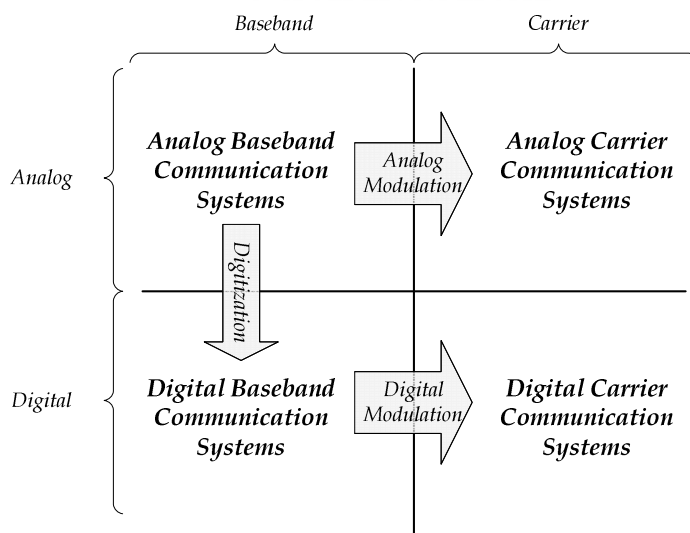


Lecture 5a: Sampling and Quantization

Dr. Mohammed Hawa
 Electrical Engineering Department
 University of Jordan

EE421: Communications I

Digitization



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Digital Systems Advantages

- Immunity to noise (threshold detection; regenerative repeaters).
- Multiplexing at the baseband level (e.g., TDM) and carrier level (e.g., FDM, CDMA and OFDMA).
- Spread spectrum techniques and orthogonality.
- Channel coding (i.e., error correcting codes).
- Source coding techniques (i.e., compression). *Also Encryption.*
- Exchanging SNR for bandwidth.
- Using microprocessors and DSP.
- Digital signal storage is relatively easy and inexpensive.



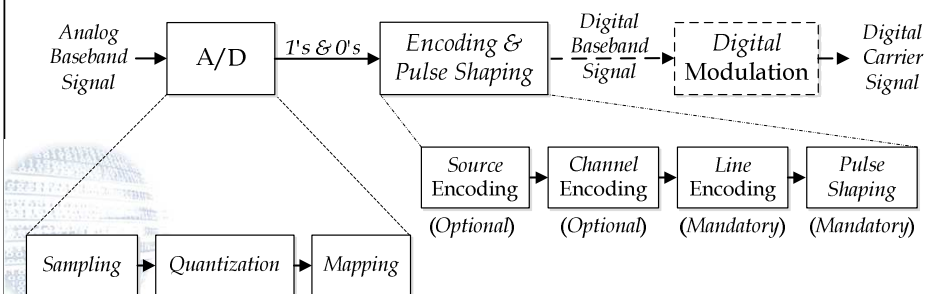
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Digitization

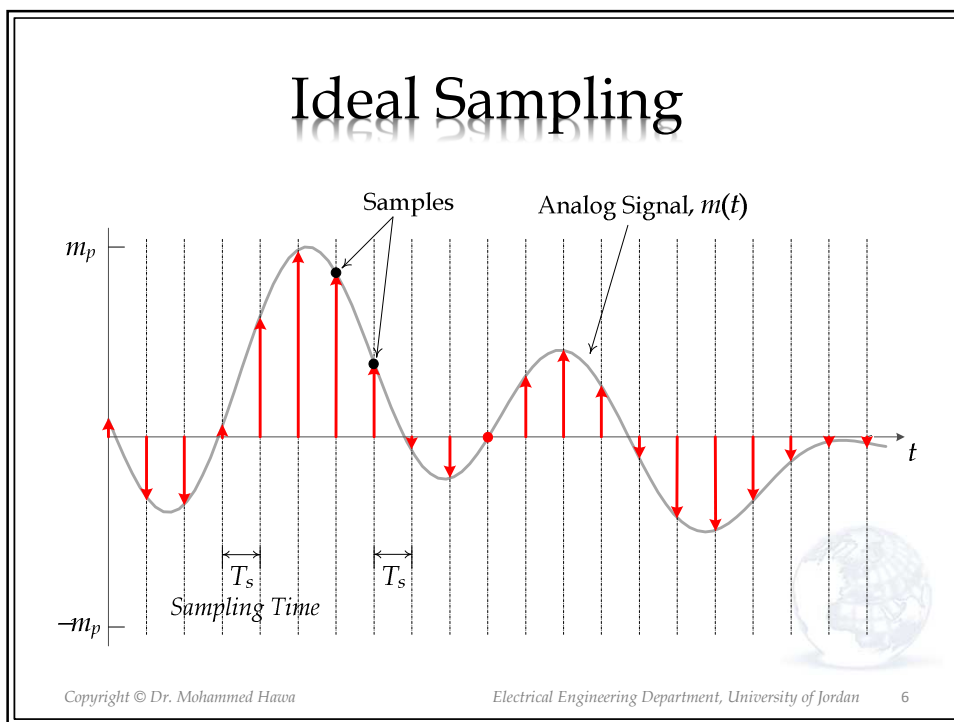
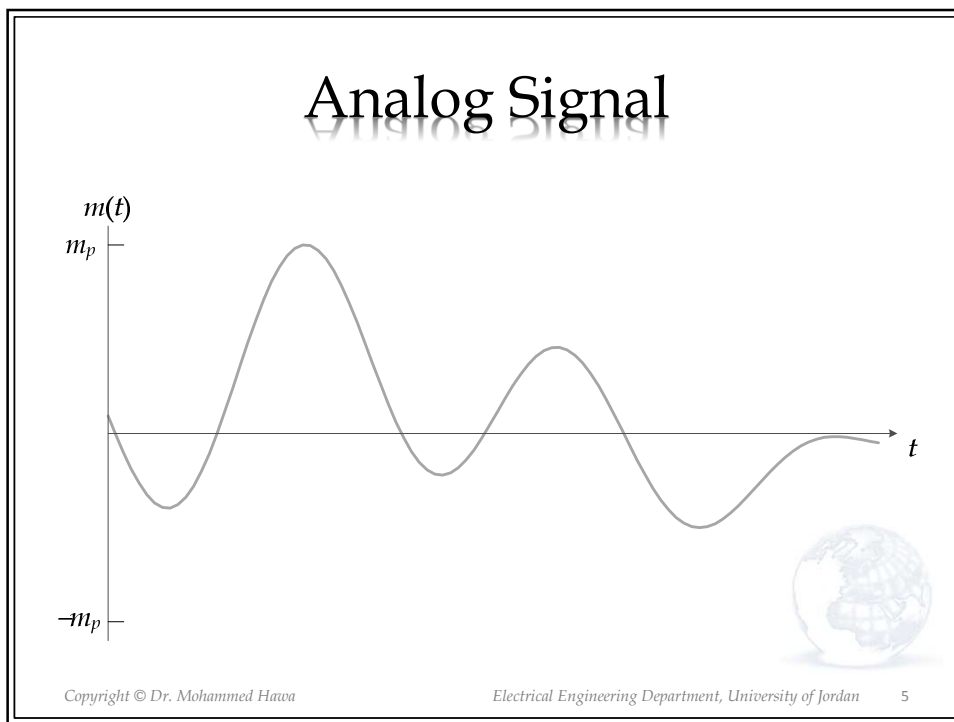
- **Sampling** (discrete analog signal).
- **Quantization** (quantized discrete signal)
- **Mapping** (stream of 1's and 0's).
- **Encoding and Pulse Shaping** (digital baseband signal).

