Chapter – 5
Data Acquisition and Transmission

5.1 Analog and Digital Transmission

Analog Transmission
- Analog signal transmitted without regard to content
- May be analog or digital data
- Attenuated over distance
- Use amplifiers to boost signal
- Also amplifies noise

Digital Transmission
- Concerned with content
- Integrity endangered by noise, attenuation etc.
- Repeaters used
- Repeater receives signal
- Extracts bit pattern
- Retransmits
- Attenuation is overcome
- Noise is not amplified

Advantages of Digital Transmission
- Increased immunity to channel noise and external interference
- Flexible operation
- Low cost LSI/VLSI technology
- Easy to use
- Common Format
    - Data, audio, video can be transmitted through same channel
- Security & Privacy
    - Encryption and coding
- Integration
    - Can treat analog and digital data similarly

Disadvantages of Digital Transmission
- High bandwidth requires
- Complex circuitry than analog

Analog Communication System
In case of analog communication, the message signal to be transmitted is analog. This analog message can be obtained from sources such as speech, video shooting etc. The analog signal varies smoothly and continuously with time. The message signal is then modulated on some carrier frequency by the modulator. The amplifier then gives this signal to the transmitting antenna. Figure below shows the basic, block diagram of analog communication system.

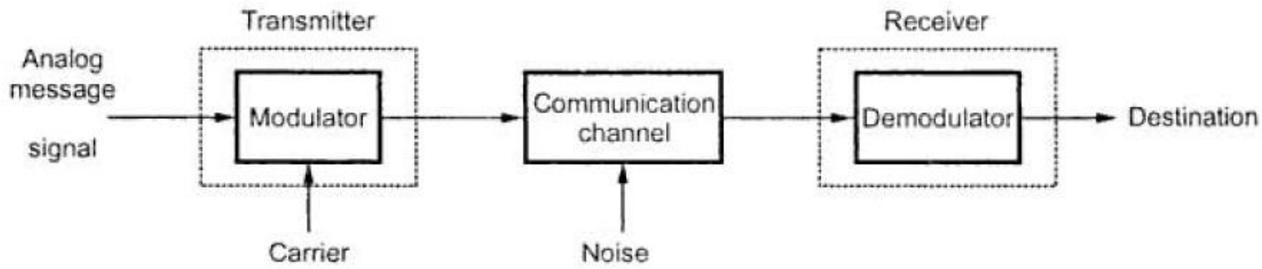


Fig: Analog communication system

Presently, all the AM, FM radio transmission and TV transmission is analog communication. The analog communication needs lower bandwidth compared to digital communication. But the effect of noise interference is more in case of analog communication.

Digital Communication System

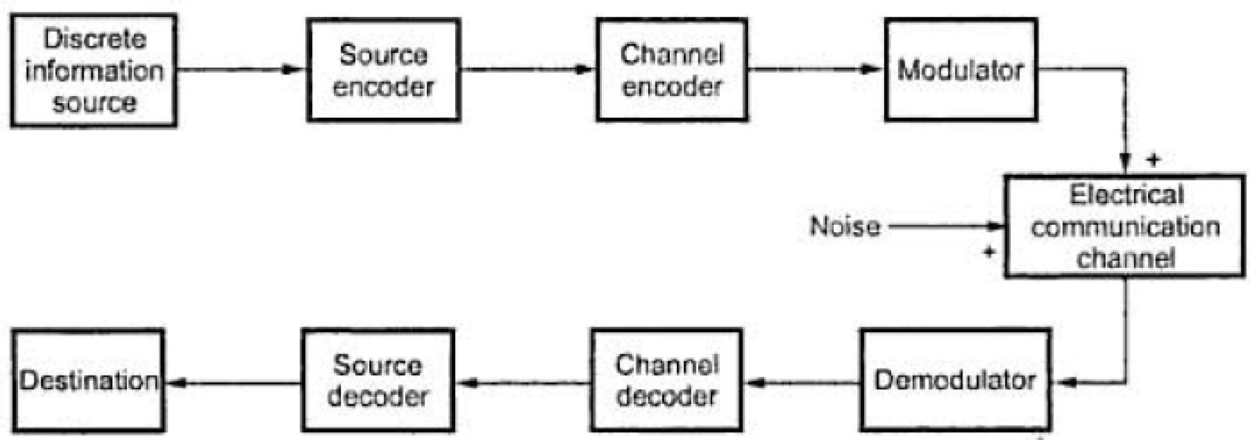


Fig: Digital communication system

- Source are converted into a sequence of binary digits which is called information sequence Represent the source by an efficient number of binary digits
- Efficiently converting the source into a sequence of binary digits is a process, which is called source encoding of data compression
- Channel encoder adds some redundancy into binary information sequence that can be used for handle noise and interference effects at the receiver.
- Digital modulator maps the binary information sequence into signal waveforms.
- Communication channel is used to send the signal from the transmitter to the receiver. Physical channels: the atmosphere, wireless, optical, compact disk,….
- Digital demodulator receives transmitted signal contains the information which is corrupted by noise
- Cannel decoder attempts the reconstruct the original information sequence from knowledge of the code used by channel encoder.
- Source decoder attempts the reconstruct the original signal from the binary information sequence using the knowledge of the source encoding methods.
- The difference between the original signal and the reconstructed signal is measured of the distortion introduced by the digital communication system

- Estimate what was send, aiming at the minimum possible probability of making mistakes

5.2 Transmission Schemes

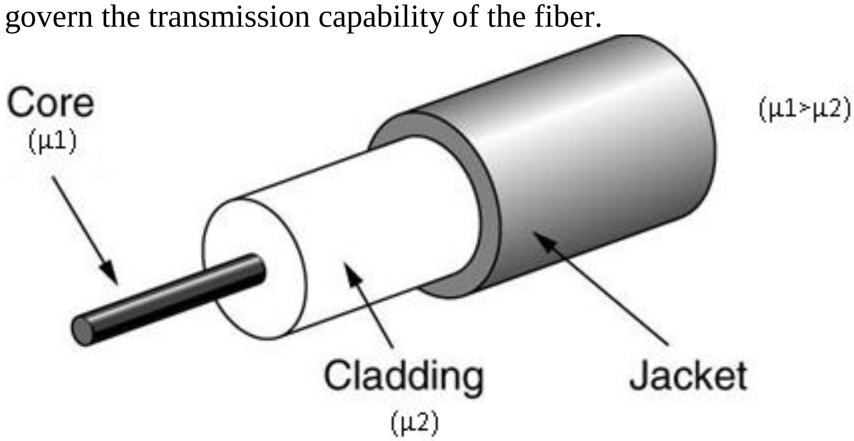
- Guided transmission media – wire (twisted pair, cable, fibre)
- Unguided – wireless (radio wave, microwave, satellite, Bluetooth)
- Characteristics and quality determined by medium and signal
- For guided, the medium is more important
- For unguided, the bandwidth produced by the antenna is more important
- Key concerns are data rate and distance

