Communication Interface:

- Communication interface is essential for communicating with various subsystems of the embedded system and with the external world
- The communication interface can be viewed in two different perspectives; namely;

  1. Device/board level communication interface (Onboard Communication Interface)

  2. Product level communication interface (External Communication Interface)

1. Device/board level communication interface (Onboard Communication Interface):

The communication channel which interconnects the various components within an embedded product is referred as Device/board level communication interface (Onboard Communication Interface)

Examples: Serial interfaces like I2C, SPI, UART, 1-Wire etc and Parallel bus interface

2. Product level communication interface (External Communication Interface):

The Product level communication interface (External Communication Interface) is responsible for data transfer between the embedded system and other devices or modules. The external communication interface can be either wired media or wireless media and it can be a serial or parallel interface.

Examples for wireless communication interface: Infrared (IR), Bluetooth (BT), Wireless LAN (Wi-Fi), Radio Frequency waves (RF), GPRS etc.

Examples for wired interfaces: RS-232C/RS-422/RS 485, USB, Ethernet (TCP-IP), IEEE 1394 port, Parallel port etc.

1. Device/board level or On board communication interfaces: The Communication channel which interconnects the various components within an embedded product is referred as Device/board level communication interface (Onboard Communication Interface)

These are classified into

1.1 I2C (Inter Integrated Circuit) Bus

1.2 SPI (Serial Peripheral Interface) Bus

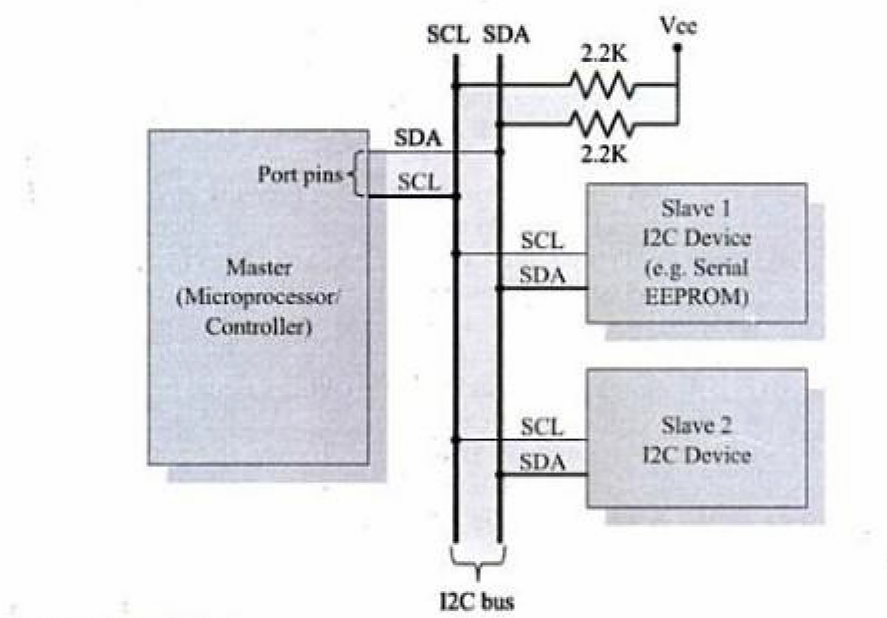
1.3 UART (Universal Asynchronous Receiver Transmitter)

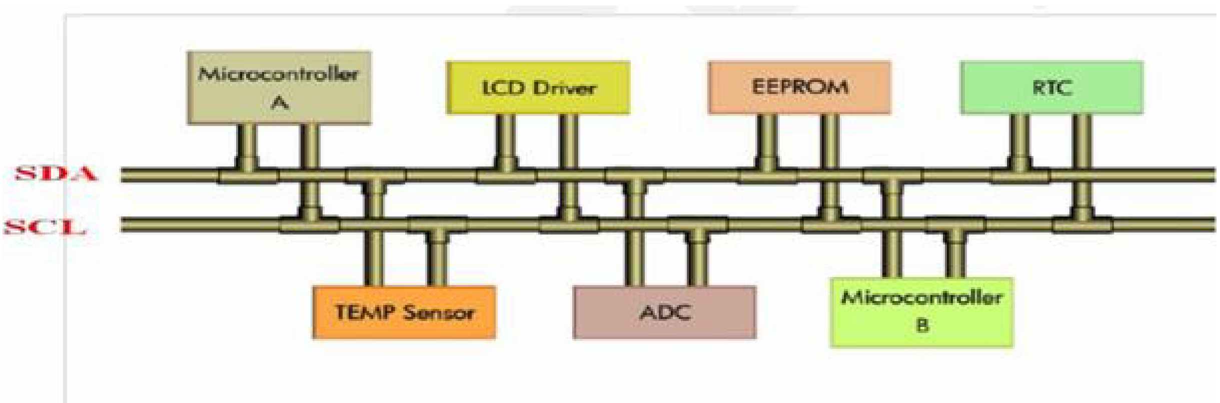
1.4 1-Wires Interface

1.5 Parallel Interface

1. I2C (Inter Integrated Circuit) Bus:

Inter Integrated Circuit Bus (I2C - Pronounced „I square C"") is a synchronous bi-directional half duplex (one-directional communication at a given point of time) two wire serial interface bus.The concept of I2C bus was developed by „Philips Semiconductors" in the early 1980"s. The original intention of I2C was to provide an easy way of connection between a microprocessor/microcontroller system and the peripheral chips in Television sets. The I2C bus is comprised of two bus lines, namely; Serial Clock – SCL and Serial Data – SDA.





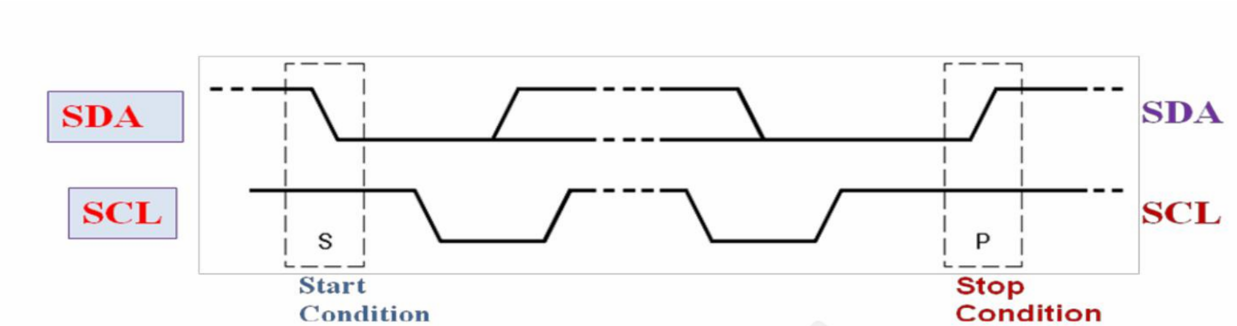
SCL line is responsible for generating synchronization clock pulses and SDA is responsible for transmitting the serial data across devices.I2C bus is a shared bus system to which many number of I2C devices can be connected. Devices connected to the I2C bus can act as either „Master" device or „Slave" device.

The „Master" device is responsible for controlling the communication by initiating/terminating data transfer, sending data and generating necessary synchronization clock pulses.

