BFF3302 SENSOR AND INSTRUMENTATION SYSTEM

ADC/DAC

By

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Chapter Description

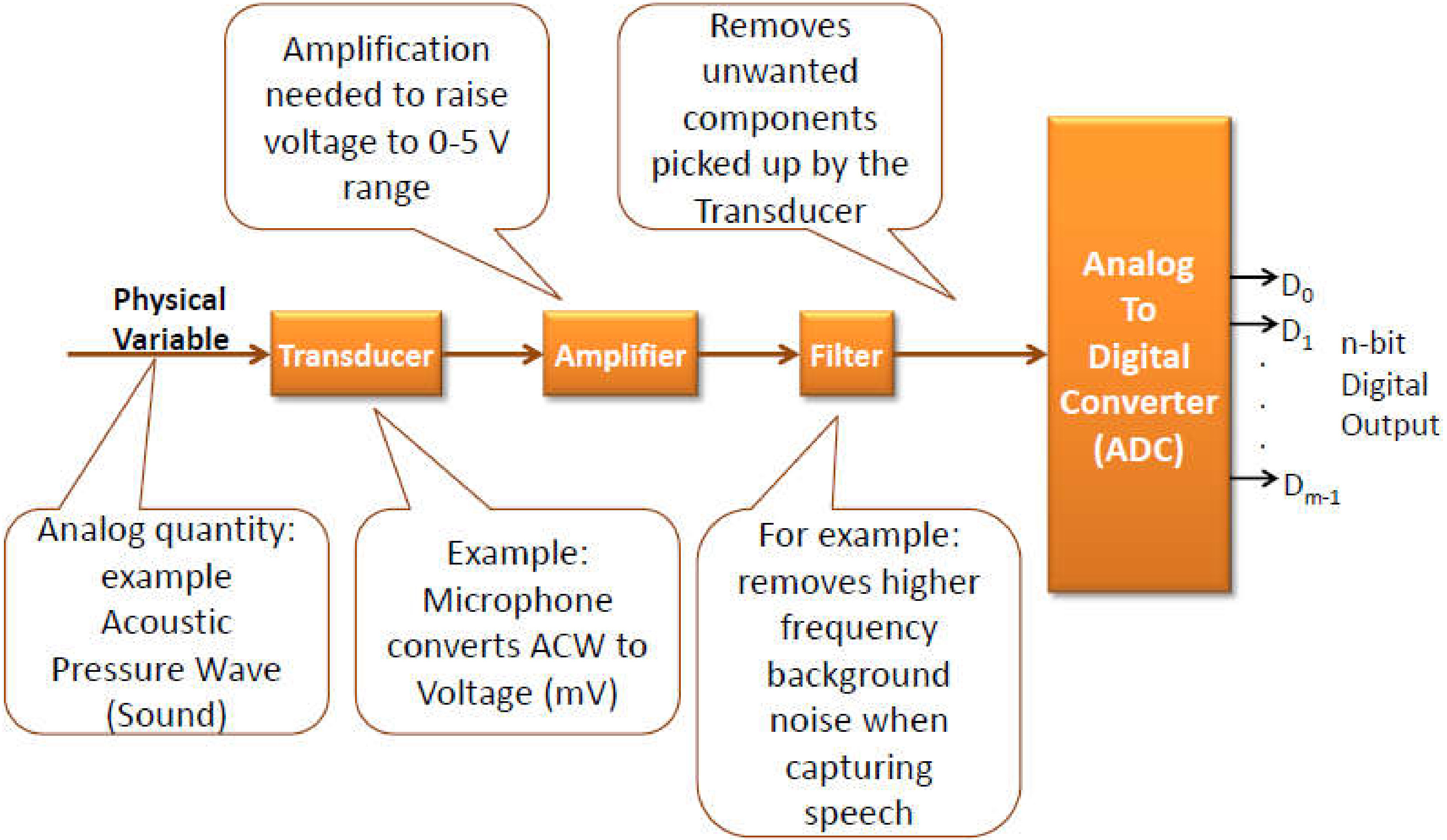
- Aims
  - Obtain basic knowledge about ADC/DAC.

- Expected Outcomes
  - Understanding in describing the principle of ADC/DAC.

- References

  - http://ece.eng.umanitoba.ca/undergraduate/ECE3610/LectureNotes/Lecture%2021%20ADC.pdf
  - http://ume.gatech.edu/mechatronics_course/ADC_F08.pdf
  - http://users.ece.utexas.edu/~valvano/Volume1/Lec10.ppt
  - B.C.Nakra and K.K. Chaudhry, 2012. Instrumentation measurement and analysis, 3rd ed., Tata-McGraw-Hill.

Analog to digital converter (ADC)



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What is ADC

- ADC → electronic integrated circuit → **transforms signal from analog (continuous) to digital (discrete)** form.
- Analog signals → directly measurable quantities.
- Digital signals → have two states (binary).

Why ADC is needed?

- Microprocessors → perform complex processing on **digitized signals**.
- Digital signals are less susceptible to additive noise.

Application of ADC

- ADC: analog signal need to process, store, or transporte in **digital form**.
- Examples of ADC: **volt meters**, **cell phone**, **thermocouples**, **digital oscilloscope**.
- Commonly use microcontroller 8, 10, 12, or 16 bit ADCs.

A-D and D-A converters

- An analog output form any electromechanical transducer may be in certain cases, have to be converted to a digital form especially where a **digital computer** has to be used.

- This done by using an A-D converter between the transducer and the computer or a digital recording element.

- The reverse is also possible using D-A converters.

