Sensor Plug & Play
The New Standard for Automated Sensor Measurement

The term "smart sensor" implies a sensor with more on-board intelligence than just a device capable of producing an analogue signal proportional to a measurand.

Some of the added intelligence may include a linearizing circuitry, look-up tables for cross talk, or temperature compensation tables. The latest in sensor added intelligence is "Transducer Electronic Data Sheet" acronymed as "TEDS".

An EEPROM imbedded in the sensor houses critical sensor information enabling plug-and-play operation. Hence a smart sensor with TEDS would thus have a mixed mode interface, the traditional analogue signal mode accessed by a typical signal conditioner or a data acquisition system, and the digital data flow from the EEPROM accessed by a low-cost serial link. Figure 1 is a block diagram depicting the concept of mixed mode interface used in plug-and-play sensors.

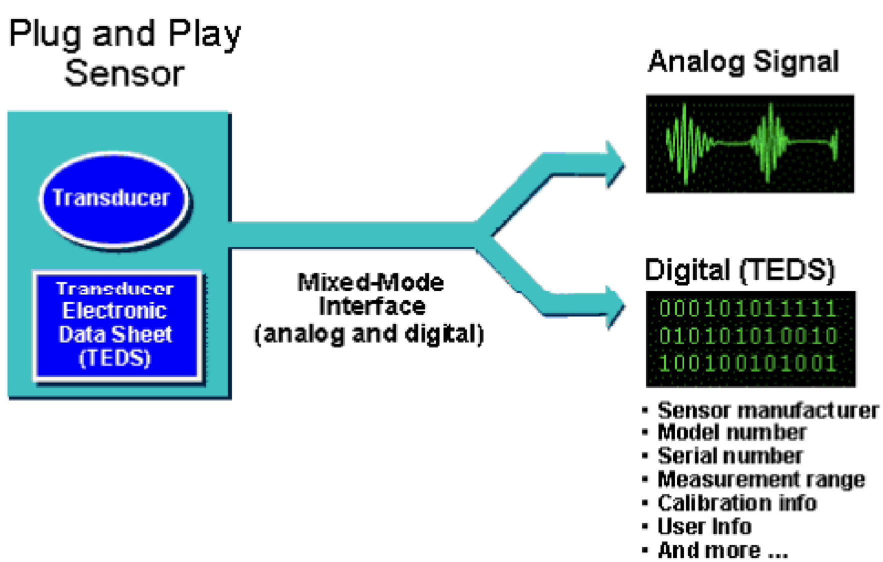


Figure 1- Mixed-Mode Interface of a Plug & Play Sensor.

The EEPROM contains the binary TEDS information that identifies and describes the sensor such as manufacturer, model number, serial number, range, sensitivity and calibration information. This information that used to be manually entered now would flow swiftly to the measuring software not only saving time but also increasing the general integrity and reliability of the measurement.

TEDS Structure;
The TEDS information is divided into three key sections;

- Basic TEDS; contains the required sensor identification information, including manufacturer, model number, and serial number, Table 1.
- Standard TEDS; contains the specific data typically needed to properly configure the electrical interface and convert the measurements into engineering units, e.g. measurement range, electrical output range, sensitivity, power requirements, and calibration data. This section defines everything needed to make a measurement using the sensor. Tables 2, 3 & 4
- User section; information regarding sensor location, calibration due date, etc can be entered in this section by the user.

Tables 1, 2, 3 & 4 are given in Appendix A.

TEDS Formats / Templates:
IEEE 1451.4 standard defines different formats/templates for different sensor types. The template provides a means for the measurement system to convert binary data stored in a smart TEDS sensor EEPROM into meaningful specifications for the sensor. The standard defines templates for accelerometers, thermocouples, strain gage sensors, etc with voltage or current outputs. Within these templates, manufacturers can also define custom sub templates that can be used instead of or in addition to standard templates.
Appendix B is a block diagram explaining the relationship between the templates, the TEDS information, the software and the final decoded data sheet of the sensor.
Appendix C is a typical paper calibration sheet normally shipped with a legacy sensor. Appendix D is screen capture of the same information as read by a TEDS software. Appendix D is only given to help envision the data stream processing. The main benefit of a TEDS capable sensor, is the ability of the associated Plug & Play hardware to process such information into scaling the sensor and minimizing the human intervention in the measurement process.

