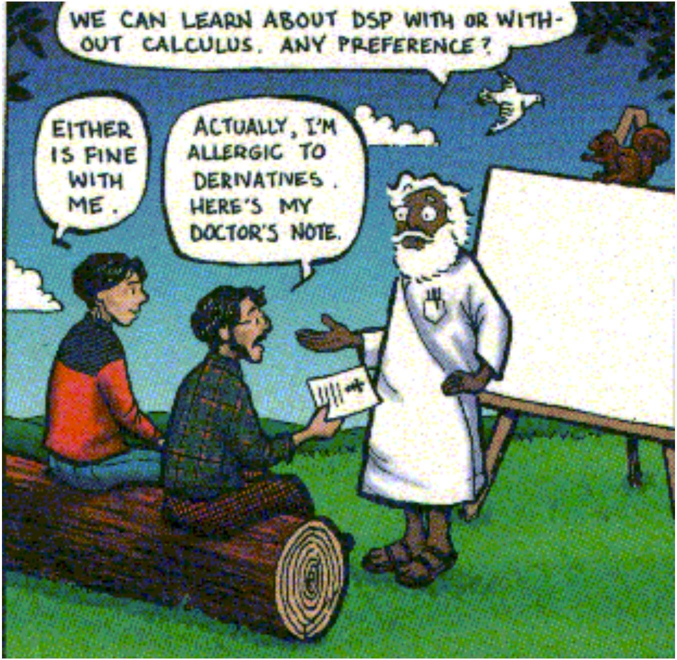
Sinyal Sistem
Week 2b – 3a: Periodic Sampling

@btatmaja

Compiled from : -David Marshall: Scientific Computing...
-Mark D. Shattuck, Image Analysis, HOS 2015

Periodic Sampling

- From time scaling to resampling
- Sampling Theorem and Aliasing
- Konvolusi
- Korelasi


WE CAN LEARN ABOUT DSP WITH OR WITH-OUT CALCULUS. ANY PREFERENCE?
EITHER IS FINE WITH ME.
ACTUALLY, I'M ALLERGIC TO DERIVATIVES. HERE'S MY DOCTOR'S NOTE.

Sample Rates and Bit Size

Bit Size — Quantisation

How do we store each sample value (**Quantisation**)?

8 Bit Value (0-255)

16 Bit Value (Integer) (0-65535)

Sample Rate

How many Samples to take?

11.025 KHz — Speech (Telephone 8 KHz)

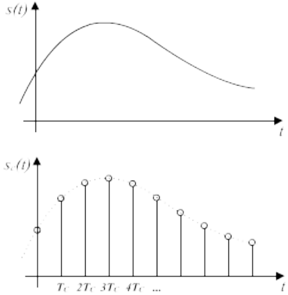
22.05 KHz — Low Grade Audio (WWW Audio, AM Radio)

44.1 KHz — CD Quality

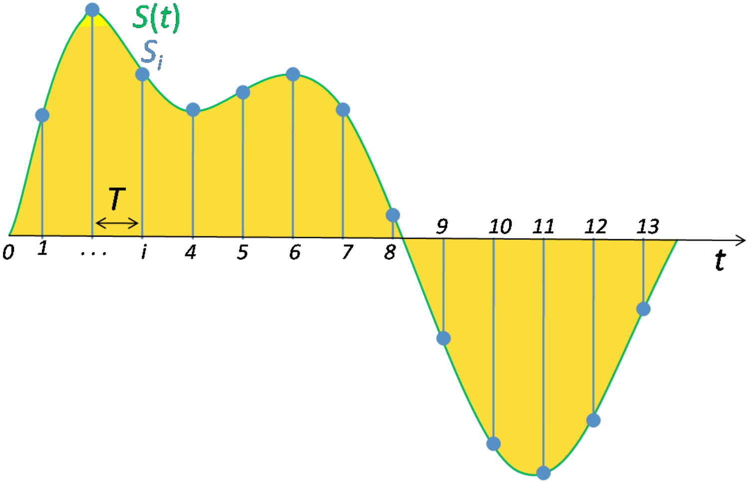
Digital Sampling (1)