DIGITIZATION PROCESS

1. Sample analog signal at discrete points → periodic intervals.

2. For each sample → round off the analog voltage value to a discrete voltage value.

A-D converters

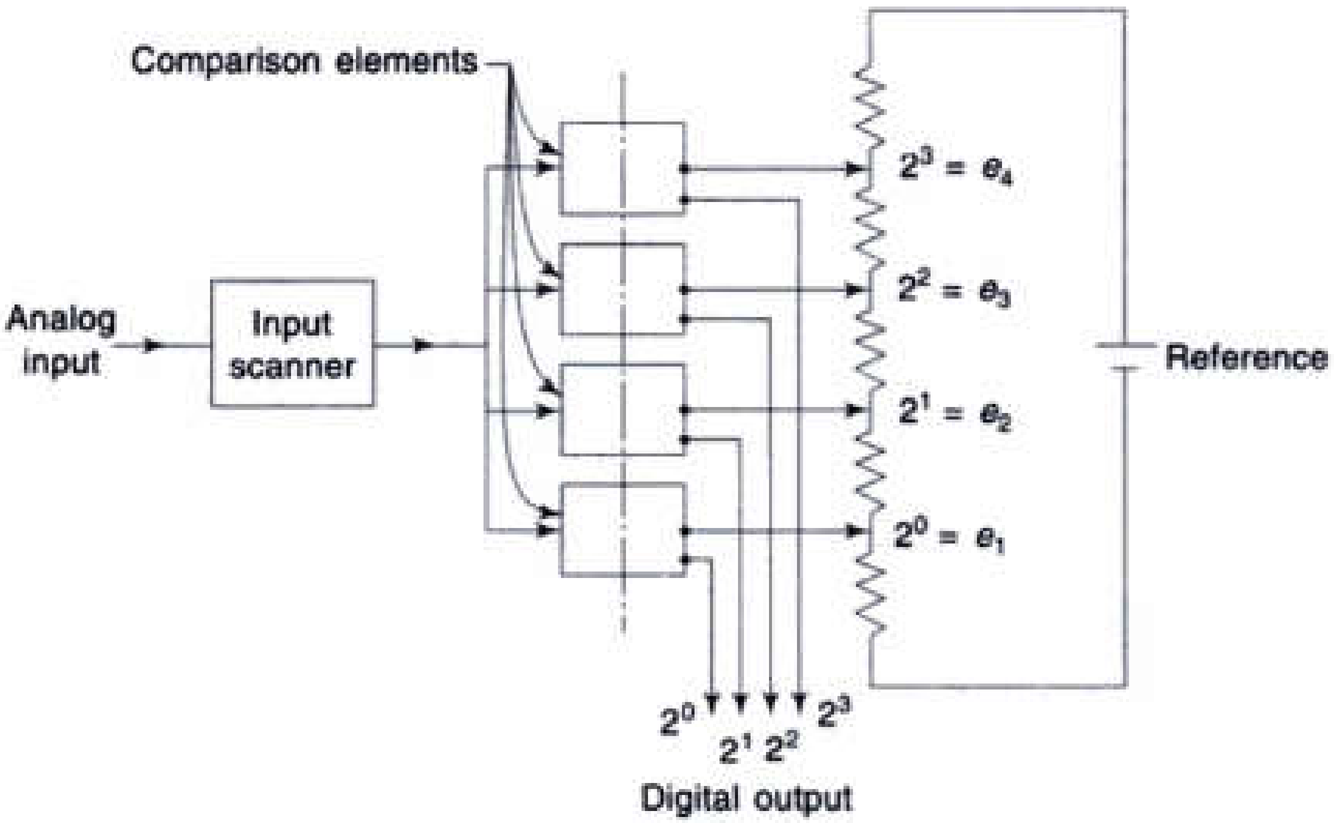
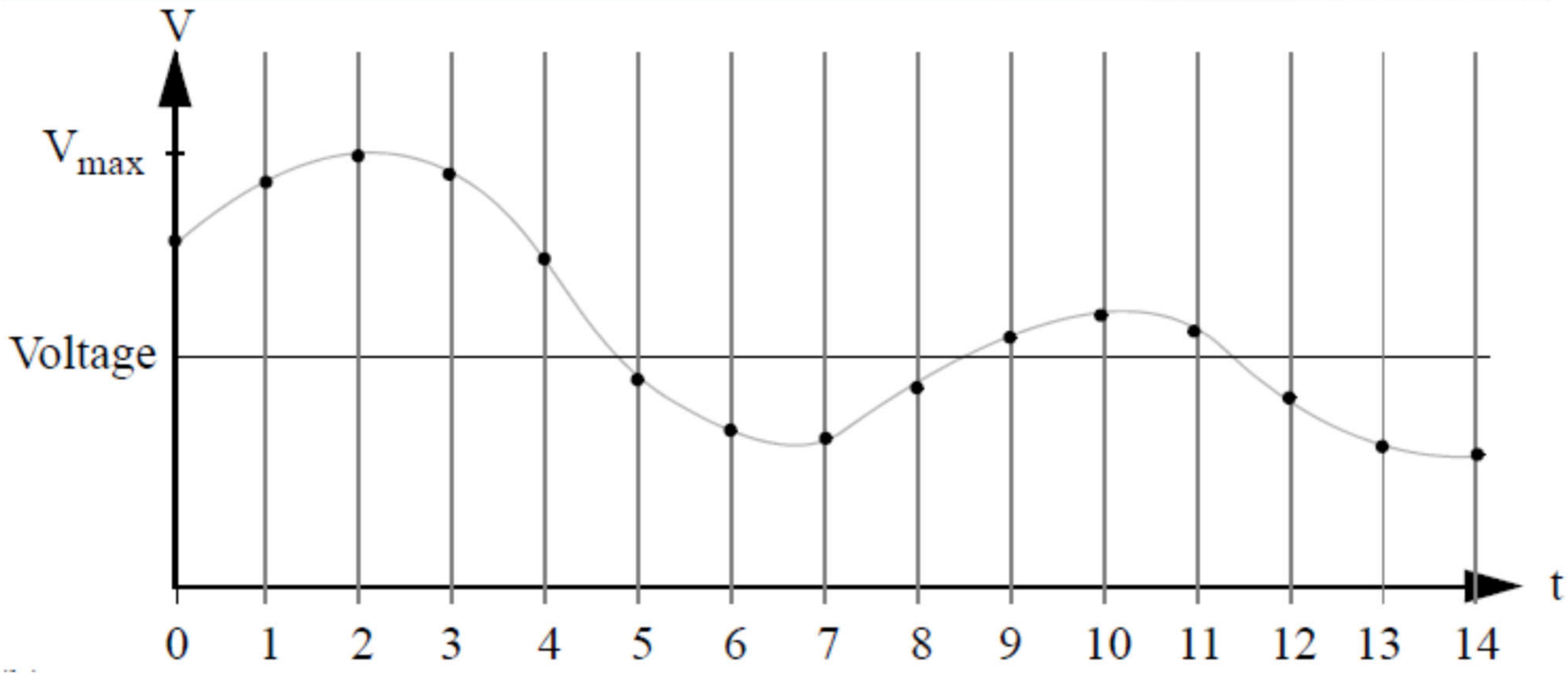


Fig. 5.30 *Potentiometric type A–D converter*

B.C.Nakra and K.K. Chaudhry, 2012. Instrumentation measurement and analysis, 3rd ed., Tata-McGraw-Hill.



