A Sensor Network for Buildings Based on the DALI Bus

Yuan Ma and Darold Wobschall

Esensors Inc. and University at Buffalo

Buffalo, NY

www.eesensors.com

Sensors Application Symposium (SAS)
San Diego, Feb. 2006

b

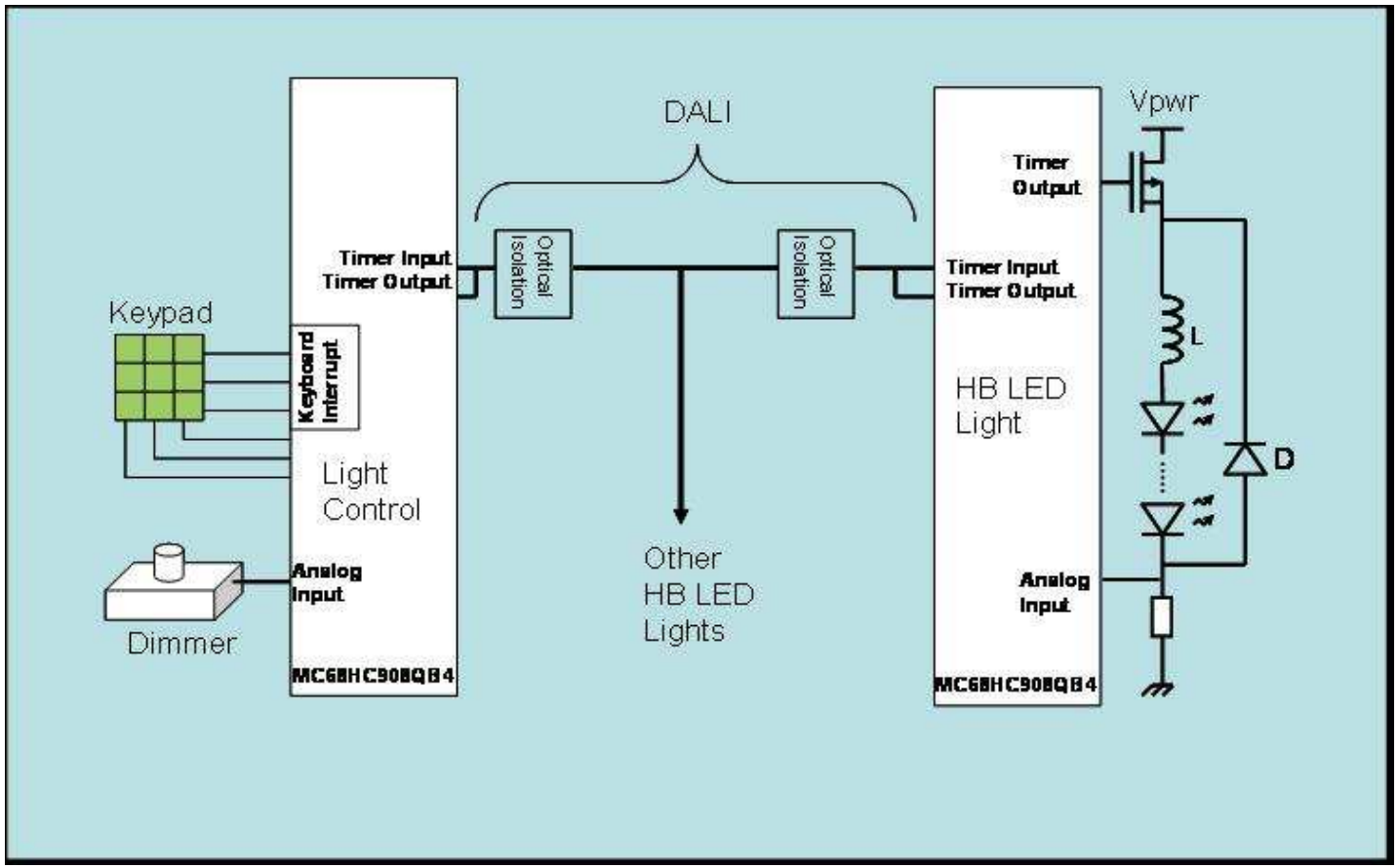
Goals

- To develop and demonstrate a an extended version of the DALI bus suitable for sensor data acquisition.
- To provide a conversion of the DALI to IEEE 1451 format.

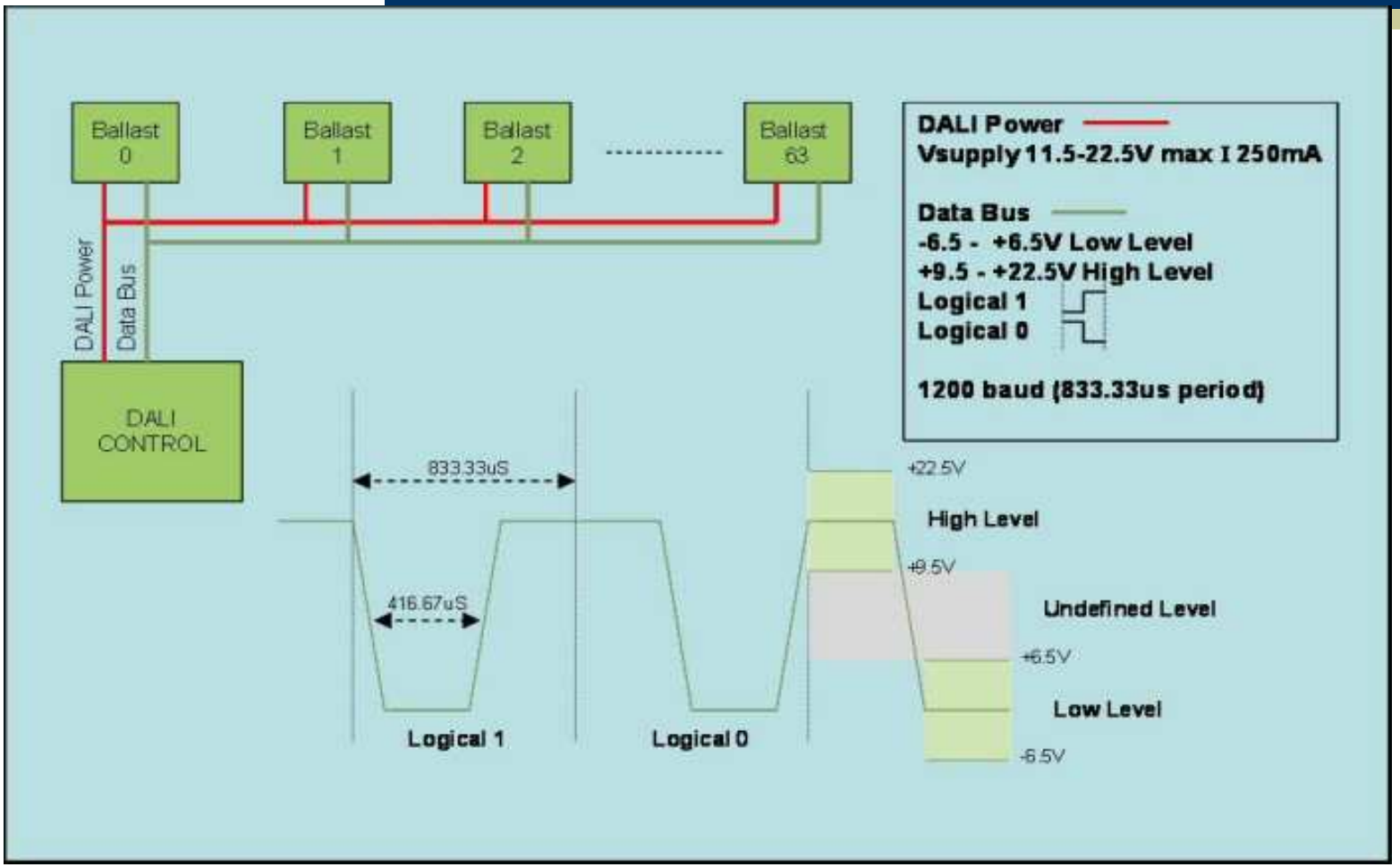
Description of Standard DALI Bus

- DALI: Digital Addressable Lighting Interface
- Developed for building lighting control, especially ballasts
- Two-wire bus: 12/15 volts with 250 mA current limit
- Master data is standard RRZ (like UART, but bi-phase encoding, 1200 bits/sec)
- Slave (remote) device shorts bus for logic 0.
- 16-bit command with 8-bit return, with timeouts
- Operates up to 300 meters (14 to 22 gage wire)