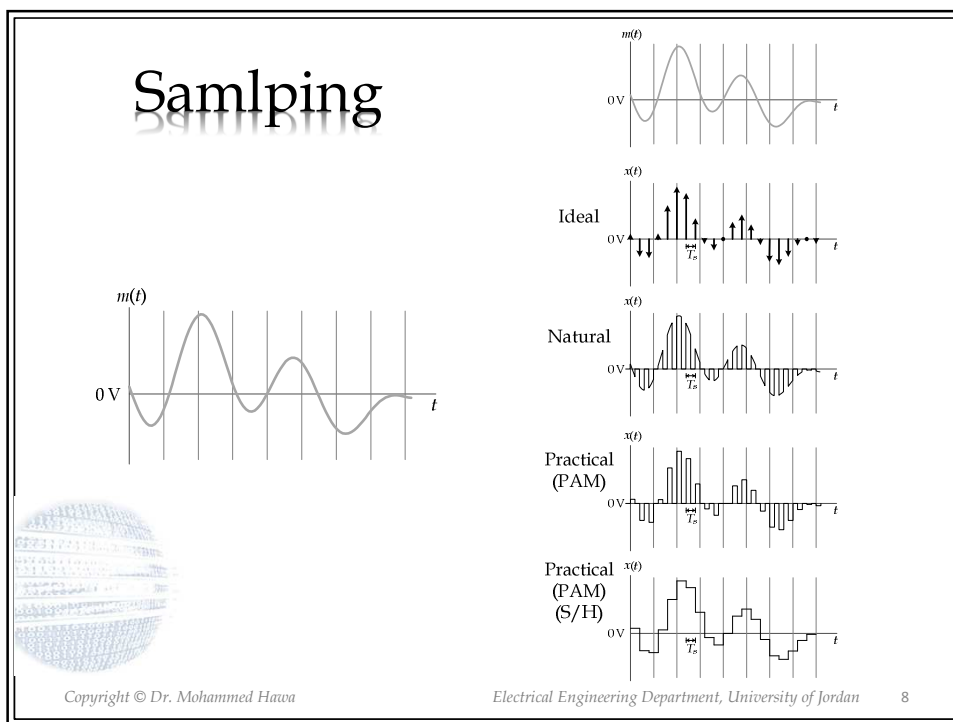
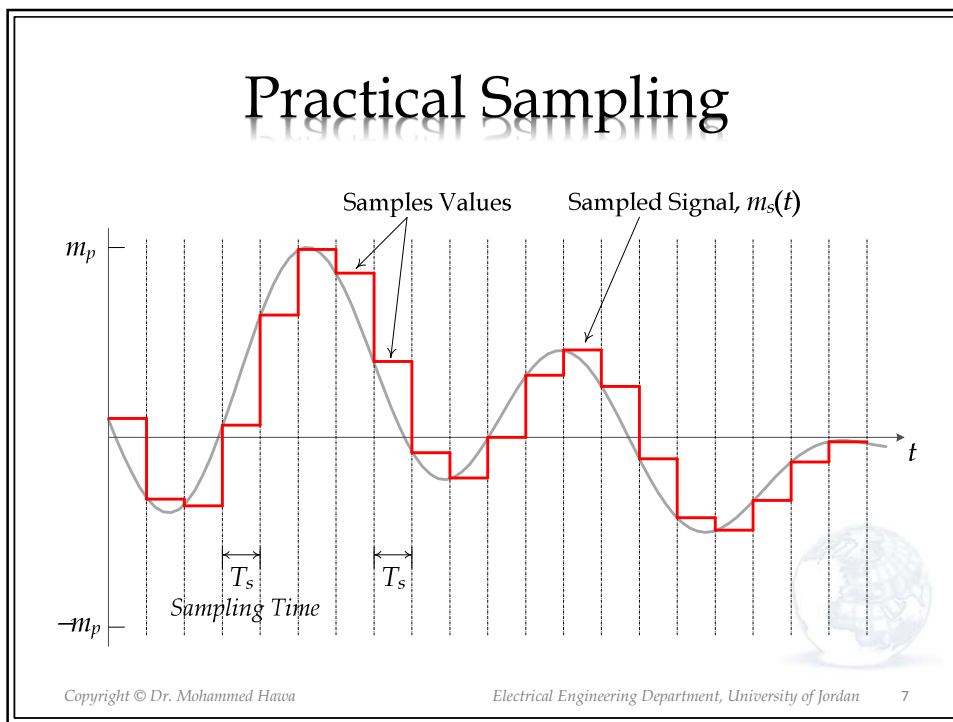


