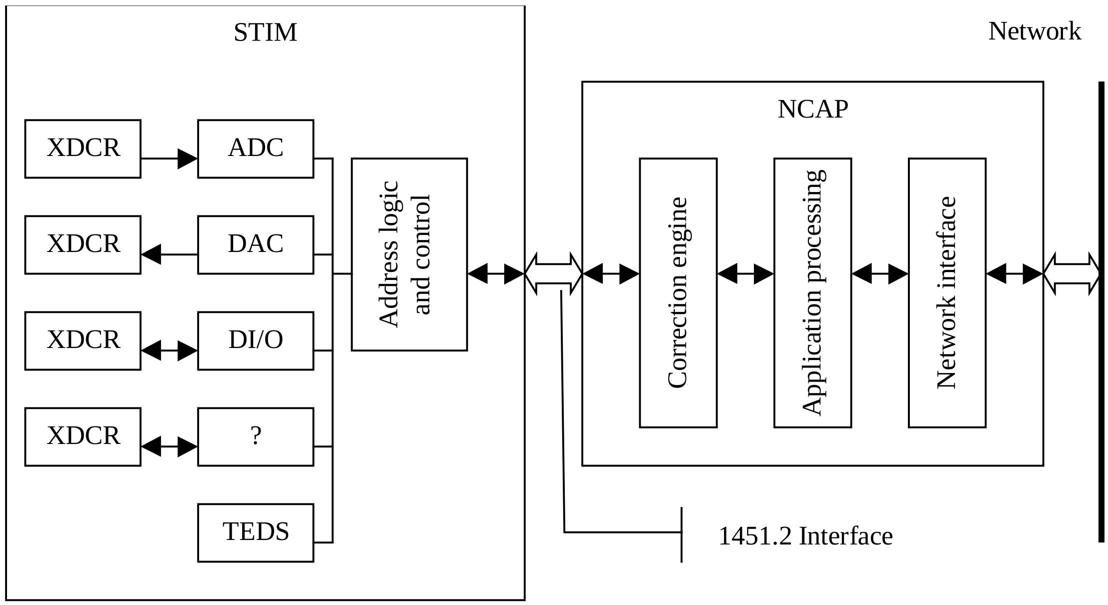

Figure 1

3 Correction model

The operational model for a STIM NCAP combination calls for the NCAP to read the TEDS information and to reconfigure itself appropriately. As part of this reconfiguration process, the channel correction coefficients are uploaded from the TEDS and made available to the correction engine of the NCAP. Conceptually the correction engine operates between a set of registers containing the raw transducer channel values and a set of registers containing application channel values expressed in the appropriate units. When new values for an actuator are provided by the application process the correction engine processes these into the appropriate raw form required by the actuators. Likewise, when new raw values are acquired from sensor, these values are corrected into the appropriate application ready values. This model is illustrated in figure 2.

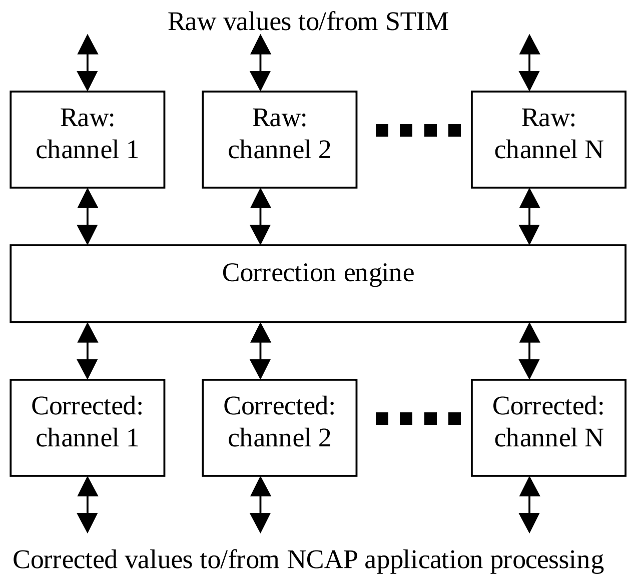

Figure 2

The correction function is defined by 1451.2 as a multinomial (multivariate polynomial) of the form shown in equation 1:

$$\sum_{i=0}^{D(1)}\sum_{j=0}^{D(2)}\cdots\sum_{p=0}^{D(n)} C_{i,j,\cdots,p}[X_1 - H_1]^i[X_2 - H_2]^j\cdots[X_n - H_n]^p \qquad \text{Equation 1}$$