Standard DALI Block Diagram



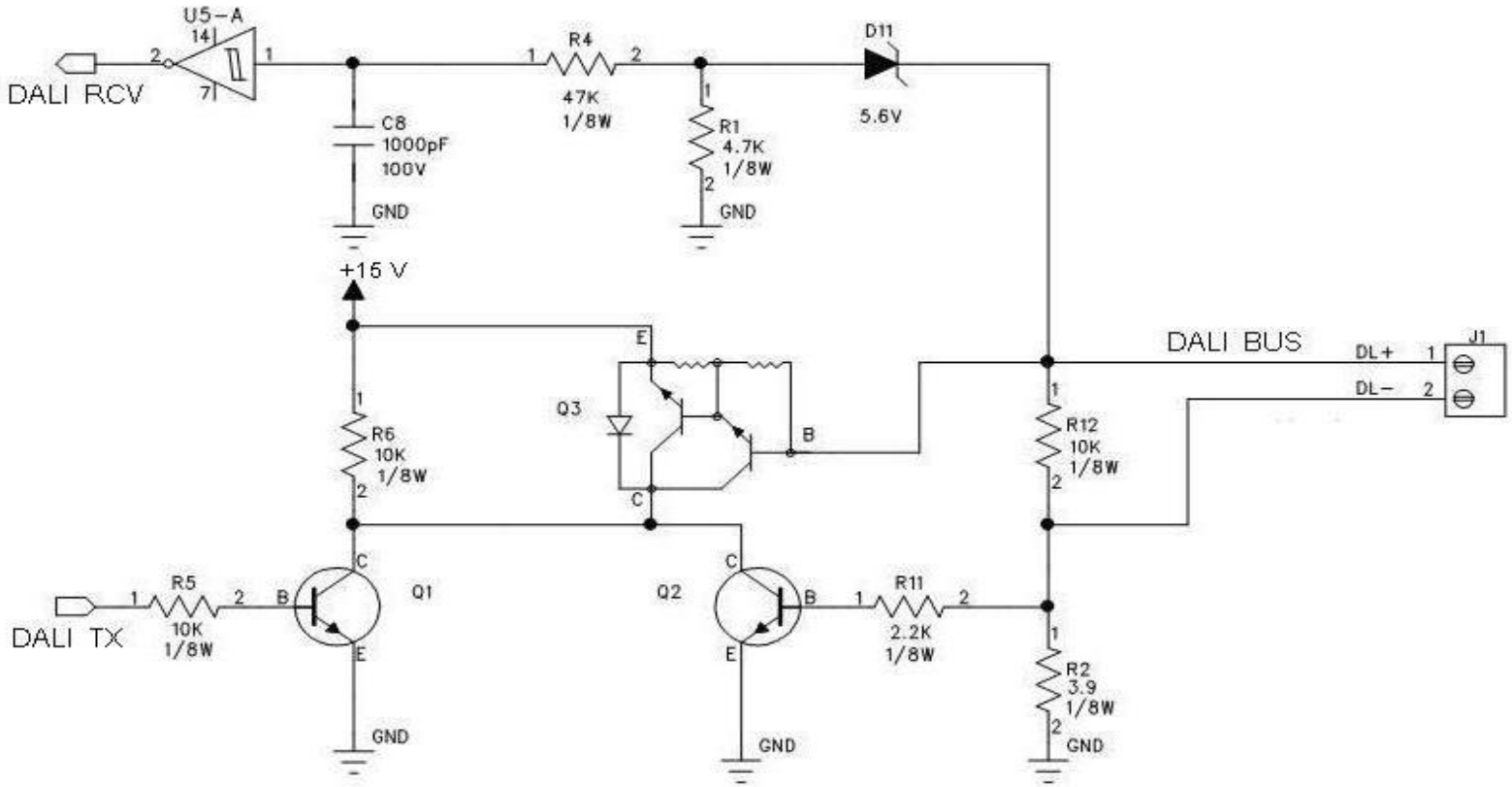
DALI Bus Waveform



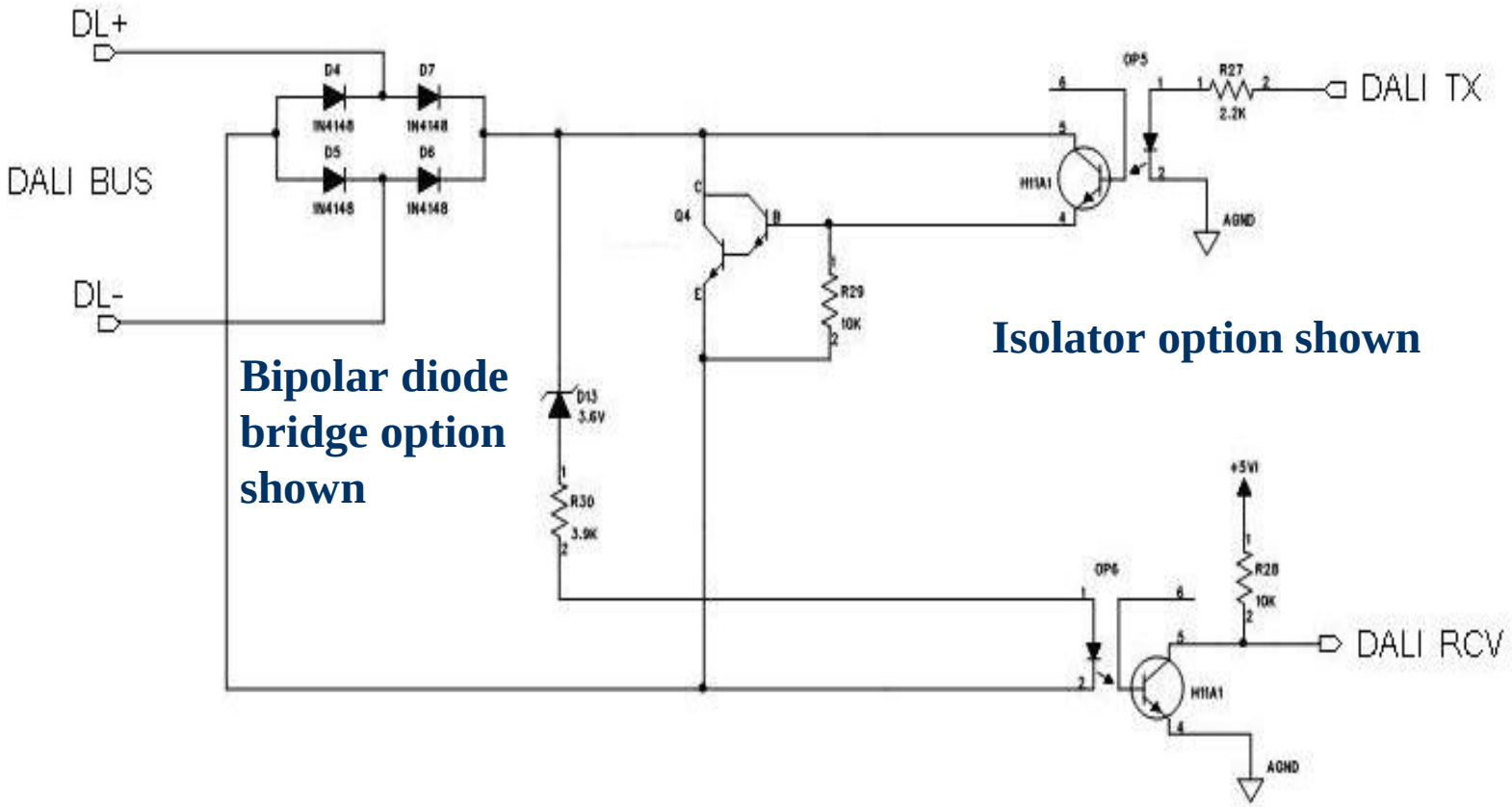
DALI Bus Characteristics

- Data and power on two wires
- Oriented to lighting control
- Many DALI device suppliers
- Noise immune (low data rate, higher voltage/current bus)
- Data return too slow and limited for sensor data

DALI Master (Driver) Interface Circuit



DALI Remote (Slave) Interface Circuit

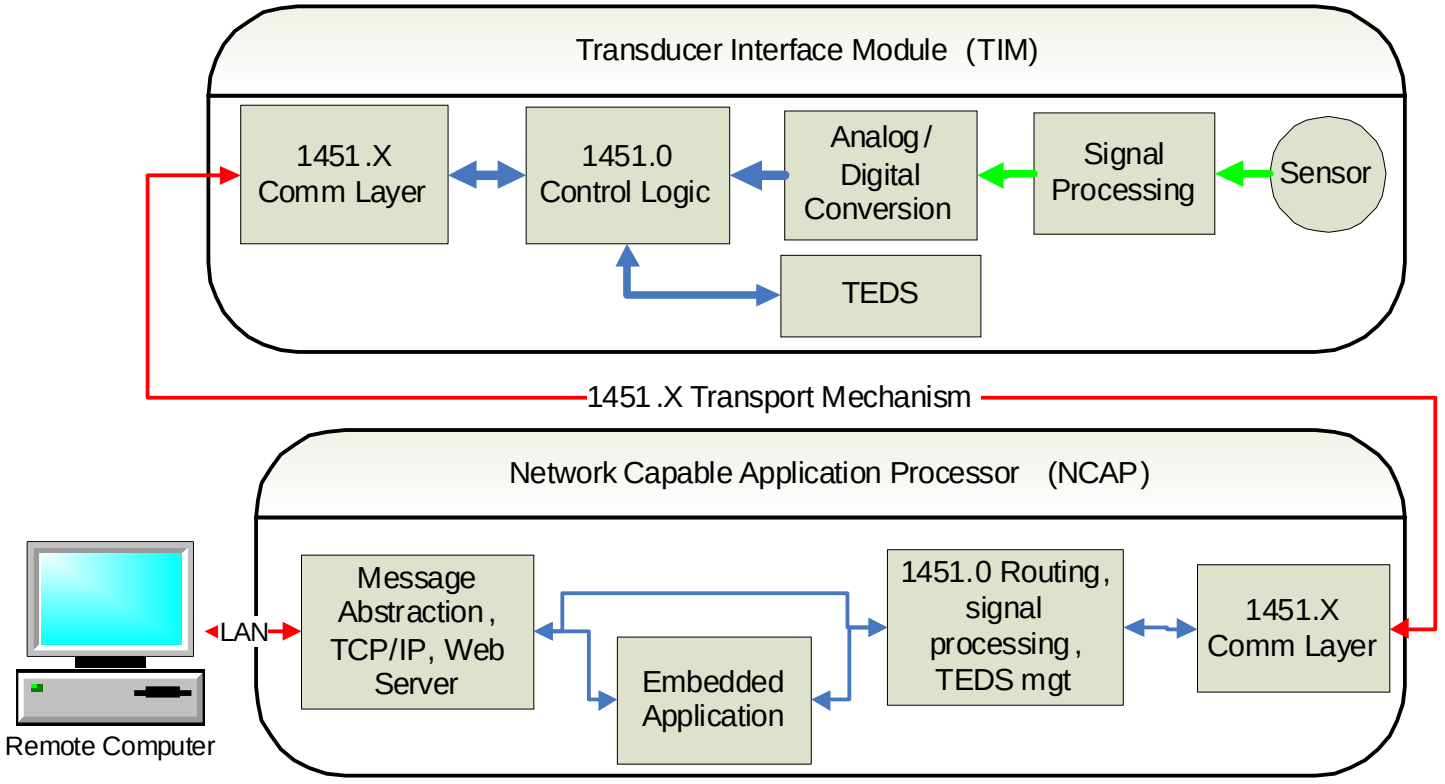


Extended DALI Concept

- Use same voltage/current limit as standard DALI
- Be compatible with standard DALI (co-existence on same bus)
- Increase speed to 9600 Bits/sec (standard DALI ignores)
- Increase data return (7+ bytes)
- Provide TEDS (IEEE 1451.4) for ID
- Provide gateway to IEEE 1451.0 (Dot 0) protocol
- Also provide wireless option

A review of the

IEEE 1451 Smart Transducer Concept



From Smart Sensor Systems

Master=NCAP, Slave=TIM

IEEE 1451.0 (Dot 0) Format

- Required: **Transducer Electronic Data Sheet (TEDS)**
  [Memory block with defined format]
  - MetaTEDS
  - Channel TEDS
  - Calibration TEDS (unless SI units)
  - Xdr-name TEDS
  - Phy TEDS
  - Also optional TEDS
- Data Transmission [specific octet format]
  - TEDS/Status requests
  - Triggering and configuration
  - Sensor read commands and data return
  - Actuator write commands and data sending

Dot 0 Command/Response Structure

Byte Number	Description
1	Destination Transducer Channel Number (Most significant byte)
2	Destination Transducer Channel Number (Least significant byte)
3	Command Class
4	Command Function
5	Length (Most significant byte)
6	Length (Least significant byte)
7-N	Command dependent bytes

NCAP Command Message Structure

Byte Number	Description
1	Success/Fail Flag
2	Length (Most significant byte)
3	Length (Least significant byte)
4-N	Reply dependent bytes

TIM Reply Message Structure

Simplified (Dot 4) TEDS
(developed for IEEE 1451.4)

- UUID (Universal Unique Identifier)

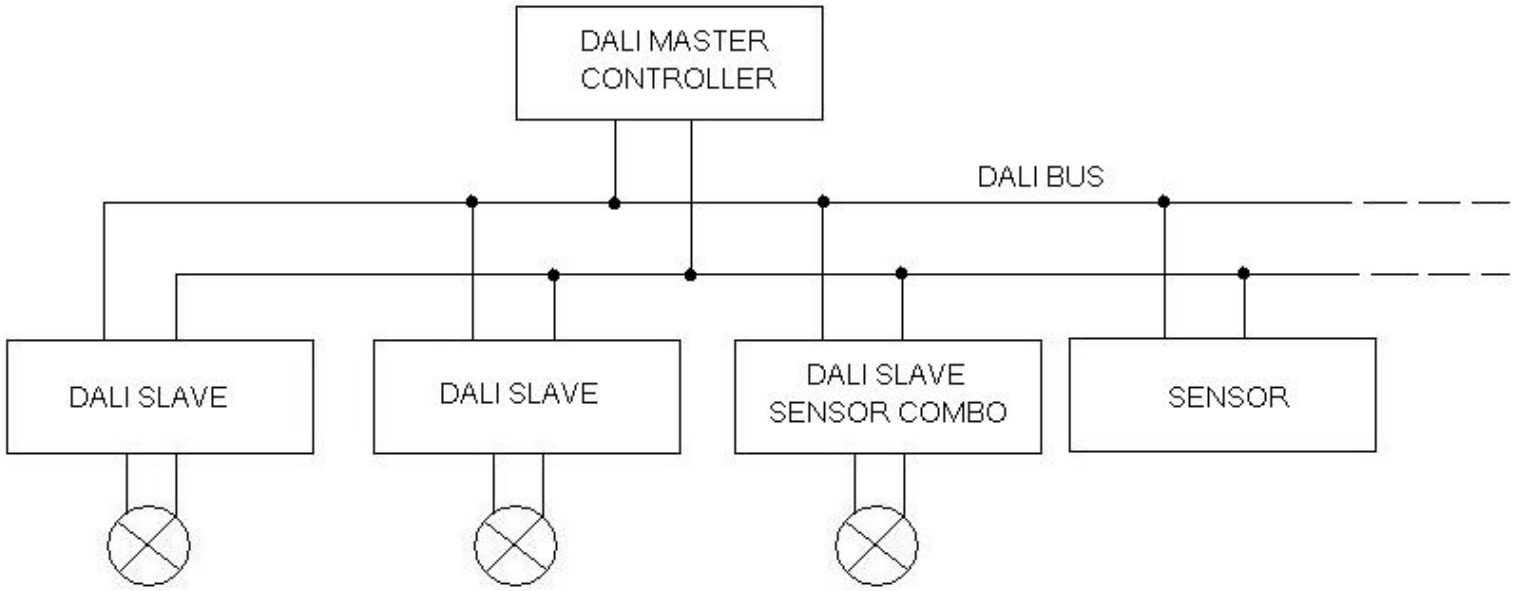
  Supplied by EEPROM (DS2433) manufacturer (6 bytes)
- Basic TEDS (8 bytes)
  - Model Number (15 bits)
  - Version Letter (5 bits, A-Z)
  - Version Number (6 bits)
  - Manufacturer ID (14 bits)
  - Serial Number (6 bits)
- Manufacturer's TEDS