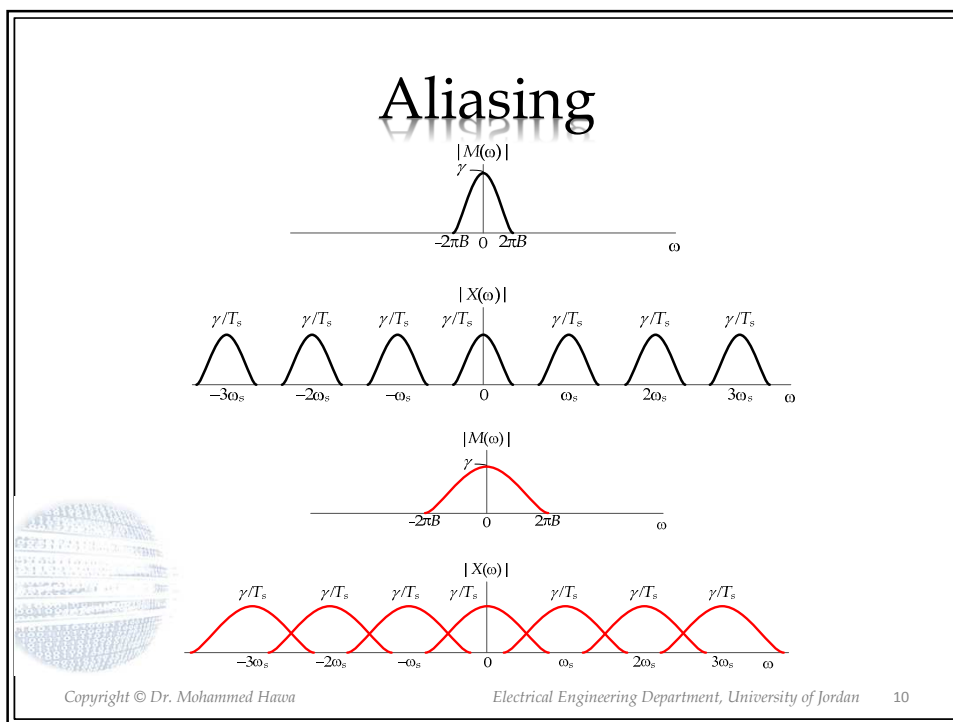
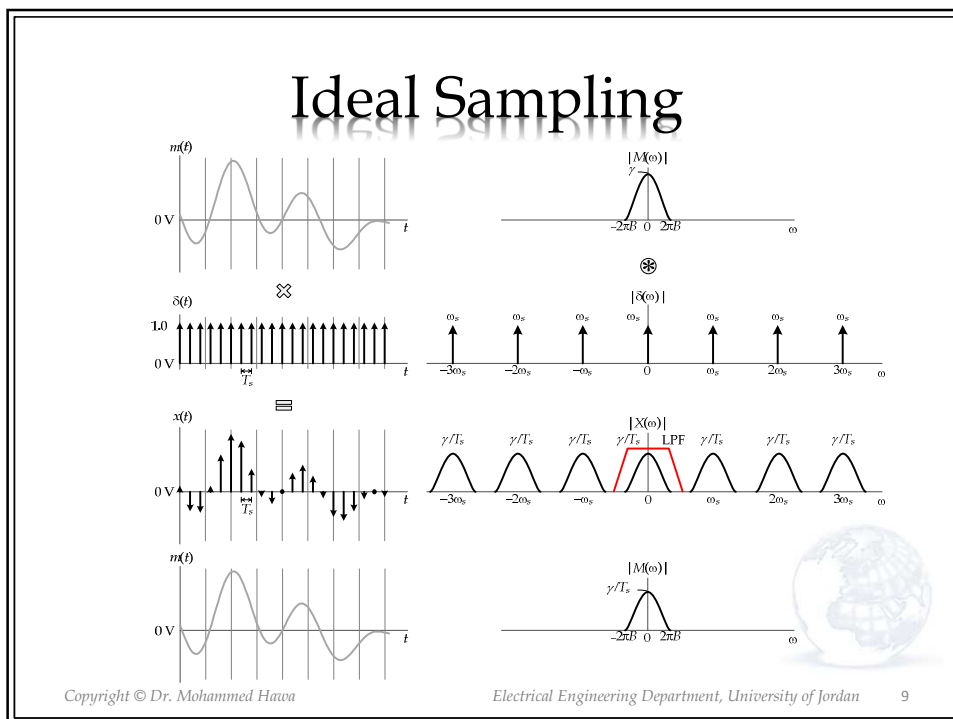
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Anti-Aliasing Filter

