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Communication systems

COMMUNICATION systems
Third stage
Electrical Power & Machines
Engineering Department
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Lecture 4

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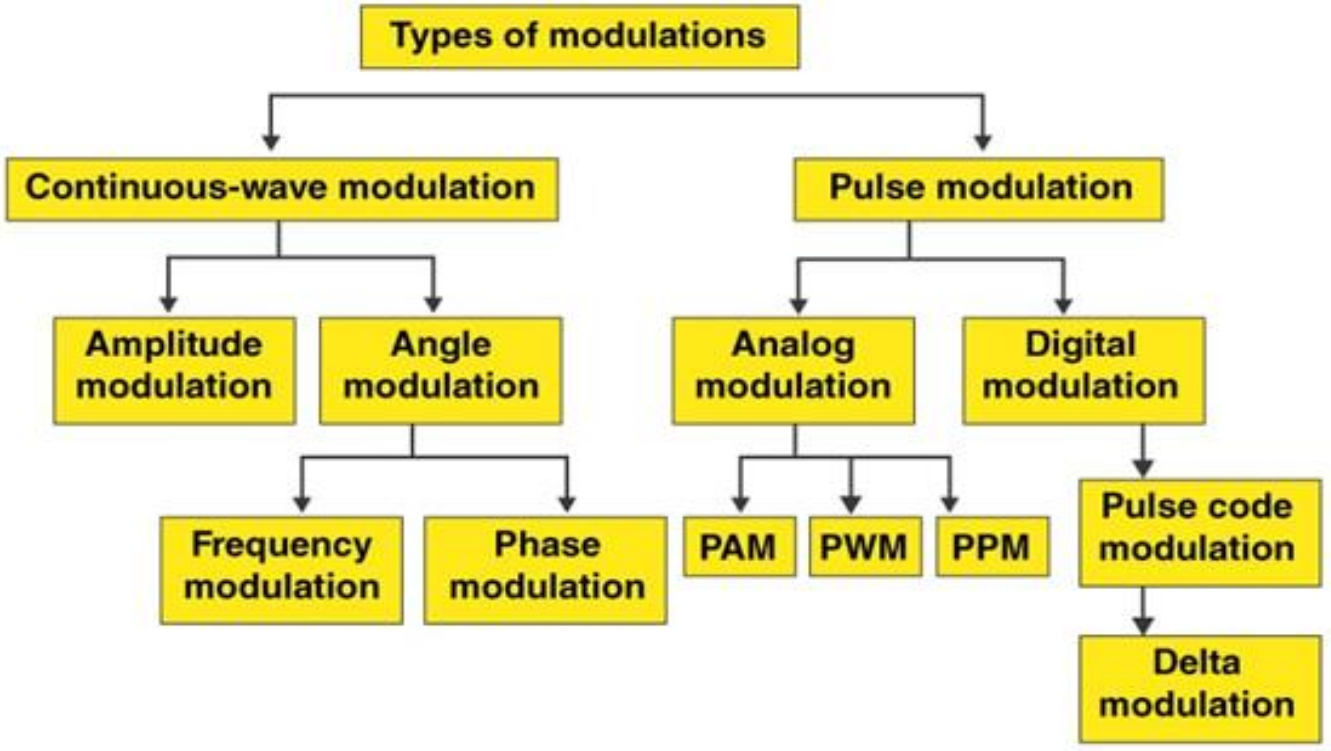
Modulation

What is Modulation?

Two signals are involved in the modulation process. Message signals are also known as baseband signals. Baseband signals are the band of frequencies representing the original signal. This is the signal to be transmitted to the receiver. The frequency of such a signal is usually low. The other signal involved in this is a high-frequency sinusoidal wave. This signal is called the carrier signal.

The frequency of the carrier signals is almost always higher than that of the baseband signal. The amplitude of the baseband signal is transferred to the high-frequency carrier. Therefore, **modulation can be defined as**

, The process of superimposing a low-frequency signal on a high-frequency carrier signal.