  Sensor type and calibration parameters (16 bytes)

Conversion to Dot 0 TEDS done in NCAP

Dot 4

Block Diagram of Extended DALI Bus



Extended DALI Data Frame Format

Control Field	Data Field	CRC Field	ACK Filed

Arbitration (1-byte)	Description + Length (1byte)	Slave ID (1 byte)	Command/Data (N bytes)	CRC (2 bytes)	FF hex (1 byte)

Examples of Master Slave Responses

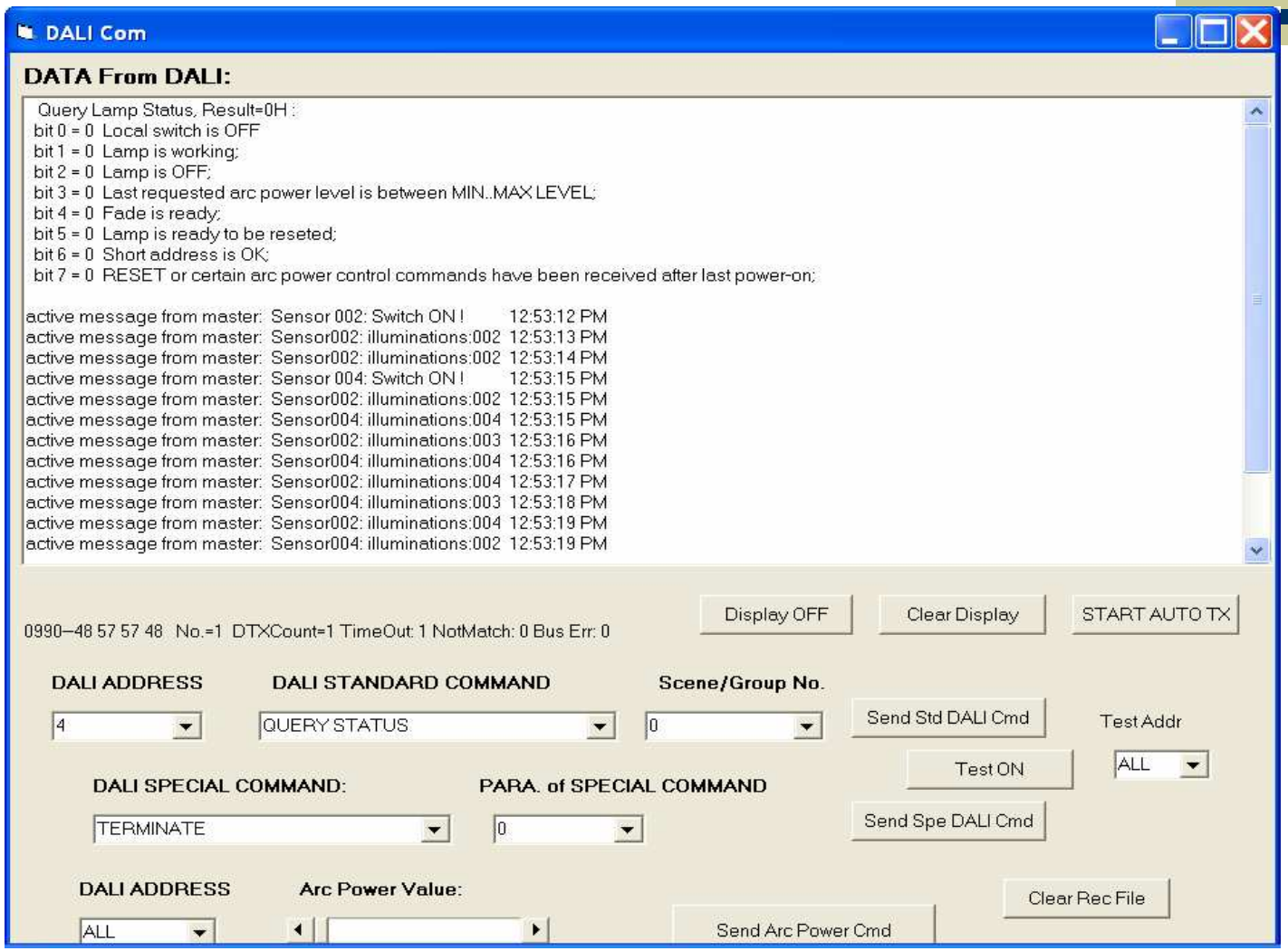
Master Requests Illumination and Temperature from Slave

Data Field			
Slave address	0x01(inquiry Command)	Illumination code	Temperature code

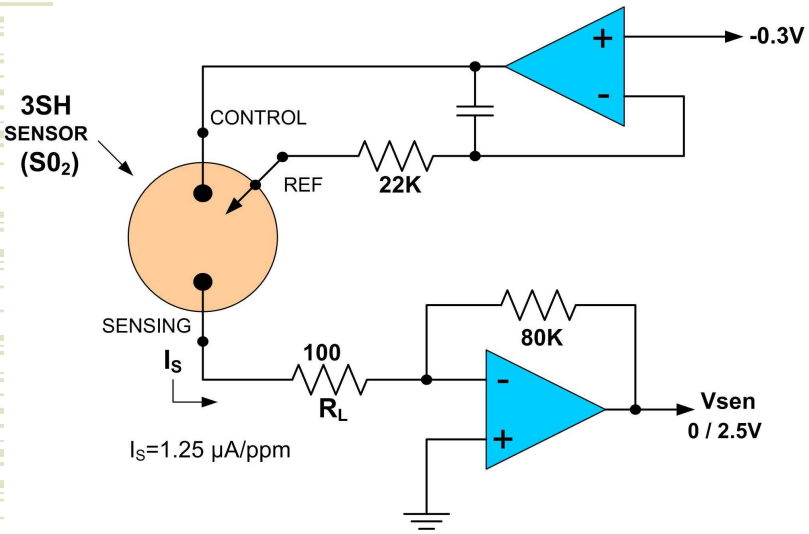
Slave Response (Illumination and Temperature Data to Master)

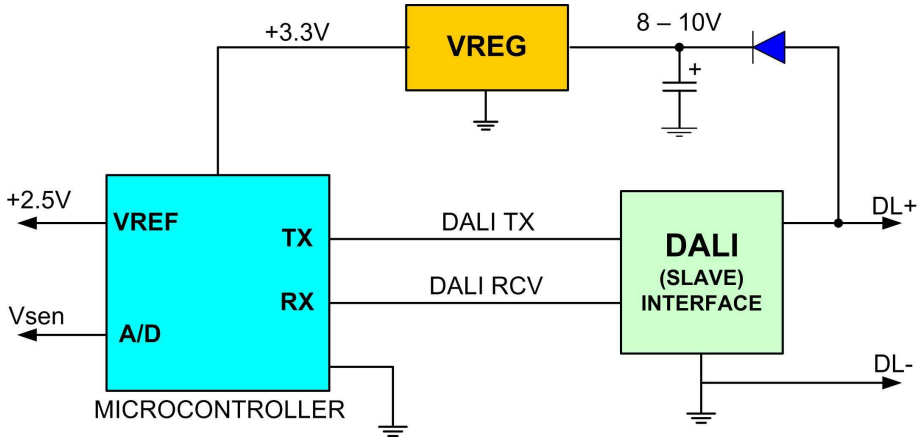
Data Field					
Slave address	0x01(Answer Inquiry)	Illumination code	Illumination Data	Temperature code	Temperature Data

Data Readout Examples
(via Internet)