Class I Plug and Play Sensor Interface:
Class I interfaces are primarily intended for constant current powered transducers (piezoelectric) such as accelerometers and defines a scheme for sequentially switching between analog mode and digital TEDS mode. Figure 2 is a schematic of this interface.

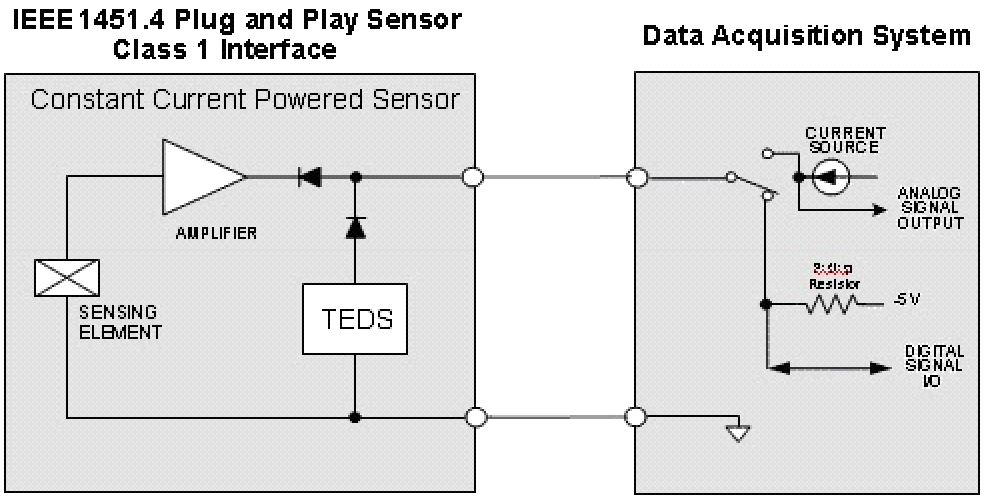


Figure 2- Class I Plug & Play Sensor Interface

Class II Plug and Play Sensor Interface:
Most sensor types implement a form of the class II interface, which requires two dedicated wires for digital TEDS communication. The 2-wire TEDS interface is added in parallel to the analogue interface. This method makes retrofitting existing sensors more convenient, whether the sensor has voltage or current, amplified or unamplified, outputs etc. Figure 3 is an illustration of this scheme.

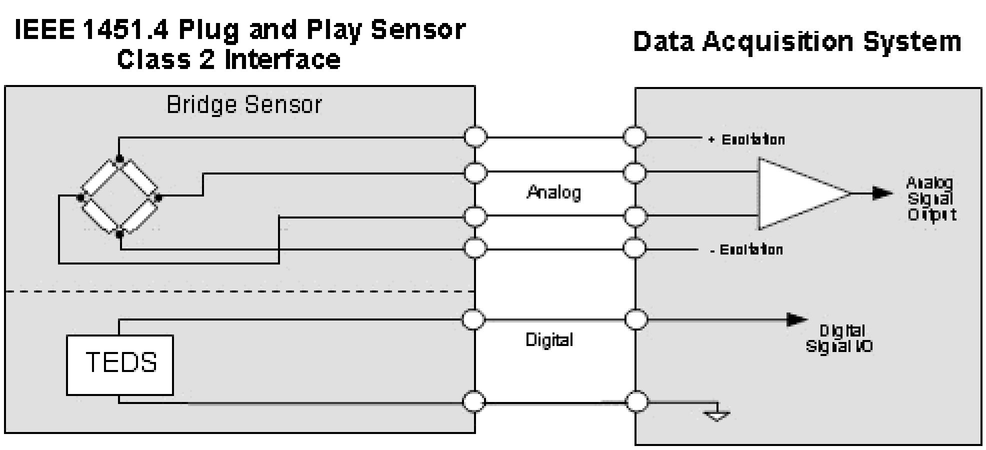


Figure 3- Class II Plug & Play Sensor Interface

Sensor Plug and Play Software & Hardware:
Any data acquisition and signal conditioning products that display the Sensors Plug&Play logo, are compatible with any other Sensors Plug&Play products. Figure 4 is a block diagram showing the components of a Sensors Plug&Play System.

