DIGITAL COMMUNICATION

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PCM AND QUANTIZATION

Recap on Digital Communication System
Pulse Coded Modulation (PCM)
Quantization and Types

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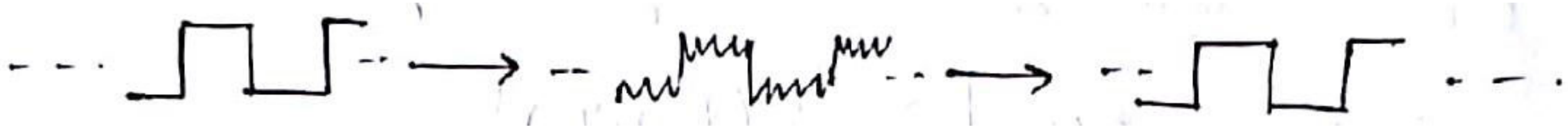
WHY DIGITAL COMMUNICATION?

Recap

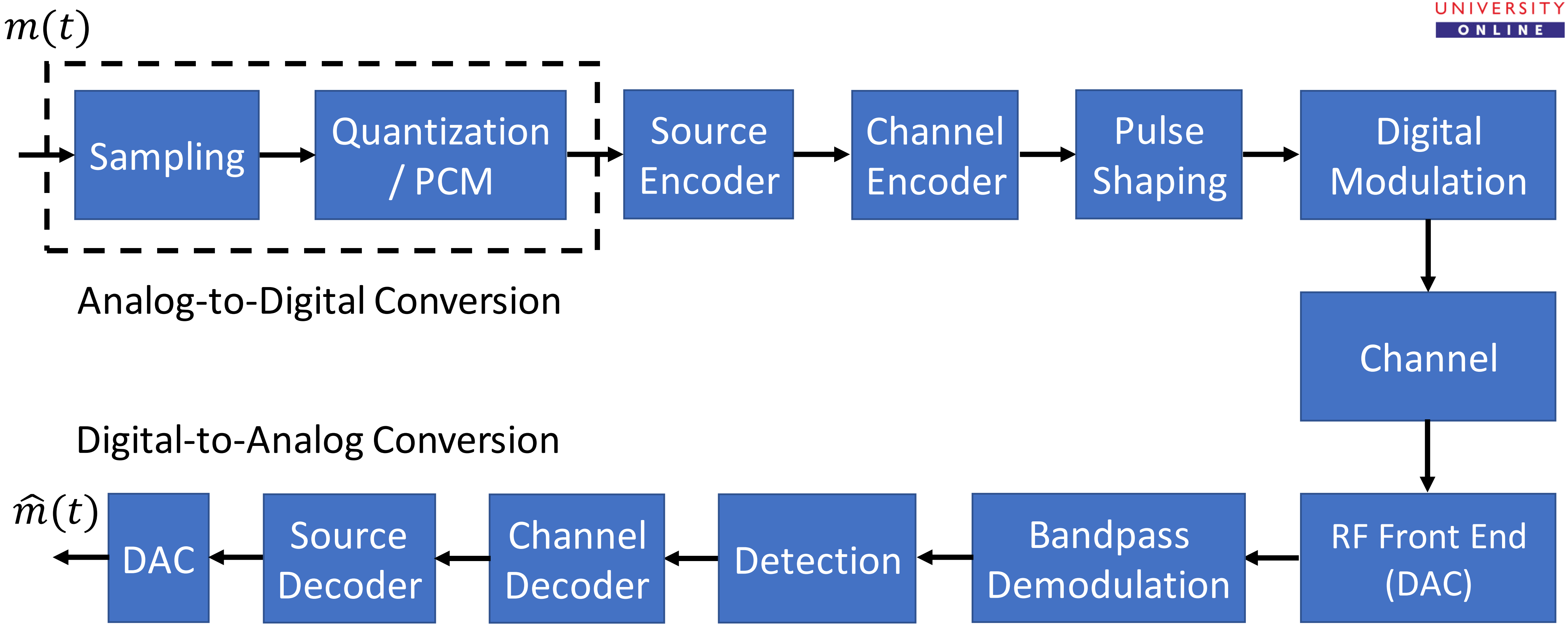
- “Better” representation in terms of 0s and 1s
- In analog communication, distortion due to channel effects and noise are severe and cannot be undone as opposed to digital



- Can store data on a computer
- Common format/protocol for communication/storage for different types of signals: Voice, image, video, biomedical data, etc.
- Data compression, error correction and encryption can be performed
- Processor/algorithmic approach in place of components/circuits
- Without digital data and communication we would not have conceived internet, wireless communication and other modern technologies!