Sampling process basically involves:

- **Measuring** the **analog signal** at **regular discrete intervals**
- **Recording** the **value** at **these points**



Digital Sampling (2)



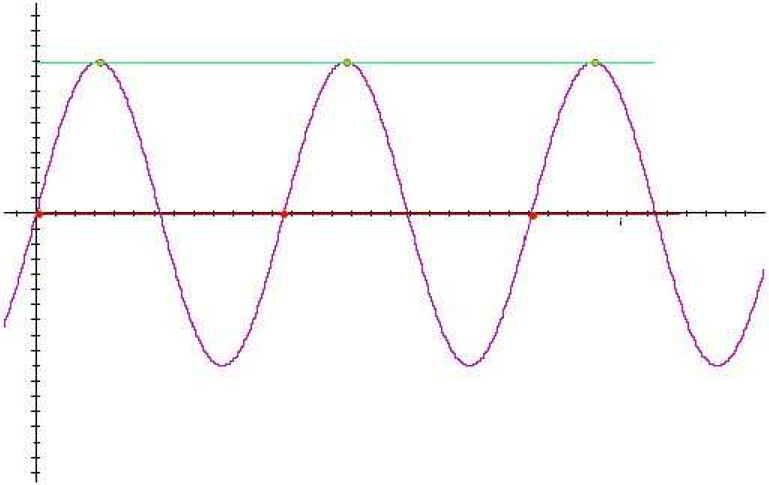
Nyquist's Sampling Theorem

The **Sampling Frequency** is **critical** to the **accurate reproduction** of a **digital version** of an analog waveform

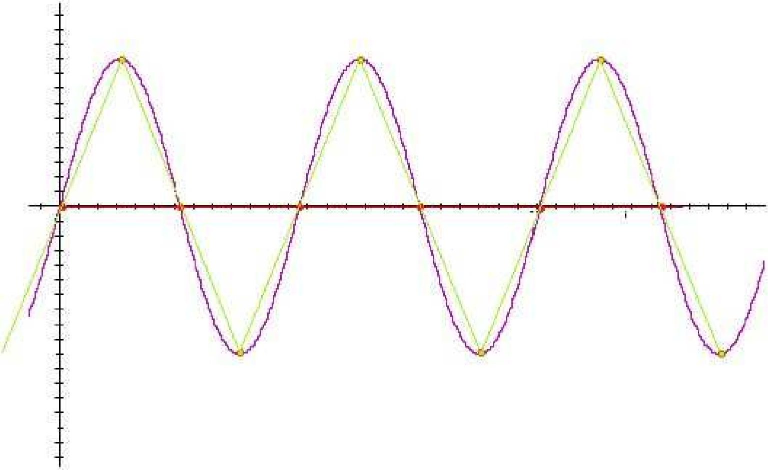
Nyquist's Sampling Theorem

The Sampling frequency for a signal must be **at least twice** the **highest frequency component** in the signal.

