Instrumentation (II/II)

Course Code: ENEX - 252
(Module#5)

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Chapter#5

Connectivity Technology in Instrumentation

✓ Class Outline

1. Introduction to Wired and Wireless Communication
2. Wired Connectivity: UART I2C SPI and CAN
3. RF Modem Bluetooth WiFi NFC ZIGBEE and LORA
4. Wireless sensor network and its technology
5. Data Acquisition System

Introduction to Wired and Wireless Communication

Wired Communication System

- Wired Communication implies transmission of data from the transmitter to the receiver (a end point destination) over a wired physical medium.
- ✔ Examples of wired communication includes Telephone lines and Television transmission system.
- It may use devices like ethernet, RS-232 or RS-485 cables or Universal Serial Bus (USB) for data transmission.

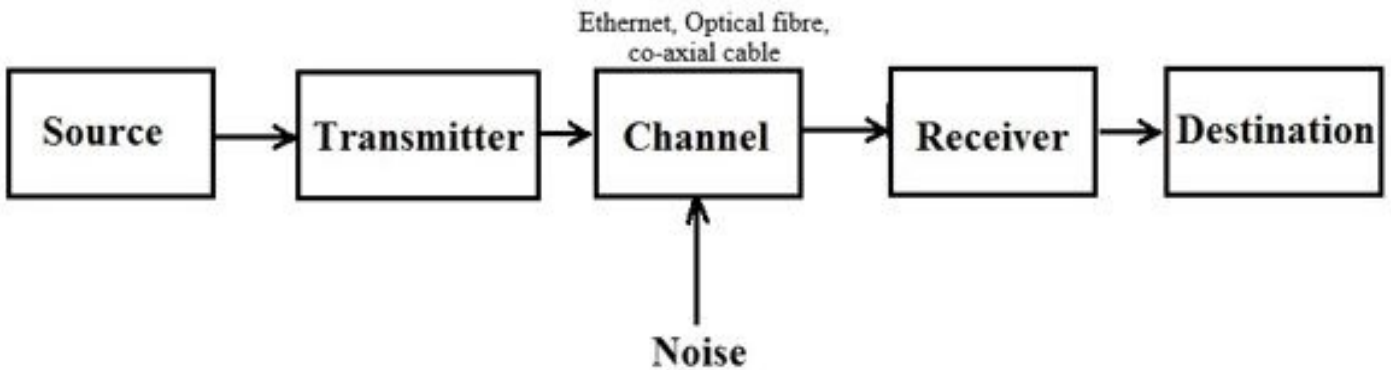


Fig. 1 Generic wired communication diagram

Introduction to Wired and Wireless Communication

A typical Digital Communication System

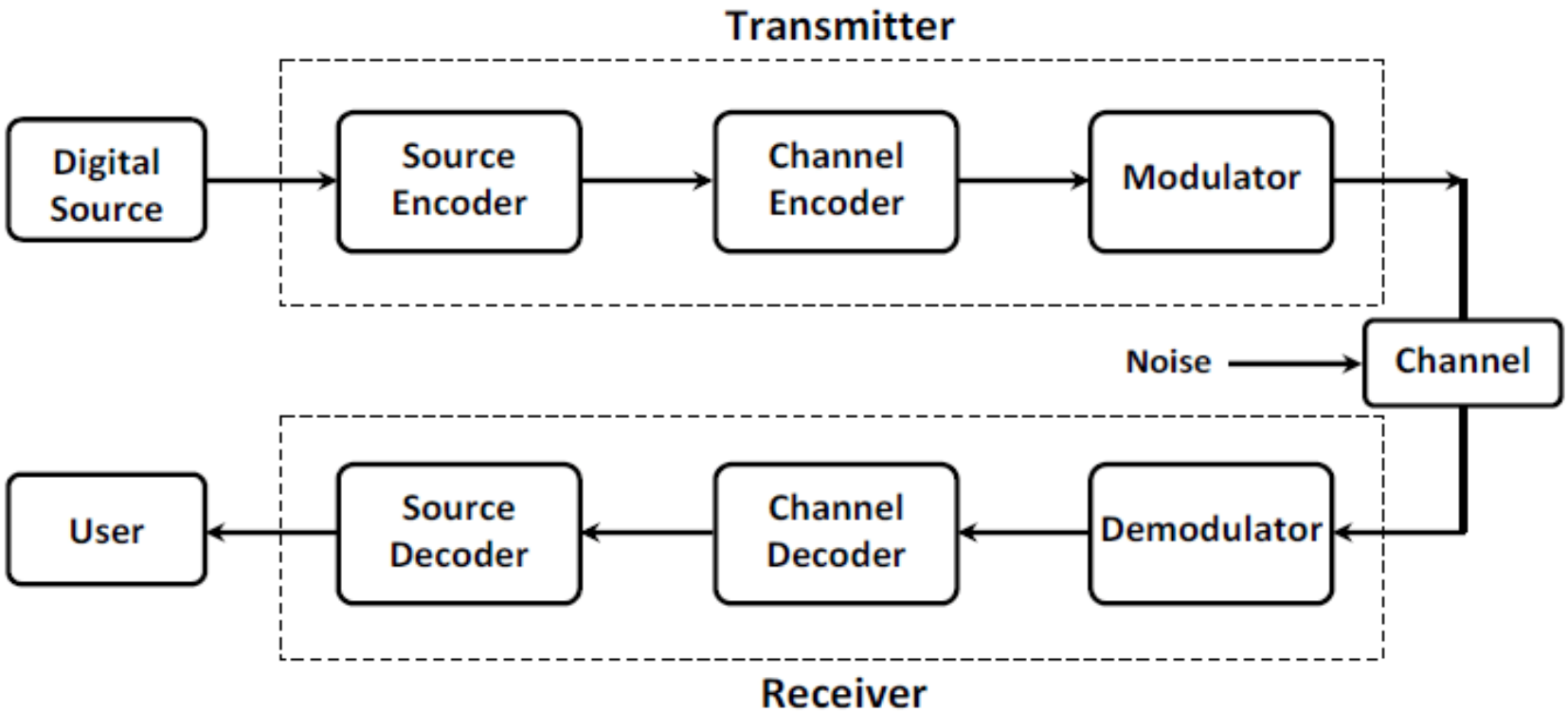


Fig. 2 Generic Diagram for Digital communication system

Introduction to Wired and Wireless Communication

Wired Communication protocols

- The wired communication can be internal as well as external.
- The internal protocols imply communication from a processor or microcontroller to another peripheral on the same silicon board or circuit board and these are:
  - ✔ I2C
  - ✔ SPI
- The external protocols are communication from one device to another which are physically separate from each other.
- The external protocols are:
  - ✔ Ethernet
  - ✔ RS-232
  - ✔ UART/USART
  - ✔ USB

Introduction to Wired and Wireless Communication

Wired Communication System

- Wireless communication is the process of transmitting and receiving data or signals over the air between two or more devices using wireless technologies such as RF (Radio Frequency), Wi-Fi, Bluetooth, infrared wave, etc.

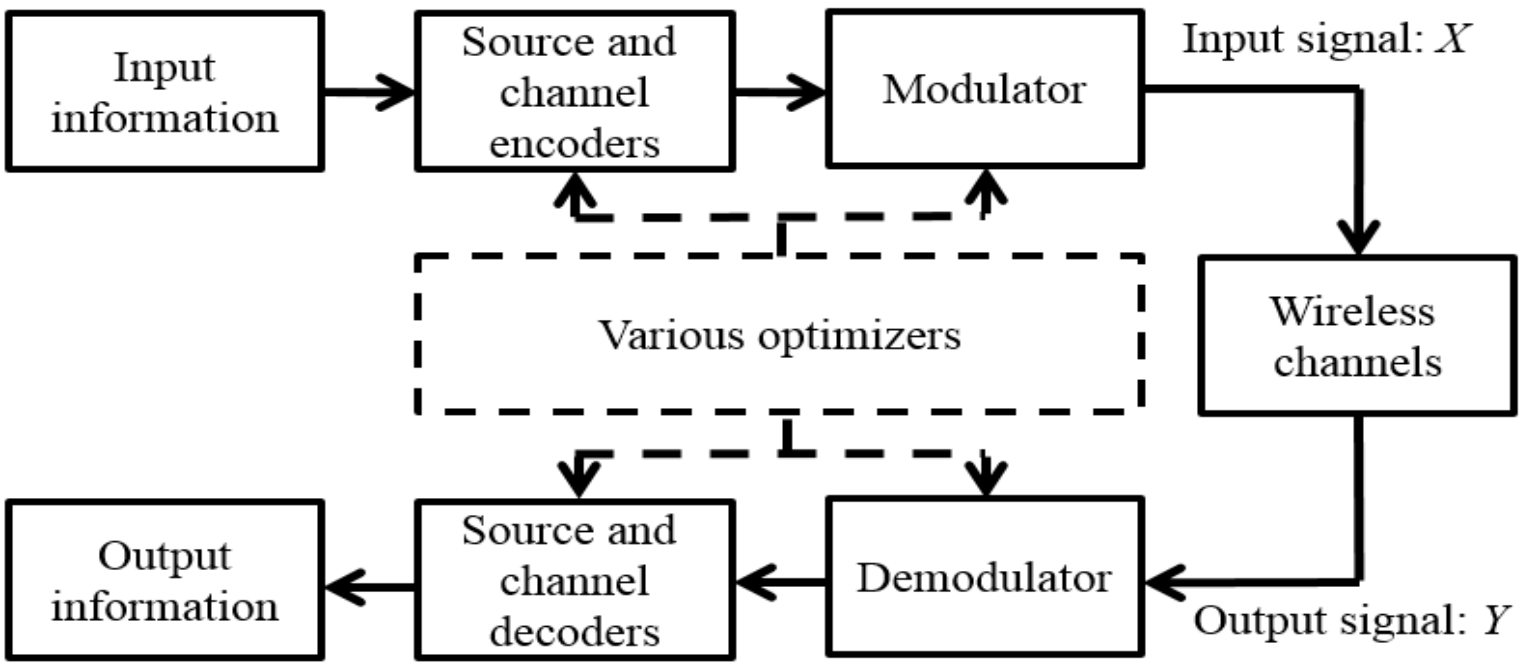


Fig. 3 Generic wireless communication diagram

Introduction to Wired and Wireless Communication

Type of Wireless Communication Technologies

Technology	Description	Range
RF (Radio Frequency)	Used in remote controls, RF modems	100 m – few km
Bluetooth	Short-range, low-power communication	∼10 m
Wi-Fi	Medium-range, high-speed data	∼100 m
ZigBee	Low-power mesh networking	∼10–100 m
LoRa	Long-range, low-power for IoT	Up to 10+ km
NFC	Near Field Communication	<10 cm
Infrared (IR)	Remote controls, line-of-sight needed	∼5 m
Cellular (2G–5G)	High-speed mobile networks	City-scale
Satellite	Long-range, global communication	Worldwide

- ✔ A protocol refers to procedures and rules determined to, for example, mutually transmit data without errors between differing systems in data communication (digital communication) systems, including computers.

Wired Connectivity: UART I2C SPI and CAN

Inter-Integrated Circuit (I2C): | wired Communication

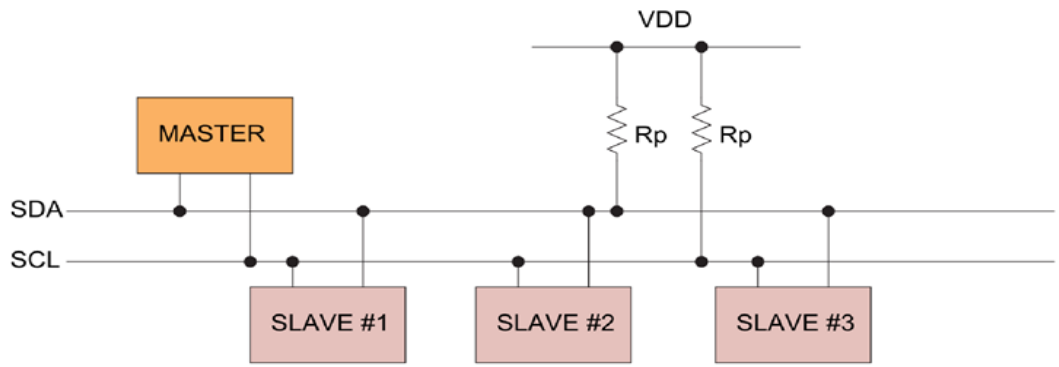


Fig. 4 Generalized I2C connection

- The I2C bus uses only two bidirectional lines, Serial Data Line (SDA) and a Serial Clock Line (SCL) – **synchronous**
- I2C compatible devices connect to the bus with open-collector (BJT) or open-drain pins which pull the line LOW.
- When there is no transmission of data, I2C bus lines turn idle in HIGH state; the lines are passively pulled high.

Wired Connectivity: UART I2C SPI and CAN

Inter-Integrated Circuit (I2C): | wired Communication

- Transmission occurs by toggling the lines by pulling LOW and releasing HIGH; Bits are clocked on falling clock edges.
- The standard data transfer rate is 100kbits/s while the Fast Mode transfer rate is 400kbits/s.

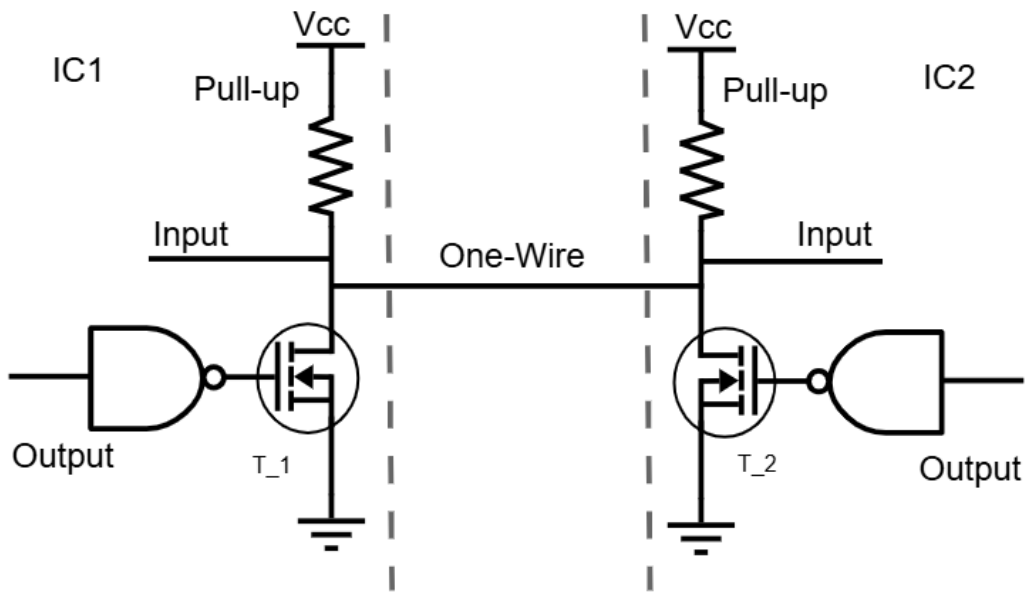


Fig. 5 Open-Drain Circuit with Pull-Up Resistors

Wired Connectivity: UART I2C SPI and CAN

Inter-Integrated Circuit (I2C): | wired Communication

✔ Following is the master write byte pulse diagram.