BLOCK DIAGRAM OF A DIGITAL COMMUNICATION SYSTEM

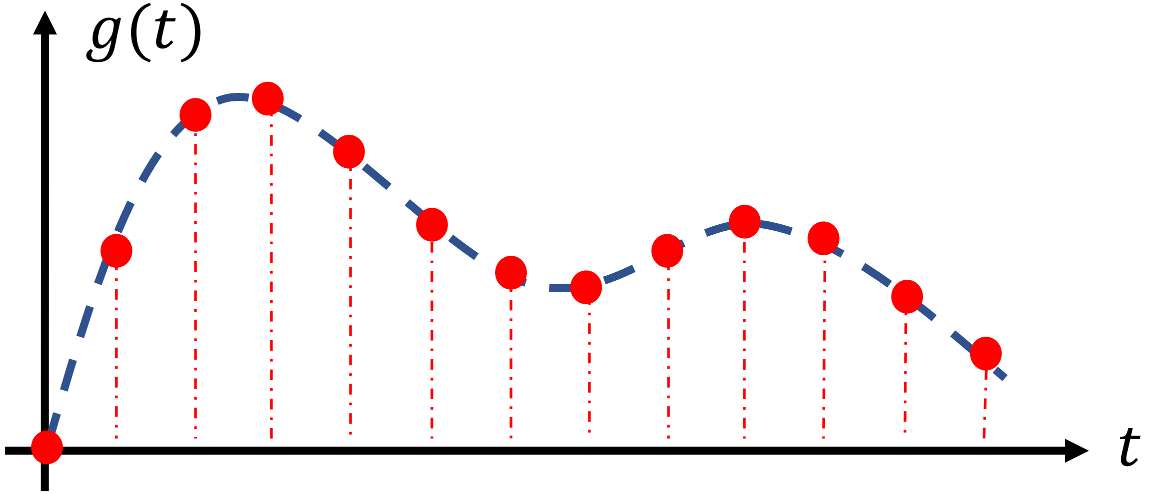
Recap and More Details

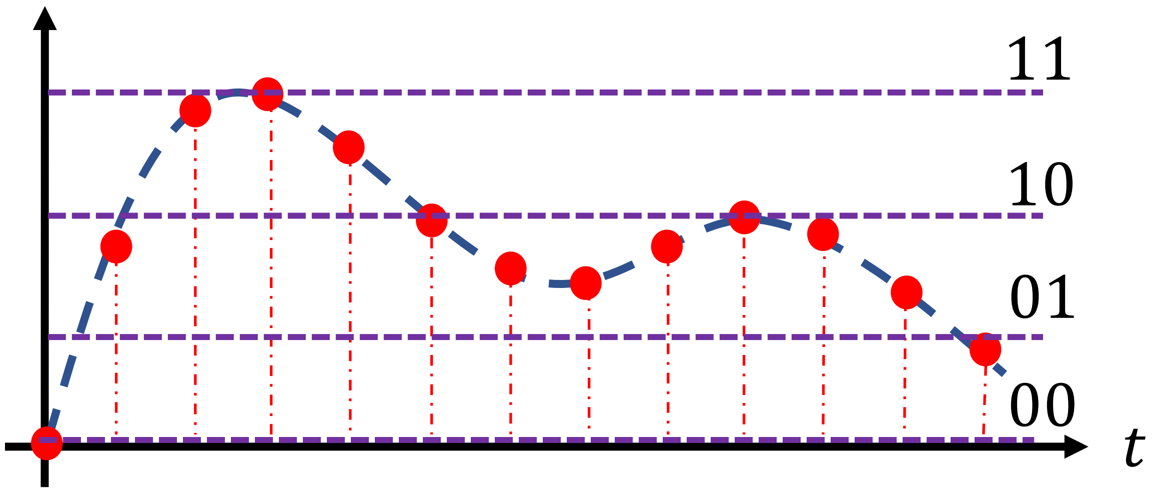


SAMPLING

Recap

- Sampling is a process that
  - Converts a continuous-time signal to a discrete-time signal
  - Converts a continuous-time random process to a discrete-time random process
  - Discrete-time random process – Indexed set of random variables in discrete-time, i.e., a sequence of random variables
  - Each sample has an amplitude taken from a continuous range of values
- Perfect reconstruction is possible when sampled at Nyquist rate $f_s \geq 2W$ Hz





PULSE CODED MODULATION (PCM)