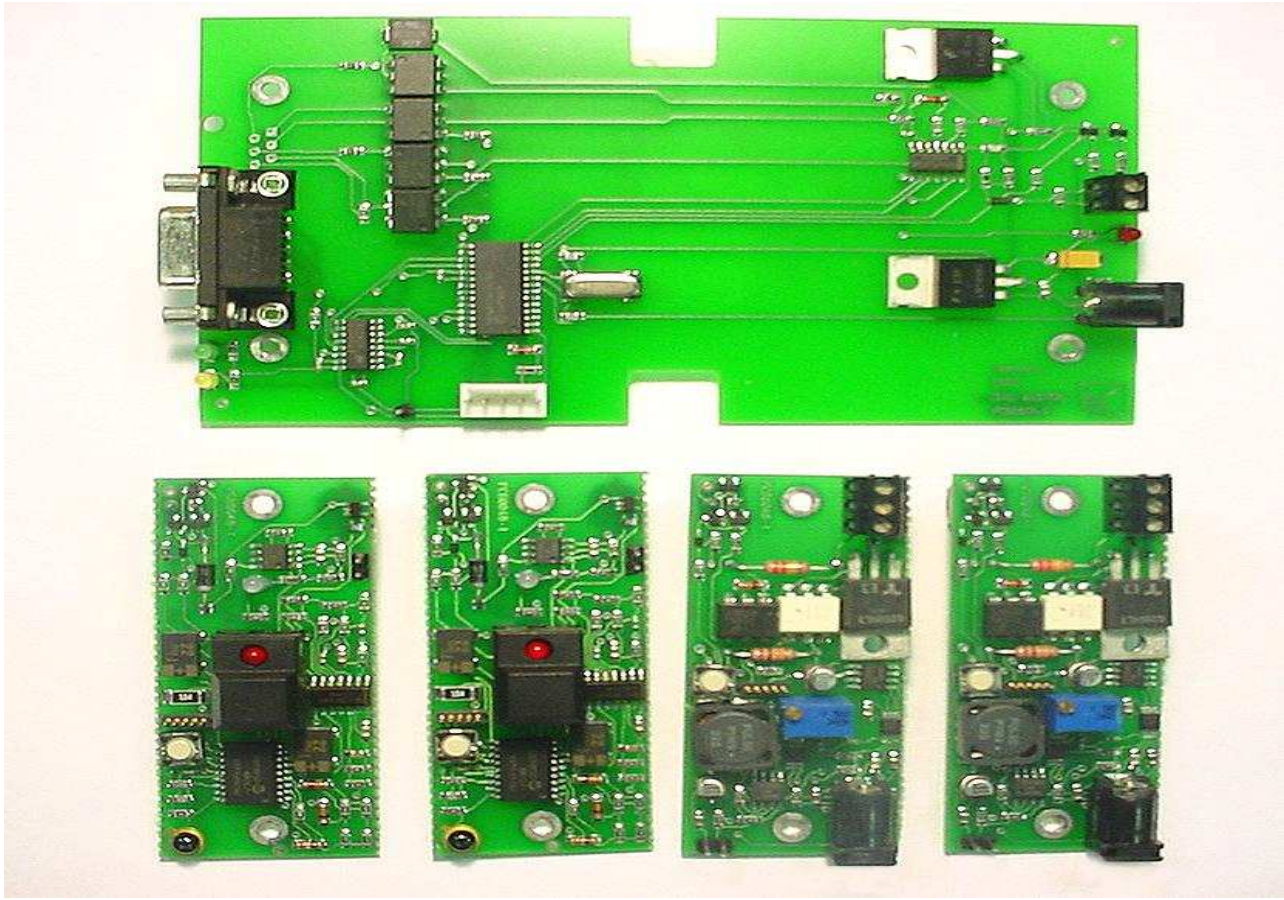


Amperometric Sensor on DALI bus



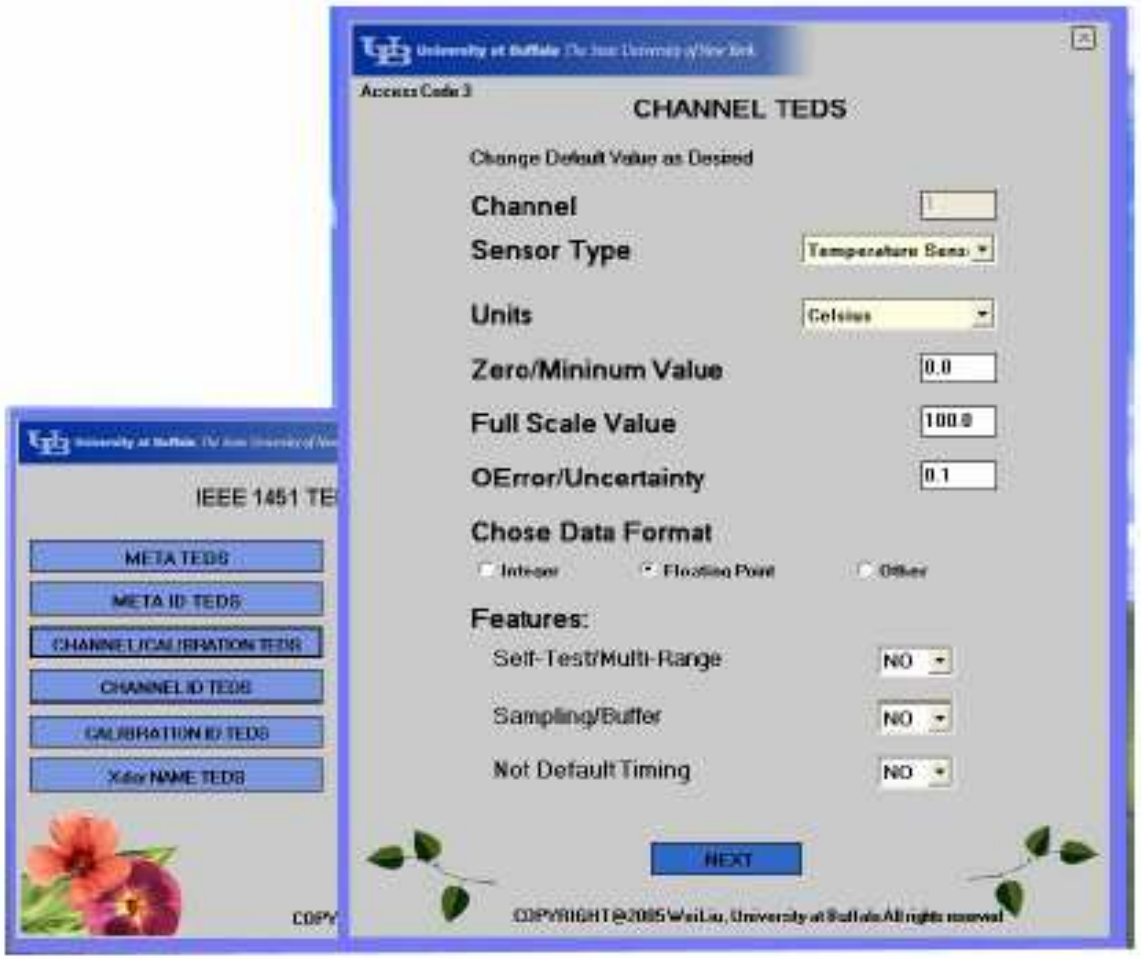


Prototype DALI Master and Slave Circuit Boards



TEDS Compiler

- Part of Ph. D. thesis
  Wai Liu
  (Univ. at Buffalo)
- Copy of thesis is available free



References

- Wai Liu, “Design of TEDS Writer, Reader and Testing System for Transducer Interface Modules based on the IEEE 1451 Standard“, Ph. D. thesis (SUNY/Buffalo, EE Dept), May 2006.
- IEEE Std.

- D. Wobschall, “A Minimal Dot4 NCAP with a Compatible Sensor Bus”, SiCon/05 (Houston).
- www.eesensors.com/IEEE1451

Summary

- We have developed an extension of the DALI bus which is suitable for acquiring sensor data.
- Bus was tested with bus consisting of mix of sensors and conventional DALI lighting devices
- The IEEE 1451 protocol with the Dot 4 TEDS and Dot 0 on the network was demonstrated.

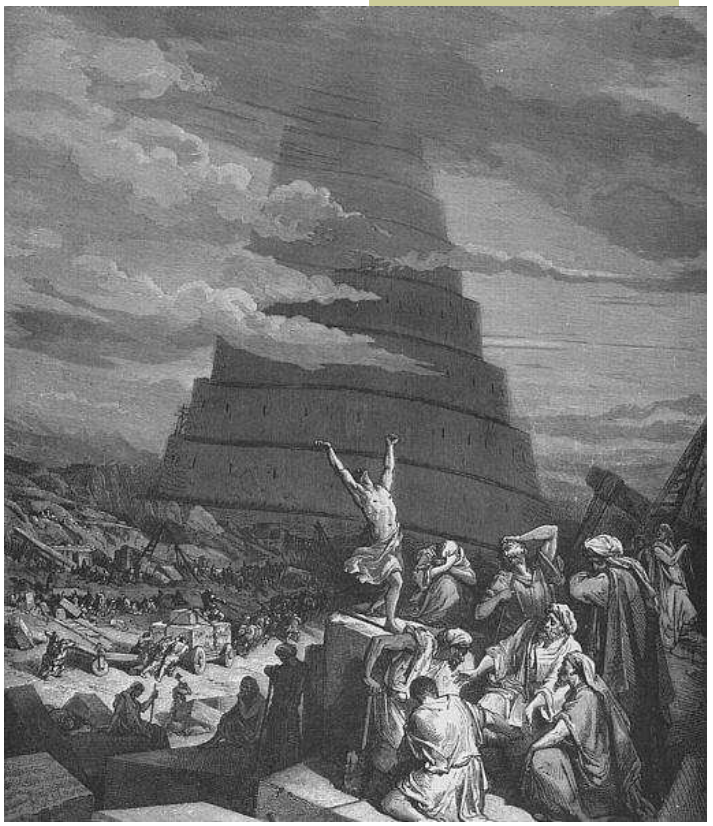
Further information: designer@eesensors.com

Backup Slides

www.eesensors.com

IEEE 1451 – the Universal Transducer Language

- Over 100 sensor network protocols in common use
- Narrow solutions and borrowed protocols have not worked
- IEEE 1451 is the best universal solution
- Sensor engineers in the fragmented sensor industry need a simple method of implementation
- How can it be done?



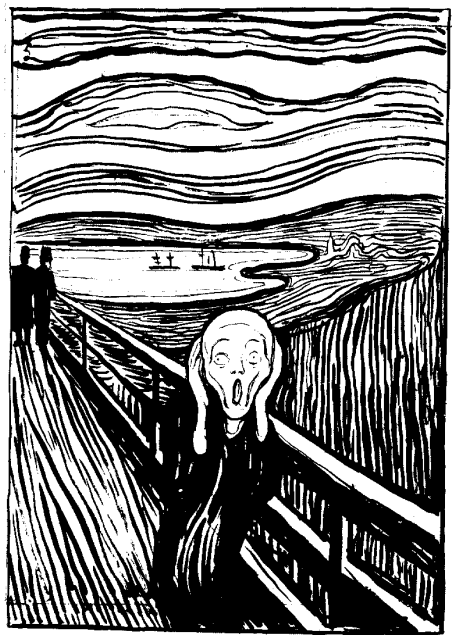
The Tower of Babel

IEEE 145.0 (Dot 0) Advantages

- Comprehensive enough to cover nearly all sensors and actuators in use today (not 20/80% approach)
- Many operating modes
  (buffered, no-buffer, grouped sensors, timestamps, timed data, streaming …)
- Extensive units, linearization and calibration options
- Multiple timing and data block size constraints handled.
- Compatible with most wired and wireless sensor buses and networks (point-to-point, mesh, TIM-to-TIM, mixed networks).
- Efficient binary protocol (especially suitable for wireless)

But the Complexity!

- A comprehensive standard is necessarily complex
- There was little adoption of the original IEEE 1451.2 (TII) standard because of its perceived complexity
- Manual preparation of the TEDS is not practical
- A TEDS compiler is needed
- A compliance test procedure is also desirable to prove that the design is correct



Munch –The scream

TEDS Format

- General format for each TEDS section:

Field	Description	Data Type	Number of Bytes
-------	TEDS Length	UInt32	4 bytes
1 to N	Data Block	Variable	Variable
-------	Checksum	Uint16	2 bytes

- Binary TEDS Tuple format for each data block:

  Type-Length-value (TLV)

  Example: 01 02 A3 04

  Field type is 1, Length is 2 bytes, field value is “A304” hex

- Field example: Meta-TEDS (TEDS # 1)

  13: Number of Implemented Transducer Channels (default=1)

TEDS Sections Implemented

- Meta TEDS
- Meta ID TEDS
- Transducer Channel TEDS
- Transducer Channel ID TEDS
- Calibration TEDS
- Calibration ID TEDS
- XdrcName TEDS

Referenced by TEDS section/access code (e.g. #1 for Meta-TEDS)