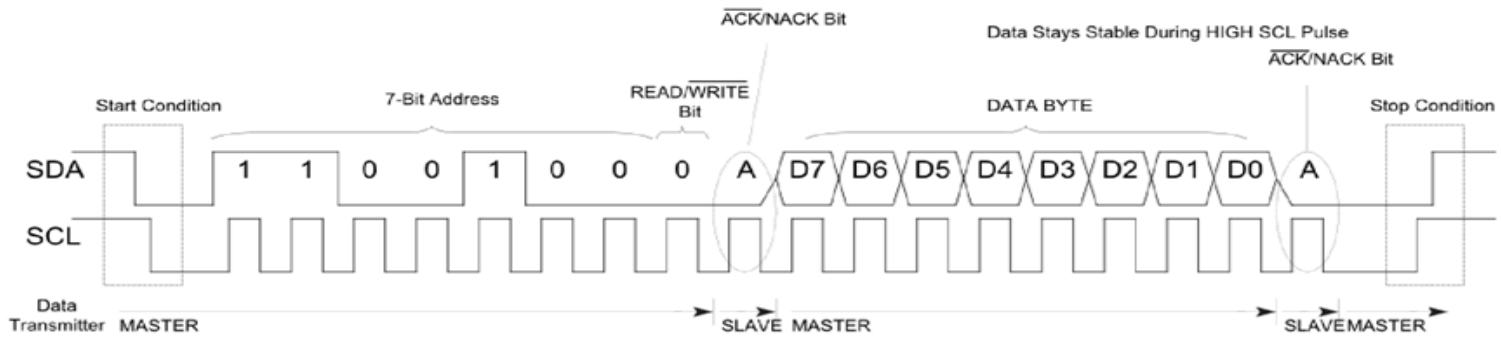


Fig. 6 I2C write byte transmission

✔ Following is the master read byte pulse diagram.

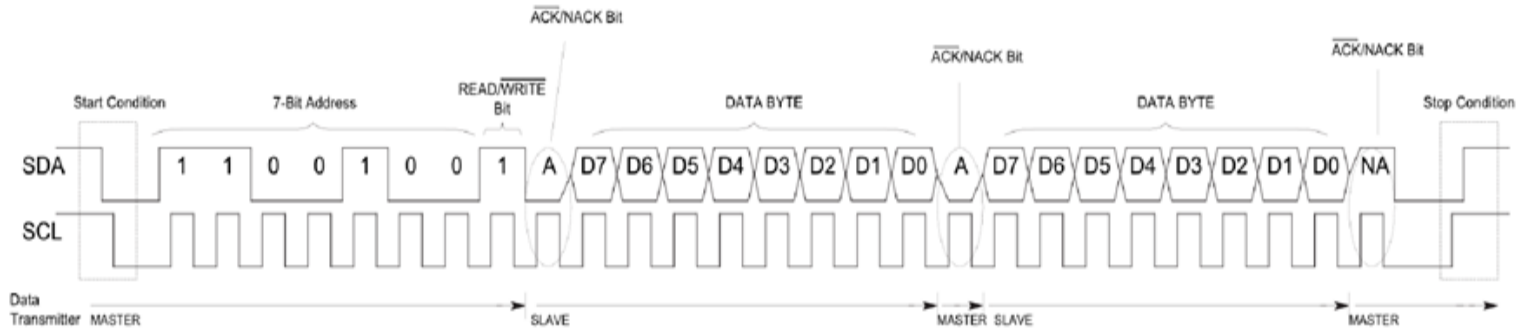


Fig. 7 I2C read byte transmission

Wired Connectivity: UART I2C SPI and CAN

Seiral Peripheral Interface(SPI): | wired Communication

- Serial Peripheral Interface (SPI) is the process of **synchronous** serial communication protocol.
- It is mainly used for connecting the microcontrollers to peripheral devices like sensors, displays, and memory chips.
- It facilitates the full-duplex, synchronous serial communication between one or more slave devices and a microcontroller.

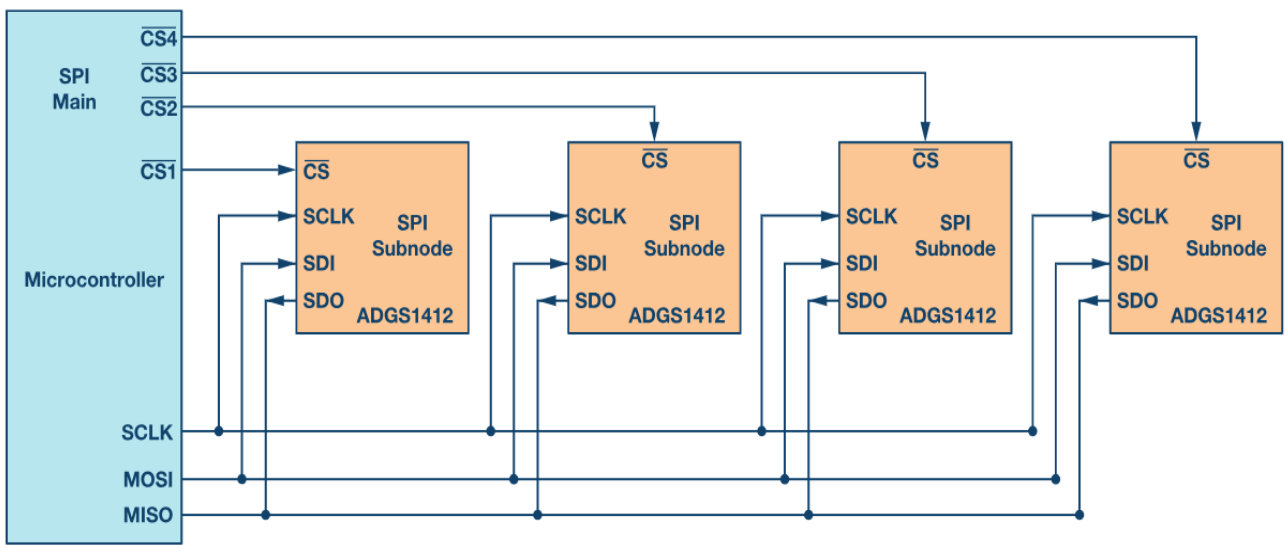


Fig. 8 SPI enabled Master Slave communication

Wired Connectivity: UART I2C SPI and CAN

Seiral Peripheral Interface(SPI): | wired Communication

- ✔ **Master Device:** The master device controls the process of transformation of data on the SPI bus. It controls the data flow and it generates the clock signal. Generally, the master device is the microcontroller or specialized SPI controller.
- ✔ **Slave Device:** Slave devices are peripheral devices that are connected to the SPI bus and controlled by master devices. Every slave device has a different slave select (SS) line, allowing the master to select which device it wants to communicate with.
- ✔ **SPI Bus:** SPI bus is a physical connection over which data transfer between the slave devices and the master takes place. It contains four signal lines:

  Chip Select ($\overline{CS}$); Master Out Slave In (MOSI),

  Master In Slave Out (MISO) and Serial Clock (SCK),

Wired Connectivity: UART I2C SPI and CAN

Seiral Peripheral Interface(SPI): | Wired Communication

- SPI uses the Shift registers. The master clock generator provides the clock to the shift registers of master and slave.
- The shift register is of 8 bits, hence it takes 8 clock pulses to transfer the content of the master's shift register into the slave's shift register (Via MOSI line) and at the same time transfer the content of the slave's shift register into the master's shift register (Via MISO line) is also possible.

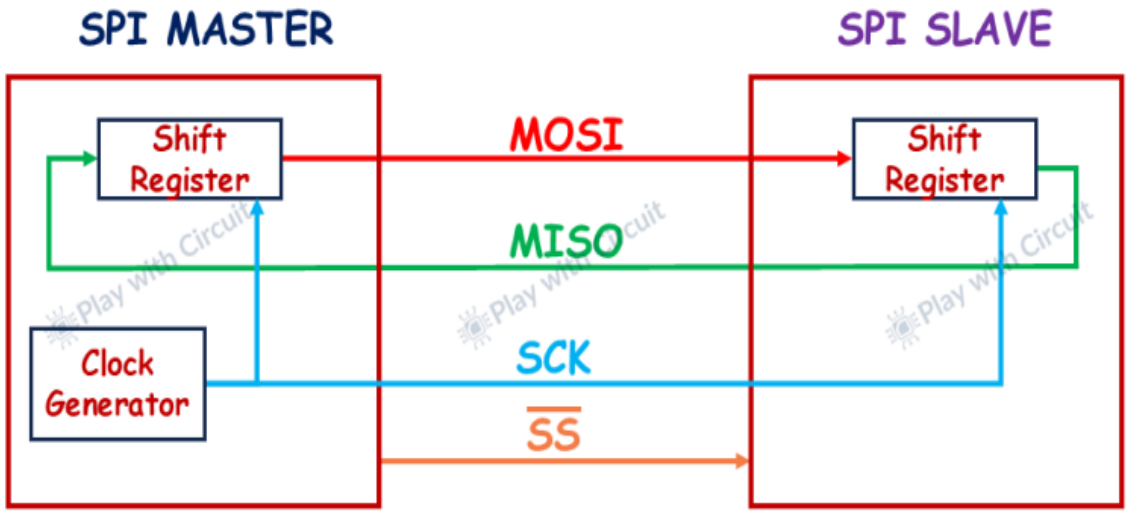
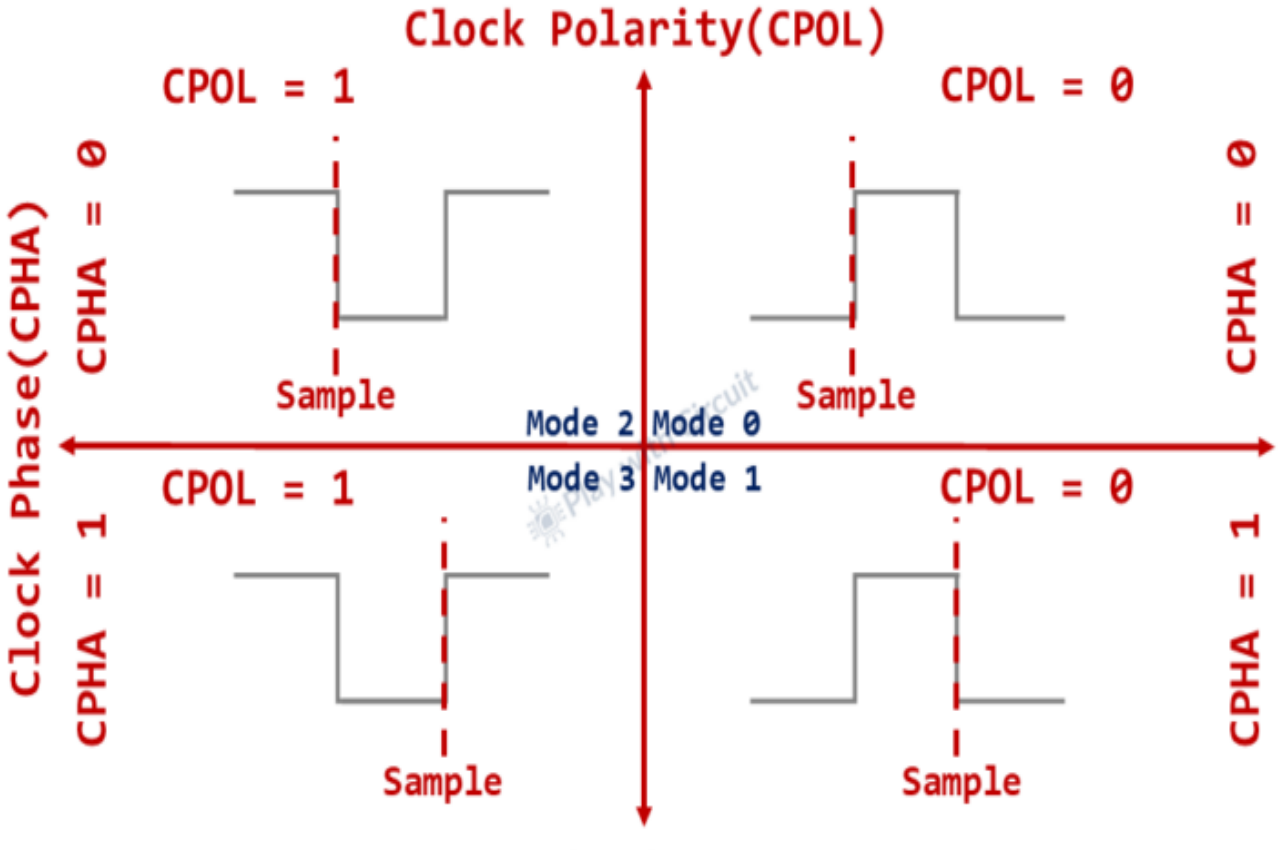


Fig. 9 SPI Shift Register used Master-Slave communication

Wired Connectivity: UART I2C SPI and CAN

Seiral Peripheral Interface(SPI): | wired Communication



Wired Connectivity: UART I2C SPI and CAN

Seiral Peripheral Interface(SPI): | wired Communication

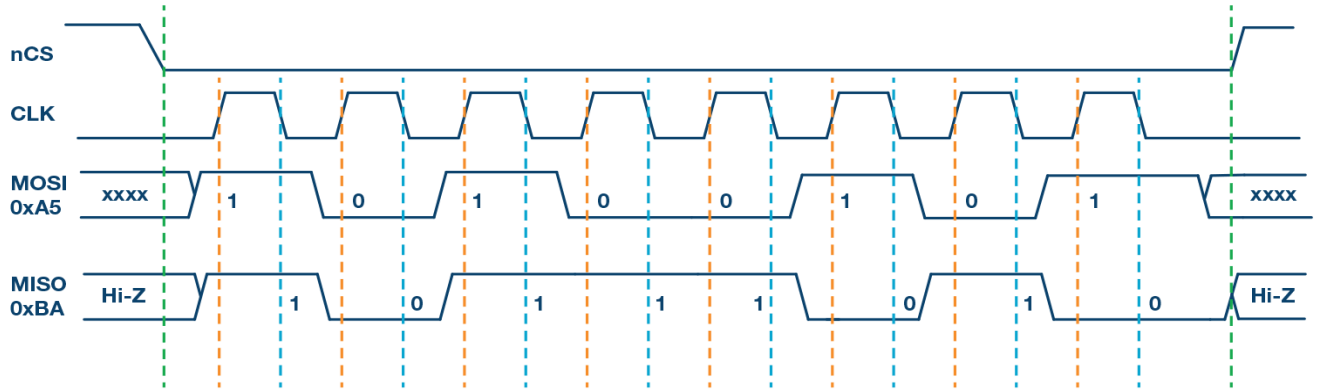


Fig. 10 SPI Mode 0, CPOL = 0, CPHA = 0: CLK idle state = low, data sampled on rising edge and shifted on falling edge.