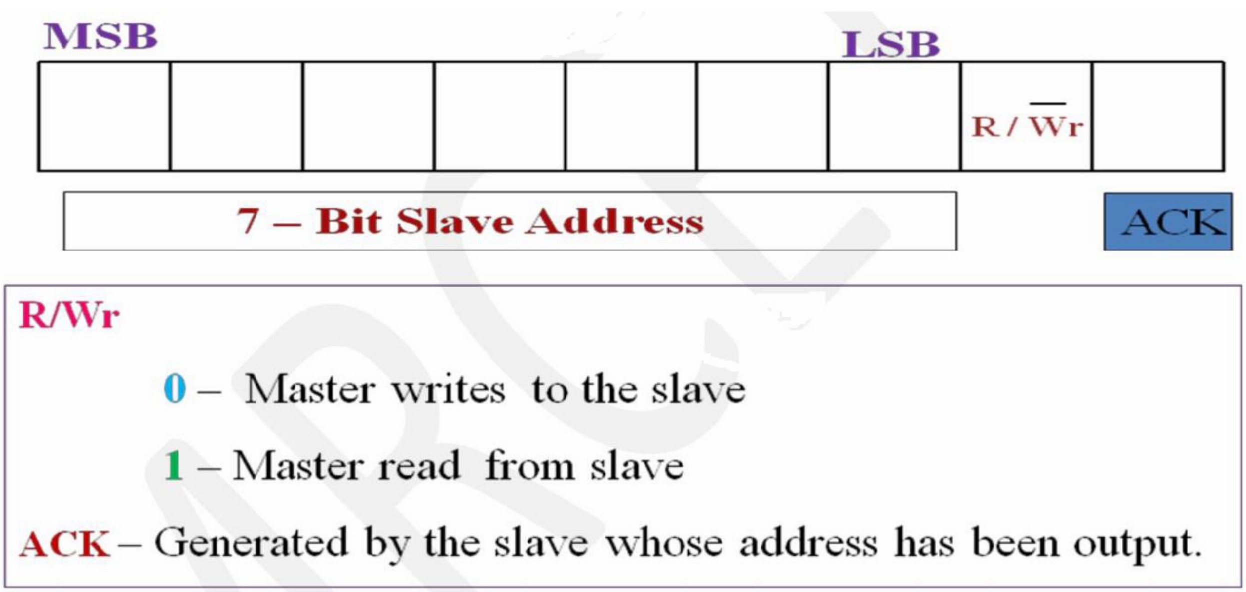
Slave devices wait for the commands from the master and respond upon receiving the commands. Master and „Slave" devices can act as either transmitter or receiver. Regardless whether a master is acting as transmitter or receiver, the synchronization clock signal is generated by the „Master" device only.I2C supports multi masters on the same bus.

The sequence of operation for communicating with an I2C slave device is:

1. Master device pulls the clock line (SCL) of the bus to ‘HIGH’
2. Master device pulls the data line (SDA) ‘LOW’, when the SCL line is at logic ‘HIGH’ (This is the ‘Start’ condition for data transfer)



3. Master sends the address (7 bit or 10 bit wide) of the ‘Slave’ device to which it wants to communicate, over the SDA line.
4. Clock pulses are generated at the SCL line for synchronizing the bit reception by the slave device.
5. The MSB of the data is always transmitted first.
6. The data in the bus is valid during the ‘HIGH“’ period of the clock signal
7. In normal data transfer, the data line only changes state when the clock is low.



8. Master waits for the acknowledgement bit from the slave device whose address is sent on the bus along with the Read/Write operation command.

9. Slave devices connected to the bus compares the address received with the address assigned to them

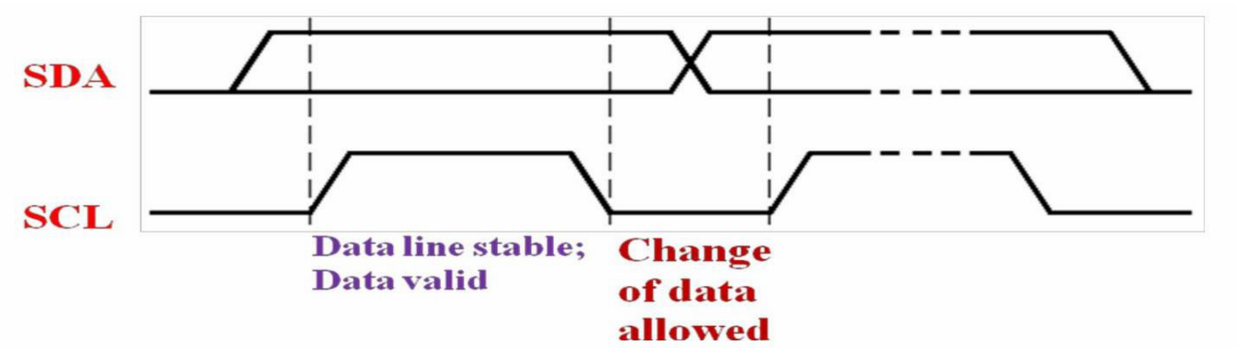
10. The Slave device with the address requested by the master device responds by sending an acknowledge bit (Bit value =1) over the SDA line

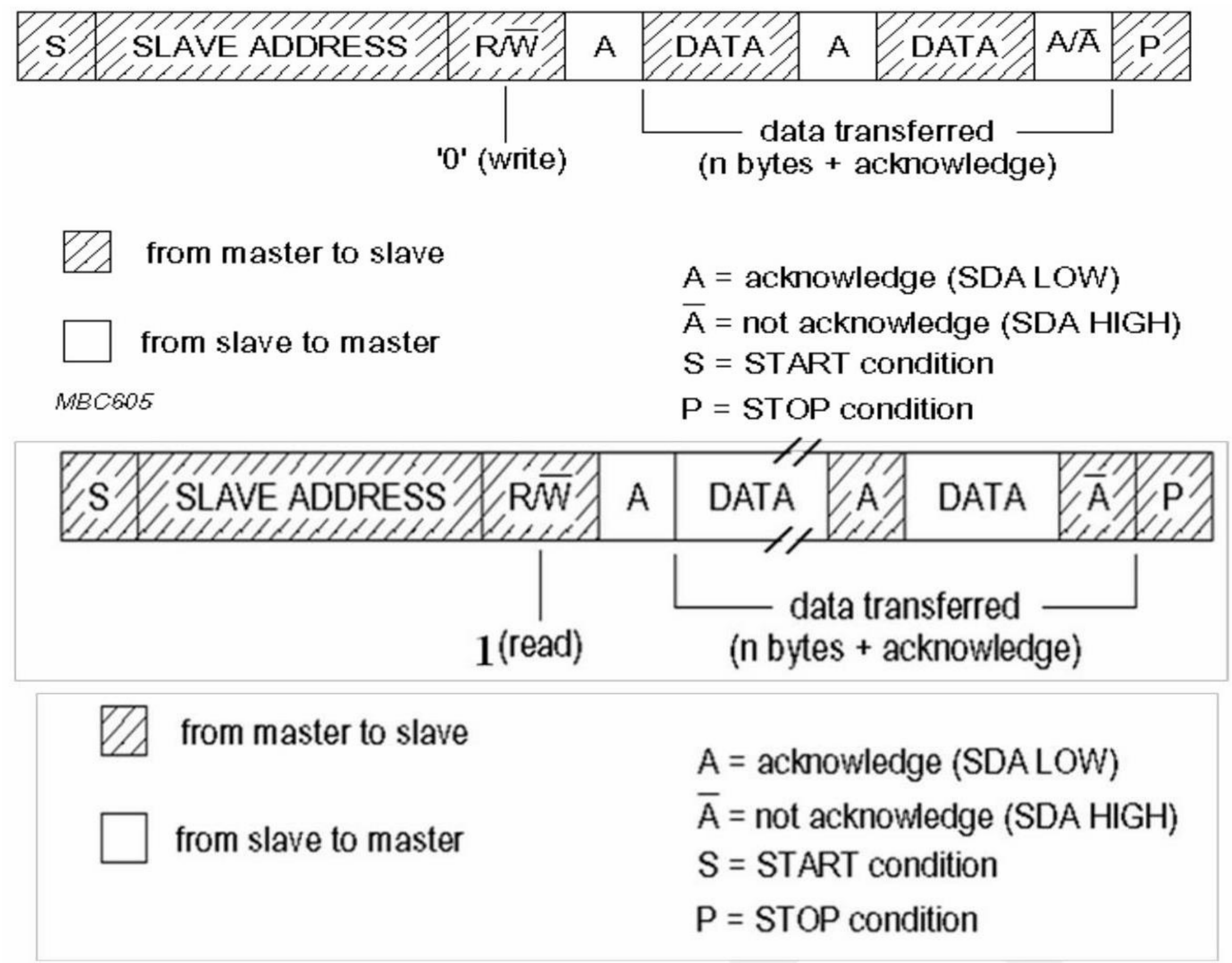
11. Upon receiving the acknowledge bit, master sends the 8bit data to the slave device over SDA line, if the requested operation is „Write to device".

