SMART SENSORS AND SENSOR NETWORKS

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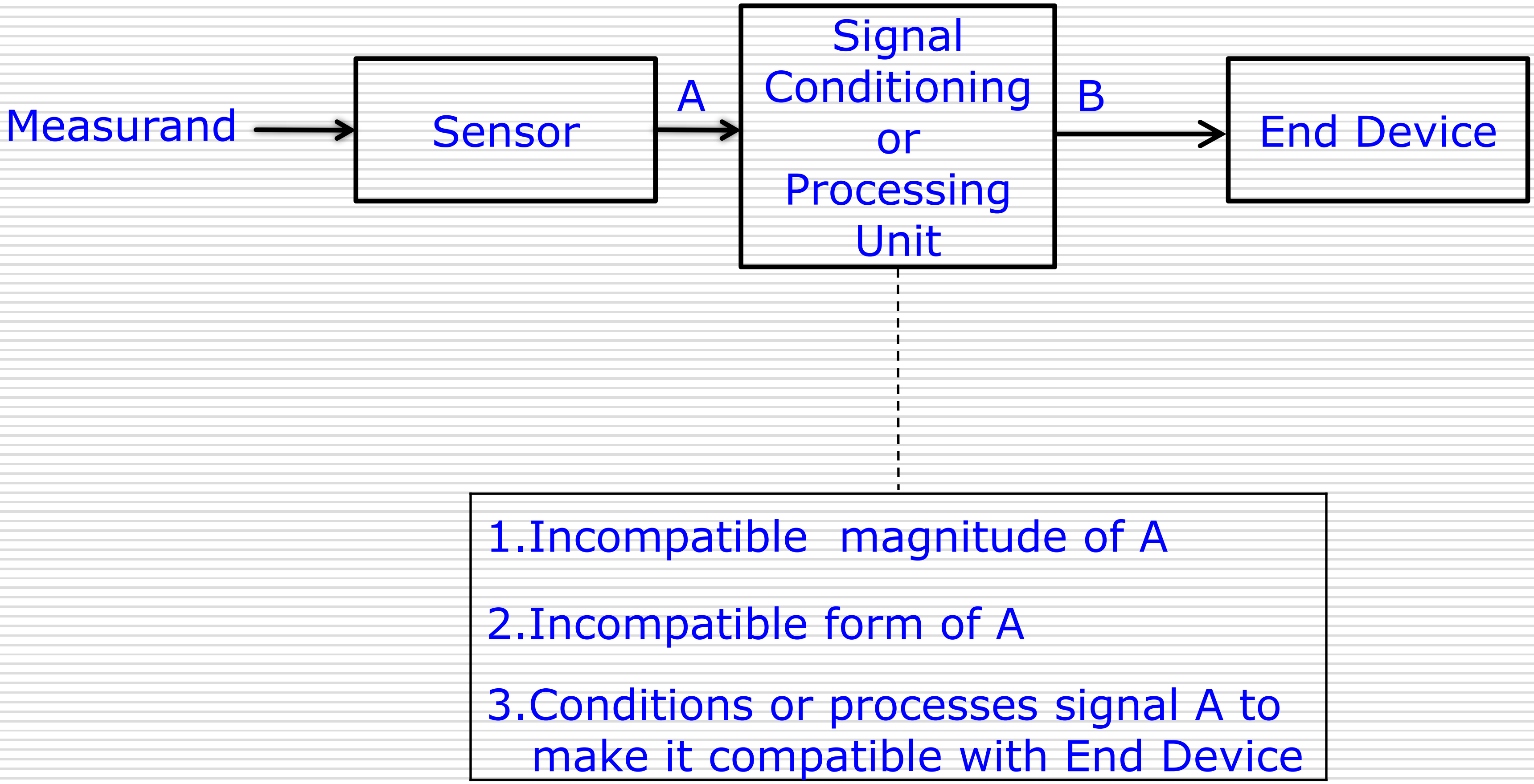
Outline

1. Smart Sensors
2. Smart Sensor Technologies
3. Examples of Smart Sensors
4. Sensor Networks
5. Wired Network Protocols
6. Wireless Network Protocols
7. IEEE 1451
8. Wireless Sensor Network (WSN)
9. Applications of WSN

Smart Sensors

Instrumentation System



Sensor Versus Transducer

- Sensor : Senses input quantity and converts into an electrical output

- Transducer: Converts one form of energy into another form for instrumentation or control

- Input transducer ⇔ Sensor

- Output transducer ⇔ Actuator

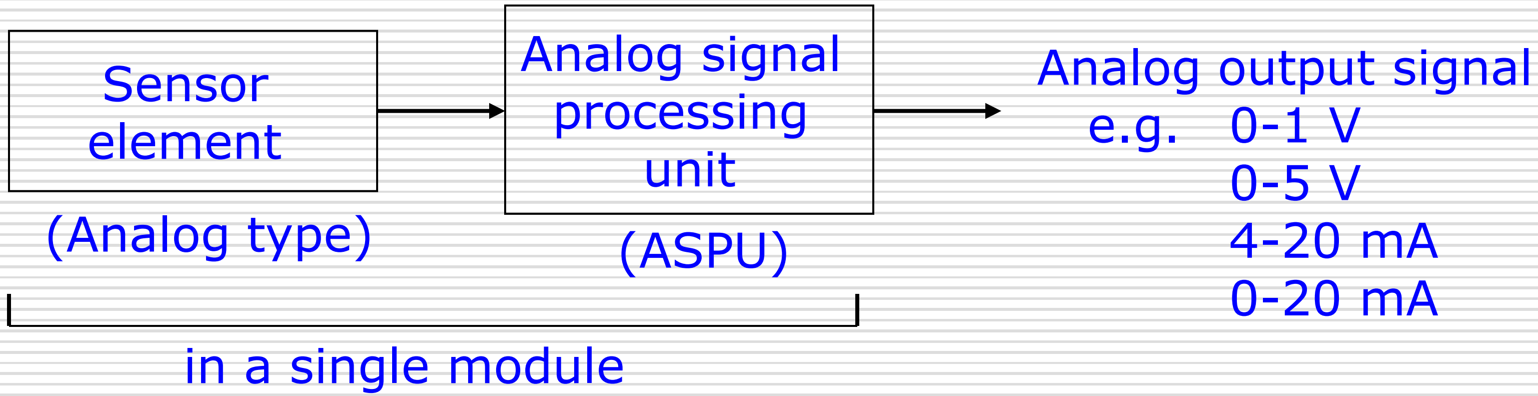
What is a Smart Sensor?

- No standard definition so far.
- Smart sensor is a module containing the sensor element(s) suitably integrated with the necessary electronics, such that the output is fully or easily compatible with the intended end device(s).
- The module takes the form of
  - Single chip (desirable)
  - Single board (minimum requirement)

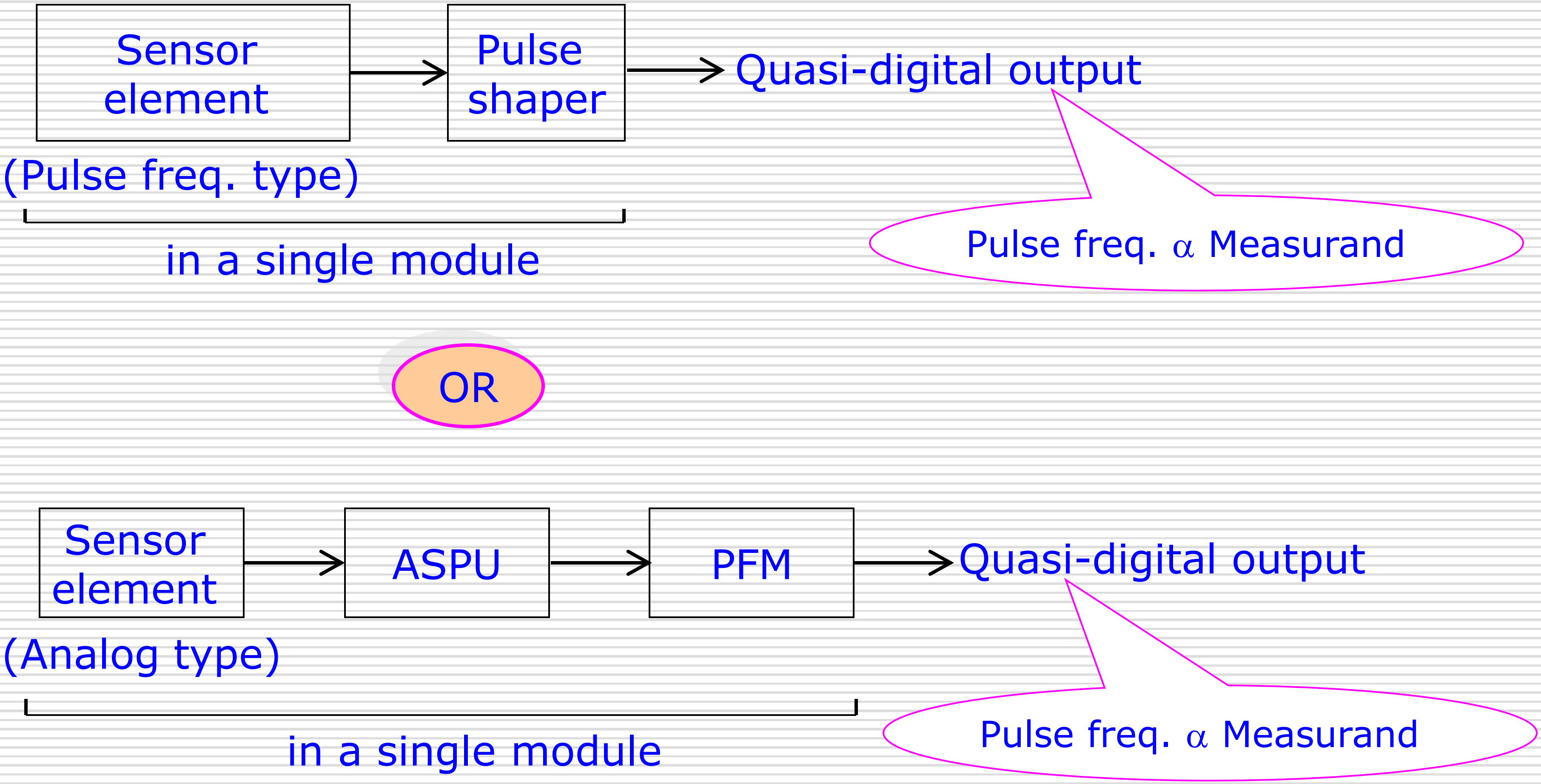
Four Levels of Integration

- I Level : Smart sensor with analog or quasi-digital output
- II Level : Smart sensor with digital output
- III Level : Intelligent sensor
- IV Level : Network sensor