BLOCK DIGRAM OF MODULATION

Pulse Code Modulation (PCM)

Pulse Code Modulation (PCM)

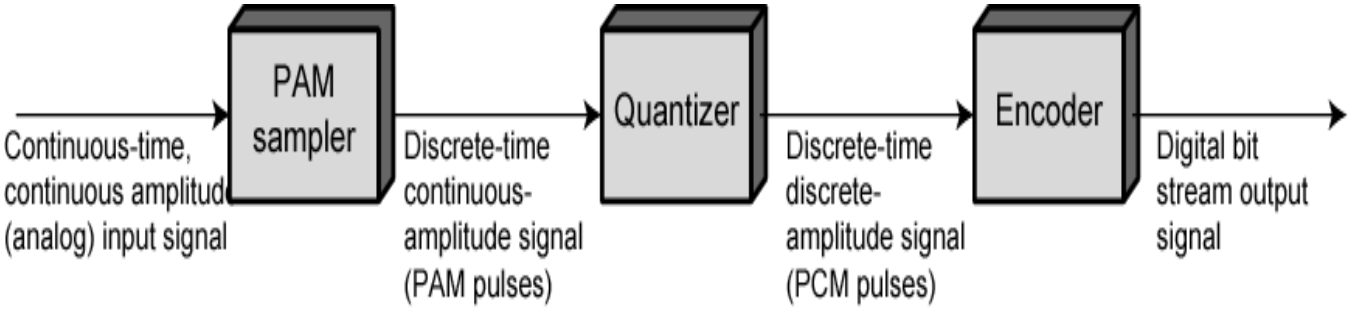
- The most common technique for using digital signals to encode analog data is PCM.

- *Example: To transfer analog voice signals off a local loop to digital end office within the phone system, one uses a codec.*

- Because voice data limited to frequencies below 4000 HZ, a codec makes 8000 samples/sec. (i.e., 125 microsecond/sample).

- If a signal is sampled at regular intervals at a rate higher than twice the highest signal frequency, the samples contain all the information of the original signal.