Design Factors

- Bandwidth
  - Higher bandwidth gives higher data rate
- Transmission impairments
  - Attenuation
- Interference
- Number of receivers
  - In guided media
  - More receivers (multi-point) introduce more attenuation (need more amplifies or repeaters)

5.2.1 Fiber Optics

- Optical Fiber is a cylindrical waveguide system through which the optical wave can propagate.
- An Optical Fiber consists of three main parts: Core, Cladding and Jacket (See Figure)
- An optical fiber is a dielectric (nonconductor of electricity) waveguide made of glass or plastic. As shown in Figure below, it consists of three distinct regions: a core, the cladding, and a sheath or jacket. The sheath or jacket protects the fiber but does not govern the transmission capability of the fiber.



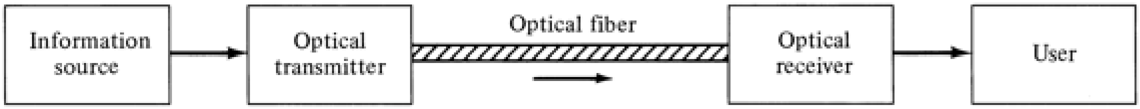


Fig: Optical Fiber transmission block diagram

Optical fibers come in two types:

1. **Single-mode fibers:**

   It is used to transmit one signal per fiber (used in telephone and cable TV). They have small cores (9 microns in diameter) and transmit infra-red light from laser.

   A Fiber having very narrow core (core diameter of the order of wavelength of light injected) is called Single mode fiber. The light travels only along the cores without reflection and with no model dispersion.

   Because of it high performance it is used for long distance, very high speed, large bandwidth applications.

2. **Multi-mode fibers:**

   It is used to transmit many signals per fiber (used in computer networks). They have larger cores (62.5 microns in diameter) and transmit infra-red light from LED.

   The multimode fiber has larger core diameter than single mode fiber. The core diameter is about 40 um and that of cladding is 70 um. The relative refractive difference is also larger than single mode fiber. They are not suitable for long distance communication due to large dispersion and attenuation of the signal. The fabrication of multi fiber is less difficult and so the fiber is not costly.

There are two types of optical fibers based on refractive index

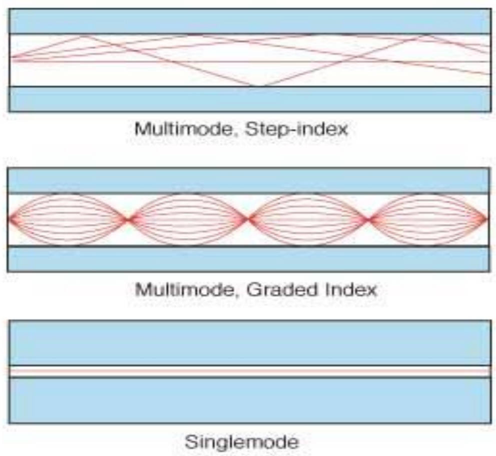
1. **Step-index Optical Fiber**

- In step index optical fiber, the core and cladding has their uniform refractive index, say $\mu 1$ and $\mu 2$ respectively.
- These fibers have greatest range of core sizes (50-200 um).
- The light rays propagate through it are in the form of meridional rays which cross the fiber axis during every reflection at the core-cladding boundary.
- **Advantages -** relatively easy to manufacture, cheaper than other types, larger layer NA, they have longer life times than laser diodes
- **Disadvantages –** lower bandwidth, high dispersion and smearing of signal pulse.

2. **Graded-index optical fiber**

- In Graded-index Optical Fibers the refractive index of core gradually decreases from the centre towards the core-cladding interface. The cladding has a uniform refractive index profile.
- The light lays propagate through it in the form of skew rays or helical rays. They do not cross the fiber axis at any time and are propagating around the fiber axis in helical or spiral manner.
- There is a periodic self focusing of the rays. Due to this self focusing the signal distortion is very low.

- ***Advantages*** – Dispersion is low, bandwidth is greater than step-index multimode fiber and easy to couple with optical source.
- ***Disadvantages*** – Expansive and very difficult to manufacture.



Advantages of Optical Fiber

- Thinner
- Less Expensive
- Higher Carrying Capacity
- Less Signal Degradation& Digital Signals
- Light Signals
- Non-Flammable
- Light Weight
- Enormous capacity
- Low transmission loss
- Cables and equipment have small size and weight
- Immunity to interference
- Electrical isolation
- Signal security
- Silica fibers have abundant raw material

Disadvantages of Optical Fiber

- Requires skilled manpower for installation
- Difficult to repair and maintenance
- High equipment and manufacturing cost
- Splicing (joining two optical fibers) is difficult