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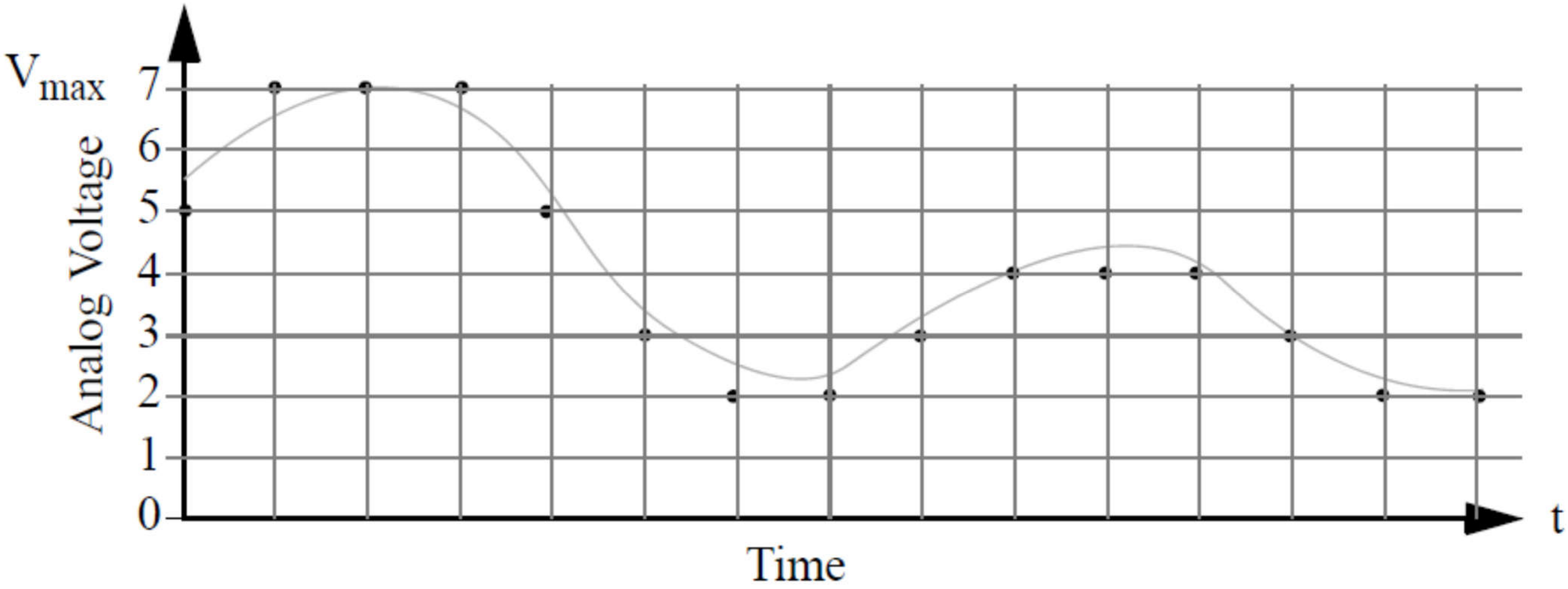

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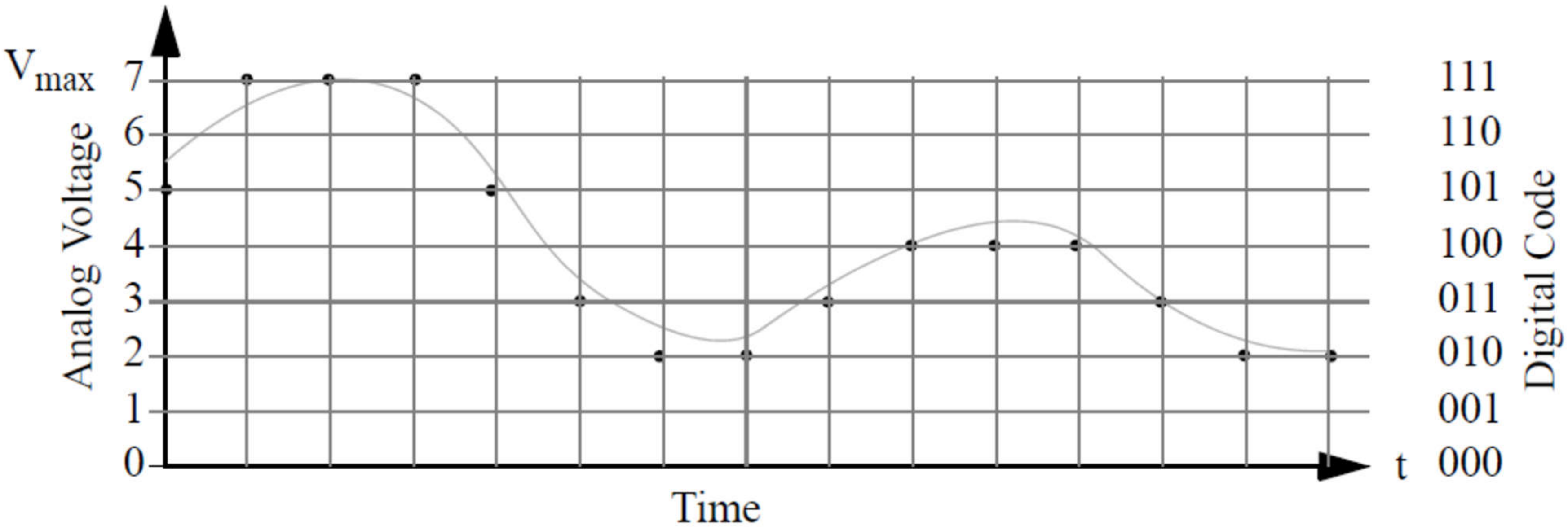