Here the X_n represent the input variables to the correction engine, that is, raw values from sensors or application values for actuators. The H_n represent offsets to the input variables and the D(k) represents the degree of the input X_k , that is, the highest power to which $[X_k - H_k]$ is raised in any term of the multinomial. The $C_{i,j,\ldots,p}$ represent the correction coefficients for each term. D(k), H_n, and $C_{i,j,\ldots,p}$ are data obtained from the TEDS. In addition, the TEDS contains information defining the datatypes, units, whether a transducer is a sensor or an actuator, and other information necessary in configuring the correction engine.

The range of each input variable is segmented into regions effectively segmenting the space defined by all variables into regions. For each of these regions, the TEDS will contain a set of coefficients applicable to equation 1. An example of this segmentation is shown in figure 3 for the two-dimensional case.

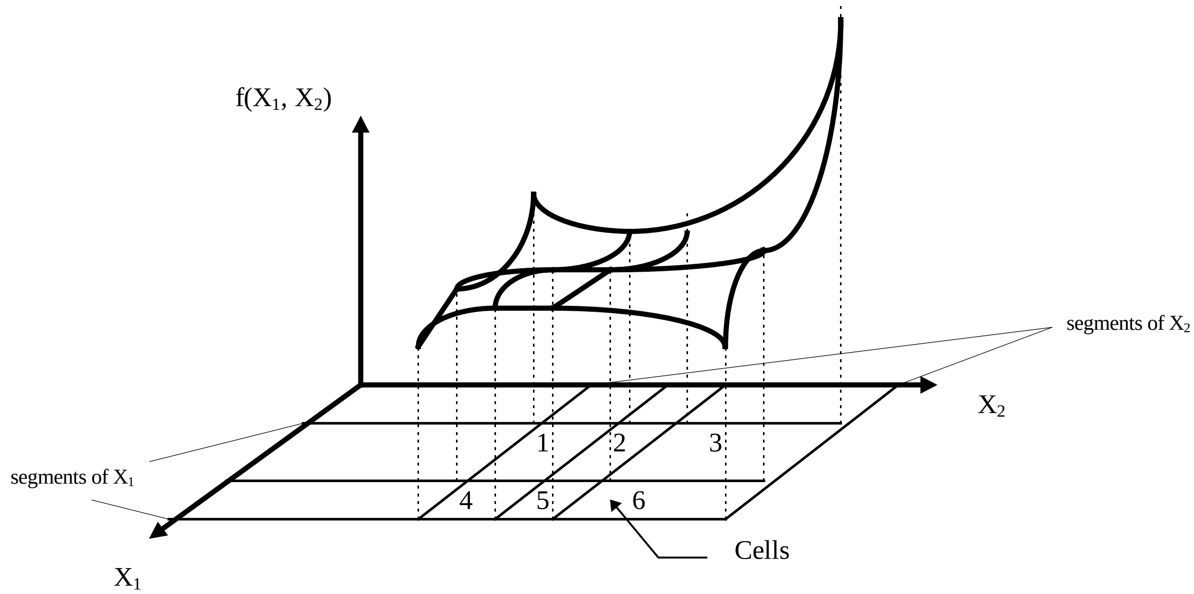

Figure 3

The purpose of the segmentation is to allow a trade-off between the granularity of the segmentation and the degree of the multinomial. For example, if the segmentation of figure 3 was fine enough to permit linear corrections in each cell, then the resulting multinomial for each cell would appear as in equation 2.

$$f(X_1, X_2) = C_{00} + C_{01} \bullet (X_1 - H_1) + C_{10} \bullet (X_2 - H_2) + C_{11} \bullet (X_1 - H_1) \bullet (X_2 - H_2)$$

Equation 2

With a segmented correction space, the correction first identifies the proper segment based on the input values and then uses the appropriate set of coefficients to apply the correction.