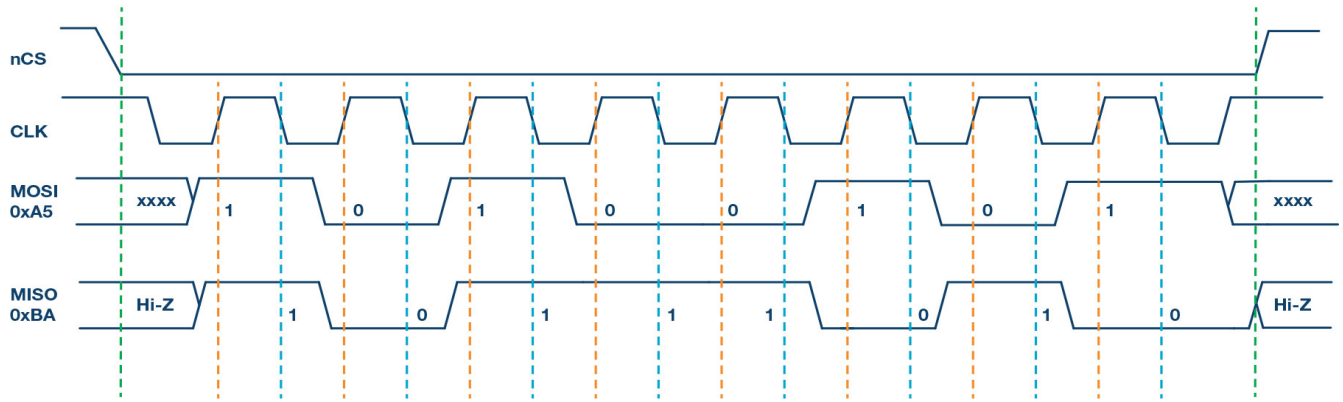


Fig. 11 SPI Mode 3, CPOL = 1, CPHA = 1: CLK idle state = high, data sampled on the rising edge and shifted on the falling edge.

Wired Connectivity: UART I2C SPI and CAN

Seiral Peripheral Interface(SPI): | wired Communication

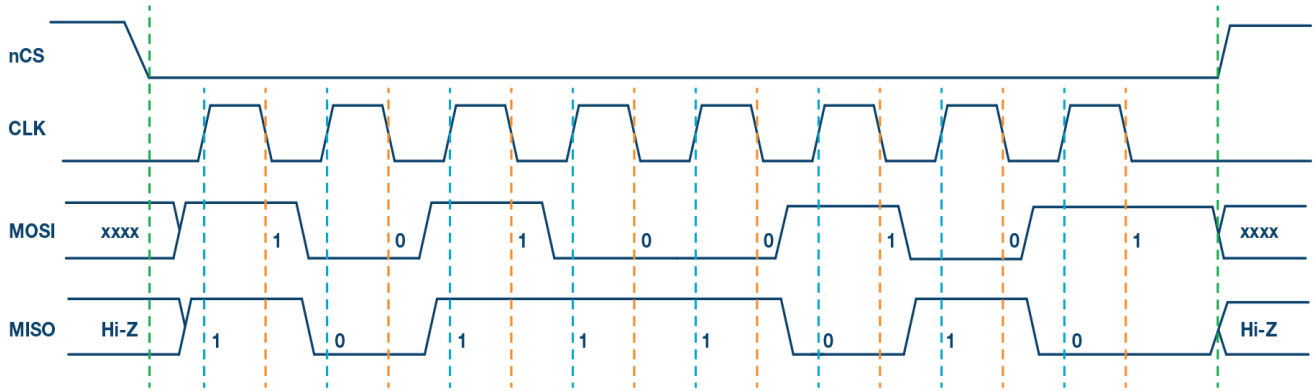


Fig. 12 SPI Mode 1, CPOL = 0, CPHA = 1: CLK idle state = low, data sampled on the falling edge and shifted on the rising edge.

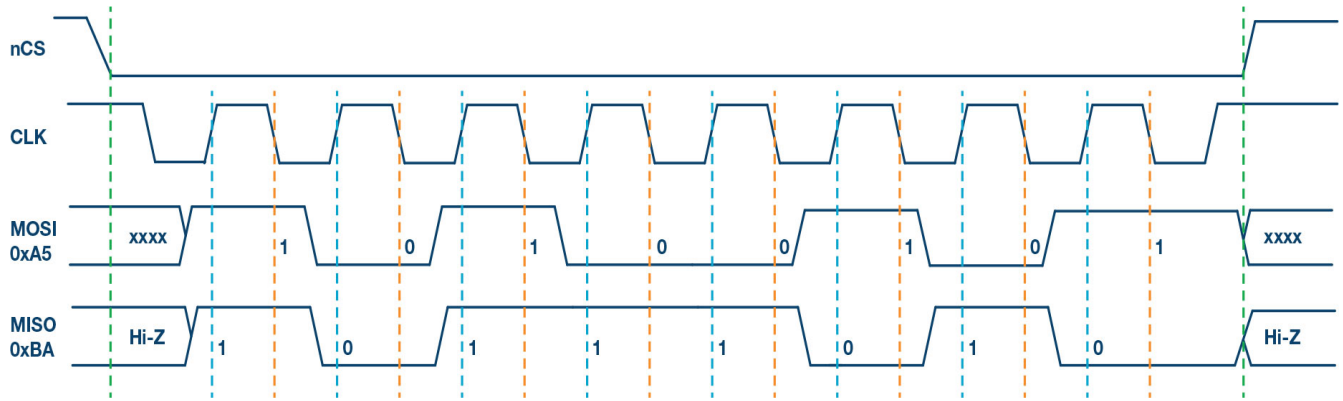


Fig. 13 SPI Mode 2, CPOL = 1, CPHA = 0: CLK idle state = high, data sampled on the falling edge and shifted on the rising edge

Introduction

Intro

-

Universal Serial Asynchronous Receiver Transmitter (USART)

Serial Asynchronous Data Transmission

- Transmitter and receiver are not synchronized.
- transmitter sends data character by character, i.e one data unit at a time.
- each data unit starts with start bit and end with stop bit.
- it also includes one parity bit to indicate even or odd parity of data – for error detection at receiver side.
- for an ASCII character, data unit contains:
  - ✔ 1 start bit
  - ✔ 7 or 8 bit character
  - ✔ 1 parity bit
  - ✔ 1 or 2 stop bit.

Universal Serial Asynchronous Receiver Transmitter

Serial Asynchronous Data Transmission...

- when there is no data over the line, there is constant high.
- to indicate start of data unit, line goes low for one bit (time), then actual data unit is sent.
- while sending data, least significant bit(LSB) is send first.
- after data bit and parity bit, the signal line goes high to indicate stop.

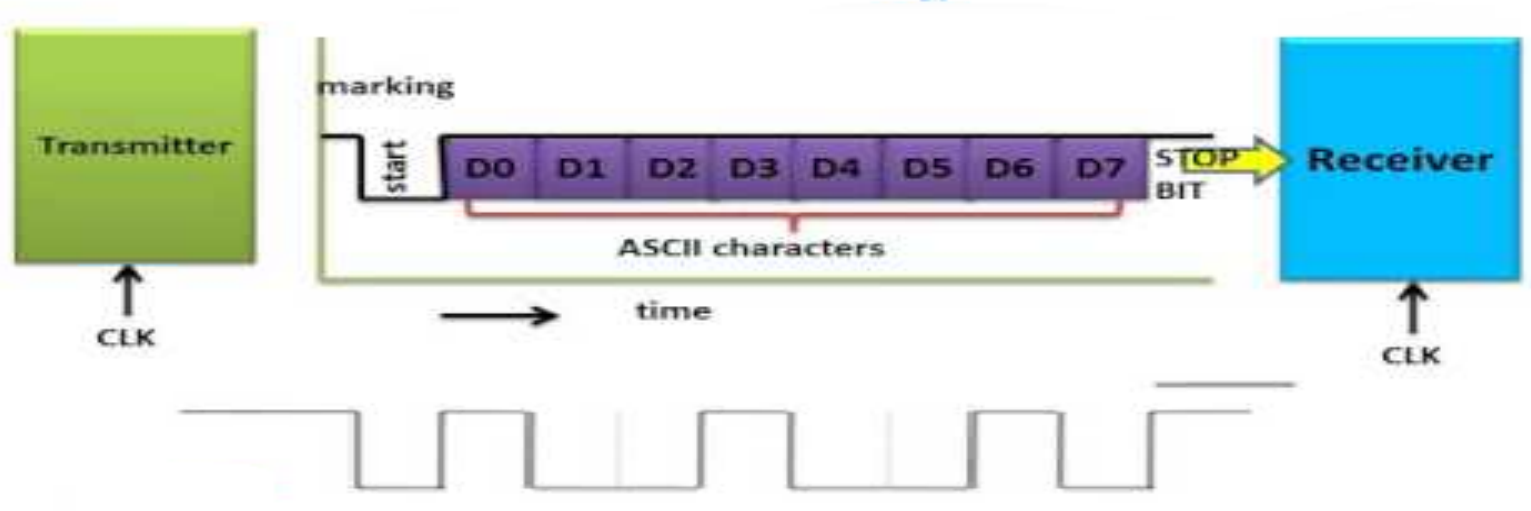


Fig. 14 Asynchronous Serial Transmission Format

Universal Serial Asynchronous Receiver Transmitter

Serial Asynchronous Data Transmission...

- since there is start-bit and stop-bit, there might be gap between two data unit.
- all bits including start-bit, stop-bit, and parity-bit determine the baud rate.
- generally stop-bit and start-bit includes gaps to allow transmitter and receiver synchronize the data transmission.

Note:

✍ Generally, asynchronous communication is preferred for slow speed peripherals to communicate with computer.

✍ It does not need complex and costly hardware as compared to synchronous transmission.

Universal Serial Asynchronous Receiver Transmitter

Serial Data Unit (SDU) and Serialization

- ✔ 1 start bit $\longrightarrow$ always low
- ✔ 7 or 8 bit data unit
- ✔ 1 parity bit
- ✔ 1 or 2 stop bit $\longrightarrow$ always high.

Baud Rate	**Time**
110	9.09 ms
300	3.33 ms
1200	833 μs
2400	417 μs

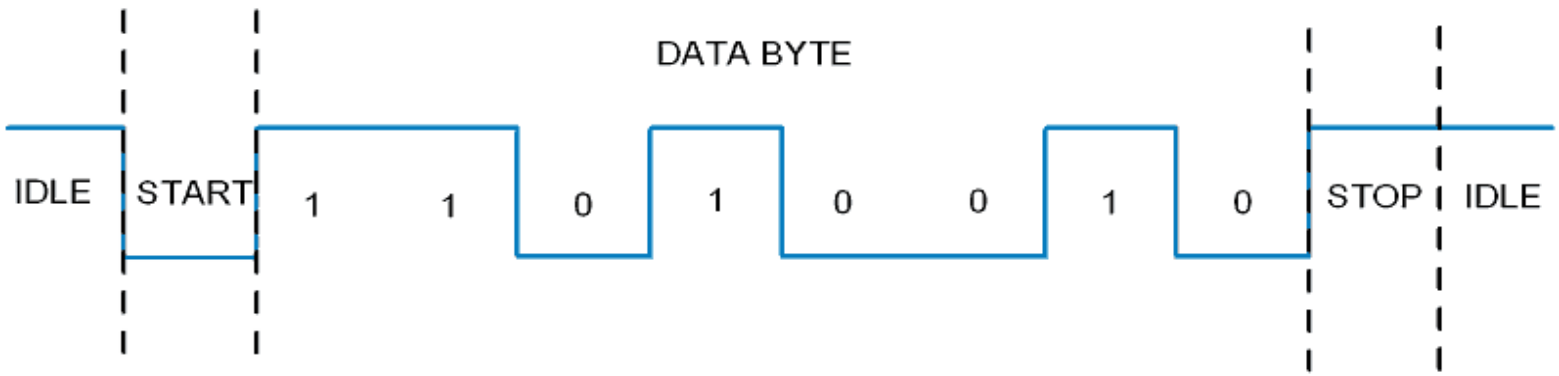


Fig. 15 UART Frame Format ~~(even parity system)~~

Universal Serial Asynchronous Receiver Transmitter

Serial Data Unit (SDU) and Serialization ...

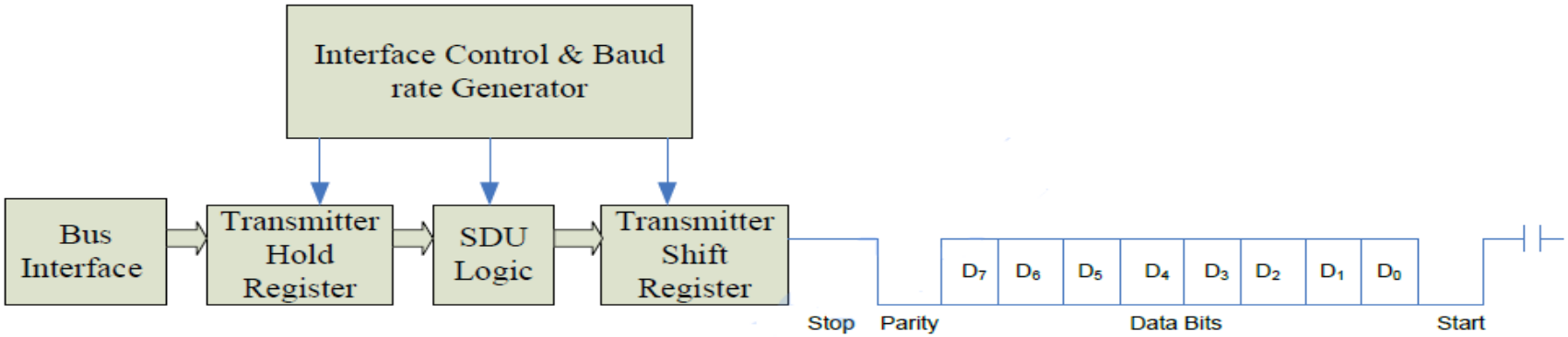


Fig. 16 SDU at transmitting side

- Output Buffer (TX Hold Register) first will be loaded with data from CPU fetched by bus interface circuit.
- According to SDU format, SDU logic puts the start bit at first, and calculate the parity.
- it appends the parity bit to the MSB data bit then stop bit.
- then data is transferred to transmitter shift register.
- For no data, transmitter shift register possesses a logic high.

Universal Serial Asynchronous Receiver Transmitter

Serial Data Unit (SDU) and Serialization ...

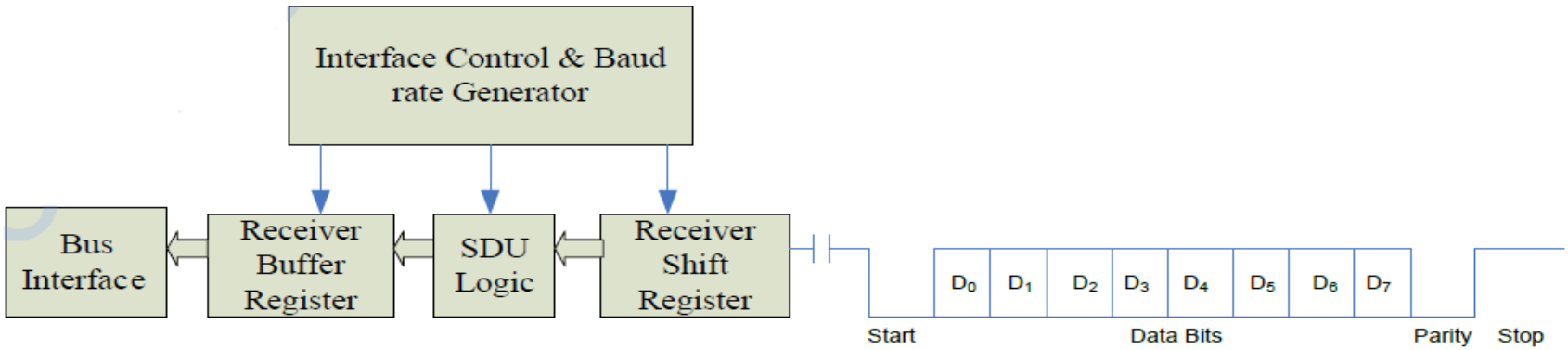


Fig. 17 SDU at receiving side

- Inverse process will go at receiving side
- start bit (logic 0) act as trigger to receive the serial data.
- Firstly, SDU bits are loaded into receiver shift register
- Receiving SDU Logic separates the start, stop, and parity bits
- extracted data bits are then transferred to receiver buffer register from which CPU reads the data byte as received data.

