

Digital Transmission

Digital transmission is the transmittal of digital signal between two or more points. The signal can be binary or any other form of discrete level digital pulses.

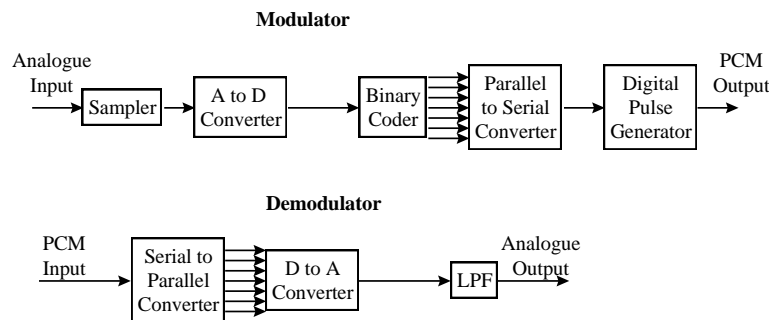
Pulse Modulation – consist essentially of sampling analog information signals and then converting those samples into discrete pulses and transporting the pulses from a source to a destination over physical medium.



Methods of Pulse Modulation

1. Pulse Width Modulation
2. Pulse Position Modulation
3. Pulse Amplitude Modulation
4. Pulse code Modulation
5. Pulse Frequency Modulation

PCM - Pulse Code Modulation is the only digitally encoded modulation technique that is commonly used in digital transmission.



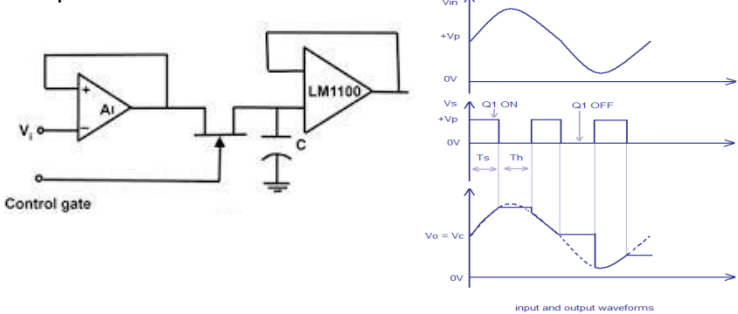
BPF – limits the frequency of the analog input signal to standard voice band frequency range of 300Hz-3KHz.

Sample and Hold – periodically sample the analog input signal and converts those samples to multilevel PAM signal.

Analog to Digital – convert the PAM samples to parallel PCM codes

Parallel to Serial – convert the parallel PCM codes to serial binary data.

Sample and Hold Circuit



Q1 (FET) – act as a simple analog switch.

- When Q1 is on, it provides a low impedance path to deposit analog sample voltage across C. The time the Q1 is on is called **aperture or acquisition time**.

When Q1 is off, C does not leave complete path to discharge through and therefore store the sampled voltage. During this time the ADC convert the sample voltage to a PCM code.

$$i = C \frac{dv}{dt} \quad C = i \frac{dt}{dv}$$

The charge time constant where Q is on: $t = RC$

Where t = one charge time constant

R = output impedance of Z, pulse resistance of Q

C = capacitance value of C (farads)

Accuracy %	Charge Time
10	2.3 t
1	4.6 t
0.1	6.9 t
0.01	9.2 t

Where:

C – max. capacitance (f)

i – max. output current from Z

dv – max. change in voltage

dt – charge time or acquisition time

Example:

For the sample and hold circuit, determine the largest value capacitor that can be used. Use an output impedance for Z of 10Ω, an ON resistance for Q of 10Ω, an acquisition time of 10μs, a max. peak to peak input voltage of 10V, a maximum output current from Z of 10mA and an accuracy of 1%.

Sampling Rate – the nyquist sampling rate (f_s) that can be used for a given PCM system.

$f_s \geq 2f_a$ where: f_s = minimum nyquist sample rate (Hz)

f_a = maximum analog input freq.

$f_s = 2 * f_a$ is called the Nyquist sampling rate.

a. No Aliasing (fold over distortion)

b. With aliasing distortion

Example:

For a PCM system with a max. audio input freq of 4KHz, determine the minimum sample rate and alias freq. produce if a 5KHz audio signal were allowed to enter the sample and hold circuit.

THREE BIT PCM CODE

sign	magnitude	decimal	Quantization range
1	11	+3	+2.5 V to 3.5 V
1	10	+2	+1.5 V to 2.5 V
1	01	+1	+0.5 V to 1.5 V
1	00	+0	+0 V to 0.5 V
0	00	-0	0 to -0.5 V
0	01	-1	-0.5 V to -1.5 V
0	10	-2	-1.5 V to -2.5 V
0	11	-3	-2.5 V to -3.5 V

Example: For the PCM coding Scheme, determine the quantized voltage (Q_v), quantization error (Q_e) and PCM code for analog sample voltage of 1.07 V.