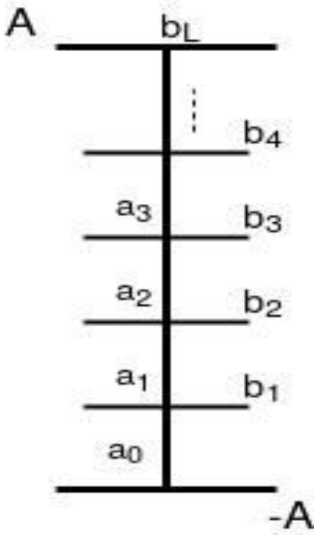
Quantization and Bit Encoding

- PCM is the process of representing the sequence of samples by a sequence of bits
- Each sample is represented by a bit pattern. Works on amplitude and not on time
- PCM involves two steps:
  1. Quantization
  2. Bit Encoding
- Quantization: Approximating each sample by the nearest value from a discrete set of values
- We assume that all sample values are within the overload represented by $\pm A$ V
- The range $[-A, A]$ is divided into L levels. Each sample is approximated by the mid-point of the level it belongs to
- Quantization converts a set of continuous random variables to a set of discrete random variables

QUANTIZATION

Quantization Equations

- The range $[-A, A]$ is divided into L levels. Let $b_0, b_1, b_2, \dots, b_L$ indicate the level boundaries and $a_0, a_1, a_2, \dots, a_{L-1}$ indicate the mid-point of these levels
- The quantization rule is given by $y(n) = a_k$, if $b_k \leq x(n) \leq b_{k+1}$
- Suppose each sample is represented using N bits, then we have $L = 2^N$ levels
- A quantizer which divides the range [-A,A] into $L = 2^N$ levels of equal width is called as a uniform quantizer. This procedure is called as uniform quantization



- It can be seen that the step size for each level

$$\Delta = {}^{2A}/_{L}$$

- Quantization error is given by

$$q(n) = y(n) - x(n)$$

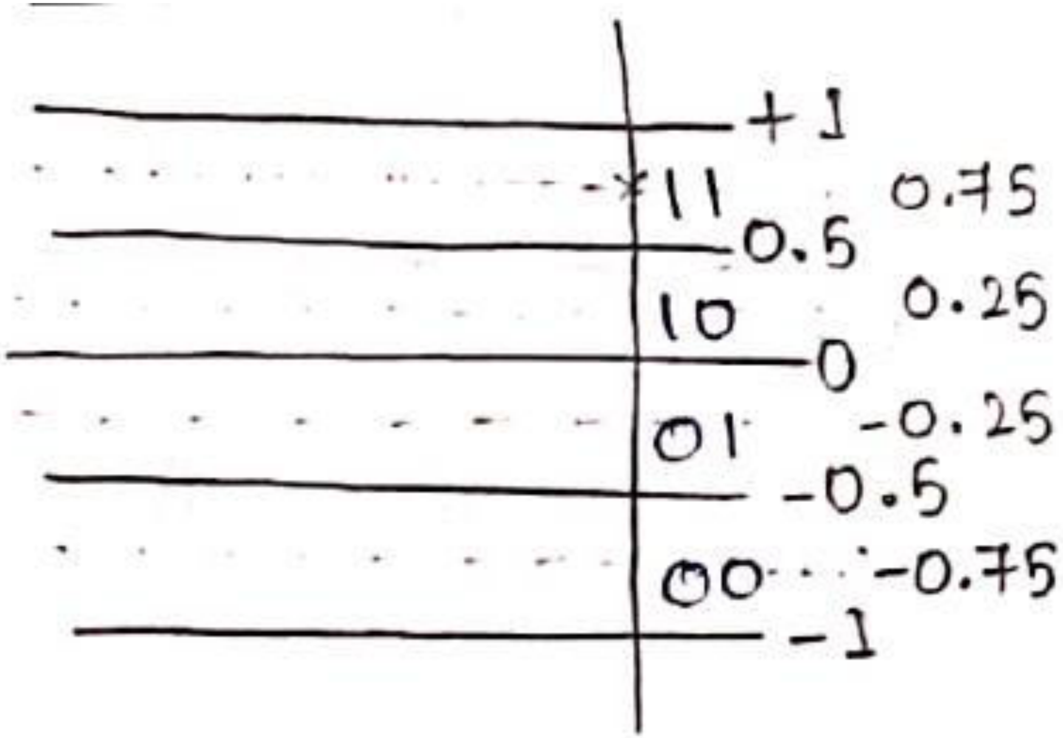
- This error cannot be corrected/removed

QUANTIZATION

An Example

Let the sequence of samples from the output of a sampler be given as

0.35, 0.51, 0.65, 0.28, -0.06, -0.43, -0.71. Design a uniform quantizer with $L = 4$, in $[-1, 1]$

