ECE 455/555

Chapter 5D
Signal Encoding Techniques –

Analog Data, Digital Signal
Analog Data, Analog Signal

1

Analog Data, Digital Signal

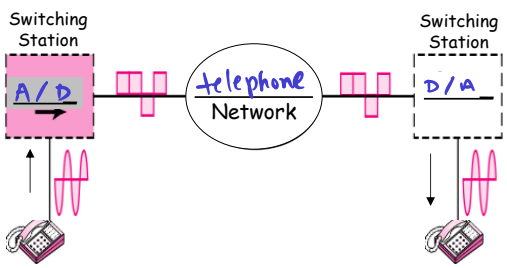
1. The process of converting analog data into digital form is known as digitization

   - Makes use of modern digital transmission facilities

2. Digitization of analog signals started with telephone companies because of distortion of analog signals that were used for long-distance communications

2

3. Example of early digitization of telephone network
   - Digitize the analog data (i.e. voice)
   - Transmit as a digital signal because
     - Digital signals are less prone to noise and distortion.
   - Convert back to an analog signal at the receiver



3

4. The device used for converting analog data into digital form for transmission, and subsequently recovering the original analog data from the digital

   is known as a coder-decoder or Codec .

5. Two techniques that are used in codecs are:

   a) Pulse code modulation (PCM)
   Used to digitize voice in the North American telephone system.

   b) Delta modulation (DM).

4

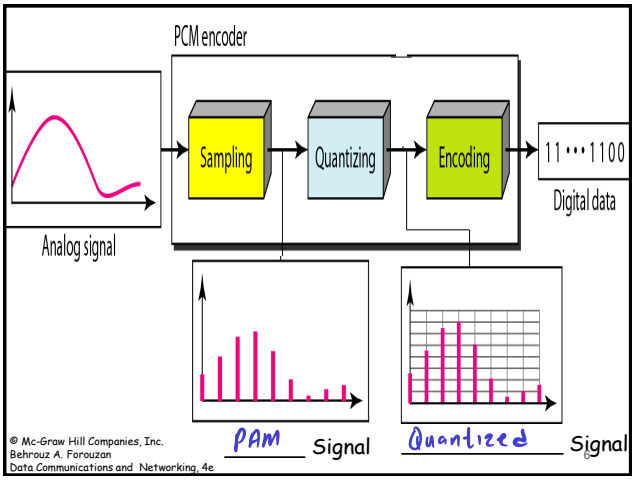
Pulse Code Modulation (PCM)

A. PCM has 3 processes
   1. The analog signal is sampled.
   2. The resulting signal (called a PAM signal) is quantized. (Pulse amplitude modulation)
   3. The quantized values are encoded as streams of bits.

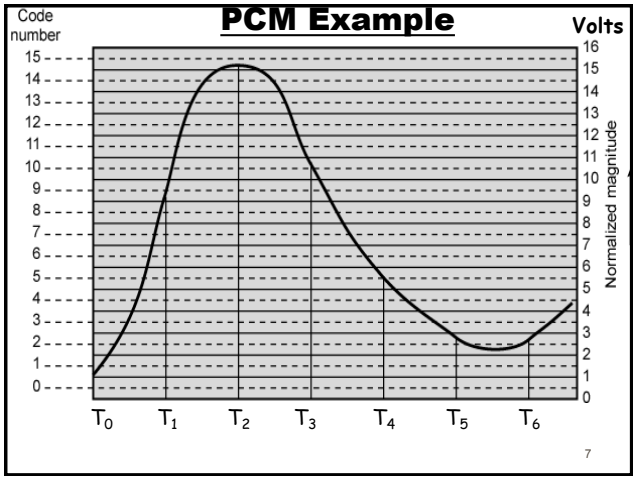
B. Sampling is based on Nyquist theorem:

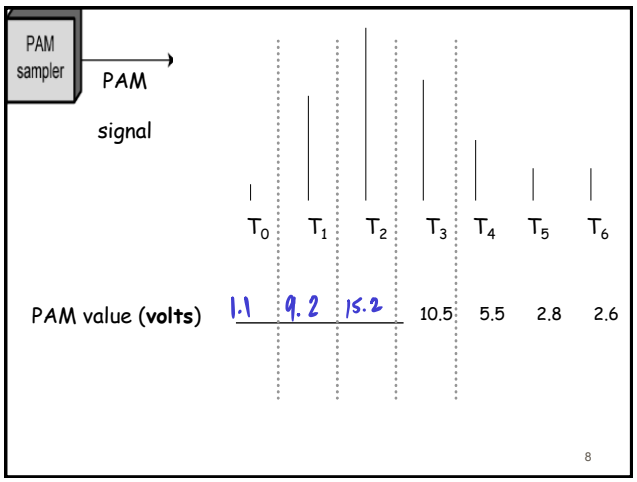
$freq_{sampling} \geq$ 2 * $freq_{max\ of\ sample}$

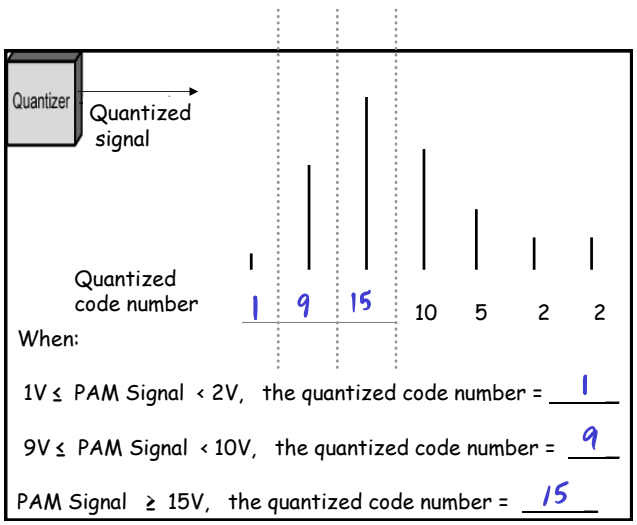
5

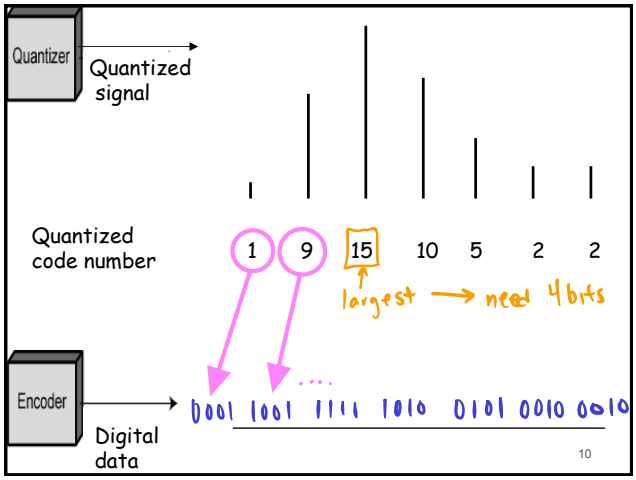


6


PCM Example
Code number
Volts
Normalized magnitude
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
T_0 T_1 T_2 T_3 T_4 T_5 T_6
7


PAM sampler
PAM signal
T_0 T_1 T_2 T_3 T_4 T_5 T_6
PAM value (volts)
1.1 9.2 15.2 10.5 5.5 2.8 2.6
8


Quantizer
Quantized signal
Quantized code number
1 9 15 10 5 2 2
When:
1V ≤ PAM Signal < 2V, the quantized code number = 1
9V ≤ PAM Signal < 10V, the quantized code number = 9
PAM Signal ≥ 15V, the quantized code number = 15



C. Each PAM sample is approximated by being quantized into one of *k* levels

1) Quantized values are approximations of the original signal, hence you have quantizing or quantization noise.

2) The SNR for quantization noise is expressed as

SNR_{dB} = $6.02n + 1.76$
where *n* = # of bits per analog sample

3) Therefore, SNR is improved by increasing the number of quantization levels/bits.