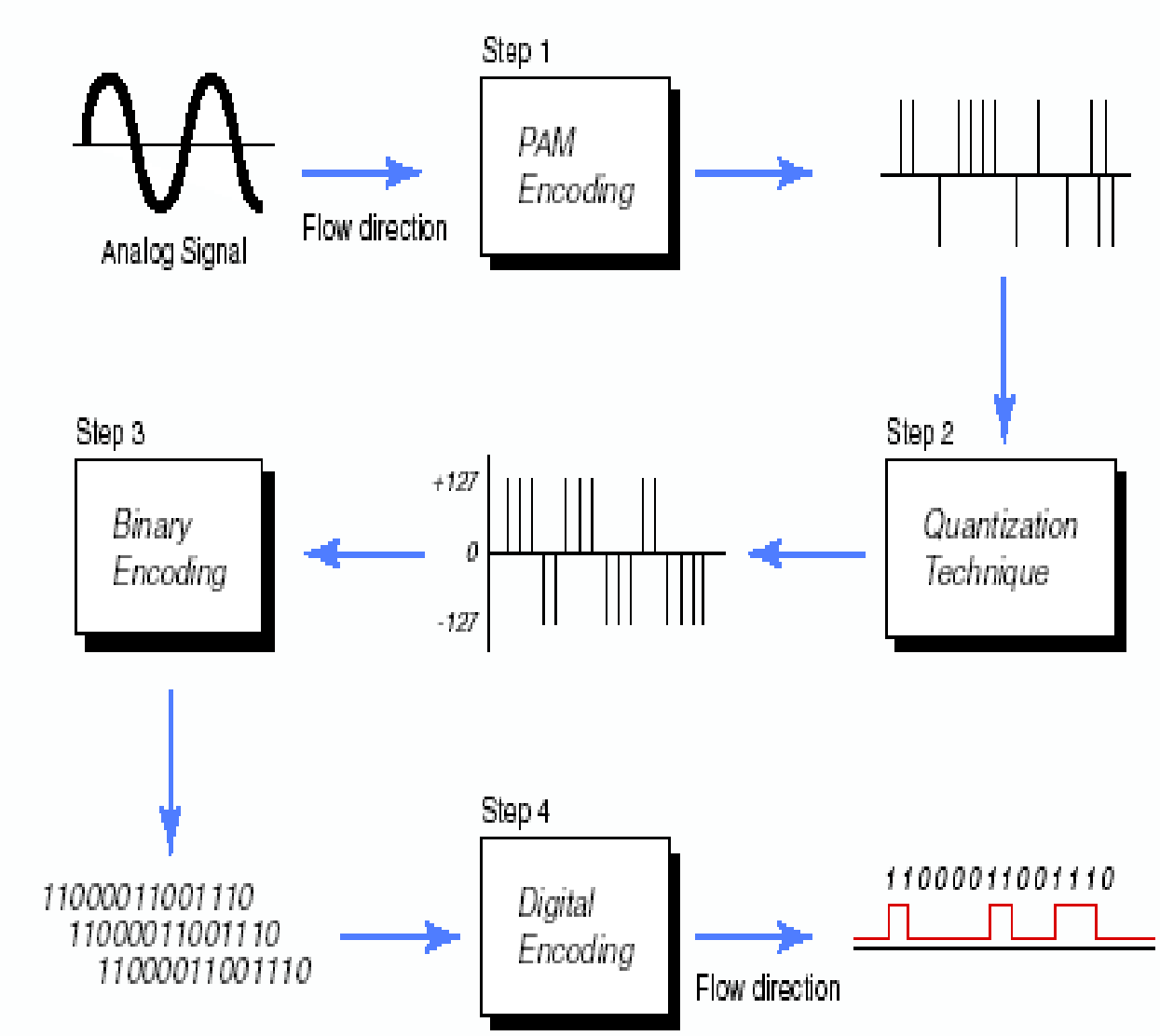
PCM Block Diagram



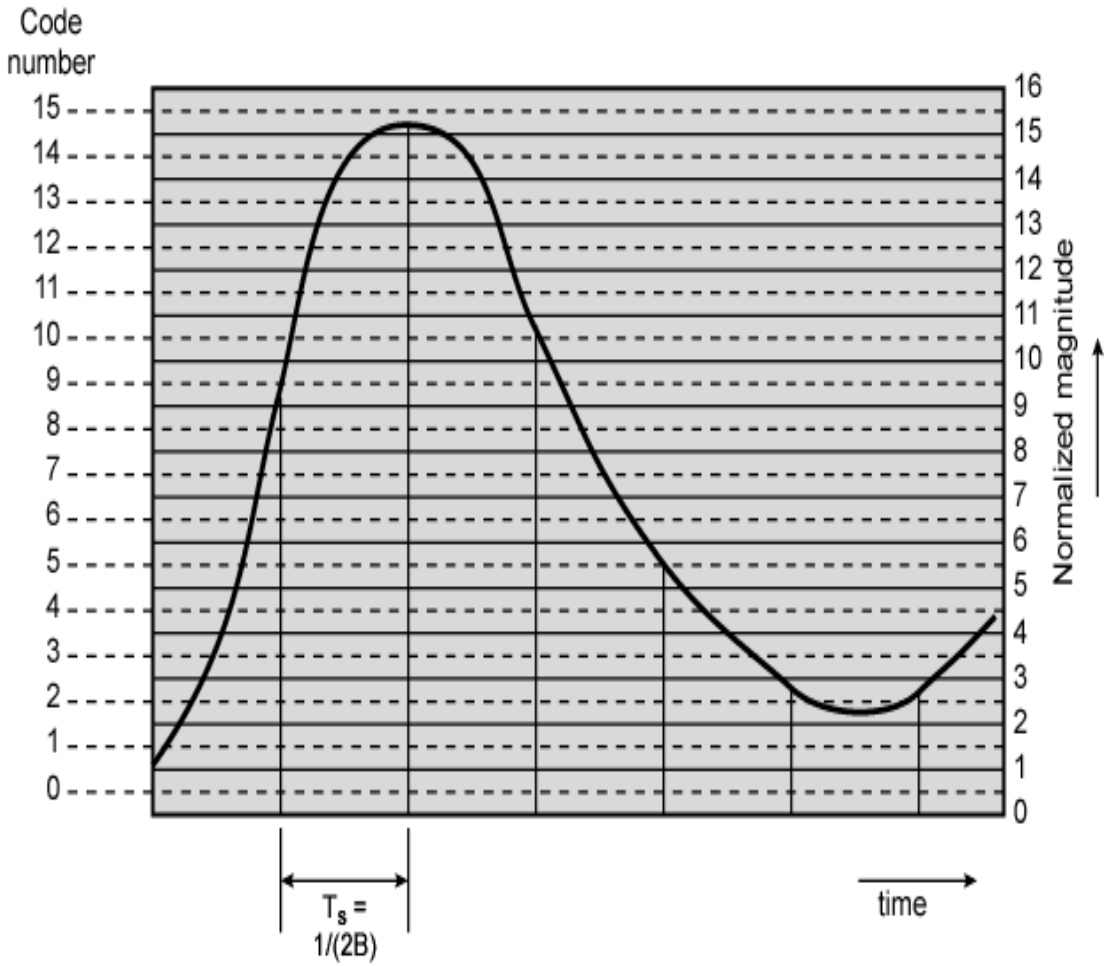
- **Most common form of analog to digital modulation**
- **Four step process**
  - **- Signal is sampled using PAM (sampled)**
  - **- Integer values assigned to signal (PAM)**
  - **- Values converted to binary (Quantized)**
  - **- Signal is digitally encoded for transmission (Encoded)**