RF Modem Bluetooth WiFi NFC ZIGBEE and LORA

RF modem

- An RF modem (Radio Frequency modem) is a device used to enable wireless communication between two or more electronic systems using radio waves.
- It acts like a wireless serial port, allowing devices like computers, microcontrollers, or sensors to communicate without cables – making signal suitable to transmit over the wireless medium.
- It modulates digital data (converts from digital to radio signal for transmission) and demodulates received RF signals back to digital — hence the name modem (modulator + demodulator).

IEEE 802 Standards Family

IEEE 802 is a family of standards developed by the Institute of Electrical and Electronics Engineers (IEEE) that primarily deals with local area networks (LANs) and metropolitan area networks (MANs).

It includes many sub-standards related to wired and wireless networking, such as:

- **IEEE 802.3** — Ethernet (wired LAN)
- **IEEE 802.11** — Wi-Fi (wireless LAN)
- **IEEE 802.15** — Wireless Personal Area Networks (e.g., Bluetooth, ZigBee)
- **IEEE 802.16** — WiMAX (Wireless MAN)

RF Modem Bluetooth WiFi NFC ZIGBEE and LORA

RF modem

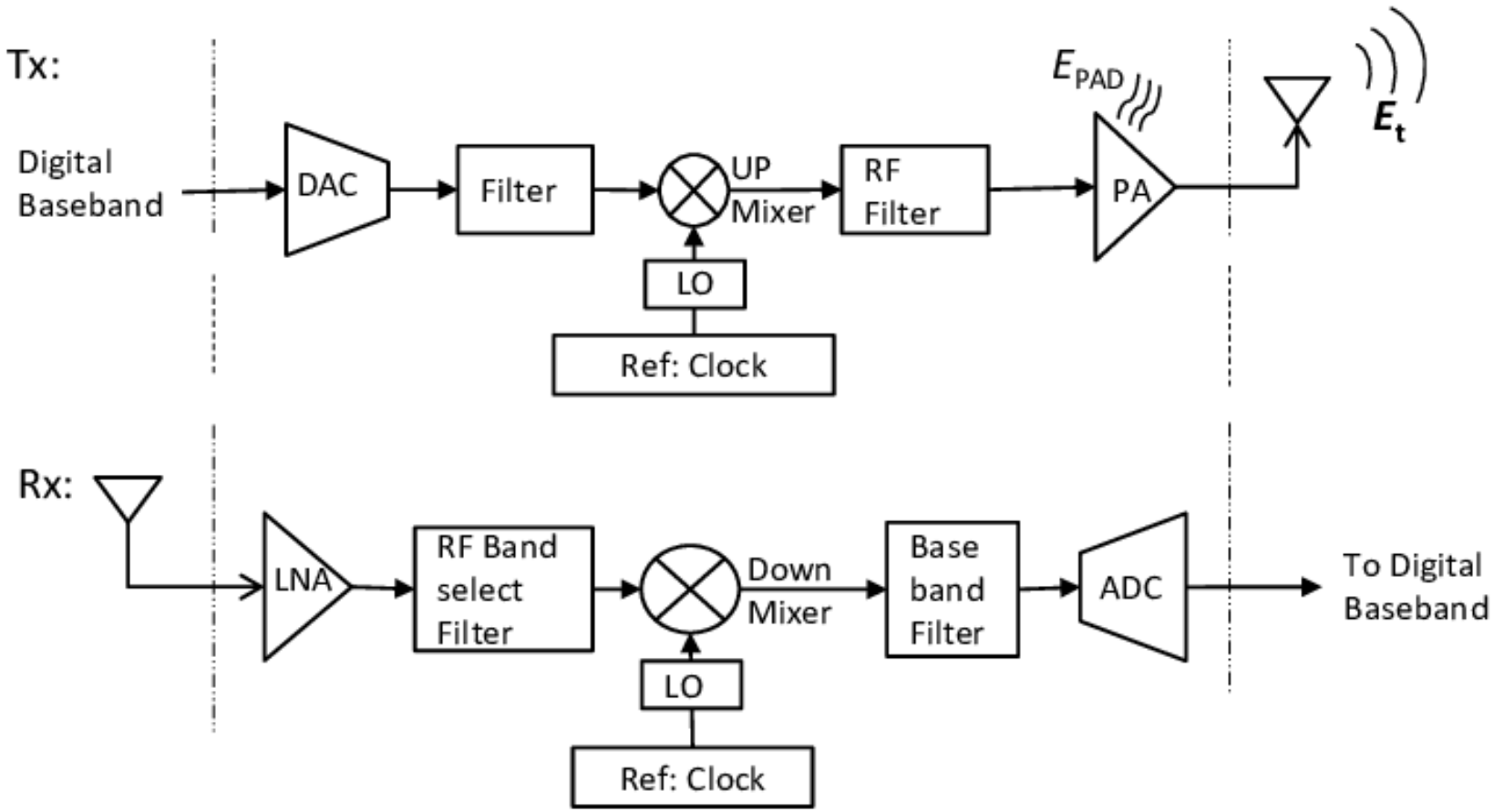


Fig. 18 Block diagram of the RF Trans-Receiver circuit

Some Common Modulation Techniques

Modulation	Full Form	Description
FSK	Frequency Shift Keying	Changes frequency to represent bits
GFSK	Gaussian FSK	Smooth FSK with reduced bandwidth
ASK	Amplitude Shift Keying	Changes amplitude for 0s and 1s
OOK	On-Off Keying	Simple ASK, carrier on = 1, off = 0
O-QPSK	Offset Quadrature Phase Shift	Used in ZigBee for better spectral efficiency
OFDM	Orthogonal Frequency Division	High-speed data via multiple subcarriers (Wi-Fi)
CSS	Chirp Spread Spectrum	Frequency sweeps used in LoRa for noise immunity

Some of the blocks in the diagram

- ✔ LO: Local Oscillator;
- ✔ PA : Power Amplifier;
- ✔ LNA: Low Noise Amplifier;
- ✔ Base Band: original signal before modulation.

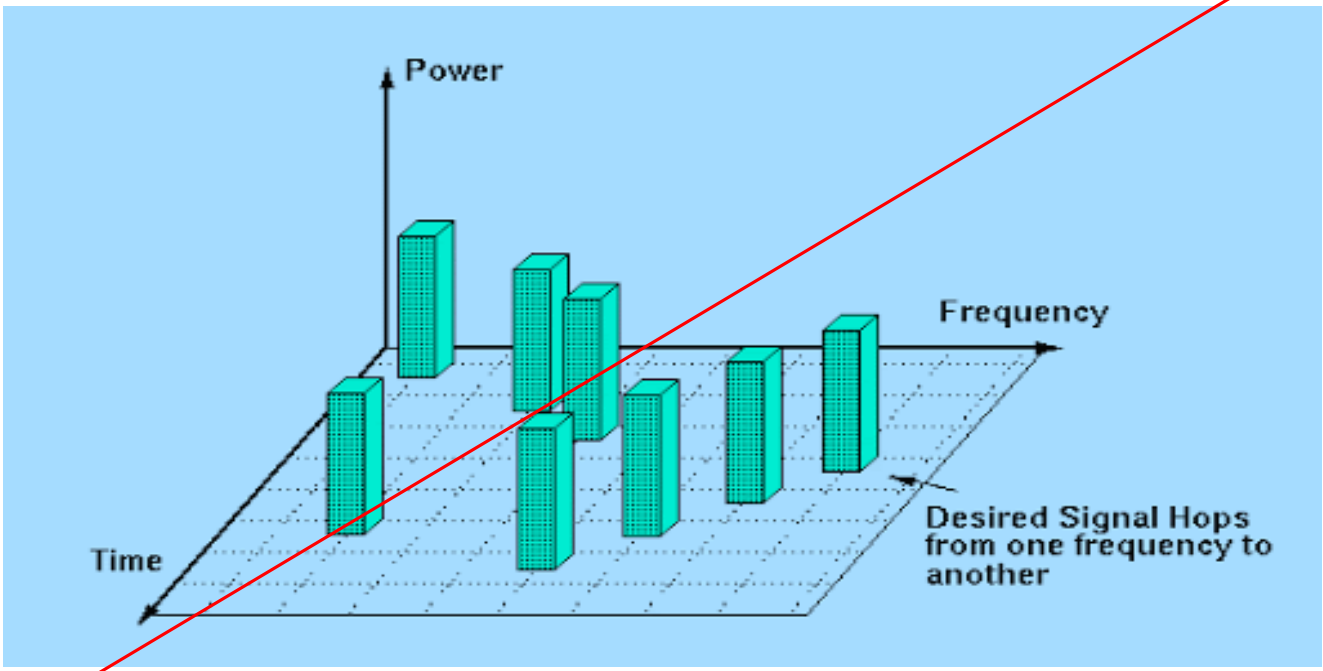
Bluetooth

Basics of Bluetooth Technology

- is global standard radio frequency, physical level agreement/protocol, free of cost (open wireless).
- Bluetooth was standardized as IEEE 802.15.1; Bluetooth Special Interest Group (SIG) maintain specifications.
- used in short-range point-to-multipoint voice and data transfer (transmission can be done through solid, non-metal object).
- it has minimal coverage of 10cm to 10m; however, increasing transmission power could cover 100m.
- Bluetooth technology can facilitate ad-hoc networks in both stationary and mobile environment.
- communication frequency is 2.45 GHz (2.402 GHz – 2.48 GHz), signal strength of 1mW, for use by industrial, scientific and medical devices.

Bluetooth...

Basics of Bluetooth Technology



- it uses spread-spectrum frequency hopping.
- it can randomly hop 79 frequency bands.
- transmitter can change frequencies 1600 times every second.
- it can create personal area network (PAN) or piconet.

Bluetooth...

✍ Characteristics of Bluetooth

- operates in 2.45 GHz
- uses Frequency Hopping Spread Spectrum (FHSS) where radio transceiver hop frequencies in pseudo-random fashion.
- non line-of-sight (LOS) transmission is possible through non-metallic object (wall); omni-directional transmission.
- built in security (without tapping probability).
- support max 8 devices with one master and rest as slave.
- easy integration of TCP/IP network.
- regulated by government for use free of cost.

Bluetooth...

Bluetooth Connection

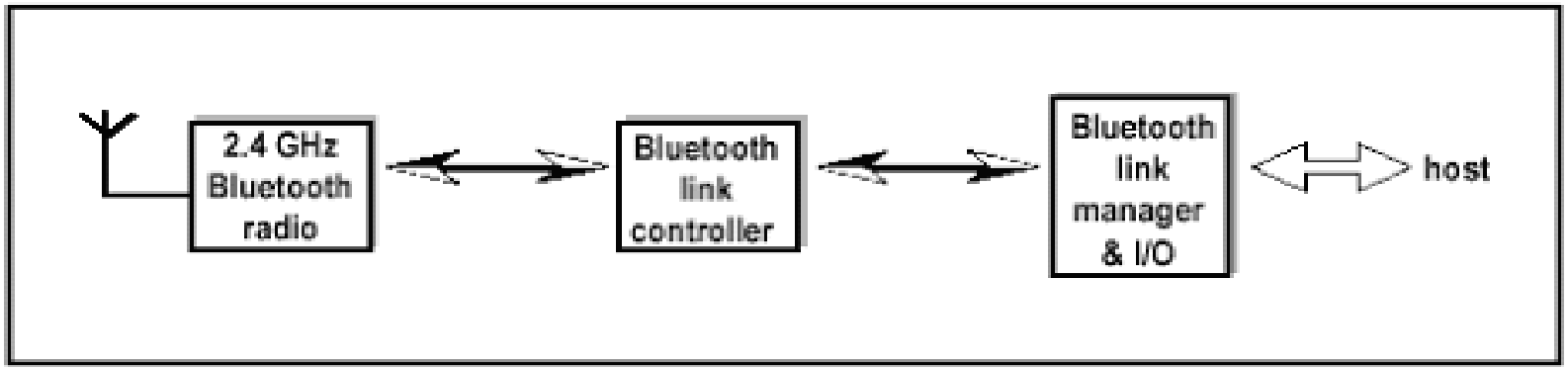


Fig. 19 Different functional blocks in Bluetooth System

- connection is maintained until they are (a) broken, (b) out of coverage, and (c) deliberate disconnect.

Bluetooth Class	***Max Power***	***Range(Approximate)***
Class 1	100 mW / 20 dBm	100 m
Class 2	2.5 mW / 4 dBm	10 m
Class 3	1 mW / 0 dBm	1 m

Bluetooth...

Bluetooth Radio: | Bluetooth Connection

- **Wireless Transmission:**
  Sends/receives data packets wirelessly.
- **Frequency Hopping:**
  Utilizes frequency hopping spread spectrum for transmission.
- **Power Management:**
  Controls power levels for efficient energy usage.

Bluetooth Link Controller: | Bluetooth Connection

- **Connection Management:**
  Establishes, maintains, and terminates connections.
- **Packet Formation:**
  Constructs and segments data packets for transmission.
- **Error Correction:**
  Implements error correction techniques for data integrity.

Bluetooth...

Bluetooth Link Management: | Bluetooth Connection

- **Connection Setup:**

  Initiates connection establishment and authentication.