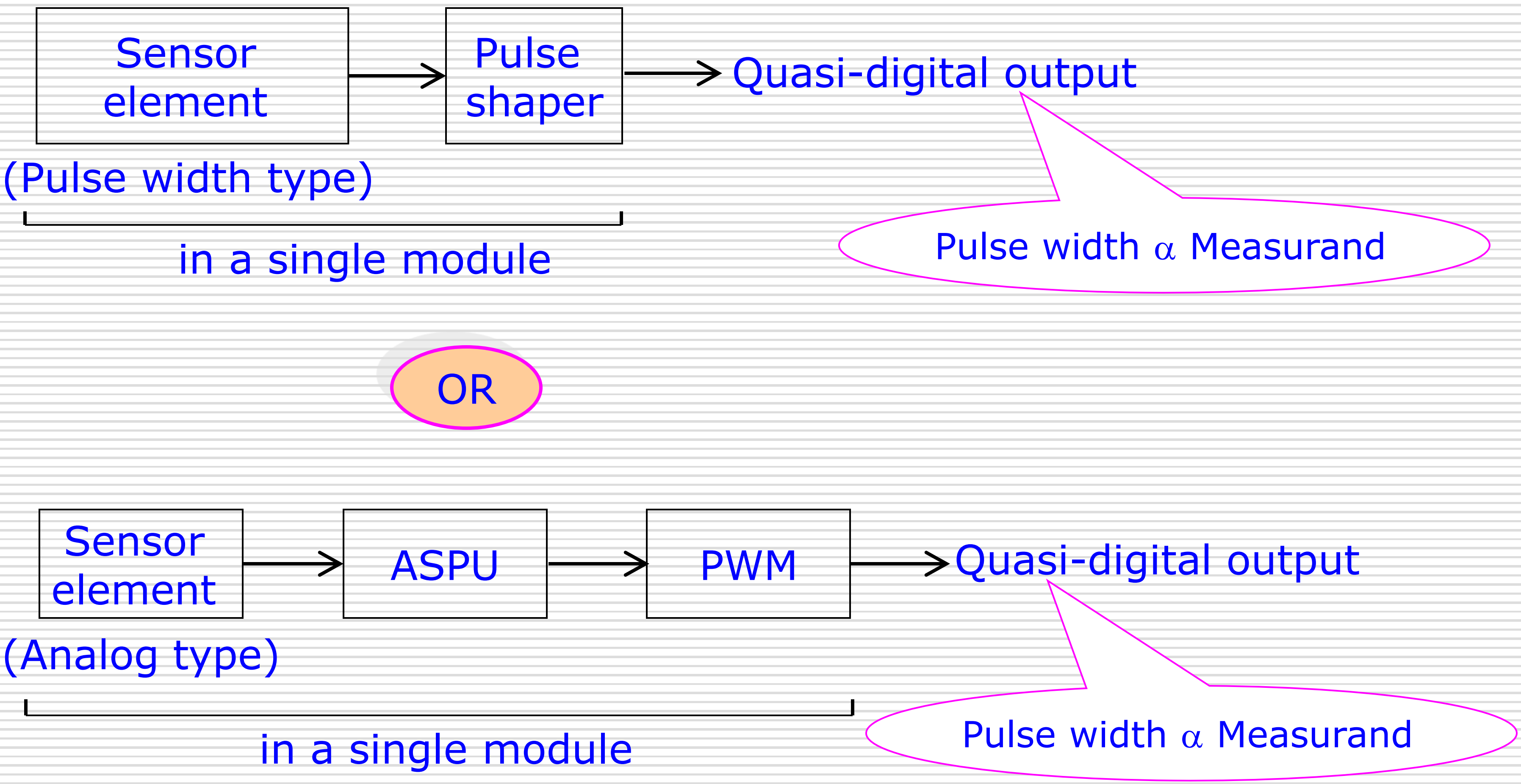
Smart Sensor with Analog Output



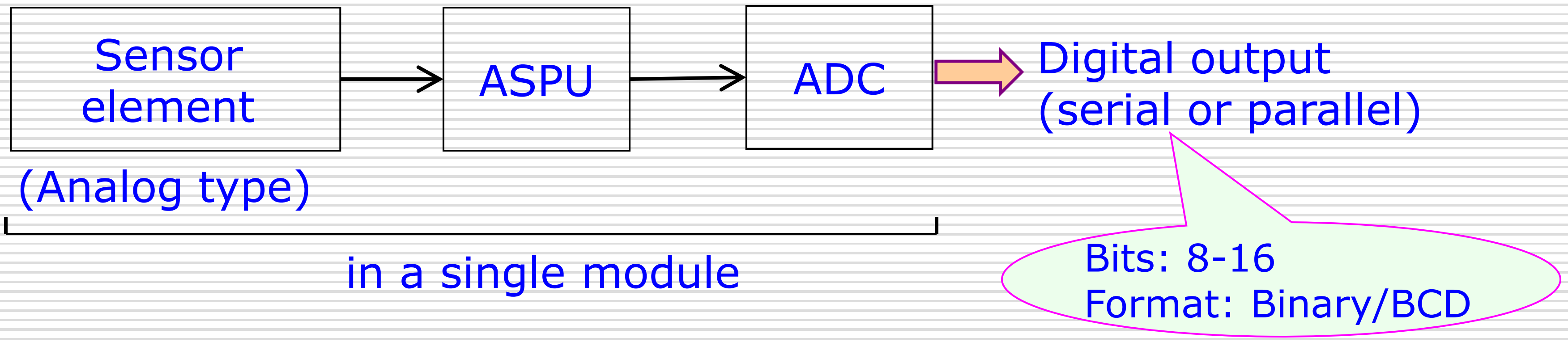
Smart Sensor with Pulse-Frequency Output



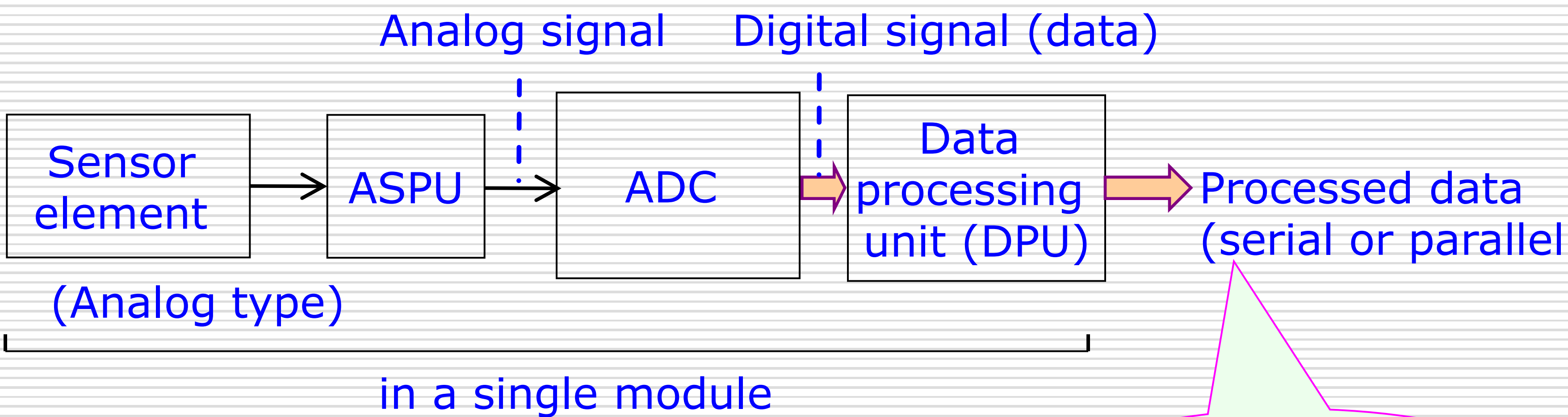
Smart Sensor with PWM Output



Smart Sensor with Digital Output



Intelligent Sensor



Can be readily connected to a host computer or other digital system

DPU = Microcontroller

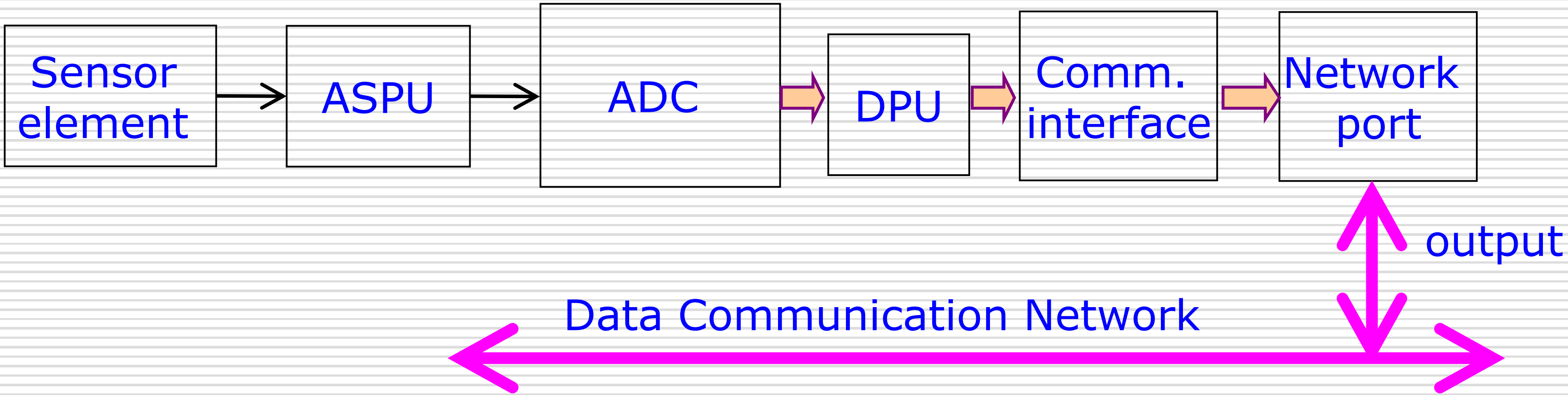
OR

μP + memory + I/O interface

OR

DSP +memory + I/O interface

Network Sensor



Advantages of Smart Sensors

1. User’s Convenience
   - No wiring
   - Compact size
   - No design of SC
   - No selection of SC
2. Superior Performance
   - No external noise, resulting in high SNR
   - Sensor-specific SC circuits perform better
   - Negative feedback to reduce nonlinearity
   - Compensating circuits to reduce sensitivity to temp./ voltage
3. High Reliability
   - Reduced component count
   - Reduced wiring
4. Cost Reduction
   - Electronics and sensor made concurrently
   - Mass production

Smart Sensor Technologies

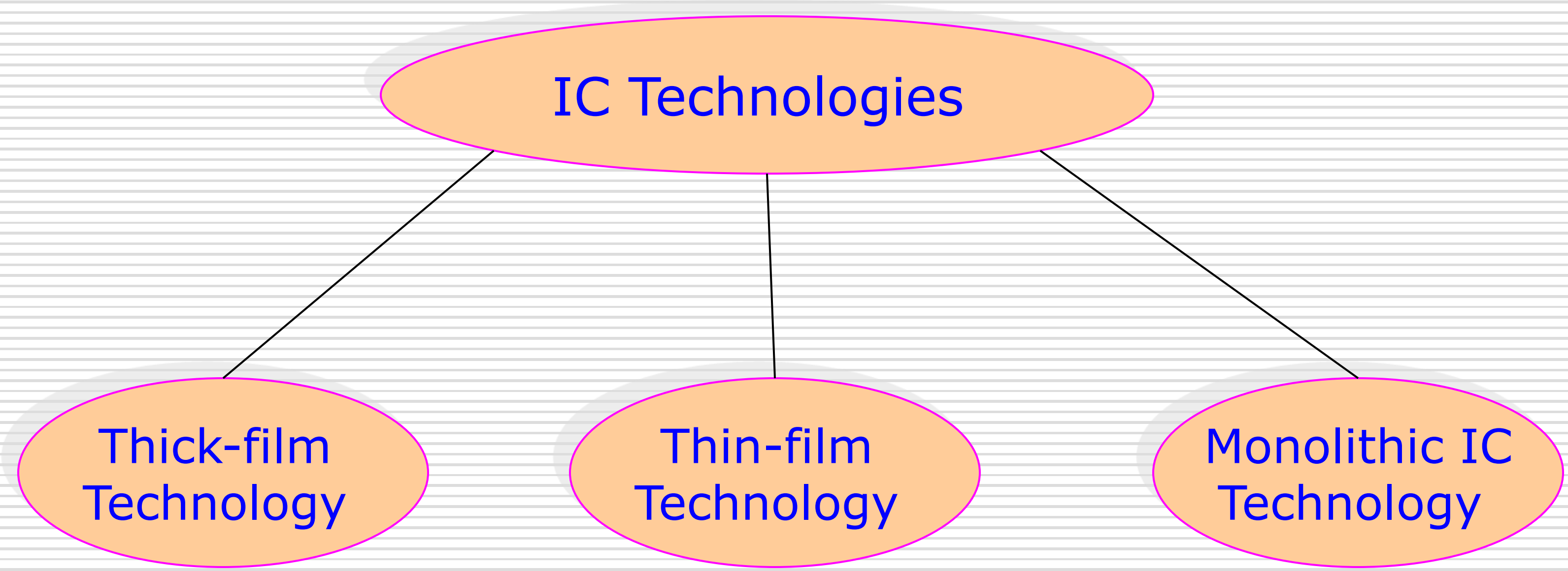
Smart Sensor Technologies

Two types of technologies used:

- IC Technologies
  (Originally developed for producing micro-electronic components and circuits)

- Micromachining Technologies
  (Originally developed for producing micro-mechanical components and systems)

IC Technologies & Capabilities

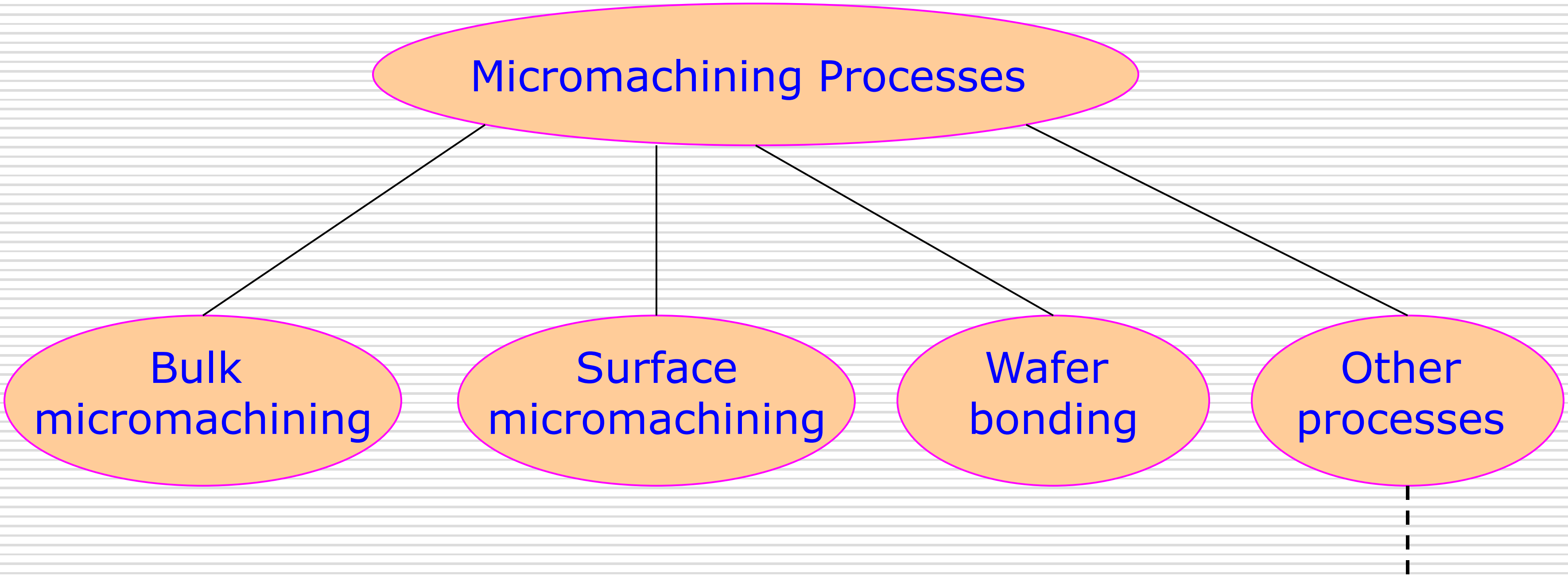


- R, C & L
- Conductors
- Sensor elements
- Sensor supports

- R & C
- Conductors
- Sensor elements

- R & C
- Diodes & transistors
- Conductors
- Sensor elements

Micromachining Technologies



- LIGA process
- Micro-milling
- Plasma etching
- Deep Reactive Ion Etching (DRIE)

Examples of Smart Sensors

Smart Humidity and Temperature Sensor

SHT 71/75/10/11/15

Manufacturer: Sensirion Corp.