Cont'd

- Analog signal is sampled.
- Converted to discrete-time continuous-amplitude signal (Pulse Amplitude Modulation)
- Pulses are ***quantized*** and assigned a digital value.
  - A 7-bit sample allows 128 quantizing levels.
- PCM uses non-linear encoding, i.e., amplitude spacing of levels is non-linear
  - There is a greater number of quantizing steps for low amplitude
  - This reduces overall signal distortion.
- This introduces *quantizing error (or noise).*
- PCM pulses are then encoded into a digital bit stream.
- 8000 samples/sec x 7 bits/sample = 56 Kbps for a single voice channel.


Step 1
PAM
Encoding
Analog Signal
Flow direction
Step 2
Quantization
Technique
+127
0
-127
Step 3
Binary
Encoding
1100011001110
1100011001110
1100011001110
Step 4
Digital
Encoding
Flow direction
1100011001110

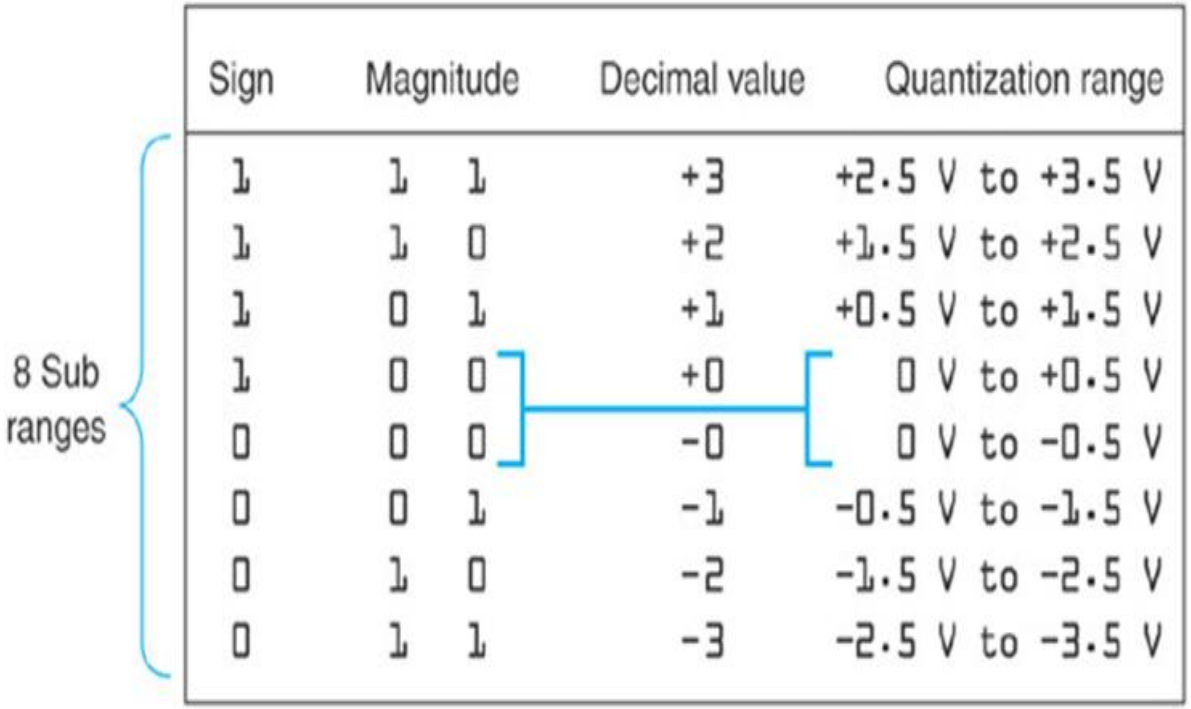
PCM Example



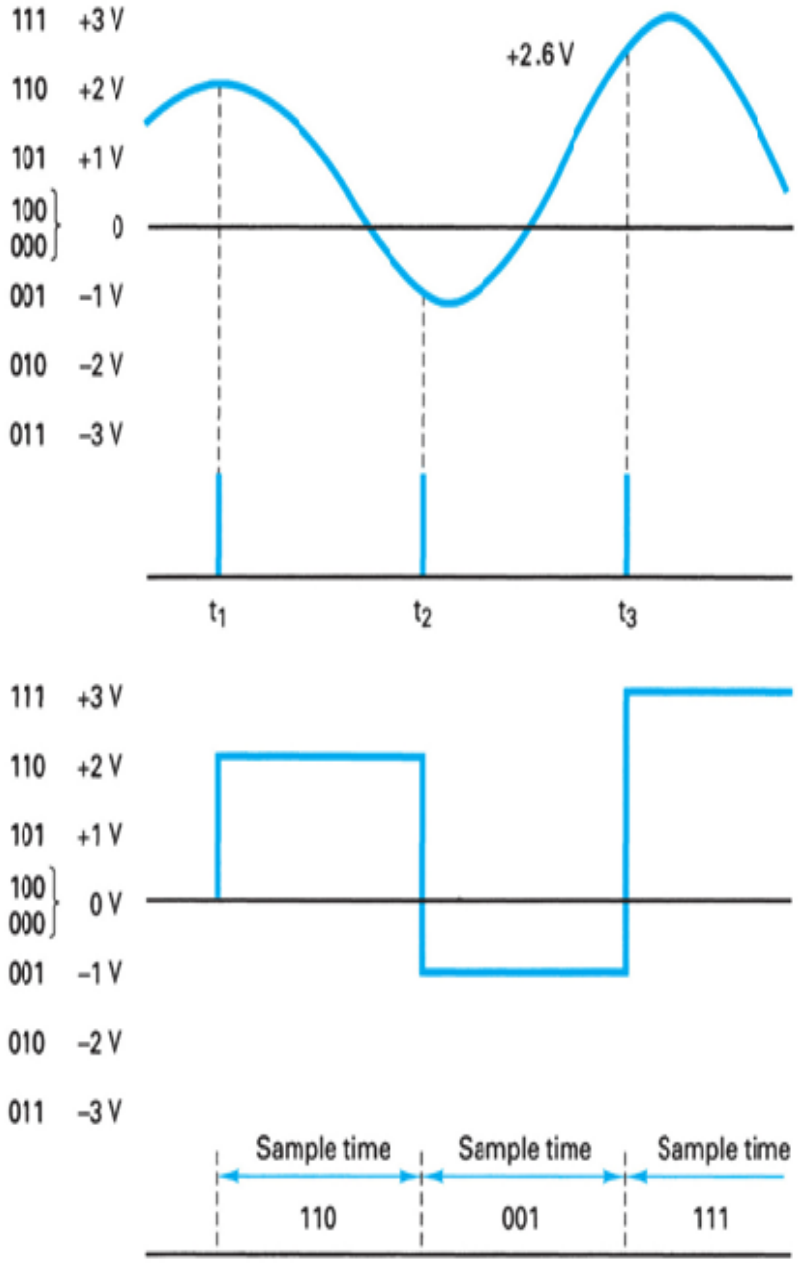
PAM value	1.1	9.2	15.2	10.8	5.6	2.8	2.7
quantized code number	1	9	15	10	5	2	2
PCM code	0001	1001	1111	1010	0101	0010	0010

Quantization

- a process of converting an infinite number of possibilities to a finite number of conditions (rounding off the amplitudes of flat-top samples to a manageable number of levels).