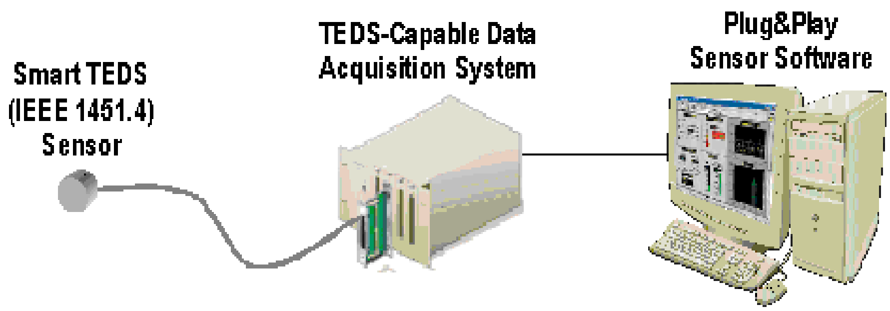


Figure 4- Components of Sensor Plug & Play System

While the EEPROM hosting the TEDS resides in the sensor, the software to read, write, or configure the TEDS resides in the computer of figure 4. One such software is "DAQmx" published by National Instruments. While compatible with their LabVIEW, NI also publishes a large library of free downloadable drivers to handle different types of sensors.

A useful piece of hardware offered by NI, is the LabVIEW PDA Module, a portable solution to reading and writing the TEDS of smart sensors. A add on to LabVIEW, the PDA Module allows to create executable files to run on a PocketPC or a Palm.

Software Requirements;

Application Software:	LabVIEW Base Package 7.1
Additional Software:	LabVIEW TEDS Library
Language:	LabVIEW

Hardware Requirements;

Hardware Group:	Multifunction DAQ (MIO)
Driver:	NI-DAQmx7.2
Additional Hardware:	LabVIEW PDA Module
	NI Sensor Plug & Play Hardware

SensorData also offers Sensor Plug & Play software compatible with IEEE 1451.4 and is customized to its products. This software handles the more intricate features of the product which are lost in the generalization of the currently available products.

Virtual TEDS;

To add a Sensor Plug & Play capability to an existing sensor that does not have an EEPROM memory to host the TEDS, SensorData provides the capability of downloading a virtual TEDS via the internet. Thus the large installed base of legacy analogue sensors can realize the benefits of TEDS without being retrofitted with an embedded EEPROM. Virtual TEDS files are also valuable in applications where sensor operating conditions prohibit the use of EEPROMs or any other electronics on board.

Figure 5 is a block diagram of a virtual TEDS application.