12. If the requested operation is „Read from device", the slave device sends data to the master over the SDA line.

13. Master waits for the acknowledgement bit from the device upon byte transfer complete for a write operation and sends an acknowledge bit to the slave device for a read operation

14. Master terminates the transfer by pulling the SDA line „HIGH" when the clock line SCL is at logic „HIGH" (Indicating the „STOP" condition).



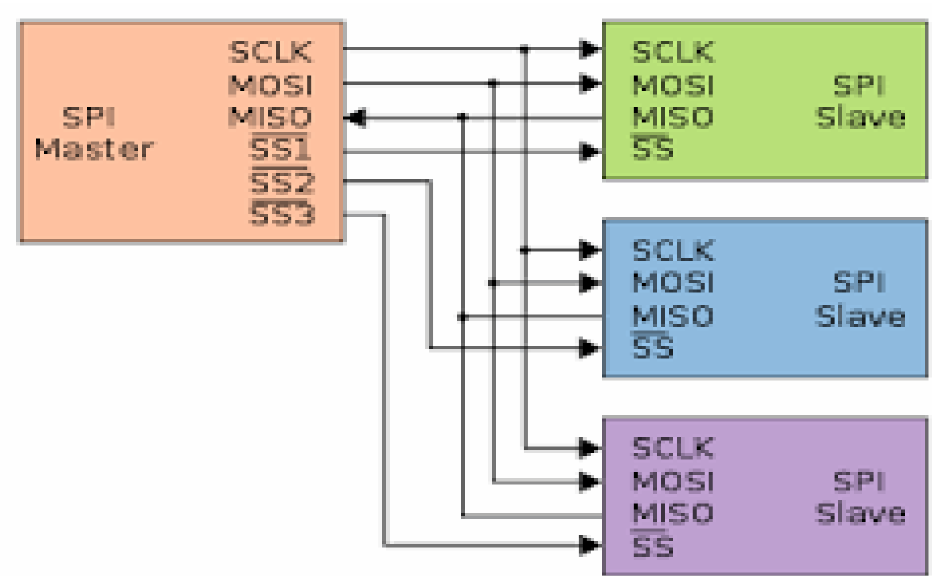


Serial Peripheral Interface (SPI) Bus:

The Serial Peripheral Interface Bus (SPI) is a synchronous bi-directional full duplex four wire serial interface bus. The concept of SPI is introduced by Motorola. SPI is a single master multi-slave system.

➢ It is possible to have a system where more than one SPI device can be master, provided the condition only one master device is active at any given point of time, is satisfied.

➢ SPI is used to send data between Microcontrollers and small peripherals such as shift registers, sensors, and SD cards.



SPI requires four signal lines for communication. They are:

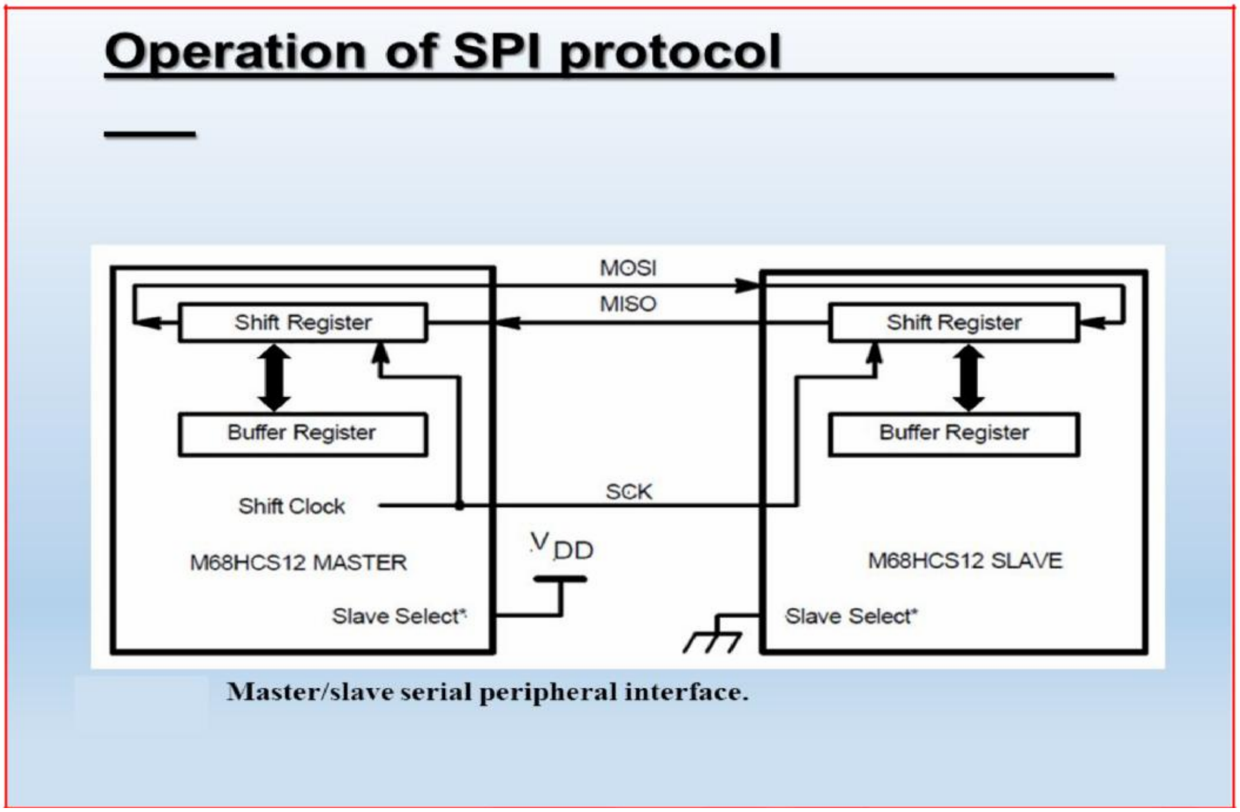
Master Out Slave In (MOSI): Signal line carrying the data from master to slave device. It is also known as Slave Input/Slave Data In (SI/SDI)
Master In Slave Out (MISO): Signal line carrying the data from slave to master device. It is also known as Slave Output (SO/SDO).

Serial Clock (SCLK): Signal line carrying the clock signals

Slave Select (SS): Signal line for slave device select. It is an active low signal.