Source of Information: www.sensirion.com

Salient Features

- Senses relative humidity and temperature
- Also measures dew point
- Single chip sensor-cum-transmitter
- Capacitive polymer sensing element for relative humidity
- Band-gap for temperature sensing
- CMOS & micromachining technologies combined
- Patented as "CMOS Sens" Technology
- Serial digital output
- Self calibration
- Evaluation kits from the manufacturer

Devices in SHTxx Series

Pin-Type Package

SHT 71

SHT 75

SMD Package

SHT 10

SHT 11

SHT 15

Technical Data

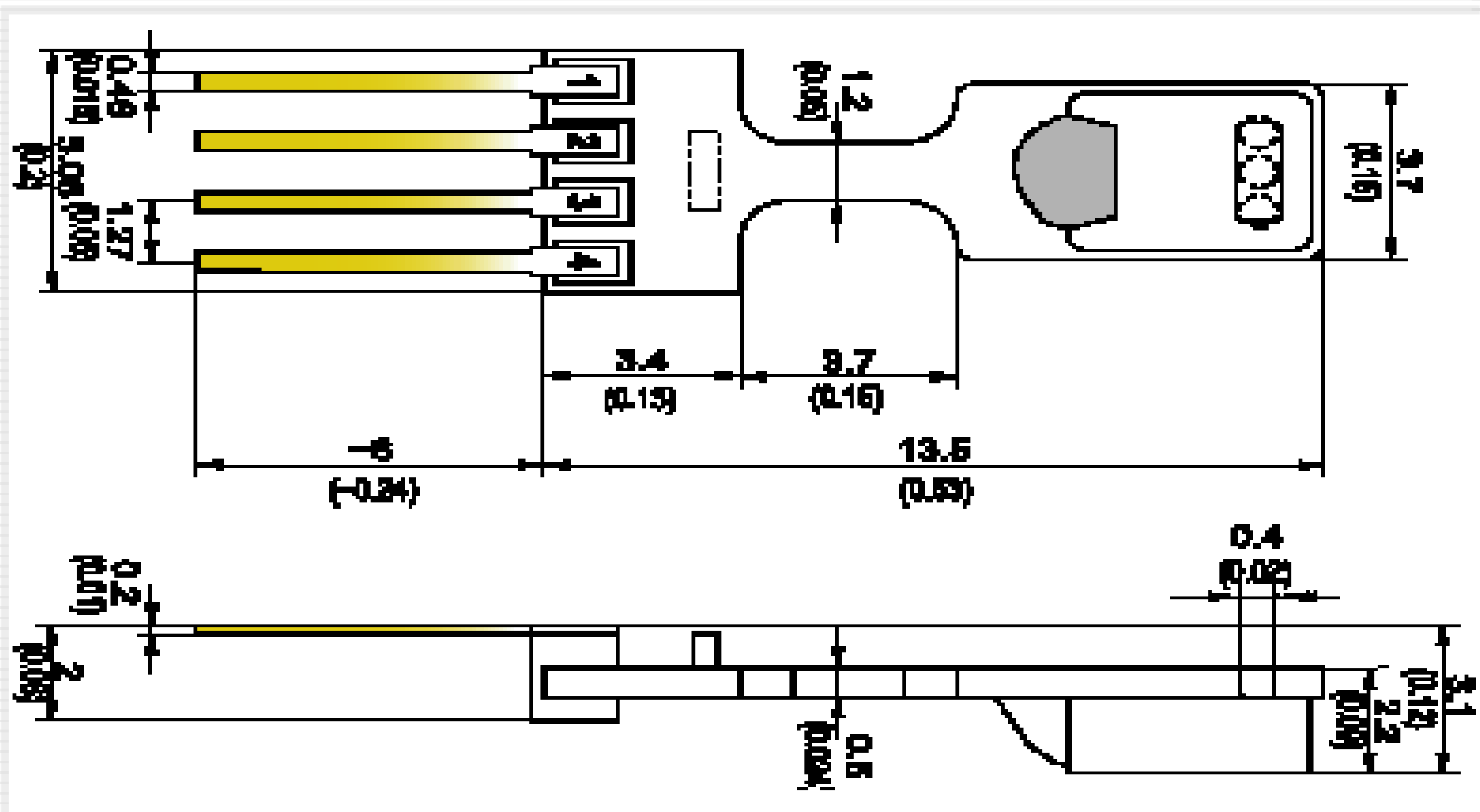
Feature	SHT 71	SHT 75	SHT 10	SHT 11	SHT 15
RH Accuracy	± 3%	± 1.8%	± 4.5%	± 3%	± 2%
RH Range	0-100%				
RH Stability	<0.5% per year				
Temp. Accuracy @ 25^0C	0.4^0C	± 0.3^0C	±0.5^0C	±0.4^0C	0.3^0C
Temp. Range	-40 to + 120^0C				
Power Consumption	30μW	20μW	30μW	30μW	30μW
Response Time	4s				
Package	4-Pin SIL		SMD (LCC)*		

**Surface mounting device (leadless chip carrier)*

Dimensions of SHT7x

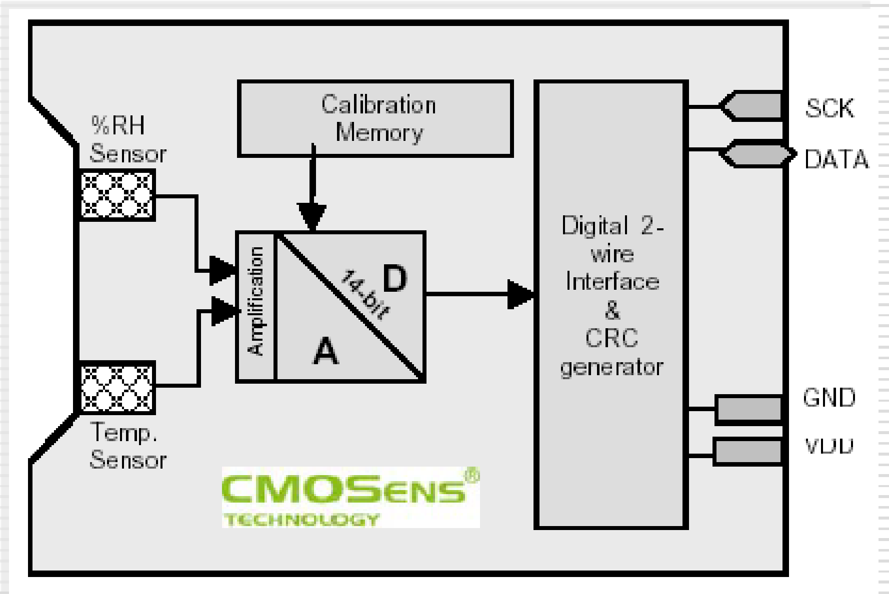
SMD
3.5*5*2mm

SIL
5*15*3mm



Block Diagram

Pin No.	Pin Name	Description
1	SCK	Serial clock input
2	VDD	Supply 2.4 – 5.5 V
3	GND	Ground
4	DATA	Serial data bidirectional



Serial interface of SHTxx is not compatible with I^2C interfaces.

Smart Acceleration Sensor

or

iMEMS Accelerometer

ADXL 150/250/210/311

Manufacturer: Analog Devices

Source of Information: www.analog.com

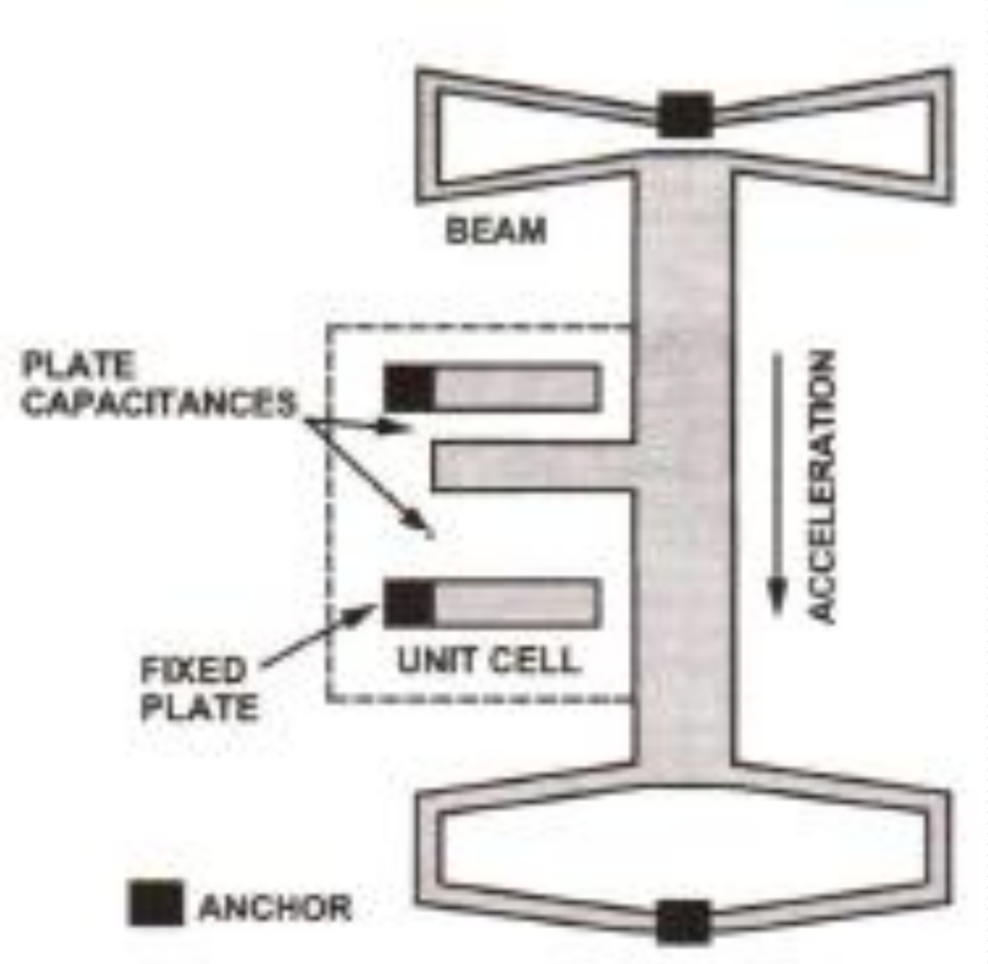
ADXL Series

- ADXL 150: Single-axis
  - 14-Pin dual-in-line (DIL) package
  - DC output
- ADXL 250: Dual-axis
  - 14-Pin dual-in-line (DIL) package
  - DC output
- ADXL 210: Dual-axis
  - 8-Terminal leadless chip carrier (LLC) package
  - PWM output
- ADXL 311: Dual-axis
  - 8-Terminal leadless chip carrier (LLC) package
  - DC output

Common Features of ADXL

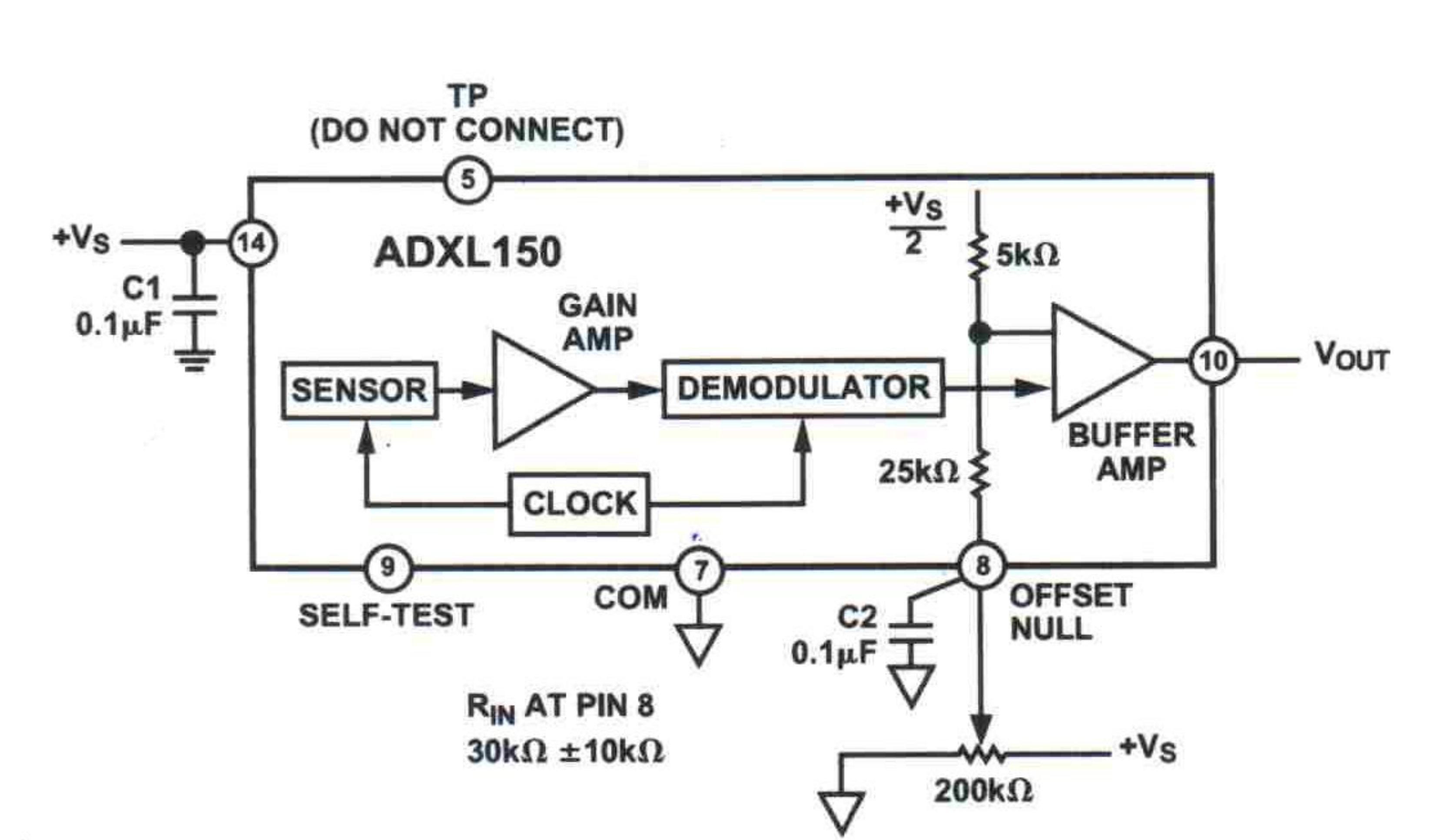
- Sensing element and ASPU on a single IC chip
- Can measure dynamic acceleration (vibrations) as well as static acceleration (gravity)
- Ultra-small package
- Ultra-low weight (<1 gram)
- Low power (<0.5 mA@ Vs)
- Single-supply operation
- Large bandwidth
- Bandwidth adjustment with a single capacitor
- Output is ratiometric to supply voltage
- Self test feature
- 1000 g shock survival
- Sensing element fabricated using proprietary surface micromachining process.