11

Example 1:
What is the minimum sampling rate for PCM if the frequency of the analog signal varies from 2000Hz to 6000Hz?
Answer: Nyquist formula:
The min sampling rate = $2 \times 6000\ Hz = 12\ kHz$

Example 2: We have sampled a low-pass signal with a bandwidth of 200 kHz using 1024 levels of quantization.
a) What is the bit rate of the digitized signal?
b) What is the SNR_{dB} of this signal?

Answer:
a) Sampling rate = $2 \times 200\ kHz = 400\ kHz$ = 400,000 samples per sec
# of bits/sample = $\log_2 1024 = 10$ bits per sample
bit rate = $10 \times 400{,}000 = 4\ Mbps$

b) $SNR_{dB} = 6.02n \times 1.76 \Rightarrow 6.02(10) \times 1.76$
$= 61.96\ dB$

12

Example 3:
We wish to digitize the human voice with a quantization SNR_{dB} above 40 dB. What is the minimum number of bits per sample? What is the bit rate?
(Note: Human voice normally contains frequencies from 0 to 4000 Hz).

Answer

SNR_{dB} = $40 = 6.02n + 1.76$

n = min # of bits = $\frac{40 - 1.76}{6.02} = n = 7$ bits

Sampling rate = $2 \times 4000 = 8$ kHz

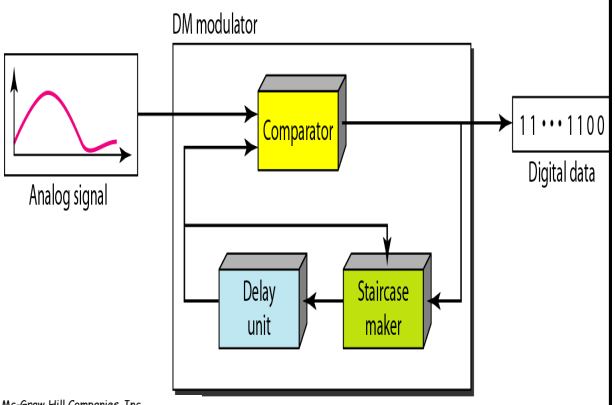
bit rate = $7 \times 8000 = 56$ kbps

13

Delta Modulation

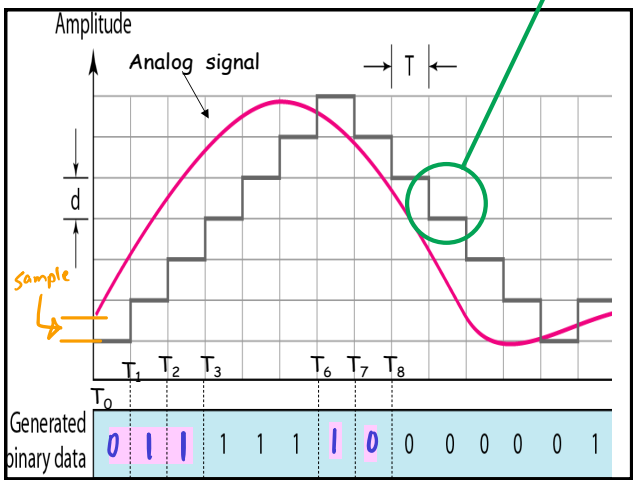
- Less complex than PCM
- A bit stream is produced by approximating the derivative of an analog signal rather than its amplitude
- Analog input is approximated by a staircase function
- Move up or down one level (δ) at each sample interval
- Binary behavior
  - Function moves up or down at each sample interval

14



15

This is noise



If sig > T_0, then T_1 step up and output = 1

If sig < T_0, then T_1 step down and output = 0

If signal is higher, output steps up. Generated data is 1.

- Delta Modulation
  - — Reduces data or bit rate
  - —Simpler implementation than PCM
  - — Used for signals with low frequency components

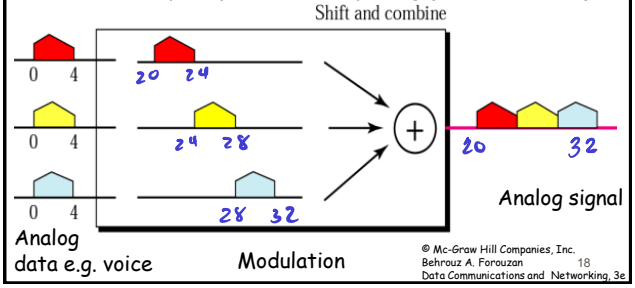
because PCM is slow in following a signal