TX: $m(t) \rightarrow$ LPF \rightarrow Sampler $\rightarrow x(t)$

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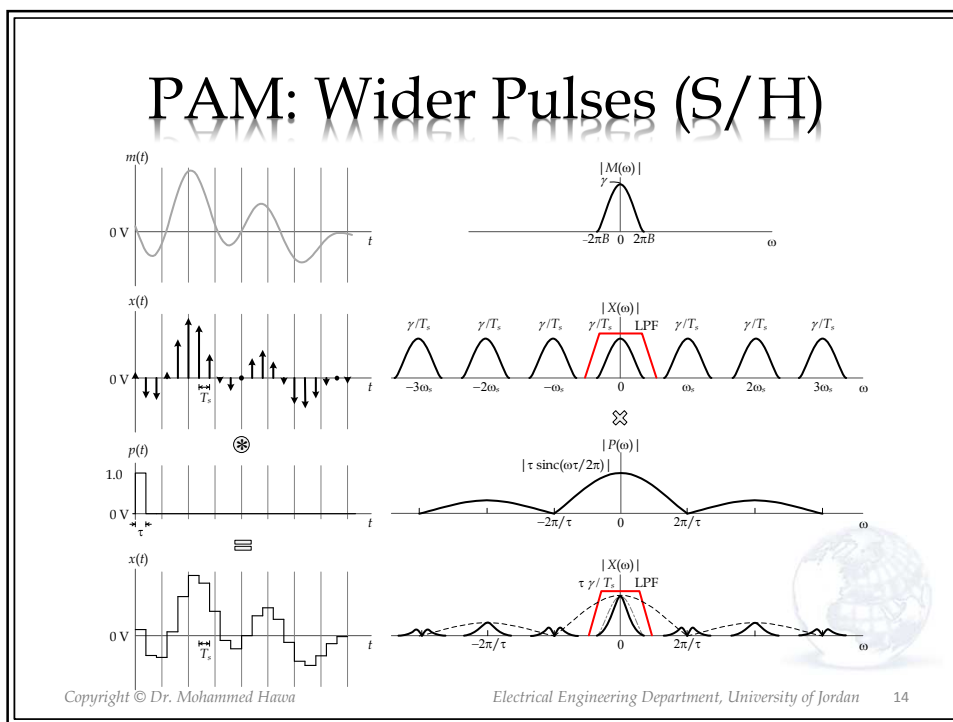
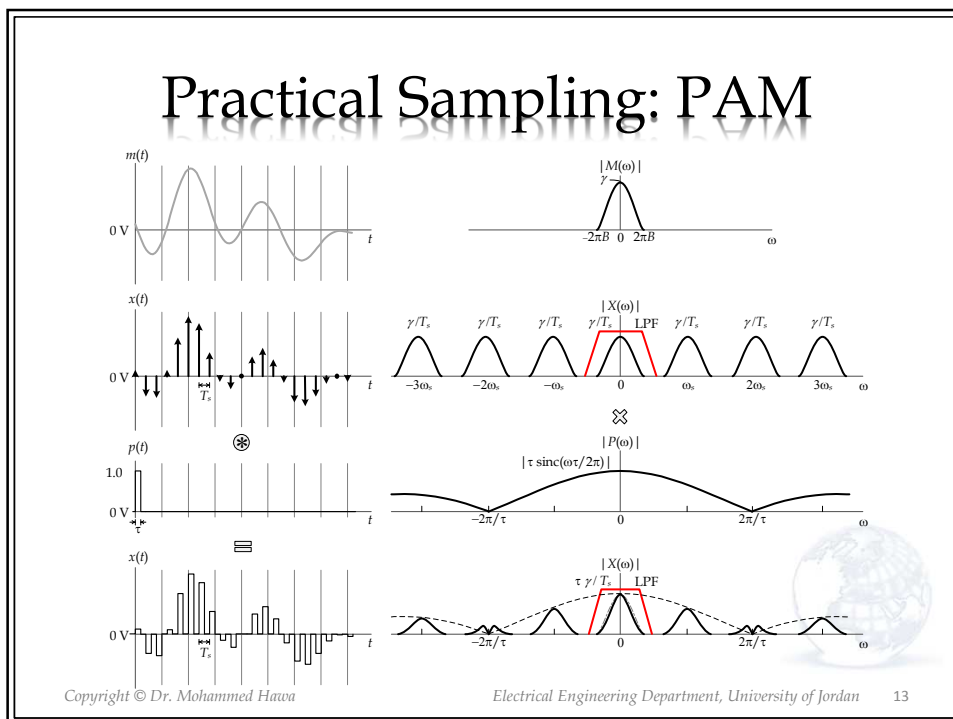
Natural Sampling