4 Conventional use of the correction model

The correction model was designed to allow the correction of a primary transducer for non-linear effects in the transducer itself and for the effects of other variables such as temperature on the transducer's behavior.

For example, a pH probe used to measure the pH of a solution typically has as an output a current. The translation of this output current into pH is non-linear and temperature dependent. By assigning the current probe itself to say the X_1 channel and a temperature sensor to the X_2 channel, a corrected value for pH can be computed. The useful range of the probe signal is segmented both in current and temperature dependence in such a way as to allow low order multinomial correction such as shown in equation 2. These coefficients are placed in the correct TEDS fields. These corrections are then part of the STIM and may be used by any NCAP that conforms to the correction model and the 1451.2 protocol. The application writer need not be concerned with the details of the correction.

The correction model is used in the same way to correct an actuator for some other variable such as temperature. The only difference is whether the inputs to the correction engine come from the application side or the transducer side. This distinction is also specified in the TEDS on a per channel basis.

5 Use of the correction model to implement auto-ranging

In many cases the wide dynamic range of the signals applied to signal conditioning circuitry processing the raw transducer signal must be ranged. Using well-known techniques, it is possible to design circuitry that automatically selects the appropriate input amplification or attenuation to keep the signals in an appropriate range for the electronics. If these ranges are assigned an index value that is made available as a STIM channel, then this value may be used in the correction process just as any other transducer output. Such a signal appears as a 'virtual sensor' to the correction process. If the range were set, rather than being auto-ranged, then the value would be an input and it would be a 'virtual actuator'. Here the term virtual indicates that the variable in question refers to some internal state of the STIM rather than directly reflecting some external aspect of the physical world.

In either case, the correction coefficients would be separately computed for each range of this 'virtual channel' and incorporated in the correction process. Equation 2 would have terms for three variables if the temperature corrected pH transducer also had an auto-ranging feature on the pH probe. In this case, the 'range' variable would be segmented such that each distinct range value occupied a single segment. The correction coefficients for the other two channels would appear exactly as before except that the actual values of the coefficients would depend on the value of the range virtual channel. The application writer would not need to manage any of the ranging corrections, they are all handled within the correction model.

Similar corrections to account for such features as adjustable bandwidth or other adjustable signal conditioning attributes can clearly be handled with the same technique.

6 Derived measurements using the correction model

Another use of the correction model is to derive secondary measurements from the primary measurements available from the individual channels. For example if two independent pressure transducers were assigned to channels 1 and 2, then a virtual channel, say 3, could be assigned to represent differential pressure. The channel is virtual because there is no actual differential pressure gauge. If in equation 2 the coefficients were assigned the values $H_1 = H_2 = C_{00} = C_{11} = 0$, $C_{10} = 1$, and $C_{10} = -1$, the equation would result in a computation in the correction engine producing the difference between channels 1 and 2.

This technique can be used for generating any derived quantity representable as a multinomial expression of primary values. Examples are power as the product of current and voltage and the absolute value of a quantity. Note that the absolute value example depends on the segmentation properties of the correction model.

7 Configuration dependent measurements using the correction model

The correction model may also be used to alter the computations and presentation depending on measurement configuration options detectable by the STIM. For example, a STIM with four voltage and current probes designed for three phase power measurements can be designed to determine whether the configuration is Wye or Delta and the phase order. The results of this determination may be presented as virtual channels. For each such configuration, a separate set of coefficients would be selected based on the segmentation these virtual channel values. This would allow not only variations in the computations, but presentation of the phases in the correct order.

8 Conclusion

The IEEE1451.2 standard is expected to be widely adopted in the industrial automation industry. The standard provides adequate descriptive information about a transducer to allow automatic configuration of applications using the transducer. The defined interface is quite flexible allowing up to 255 channels with provision for controlling the sample timing of the channels. In addition, the correction coefficients allow for calibration information to remain with the transducer rather than in a configuration file in some auxiliary computer.

The correction process may also be used to implement useful computations normally requiring special code in the users application specifically matched to the transducer.

9 Reference

[IEEE]: “IEEE1451.2 A Smart Transducer Interface for Sensors and Actuators-Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats”, IEEE Standards Department, 445 Hoes Lane, Post Office Box 1331, Piscataway, NJ 08855-1331