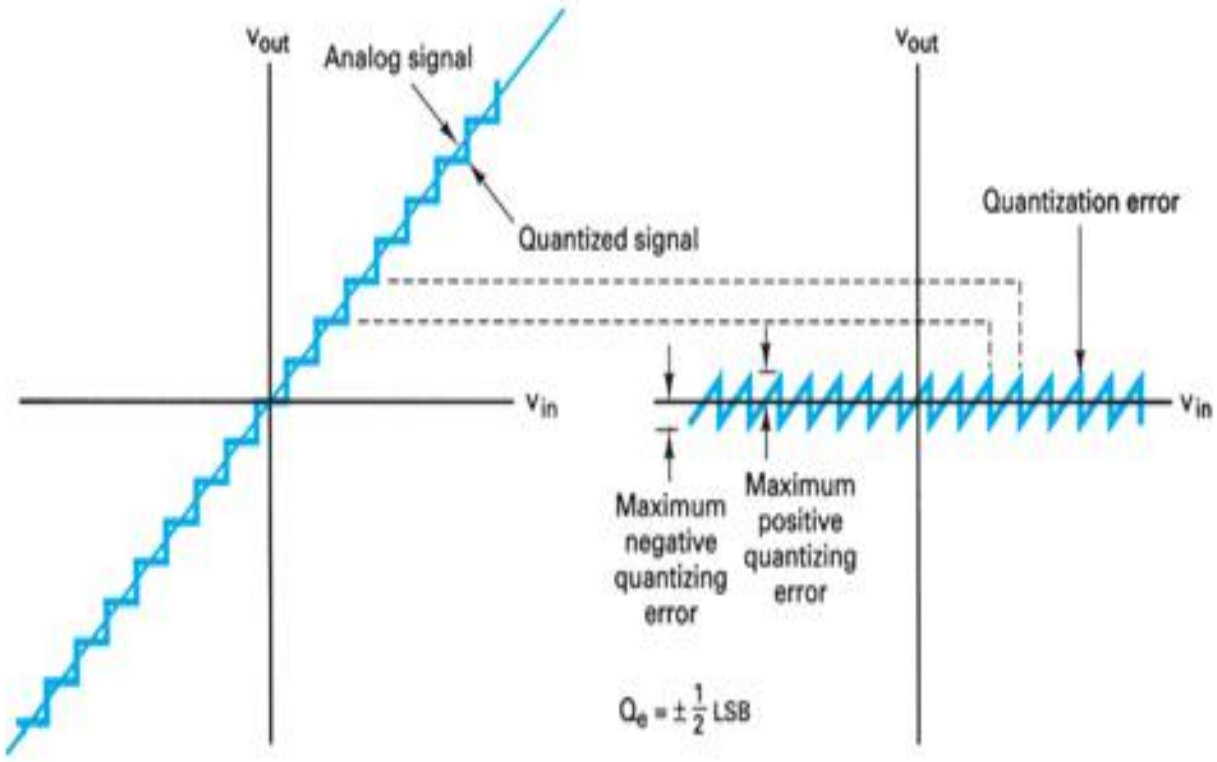
Sign	Magnitude		Decimal value	Quantization range
1	1	1	+3	+2.5 V to +3.5 V
1	1	0	+2	+1.5 V to +2.5 V
1	0	1	+1	+0.5 V to +1.5 V
1	0	0	+0	0 V to +0.5 V
0	0	0	-0	0 V to -0.5 V
0	0	1	-1	-0.5 V to -1.5 V
0	1	0	-2	-1.5 V to -2.5 V
0	1	1	-3	-2.5 V to -3.5 V


111 +3 V
110 +2 V
101 +1 V
100
000
0
001 −1 V
010 −2 V
011 −3 V
+2.6 V
t1
t2
t3
111 +3 V
110 +2 V
101 +1 V
100
000
0 V
001 −1 V
010 −2 V
011 −3 V
Sample time
Sample time
Sample time
110
001
111

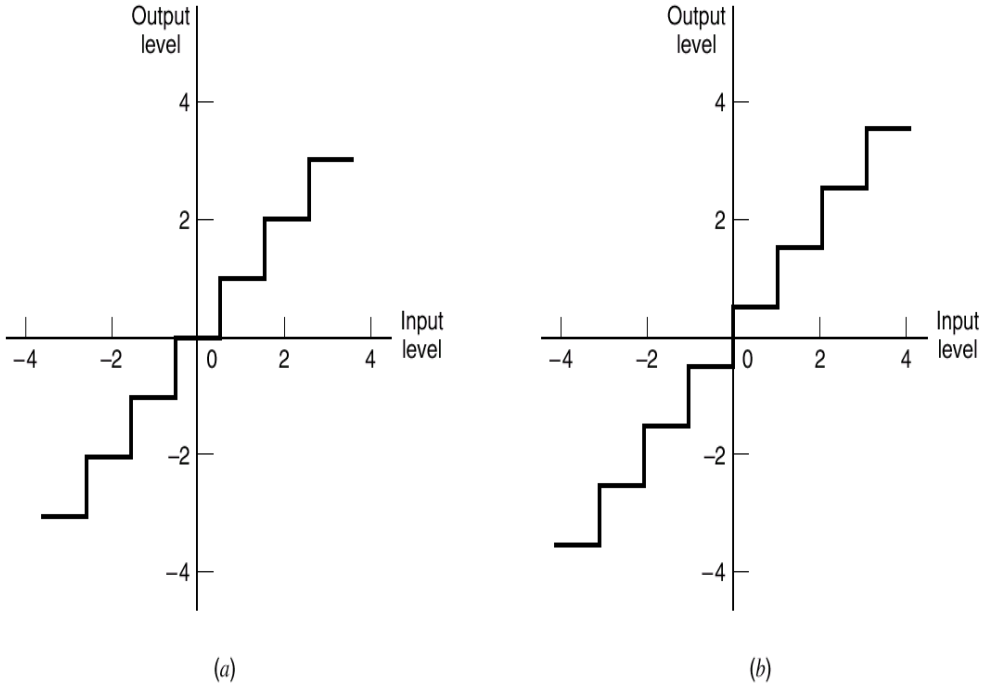
Cont'd

- **The *quantization interval @ quantum* = the magnitude difference between adjacent steps.**
- **The *resolution* = the *magnitude of a quantum* = the voltage of the minimum step size.**
- **The *quantization error* = the quantization noise = ½quantum = (original sample voltage – quantize level)**
- **PCM code = (sample voltage/resolution)**