\otimes

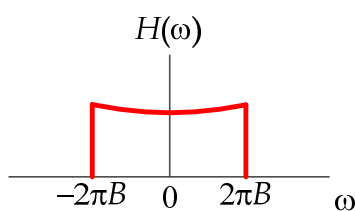
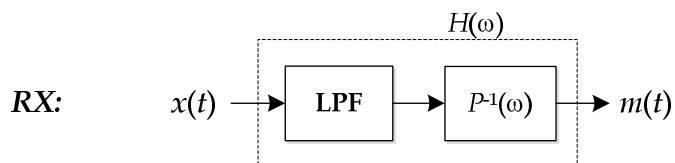
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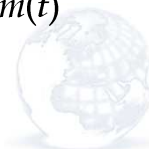
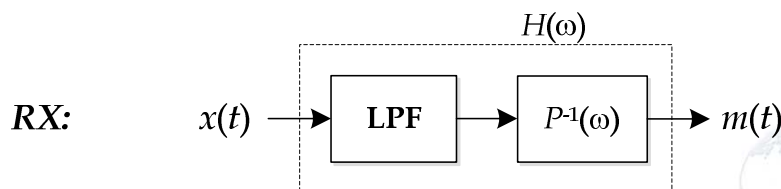
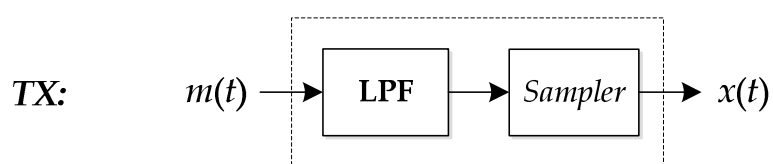
Distortion solved by Equalizer



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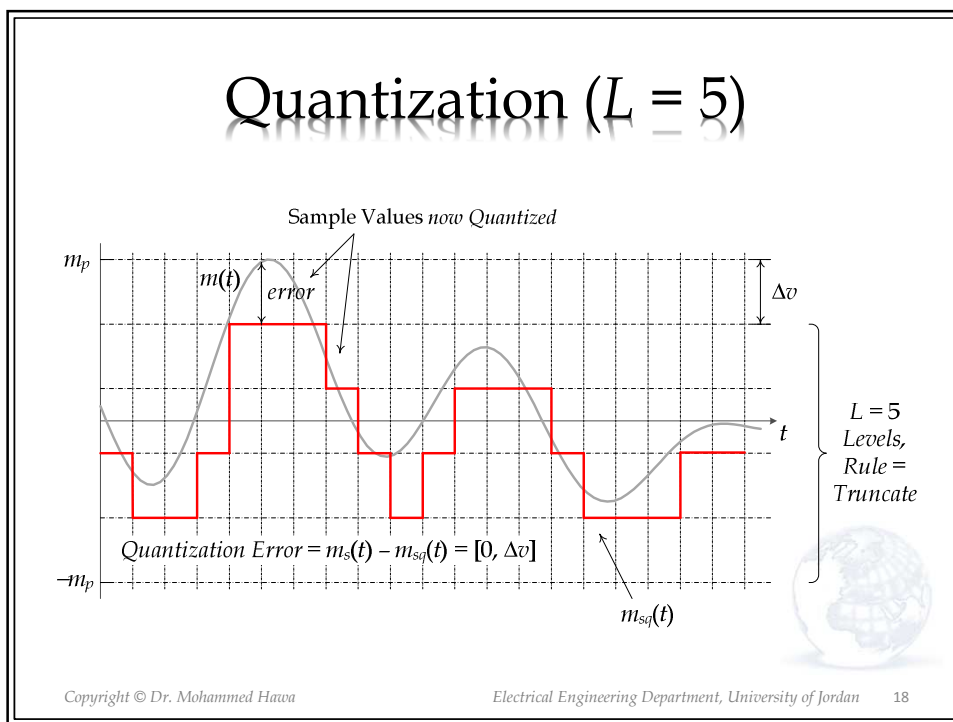
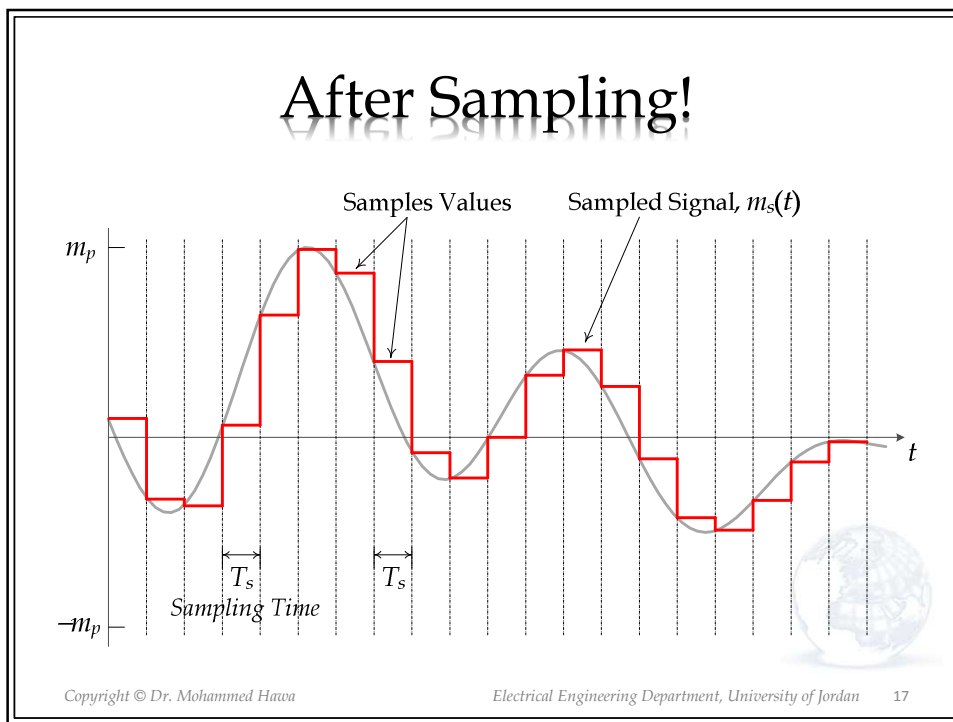
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Summary