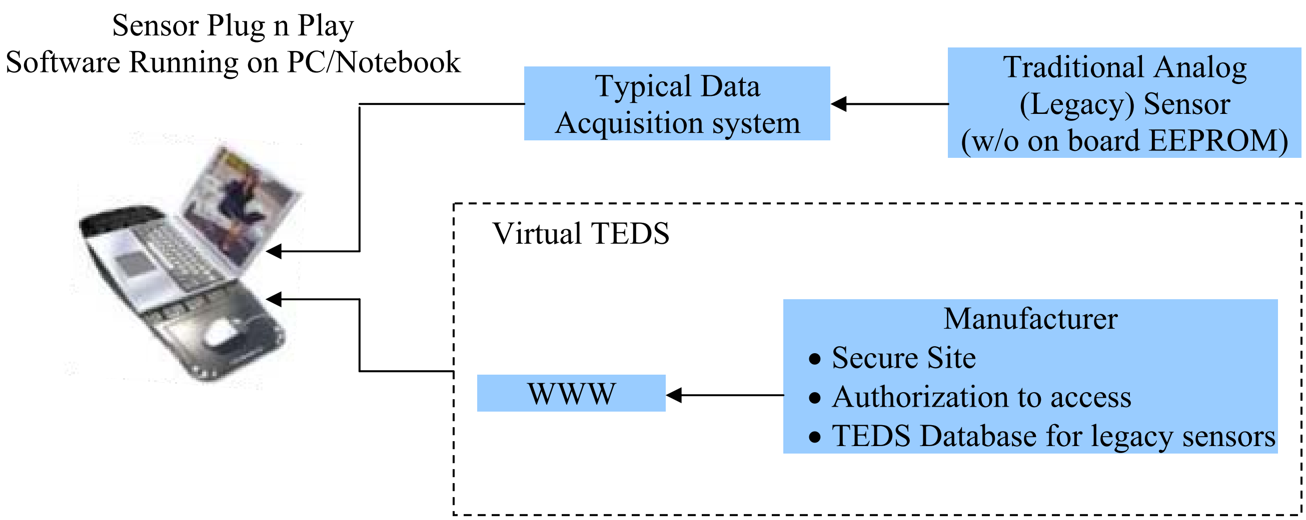


Figure 5- Using Virtual TEDS to upgrade a Legacy Analogue Sensor for Plug & Play operation.

Appendix A- IEEE 1451.4 Templates for Different Sensors

Table 1- The TEDS Structure

Basic TEDS (64 bits)		**Bit Length**	**Allowable Range**
	Manufacturer ID	14	17 – 16381
	Model Number	15	0-32767
	Version Letter	5	A-Z (data type Chr5)
	Version Number	6	0-63
	Serial Number	24	0-16777215
Standard and Extended TEDS	Selector (2 bits)		
	Template ID (8 bits)		
	Standard Template TEDS (ID = 33) Table 2		
	Selector (2 bits)		
	Template ID (8 bits)		
	Calibration TEDS Template (ID = 40) Table 3		
User Data			

Table 2- Enumeration of Select Case Values for "Physical Measurand (Units)

Case	Physical Units	Case	Physical Units	Case	Physical Units	Case	Physical Units
0	K	12	Pa	24	radian/s	36	gpm
1	°C	13	Psi	25	rpm	37	cfm
2	strain	14	Kg	26	Hz	38	l/min
3	microstrain	15	G	27	g/l	39	RH
4	N	16	m	28	kg/m^3	40	%
5	lb	17	mm	29	$mole/m^3$	41	Volts
6	kgf	18	in	30	mole/l	42	Volts rms
7	m/s^2	19	m/s	31	m^3/m^3	43	Amperes
8	ga	20	mph	32	l/l	44	Amperes rms
9	Nm/radian	21	fps	33	kg/s	45	Watts
10	Nm	22	radians	34	m^3/s		
11	Oz-in	23	degrees	35	m^3/hr		