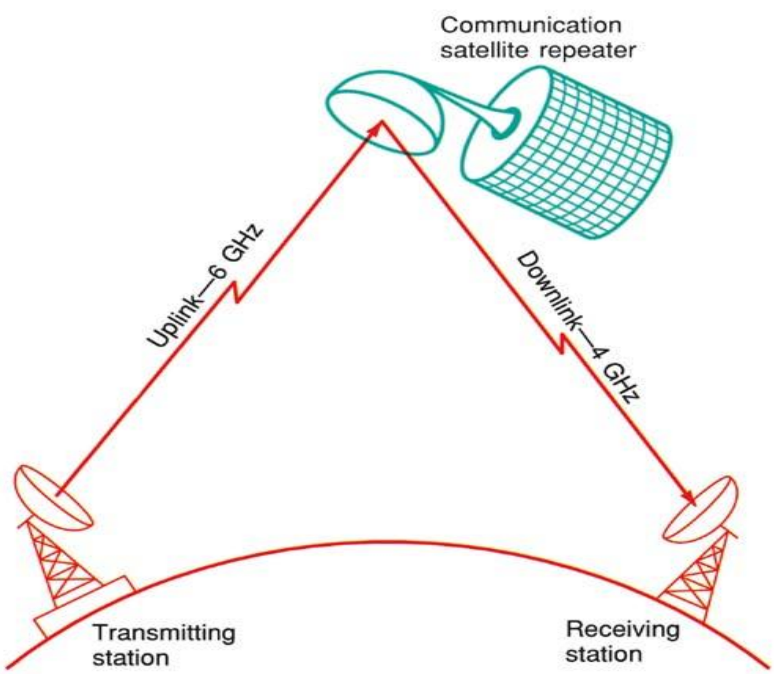
Applications of Optical Fiber

- In communication – Compared to a conventional system they offer better reliability, large information transmission capacity, cost effective etc.
- Fiber Optic Sensors – They are used to convert various input variable into light signals
- In Medical Science – With the advent of fiber optics the otherwise inaccessible parts of the body are now visible to the surgeon without actually cutting through the body. Ex. Endoscopy.

- Military Applications – Optical Fiber are lighter in transportation and more reliable in terms of secrecy as compared to conventional systems.
- Entertainment – A coherent Optical Fiber bundle offers better enlargement of the image displayed on a TV or screen.

5.2.2 Satellite

- A Satellite communication system consists of ground stations for transmitting and receiving signals and a communication satellite in the space.
- A satellite is simply a repeater
- It consists of several transponders each of which listens to some portion of the spectrum, amplifies the incoming signal and then rebroadcasts it at another frequency to avoid interference with the incoming signal.
- The range of frequencies used for transmission of signals from ground station to the satellite is ***uplink*** frequency and those used for transmission of signals from satellites to ground station is ***downlink*** frequency. Uplink and downlink frequencies are different to avoid interference.
- The downlink beam can be broad, covering a substantial fraction of the earth's surface (used in broadcasting) or narrow beam covering only a hundreds of km in diameter.



Two major elements of Satellite Communications Systems are

1. Space Segment
2. Ground Segment

The Space Segment includes

- Satellite
- Means for launching satellite
- Satellite control centre for station keeping of the satellite

The ground segment of satellite communications system establishes the communications links with the satellite and the user. The functions of the ground segment are to transmit the signal to the satellite and receive the signal from the satellite.
The ground segment consists:

- Earth Stations: It consists of transmitting equipment, receiving equipments and antenna system.
- Rear Ward Communication links
- User terminal and interface network

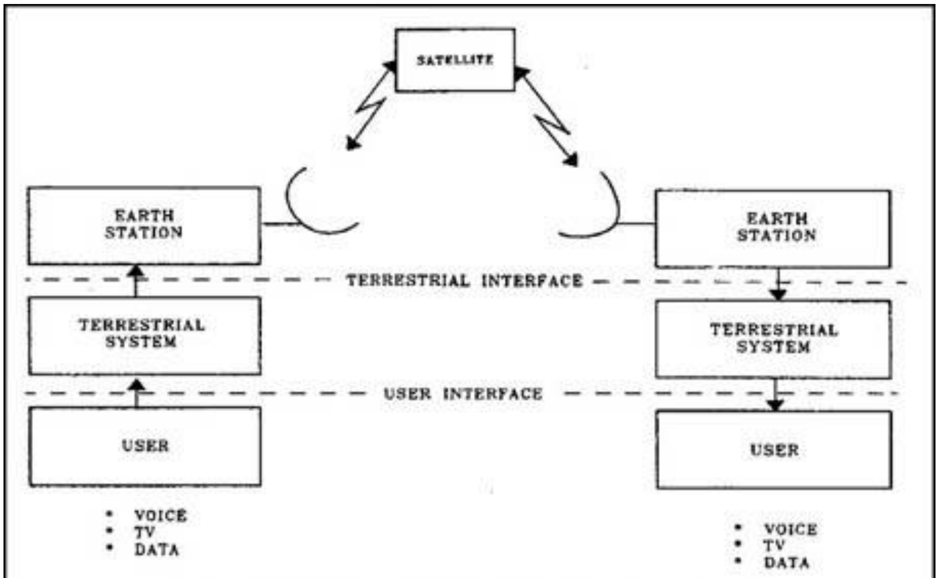


FIG. 2. ELEMENTS OF A SATELLITE COMMUNICATION SYSTEM

Types of Satellite

1. Low Earth Orbit (LEO)

- LEO satellites are much closer to the earth than GEO satellites, ranging from 500 to 1,500 km above the surface.
- LEO satellites don't stay in fixed position relative to the surface, and are only visible for 15 to 20 minutes each pass.
- A network of LEO satellites is necessary for LEO satellites to be useful.

Advantages

- A LEO satellite's proximity to earth compared to a GEO satellite gives it a better signal strength and less of a time delay, which makes it better for point to point communication.
- A LEO satellite's smaller area of coverage is less of a waste of bandwidth.

Disadvantages

- A network of LEO satellites is needed, which can be costly
- LEO satellites have to compensate for Doppler shifts cause by their relative movement.
- Atmospheric drag affects LEO satellites, causing gradual orbital deterioration.

2. Medium Earth Orbit (MEO)

- A MEO satellite is in orbit somewhere between 8,000 km and 18,000 km above the earth's surface.
- MEO satellites are similar to LEO satellites in functionality.
- MEO satellites are visible for much longer periods of time than LEO satellites, usually between 2 to 8 hours.
- MEO satellites have a larger coverage area than LEO satellites.

  Advantage
  - A MEO satellite's longer duration of visibility and wider footprint means fewer satellites are needed in a MEO network than a LEO network.

  Disadvantage
  - A MEO satellite's distance gives it a longer time delay and weaker signal than a LEO satellite, though not as bad as a GEO satellite.

3. Geostationary Earth Orbit (GEO)

- These satellites are in orbit 35,863 km above the earth's surface along the equator.
- Objects in Geostationary orbit revolve around the earth at the same speed as the earth rotates. This means GEO satellites remain in the same position relative to the surface of earth.