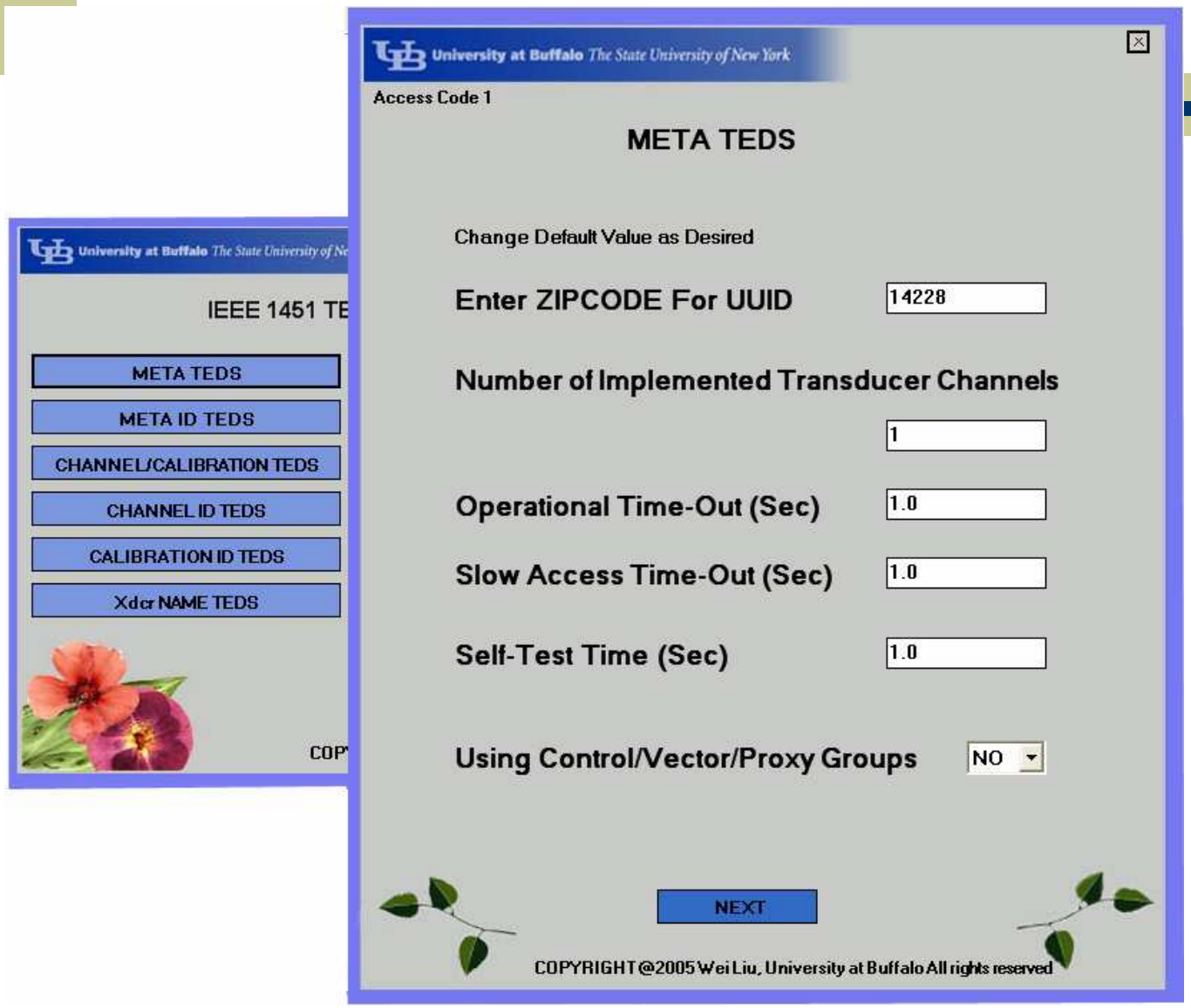
Standard Transducer Units
(binary format)

SI Based Units

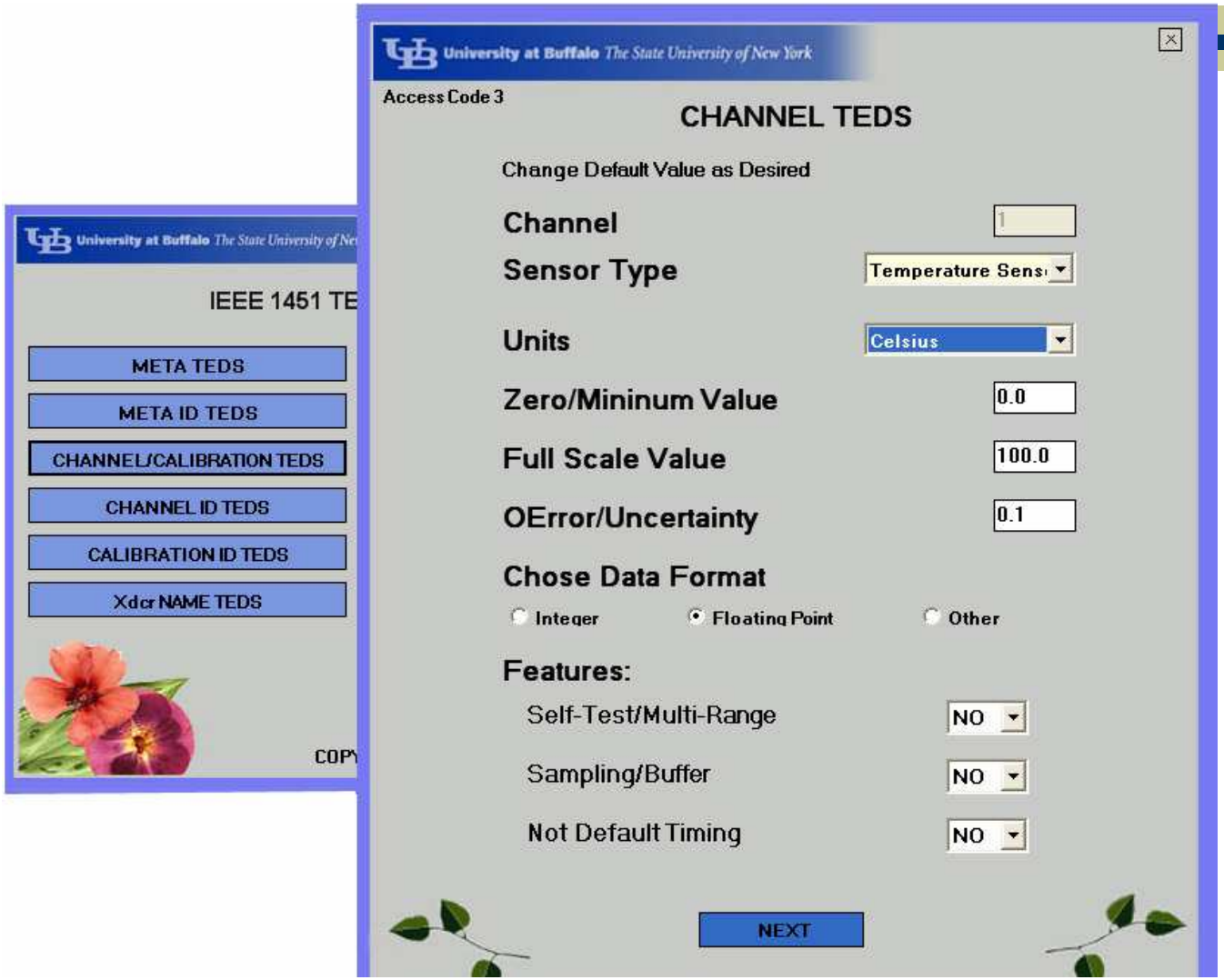
Base Quantity	Name	Unit Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	Kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Field	Description	Data Type	Number of octets
1	Physical units interpretation	UInt8	1
2	(2 * <exponent of radians>) + 128	UInt8	1
3	(2 * <exponent of steradians>) + 128	UInt8	1
4	(2 * <exponent of meters>) + 128	UInt8	1
5	(2 * <exponent of kilograms>) + 128	UInt8	1
6	(2 * <exponent of seconds>) + 128	UInt8	1
7	(2 * <exponent of amperes>) + 128	UInt8	1
8	(2 * <exponent of kelvins>) + 128	UInt8	1
9	(2 * <exponent of moles>) + 128	UInt8	1
10	(2 * <exponent of candelas>) + 128	UInt8	1

Meta-TEDS Writer Screen



Channel/Calibration TEDS (for linear sensors)



Text Based TEDS
(human readable)

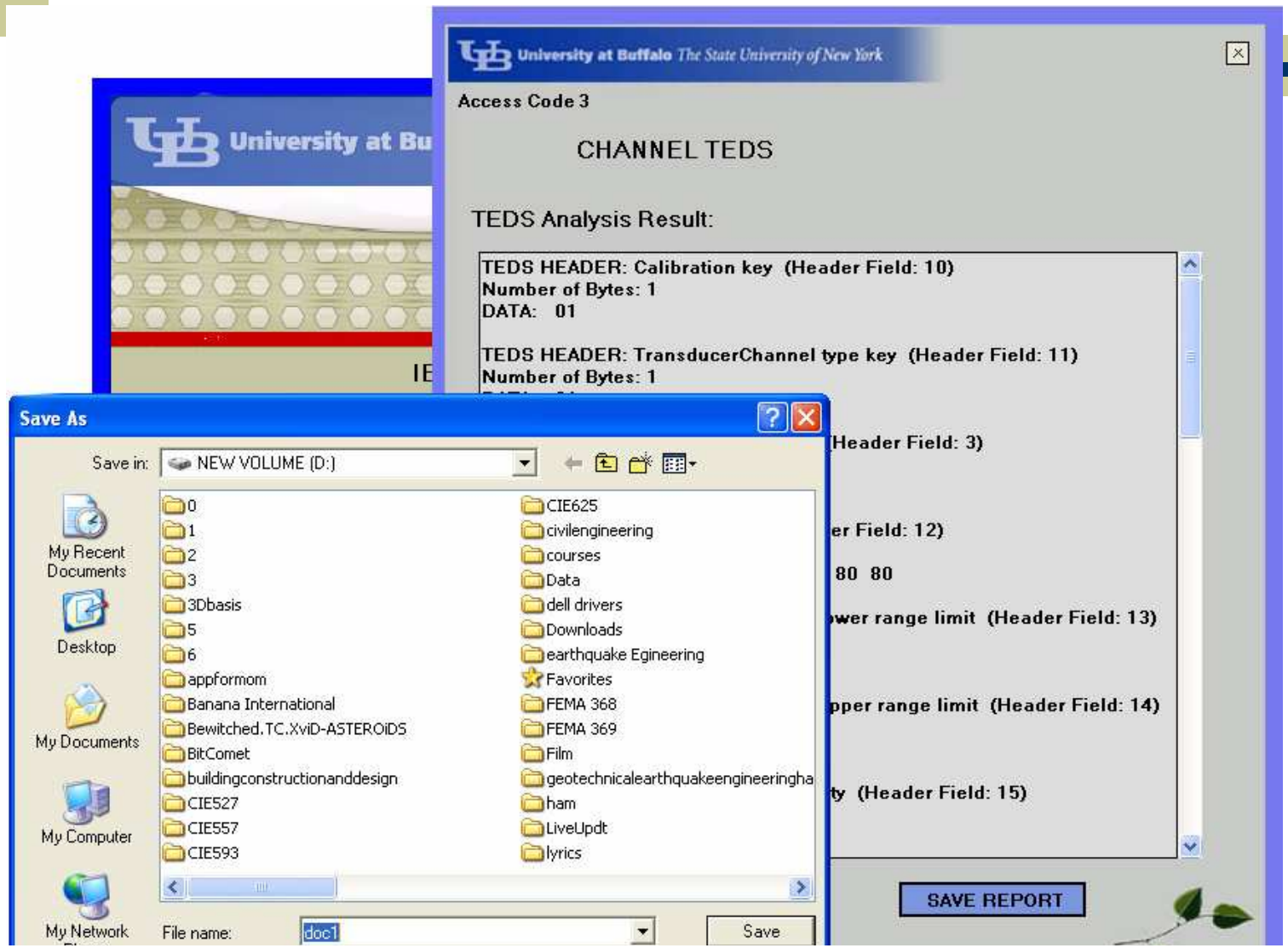
- Meta ID TEDS
- Transducer Channel ID TEDS
- Calibration ID TEDS
- XdcrName TEDS (required)

ASCII or XML – multiple languages available

EN: English

QC: computer language (additional data)