- **Security Enforcement:**

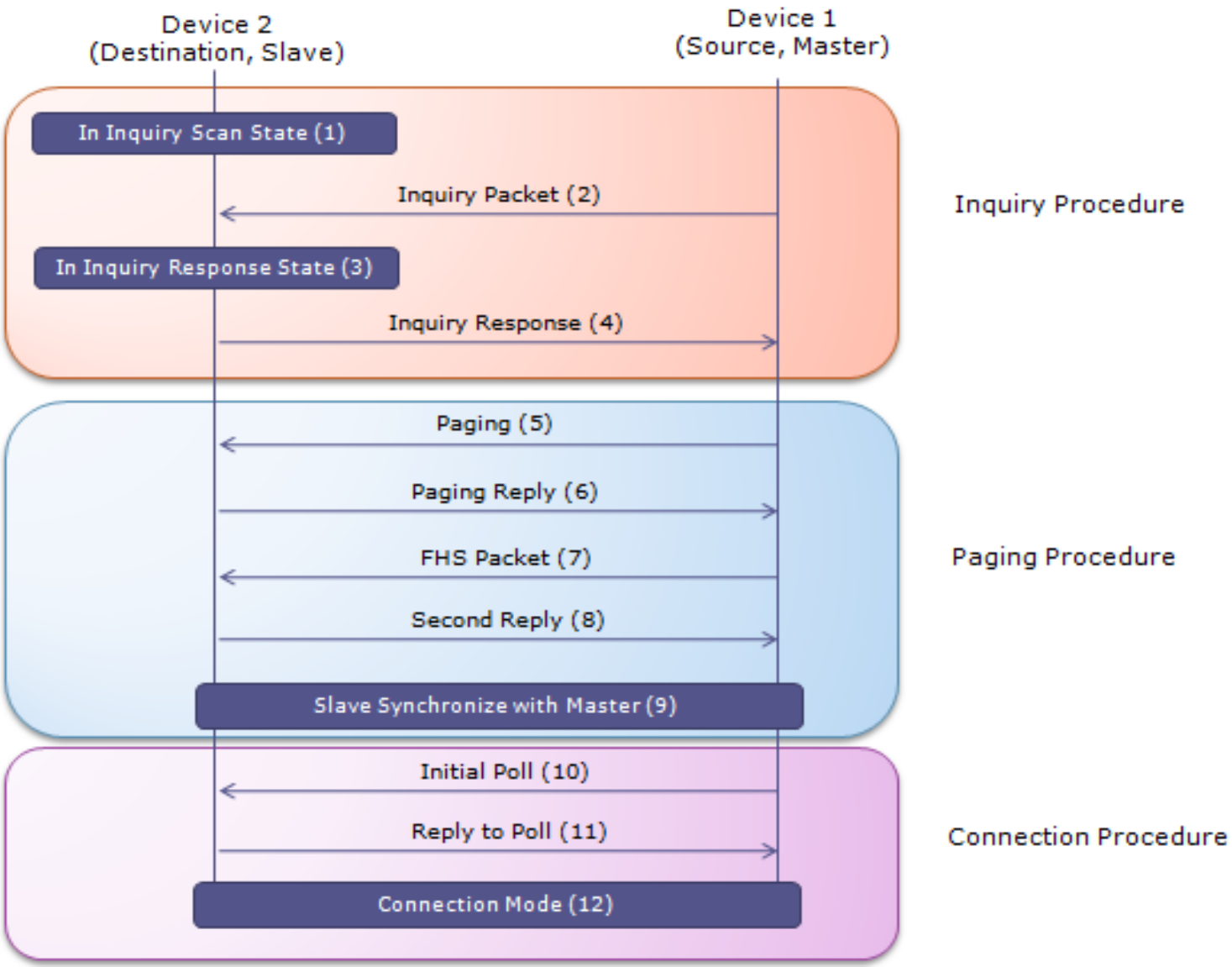
  Enforces authentication, encryption for secure connections.

- **Power Management:**

  Implements power-saving features for energy efficiency.

Bluetooth...

Bluetooth Connecting Process



Bluetooth...

Bluetooth Connecting Process...

#1 ✍ Inquiry:

- when two unknown bluetooth devices come together, one must run inquiry to discover other.
- once inquiry request send, the request will be responded with its address and other information (type of device) if necessary.

#2 ✍ Paging (connecting):

- once the address of each is known to each other, connection is formed and forming the connection is paging (Frequency Hopping Synchronization (FHS), clk info).

#3 ✍ Connection:

- once the paging is completed, devices enter to connection state.
- at connected mode, active participation is possible to communicate ie data transfer.

Bluetooth...

Different Connection Mode

#1 ✍ Active Mode:

- regular connection mode where the device can actively transmit or receive data (between master and slave).

#2 ✍ Sniff Mode:

- power saving mode – less active or reduced activities
- slave sleeps for predetermined time, recurring, and listen master only after preset values (eg: 100 ms) – scheduled wake up

#3 ✍ Hold Mode:

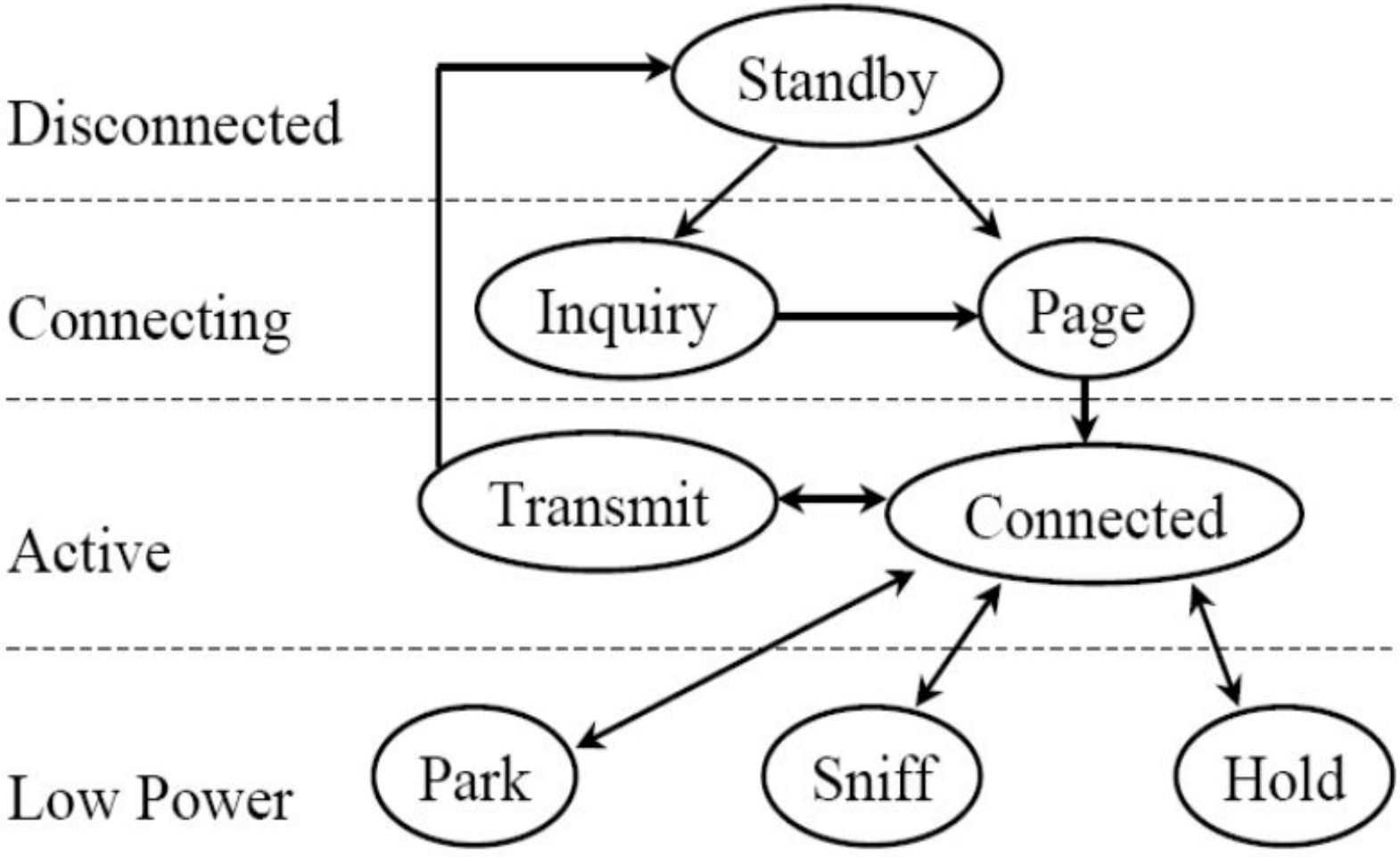
- power saving mode (stop transmission for other tasks)
- slave sleeps for one fixed predetermined time interval .
- master can command device to hold – wake up after hod time.

#4 ✍ Park Mode:

- deepest sleep mode; needs polling to re-activate slave.
- it sleeps until master command to wake up at T-beacon time.

Bluetooth ...

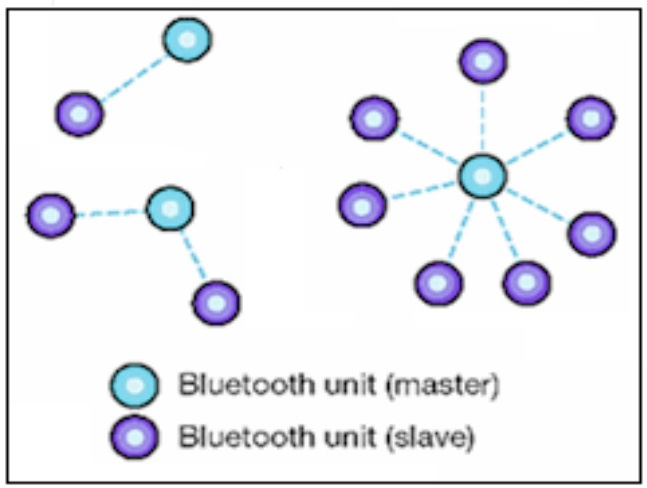
Different Operational State of Bluetooth Device



Bluetooth Network Topology

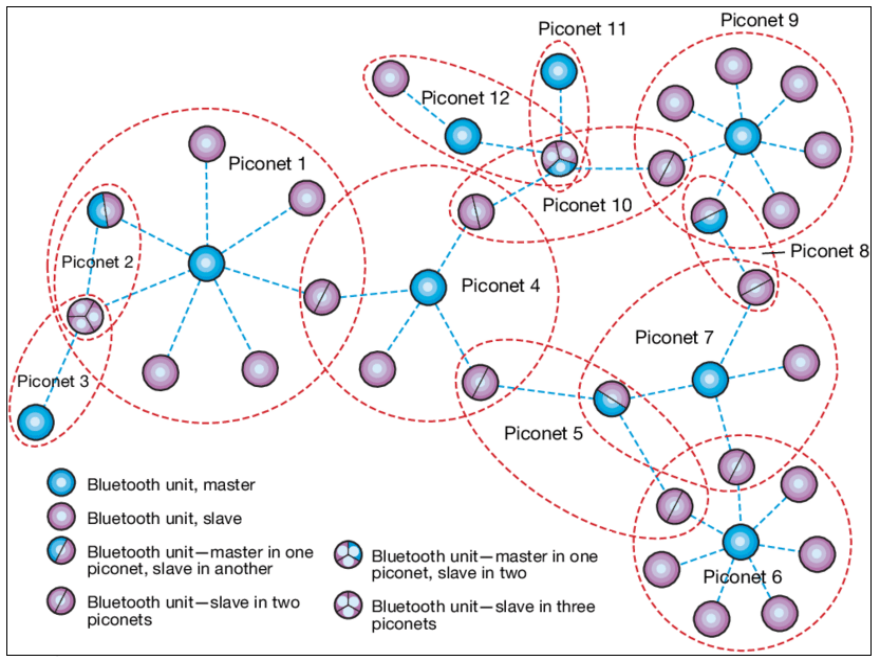
piconet

- max 8 devices (one master and 7 slaves).
- Master/Slave, frequency hopping;
- up to 7 active slave and up to 255 parked slaves;
- no central network structure; only Ad-hoc network.



scatternet

- inter-connected piconets; one master per piconet.
- a few devices shared between piconets.
- no central network structure; only Ad-hoc network.



Bluetooth ...

Bluetooth Protocol Stack

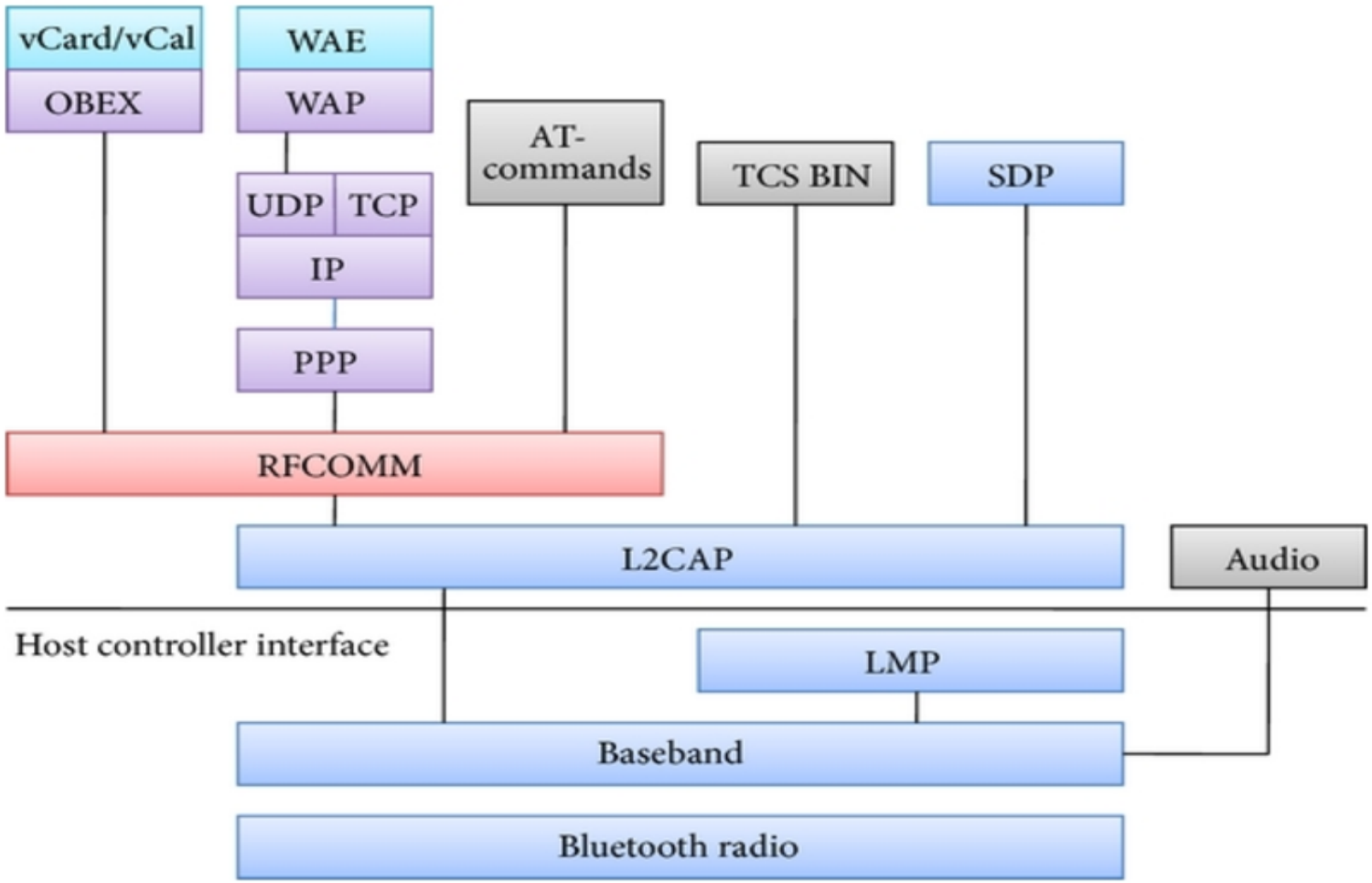
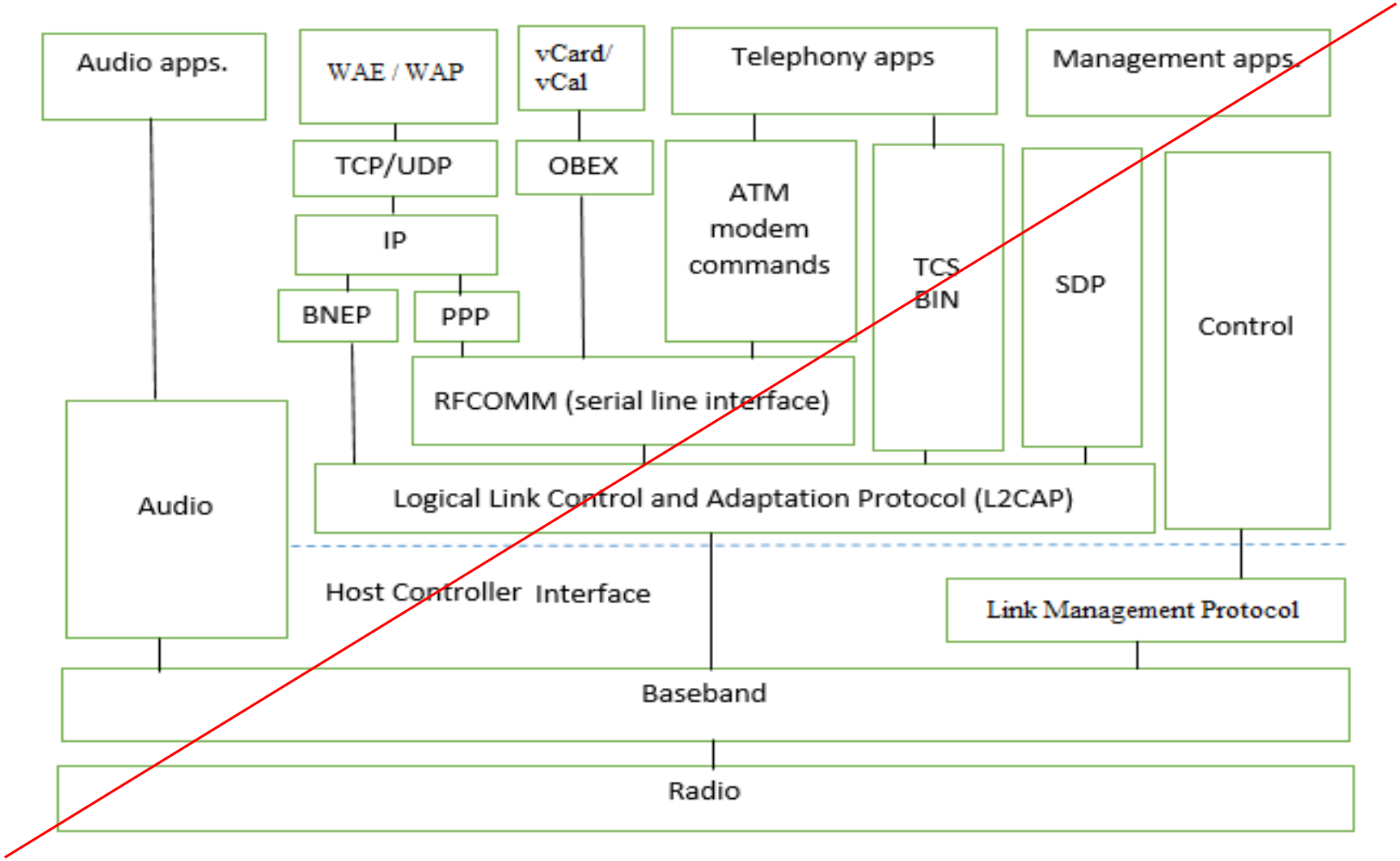