  Advantages
  - A GEO satellite's distance from earth gives it a large coverage area, almost a fourth of the earth's surface.
  - GEO satellites have a 24 hour view of a particular area.
  - These factors make it ideal for satellite broadcast and other multipoint applications.

  Disadvantages
  - A GEO satellite's distance also cause it to have both a comparatively weak signal and a time delay in the signal, which is bad for point to point communication.
  - GEO satellites, centered above the equator, have difficulty broadcasting signals to near Polar Regions.

Advantages of Satellites

- The coverage area of a satellite greatly exceeds that of a terrestrial system.
- Multiple signals can be superimposed at a time so capacity increased
- Transmission cost of a satellite is independent of the distance from the center of the coverage area.
- Satellite to Satellite communication is very precise.
- Higher Bandwidths are available for use.

Disadvantages of satellite

- Bandwidth is decreased due to gradually becoming used up
- Launching satellites into orbit is costly.
- There is a larger propagation delay in satellite communication than in terrestrial communication.

Service Types (Application Area) of Satellite

- Fixed Service Satellites (FSS)
  - Example: Point to Point Communication
- Broadcast Service Satellites (BSS)
  - Example: Satellite Television/Radio
  - Also called Direct Broadcast Service (DBS).
- Mobile Service Satellites (MSS)
  - Example: Satellite Phones

Different kinds of satellites use different frequency bands.

- **L**–Band: 1 to 2 GHz, used by MSS
- **S**-Band: 2 to 4 GHz, used by MSS, NASA, deep space research
- **C**-Band: 4 to 8 GHz, used by FSS
- **X**-Band: 8 to 12.5 GHz, used by FSS and in terrestrial imaging
- **Ku**-Band: 12.5 to 18 GHz: used by FSS and BSS (DBS)
- **K**-Band: 18 to 26.5 GHz: used by FSS and BSS
- **Ka**-Band: 26.5 to 40 GHz: used by FSS

5.2.3 Bluetooth Devices

Bluetooth

- Bluetooth is a global standard Radio Frequency (RF) specification for short-range, point-to-multipoint voice and data transfer. Bluetooth can transmit through solid, non-metal objects. Its nominal link range is from 10 cm to 10 m, but can be extended to 100 m by increasing the transmit power. It is based on a low-cost, short-range radio link, and facilitates ad hoc connections for stationary and mobile communication environments.
- A standard for wireless electronics communication “Open Wireless”.
- It provides agreement at the physical level -- Bluetooth is a radio-frequency standard.
- It also provides agreement at the next level up, where products have to agree on when bits are sent, how many will be sent at a time and how the parties in a conversation can be sure that the message received is the same as the message sent.
- Bluetooth communicates on a frequency of 2.45 gigahertz, which has been set aside by international agreement for the use of industrial, scientific and medical devices (ISM).
- Bluetooth devices avoid interfering with other systems:
- Very weak signals of 1 mill watt. (Average cell phones can transmit a signal of 3 watts.)
- Range of a Bluetooth device to about **10 meters**.
- Bluetooth uses a technique called **spread-spectrum frequency hopping**.
- In this technique, a device will use 79 individual, randomly chosen frequencies within a designated range, changing from one to another on a regular basis. In the case of Bluetooth, the transmitters change frequencies 1,600 times every second
- Bluetooth systems create a personal-area network (PAN), or **piconet**,
- There is frequency hopping with once the piconet is established.
- Many piconets are possible in the same room.
- Half-duplex communication or full-duplex communication.
- Bluetooth can send data at more than 64 kilobits per second (Kbps) in a full-duplex link -- a rate high enough to support several human voice conversations.

- Half-duplex link -- connecting to a computer printer, for example -- Bluetooth can transmit up to 721 kilobits per second (Kbps) in one direction, with 57.6 Kbps in the other. If the use calls for the same speed in both directions, a link with 432.6-Kbps capacity in each direction can be made.

Bluetooth Connection

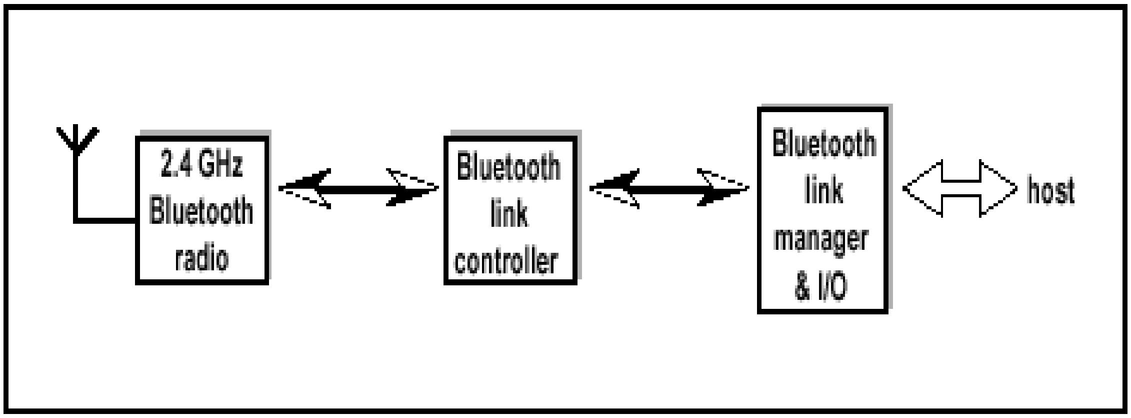


Figure 1.1: Different functional blocks in the Bluetooth system

Bluetooth uses the concept of Master/Slave mode of data communication which is packet based.

