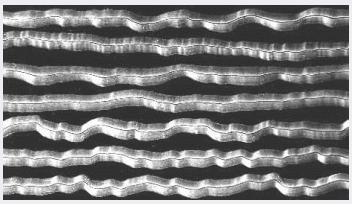
Dept. of Computer Science and Engineering
University of Rajshahi
www.ru.ac.bd

Dr. Shamim Ahmad

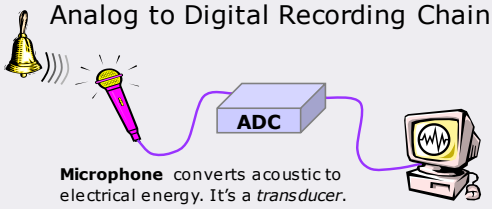
Analog Representations of Sound

Magnified phonograph grooves, viewed from above:



When viewed from the side, channel 1 goes up and down, and channel 2 goes side to side.

Analog to Digital Recording Chain



Microphone converts acoustic to electrical energy. It's a *transducer*.

Continuously varying electrical energy is an **analog** of the sound pressure wave.

ADC (Analog to Digital Converter) converts analog to digital electrical signal. Digital signal transmits binary numbers.

DAC (Digital to Analog Converter) converts digital signal in computer to analog for your headphones.

Analog versus Digital

Analog

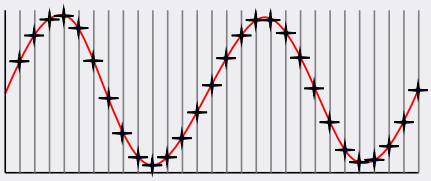
Continuous signal that mimics shape of acoustic sound pressure wave

Digital

Stream of discrete numbers that represent instantaneous amplitudes of analog signal, measured at equally spaced points in time.

Analog to Digital Conversion

Instantaneous amplitudes of continuous analog signal, measured at equally spaced points in time.



A series of "snapshots"

Analog to Digital Overview

Sampling Rate

How often analog signal is measured [samples per second, Hz]

Example: 44,100 Hz

Sampling Resolution

[a.k.a. "sample word length," "bit depth"] Precision of numbers used for measurement: the more bits, the higher the resolution.

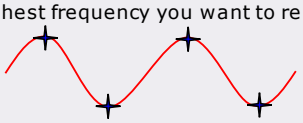
Example: 16 bit

Sampling Rate

Determines the highest frequency that you can represent with a digital signal.

Nyquist Theorem:

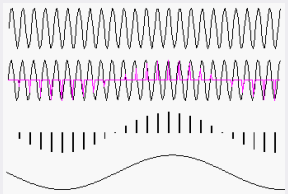
Sampling rate must be at least twice as high as the highest frequency you want to represent.



Capturing just the crest and trough of a sine wave will represent the wave exactly.

Aliasing

What happens if sampling rate not high enough?



That's called **aliasing** or **foldover**. An ADC has a low-pass **anti-aliasing filter** to prevent this.

Synthesis software can cause aliasing.

Common Sampling Rates

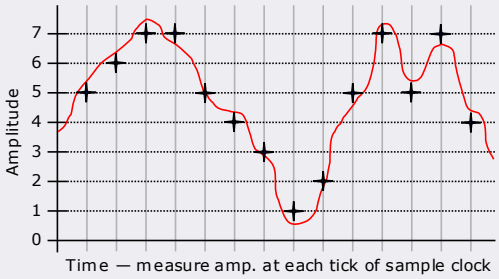
Which rates can represent the range of frequencies audible by (fresh) ears?

Sampling Rate	Uses
44.1 kHz (44100)	CD, DAT
48 kHz (48000)	DAT, DV, DVD-Video
96 kHz (96000)	DVD-Audio
22.05 kHz (22050)	Old samplers

Most software can handle all these rates.

3-bit Quantization

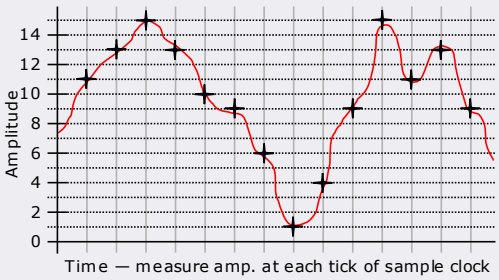
A 3-bit binary (base 2) number has $2^3 = 8$ values.



A rough approximation

4-bit Quantization

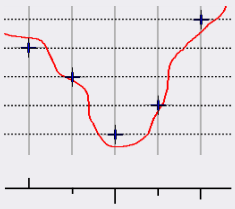
A 4-bit binary number has $2^4 = 16$ values.



A better approximation

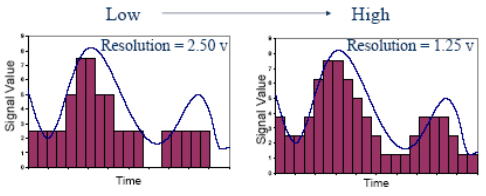
Quantization Noise

Round-off error: difference between actual signal and quantization to integer values…



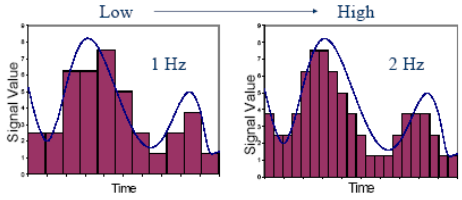
Random errors: sounds like low-amplitude noise

Accuracy - Resolution



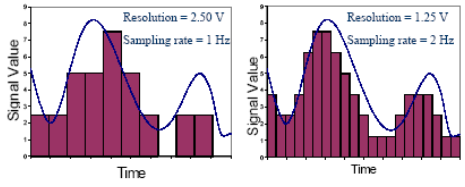
Resolution = analog quantization size (Q)
- 2 bit converter → $10v/2^2=2.50v$
- 3 bit converter → $10v/2^3=1.25v$

Accuracy - Sampling Rate



Sampling rate - Frequency which ADC evaluates analog signal

Accuracy



Both sampling rate and resolution can be increased to obtain better accuracy.

The Digital Audio Stream

It's just a series of sample numbers, to be interpreted as instantaneous amplitudes: one for every tick of the sample clock.

Previous example:

```
11 13 15 13 10 9 6 1 4 9 15 11 13 9
```

This is what appears in a sound file, along with a **header** that indicates the sampling rate, bit depth and other things.

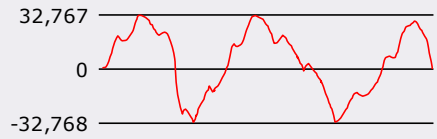
Common Sampling Resolutions

Word length	Uses
8-bit integer	Low-res web audio
16-bit integer	CD, DAT, DV, sound files
24-bit integer	DVD-Video, DVD-Audio
32-bit floating point	Software (usually only for internal representation)

16-bit Sample Word Length

A 16-bit integer can represent 2^{16}, or 65,536, values (amplitude points).

We typically use **signed** 16-bit integers, and center the 65,536 values around 0.



Audio File Size

CD characteristics…

- Sampling rate:
  44,100 samples per second (44.1 kHz)
- Sample word length:
  16 bits (i.e., 2 bytes) per sample
- Number of channels:
  2 (stereo)

How big is a 5-minute CD-quality sound file?

Audio File Size

How big is a 5-minute CD-quality sound file?

44,100 samples * 2 bytes per sample * 2 channels
= 176,400 bytes per second

5 minutes * 60 seconds per minute
= 300 seconds

300 seconds * 176,400 bytes per second
= 52,920,000 bytes = c. 50.5 megabytes (MB)