Sensing Element of ADXL



(Source: Data sheets of ADXL150)

Block Diagram of ADXL 150



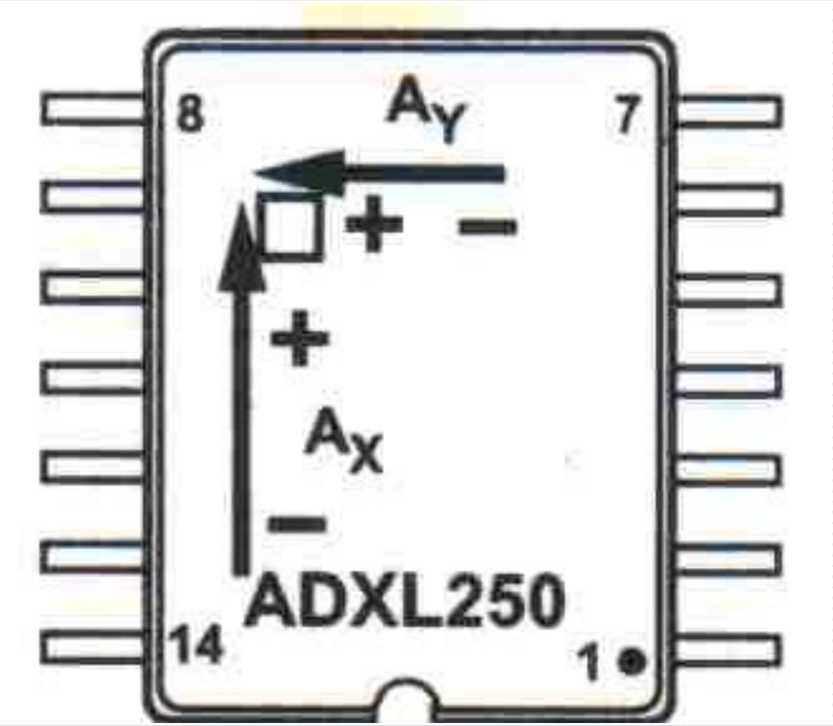
Trim potentiometer used for offset nulling

Specifications of ADXL 150

Input Range	:	± 50 g
Power Supply (V_s)	:	4.0 V to 6.0 V Nominal value 5.0 V
Sensitivity @ V_s = 5V	:	38 mV/g
Transverse Sensitivity	:	± 2%
Zero-g offset	:	0.5 V_s
Output Swing	:	0.25 V to V_s-0.25 V
Sensor Resonant Freq.	:	24 kHz
3dB Bandwidth	:	1 kHz
Output change on Self Test	:	0.25 to 0.60 V
Operating Temperature	:	0 to 70^0C

Physical Data of ADXL 250

- 14-pin DIL package
- Sensitive axes are A_x and A_y



(Source: Data sheets of ADXL250)