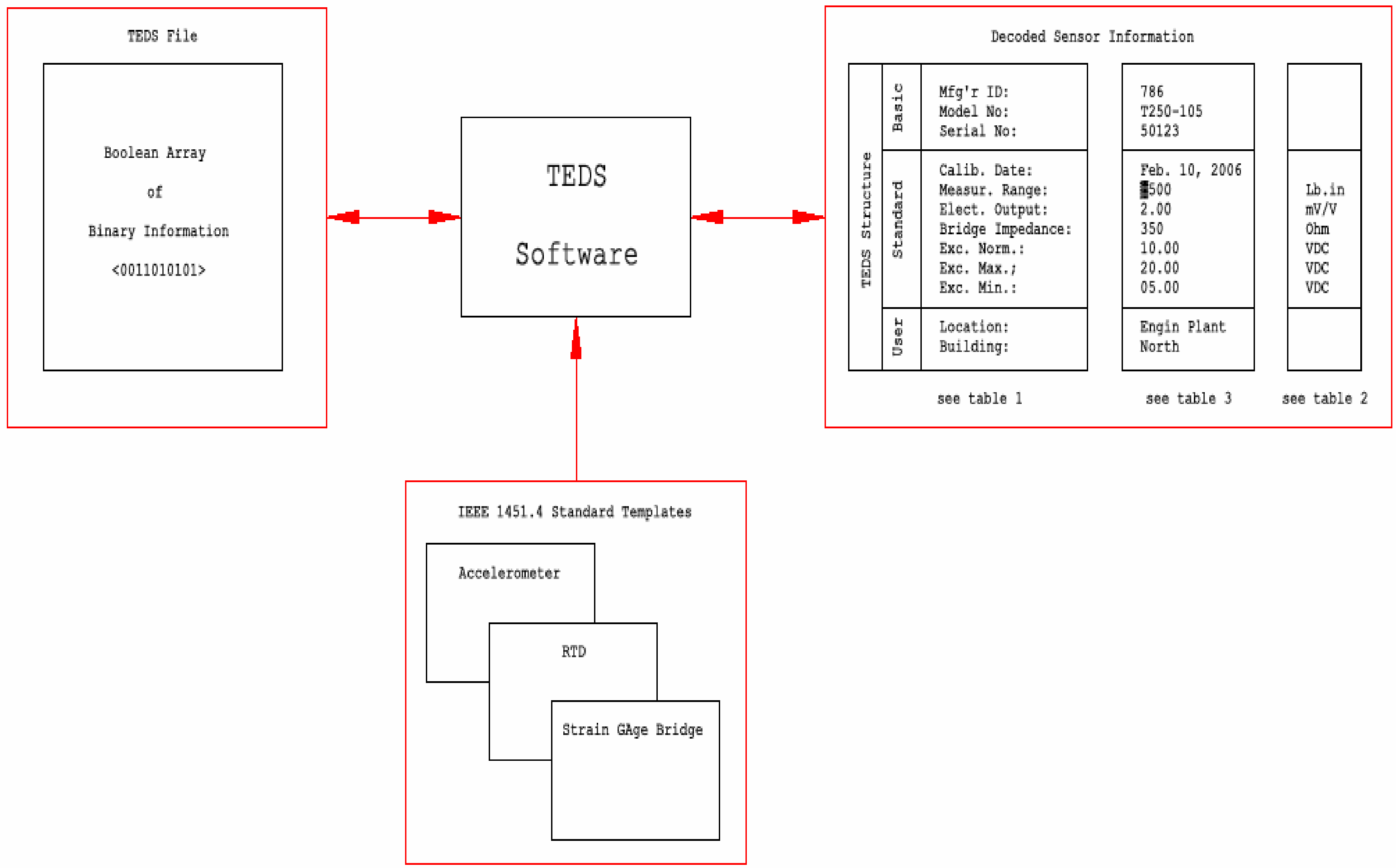
Table 3- Standard Template TEDS

Select	Property	Description	Access	Bits	Data Type (and Range)	Units
-	TEMPLATE	Template ID	-	8	Integer (value = 33)	-
-	%ElecSigType	Electrical signal type	ID	-	Assign = 3, "Bridge Sensor"	-
Select Case – Selects Type of Physical Measurand (Units)				6	Select Case	-
Cases 0 - 45	%MinPhysVal	Minimum physical value	CAL	32	Single	Various*
	%MaxPhysVal	Maximum physical value	CAL	32	Single	Various*
Select Case – Selects Full-Scale Electrical Value Precision				2	Select Case	-
Case 0 (11 bits)	%MinElecVal	Minimum electrical output	CAL	11	ConRes(±1E-3, step 1E-6)	V/V
	%MaxElecVal	Maximum electrical output	CAL	11	ConRes (±1E-3, step 1E-6)	V/V
Case 1 (19 bits)	%MinElecVal	Minimum electrical output	CAL	19	ConRes (±6.55E-3, step 25E-9)	V/V
	%MaxElecVal	Maximum electrical output	CAL	19	ConRes (±6.55E-3, step 25E-9)	V/V
Case 2 (32 bits)	%MinElecVal	Minimum electrical output	CAL	32	Single	V/V
	%MaxElecVal	Maximum electrical output	CAL	32	Single	V/V
-	%MapMeth	Mapping Method	ID	-	Assign = 0, "Linear"	-
-	%BridgeType	Bridge type	ID	2	Enumeration: Quarter |Half |Full	-
-	%SensorImped	Bridge element impedance	ID	18	ConRes (1 to 26.2k, step 0.1)	Ohms
-	%RespTime	Response time	ID	6	ConRelRes (1E-6 to 7.9, ±15%)	Seconds
-	%ExciteAmplNom	Excitation level, nominal	ID	9	ConRes (0.1 to 51.1, step 0.1	Volts
-	%ExciteAmplMin	Excitation level, min.	ID	9	ConRes (0.1 to 51.1, step 0.1)	Volts
-	%ExciteAmplMax	Excitation level, max.	ID	9	ConRes (0.1 to 51.1, step 0.1)	Volts
-	%CalDate	Calibration date	CAL	16	DATE	-
-	%CalInitials	Calibration initials	CAL	15	CHR5	-
-	%CalPeriod	Calibration period	CAL	12	UNINT	Days
-	%MeasID	Measurement location ID	USR	11	UNINT	-