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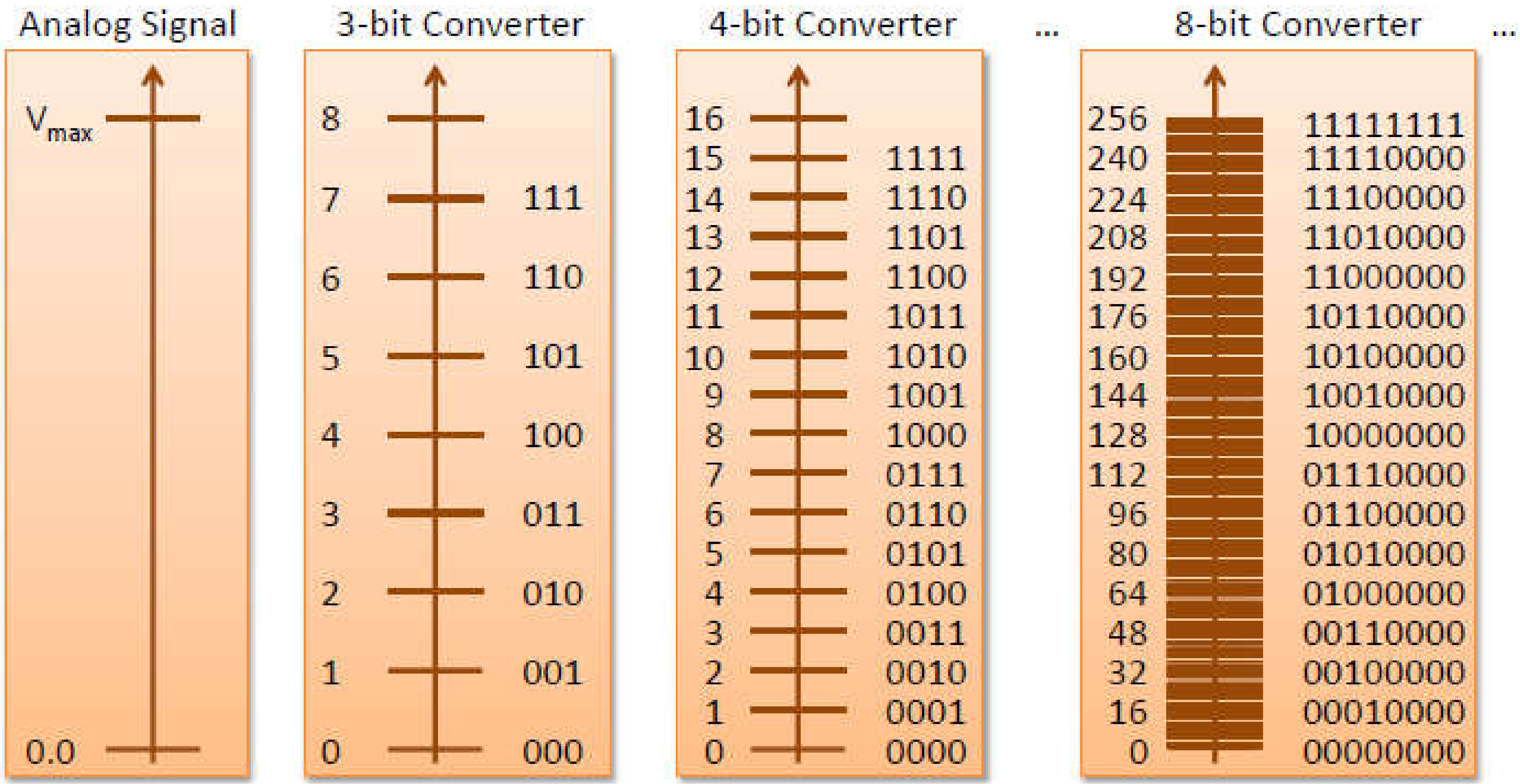

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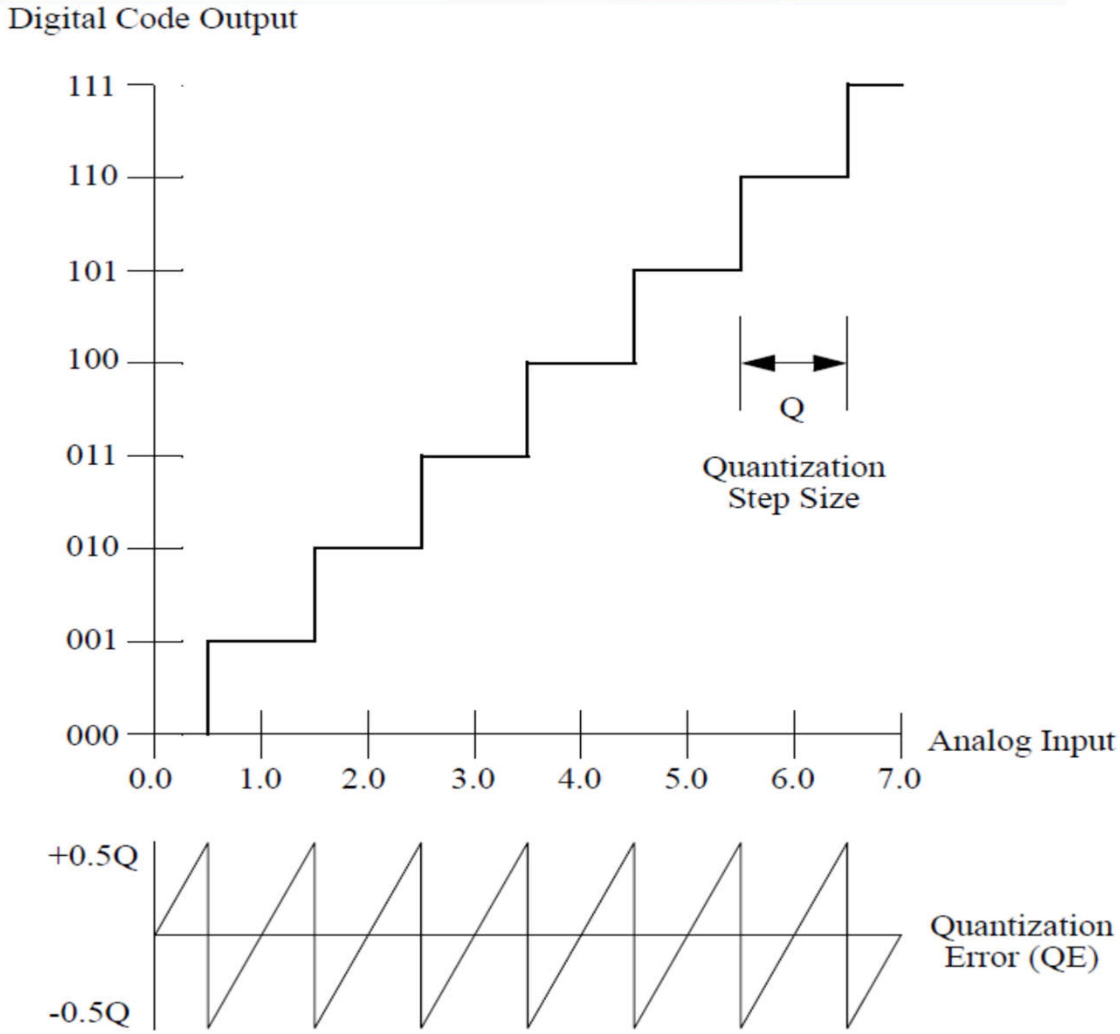
ROUND-OFF ERROR (QUANTIZATION ERROR)



