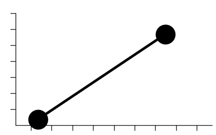
Analog and Digital

Analog vs. Digital

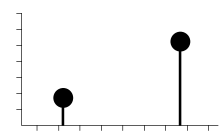
- Analog signal is direct, “continuous”, recording of voltage
- Digital is a numerical, “discrete” representation of that voltage

Analog-Continuous



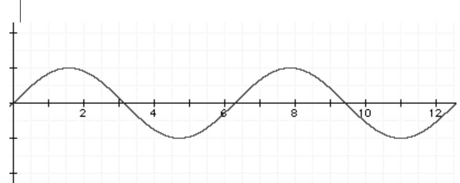
- Moving from one value to another: must include all intermediate values

Digital-Discrete



- Moving from one value to another occurs without intermediate values

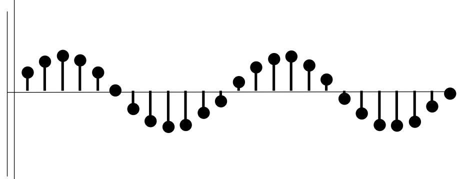
Voltage-Based Systems are Analog



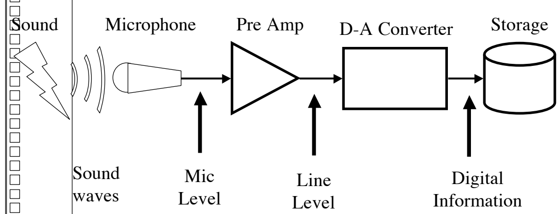
How does digital work?

- Analog, continuous signal is “Sampled”

Digital-Discrete Samples of Analog Waveform



How Sound is captured for digital systems



Analog

- Advantages:
  - Infinite variability
- Disadvantages
  - Analog electronics can drift
  - Noise introduced on analog line is reproduced as unwanted sound
  - Successive generations degrade
  - Difficult to edit/manipulate (tape and razor blades)

Digital

- Advantages
  - Digital electronics do not drift
  - Noise introduced on digital line is ignored
  - Successive generations are perfect copies
  - Easy to edit/manipulate (computers and hard drives)
- Disadvantages
  - Not infinitely variable (amount of storage space/processing power limits resolution)

The Sample

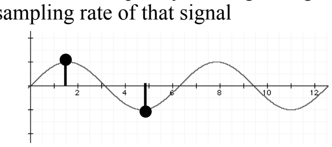
- Basic component of digital sound
- Contains two values
  - Time (relative to master clock)
  - Displacement

Sample Rate

- The number of samples per second
- Standard rates are
  - 44,100 Hz (CD Rate)
  - 48,000 Hz (DAT Rate)
  - 8,000 Hz (Telephone Rate)
  - 96,000 Hz (Newer rates)

The Nyquist Frequency

- Nyquist figured out that the highest frequency to be sampled is _ the sampling rate
- The maximum frequency of a digital signal is 1/2 the sampling rate of that signal



Highest Possible Frequency per Sample Rate

Sample Rate	Nyquist Frequency
44,100	22,050
48,000	24,000
8,000	4,000

Digital Uses Binary (instead of Decimal) Numbers

Why? Computers work in Binary.

0	1
off	on

The bit

- Binary digit
- Smallest component of digital number
- Combining multiple bits gives us the ability to count larger numbers

Counting in base 2

0 = 0
1 = 1
10 = 2
11 = 3
100 = 4

Note that squares are equivalents

Base 2	Base 10
$10_2 = 2^1$	$10 = 10^1$
$100_2 = 2^2$	$100 = 10^2$
$1000_2 = 2^3$	$1000 = 10^3$
$10000_2 = 2^4$	$10000 = 10^4$

Other Values

- Nibble = 4 bits
- Byte = 8 bits
- Word = machine dependent

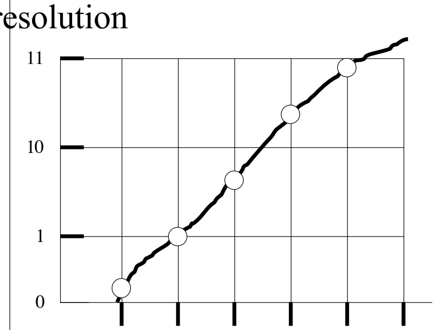
Digital Characteristics

- Resolution of Loudness/Amplitude=Number of bits
- More bits equals higher resolution amplitude (subtle but significant effect)
- Resolution of Frequency=1/2 Number of samples (not subtle effect)