Two-Terminal IC Temperature Sensor

AD590/AD592

Manufacturer: Analog Devices

Source of Information: www.analog.com

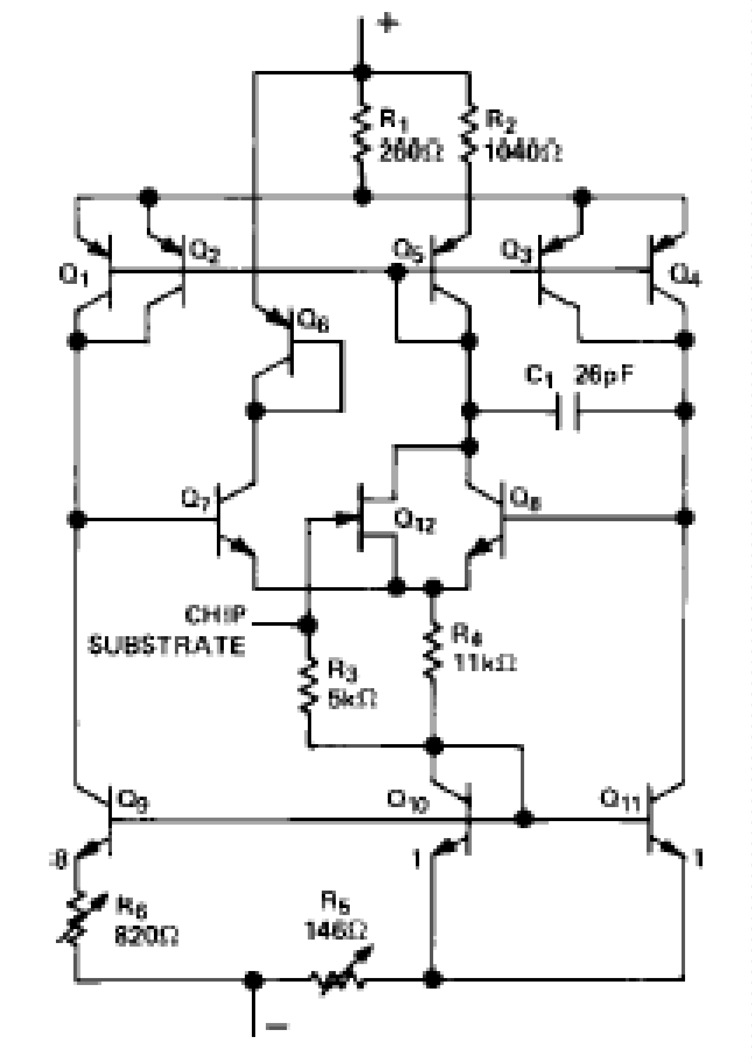
Salient Features of AD590 / 592

- Principle: Sensitivity of band gap voltage of silicon junction to temperature

- Temperature range : -55^0C to + 150^0C

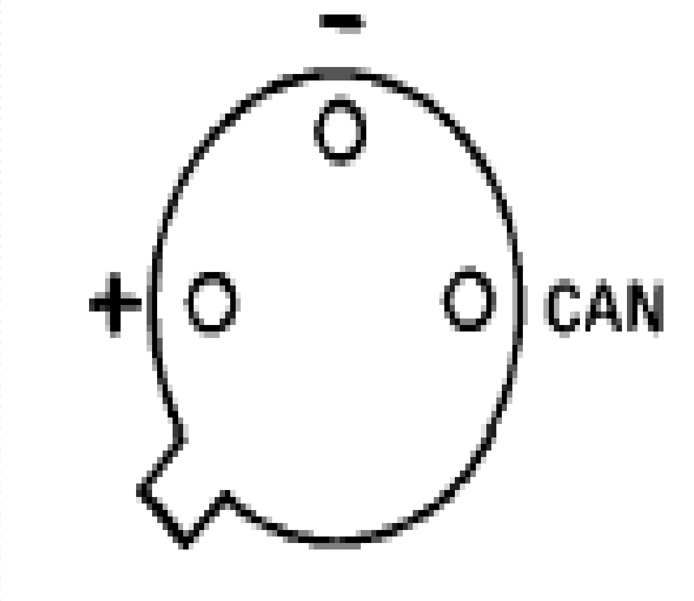
- Output: 1 μA / K

Schematic Diagram

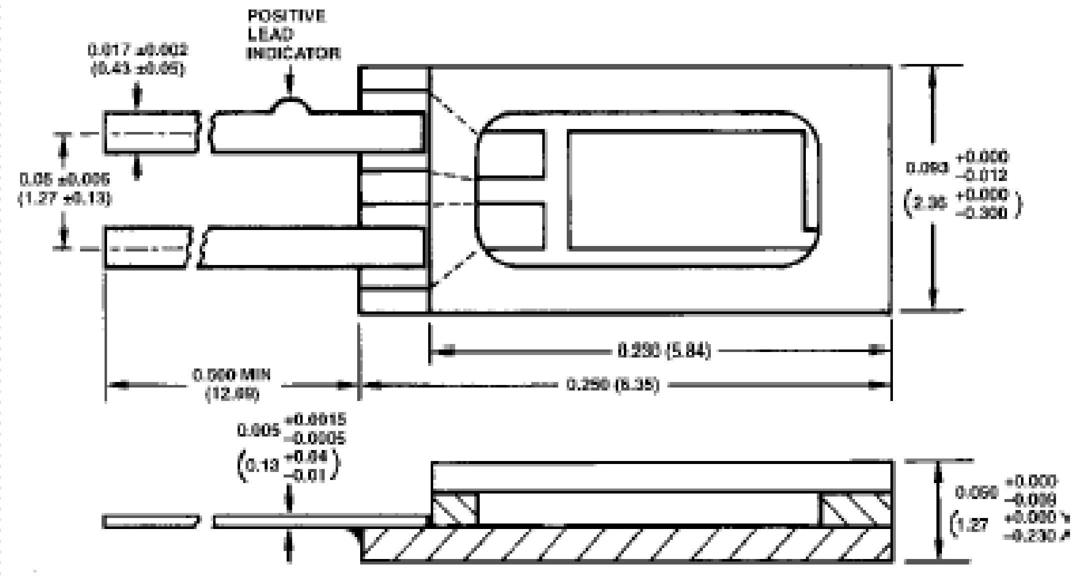


Package and Pins

TO52 Package

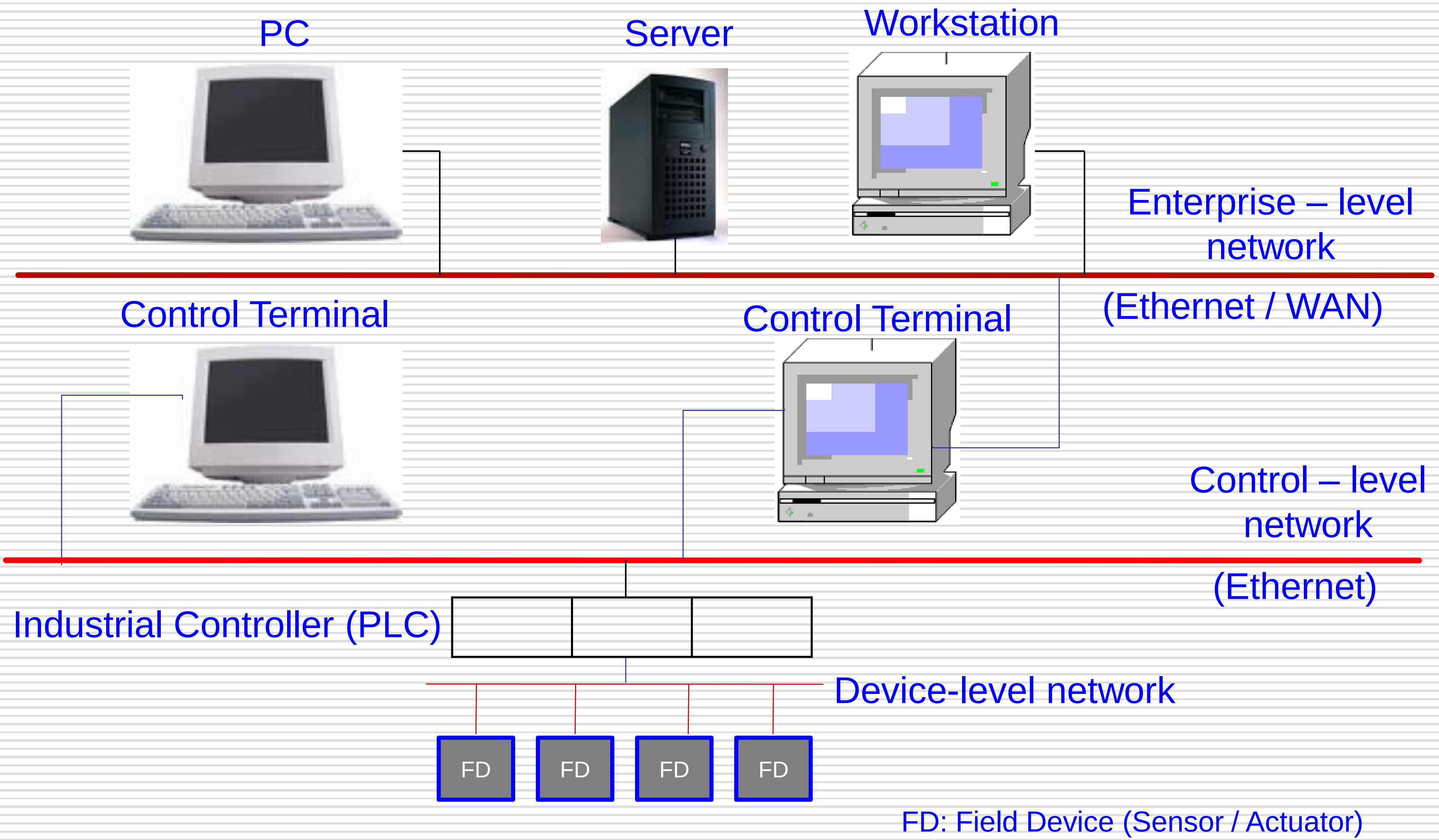


Flat Package

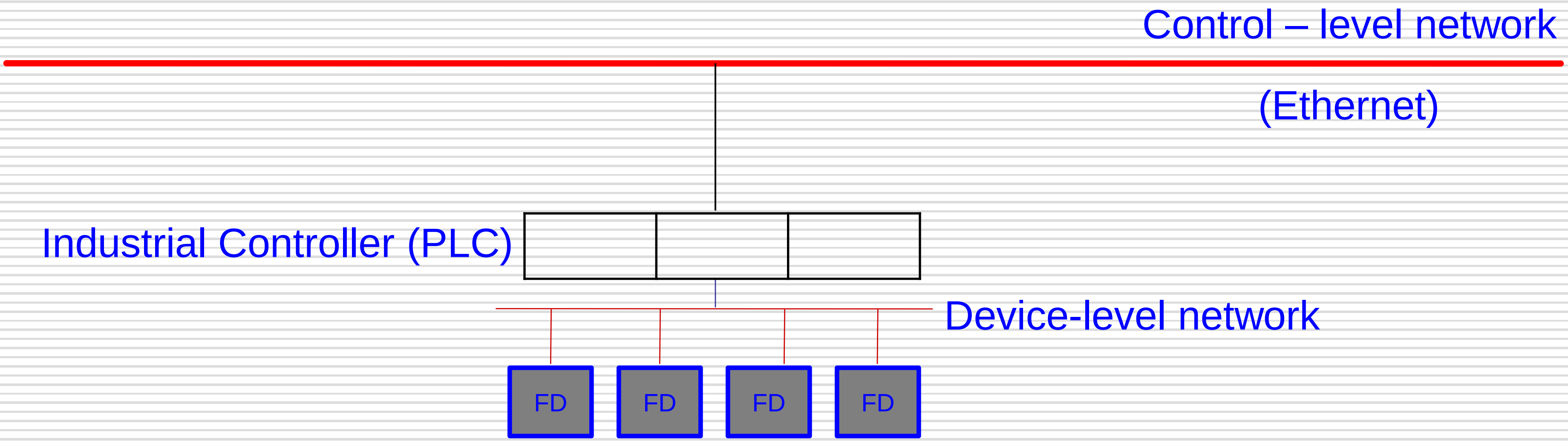


Sensor Networks

Hierarchy of Industrial Data Networks

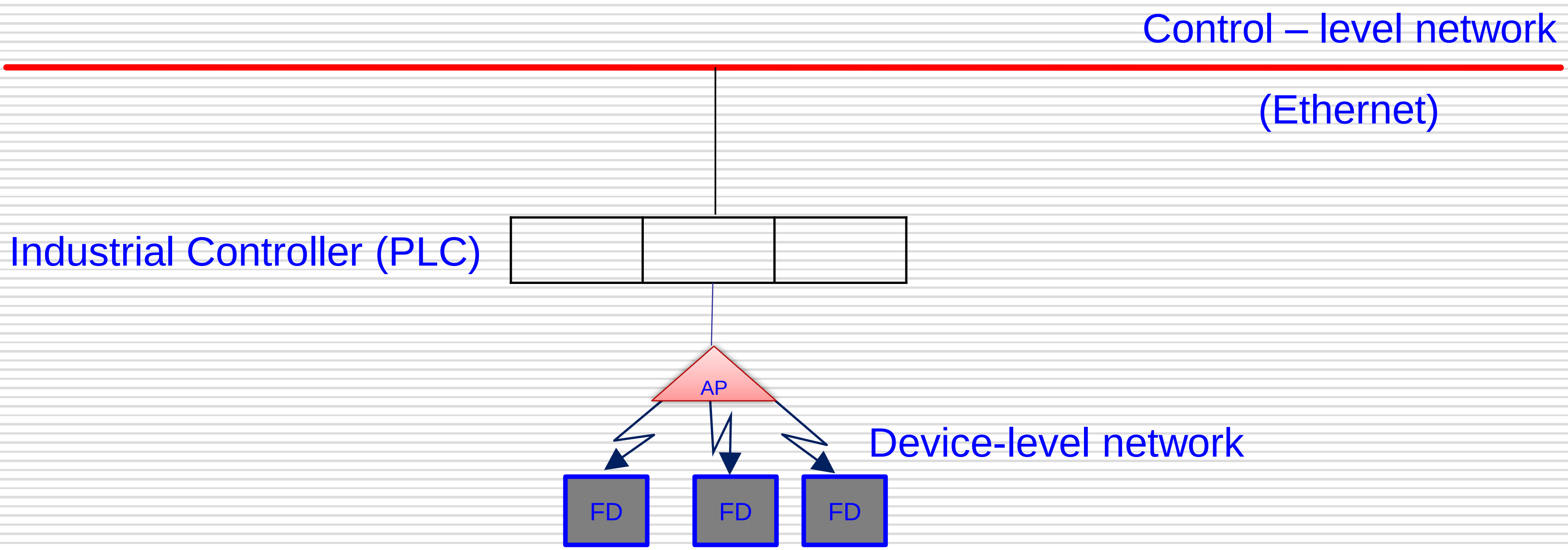


Device-Level Wired Network



FD: Field Device (Sensor / Actuator)

Device-Level Wireless Network



FD: Field Device (Sensor / Actuator)
AP: Access Point or Wireless router

Device Level Networks: Special Requirements

- Low latency or end-to-end delay
- Low power consumption or long battery life
- High network reliability
- High data security
- Low bandwidth

Device-Level Networks: Technologies/Protocols

Technologies/Protocols for Wired Networks

- RS422
- RS485
- MODbus
- Foundation Fieldbus
- HART
- CAN
- LON
- BACNet

Technologies/Protocols for Wireless Networks

- Zigbee
- Wi-Fi
- Bluetooth
- Wireless Fieldbus

Networking of Sensors: Four Situations

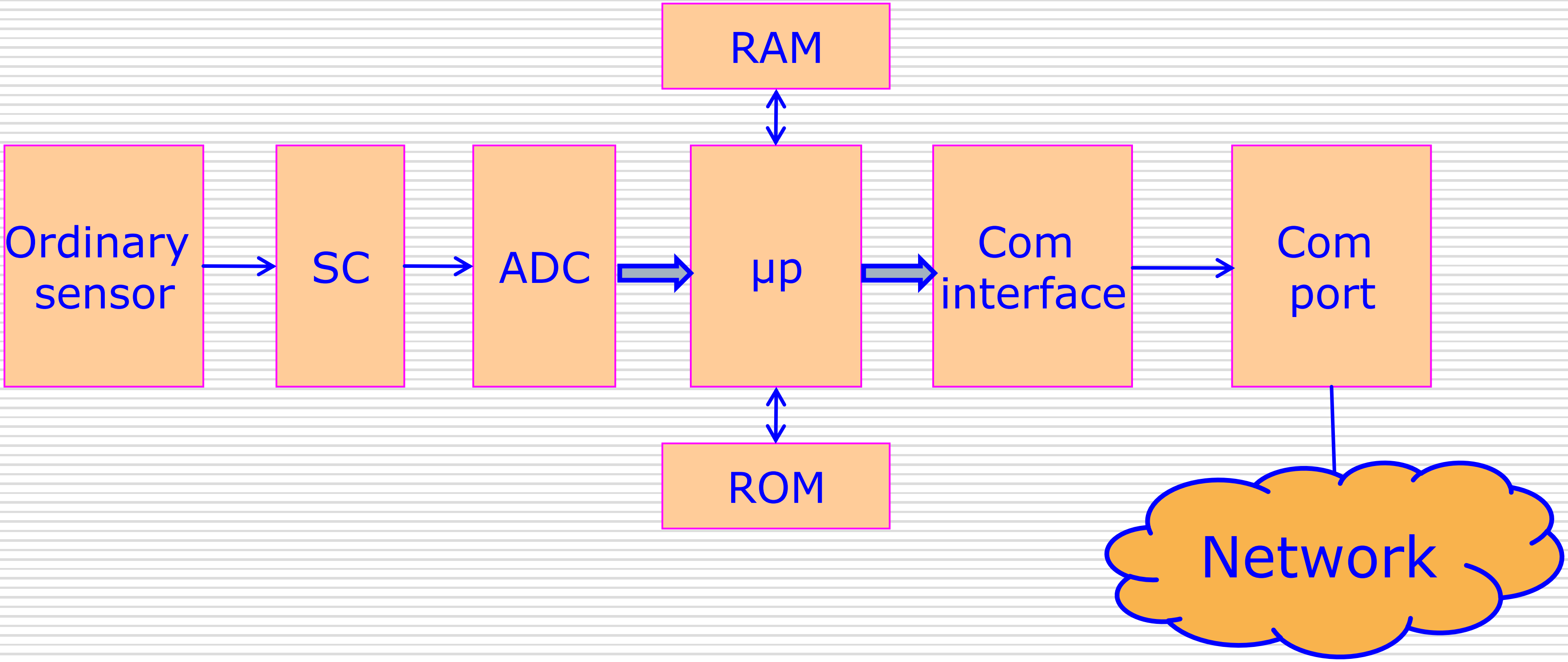
Situation A – Ordinary Sensor + SC + MPU + Interface

Situation B – Network Sensor

Situation C – Smart Sensor + Custom Interface

Situation D – Smart Sensor + IEEE 1451 Interface

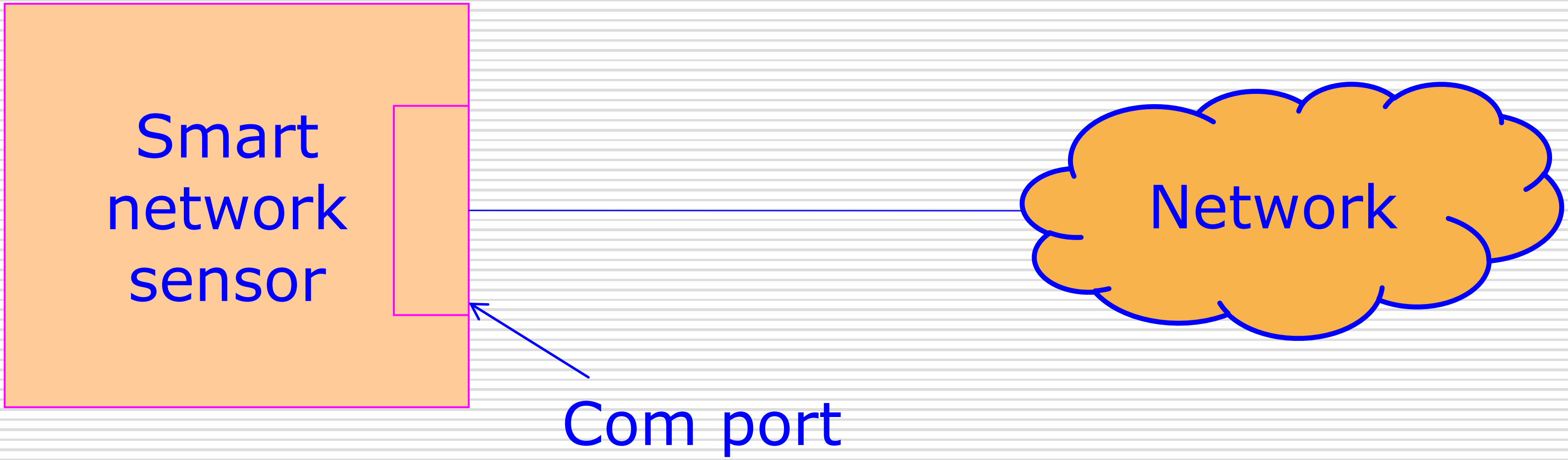
Situation A: Ordinary Sensor + SC + MPU + Interface