1. Passive State
2. Inquiry; Search of devices
3. Paging; Synchronization
4. Access Point Service Discovery; Wireless link
5. Channel Creation
6. Pairing; Optional (require pin code)

Class	Maximum Permitted Power (mW)	Maximum Permitted Power (dBm)	Range (approximate)
Class 1	100 mW	20 dBm	~100 meters
Class 2	2.5 mW	4 dBm	~10 meters
Class 3	1 mW	0 dBm	~1 meter

Bluetooth Characteristics

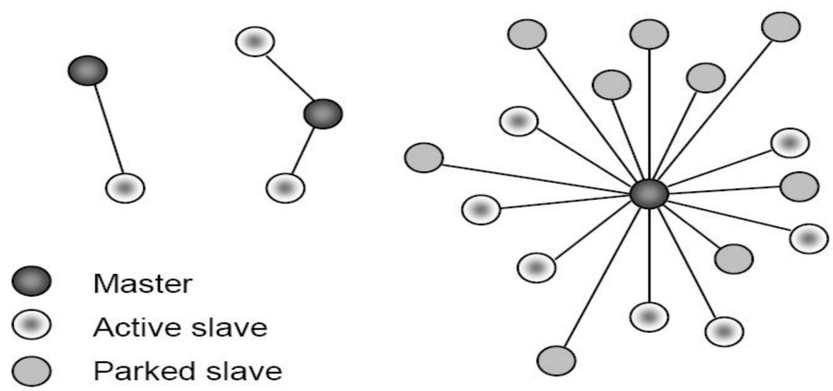
Bluetooth characteristics:

- Operates in the 2.4 GHz Industrial-Scientific-Medical (ISM) band.
- Uses Frequency Hop (FH) spread spectrum, which divides the frequency band into a number of hop channels. During a connection, radio transceivers hop from one channel to another in a pseudo-random fashion.
- Supports up to 8 devices in a piconet (two or more Bluetooth units sharing a channel).
- Built-in security.
- Non line-of-sight transmission through walls and briefcases.
- Omni-directional.
- Supports both isochronous and asynchronous services; easy integration of TCP/IP for networking.

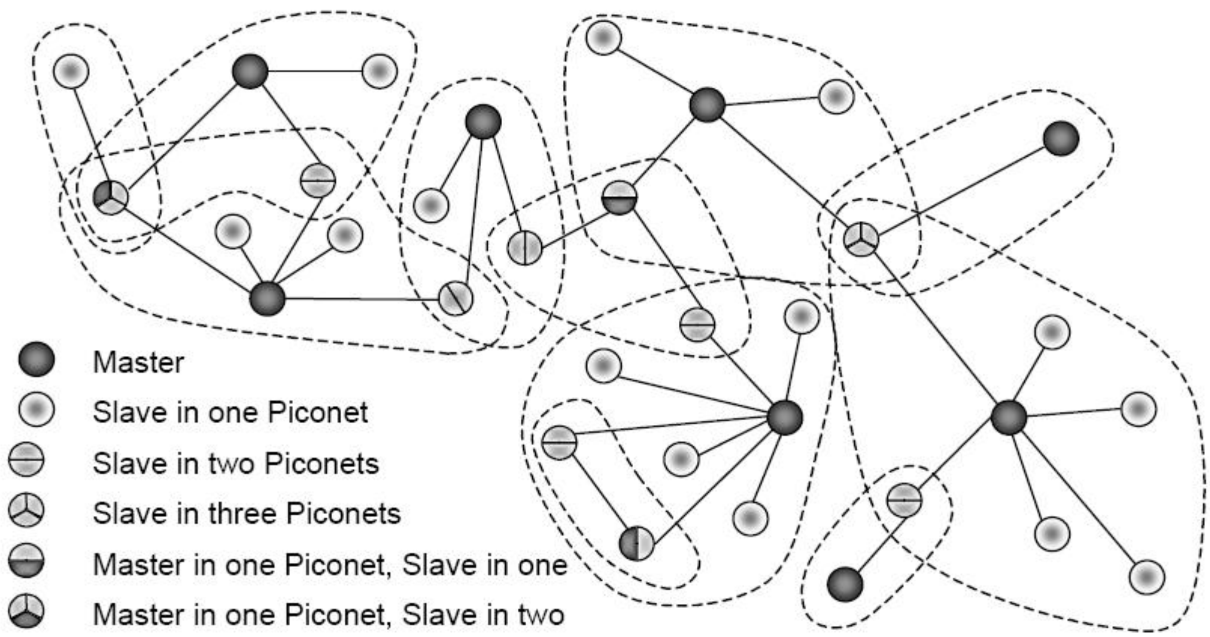
- Regulated by governments worldwide.

Bluetooth Network Topology

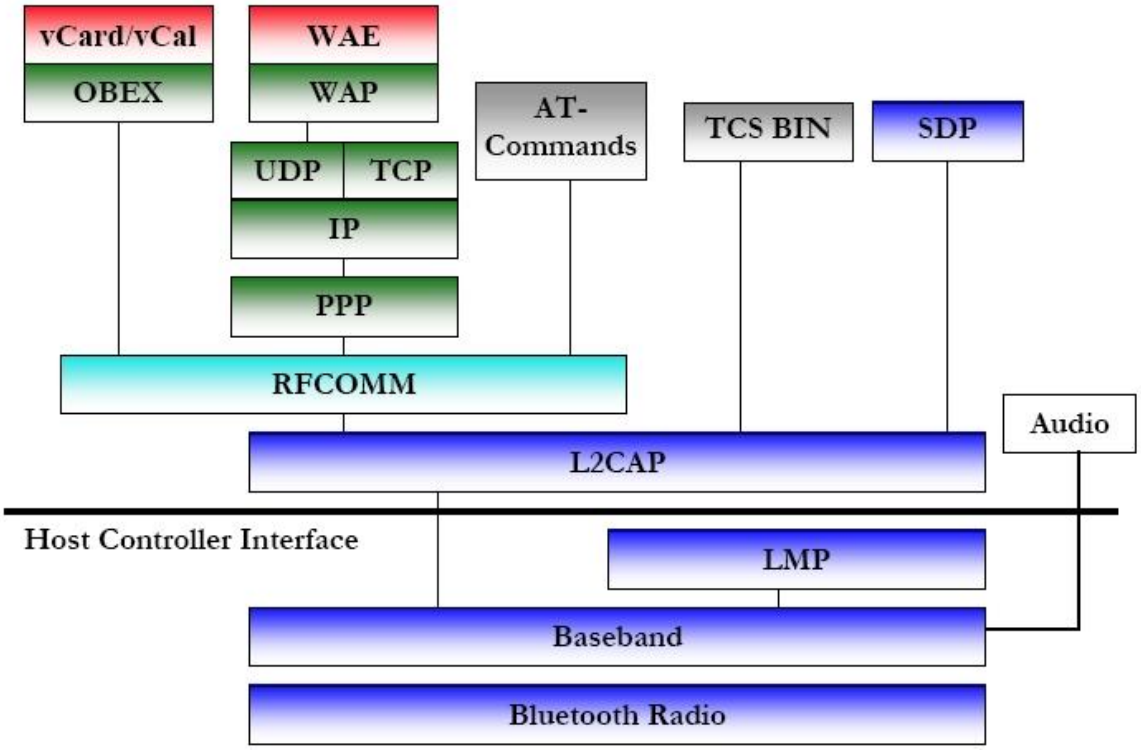
1. **Piconet**
   - A maximum of 8 devices (7 active slaves plus 1 master) form a Piconet
   - A piconet is characterized by the master: frequency hopping scheme, access code, timing synchronization, bit rate allocated to each slave
   - Only one master: dynamically selected, roles can be switched
   - Up to 7 active slaves; up to 255 parked slaves
   - No central network structure: "Ad-hoc" network