QUANTIZATION ERROR



Types of Quantization

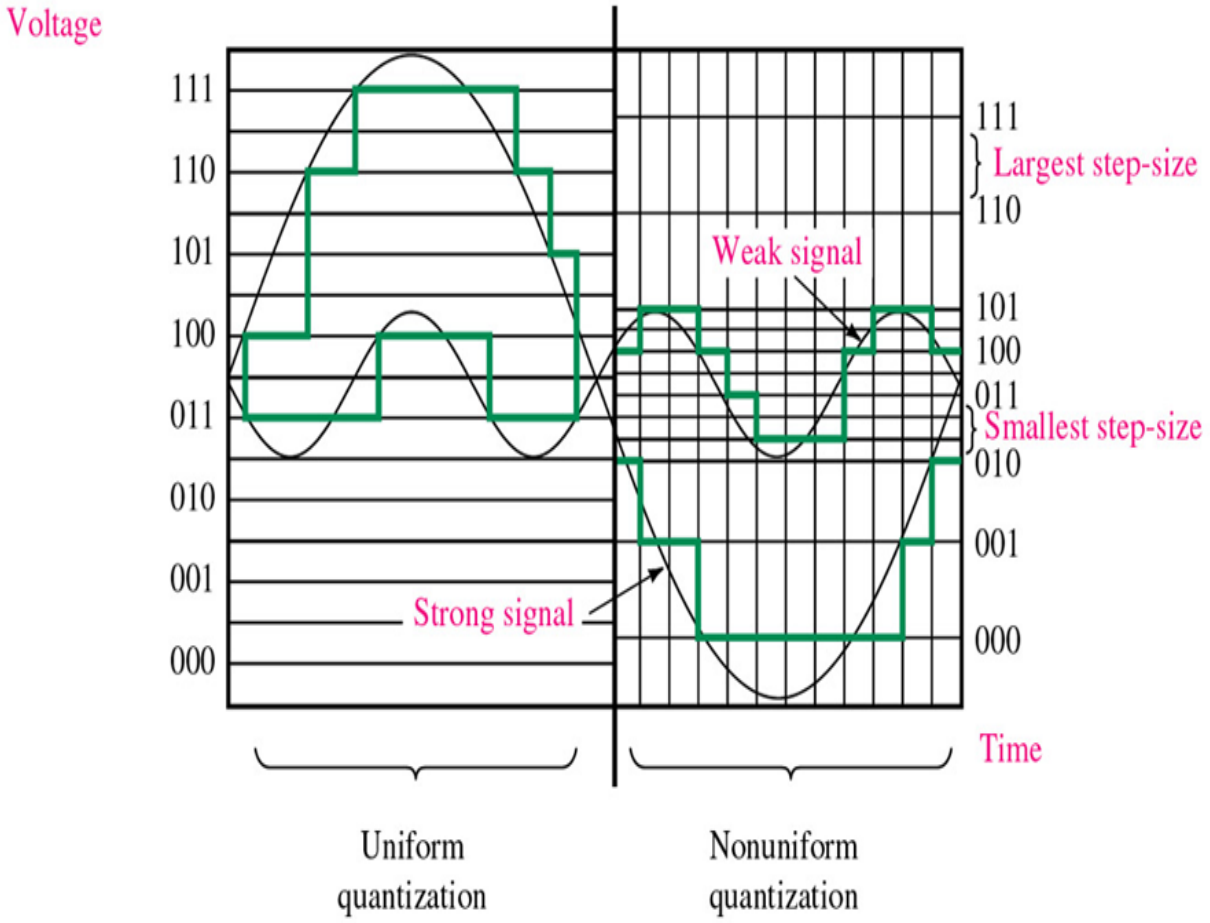


Midtread

Midrise

Types of Quantizer

1. Uniform type, the levels of the quantized amplitude are uniformly spaced.
2. Non-uniform type, the levels are not uniform.