Advantage
- ❖ Flexibility

Disadvantages
- ❖ Cumbersome
- ❖ Only expert can do
- ❖ Expensive

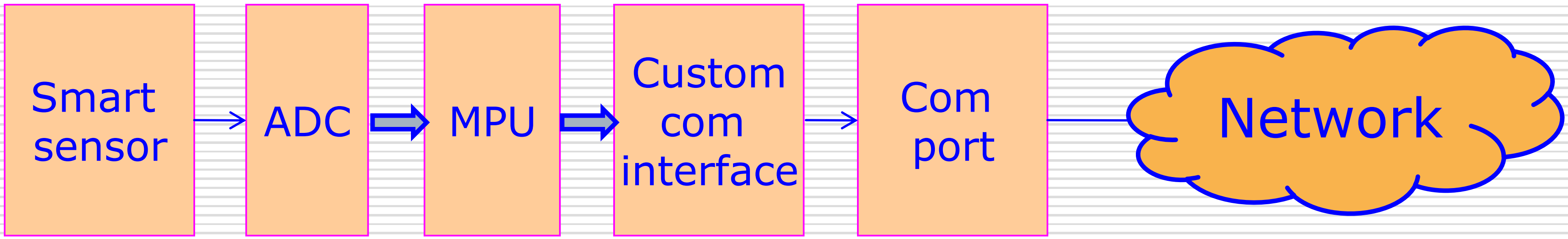
Situation B: Network Sensor



Advantages
- ❖ Simple
- ❖ Fast
- ❖ No expertise required

Disadvantage
- ❖ No flexibility of network protocol

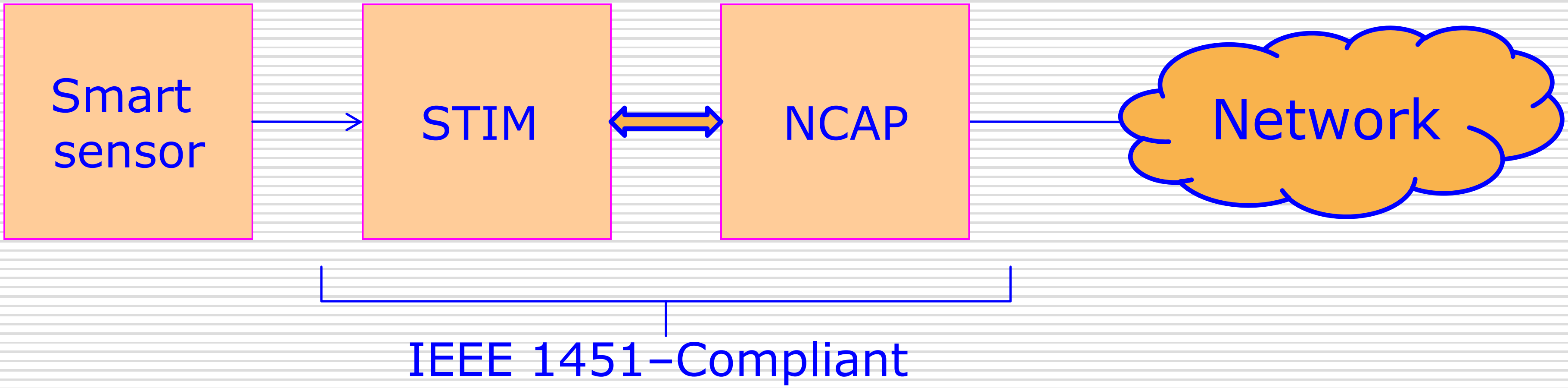
Situation C: Smart Sensor + Custom Interface



Advantage
- ❖ No SC required

Disadvantages
- ❖ Cumbersome
- ❖ Only expert can do

Situation D: Smart Sensor + IEEE1451 Interface



Advantages

- ❖ No SC required
- ❖ Flexibility of network protocol

Disadvantage

- ❖ Needs STIM & NCAP

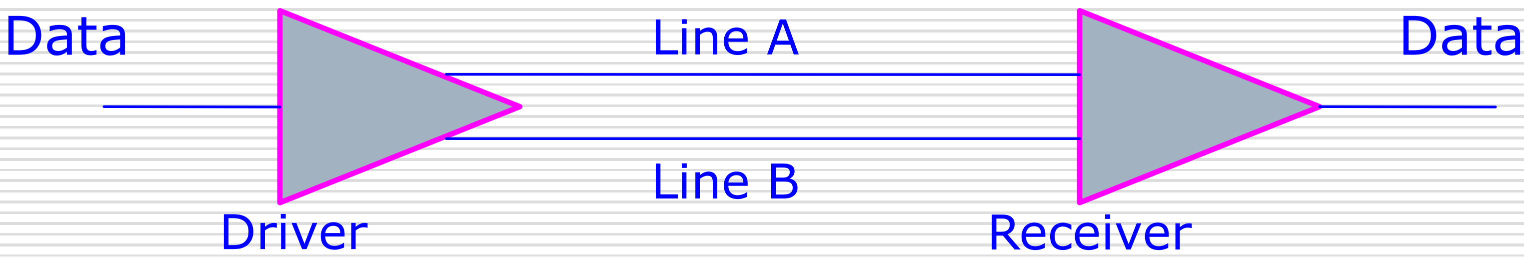
Wired Network Protocols

RS485 Protocol

- Recommended by EIA, it is an industry standard
- Specifies balanced differential signals
- Supports Master-Slave mode
- Supports half-duplex as well as full-duplex communication
- Allows upto 32 drivers and 32 receivers
- Maximum data rate: 10 Mbps @ cable length upto 12m
- Maximum cable length: 1200m @ 100 kbps

Balanced Mode Transmission

- Driver (transmitter) converts SE signal to differential signal
- Receiver translates diff. signal back to SE signal
- CM noise induced in two lines is rejected by receiver



- Signal Levels:

Logic 0	: Line B more positive than Line A
Logic 1	: Line A more positive than Line B
Differential voltage	: 0.4 V to 12 V

- Max CM voltage permitted: ±7V
- Twisted pair provides transposition of lines A & B

MODBUS

1. Open, serial communication protocol
2. Suitable for field-device networks
3. Developed and introduced in 1979 by Modicon for use in PLCs
4. Now an industry standard
5. Modbus implementations:
   - Modbus over serial line
   - Modbus over TCP/IP
   - Modbus over high speed token passing network (Modbus Plus)

Modbus Over Serial Line

1. Application layer is completely specified

2. Serial line options: (i) RS-422
   (ii) RS-485

3. MAC protocol: Master-slave

4. Transmission modes: (a) RTU
   (b) ASCII

Modbus Protocol Stack

	OSI Reference Model	Modbus Protocol
7	Application	Modbus Application Protocol
6	Presentation	
5	Session	
4	Transport	Empty
3	Network	
2	Data Link	Master-Slave Protocol
1	Physical	RS-422 or RS-485 Protocol

Master-Slave Protocol

1. Communication always initiated by master
2. A slave transmits data (replies) only on master's request
3. Slave mode never communicate with each other
4. Master node initiates only one transaction at a time
5. Master's request to slaves are either in "Unicast" mode or in "Broadcast" mode

Request/Response Modes

Unicast Mode:

- Master addresses an individual slave
- Only the addressed slave replies to master

Broadcast Mode:

- Master addresses all slaves on the bus
- All slaves accept “broadcast message” for “writing function”
- No reply is sent to master

Coding & Bit Sequence in RTU Mode

Coding System:

- 8-bit binary (byte)
- Hexadecimal characters 0-9 and A-F
- Two hexadecimal characters per byte

Bit Sequence if parity is used:

11 bits per data byte

Start bit	8 data bits (LSB ….. MSB)	Parity bit	Stop bit

Bit Sequence if parity is not used:

11 bits per data byte

Start bit	8 data bits (LSB ….. MSB)	Stop bit	Stop bit

Modbus Message Frame in RTU Mode

Field	Master-to-Slave Message (Request)	Slave-to-Master Message (Response)
1. Address	Slave address	Slave address
2. Function Code	Indicates to slave the kind of action to perform	Indicates the kind of response
3. Data	Request parameters	Response parameters & values
4. Error Check Code	CRC	CRC

Bytes	1	1	0-252	2
	Address	Function Code	Data	Error Check Code

Coding & Bit Sequence in ASCII Mode

Coding System:

- 7-bit ASCII characters
- Hexadecimal characters 0-9 and A-F
- One hexadecimal character per ASCII character

Bit Sequence if parity is used:

10 bits per ASCII character

Start bit	7 data bits (LSB …MSB)	Parity bit	Stop bit

Bit Sequence if parity is not used:

10 bits per data byte

Start bit	7 data bits (LSB …MSB)	Stop bit	Stop bit

Modbus Message Frame in ASCII Mode

Field	Master-to-Slave Message (Request)	Slave-to-Master Message (Response)
1. Start Delimiter	:	:
2. Address	Slave address	Slave address
3. Function Code	Indicates to slave the kind of action to perform	Indicates the kind of response
4. Data	Request parameters	Response parameters & values
5. Error Check Code	LRC	LRC
6. End Delimiter	CR, LF	CR, LF

Characters	1	2	2	0-2x252	2	2
	Start delimiter	Address	Function code	Data	LRC	End delimiter CR, LF

Foundation Fieldbus

- Field-buses are fully-digital network protocols
- Developed by industry for networking of field devices on plant/factory floor
- Application Area: Industrial Measurement & Control
- Common standard for Field-bus: IEC-61185

Important Field-buses

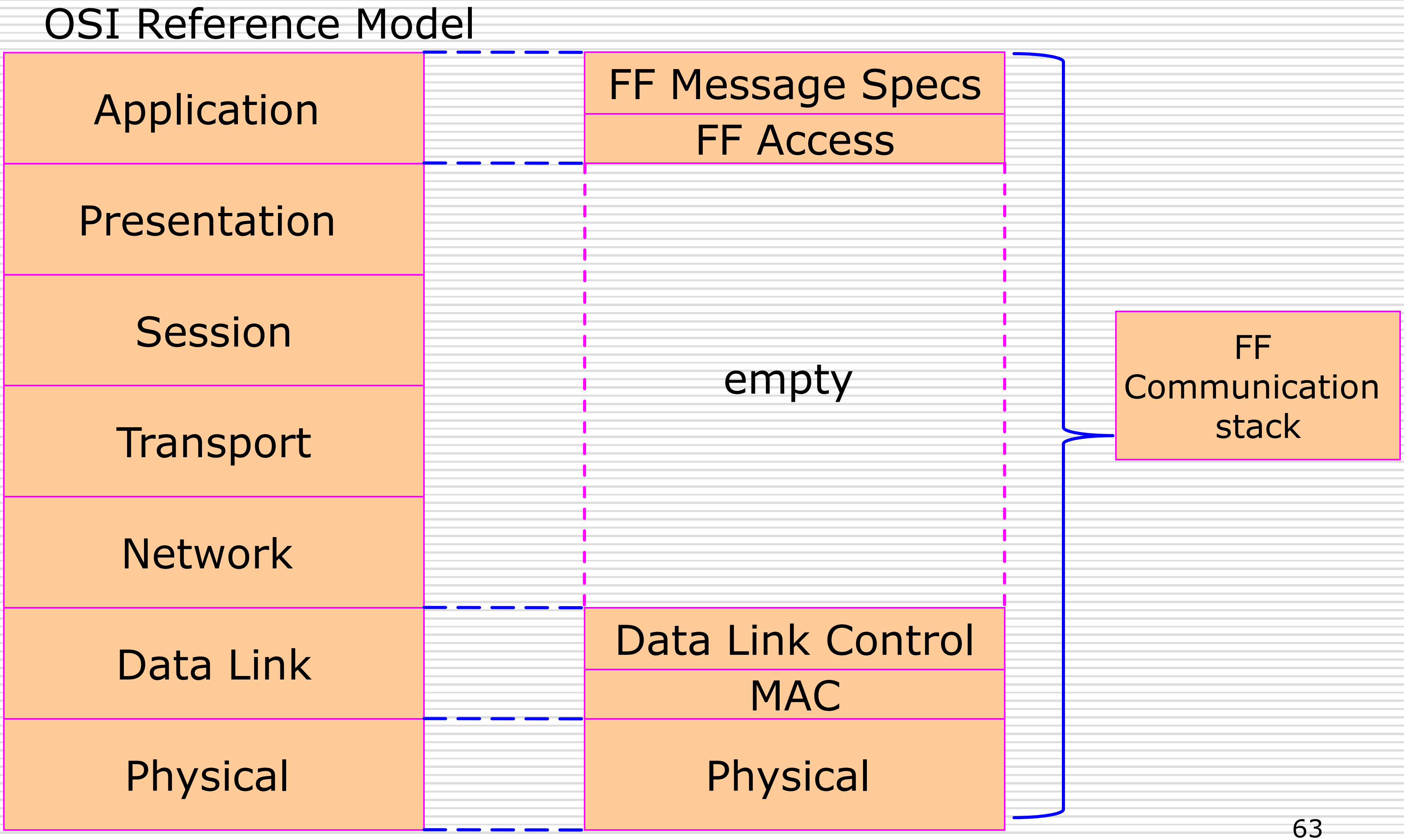
S. No.	Bus	Developer	Year	Application Area
1	Modbus	AEG Modicon	1980	Process Control
2	MAP(1)	General Electric	1980	Manufacturing plants
3	LON(2)	Echelons	1991	Building automation energy distribution
4	Profibus(3)	Siemens	1994	Process control
5	SDS(4)	Honeywell	1994	Process control
6	CAN(5)	Bosch	1995	Automobiles
7	Foundation Fieldbus	Fieldbus Foundation	1997	Process control

(1) Manufacturing Automation Protocol
(2) Local Operation Network
(3) Process Control Fieldbus
(4) Small Distributed System
(5) Controller Area Network

Foundation Fieldbus: Key Features

- Fieldbus Foundation: A world-wide consortium of manufacturers and industry groups
- Developed as an open fieldbus-protocol
- Being adopted world over by most of manufacturers and users for industrial measurement & control (automation)
- Protocol defines physical, data link and application layers

Foundation Fieldbus Protocol Stack



Communication Rates

31.25 kbps Rate:

- Specified as intrinsically-safe option
- Supports applications that need high security but moderate data rates
- Control data, measurement data

1 Mbps and 2 Mbps Rates:

- Specified as non-intrinsically-safe options
- Supports applications that need high data rates
- Configuration data, self-test command etc.