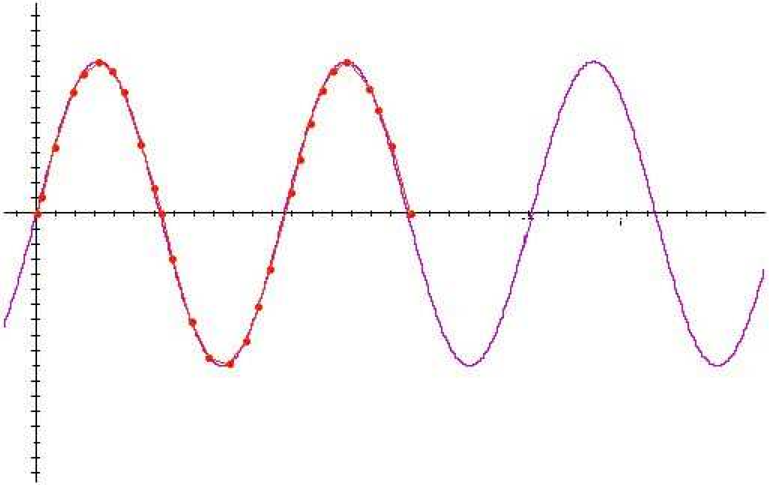
Sampling at Signal Frequency



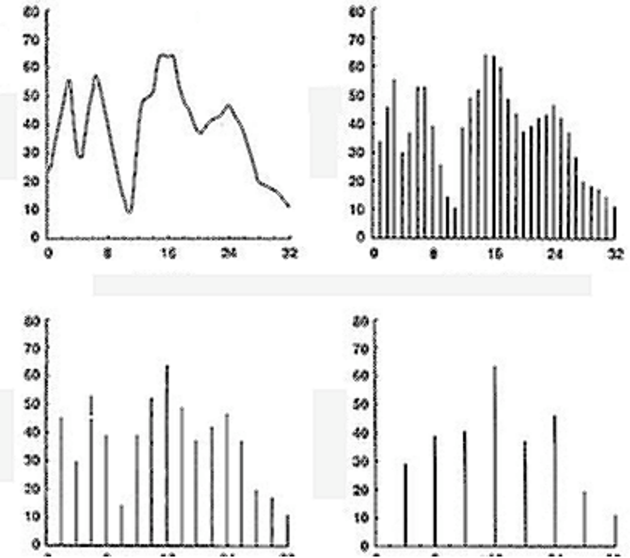
Sampling at Twice Nyquist Frequency



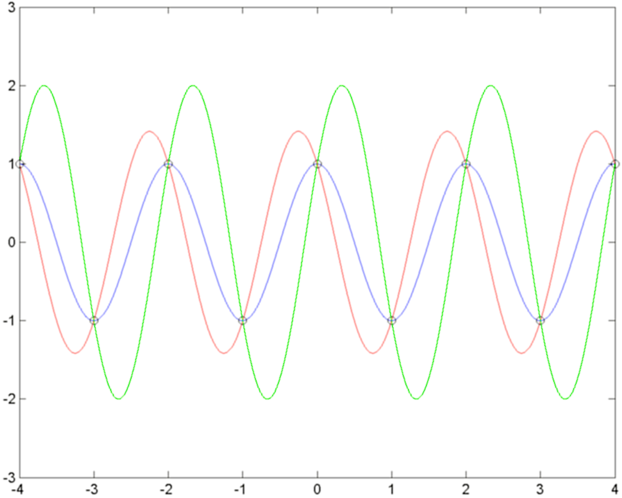
Sampling at above Nyquist Frequency



If you get Nyquist Sampling Wrong? (1)



If you get Nyquist Sampling Wrong? (2)



Implications of Sample Rate and Bit Size (1)

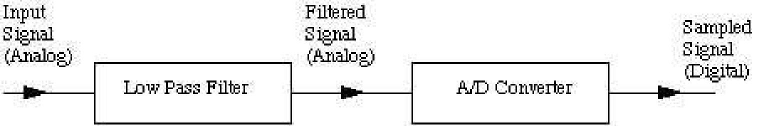
Affects Quality of Audio

- Ears do not respond to sound in a linear fashion
- Decibel (**dB**) a logarithmic measurement of sound
- 16-Bit has a signal-to-noise ratio of 98 dB — virtually inaudible
- 8-bit has a signal-to-noise ratio of 50 dB
- Therefore, 8-bit is roughly 8 times as noisy
    - 6 dB increment is twice as loud

Practical Implications of Nyquist Sampling Theory

Filtering of Signal

- Must (low pass) filter signal before sampling:



- Otherwise **strange artifacts** from high frequency (**above** Nyquist Limit)signals would appear in the sampled signal.

Why are CD Sample Rates 44.1 KHz?