Signal to Quantization Noise Ratio (SQR)

- **The worst-case voltage SQR**

$$SQNR_{(\min)} = \frac{resolution}{Q_e}$$

- **SQR for a maximum input signal**

R =resistance (ohm)

v = rms signal voltage

q = quantization interval

- **The signal power-to-quantizing noise power ratio**

$$SQNR_{(\max)} = \frac{V_{\max}}{Q_e}$$

$$SQNR_{(dB)} = 10\log\frac{\text{average signal power}}{\text{average quantization noise power}}$$

$$= 10\log\frac{v^2/R}{(q^2/12)/R} = 10\log\left[\frac{v^2}{q^2/12}\right]$$

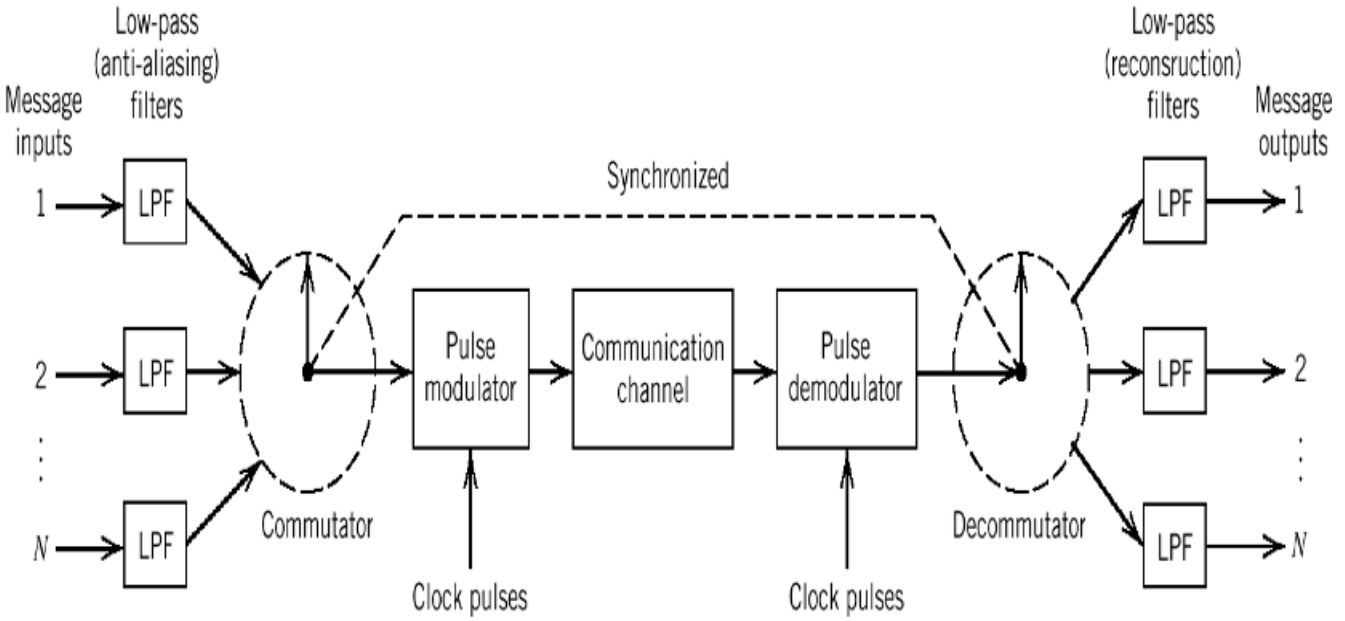
Virtues & Limitation of PCM

- The most important advantages of PCM are:
- Robustness to channel noise and interference.
- Efficient regeneration of the coded signal along the channel path.
- Efficient exchange between B_T and *SNR*.
- Uniform format for different kind of base-band signals.
- Flexible TDM.
- Secure communication through the use of special modulation schemes of encryption.
- These advantages are obtained at the cost of more complexity and increased B_T.
- With cost-effective implementations, the cost issue no longer a problem of concern.
- With the availability of wide-band communication channels and the use of sophisticated data compression techniques, the large bandwidth is not a serious problem.

Time-Division Multiplexing

- This technique combines time-domain samples from different message signals (sampled at the same rate) and transmits them together across the same channel.
- The multiplexing is performed using a commutator (switch). At the receiver a decommutator (switch) is used in synchronism with the commutator to demultiplex the data.
- TDM system is very sensitive to symbol dispersion, that is, to variation of amplitude with frequency or lack of proportionality of phase with frequency. This problem may be solved through *equalization* of both magnitude and phase.
- One of the methods used to synchronize the operations of multiplexing and demultiplexing is to organize the mutiplexed stream of data as frames with a special pattern. The pattern is known to the receiver and can be detected very easily.

Block diagram of TDM-PCM communication system



Time division multiplexing of two PAM signals