2. **Scatternet**
   - Interconnected piconets, one master per piconet
   - A few devices shared between piconets
   - No central network structure: "Ad-hoc" network



Bluetooth Protocol Stack



- Radio layer: defines the requirements for a Bluetooth transceiver operating in the 2.4 GHz ISM band
- Baseband layer: describes the specification of the Bluetooth Link Controller (LC) which carries out the baseband protocols and other low-level link routines
- Link Manager Protocol (LMP): is used by the Link Managers (on either side) for link set-up and control
- Host Controller Interface (HCI): provides a command interface to the Baseband Link Controller and Link Manager, and access to hardware status and control registers
- Logical Link Control and Adaptation Protocol (L2CAP): supports higher level protocol multiplexing, packet segmentation and reassembly, and the conveying of quality of service information
- RFCOMM protocol: provides emulation of serial ports over the L2CAP protocol. The protocol is based on the ETSI standard TS 07.10
- Service Discovery Protocol (SDP): provides a means for applications to discover which services are provided or available.

How will Bluetooth communicate with other hardware?

- USB
    - USB 2.0 compliant. The module is a USB full-speed class device (12 Mbps) and has the full functionality of a USB slave.
- UART

  - Signals supported are Rx, Tx, RTS and CTS. The module is DCE, Data Circuit-terminal Equipment. The maximum UART speed is 460.8 kbps
- PCM
  - The PCM data can be: Linear PCM 13-16 bit, μ-law 8 bit, A-law 8 bit. The PCM sync is 8 kHz and the PCM clock 200 kHz – 2 MHz.

What could be done with Bluetooth?

- Wireless package handling
- Secure and instant credit transactions
- Phones headsets computers networks
- Security-selective access
- Anywhere a wire is currently run

Bluetooth Applications

- Bluetooth profiles were written to make sure that the application level works the same way across different manufacturers' products
- Bluetooth applications:
  - Wireless control of and communication between a cell phone and a hands free headset or car kit.
  - Wireless networking between PCs in a confined space and where little bandwidth is required
  - Wireless communications with PC input devices such as mice and keyboards
  - Wireless communications to PC output devices such as printers
  - Built-in in modern laptops or dongles
  - Wireless communications with PC input devices such as mice and keyboards
  - Wireless communications to PC output devices such as printers
  - Transfer of files between devices via OBEX
  - Replacement of traditional wired serial communications in test equipment, GPS receivers and medical equipment
  - Thus often a serial interface is emulated over the BT link as shown on the following slides ...
  - Remote controls where infrared was traditionally used

Advantages

  - Uses low power
  - Can connect various type of devices
  - Free of cost
  - Ad Hoc hardware can be established by Bluetooth connection
  - Simple, Secure and Global data transfer
  - Less time consumption

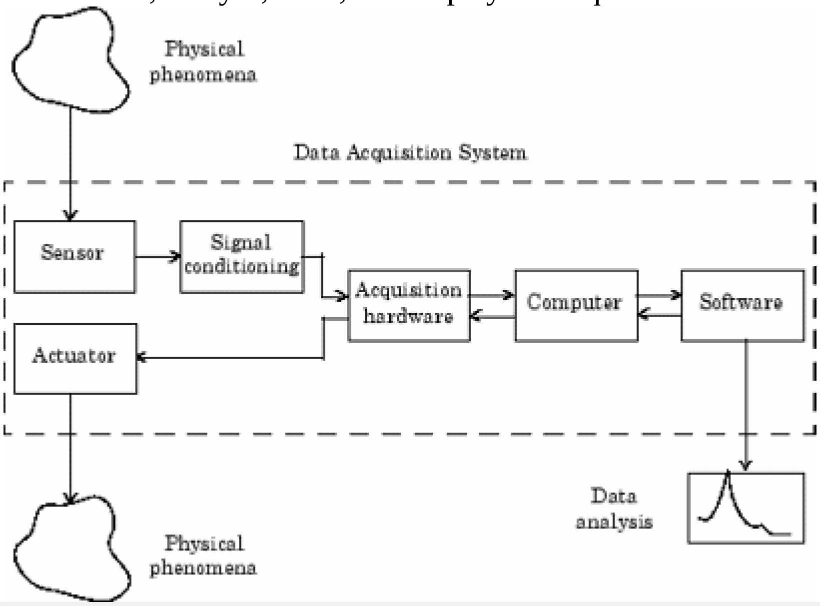
Disadvantages

  - Large data transmission is difficult
  - Bluejack is not possible (Bluejacking problem)

5.3 Data Acquisition System

A data acquisition system consists of many components that are integrated to:

- Sense physical variables (use of transducers)
- Condition the electrical signal to make it readable by an A/D board
- Convert the signal into a digital format acceptable by a computer
- Process, analyse, store, and display the acquired data with the help of software



Components	Description
Data acquisition hardware	At the heart of any data acquisition system lies the data acquisition hardware. The main function of this hardware is to convert analog signals to digital signals, and to convert digital signals to analog signals.
Sensors and actuators (transducers)	Sensors and actuators can both be *transducers*. A transducer is a device that converts input energy of one form into output energy of another form. For example, a microphone is a sensor that converts sound energy (in the form of pressure) into electrical energy, while a loudspeaker is an actuator that converts electrical energy into sound energy.
Signal conditioning hardware	Sensor signals are often incompatible with data acquisition hardware. To overcome this incompatibility, the signal must be conditioned. For example, you might need to condition an input signal by amplifying it or by removing unwanted frequency components. Output signals might need conditioning as well. However, only input signals conditioning is discussed in this chapter.
Computer	The computer provides a processor, a system clock, a bus to transfer data, and memory and disk space to store data.
Software	Data acquisition software allows you to exchange information between the computer and the hardware. For example, typical software allows you to configure the sampling rate of your board, and acquire a predefined amount of data.