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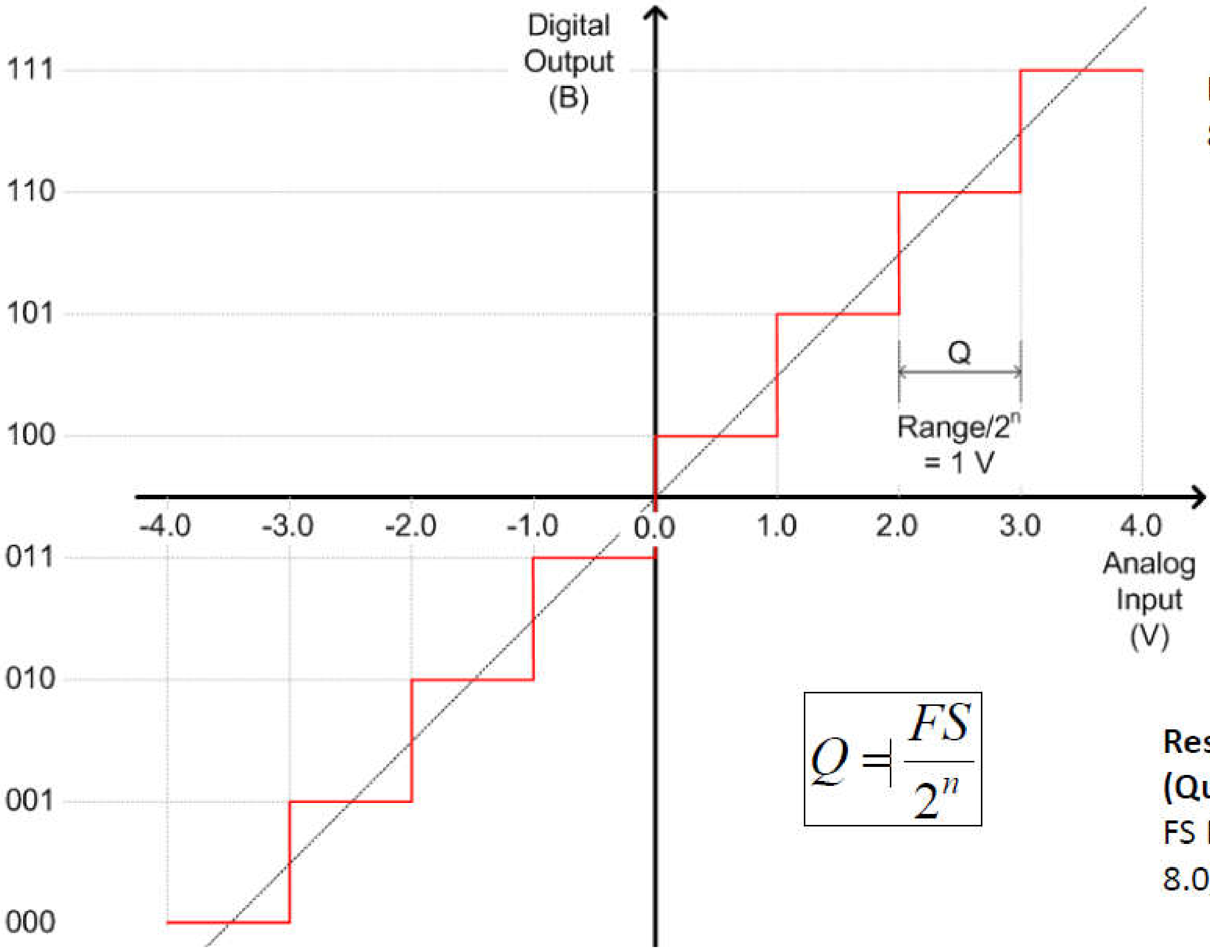
3-BIT BIPOLAR EXAMPLE (LACKS A DIGITAL ZERO REPRESENTATION)



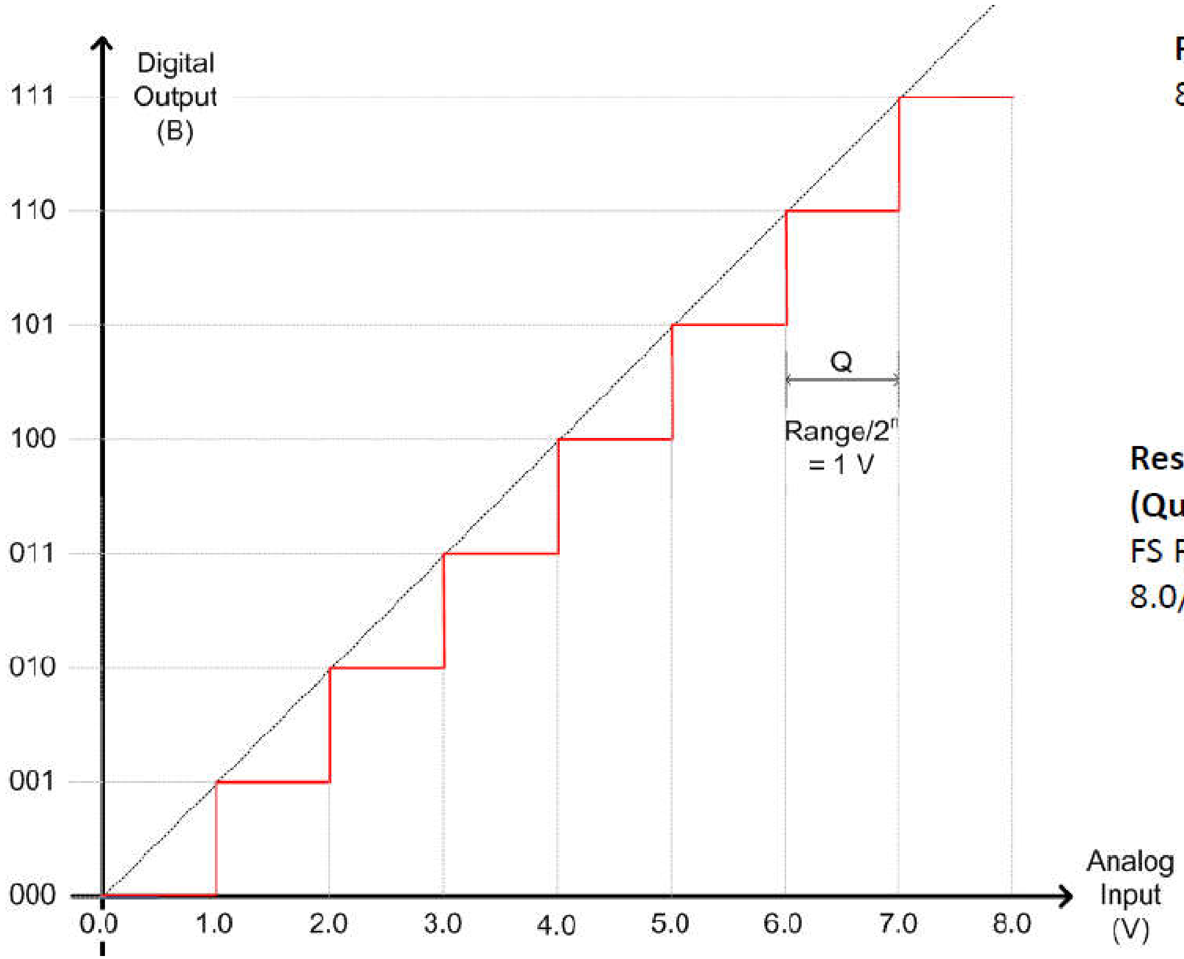
$$Q = \frac{FS}{2^n}$$

Full Scale (FS) Range:
8.0 V

Precision:
3-Bit,
8 Possibilities

Resolution
(Quantization Step Size, Q):
FS Range/Number of Steps
8.0/8 = 1.0 V

3-BIT UNIPOLAR EXAMPLE (HAS DIGITAL ZERO REPRESENTATION)