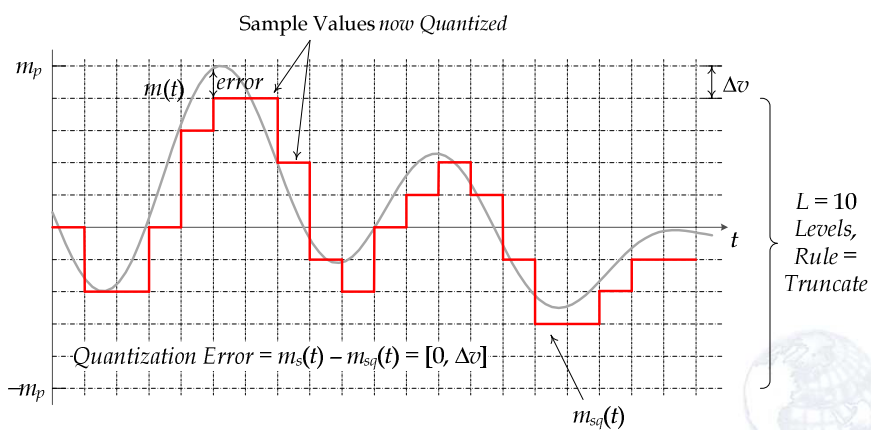


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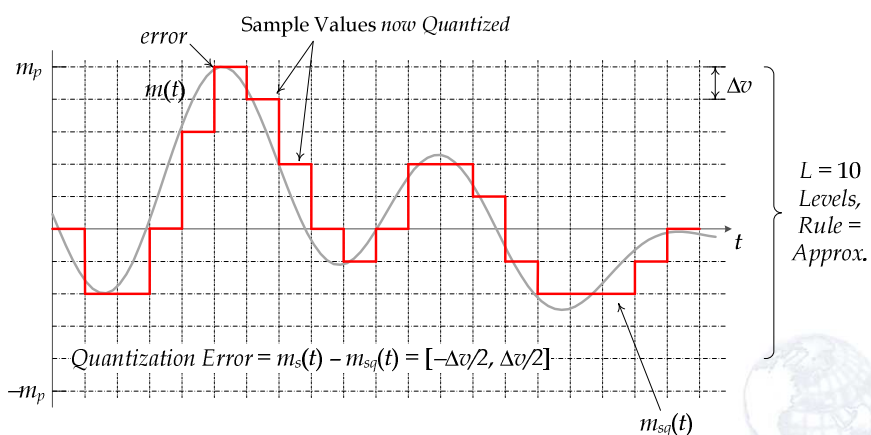
Quantization ($L = 10$)