Fig. 20 Bluetooth Protocol Stack

Bluetooth ...

Bluetooth Protocol Stack...



Bluetooth Protocol Stack

Bluetooth..

Bluetooth Protocol Stack

#1 ✍ Bluetooth Radio

- defines air interface, frequency bands, frequency hopping specifications, modulation techniques, and transmit power.

#2 ✍ Baseband Layer

- addressing scheme, packet frame format, timing and power control algorithms for connection within piconet.

Bluetooth..

Bluetooth Protocol Stack...

#3 ✍ Link Management Protocol (LMP)

- it is responsible to establish link between bluetooth devices and maintain the link between them.
- it includes authentication and encryption specification.

#4 ✍ Logical Link Control and Adaptation Protocol (L2CAP)

- it adapts/converts upper layer frame to baseband layer frame format and vice versa.
- takes care of both connection-oriented (telephone connection) and connection-less services (packet based communication).

Bluetooth..

Bluetooth Protocol Stack...

#5 ✍ Host Controller Interface (HCI)

- provides a common interface to the baseband link controller and link management protocol, and access to hardware status and control registers.

#6 ✍ Service Discovery Protocol (SDP)

- queries about device information is handled by this protocol
- so responsible for connection.

#7 ✍ TCS-BIN

- It specifies all call control signaling and mobility management procedures; it takes care of establishing speech and data calls.

Bluetooth..

Bluetooth Protocol Stack...

#8 ✍ RFCOMM Protocol

- it is cable replacement protocol (wireless protocol)
- functions as virtual serial port and transport binary data bits.
- basically emulates RS232 specifications over bluetooth radio.
- Point to point protocol (PPP) to transfer IP datagrams, TCP/UDP/IP, OBEX and WAE/WAP protocols are adopted protocol in Bluetooth - defined by other standard bodies.
- OBEX is object exchange protocol developed by IrDA (infrared data association) – similar to HTTP (session level protocol).
- WAE provides Wireless Application Environment and WAP provides Wireless Application Protocol. (bluetooth tethering?)

Bluetooth..

Bluetooth Applications

- wireless control and communication between cell phone and heads free headset or car kit.
- wireless networking between PCs in confined space with little bandwidth (PAN with PCs using bluetooth wireless).
- wireless input connection such as mice, keyboards.
- wireless output device such as printer.
- transfer of files between devices via OBEX (Object Exchange Protocol– binary object file)
- replacement of wired devices with wireless devices: medical equipment, GPS receivers.
- replacement of remote controls which uses infrared traditionally.

Bluetooth..

Bluetooth Advantage

- uses lower power
- can connect various type of devices.
- free of cost frequency band
- Ad-Hoc hardware can be established by Bluetooth connection
- simple, secure and global data transfer.
- less time consumption.

Bluetooth Disadvantage

- Large data transmission is difficult
- Bluejack problems (receive of unsolicited message).

WiFi (Wireless LAN - 802.11)

Introduction to WiFi

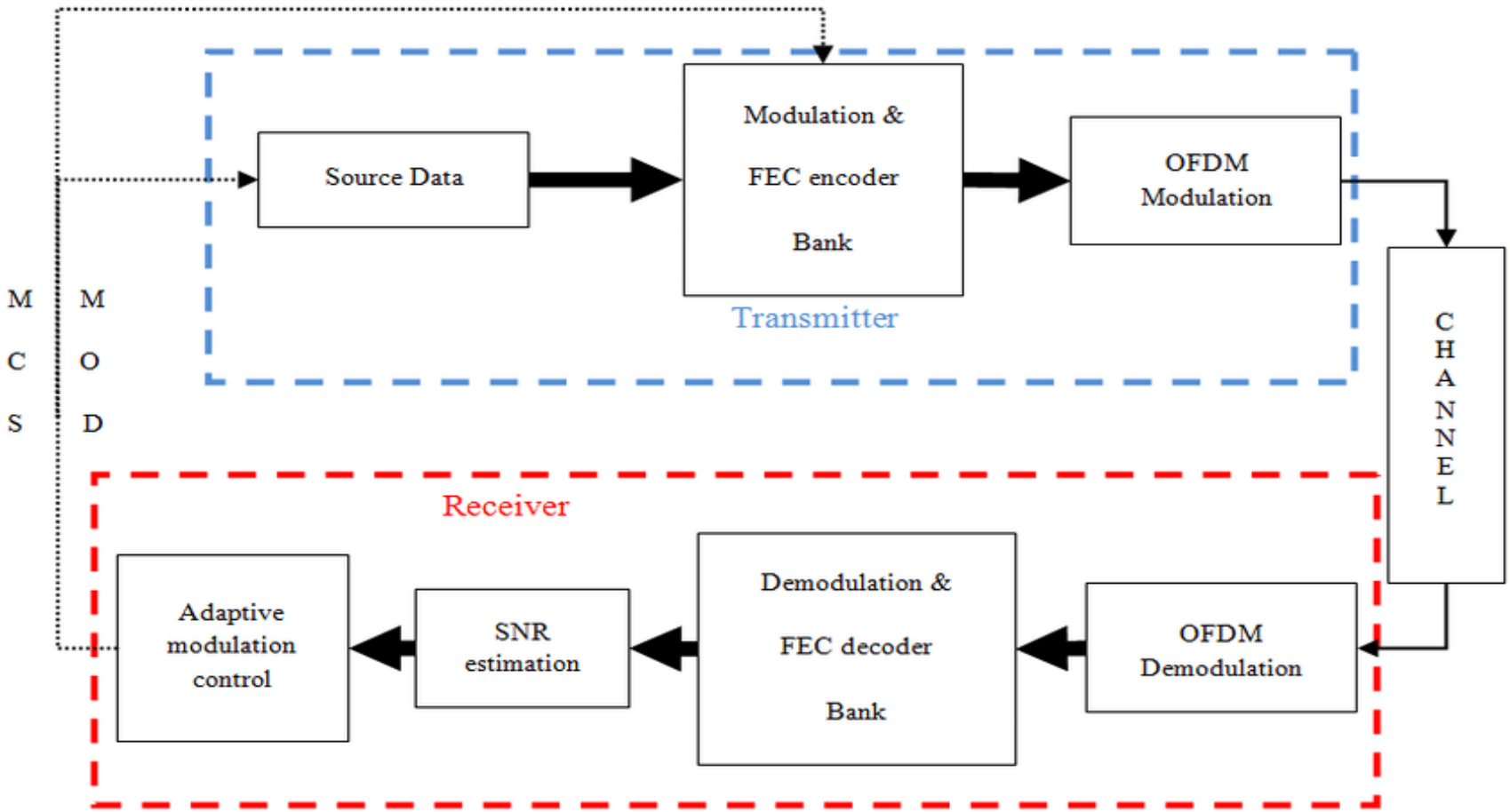


Fig. 21 A typical WiFi Trans-receiver Diagram

WiFi (Wireless LAN - 802.11)

WiFi Functional block

Block	**Function**
Source Data	Original binary data
FEC Encoder & Modulator Bank	Error protection + signal modulation; **Modulation**: BPSK, QPSK, 16-QAM, 64-QAM **FEC Encoder**: Convolutional coding, Low Density Parity Check (LDPC)
OFDM Modulation	Converts data to OFDM format
Channel	Wireless medium with noise and distortion
OFDM Demodulation	Recovers symbols from OFDM signal
Demodulator & FEC Decoder	Converts back to binary and corrects errors
SNR Estimation	Measures signal quality – channel condition
Adaptive Modulation Control	Chooses best MCS for future transmissions

☛ **Note:** MCS – Modulation and Coding Scheme

WiFi (Wireless LAN - 802.11)

Charecteristics of WiFi

Feature	**Description**
Standard	IEEE 802.11 series
Bands	2.4 GHz, 5 GHz, 6 GHz (Wi-Fi 6E)
Speed	Up to 10+ Gbps (Wi-Fi 6/6E)
Range	30–200 meters (depending on environment)
Modulation	OFDM with QAM (up to 1024-QAM in Wi-Fi 6)
Access Method	CSMA/CA
Security	WPA2, WPA3
Interoperability	High (standardized protocol)

Zigbee

Introduction to ZigBee

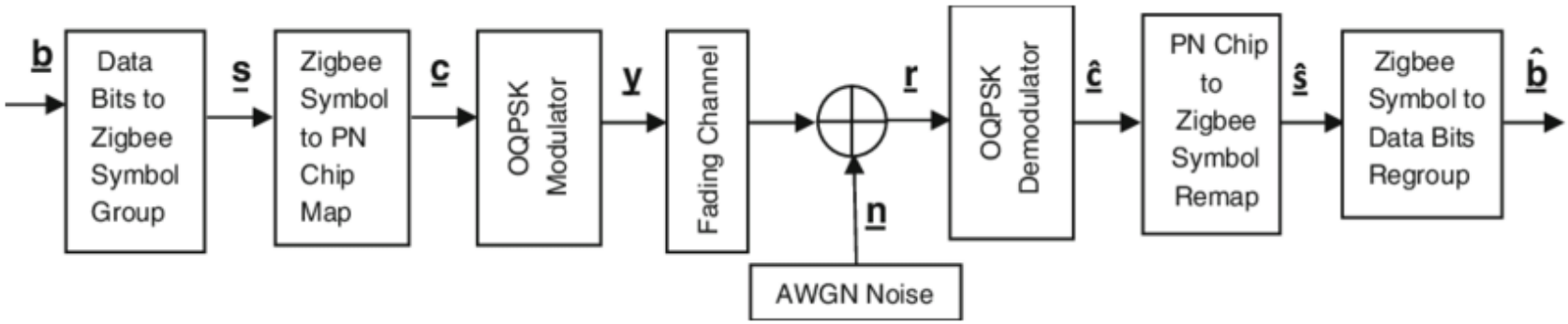


Fig. 22 A typical ZigBee Trans-receiver Diagram

Stage	**Block**	**Function**
Tx	Data Bits → Symbols	Group bits into 4-bit ZigBee symbols
	Symbol to PN Chips	Map each symbol to 32-chip DSSS code
	O-QPSK Modulator	Modulate using Offset-QPSK
Channel	Fading + AWGN	Simulates real-world signal degradation
Rx	Demodulator	Extract chip stream from waveform
	Chips to Symbols	Match received chip stream to known symbols
	Symbols to Bits	Reassemble original bitstream

Zigbee

Introduction to ZigBee

- ZigBee is a low-power wireless mesh network protocol based on IEEE 802.15.4, optimized for low-data-rate, low-power applications like home automation and industrial controls.