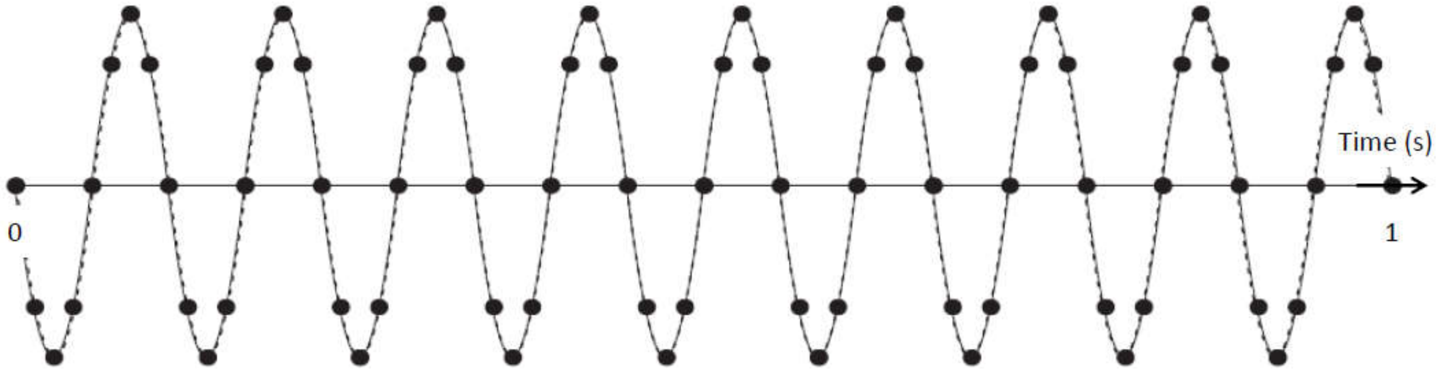
Full Scale (FS) Range:
8.0 V

Precision:
3-Bit,
8 Possibilities

Resolution (Quantization Step Size, Q):
FS Range/Number of Steps
8.0/8 = 1.0 V

$$Q = \frac{FS}{2^n}$$

SAMPLING RATE



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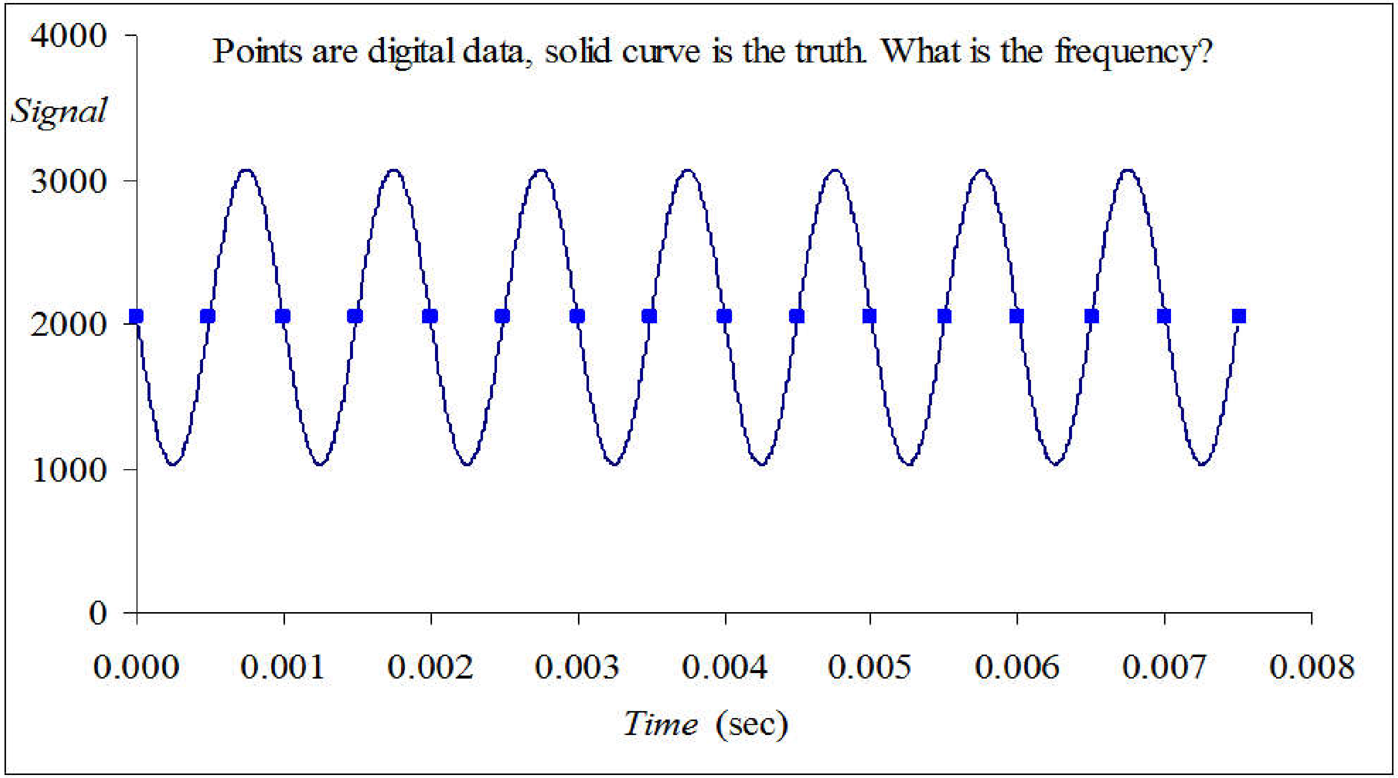
❑1000Hz signal sampled at 2000Hz