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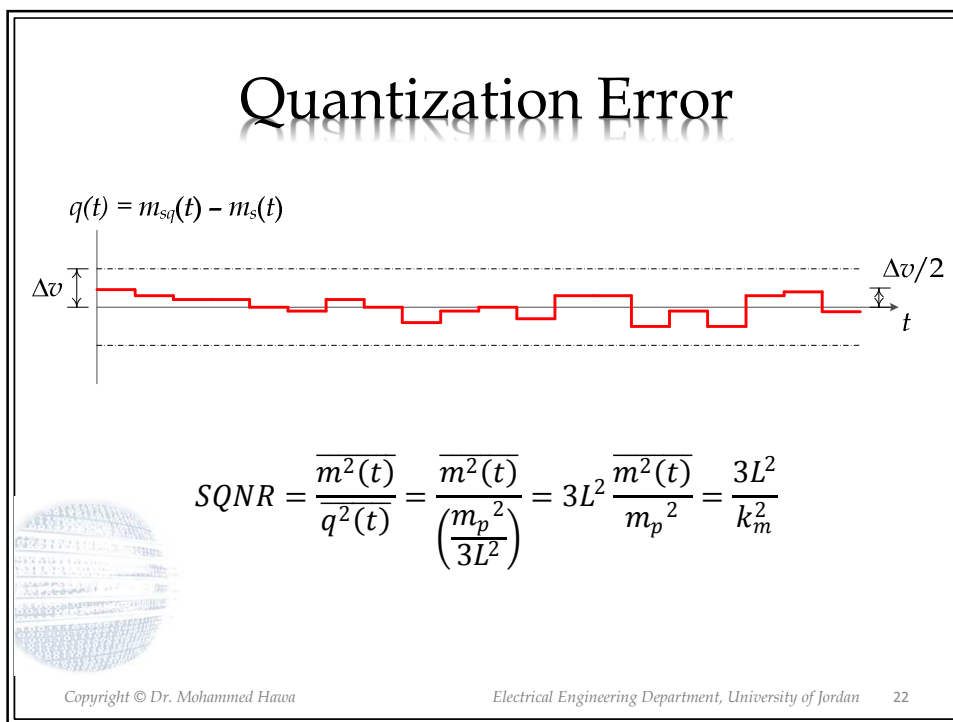
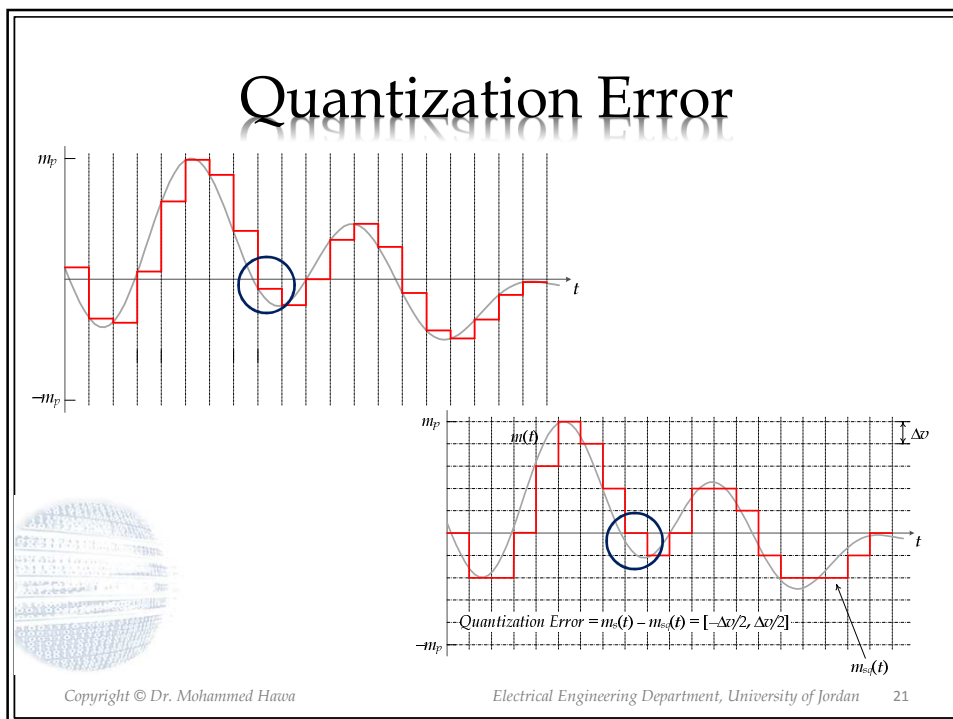
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Quantization (Approx.)

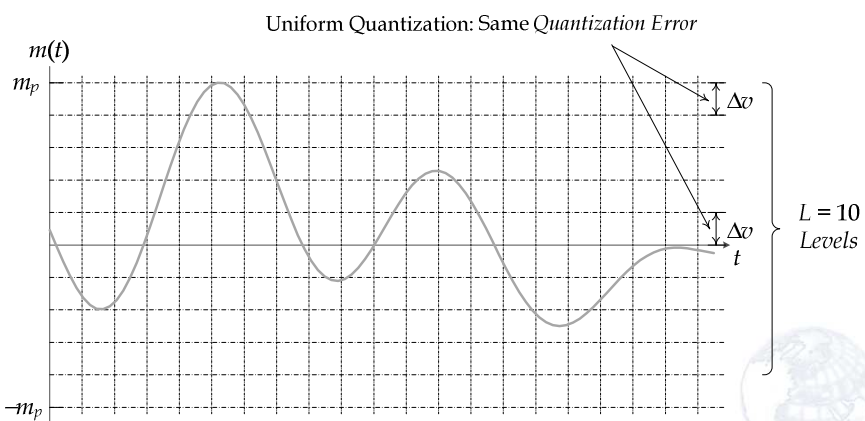


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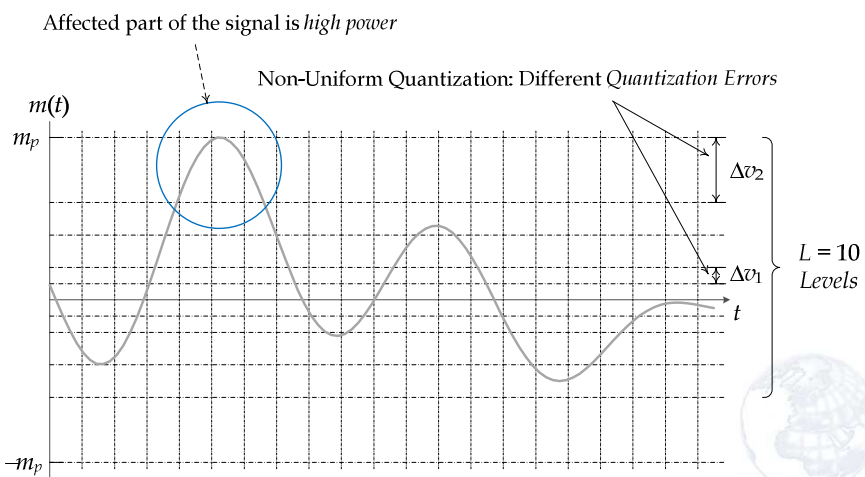
Uniform Quantization



