CG1111: Engineering Principles and Practice I

Basics of Signal Processing

NUS
National University of Singapore

Signals

- A signal is a function of one or more variables that conveys information about some (usually physical) phenomenon
- Examples of signals we have seen so far
  - Time-varying voltage measured across a resistor
    - ✓ V(t) -> where V is the dependent variable and time t is the independent variable
  - Time-varying current through an inductor
  - Audio signal obtained from a microphone's output
  - Various waveforms generated using a function generator

Classification of Signals

- Continuous signals
  - Independent variable is a continuous variable
  - Examples
    - ✓ Sine wave from a function generator
    - ✓ Speech signal received from a microphone
- Discrete signals
  - Independent variable takes on discrete values, for example integers
  - Examples
    - ✓ Weekly stock market index
    - ✓ Speech signal stored on a digital computer

Continuous vs Discrete Time signals

- A discrete signal may represent successive samples of a phenomenon for which the independent variable is continuous
- For instance, a continuous signal, such as an audio signal is sampled at an appropriate frequency to obtain discretized samples representing the continuous signal that gets stored in a digital format on a computer

Classification of Signals

Other classifications of signals include

- Analog vs Digital
- Periodic vs Aperiodic
- Deterministic vs Random
- Even vs Odd signals
- And so on

Note: these classes of signals are not disjoint, i.e., there are digital signals that are periodic, continuous time signals that are analog, etc

Sampling

- The process of converting a signal from continuous time to discrete time by measuring the signal at certain intervals of time is known as sampling
- Each measurement is referred to as a sample
- The sampling rate or frequency is the number of times a signal is read in a second (for eg. 100 times in a second, i.e. 100 Hz, which means the signal is sampled once every 1/100 seconds)

Sampling Theorem

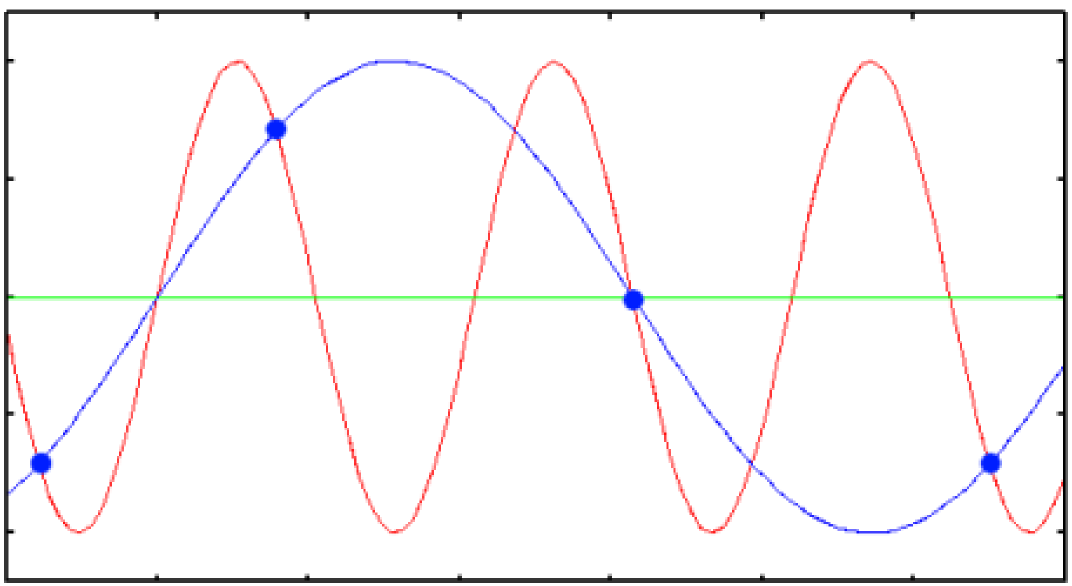
- How frequently should the signal be sampled to ensure that information contained in the signal is preserved?
- The Sampling Theorem states that the information contained in a signal would be preserved if it is sampled at a frequency *f*, where *f* is equal or greater than twice the maximum frequency in the signal.

Nyquist rate, Nyquist Frequency

- The minimum sampling rate that is required to well represent a continuous time signal with highest frequency component f is given by $2 \times f$ and this frequency is known as the Nyquist rate
- For a given sampling rate f_s, perfect reconstruction is guaranteed possible for a continuous signal whose highest frequency is $f_s/2$, which is known as a the Nyquist frequency
  - For example, audio CDs have a sampling rate of 44100 samples/sec. Therefore, the Nyquist frequency is 22050 Hz

Aliasing

- When the sampling rate is lower than the Nyquist rate, the signal reconstructed from samples(using DAC) is different from the original continuous signal. This effect is known as aliasing.



The red waveform represents the original continuous time signal. The blue dots represent samples obtained from the continuous signal at a sampling rate lesser than the Nyquist rate

THANK YOU