Dynamic Range (DR)

- the number of PCM bits transmitted per sample is determined by several variables including maximum allowable input amplitude, resolution and dynamic range.

- it is the ratio of the largest possible magnitude to the smallest possible magnitude (other than 0) that can be decoded by DAC in the receiver.

Where: DR = dynamic range (unitless)

$$DR = \frac{V_{max}}{V_{min}}$$

V_{min} = the quantum value (resolution)

V_{max} = the maximum voltage magnitude

$$DR = \frac{V_{max}}{\text{resolution}}$$

Expressed in dB: $DR_{dB} = 20 \log \frac{V_{max}}{V_{min}} ; (DR_{dB})^2 = 20 n \log 2 ; \text{where } n = \text{number of PCM bits}$

$$DR = 2^n - 1$$

$$\log 2^n = \log (DR + 1)$$

$$n \log 2 = \log (DR + 1)$$

$$n = \frac{\log (DR + 1)}{\log 2}$$

Coding Efficiency – is numerical indication of how efficiently a PCM code is utilized.

Coding Efficiency = [min. # of bits (include sign bit) / actual # of bit (include sign bit)] x 100

Example: For a minimum line speed with an 8-bit PCM for speech signal ranging to 1 volt,

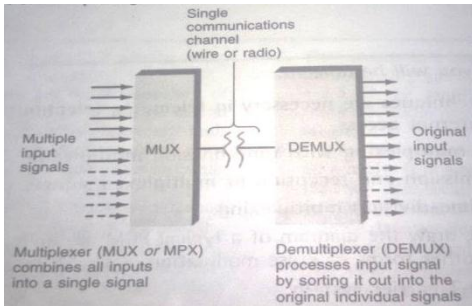
a) calculate the resolution and quantization Error

b) Dynamic range for 0.01 V resolution, minimum number of bits required to achieve DR and coding efficiency

MULTITPLEXING PRINCIPLES

Multiplexing - is the process of simultaneously transmitting two or more individual signals over a single communication channel, cable or wireless.

- Accomplished by an electronic circuit known as multiplexer.



Applications of Multiplexing:

1. Telephone System
2. Telemetry
3. Satellites
4. Modern Radio and TV broadcasting

Spatial Multiplexing or Frequency Reuse

-The transmission of multiple wireless signals on a common frequency in such a way that they do not interfere with one another

Applications of Spatial Multiplexing:

1. Satellite
2. Cellular Telephone System

Two most common types of Multiplexing:

1. Frequency-Division Multiplexing (FDM)

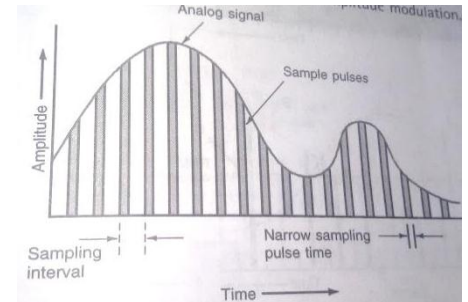
- used for analog information
- multiple signals share the bandwidth of a common communication channel
- Frequency-Division Multiple Access (FDMA)

FDM Applications:

- Telemetry-sensors generate electric signals that change in some way in response to changes in physical characteristics.
- Telephone system-used to send multiple telephone conversations over a minimum number of cables
- Cable TV- multiple TV signals, each in its own 6-MHz channel are multiplexed on a common coaxial cable or fiber-optic cable sent to nearby homes.
- FM stereo Broadcasting

2. Time-Division Multiplexing (TDM)

- used for digital information
- Multiple signals are transmitted in different time slots on a single channel
- Multiple signals take turns transmitting over a single channel
- Time-Division Multiple Access (TDMA)
- transmission of digital data is straightforward in that the incremental data is already broken up into chunks which can easily be assigned to different time slots.
- can also be used to transmit continuous analog signal by sampling the analog signal repeatedly at a high rate and converting samples to produce proportional binary numbers and transmitting them serially.
- sampling an analog signal produces **PULSE AMPLITUDE MODULATION (PAM)**.
- most popular form of TDM uses **PULSE CODE MODULATION (PCM)** – highly resistant to noise, reliable and inexpensive to implement.



CODE-DIVISION MULTIPLE ACCESS (CDMA) –widely used in cellphone system to allow many cell phone subscribers to use a common bandwidth at the same time. It uses a technique called spread spectrum to make this type of multiplexing.

PAM Multiplexers – samples multiple analog signal sources, the resulting pulses are interleaved and then transmitted over a single channel.

PCM Multiplexers – used to transmit analog signals, these signals are sampled with multiplexer, then converted by an A/D converter into a series of binary numbers and are converted from parallel to serial format.

DUPLEXING – the method by which two-way communications are handled.

Full Duplexing – two stations can send and receive simultaneously.

Two ways of Duplexing:

1. Frequency Division Duplexing (FDD) – more widely used but requires more spectrum space.
2. Time Division Duplexing (TDD) – more economical of spectrum space but harder to implement as precise timing and synchronization is required.