✔ **Key Characteristics:**

Frequency: 2.4 GHz globally (also supports 868/915 MHz)

Range: 10 – 100 meters (can extend via mesh)

Data Rate: 250 kbps

Topology: Mesh, star, or cluster-tree

Security: 128-bit AES encryption

Zigbee

Interfacing ZigBee with Arduino

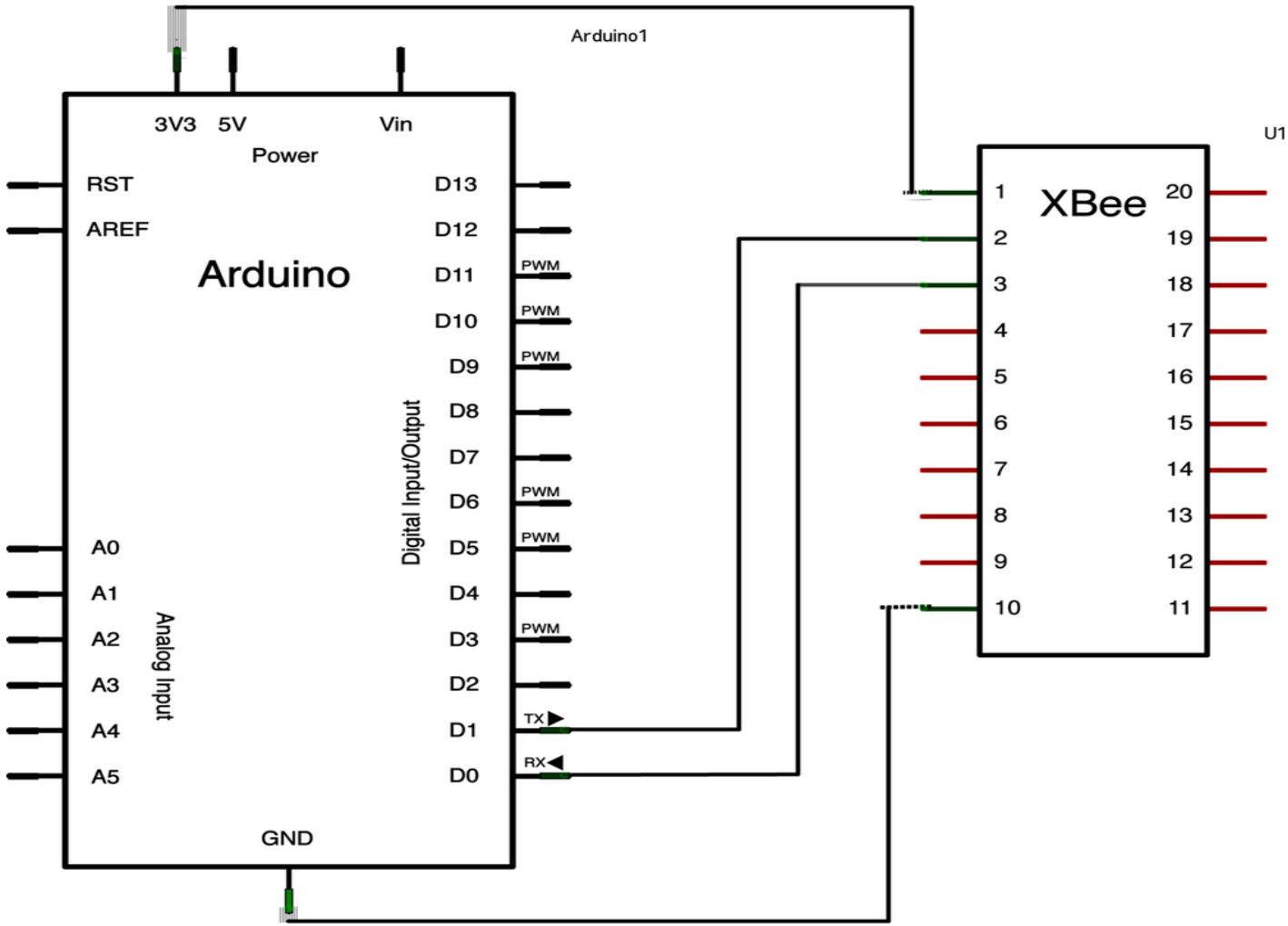


Fig. 23 Interfacing ZigBee with microcontroller

Near Field Communication (NFC)

What is NFC?

- NFC (Near Field Communication) is a short-range wireless communication technology that allows two electronic devices to exchange data when placed very close together — typically within 4 cm (1.5 inches) – uses ASK/O-QPSK modulation.
- It works based on RFID (Radio Frequency Identification).
- Uses 13.56 MHz frequency band (unlicensed ISM band).
- Supports two-way communication, unlike RFID which is usually one-way.(ISM : Industrial, Scientific, and Medical Radio Bands)

✔ There are two modes:

Active Mode: Both devices generate a radio frequency field.

Passive Mode: One device generates the field; the other responds using load modulation (e.g., NFC tags).

Near Field Communication (NFC)

Some NFC Applications

Application	**Example**
Contactless Payments	Google Pay, Apple Pay, Samsung Pay
Smart Cards	Metro cards, ID cards, hotel keys
Device Pairing	Quickly connect Bluetooth speakers, etc.
Information Sharing	Share contact info or files between phones
Authentication	Secure door access, logins

Near Field Communication (NFC)

Comparision between NFC and Bluetooth

Feature	**NFC**	**Bluetooth**
Range	$\sim$ 4 cm	$\sim$ 10 meters
Speed	Up to 424 kbps	Up to 2 Mbps
Pairing	Not needed	Required
Power Use	Very low / Passive possible	Moderate
Security	High (short range)	Moderate
Best for	Payments, ID, authentication	Audio, file transfer, IoT control
Ease of Use	Tap to trigger	Manual pairing

Introduction

Intro

-

Long Range – LoRA

Long-distance, low-power, and low-data-rate

- Mainly applicable in IoT applications
- Go yourself.

Wireless sensor network and its technology

Wireless Sensor Network (WSN)

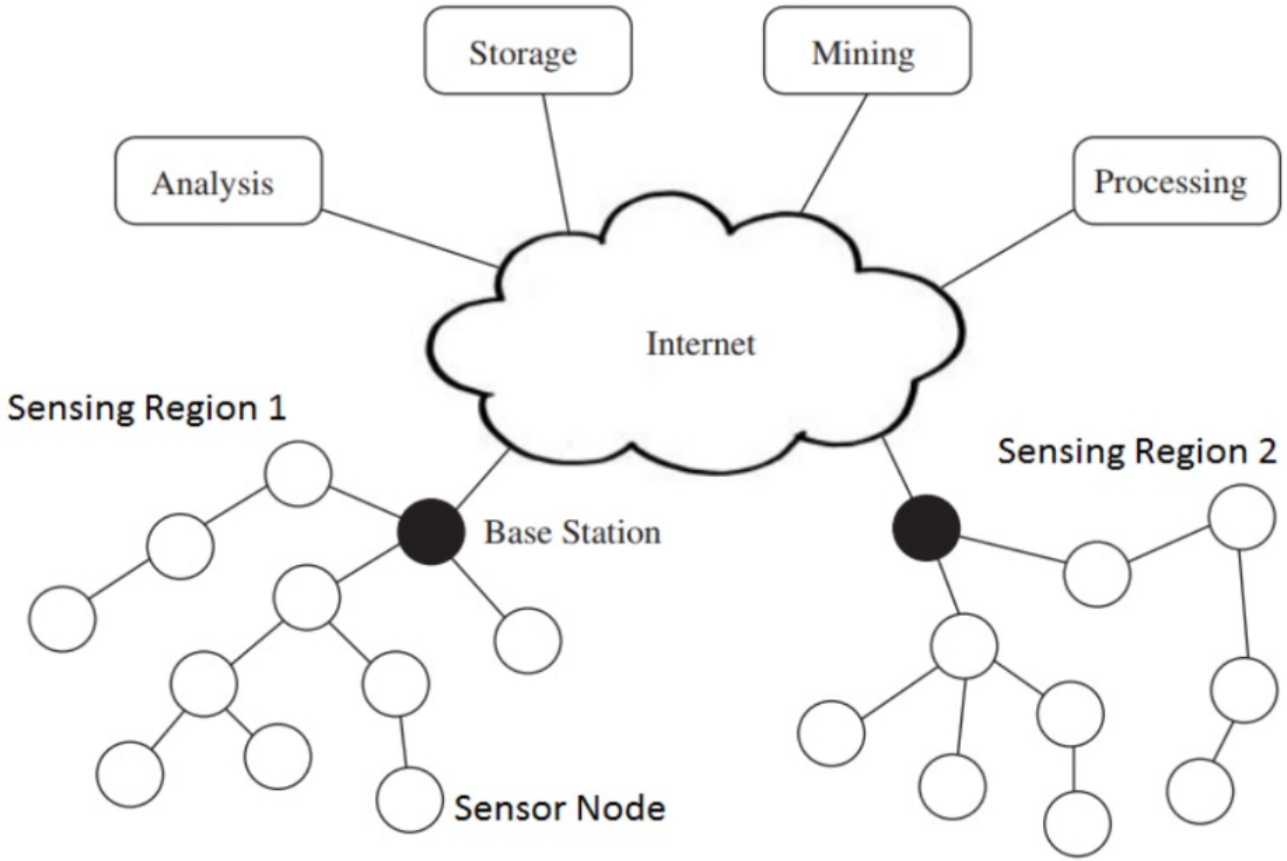


Fig. 24 A typical Wireless Sensor Network

Wireless sensor network and its technology

Introduction to WSN

- A Wireless Sensor Network is a collection of spatially distributed autonomous sensors that monitor physical or environmental conditions and cooperatively pass their data through the network to a central location or base station.

✔ **Key Components:**

- **Sensor Nodes**: Sense data from the environment.
- **Sink/Base Station**: Gathers data from sensor nodes and sends it to the server.
- **Communication Module**: Handles wireless data transmission (e.g., ZigBee, Bluetooth).
- **Power Unit**: Usually a battery – battery backed up; energy-efficient design is critical.
- **Processing Unit**: Performs data processing and controls communication.

Wireless sensor network and its technology

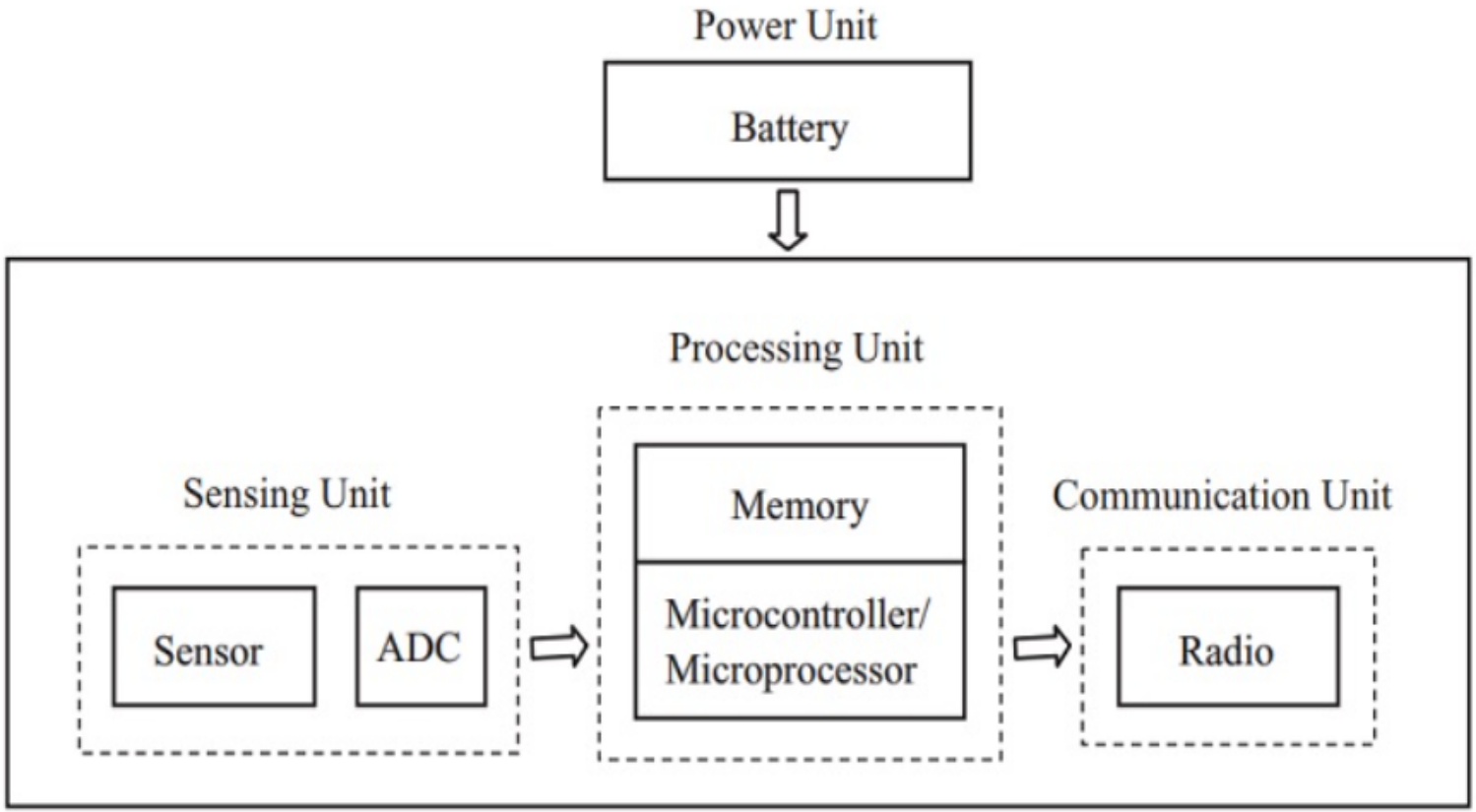


Fig. 25 A typical sensor node in Wireless Sensor Network

Wireless sensor network and its technology

WSN Technologies:

- **Terrestrial WSNs:** Deployed on land for environmental or industrial monitoring.
- **Underground WSNs:** Used for mining, soil monitoring.
- **Underwater WSNs:** Applied in ocean monitoring.
- **Mobile WSNs:** Sensor nodes are mobile (used in vehicles, animals).
- **Wireless Body Area Networks (WBAN):** Used in healthcare to monitor body functions.

Wireless sensor network and its technology

WSN Technologies:

- **ZigBee**: Low power, short-range, mesh networking.
- **Bluetooth Low Energy (BLE)**: For short-range, low-energy communication.
- **Wi-Fi**: Used in high-data-rate applications, but consumes more power.
- **LoRa (Long Range)**: For long-range, low-power IoT applications.

Introduction

Intro

-

Data Acquisition System

- Data acquisition system is the process of collecting the input data in digital form suitable for analysis and storage.
- Data collection should be timely, accurately and economically.
- Data acquisition system consists:
  1. transducer (sensor)
  2. signal conditioner
  3. data conversion and processing
  4. multiplexer, transmission
  5. storage and display system
  6. software for data processing
- Analog signals are generally acquired and converted into digital form for processing, transmission, display and storage.
- sometime data acquired can be used for controlling a process in process plant.

Data Acquisition System...

- transducer is device that converts input energy of one form into another energy form.
- signal conditioning make signals compatible to forward acquisition; removing unwanted frequency components; amplifying amplitude.