Physical Frame Format

Octets	1	1	n+4	2
	Preamble	Start delimiter	Data from DLL	End delimiter

	Destination address	Source address	Data from AL	Frame check sequence (CRC)
Octets	1	1	n	2

MAC Protocol

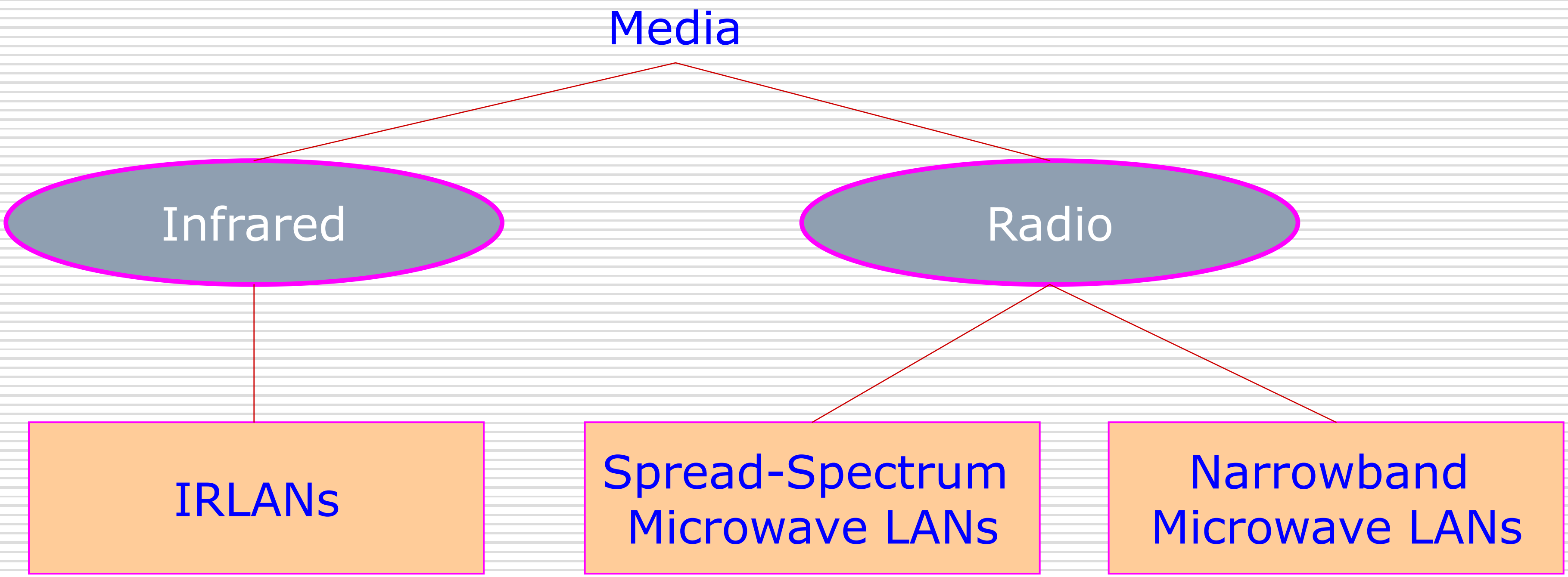
- Network can have multiple masters
- So MAC Protocol is fusion of:
  - Token-passing principle
    - Used by masters to initiate communication
    - Token passed to next master after communication is finished
  - Polling principle
    - Used by the master to poll slaves
    - The master requests, the addressed slave responds
    - So all frames contain SA and DA

Wireless Network Protocols

Wireless LANs

1. Wireless LAN or WLAN uses RF links
2. Advantages of LAN
   - Easy and fast deployment
   - Nomadic and mobile access
   - Connecting field devices in inaccessible locations.
3. Major Issues
   - Data security against Noise & interference
   - Interception & eavesdropping
   - Jamming
4. Share of WLANs in LAN-market increasing fast

WLAN Technologies



- Limited to a single room
- Range: 10-50m
- Data rate: 1-10 Mbps

- Most common type WLAN
- Range: 30-250m
- Data rate: 1-60 Mbps

- Little used
- Range: 10-50m
- Data rate: 10-20 Mbps

Spread Spectrum LANs

- "Spread Spectrum" technique is a form of coding for wireless communication
- Advantages of "Spread Spectrum":
  - Jamming is difficult
  - Interception is difficult
  - Reception quality is good
- Uses a pseudorandom spreading code
- Techniques:
  - Frequency-hopping (FHSS)
  - Direct-sequence (DSSS)
- Topologies: Hub, Peer-to-peer
- Spectrum: ISM microwave frequency bands

ISM Bands

- License-free microwave frequency bands
- For Industrial, Scientific and Medical purposes
- Only low-power transmissions (upto 1W) allowed
- Three ISM bands:
  - ISM-900: Frequency band around 900 MHz
  - ISM-2.4: Frequency band between 2.4 & 2.5 GHz
  - ISM-5: Frequency band between 5 & 6 GHz
- ISM-900 Band: 900 MHz devices are least expensive, suits non-LOS applications.
- ISM-2.4 Band: Widely used for LOS applications.
- ISM-5 Band: Uncluttered as 5GHZ devices are most expensive, suits only LOS applications.

WiFi/IEEE 802.11

- WiFi means Wireless Fidelity (Technology/Protocol)
- WiFi provides wireless internet access in neighbourhood
- IEEE 802.11 is "Wireless LAN Standard"
- WiFi Alliance (formed in 1999) promotes IEEE 802.11 standard
- Earlier called "Wireless Ethernet Compatibility Alliance"
- It Certifies 802.11 products for interoperability
- IEEE 802.11-1997 (original)
- IEEE 802.11a-1999
- IEEE 802.11b-1999
- IEEE 802.11g-2002

IEEE 802.11: Scope & Keypoints

MAC layer

Point coordination function (PCF)
Distributed coordination function (DCF)

Physical layer

IR	**2.4 GHz**	**2.4 GHz**	**5 GHZ**	**2.4 GHz**	**2.4 GHz**
850-950 nm	FHSS	DSSS	OFDM	DSSS	DSSS/ OFDM
1, 2 Mbps	1, 2 Mbps	1, 2 Mbps	6-54 Mbps	5.5, 11 Mbps	6-54 Mbps
IEEE 802.11 (original)			IEEE802.11a	IEEE802.11b	IEEE802.11g

Zigbee/IEEE 802.15.4

- Zigbee technology addresses needs of industrial measurement and control (automation)
- Zigbee Alliance is consortium of 150^{+} companies
- Includes Honeywell, Motorola, Phillips, Samsung, Mitsubishi
- IEEE 802.15.4 is "Low-Rate Wireless PAN Standard"
- Zigbee Alliance promotes IEEE 802.15.4 standard
- IEEE 802.15.4 defines only Physical and MAC layers
- Connectivity with fixed, portable and moving devices

Zigbee Technology

- Developed to meet the special requirement of wireless sensor & actuator networks
  - Low bandwidth
  - Low latency
  - Long battery life
  - High data security
  - High network reliability
- Not attractive for business communication networks because of low data rate.

Zigbee Versus WiFi

- Zigbee technology preferred to WiFi technology in industrial environment

- Merits of Zigbee
  - Lower cost
  - Lower complexity
  - Lower latency
  - Lower message overhead
  - Lower power requirement

- Limitations of Zigbee
  - Lower data rate
  - Smaller range

IEEE 802.15.4

- Data rates: 20, 40 & 250 Kbps
- Topologies: Star
  Mesh (Peer-to-peer)
- MAC logic: CSMA/CA
- Device addressing: Dynamic
- Frequency bands
  - ISM-900: 2 MHz channel BW, 20 & 40 kbps
  - ISM-2.4: 5 MHz channel BW, 250 kbps
- Transmission technique: DSSS
- Transmitter power: 1 mw or more
- Range: 10 m or more
- Receiver sensitivity (for packet error rate < 1%)
  - - 85 dBm for 2.4 GHz frequency band
  - - 92 dBm for 900 MHz frequency band

IEEE 802.15.4 MAC Layer

- Standard recognizes 2 type of devices:
  - Full-Function Device (FFD)
    - Can perform job of Network (or PAN) Coordinator
    - Can also function as a normal device
- Reduced-Function Device (RFD)
  - Or normal device
  - Simpler in design than FFD
  - Minimal flash ROM requirement
  - Can’t function as Network Coordinator
- Network (PAN) Coordinator
  - Initiates all network communications
  - Can communicate directly with any device
  - Can transmit beacon (in becoming system)

IEEE 802.15.4 MAC Protocol

- MAC protocol is based on CSMA/CA
- The standard supports
  - Star topology
  - Mesh (peer-to-peer) topology
- Addressing mode
  - For Star: Network & device identifiers
  - For Mesh: Source & destination addresses

IEEE 802.15.4 MAC Protocol

- Flexible MAC protocol to handle 3 types of data
- Periodic Data
  - Beaconing system to handle data
  - Beacon sent by Network Coordinator periodically
  - Period can vary from 15.36 ms to 15.36 x 2^{14} ms ≅4 min
  - Period is a trade off between message latency and power consumption
  - Device wakes up, sends data if any, and then goes back to sleep mode
- Intermittent Data
  - Network coordinator sends message as and when necessary
  - Beaconless mechanism, power saving mode
  - Device sleeps most of time
- Low-Latency Data
  - Guaranteed time slot (GTS) system
  - Network coordinator allots some time to the device to transmit its data without contention

IEEE 1451

IEEE 1451

- A set (family) of standards for "Smart Transducer Interface for Sensors and Actuators".
- Sponsored by "Technical Committee on Sensor Technology" of "IEEE Instrumentation and Measurement Society".
- Cosponsored by "National Institute of Standards and Technology", a division of the U.S. Department of Commerce.

Why IEEE 1451?

- There are several network standards and proprietary network protocols in use for field (device-level) networking.
- It would be too expensive for manufacturers to produce separate smart transducers (sensors and actuators) for each network protocol on the market.
- Hence strong need was felt by manufacturers to create a set of open standards specifying *network-neutral* and *vendor-independent* interfaces for connecting smart transducers *to networks and instrumentation systems* with assured *interoperability*.
- The outcome is IEEE 1451 standards.

Approved IEEE 1451 Standards

IEEE 1451.2 (1997)	:	"Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats"
IEEE 1451.1 (1999)	:	"Network Capable Application Processor (NCAP) Information Model"
IEEE 1451.3 (2003)	:	"Digital Communication and Transducer Electronic Data Sheet (TEDS) Formats for Distributed Multidrop Systems"
IEEE 1451.4 (2004)	:	"Mixed-Mode Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats"
IEEE 1451.0 (2006)	:	"Communication Abstraction Between NCAP and STIM, Common TEDS and STIM-Commands"
IEEE 1451.5 (2007)	:	"Wireless Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats"

Proposed IEEE 1451 Standards

IEEE 1451.6	:	"High-Speed CANopen-Based Transducer Network Interface for Intrinsically-Safe and Non-Intrinsically-Safe Applications"
IEEE 1451.7	:	"Transducers to Radio Frequency Identification (RFID) Systems Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats"

Meaning of Smart Transducer

- In the context of IEEE 1451 standards, a smart transducer is a transducer (sensor or actuator) with such built-in functionalities (achieved through on-chip or on-board electronic circuits) as would facilitate its *interfacing to instrumentation systems* and *data networks*.

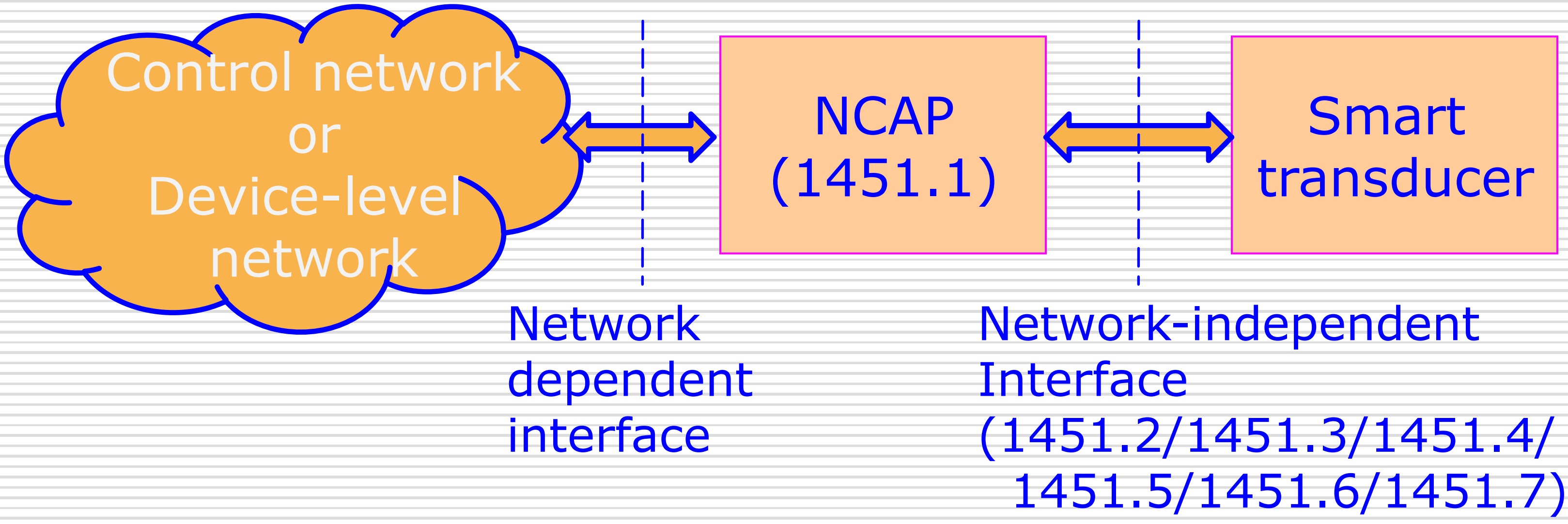
- Compliance to IEEE 1451 standards also requires the following features in smart transducer:
  a) Self identification
  b) Self description
  c) Self configuration

Objectives of IEEE 1415

1. To define a set of common communication (or data transfer) interfaces for connecting smart transducers to *microprocessor-based instrumentation systems*.
2. To define a set of common communication interfaces for connecting smart transducers *to field* (or device-level) *networks in a network-independent environment*.
3. To ensure *interoperability* both in respect of transducer and data so that the user gets access to transducer and transducer-generated information seamlessly in a network or instrumentation system.
4. To ensure *self-description, self-identification* and *self-configuration* by a smart transducer when it is connected to a network or instrumentation system (to ensure *plug-and-play* feature in the transducer).