TEDS Reader


University at Buffalo The State University of New York
Access Code 3
CHANNEL TEDS
TEDS Analysis Result:
TEDS HEADER: Calibration key (Header Field: 10)
Number of Bytes: 1
DATA: 01
TEDS HEADER: TransducerChannel type key (Header Field: 11)
Number of Bytes: 1
Header Field: 3)
er Field: 12)
80 80
wer range limit (Header Field: 13)
pper range limit (Header Field: 14)
ty (Header Field: 15)
SAVE REPORT
Save As
Save in: NEW VOLUME (D:)
My Recent Documents
Desktop
My Documents
My Computer
My Network
0
1
2
3
3Dbasis
5
6
appformom
Banana International
Bewitched.TC.XviD-ASTEROiDS
BitComet
buildingconstructionanddesign
CIE527
CIE557
CIE593
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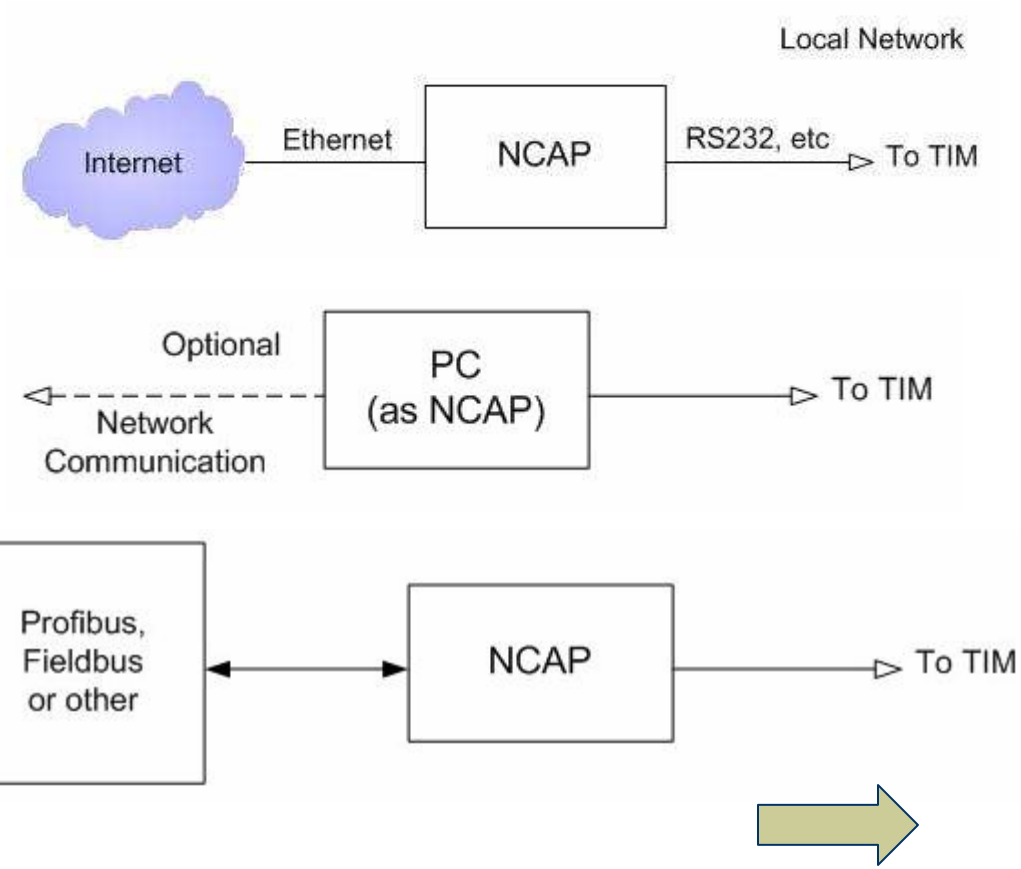
IEEE 451 TIM Compliance Tester

- TIM (Transducer Interface Module) is most complex and done by sensor design engineers
  (TIM tester can be used by the few NCAP designers)
- Tester verifies compliance of a TIM to IEEE 1451.0 (Dot 0) protocol
- Focus is on TEDS checking and data transfer format
- Physical device compliance not checked (part of other standards, e.g. RS485, Bluetooth)
- Tester uses serial bus (RS232)
- Testing may be done by Internet

Network side (NCAP) options (wired)

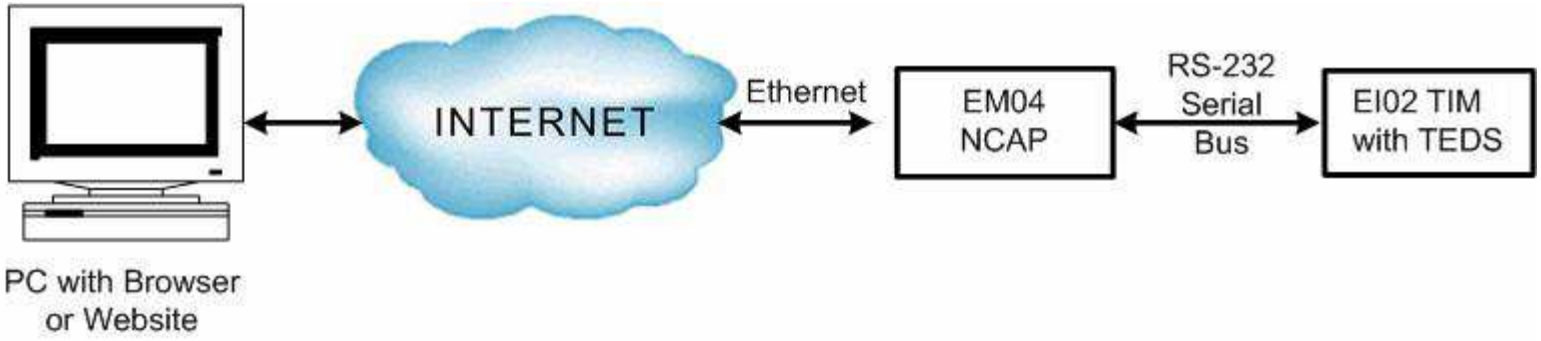
- Internet/Ethernet
- PC Readout
- Industrial network



All use Dot 0 protocol

Prototype TIM and NCAP

- NCAP interfaces to Internet via Ethernet



TEDS Compliance Tester Retrieval Sequence

- Read TIM Version
- Read IEEE p1451.0 Version
- Query Meta ID TEDS
- Query Meta TEDS
- Get Meta TEDS Content
- Query Transducer Channel TEDS
- Get Transducer Channel TEDS Content
- Query Calibration TEDS
- Get Calibration TEDS Content
- Query Transducer Channel ID TEDS
- Query Calibration ID TEDS

TIM Tester (Operating Mode)

Similar test sequence for Idle Mode

TIM Tester – Data retrieval

Serial Bus Format
and Relation to other Networks

- Tester uses RS232 serial bus only but…
- Interfaces to other physical devices (USB, RS485, Bluetooth, Zigbee, ….) available.
- TEDS retrieval is one feature
- Sensor data read (protocol check) for each channel:

  Idle mode – full scale value of sensor reading

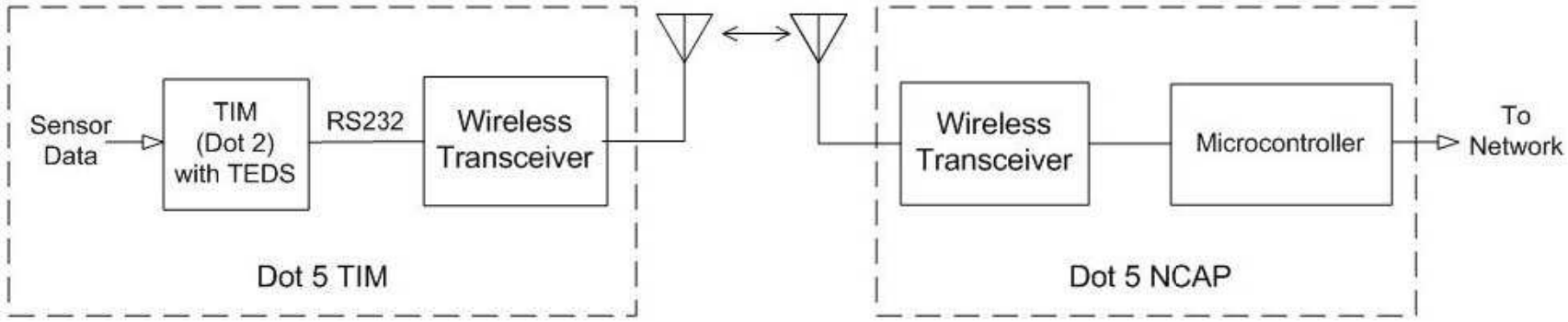
  (Checked against TEDS, error flag is not correct)

  Operating mode – actual sensor reading

  (Must be within sensor range)

Example – Wireless Connection

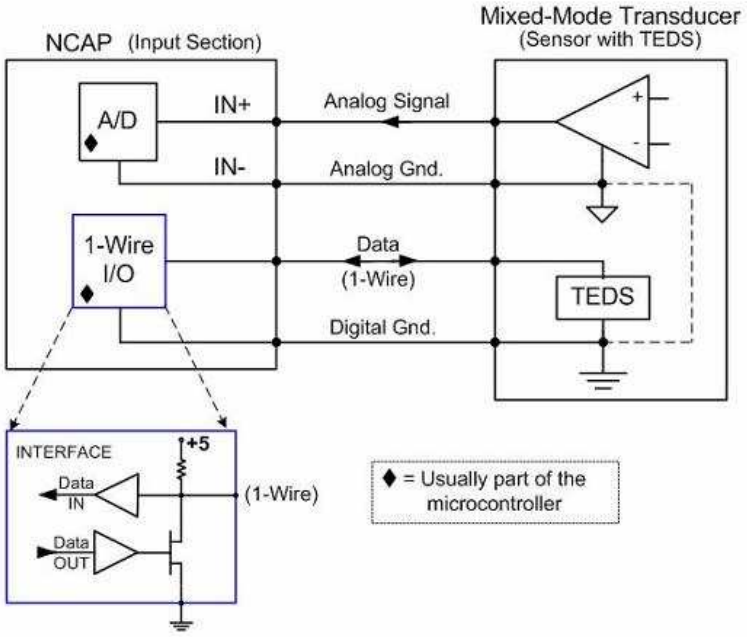
- Wireless modules with RS232 I/O when connected to Dot 2 TIMS are similar to IEEE 1451.5 TIMs (wireless version of IEEE 1451).
- Data format and TEDS are the same (both follow the Dot 0 standard)..