5.3.1 Data Loggers

- Data logger automatically makes a record of the readings of instruments located at different parts of plant.
- Data logger measures and record data effortlessly as quickly, as often, and as accurately as desired.
- These devices measure electrical output from transducer, give plant performance computation, logic analysis of alarm conditions, passes information (reading) to computer for further processing etc.
- So they are used in power generation plant, petro-chemical installations, real time processing plants etc.

Characteristics of Data Logger

a) Modularity
b) Reliability and Raggedness
c) Accuracy
d) Management Tool
e) Easy to Use

Application of Data Logger

a) Weather station recording e.g. wind speed, wind direction, temperature, relative humidity
b) Hydrographic recording e.g. water level, depth, water flow PH, conductivity
c) Soil moisture level
d) Gas pressure
e) Environmental Monitoring

Basic Operation of Data Logger

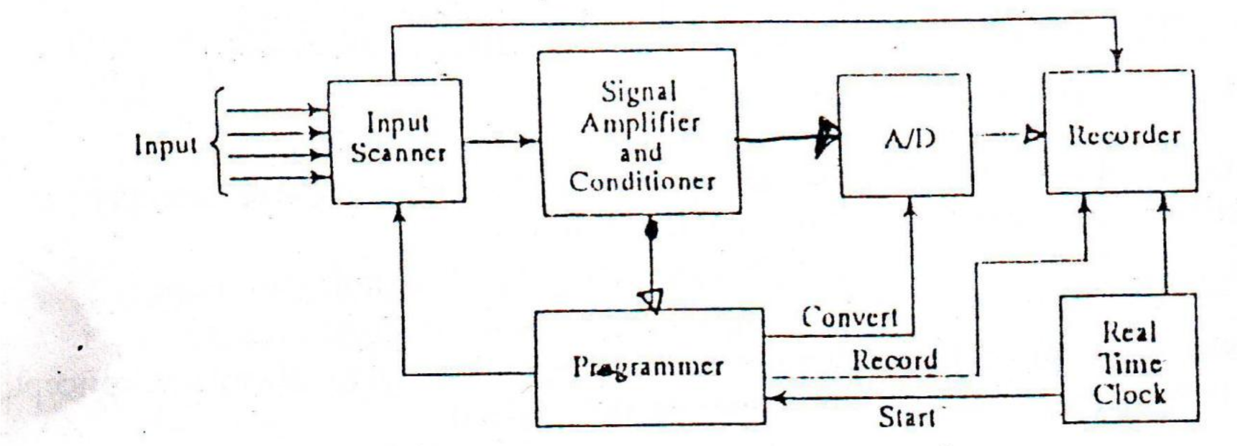


Fig. 17.27 Block Diagram of a Data Logger

1) Input Signals
   - May be
     - Pressure, transducers
     - Thermocouple
     - AC signal

   - Signals from relay, switch
   - Tachometer pulses etc.

2) Input Scanner
   - It is an automatic sequence switch which selects each signal in turn. Modern scanner have input scanner which can scan at a rate of 150 inputs per second. Characteristics of input scanner may be:
     - Low closed resistance
     - High open circuit resistance
     - Low contact potential
     - Negligible interaction between switch, enter going signal and input signal
     - Short operating time
     - Negligible contact bounce
     - Long operation life
3) Signal Amplifier & Conditioner
   - Amplifier for gain adjustment i.e. low level signal amplified up to 5v output. Characteristics are:
     - Precise and stable DC gain
     - High SNR
     - High CMMR
     - Low DC drift
     - Low output impedance
     - High input impedance
     - Good linearity
     - Wide bandwidth
   - Conditioner for scaling linear transducer or correcting curvature of non linear transducer i.e. signal is changed to more linear from and suitable for digital analysis. Characteristics are:
     - Linear scale
     - Correcting the curvature of non linear transducer
     - It may include sample and hold circuit
4) A/D Converter
   - Converts analog sample into digital data. Characteristics are:
     - Resolution
     - Accuracy
     - Conversion time
     - Full scale output voltage
     - Linearity
5) Recorder
   - Output from data logger may be recorded in any of following:
     - Typewriter, strip printer, digital tape recorder, punched tape, computer (hard drive), magnetic tape etc.
   - Characteristics are:
     - Speed
     - Memory
     - Writing technique (Serial / Parallel)

6) Programmer
    - Control all units of data conversion and operation
    - Microcontroller or microprocessor based system
    - Basic units: main frames, front panel assembly, power supply unit, scanner controller, input interface etc.
    - Operation performed by programmer:
        - Set amplifier
        - Set linearity factor
        - Set high and low alarm value
        - Start A/D conversion
        - Record reading channel
        - Identify channel and time of recording
        - Display recording
        - Reset logger

Compact Data Logger

- A typical data logger unit provides 60 channels of data in a 20x40x60 cm box weighing about 20 Kg. Most manufacturers offer local or remote add-on scanners to expand about 100 channels.
- Scan rates are modest (1-20) channels per second
- The signal processing capability is limited to simple functions such as (mx+b) scaling time averaging of single channels, group averaging of several channels and alarm signalling when preset limits are exceeded.
- Most units do allow interfacing to computers where versatile processing is possible
- This class of data logger utilise a built in microprocessor to control the interval of operation and carryout calculations through a single amplifier – A/D converter, which is automatically ranged in gain switched under program control.
- Multiplexers are available in both general purpose (two wire) and low level (two original wire plus shield) versions.
- Millivolt level signals, such as from thermocouples, generally use a shielded, twisted pair of conductors.
- Electro-mechanical read switches are used frequently in such scanners since speed requirements are modest but low noise is important.
- Since thermocouples are very common in data logger applications, reference function compensation and linearization options are always available.
- The microprocessor also stores the equation which curve-fit the thermocouple table for each.
- The system amplifier and A/D converter is the crucial element for several system accuracy.
- The microprocessor sets the amplifier gains at a proper value as each channel is sampled.
- The A/D converter are often of dual slope type or voltage to frequency converter type as the speed is modest with noise rejections
- Readout obtained by means of a built in digital indicator and two colour printers whose format is selected by front panel programming..