* Units for %MinPhysVal and %MaxPhysVal are determined by value of Select Case "**Physical Measurand** (Units)" as summarized in **Table 2**.

Table 4- Calibration TEDS Template

Property	Description	Bits	Data Type (and Range)
TEMPLATE	Template ID	8	Integer (value = 40)
%CalTable_Domain	Domain parameter	1	Electrical or physical
STRUCTARRAY CalTable	Number of data pairs *(*n)	7	Size from 1 to 127
%CalPoint_DomainValue (0)	Domain Cal Point 0 (% of full span)	16	ConRes (0 to 100%, step 0.0015)
%CalPoint_RangeValue (0)	Range Cal Deviation 0 (% of full span)	21	ConRes (-100 to 100, step 1E-4)
%CalPoint_DomainValue (1)	Domain Cal Point 1 (% of full span)	16	ConRes (0 to 100%, step 0.0015)
%CalPoint_RangeValue (1)	Range Cal Deviation 1 (% of full span)	21	ConRes (-100 to 100, step 1E-4)
…	…		…
%CalPoint_DomainValue *(*n)	Domain Cal Point *n* (% of full span)	16	ConRes (0 to 100%, step 0.0015)
%CalPoint_RangeValue *(*n)	Range Cal Deviation *n* (% of full span)	21	ConRes (-100 to 100, step 1E-4)



Appendix B- The Overall Picture

Appendix C- Sample Calibration Sheet

SensorData

STRAIN GAGE TORQUE SENSOR CALIBRATION RECORD

"System Calibration"

MODEL NO.: T260-STD SERIAL NO.: 60285 CALIBRATION DATE: 31-Aug-06 TECHNICIAN: A.A./K.A.
PRINT DATE : 01-Sep-06 SUPERVISOR:

ACTIVE AXIS : "Mz"
RATED CAPACITY : 1000.00 Lb.in = 112.99 Nm

PERFORMANCE SPECIFICATIONS :

	CLOCK WISE	C. CLOCK WISE
RATED OUTPUT (mV/V):	5.0000	-5.0000
NON-LINEARITY (+/- % OF RATED OUTPUT):	0.0500	0.0400
HYSTERESIS (+/- % OF RATED OUTPUT):	0.0140	0.0240
REPEATABILITY (+/- % OF RATED OUTPUT):	0.05	
USABLE TEMPERATURE RANGE (°F):	-20 TO 220	
COMPENSATED TEMPERATURE (°F):	68 TO 200	
TEMPERATURE EFFECT ON ZERO (% OF R.O./°F):	+/- 0.001	
TEMPERATURE EFFECT ON SPAN (% OF R.O./°F):	+/- 0.001	