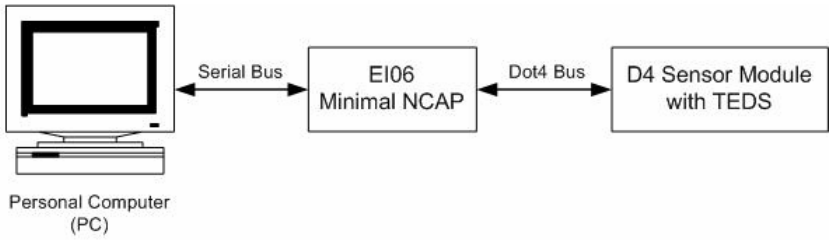


Dot 5 TIM built from a Dot 2 TIM and wireless transceiver

Alternative Tester for Dot 4 TEDS

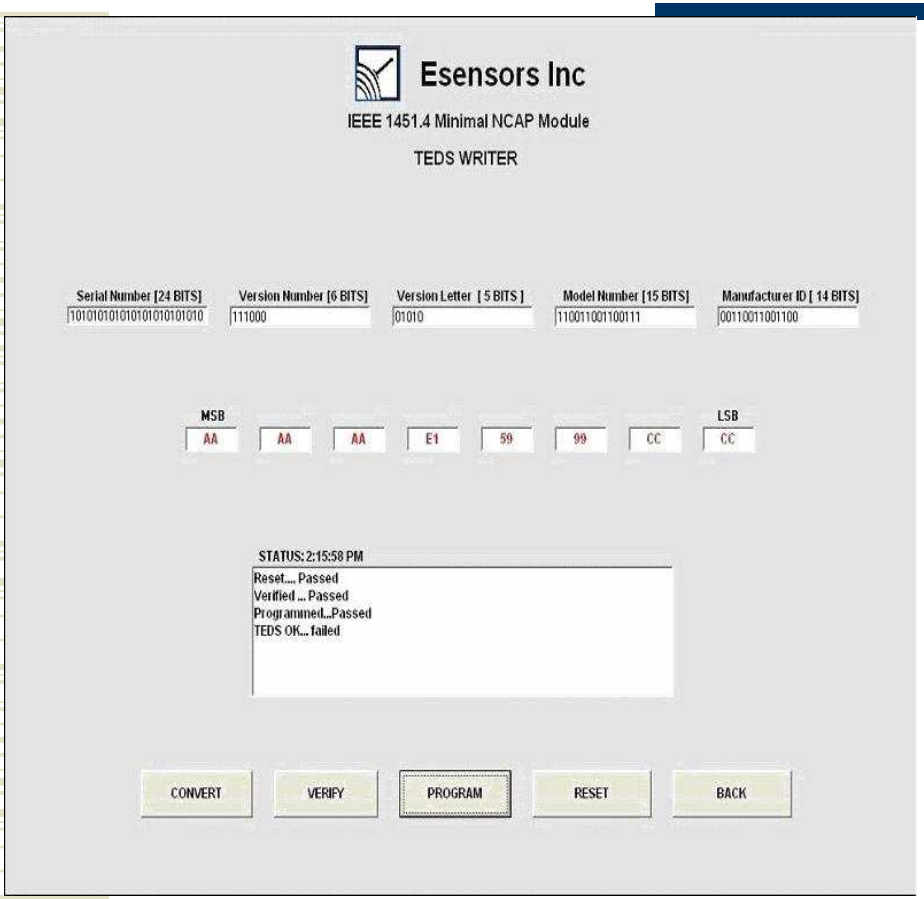
IEEE 1451.4 (only) does not use the Dot 0 format TEDS. This is a small, TEDS-only version (no digital data format is specified by the standard).

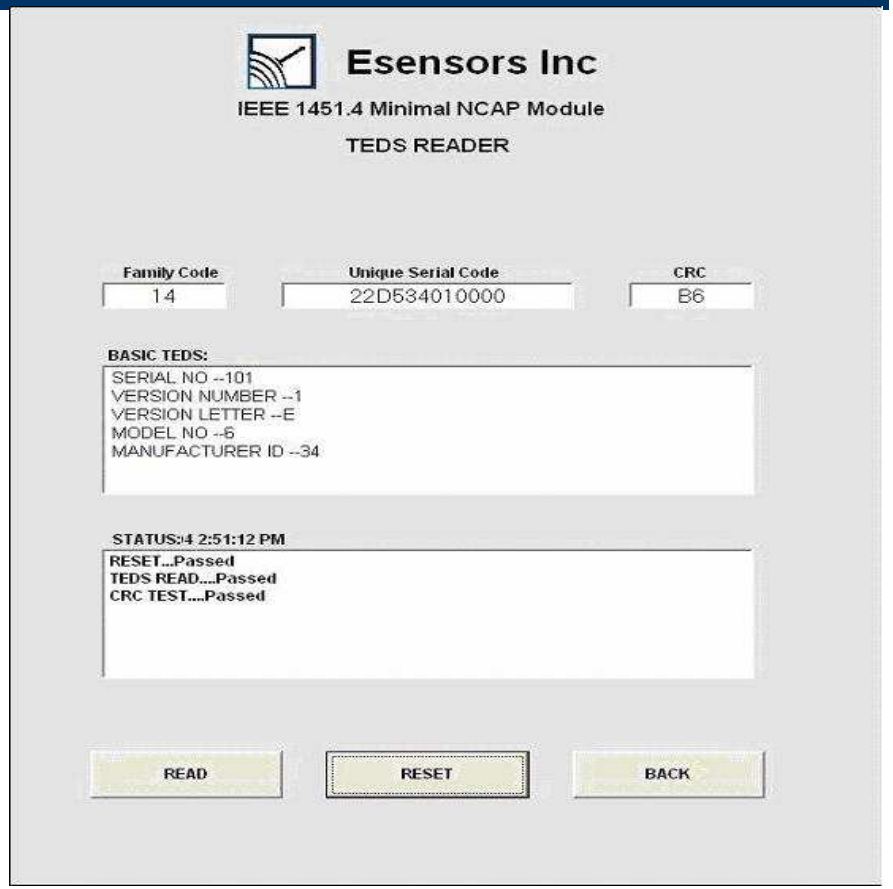




Dot 4

Dot 4 TEDS Writer and Reader
(PC Screens)