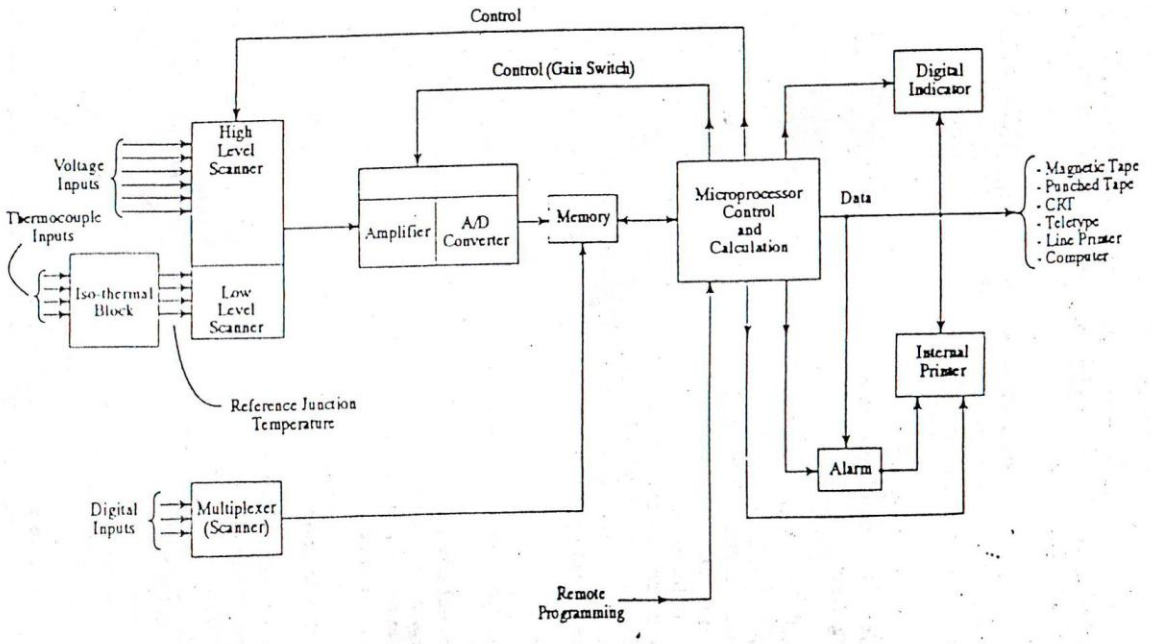


Fig. 17.29 Compact Data Logger Configuration

5.3.2 Data Archiving and Storage

Data Archiving

- Data archiving is the process of moving data that is no longer actively used to a separate data storage device for long-term retention, but can be readily accessed if required. Data archives consist of older data that is still important and necessary for future reference, as well as data that must be retained for regulatory compliance. Referential integrity should be maintained.
- Data archives are indexed and have search capabilities so that files and parts of files can be easily located and retrieved.
- Data archives are often confused with data backups, which are copies of data. Data backups are used to restore data in case it is corrupted or destroyed. In contrast, data archives protect older information that is not needed for everyday operations but may occasionally need to be accessed.

Data Storage

Storage Factors:

- Speed with which data can be accessed
- Cost per unit of data
- Reliability
  - data loss on power failure or system crash
  - physical failure of the storage device

Can differentiate storage into:

  - **volatile storage:** loses contents when power is switched off
  - **non-volatile storage**:

- Contents persist even when power is switched off.
- Includes secondary and tertiary storage, as well as batter-backed up main-memory.

Physical Storage Types:

- **Primary storage:** Fastest media but volatile (cache, main memory – RAM and ROM).
- **Secondary storage:** Non-volatile, moderately fast access time
  - also called **on-line storage**
  - E.g. flash memory, magnetic disks
- **Tertiary storage:** Non-volatile, slow access time which involves a robotic mechanism that will mount and dismount removable mass storage media into a storage device according to the system demands.
  - also called **off-line storage**
  - E.g. Tape libraries, optical jukebox etc.

Data Compression

- Process of encoding information using fewer bits than an un-encoded representation would use, through specific encoding schemes.
- Reduce consumption of expensive resources such as hard drive and transmission bandwidth.
- Trade-off between compression speed, compressed data size and quality (loss)

Types:

Lossy	**Lossless**
For the case if loss of fidelity is acceptable e.g. 6.666666 = 7	Exploit statistical redundancy in such a way to represent data without error e.g. 6.666666 = 6[6]6
Examples: Pictures (JPEG), Video (MPEG), Audio (MP3) etc.	Examples: zip, rar, Picture (PNG, TIFF), Video (Huff, YUV, AVI) etc.

RAID: Redundant Arrays of Independent Disks

It is the way of storing the data in disk organization techniques that manage a large numbers of disks, providing a view of a single disk of

- high capacity and high speed by using multiple disks in parallel, and
- high reliability by storing data redundantly, so that data can be recovered even if a disk fails

- **RAID Level 0**: Block striping; non-redundant.
- **RAID Level 1**: Mirrored disks with block striping
- **RAID Level 2**: Stripes data at the bit level, and uses code for error correction.
- **RAID Level 3**: Bit-Interleaved Parity
  - a single parity bit is enough for error correction, not just detection, since we know which disk has failed
- **RAID Level 4:** Block-Interleaved Parity; uses block-level striping, and keeps a parity block on a separate disk for corresponding blocks from *N* other disks.
- **RAID Level 5:** Block-Interleaved Distributed Parity; partitions data and parity among all $N + 1$ disks, rather than storing data in N disks and parity in 1 disk.