- The master device is responsible for generating the clock signal.
- Master device selects the required slave device by asserting the corresponding slave devices slave select signal „LOW".
- The data out line (MISO) of all the slave devices when not selected floats at high impedance state
- The serial data transmission through SPI Bus is fully configurable.
- SPI devices contain certain set of registers for holding these configurations.
- The Serial Peripheral Control Register holds the various configuration parameters like master/slave selection for the device, baudrate selection for communication, clock signal control etc.

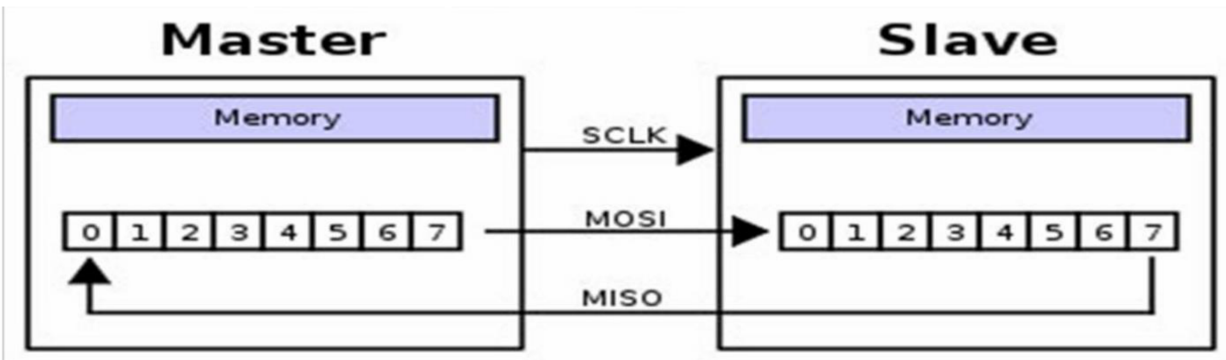
- The status register holds the status of various conditions for transmission and reception.SPI works on the principle of „Shift Register‟.
- The master and slave devices contain a special shift register for the data to transmit or receive.
- The size of the shift register is device dependent. Normally it is a multiple of 8.



Master/slave serial peripheral interface.

- During transmission from the master to slave, the data in the master‟s shift register is shifted out to the MOSI pin and it enters the shift register of the slave device through the MOSI pin of the slave device.

- At the same time the shifted out data bit from the slave device's shift register enters the shift register of the master device through MISO pin

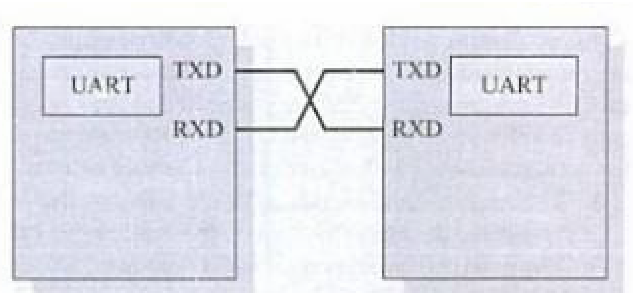


Master shifts out data to Slave, and shift in data from Slave

I2C	SPI
Speed limit varies from 100kbps, 400kbps, 1mbps, 3.4mbps depending on i2c version.	More than 1mbps, 10mbps till 100mbps can be achieved.
Half duplex synchronous protocol	Full Duplex synchronous protocol
Support Multi master configuration	Multi master configuration is not possible
Acknowledgement at each transfer	No Acknowledgement
Require Two Pins only SDA, SCL	Require separate MISO, MOSI, CLK & CS signal for each slave.
Addition of new device on the bus is easy	Addition of new device on the bus is not much easy a I2C
More Overhead (due to acknowledgement, start, stop)	Less Overhead
Noise sensitivity is high	Less noise sensitivity

Universal Asynchronous Receiver Transmitter(UART):

- Universal Asynchronous Receiver Transmitter(UART) based data transmission is an asynchronous form of serial transmission.UART based serial data transmission does not require a clock signal to synchronize the transmitting end and receiving end for transmission.Instead, it relies upon the pre-defined agreement between the transmitting device and receiving device.
- The serial communication settings(baud rate,number of bits per byte,parity, number of start bit and stop bit and flow control) for both the transmitter and receiver should be set to identical.The start and stop of communication is indicated through inserting special bits in the data stream. While sending a byte of data, a start bit is added first and a stop bit is added at the end of the bit stream.



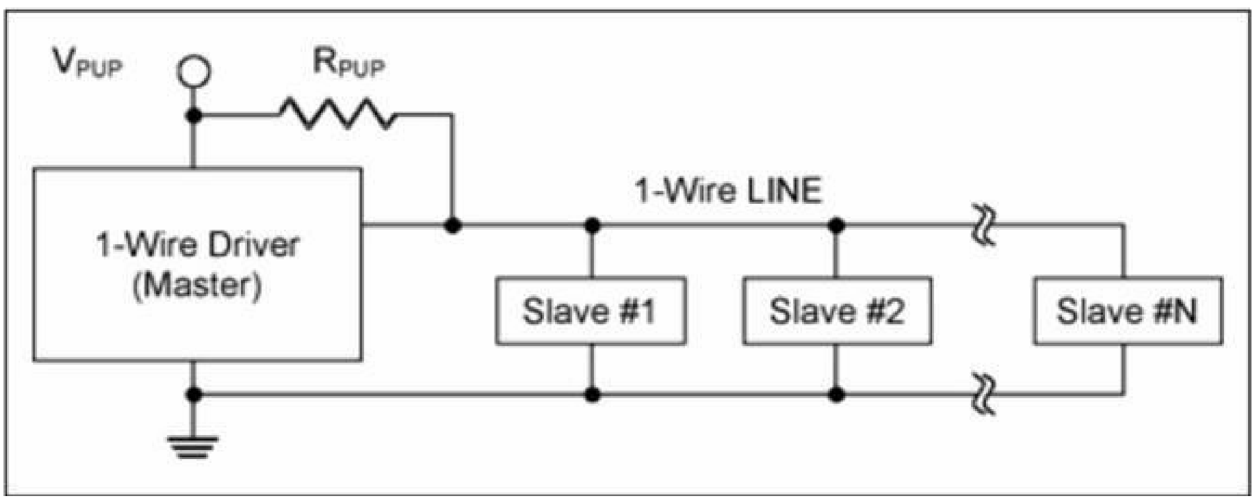
TXD: Transmitter line
RXD: Receiver line

For proper communication, the 'transmit line' of the sending device should be connected to the 'Receive line' of the receiving device.

In addition to the serial data transmission,UAT provides hardware signal support for controlling the serial data flow.

1-wire interface (protocol)

- Wire is a device communication bus system designed by Dallas Semiconductor Corp. That provides low-speed data, signaling, and power over a single conductor.
- 1-Wire is similar in concept to I²C, but with lower data rates and longer range. It is typically used to communicate with small, inexpensive devices such as digital thermometers and weather instruments.
- One distinctive feature of the bus is the possibility of using only two wires: data and ground. To accomplish this, 1-Wire devices include an 800 PF capacitor to store charge, and to power the device during periods when the data line is active
- There is always one master in overall charge, which may be a PC or a microcontroller. The master initiates activity on the bus, simplifying the avoidance of collisions on the bus. Protocols are built into the software to detect collisions. After a collision, the master retries the required communication.