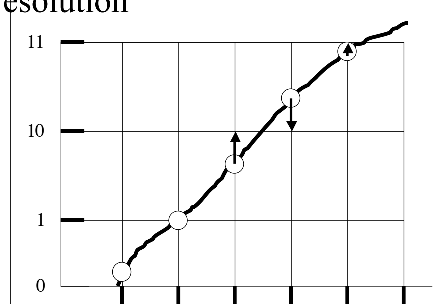
Sample Resolution

- The number of bits per sample is the resolution
- The greater the bits the better the resolution

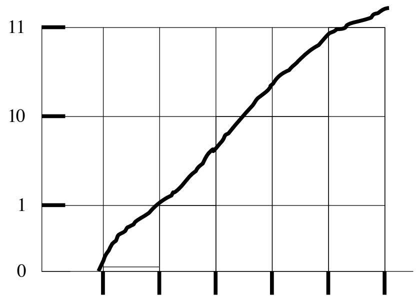
Demonstration: 2 bits of resolution



Demonstration: 2 bits of resolution



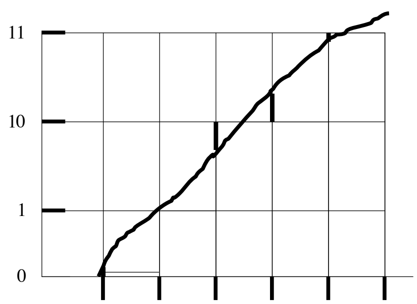
Demonstration: 2 bits of resolution



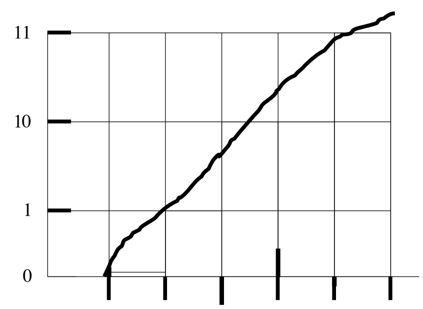
Signal to Noise Ratio

- Is equal to the number of bits * 6

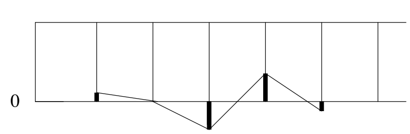
The Noise Component



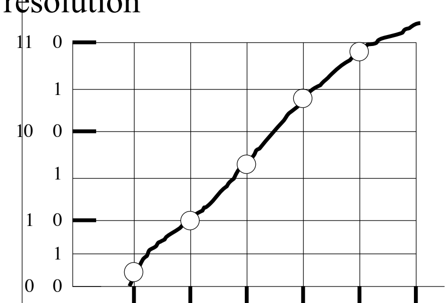
The Noise Component



Maximum amount of deviation is 1 half the distance between resolution points



Demonstration: 3 bits of resolution



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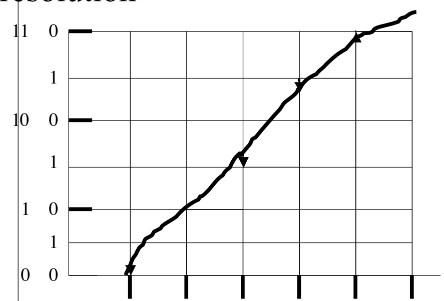
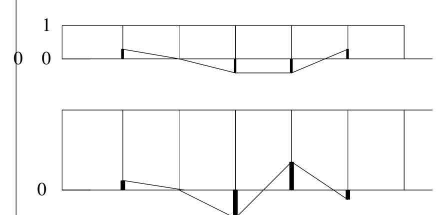


Demonstration: 3 bits of resolution

The maximum noise is now 1/2 that of the previous noise.



If waveform A is 1/2 the voltage of waveform B, What is the decibel relationship?

- 6dB

Common Digital Characteristics

- CD = 44.1kHz, 16Bits
- DAT = Up to 48kHz, 16Bits

Digital Interfacing Problems

- What happens if I play back a 48kHz recording at 44.1kHz?
- Pitch shifts down, recording goes slower

Calculating Storage Space

- Roughly 10mbytes/stereo minute at CD quality
- MPEG, other do massive compression