MECHANICAL SPECIFICATIONS :

CONTROL DOCUMENT - "SENSORDATA" DRAWING NO.: B10981
MAXIMUM SAFE OVERLOAD (WITHOUT ZERO SHIFT) : 200 % OF RATED CAPACITY
ULTIMATE LOAD (BRIDGE DESTROYED, STRUCTURE INTACT) : 300 % OF RATED CAPACITY

ELECTRICAL SPECIFICATIONS :

MEASUREMENT IS PERFORMED VIA BONDED FOIL STRAIN GAGES CONFIGURED INTO A "FULL" WHEATSTONE BRIDGE. WIRING IS DONE IN ACCORDANCE WITH THE "WESTERN REGIONAL STRAIN GAGE COMMITTEE" WIRING CODE (WRC). IF DIFFERENT, IT WILL BE STATED BELOW.

BRIDGE RESISTANCE : EXCITATION : N/A Ω WIRING CODE:
SIGNAL : N/A Ω W.R.C.-R.T.

PIN CONFIGURATION : +EXC.;RED/A -EXC.;BLK/D
+SIG.;GRN/B -SIG.;WHT/C CALR; WHT-GRN/E

BRIDGE EXCITATION : 10.00 VOLTS RMS AC MAX.
ZERO BALANCE : 0.00 % OF RATED OUTPUT

ELECTRICAL INTERFACE: BENDIX PT02E-10-6P RECEPTACLE
MATING CONNECTOR SUPPLIED

SYSTEM CALIBRATION:
INSTRUMENT MODEL NO.: DAYTRONIC 3178 A/C AMP. S/N: B04096
VOLTAGE 105-135 VAC @ 50-400 Hz

CALIBRATION TRANSFER :

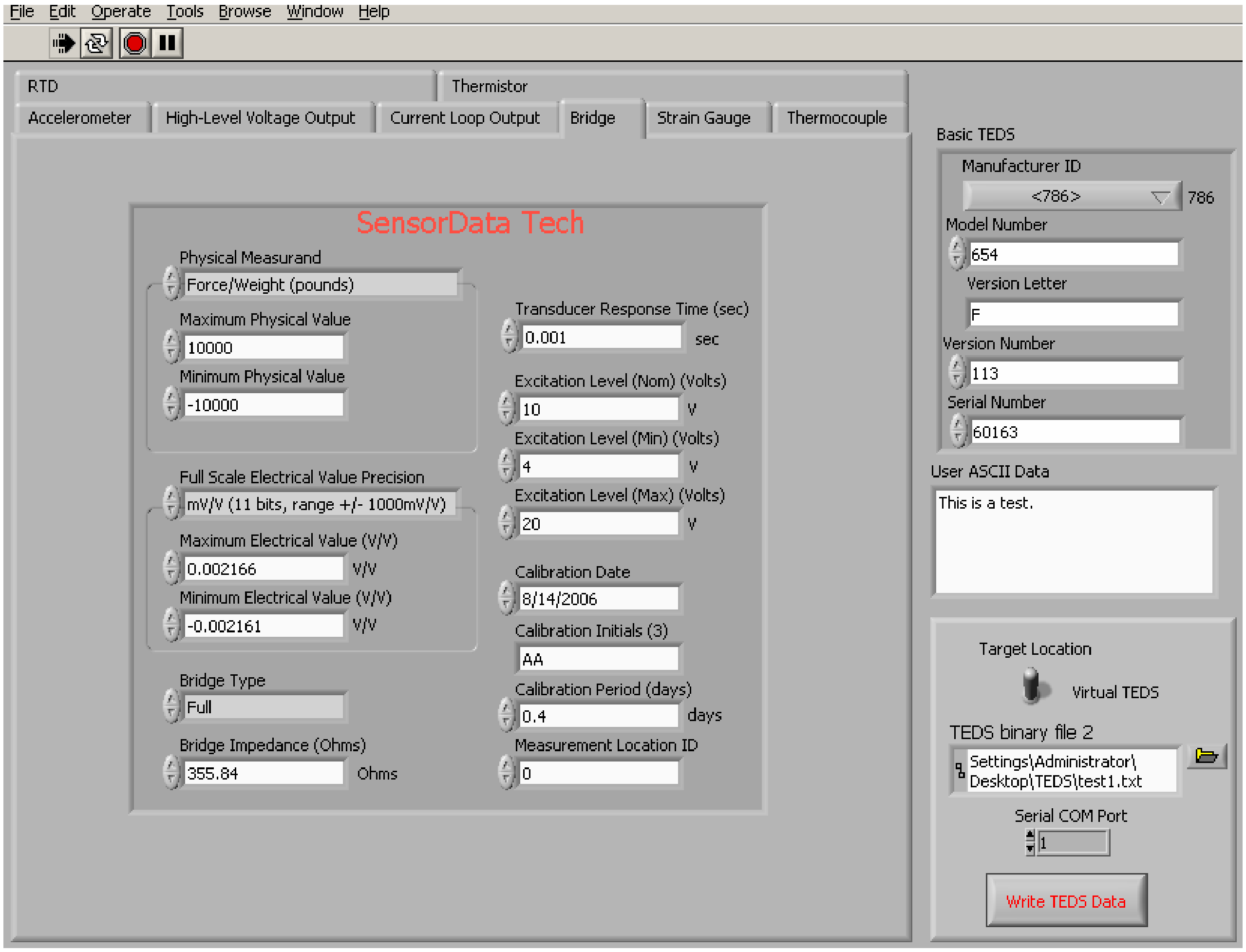
A PRECISION RESISTOR, WHEN SHUNTED ACROSS ONE LEG OF THE INTERNAL BRIDGE, PRODUCES AN ELECTRICAL SIGNAL EQUIVALENT TO A SPECIFIC APPLIED LOAD. THIS CALIBRATION METHOD IS VALID ONLY WHEN USED WITH HIGH IMPEDANCE INDICATORS.