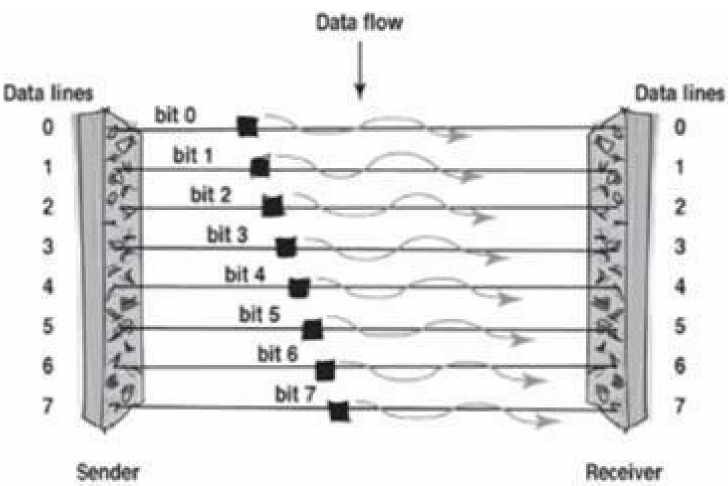
- Many devices can share the same bus. Each device on the bus has a unique 64-bit serial number. The least significant byte of the serial number is an 8-bit number that tells the type of the device. The most significant byte is a standard (for the 1-wire bus) 8-bit CRC.
- The master starts a transmission with a *reset* pulse, which pulls the wire to 0 volts for at least 480 µs. This resets every slave device on the bus. After that, any slave device, if present, shows that it exists with a "presence" pulse: it holds the bus low for at least 60 µs after the master releases the bus.

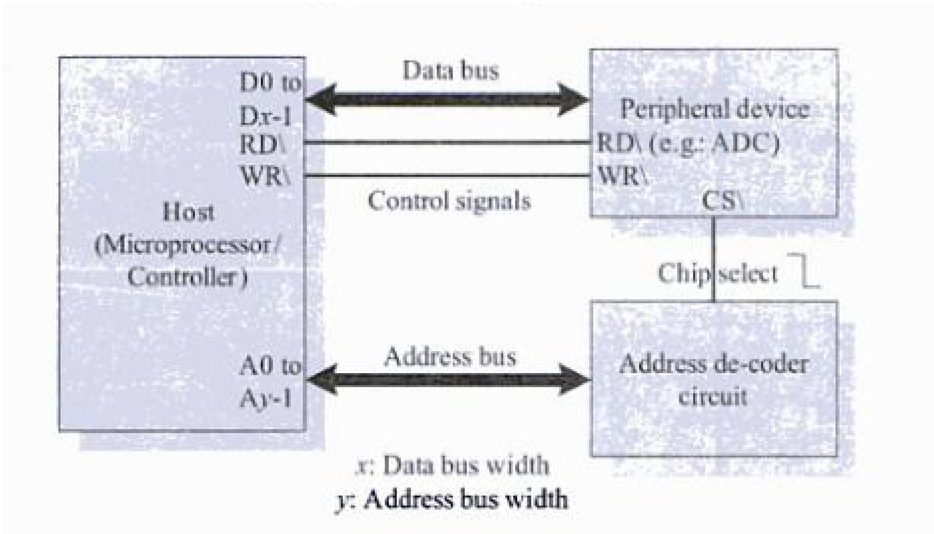
- To send a "1", the bus master sends a very brief (1– 15 µs) low pulse. To send a "0", the master sends a 60 µs low pulse.When receiving data, the master start sends a 1–15-µs 0-volt pulse to slave each bit. If the transmitting does unit wants to send a "1", it to the nothing, and the bus goes transmitting pulled-up voltage. If the "0", it pulls slave wants to send the data line to ground for 60 µs.

PARALLEL COMMUNICATION:

In data transmission, parallel communication is a method of conveying multiple binary digits (bits) simultaneously. It contrasts with communication. The communication channel is the number of electrical conductors used at the physical layer to convey bits.

Parallel communication implies more than one such conductor. For example, an 8-bit parallel channel will convey eight bits (or a byte) simultaneously, whereas a serial channel would convey those same bits sequentially, one at a time. Parallel communication is and always has been widely used within integrated circuits, in peripheral buses, and in memory devices such as RAM.





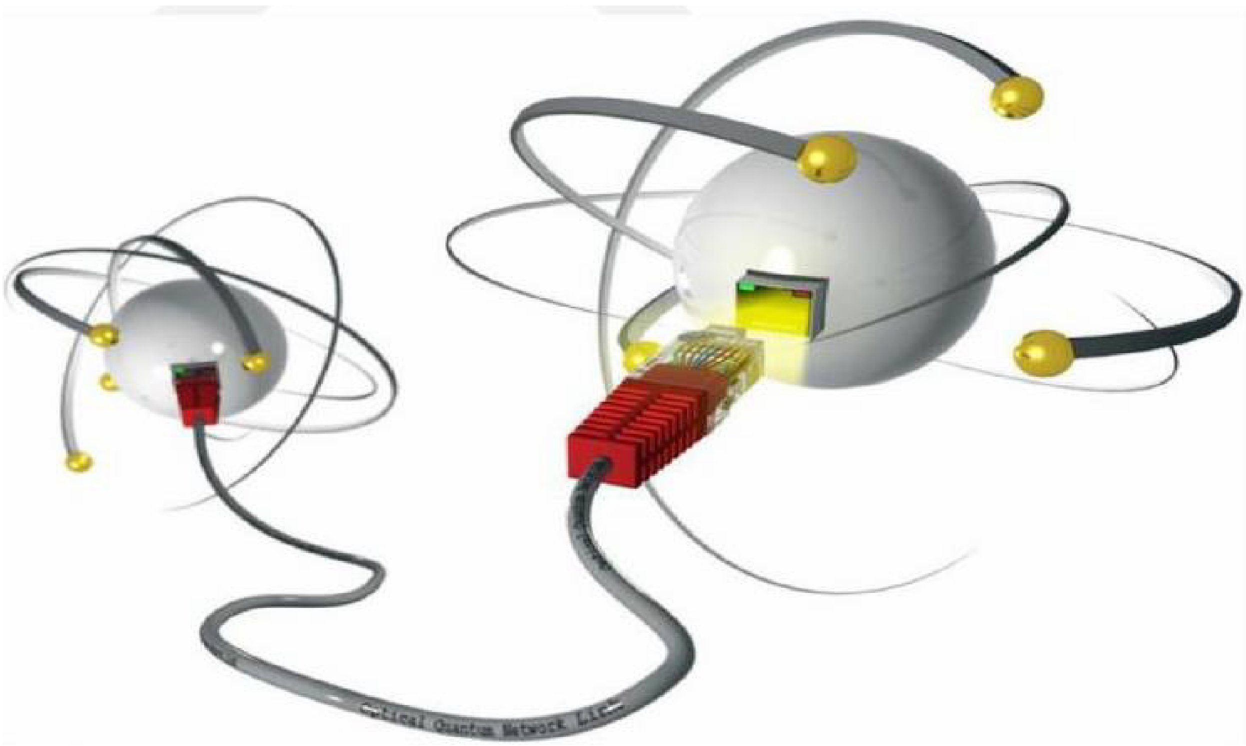
2. Product level communication interface (External Communication Interface):

The Product level communication interface" (External Communication Interface) is responsible for data transfer between the embedded system and other devices or modules

It is classified into two types
1. Wired communication interface
2. Wireless communication interface

1. Wired communication interface:

A wired communication interface is an interface used to transfer information over a wired network.
It is classified into the following types.
1. RS-232C/RS-422/RS 485
2. USB



RS-232C:

- RS-232 C (Recommended Standard number 232, revision C from the Electronic Industry Association) is a legacy, full duplex, wired, asynchronous serial communication interface
- RS-232 extends the UART communication signals for external data communication.
- UART uses the standard TTL/CMOS logic (Logic “High‟ corresponds to bit value 1 and Logic “LOW‟ corresponds to bit value 0) for bit transmission whereas RS232 use the EIA standard for bit transmission.
- As per EIA standard, a logic 0 is represented with voltage between +3 and +25V and a logic 1 is represented with voltage between -3 and -25V.
- In EIA standard, logic 0 is known as “Space‟ and logic 1 as ”Mark‟.