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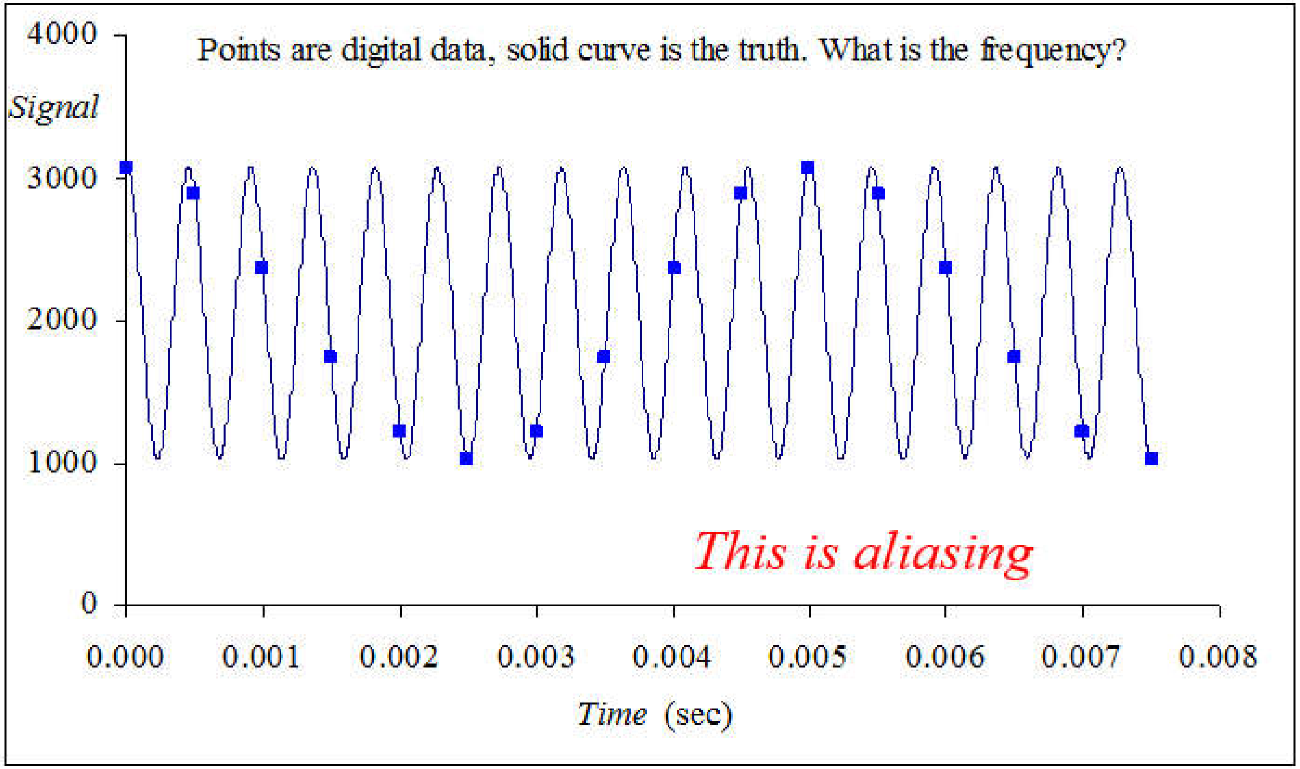
❑2200Hz signal sampled at 2000Hz



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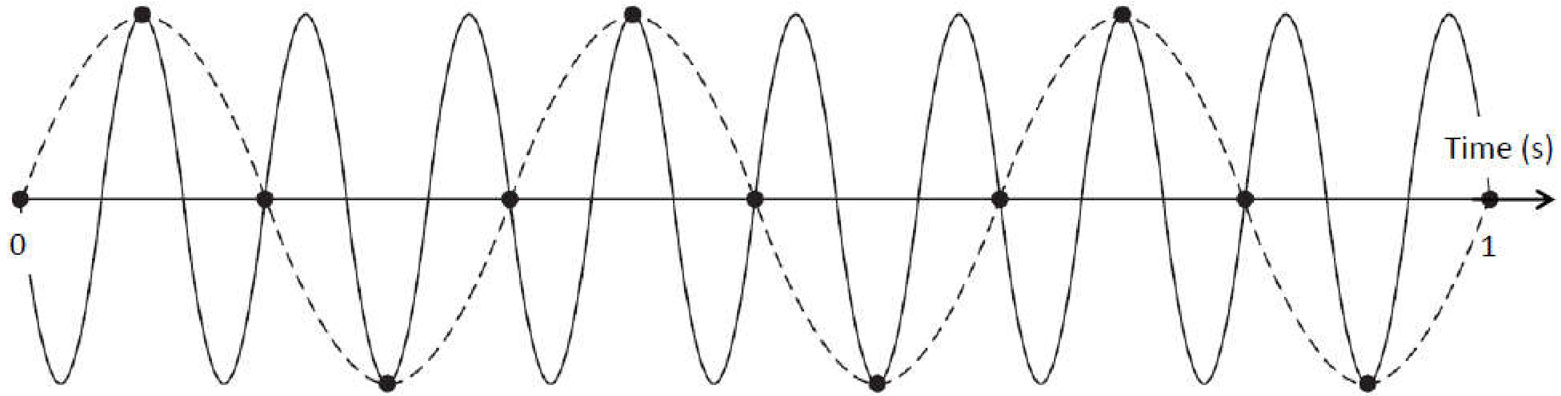
Not Enough Samples



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NYQUIST-SHANNON SAMPLING THEOREM - NYQUIST RATE

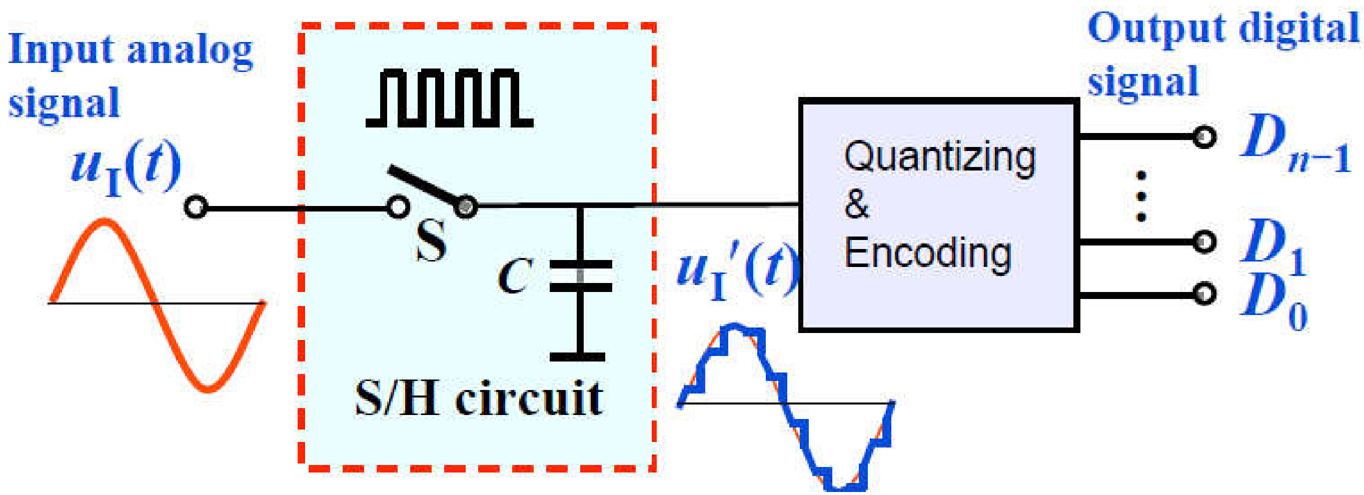
$$f_s > 2f_c$$

Sampling Frequency

Highest Frequency Component In Signal

"If a continuous signal containing no frequency components higher than f_c is sampled at a rate greater than $2f_c$, then the original signal can be completely recovered from the sampled version without any error, except for the voltage quantization error (round-off error)."