THE FOLLOWING SHUNT TRANSFER VALUES WERE DETERMINED BY THE FACTORY TO HELP USER TO ACCURATELY CALIBRATE TRANSDUCER AND/OR SET INSTRUMENT LIMITS.

Built-in k OHM, SHUNTED BETWEEN: +SIG.;GRN/B AND +EXC.;RED/A , EMULATES A " +ve " LOAD EQUAL TO
= 718.12 Lb.in
= 81.14 Nm
= 3.5906 mV/V

Built-in k OHM, SHUNTED BETWEEN: +SIG.;GRN/B AND -EXC.;BLK/D , EMULATES A " -ve " LOAD EQUAL TO
= -713.66 Lb.in
= -80.64 Nm
= -3.5683 mV/V

Appendix D



File Edit Operate Tools Browse Window Help
RTD
Thermistor
Accelerometer
High-Level Voltage Output
Current Loop Output
Bridge
Strain Gauge
Thermocouple
SensorData Tech
Physical Measurand
Force/Weight (pounds)
Maximum Physical Value
10000
Minimum Physical Value
-10000
Full Scale Electrical Value Precision
mV/V (11 bits, range +/- 1000mV/V)
Maximum Electrical Value (V/V)
0.002166 V/V
Minimum Electrical Value (V/V)
-0.002161 V/V
Bridge Type
Full
Bridge Impedance (Ohms)
355.84 Ohms
Transducer Response Time (sec)
0.001 sec
Excitation Level (Nom) (Volts)
10 V
Excitation Level (Min) (Volts)
4 V
Excitation Level (Max) (Volts)
20 V
Calibration Date
8/14/2006
Calibration Initials (3)
AA
Calibration Period (days)
0.4 days
Measurement Location ID
0
Basic TEDS
Manufacturer ID
<786> 786
Model Number
654
Version Letter
F
Version Number
113
Serial Number
60163
User ASCII Data
This is a test.
Target Location
Virtual TEDS
TEDS binary file 2
Settings\Administrator\
Desktop\TEDS\test1.txt
Serial COM Port
1
Write TEDS Data