The RS232 interface define various handshaking and control signals for communication apart from the “Transmit‟ and “Receive‟ signal lines for data communication

RS-232 supports two different types of connectors, namely; DB-9: 9-Pin connector and DB-25: 25-Pin connector.

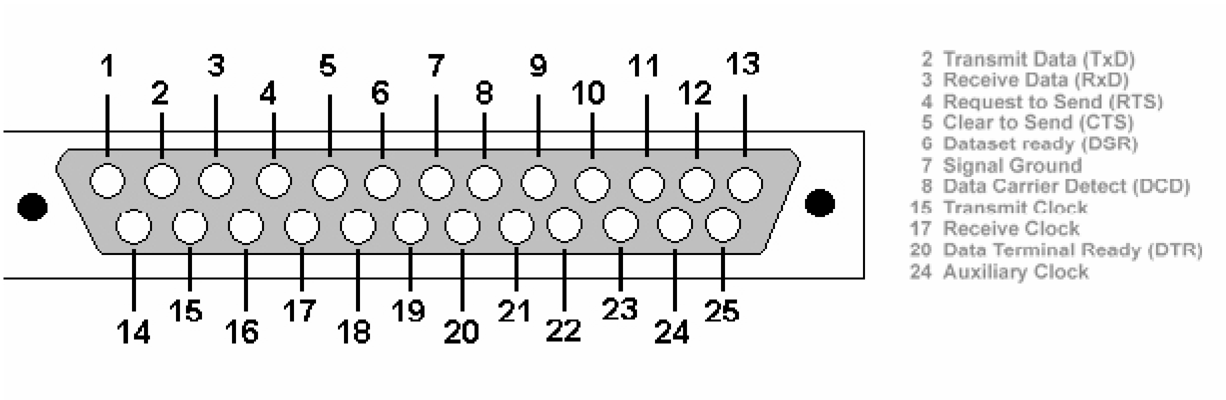
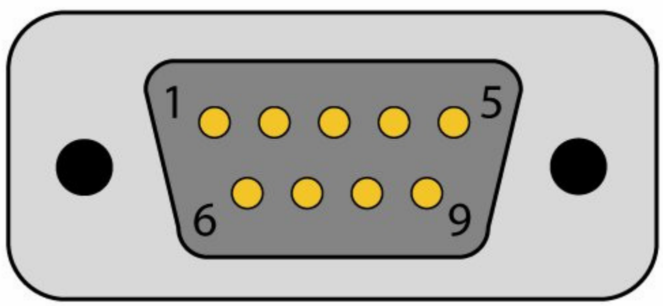


Fig: DB-25:25-Pin connector.

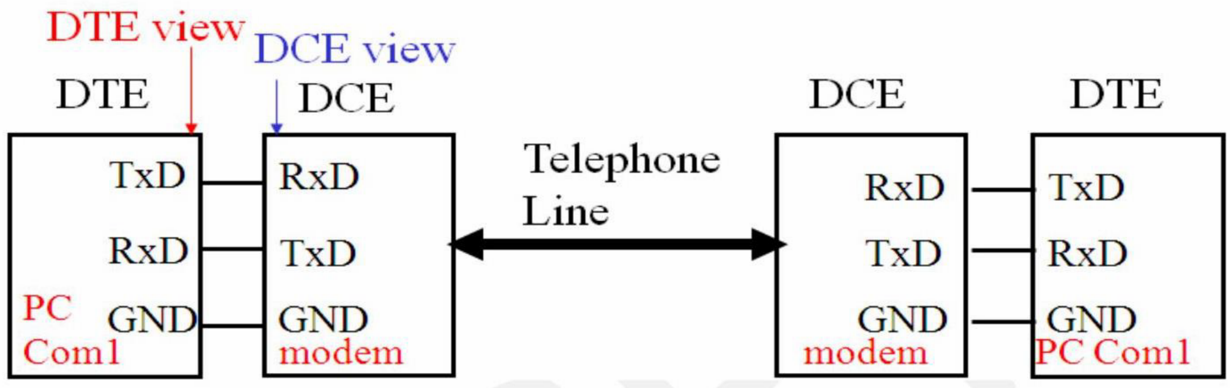
DB9M Connector



RS232 Pin Out

Pin #	Signal
1	DCD
2	RX
3	TX
4	DTR
5	GND
6	DSR
7	RTS
8	CTS
9	RI

Fig: DB-9:9-Pin connector.



- RS-232 is a point-to-point communication interface and the devices involved in RS-232 communication are called "Data Terminal Equipment (DTE)" and " Data Communication Equipment (DCE)".
- If no data flow control is required, only TXD and RXD signal lines and ground line (GND) are required for data transmission and reception.
- The RXD pin of DCE should be connected to the TXD pin of DTE and vice versa for proper data transmission.
- If hardware data flow control is required for serial transmission, various control signal lines of the RS-232 connection are used appropriately.
- The control signals are implemented mainly for modem communication and some of them may be irrelevant for other type of devices.
- The Request to Send (RTS) and Clear To Send (CTS) signals co-ordinate the communication between DTE and DCE.
- Whenever the DTE has a data to send, it activates the RTS line and if the DCE is ready to accept the data, it activates the CTS line.
- The Data Terminal Ready (DTR) signal is activated by DTE when it is ready to accept data.
- The Data Set Ready (DSR) is activated by DCE when it is ready for establishing a communication link.
- DTR should be in the activated state before the activation of DSR.
- The Data Carrier Detect (DCD) is used by the DCE to indicate the DTE that a good signal is being received.
- Ring Indicator (RI) is a modem specific signal line for indicating an incoming call on the telephone line.
- As per the EIA standard RS-232 C supports baudrates up to 20Kbps (Upper limit 19.2Kbps).
- **The commonly used baudrates by devices are 300bps, 1200bps, 2400bps, 9600bps, 11.52Kbps and 19.2Kbps.**

- **The maximum operating distance supported in RS-232 communication is 50 feet at the highest supported baudrate.**
- Embedded devices contain a UART for serial communication and they generate signal levels conforming to TTL/CMOS logic.
- A level translator IC like MAX 232 from Maxim Dallas semiconductor is used for converting the signal lines from the UART to RS-232 signal lines for communication.
- On the receiving side the received data is converted back to digital logic level by a converter IC.
- Converter chips contain converters for both transmitter and receiver.
- **RS-232 uses single ended data transfer and supports only point-to-point communication and not suitable for multi-drop communication.**

USB (UNIVERSAL SERIAL BUS):

- External Bus Standard.
- Allows connection of peripheral devices.
- Connects Devices such as keyboards, mice, scanners, printers, joysticks, audio devices, disks.
- Facilitates transfers of data at 480 (USB 2.0 only), 12 or 1.5 Mb/s (mega- bits/second).
- Developed by a Special Interest Group including Intel, Microsoft, Compact, DEC, IBM, Northern Telecom and NEC originally in 1994.
- Low-Speed: 10 – 100 kb/s
- 1.5 Mb/s signaling bit rate
- **Full-Speed: 500 kb/s – 10 Mb/s** 12 Mb/s signaling bit rate
- High-Speed: 400 Mb/s 480 Mb/s signaling bit rate
- NRZI with bit stuffing used
- SYNC field present for every packet
- There exist two pre-defined connectors in any USB system - Series “A” and Series “B” Connectors.
- Series “A” cable: Connects USB devices to a hub port.
- **Series “B” cable: Connects detachable devices (hot- swappable)**
- **Bus Topology:**