- PCM
  - — Exhibits better SNR characteristics
  - — Used for signals with higher frequency components

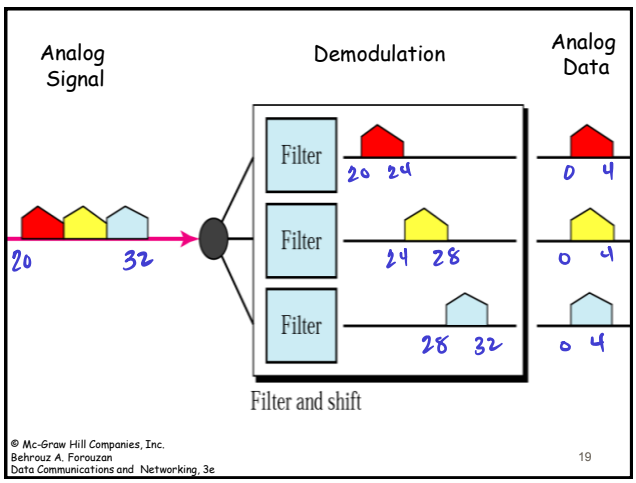
17

Analog Data, Analog Signals

- Why modulate analog signals?
  - —Higher frequency can give more efficient transmission
  - —Permits frequency division multiplexing (as shown below)

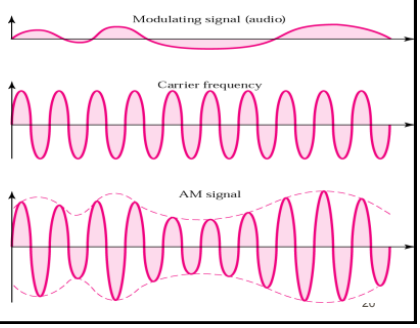


18



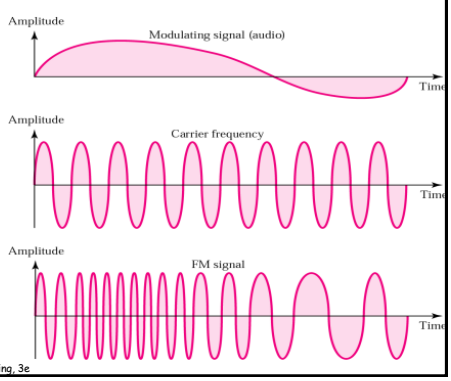
Types of Modulation

1. Amplitude Modulation (AM)
   - The carrier signal is modulated so that its amplitude varies with the changing amplitudes of the modulating signal



2. Frequency Modulation (FM)
   - The carrier signal is modulated so that its frequency varies with the changing amplitudes of the modulating signal

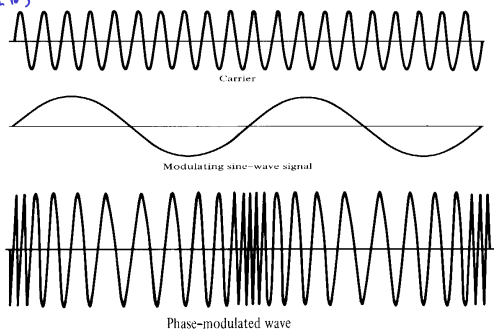
Analog data



3. Phase Modulation (pm)

— The carrier signal is modulated so that its phase varies with the changing amplitudes of the modulating signal

Analog data



22

Questions

1. What is the difference between AM and ASK?

ASK - digital data used to modulate amplitude of analog signal

AM - analog " " analog signal

2. What is the difference between FM and FSK?

FSK - digital data used to modulate frequency of analog signal

FM - analog " " frequency "

23

Assignment #6

1. Prob 5.16 in the text book
2. What is the Nyquist sampling rate of a band-pass signal with bandwidth of 200 kHz if the lowest frequency is 100 kHz?
3. Prob. 5.21
4. Prob. 5.24
   Note: Use assignment sheet (provided at class website) to answer this question.

Reading Assignment

- Nonlinear encoding

24