ADC process



2 steps:

- Sampling and Holding (S/H)
- Quantizing and Encoding (Q/E)

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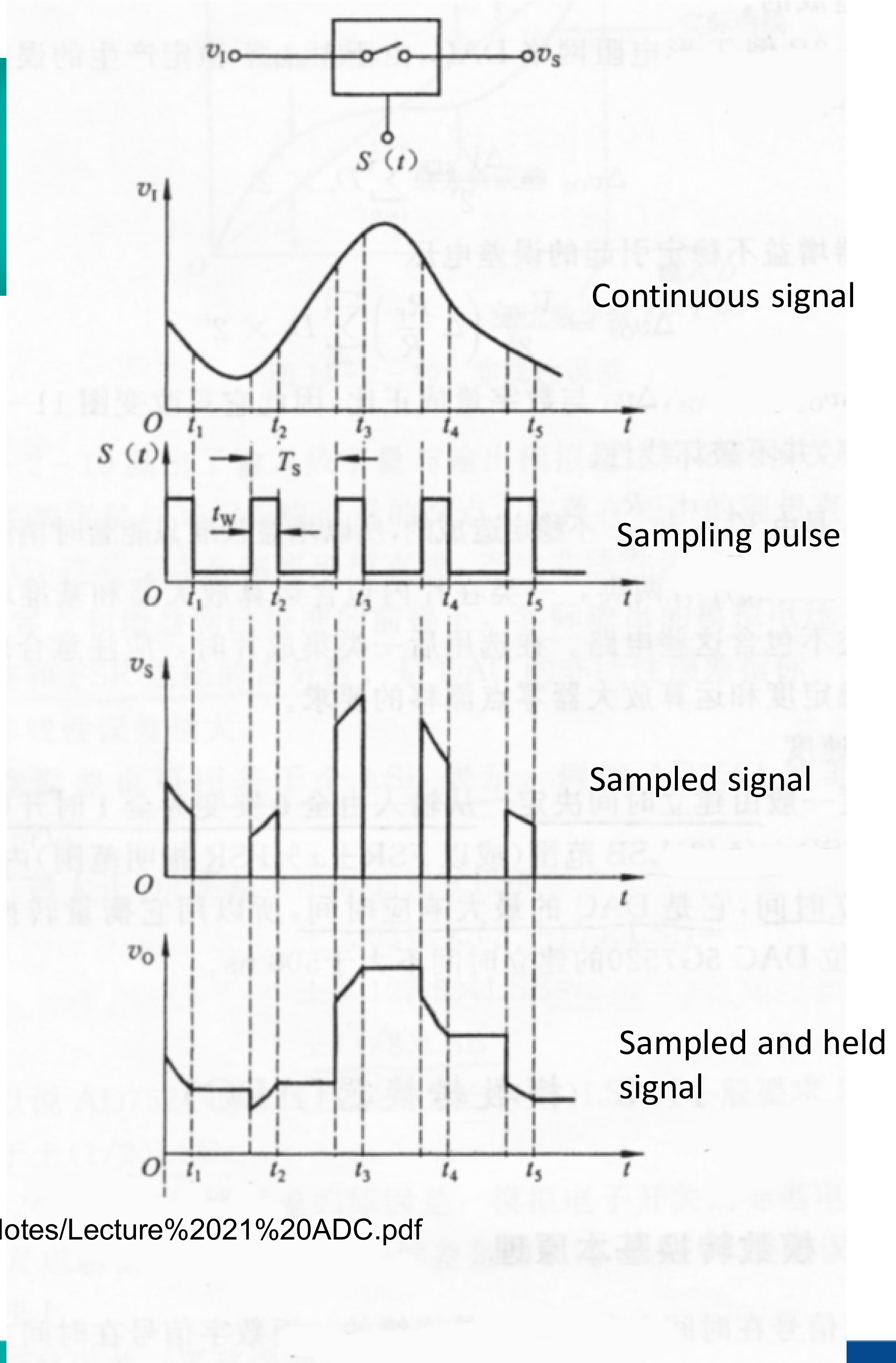
Sampling and Holding



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Quantizing and Encoding

Resolution:

The smallest change in analog signal that will result in a change in the digital output.

$$\Delta V = \frac{V_r}{2^N}$$

V = Reference voltage range

N = Number of bits in digital output.

2N = Number of states.

ΔV = Resolution

The resolution represents the quantization error inherent in the conversion of the signal to digital form.

Quantizing and Encoding

- Quantizing:

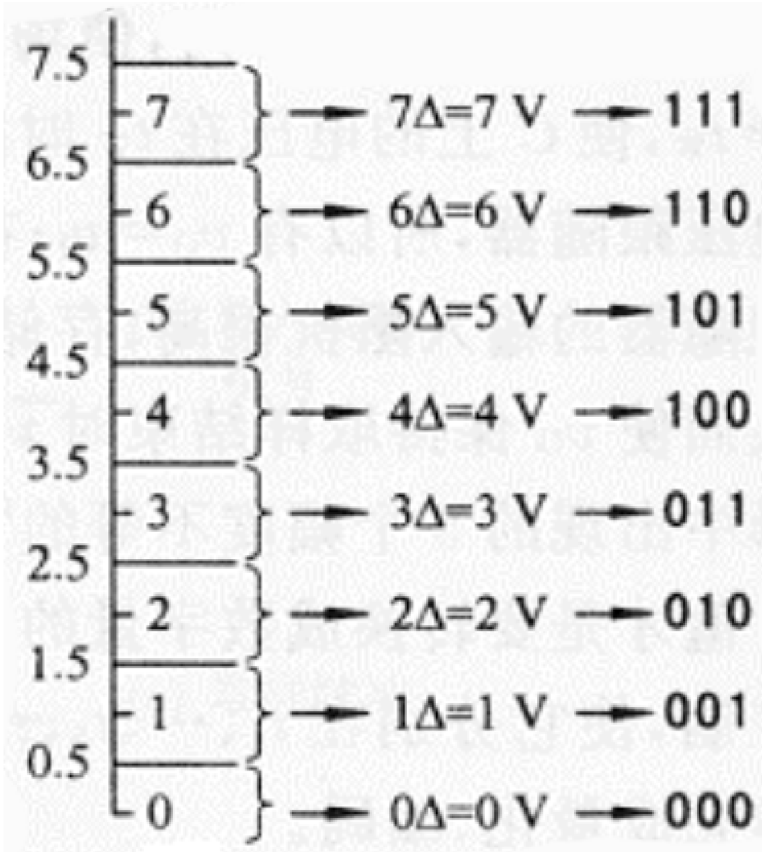
Partitioning reference signal range → discrete quanta, then match the input signal to the correct quantum.

- Encoding:

Assigning unique digital code to quantum, then allocating the digital code to the input signal.

$$\Delta V = 1V$$

Maximum quantization error=$\pm\frac{1}{2}\Delta V = \pm 0.5V$



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