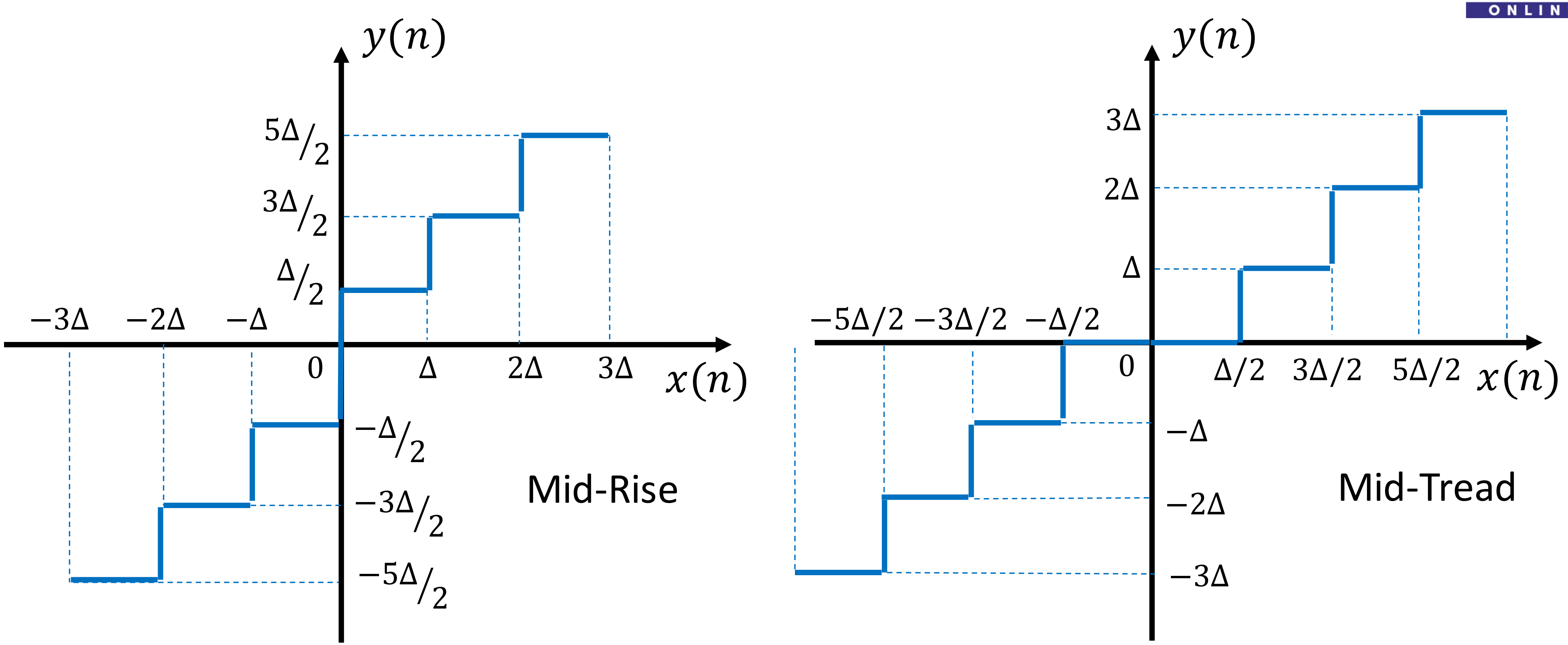


Quantization:

x(n)	y(n)	Bit Encoding
0.35	0.25	10
0.51	0.75	11
0.65	0.75	11
0.28	0.25	10
-0.06	-0.25	01
-0.43	-0.25	01
-0.71	-0.75	00

MID-RISE AND MID-TREAD QUANTIZERS

Input-Output Characteristics



MID-RISE VS. MID-TREAD QUANTIZERS

Comparison, Advantages and Disadvantages

- In mid-rise quantizer, level boundaries are $0, \pm\Delta, \pm 2\Delta, \pm 3\Delta, \ldots$, and the mid points are $\pm {}^{\Delta}/_{2}, \pm {}^{3\Delta}/_{2}, \pm {}^{5\Delta}/_{2}, \ldots$
- Mid-rise quantizer introduces a stream of samples even if no signal is present, due to the stray noise. Can be avoided by removing 0 as a boundary
- In mid-tread quantizer, level boundaries are $\pm {}^{\Delta}/_{2}, \pm {}^{3\Delta}/_{2}, \pm {}^{5\Delta}/_{2}, \ldots$, and the mid points are $0, \pm\Delta, \pm 2\Delta, \pm 3\Delta, \ldots$
- Boundaries and mid points are flipped for both mid-rise and mid-tread
- The stray noise problem is avoided in mid-tread
- The number of levels in mid-rise is $L = 2^N$, and the step size $\Delta = {}^{2A}/_{2^N}$
- The number of levels in mid-tread is $L = 2^N - 1$, and the step size $\Delta = {}^{2A}/_{2^{N}-1}$

THANK YOU

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