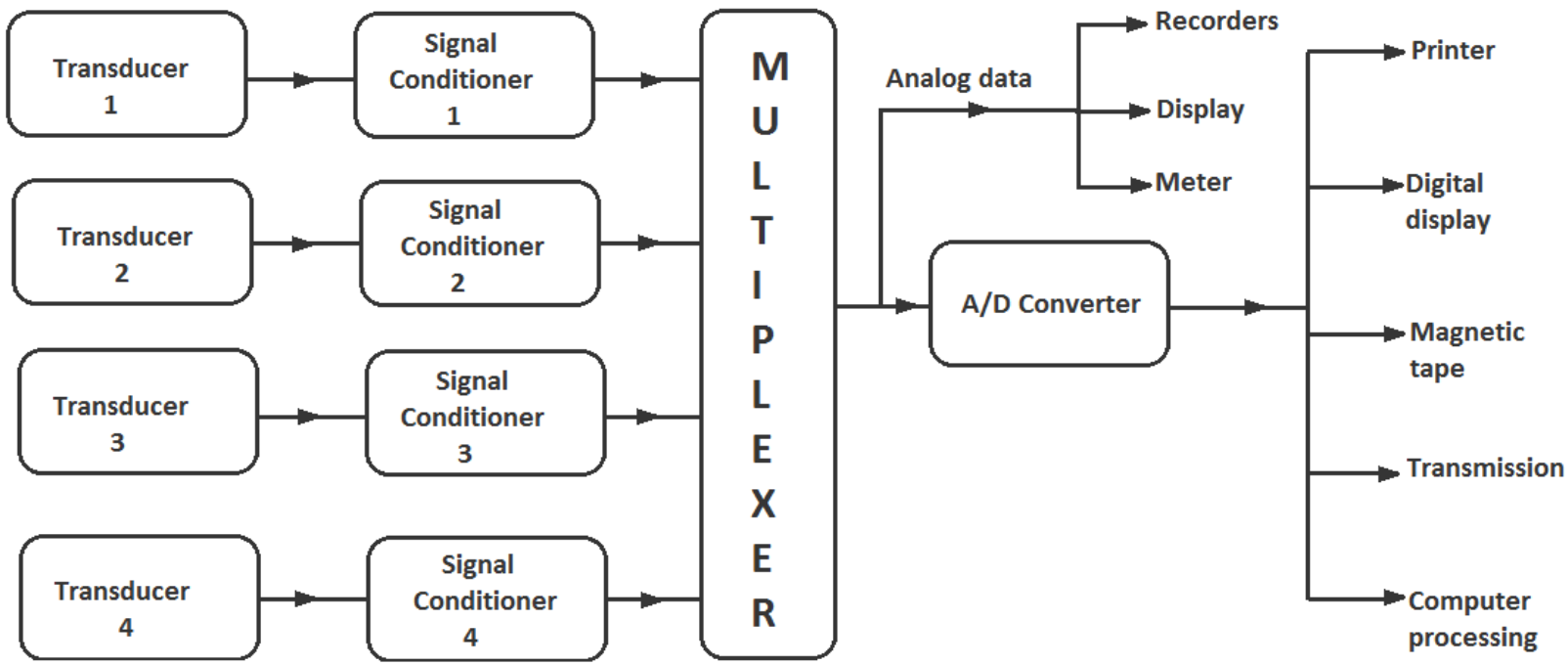


Fig. 26 General data acquisition system

Data Acquisition System...

Data Loggers

- transducers give the measure of some parameters of any process – the parameters can be used for process control after analysis, can be used for further processing.
- automatic data recorder for the readings (parameters) of remote instrumentation system.
- expectation for data logger is as quickly as effortlessly, and accurately.
- our expectation, being data reader at distant place, it should be small battery powered, portable, power efficiently and equipped with microprocessor and internal memories.

Data Acquisition System...

Characteristics of Data Loggers

- modularity: compatible component to many systems.
- reliability and ruggedness: reliable data storage/reading.
- accuracy: data measure should be as accurate as possible.
- management tool:
- Easy to Use:

Application of Data Loggers

- weather station: recording wind speed, wind direction, temperature, relative humidity.
- hydro-graphic recoding: water level, depth, water flow PH, conductivity
- soil moisture level, gas pressure
- environmental monitoring

Data Acquisition System...

Data Loggers...

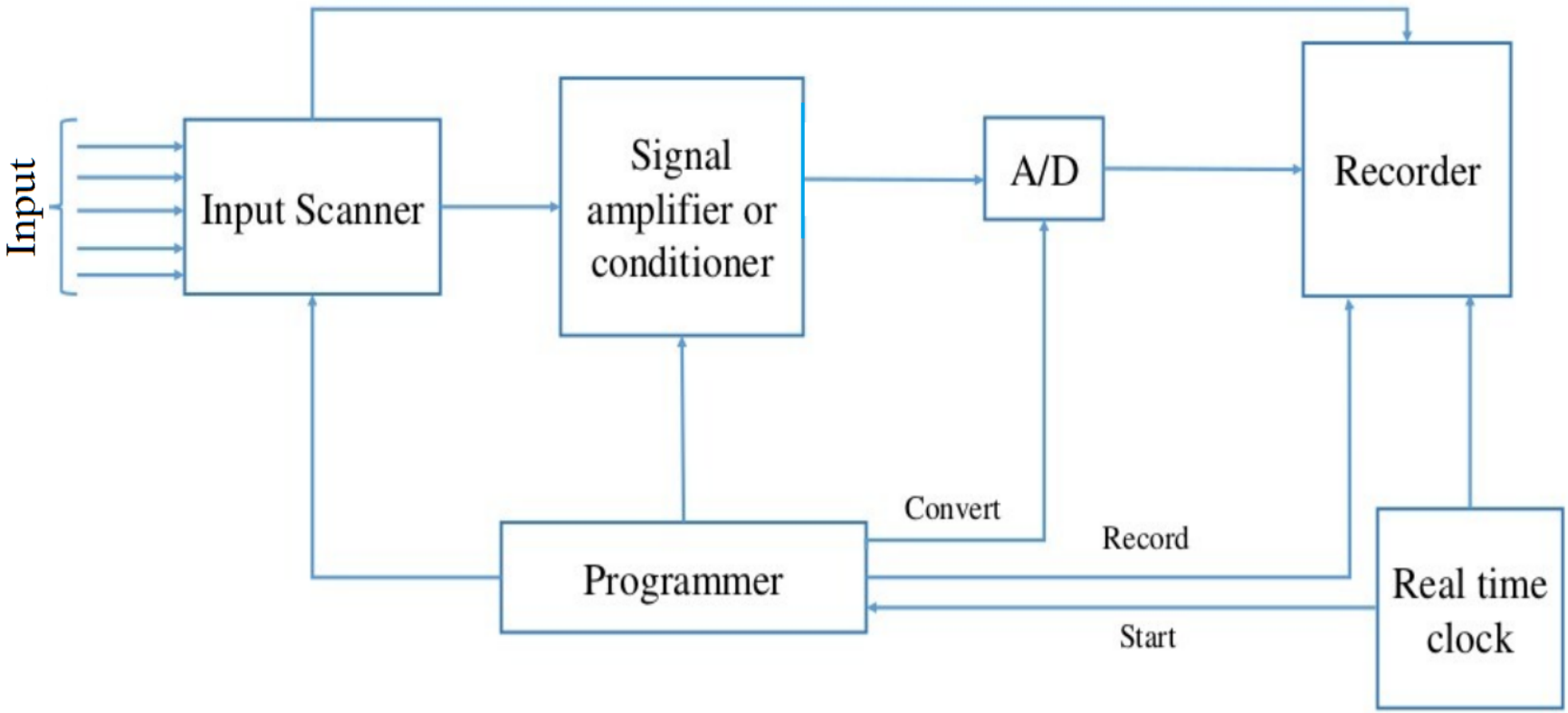


Fig. 27 Block Diagram of Data Logger

Data Acquisition System...
Data Loggers...

✍ Input Signals

- input signals may be pressure, AC signals, thermocouple, signals from relay, tachometer pulses

✍ input scanners

- is automatic sequence switch to select signals in turn.
- scanner should have low closed resistance, high open circuit resistance, low contact potential, short operating time, negligible contact bounce, long operation life.

✍ Signal Amplifiers and conditioners

- to adjust gain with low level signals
- it should be precise and stable DC gain, high SNR, high CMMR, low DC drift, low output impedance, high input impedance, good linearity, wide bandwidth.

Data Acquisition System...
Data Loggers...

✍ A/D Converter

- Converts analog to digital data
- it should have better resolution, accuracy, lower conversion time, linearity.

✍ Recorder

- data logger may be typewriter, strip printer, digital tape recorder, computer, magnetic tape.
- should have higher read/write speed;

✍ Programmer

- controls all units of data logger system
- microcontroller or microprocessor based system.
- it should perform: setting amplifier, linearity factor, A/D conversion time, reset logger, record reading channel, identify channel and time of recording.

Data Acquisition System...

Compact Data Loggers(*self study*)

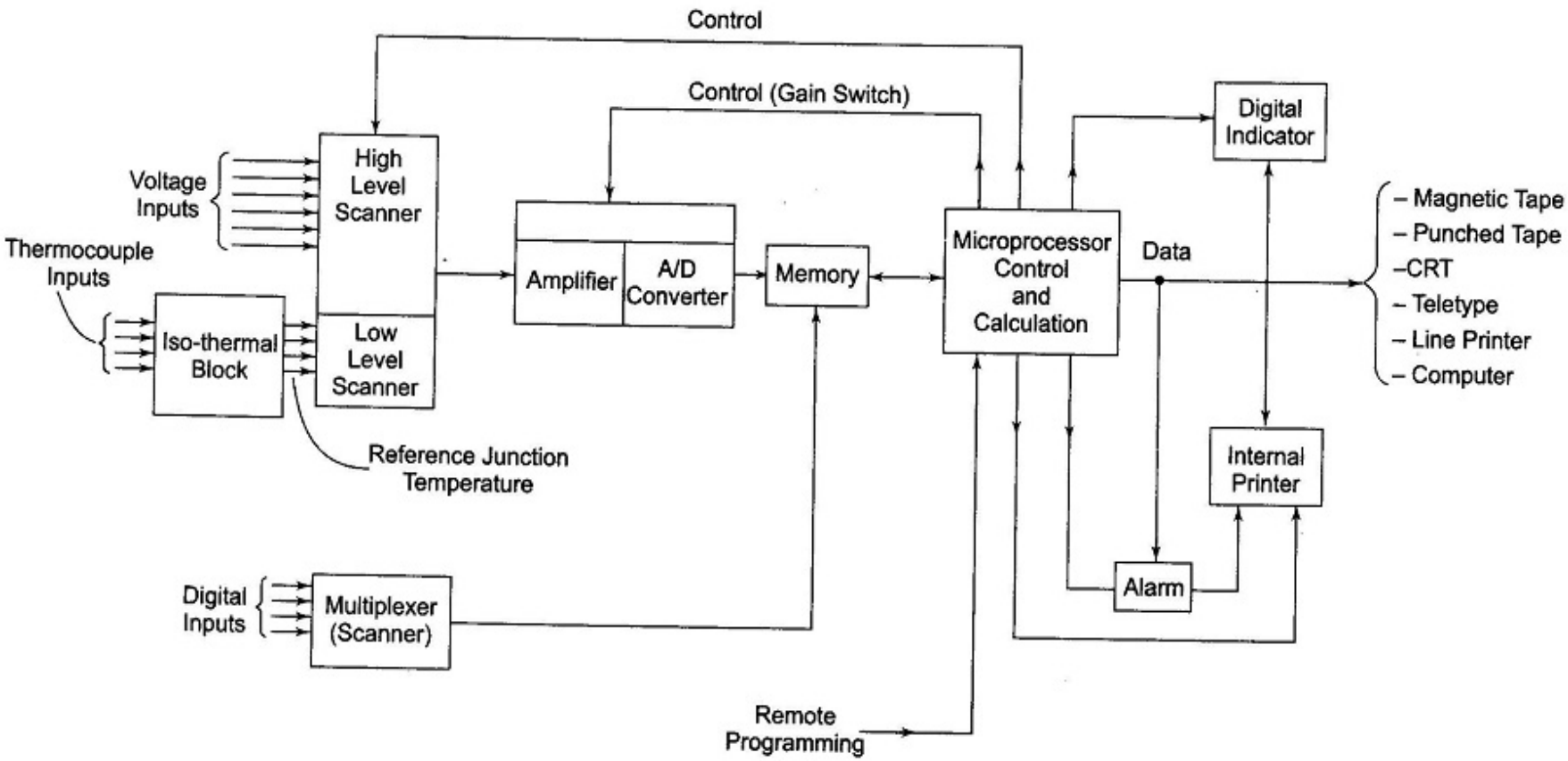


Fig. 28 Block Diagram of Compact Data Logger

Data Acquisition System...

Compact Data Loggers(*self study - explore more*)

- typical compact data logger unit provides 60 data channels
- some manufacturers offers add-on scanners to expand 100 data channels; scan rates at modest is 20 channels per second.
- most units have interface to computer for versatile processing when possible.
- uses built in microprocessor to carry out calculation on amplifiers, A/D converters.
- low level and high level scanner are available.
- milivolt level signals:
  - ✍ thermocouple signals use shielded, twisted pair cable.
- amplifiers and A/D converters are crucial for system accuracy.
- microprocessors are responsible for automatic gain.

Data Acquisition System...

Data Archiving and Storage

✍ Data Archiving

- is moving data that is no longer actively used.
- it can be readily accessible if required.
- data archives are indexed and have search capability so that data or files can be easily located or retrieved.
- make sure there is difference in data backup and data archive.
- data backup means re-storage of data when corrupted or destroyed.
- data archiving is protecting older information which may be used occasionally, not in everyday operation.

Data Acquisition System...

Data Archiving and Storage

✍ Data Storage

- recording data and retaining when needed.
- storage design factors are:
  1. speed of data access
  2. cost per unit data
  3. reliability: data loss when power failure or system crash, physical failure of storage device;

Volatile: loss of content when power is off

Non-Volatile: no content loss when power is off.

Data Acquisition System...

Different type of Data Storage

✍ Primary storage

- fastest media, it might be volatile.
- cache, main memory - RAM or ROM.

✍ Secondary storage

- online storage, non-volatile
- moderately fast to access.
- flash memory, magnetic disks.

✍ Tertiary storage

- off-line storage, non-volatile
- slow access time: tape libraries, optical jukebox.

Data Acquisition System...

Data Compression

- is the process of encoding to represent information with minimal number of bits
- reduces the bandwidth in both transmission and data storage.

Lossy Compression	***Lossless Compression***
when loss is acceptable	when loss is unacceptable
eg: Picture(JPEG), video(MPEG), audio (MP3)	eg: Zip, RAR, PNG, TIFF, video (Huff, AVI)

Data Acquisition System...

RAID: Redundant Arrays of Independent/Inexpensive Disks

- is the way of storing data in disk organization
- high capacity and high speed when multiple disk in parallel.
- high reliability by storing data redundantly, so data can be recovered even if a disk fails.
- main purpose of the RAID is data reliability, availability, performance, and capacity
- except RAID0, higher level RAID provide automatic data recovery at disk failure

✍ Note: Click RAID Description up to RAID-6

Data Acquisition System...

RAID: Redundant Arrays of Independent Disks

Category		Description	I/O Request Rate (Read/Write)	Data Transfer Rate (Read/Write)	Typical Application
Striping	0	Non-redundant	Large strings: Excellent	Small strips: Excellent	Applications requiring high performance for non-critical data
Mirroring	1	Mirrored	Good/fair	Fair/fair	System drives; critical files
Parallel access	2	Redundant via Hamming code	Poor	Excellent	
	3	Bit-interleaved parity	Poor	Excellent	Large I/O request size applications such as imaging, CAD
Independent access	4	Block-interleaved parity	Excellent/fair	Fair/poor	
	5	Block-interleaved distributed parity	Excellent/fair	Fair/poor	Applications requiring extremely high availability
	6	Block-interleaved dual distributed parity	Excellent/poor	Fair/poor	

As you go
Assignment

Assignment Module#5 is available at MS-Team.

Submission Deadline: 14th July 2025 (*Before 3:00 PM*)