Network Independence Through NCAP

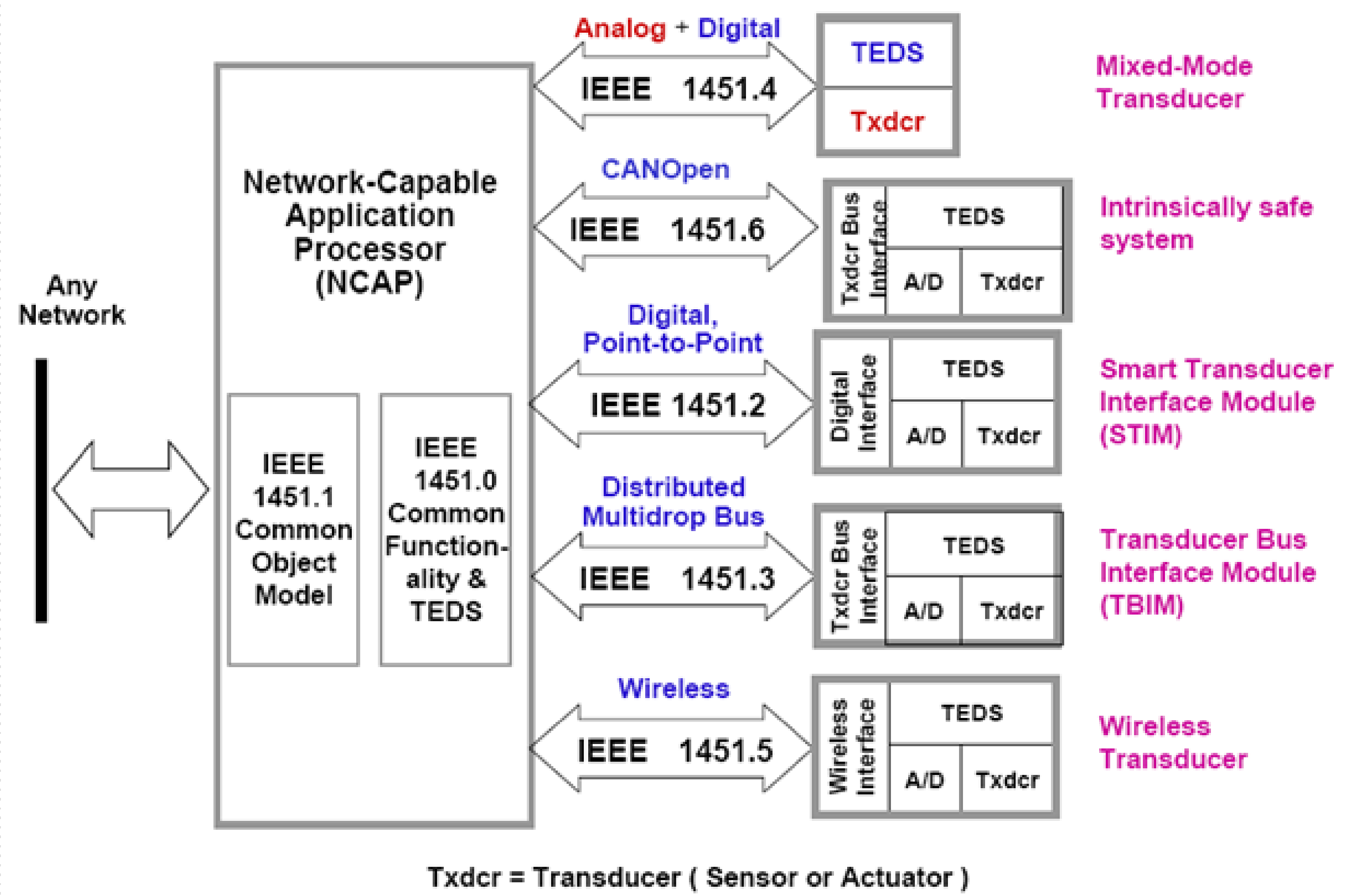
❖ IEEE 1451 standards achieve network-independence in transducer interfacing by including a middle layer of NCAP (Network Capable Application Processor).



❖ IEEE 1451.1 specifies information model of NCAP

❖ Other IEEE 1451 standards specify the interface between the smart transducer and the microprocessor.

IEEE 1451 Family of Standards



Source: http://ieee1451.nist.gov

Wireless Sensor Network (WSN)

Wireless Sensor Network

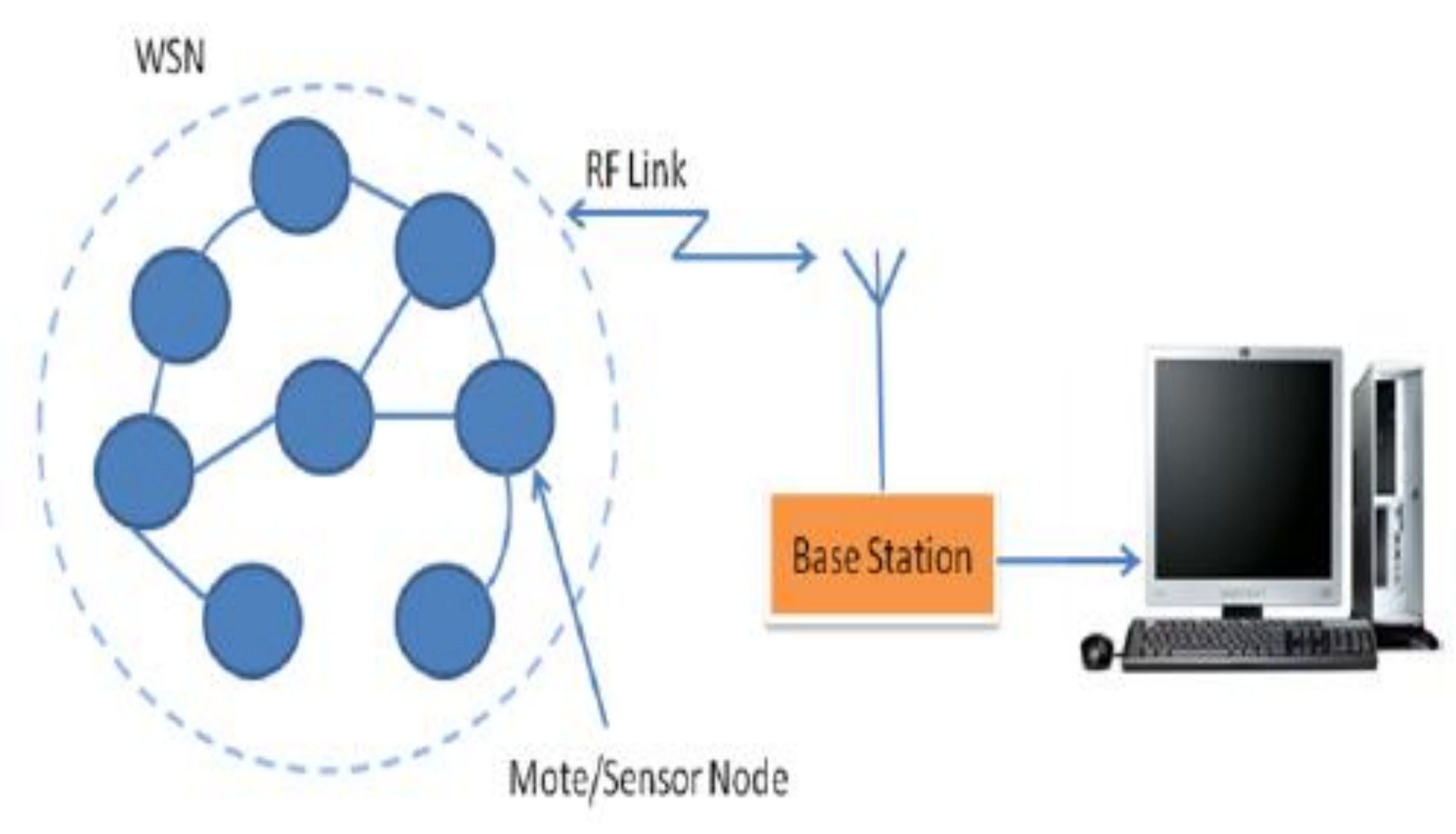
- WSN is a device-level network on factory floor or in open areas

- WSN is a special kind of ad-hoc network that consists of large no. of wireless sensor nodes.

- Need of WSNs:
  - Sensor at inaccessible or difficult-to-access locations
  - Sensors are mobile or nomadic
  - Quick deployment
  - Ad-hoc networking

WSN Architecture

1. Wireless sensor nodes, 2. Base station, 3. PC or Controller



Application of WSN

- Important considerations/ requirements:
  1. Cost
  2. Size
  3. Battery life
  4. Accuracy
- Criticality of each requirement changes with application
- Applications are emerging as the technology is new and developing
- Some application examples follow.

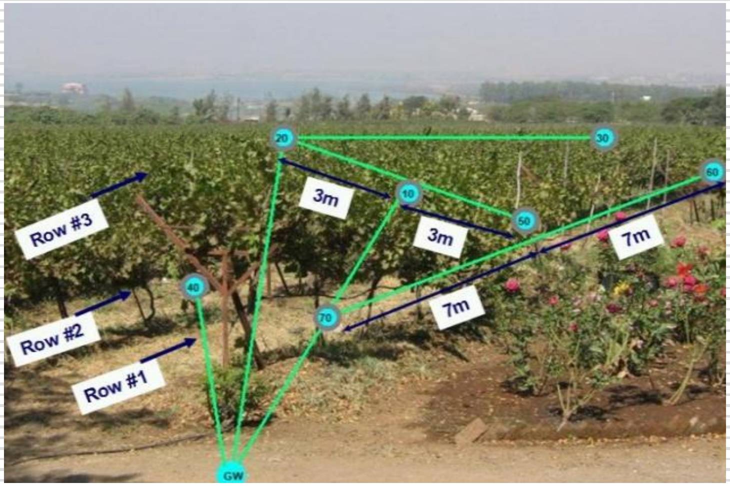
WSN Applications
Industrial

- Process Monitoring & Control
- Oil and Gas Production & Distribution
- Supply Chain
- Vibration Monitoring

WSN Applications
Environmental

➢ Precision Agriculture

Bring out fertilizer/pesticides/irrigation only where needed



➢ Habitat Monitoring

Micro-climate and wildlife monitoring
Ex: Seabird monitoring in Maine's Great Duck Island

WSN Applications
Military

- Targets Tracking
- Surveillance

- Exploration of position and strength of the enemy forces

WSN Applications
Transport

- Intra vehicle sensors
- Traffic Monitoring
- Accident Detection

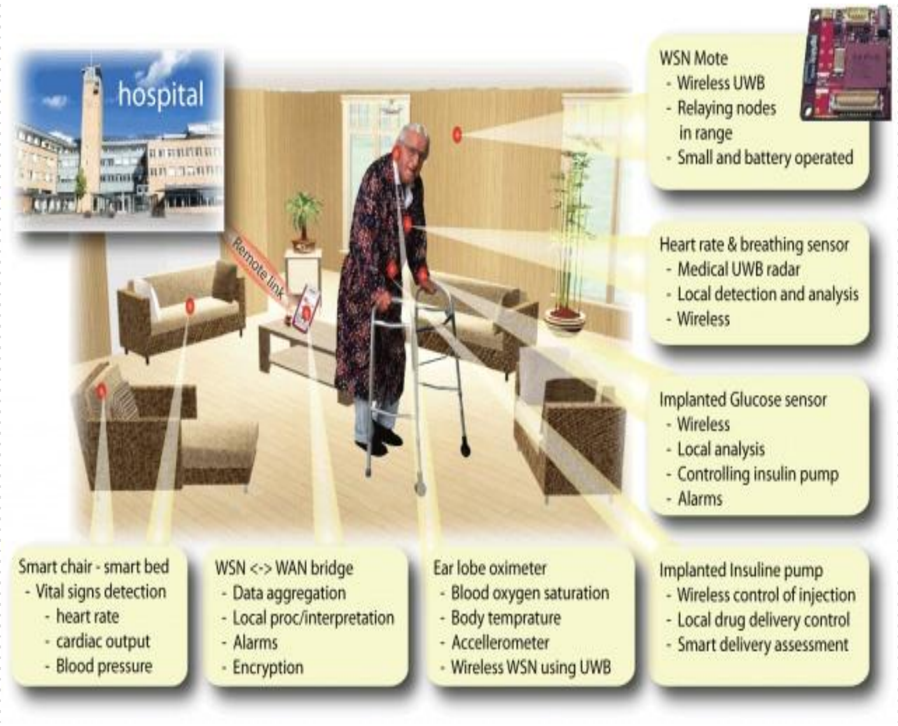
WSN Applications

Disaster Mitigation

- Wild fire detection
- Flood prediction
- Monitoring of mechanical stress levels of buildings in seismically active zones

WSN Applications
Health Care

- Patient Monitoring
- Smart Surroundings
- People Rescue



WSN Applications

Intelligent Buildings/Bridges

- Precision HVAC with individual climate
- Needs measurements about room occupancy, temperature, air flow, …
- Monitor mechanical stress after earthquakes