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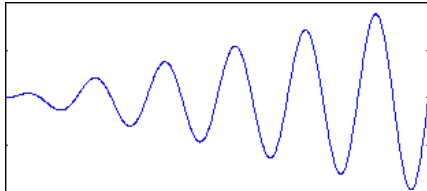
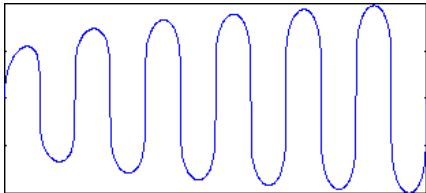
Compander




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Effect is Expansion/Compression

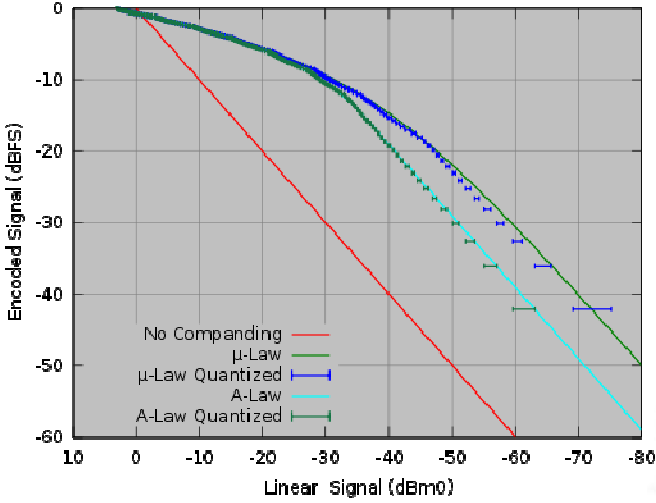






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Companding Improvement (dB)





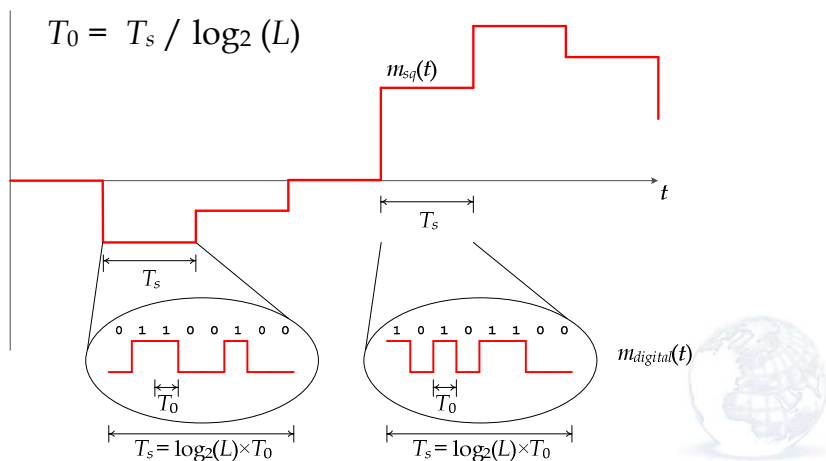
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Mapping

$$f_0 \text{ [bps]} = f_s \text{ [samples/s]} \times \log_2(L) \text{ [bits/sample]}$$

$$T_0 = T_s / \log_2(L)$$



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Source Coding



0000	→	00
0001	→	01
0010	→	1000
0011	→	1001
0100	→	1010
0101	→	1011
0110	→	110000
0111	→	110001
1000	→	110010
1001	→	110011
1010	→	110100
1011	→	110101
1100	→	110110
1101	→	110111
1110	→	111000
1111	→	111001

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Audio Compression

- Landline telephony (PCM, no compression)
 - **64 kbps**
- Linear Prediction Coding (LPC) vocoder
 - e.g., RPE-LTP (regular pulse excitation, long-term prediction) LPC codec (GSM cellular phones, Full Rate): **13 kbps**.
- Code-Excited linear Prediction (CELP) vocoder
 - Algebraic CELP(ACELP) (GSM cellular phones, Enhanced Full Rate): **12.2 kbps**
 - FS-1016 (United States Department of Defense): **4.8 kbps**



Video Compression

- | | | |
|--|---|---------------------|
| | <u>MPEG</u> | <u>ITU-T</u> |
| • MPEG-2: DVD, Digital TV Broadcasting. | MPEG-1 | H.261 |
| | ↓ | ↓ |
| • H.261: Videophone. | MPEG-2 | H.263 |
| | ↓ | ↓ |
| • H.263: Low bit rate Video Conferencing. | H.264/MPEG-4 Part 10 or AVC (<i>Advanced Video Coding</i>) | |
| | ↓ | ↓ |
| • H.264: Almost everything. | H.265/MPEG-H Part 2 or HEVC (<i>High Efficiency Video Coding</i>) | |

- ITU-T: International Telecommunication Union - Telecommunication
- MPEG: Moving Picture Experts Group

Channel Coding

1110010101111010001010100

→ 1110010101111010001010100**1011**

→ 1110010101~~0~~1010001010100**1011**

→ 1110010101111010001010100



$$C = B_{ch} \times \log_2(1 + SNR)$$