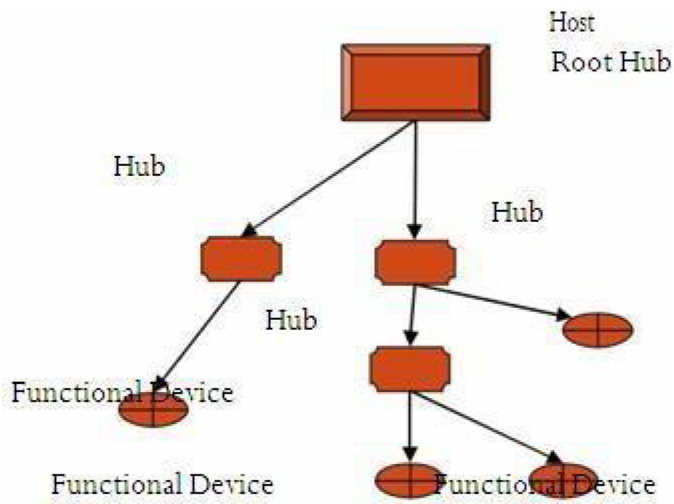
    Connects computer to peripheral devices.

    Ultimately intended to replace parallel and serial ports

    Tiered Star Topology

    All devices are linked to a common point referred to as the root hub.

    Specification allows for up to 127 (27 -1) different devices.



Four wire cable serves as interconnect of system - power, ground and two differential signaling lines.

- USB is a polled bus-all transactions are initiated by host.
  - **USB HOST**: Device that controls entire system usually a PC of some form. Processes data arriving to and from the USB port.
  - **USB HUB:** Tests for new devices and maintains status information of child devices.Serve as repeaters, boosting strength of up and downstream signals. Electrically isolates devices from one another - allowing an expanded number of devices.

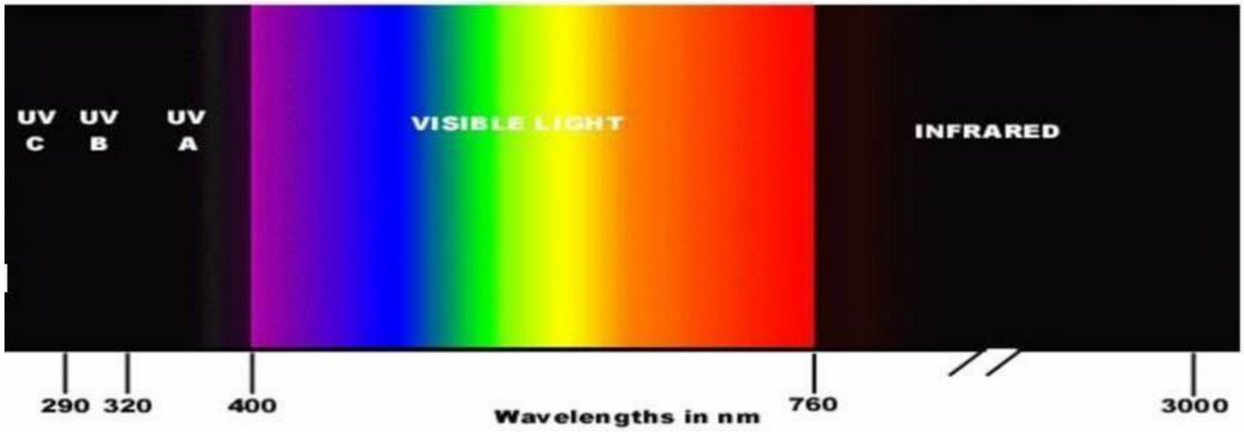
2.Wireless communication interface :

Wireless communication interface is an interface used to transmission of information over a distance without help of wires, cables or any other forms of electrical conductors.
They are basically classified into following types

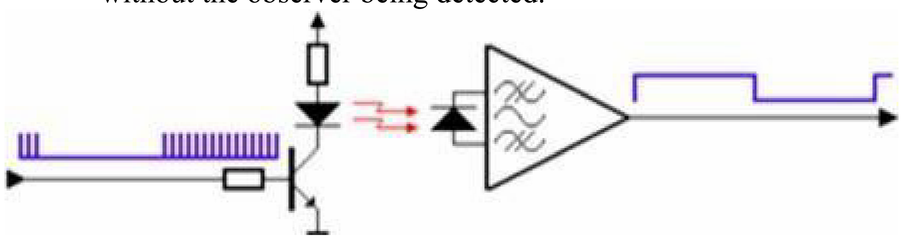
1. Infrared
2. Bluetooth
3. Wi-Fi
4. Zigbee
5. GPRS

INFRARED:

- Infrared is a certain region in the light spectrum
- Ranges from .7µ to 1000µ or .1mm
- Broken into near, mid, and far infrared
- One step up on the light spectrum from visible light
- Measure of heat



- Most of the thermal radiation emitted by objects near room temperature is infrared. Infrared radiation is used in industrial, scientific, and medical applications. Night-vision devices using active near-infrared illumination allow people or animals to be observed without the observer being detected.



IR transmission:

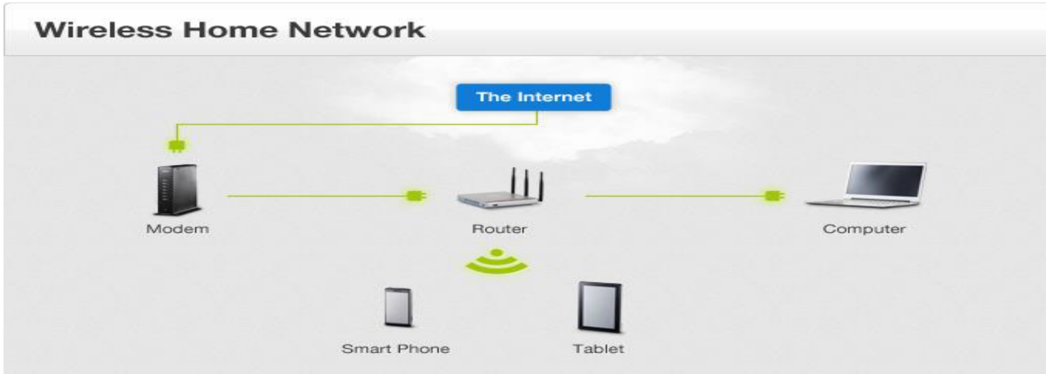
- The transmitter of an IR LED inside its circuit, which emits infrared light for every electric pulse given to it. This pulse is generated as a button on the remote is pressed, thus completing the circuit, providing bias to the LED.
- The LED on being biased emits light of the wavelength of 940nm as a series of pulses, corresponding to the button pressed. However,since along with the IR LED many other sources of infrared light such as us human beings, light bulbs, sun, etc, the transmitted information can be interfered. A solution to this problem is by modulation. The transmitted signal is modulated using a carrier frequency of 38 KHz (or any other frequency between 36 to 46 KHz). The IR LED is made to oscillate at this frequency for the time duration of the pulse. The information or the light signals are pulse width modulated and are contained in the 38 KHz frequency.
- IR supports data rates ranging from 9600bits/second to 16Mbps
- Serial infrared: 9600bps to 115.2 kbps
- Medium infrared: 0.576Mbps to 1.152 Mbps
- Fast infrared: 4Mbps

BLUETOOTH:

- **Bluetooth** is a wireless technology standard for short distances (using short-wavelength UHF band from 2.4 to 2.485 GHz)for exchanging data over radio waves in the ISM and mobile devices, and building personal area networks (PANs).Invented by telecom vendor Ericsson in 1994, it was originally conceived as a wireless alternative to RS- 232 data cables.
- Bluetooth uses a radio technology called frequency- hopping spread spectrum. Bluetooth divides transmitted data into packets, and transmits each packet on one of 79 designated Bluetooth channels. Each channel has a bandwidth of 1 MHz. It usually performs 800 hops per second, with Adaptive Frequency-Hopping (AFH) enabled
- Originally, Gaussian frequency-shift keying (GFSK) modulation was the only modulation scheme available. Since the introduction of Bluetooth 2.0+EDR, π/4-DQPSK (Differential Quadrature Phase Shift Keying) and 8DPSK modulation may also be used between compatible devices. Bluetooth is a packet-based protocol with a master- slave structure. One master may communicate with up to seven slaves in a piconet. All devices share the master's clock. Packet exchange is based on the basic clock, defined by the master, which ticks at312.5 µs intervals.
- A master BR/EDR Bluetooth device can communicate with a maximum of seven devices in a piconet (an ad-hoc computer network using Bluetooth technology), though not all devices reach this maximum. The devices can switch roles, by agreement, and the slave can become the master (for example, a headset initiating a connection to a phone necessarily begins as master—as initiator of the connection—but may subsequently operate as slave).

Wi-Fi: (Wireless Fidility)

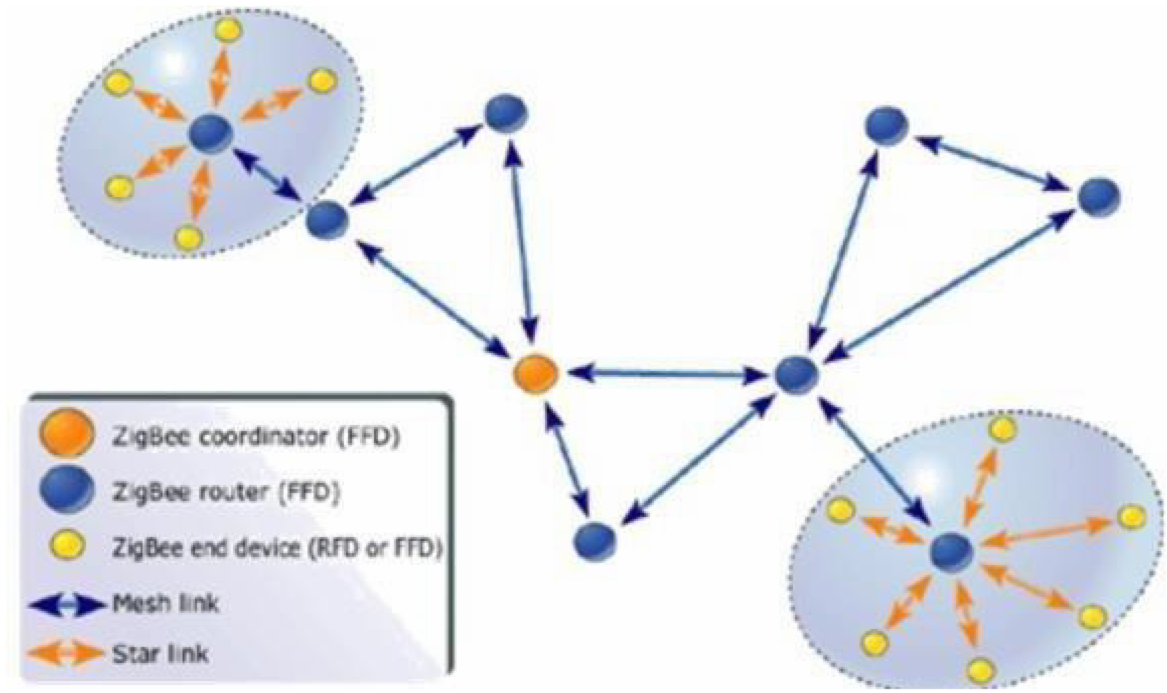
- Wi-Fi is the name of a popular wireless networking technology that uses radio waves to provide wireless high-speed Internet and network connections
- Wi-Fi follows the IEEE 802.11 standard
- Wi-Fi is intended for network communication and it supports Internet Protocol (IP) based communication
- Wi-Fi based communications require an intermediate agent called Wi-Fi router/Wireless Access point to manage the communications.
- The Wi-Fi router is responsible for restricting the access to a network, assigning IP address to devices on the network, routing data packets to the intended devices on the network.



- Wi-Fi enabled devices contain a wireless adaptor for transmitting and receiving data in the form of radio signals through an antenna.
- Wi-Fi operates at 2.4GHZ or 5GHZ of radio spectrum and they co-exist with other ISM band devices like Bluetooth.
- A Wi-Fi network is identified with a Service Set Identifier (SSID). A Wi-Fi device can connect to a network by selecting the SSID of the network and by providing the credentials if the network is security enabled
- Wi-Fi networks implements different security mechanisms for authentication and data transfer.
- Wireless Equivalency Protocol (WEP), Wireless Protected Access (WPA) etc are some of the security mechanisms supported by Wi-Fi networks in data communication.

ZIGBEE:

- **Zigbee** is an IEEE 802.15.4-based specification for a suite of high- level communication protocols used to create personal area networks with small, low-power digital radios, such as for home automation, medical device data collection, and other low-power low-bandwidth needs, designed for small scale projects which need wireless connection.Hence, zigbee is a low-power, low data rate, and close proximity (i.e., personal area) wireless ad hoc network.
- The technology defined by the zigbee specification is intended to be simpler and less expensive than other wireless personal area networks (WPANs), such as Bluetooth or Wi-Fi . Applications include wireless light switches, electrical meters with in-home-displays, traffic management systems, and other consumer and industrial equipment that require short-range low- rate wireless data transfer.
- Its low power consumption limits transmission distances to 10– 100 meters line-of-sight, depending on power output and environmental characteristics. Zigbee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones.



Zigbee Coordinator: The zigbee coordinator acts as the root of the zigbee network. The ZC is responsible for initiating the Zigbee network and it has the capability to store information about the network.

Zigbee Router: Responsible for passing information from device to another device or to another ZR.

Zigbee end device:End device containing zigbee functionality for data communication. It can talk only with a ZR or ZC and doesn't have the capability to act as a mediator for transferring data from one device to another.

Zigbee supports an operating distance of up to 100 metres at a data rate of 20 to 250 Kbps.

General Packet Radio Service(GPRS):

General Packet Radio Service (**GPRS**) is a packet oriented mobile data service on the 2G and 3G cellular communication system's global system for mobile communications (GSM).GPRS was originally standardized by the European Telecommunications Standards Institute (ETSI) GPRS usage is typically charged based on volume of data transferred, contrasting with circuit switched data, which is usually billed per minute of connection time. Sometimes billing time is broken down to every third of a minute. Usage above the bundle cap is charged per megabyte, speed limited, or disallowed.

Services offered:

- GPRS extends the GSM Packet circuit switched data capabilities and makes the following services possible:
- SMS messaging and broadcasting
- "Always on" internet access
- Multimedia messaging service (MMS)
- Push-to-talk over cellular (PoC)
- Instant messaging and presence-wireless village Internet applications for smart devices through wireless application protocol (WAP).
- Point-to-point (P2P) service: inter-networking with the Internet (IP).
- Point-to-multipoint (P2M) service]: point-to- multipoint multicast and point-to-multipoint group calls.