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Why are CD Sample Rates **44.1 KHz**?

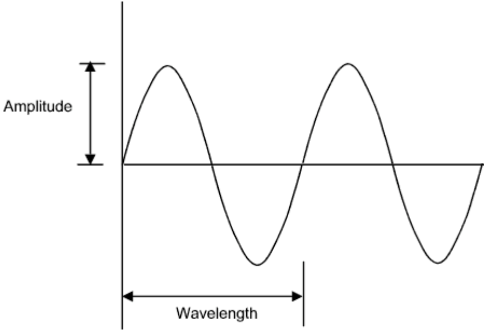
Upper range of human hearing is around 20-22 KHz — Apply Nyquist Theorem

Basic Digital Audio Signal Processing

In this section we look at some basic aspects of **Digital Audio Signal Processing**:

- Some basic definitions and principles
- Filtering
- Basic Digital Audio Effects

Simple Waveforms



- **Frequency** is the number of cycles per second and is measured in Hertz (Hz)
- **Wavelength** is *inversely proportional* to frequency i.e. Wavelength varies as $\frac{1}{frequency}$

Convolution

- Convolution and Cross Correlation

$$C(f,g)_n = \sum_{k=0}^{K-1} f_k g_{(n-k)}$$

$$X(f,g)_n = \sum_{k=0}^{K-1} f_k^* g_{(n+k)}$$

Convolution

1 3 2 1 3　　　　　　　　　　1 0 2

1 3 2 1 3

2 0 1

1

Convolution

1 3 2 1 3 1 0 2

1 3 2 1 3

2 0 1

1 3

Convolution

1 3 2 1 3 1 0 2

1 3 2 1 3

2 0 1

1 3 4

Convolution

1 3 2 1 3 1 0 2

1 3 2 1 3

2 0 1

1 3 4 7

Convolution

1 3 2 1 3

1 0 2

1 3 2 1 3

2 0 1

1 3 4 7 7

Convolution

1 3 2 1 3 1 0 2

1 3 2 1 3

2 0 1

1 3 4 7 7 2

Convolution

1 3 2 1 3 1 0 2

1 3 2 1 3

2 0 1

1 3 4 7 7 2 6

Convolution

1 3 2 1 3 1 0 2

1 3 2 1 3

2 0 1

1 3 4 7 7 2 6

full

same

valid

Convolution

- Convolution and Cross Correlation

$$C(f,g)_n = \sum_{k=0}^{K-1} f_k g_{(n-k)}$$

$$X(f,g)_n = \sum_{k=0}^{K-1} f_k^* g_{(n+k)}$$

Correlation

1 3 2 1 3 1 0 2

1 3 2 1 3

1 0 2

2

Correlation

1 3 2 1 3 1 0 2

1 3 2 1 3

1 0 2

2 6

Correlation

1 3 2 1 3 1 0 2

1 3 2 1 3

1 0 2

2 6 5

Correlation

1 3 2 1 3 1 0 2

1 3 2 1 3

1 0 2

2 6 5 5

Correlation

1 3 2 1 3   1 0 2

1 3 2 1 3

1 0 2

2 6 5 5 8

Correlation

1 3 2 1 3 1 0 2

1 3 2 1 3

1 0 2

2 6 5 5 8 1

Correlation

1 3 2 1 3 1 0 2

1 3 2 1 3

1 0 2

2 6 5 5 8 1 3

Correlation

1 3 2 1 3 1 0 2

1 3 2 1 3

1 0 2

2 6 5 5 8 1 3

full

same

valid

Convolution

- Convolution and Cross Correlation

$$C(f,g)_{nm} = \sum_{k=0}^{K-1}\sum_{l=0}^{L-1} f_{kl}\, g_{(n-k)(m-l)}$$

$$X(f,g)_{nm} = \sum_{k=0}^{K-1}\sum_{l=0}^{L-1} f_{kl}^{*}\, g_{(n+k)(m+l)}$$

Convolution