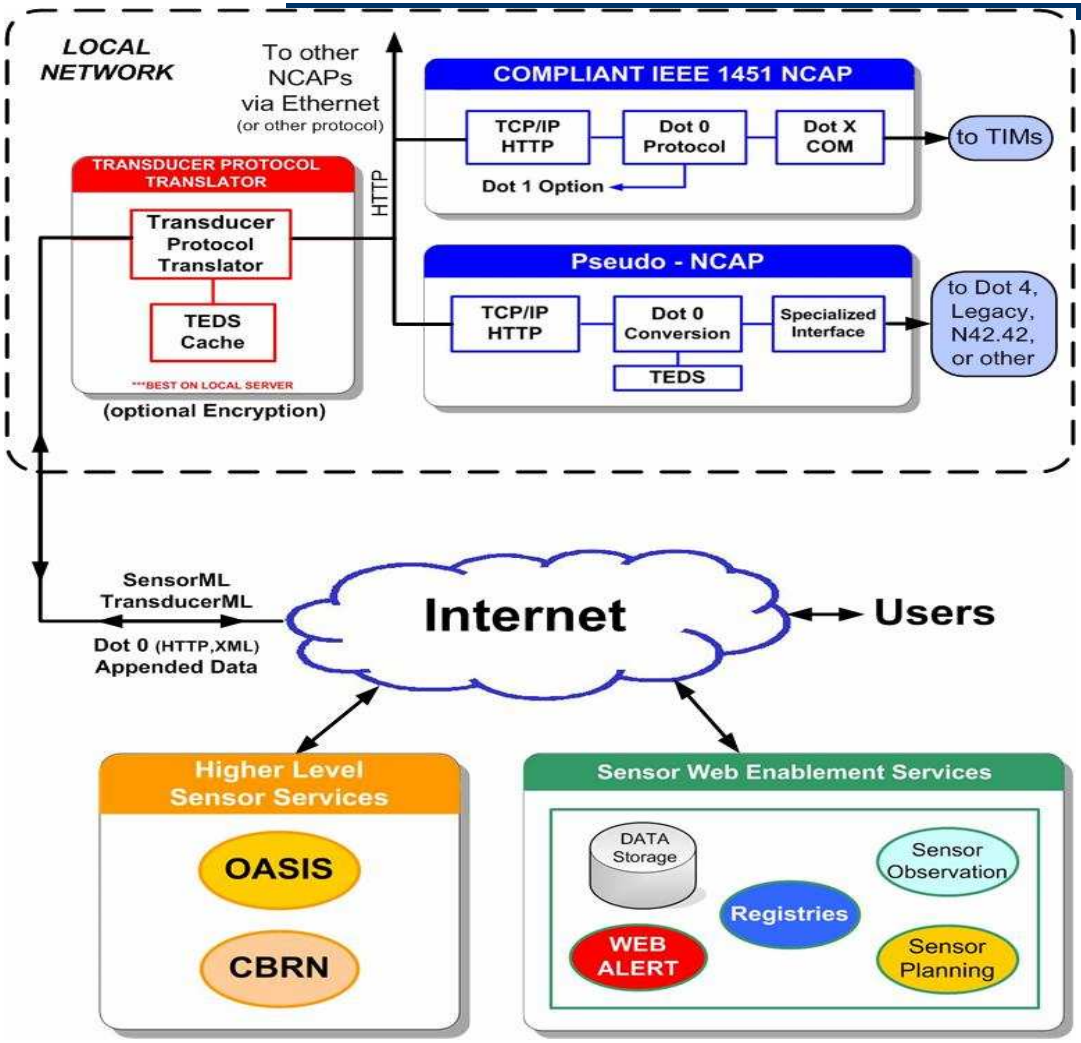


Writer

Dot 4

Reader

Harmonization of IEEE 1451 with other sensor standards

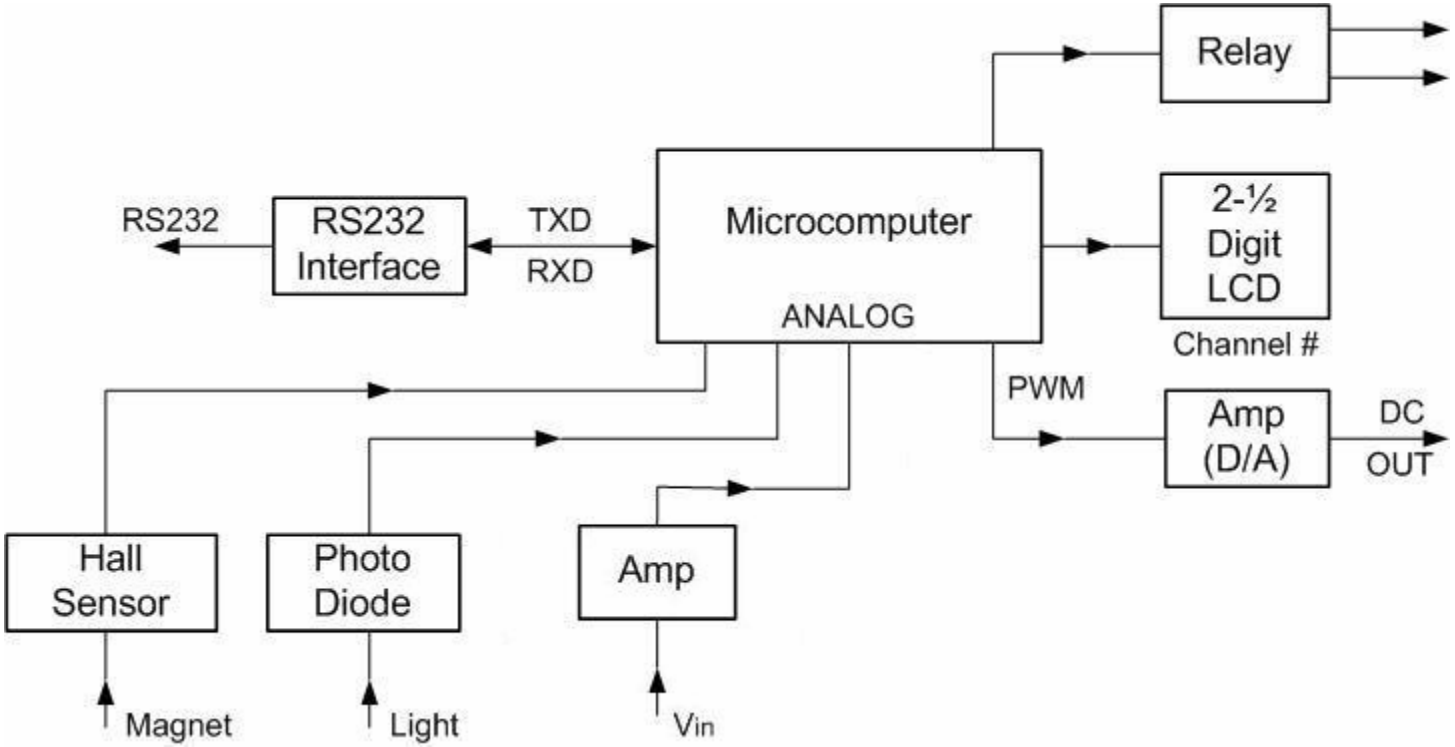


UUID Format

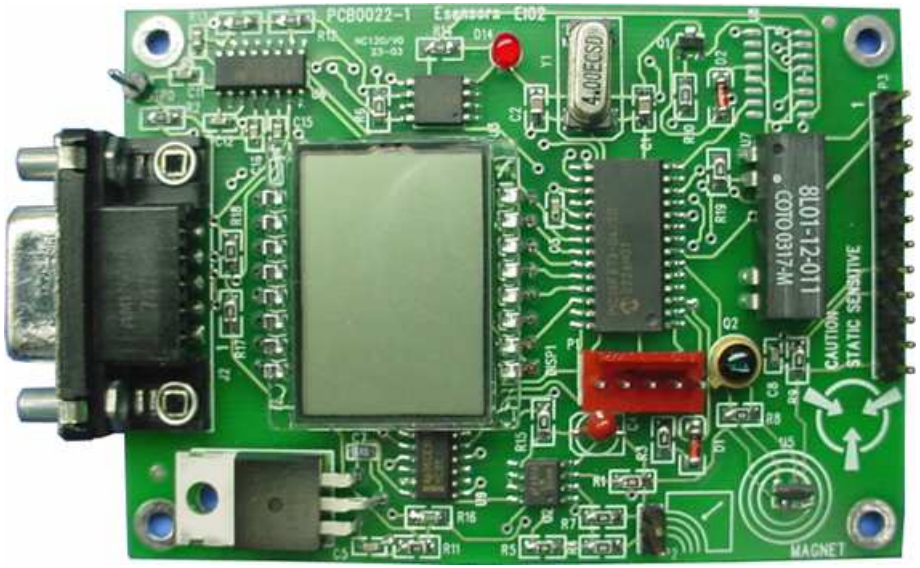
Bit Number	Data Description
Bit 1	Bit 1=0(North) Bit 1=1(South)
Bit 2-Bit 21	Manufacturer Latitude (Binary format)
Bit 22	Bit 22=0(East) Bit 22=1(West)
Bit 23-Bit 42	Manufacturer Longitude (Binary format)
Bit 43-Bit 46	Arbitrary Field=0000 (Binary format)
Bit 47-Bit 58	Year (Binary format)
Bit 59-Bit 80	Time (Binary format)

Meta-TEDS (#1), field 4 (10 bytes)

Block Diagram of a Prototype Dot 2 TIM or Smart Transducer



Prototype Dot 2 (RS232) TIM
(with 2 sensors and 1 actuator)

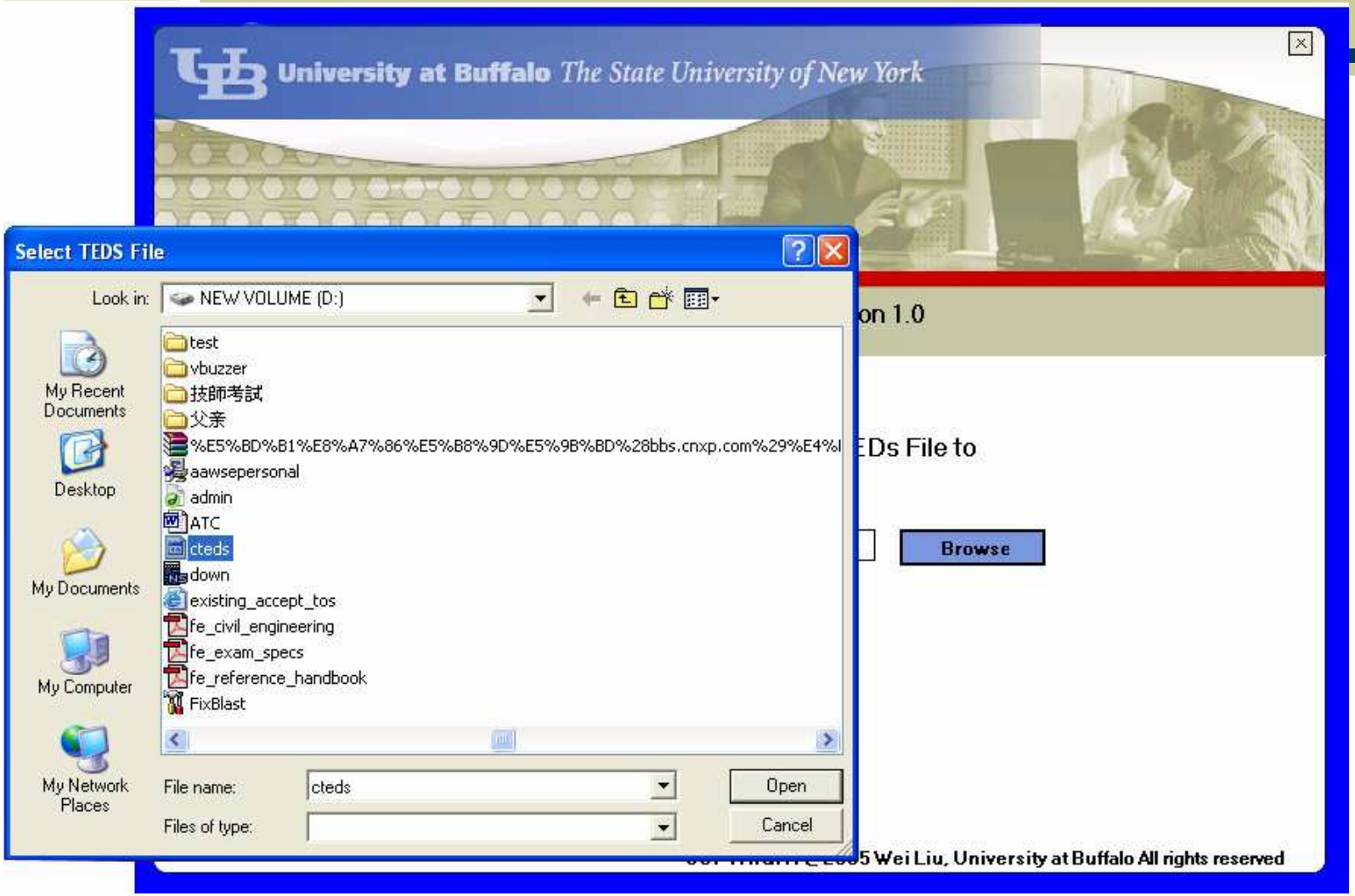


Relay

Photo

Hall effect

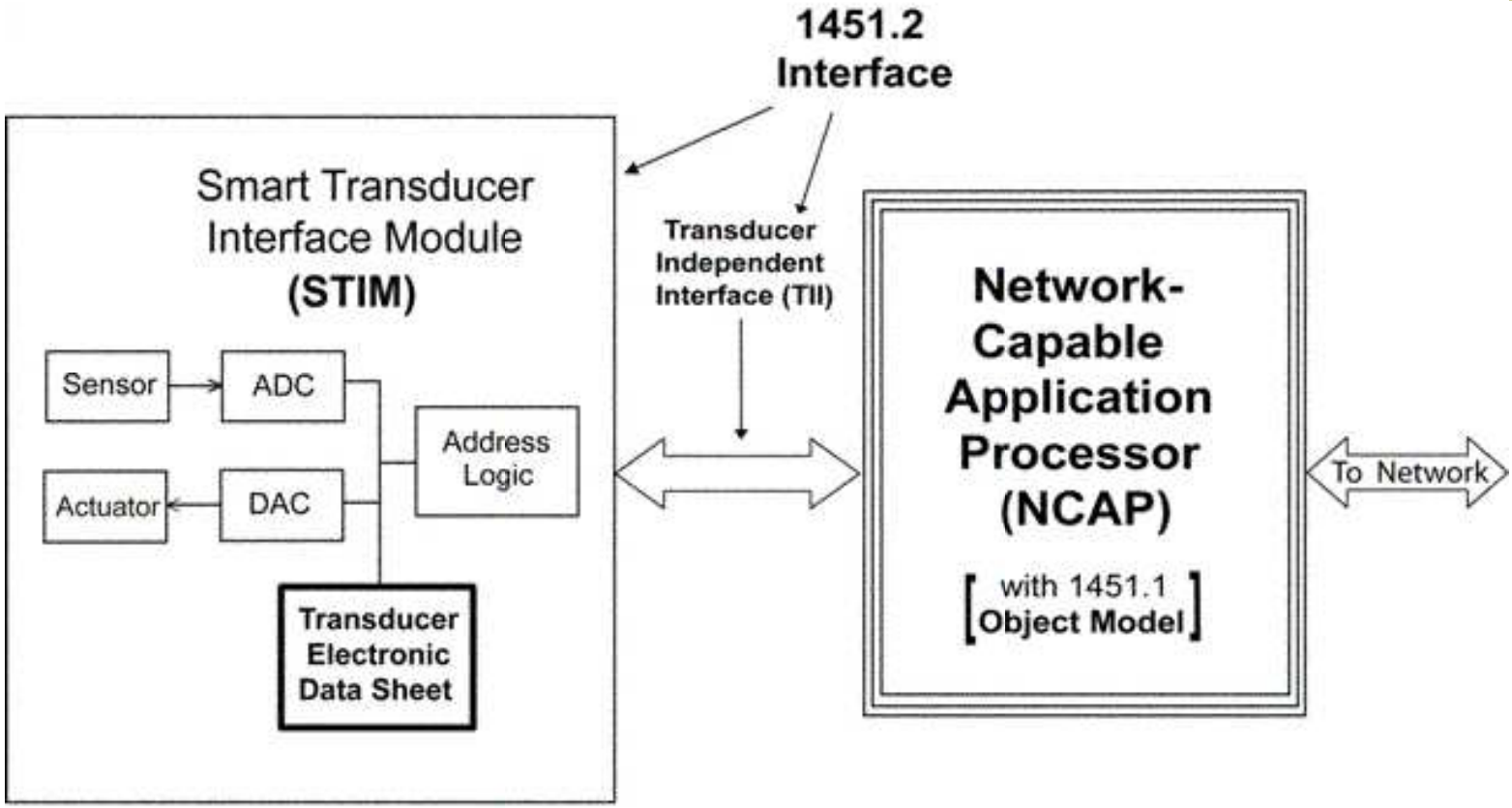
TEDS/Test Data File Save



References

- Wai Liu, “Design of TEDS Writer, Reader and Testing System for Transducer Interface Modules based on the IEEE 1451 Standard“, Ph. D. thesis (SUNY/Buffalo, EE Dept), May 2006.
- R. Johnson, et al “A Standard Smart Transducer Interface” http://ieee1451.nist.gov/Workshop_04Oct01/1451_overview.pdf
- IEEE Std. 1451.2-1907 “IEEE Standard for a Smart Transducer Interface for Sensors and Actuators – Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Format” http://ihome.ust.hk/~yangrd/pdf/ieee14512.pdf
- R. Frank “Understanding Smart Sensors”, 2nd ed, Artech House (2000)
- D. Wobschall, “Websensor Design – Smart sensors with an Internet Address” Proceeding Sensors Expo (Philadelphia, Oct. 2001)
- D. Wobschall, “A Minimal Dot4 NCAP with a Compatible Sensor Bus”, SiCon/05 (Houston).
- www.eesensors.com/IEEE1451

Original IEEE 1451.2 (Dot 2)
With 10-pin Transducer Independent Interface (TII)



Note: New name is TIM (Transducer Interface Module)

IEEE 1451 Parts

- IEEE 1451.0 Protocols & formats (final ballot, 2006)
- IEEE 1451.1 Object model (approved 1999)
- IEEE 1451.2 Serial (approved 1997)*
- IEEE 1451.3 Local network (approved 2003)
- IEEE 1451.4 Analog & TEDS (approved 2004)
- IEEE 1451.5 Wireless (close to final)
- IEEE 1451.6 Open CAN (early approval process)

* Enhancement /revision working group in process

- END