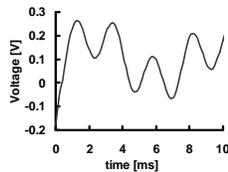# Digital Electronics

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In this lecture

- Digital & Analog Signals
- Pros and Cons of Digital System
- Analog to Digital Conversion
  - Sampling
  - Nyquist limit
  - Aliasing
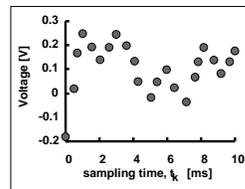 - Quantization Error

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Analog & Digital Signals

Analog

Continuous function V of *continuous* variable t (time, space etc) : V(t).

Digital

Discrete function V_k of *discrete* sampling variable t_k, with k = integer: $V_k = V(t_k)$.

Signals in Medical Imaging

- Computer Radiography:
  - Voltage proportional to light intensity
- Direct Digital Radiography:
  - Voltage proportional to X-ray intensity
- Computed Tomography:
  - Voltage proportional to X-ray intensity
- Ultrasound:
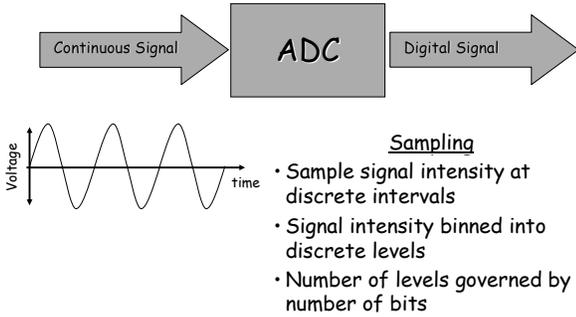 - Voltage proportional to US intensity

Analog or Digital?

Advantages of Digital Signal

- High noise immunity
- Adjustable precision
- Ease of design (automation) and
- Fabrication, therefore, low cost
- Better Reliability
- Less need for calibration and maintenance
- Ease of diagnosis and repair
- Easy to duplicate similar circuits
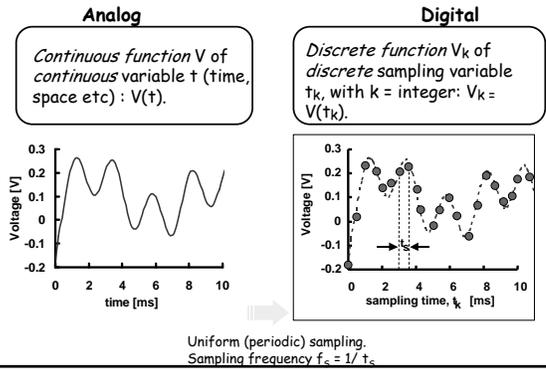- Easily controllable by computer

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Disadvantages of Digital Signals

- Lower speed
- Needs converters to communicate with real world, therefore more expensive and less precision
  - Digital to Analog (D/A)
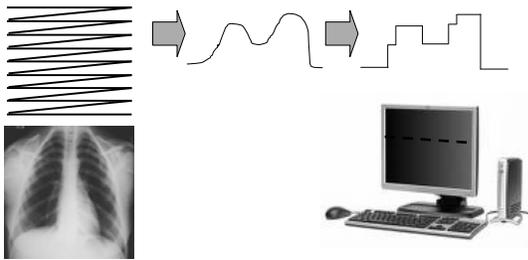 - Analog to Digital (A/D)
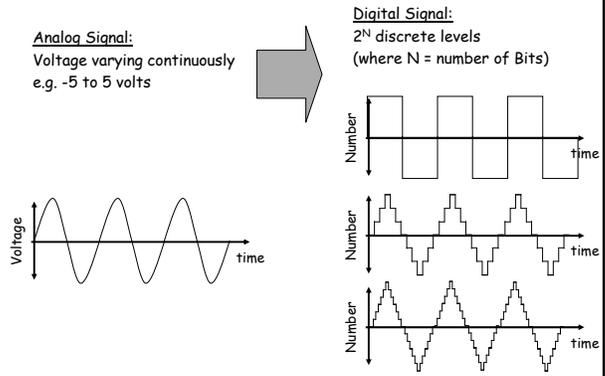
Analog to Digital Converter

Continuous Signal → **ADC** → Digital Signal

Voltage / time

Sampling
- Sample signal intensity at discrete intervals
- Signal intensity binned into discrete levels
- Number of levels governed by number of bits

Analog to Digital Convertion

Analog

Continuous function V of *continuous* variable t (time, space etc) : V(t).

Voltage [V] vs time [ms]

Digital

Discrete function V_k of *discrete* sampling variable t_k, with k = integer: $V_k = V(t_k)$.

Voltage [V] vs sampling time, t_k [ms]

Uniform (periodic) sampling.
Sampling frequency $f_s = 1/t_s$

Example: Computed Radiography

Analog to Digital Converter

Analog Signal:
Voltage varying continuously
e.g. -5 to 5 volts

Digital Signal:
2^N discrete levels
(where N = number of Bits)

Voltage / time

Number / time

Quantisation Error
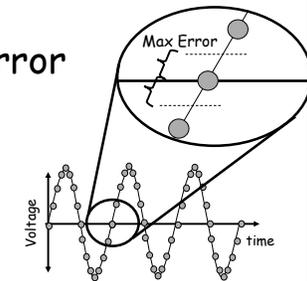

Max Error

- Digital Accuracy depends upon number of bits of ADC.

- Maximum Error
  - Analog signal amplitude range, A
  - Digital increment size, N
  - Number of bits, n
  - Maximum quantisation error is equal to half the voltage of the least significant bit

$$q_{max} = \frac{A}{N} = \frac{A}{2^{n+1}}$$

Example

An analog signal of amplitude 12v is sampled with a 8-bit ADC.

Calculate the maximum & average quantisation noise