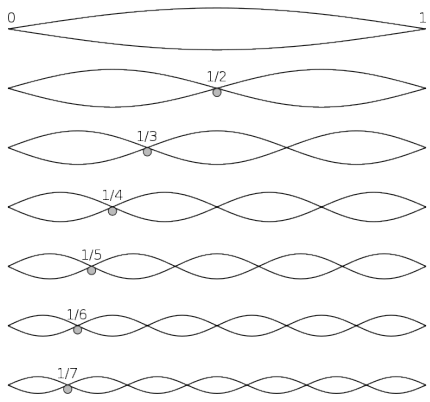
Fundamentals of

Digital Audio

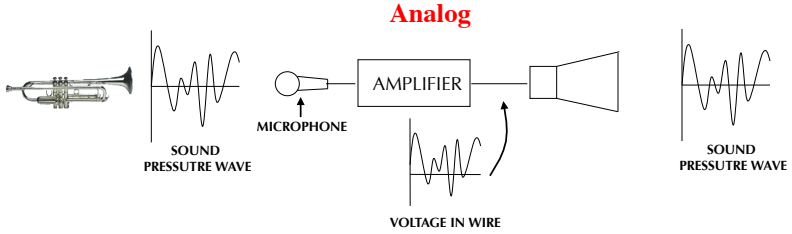
Harmonics and overtones

Frequency	Order	Name 1	Name 2	Name 3
1 · f = 440 Hz	n = 1	fundamental tone	1st harmonic	1st partial
2 · f = 880 Hz	n = 2	1st overtone	2nd harmonic	2nd partial
3 · f = 1320 Hz	n = 3	2nd overtone	3rd harmonic	3rd partial
4 · f = 1760 Hz	n = 4	3rd overtone	4th harmonic	4th partial



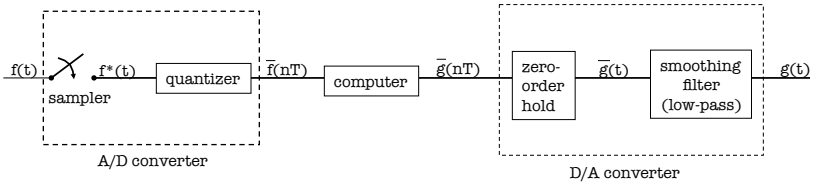
Analog vs. Digital

Analog



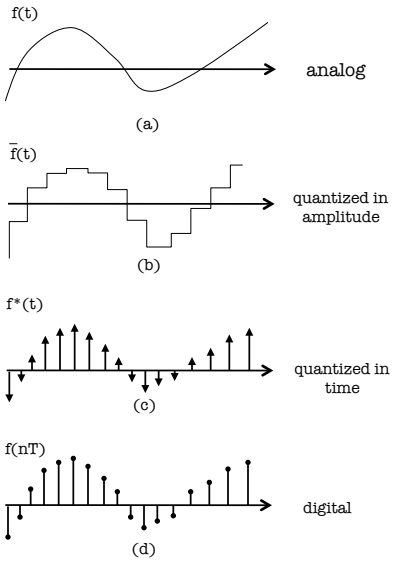
Digital

Idealized Model
Sampling / Reconstruction



Model of the sampling and desampling process

Deconstruction of Sampling



Graphic representation of types of signals:

a) analog signal

b) quantized (continuous time) signal

c) sampled data signal

d) digital signal

Fidelity

depends on:

- sampling rate
- bit depth
- (encoding scheme)

Sampling Rate

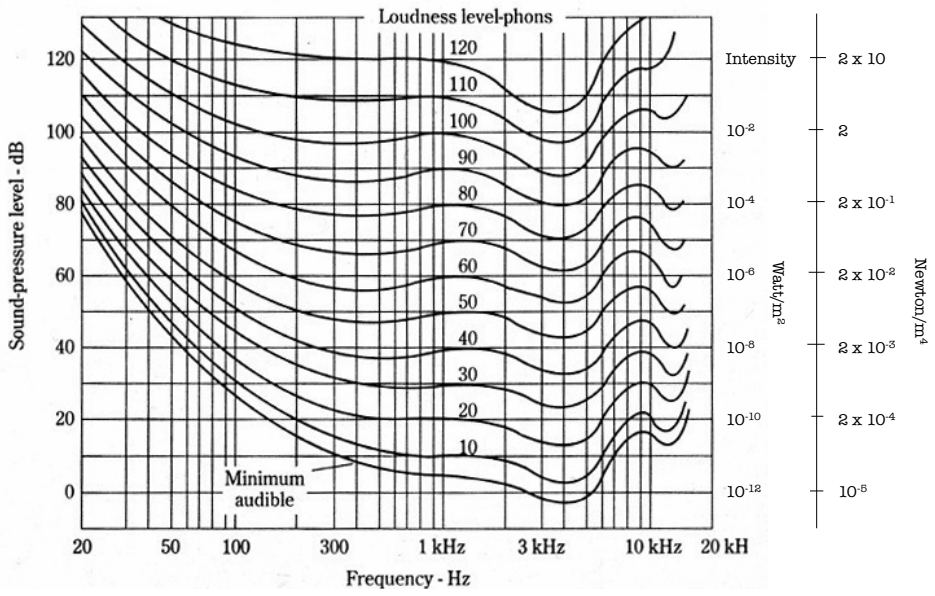
Human hearing: 20-20,000 Hz

Sampling Theorem:

Must sample twice as high as highest component

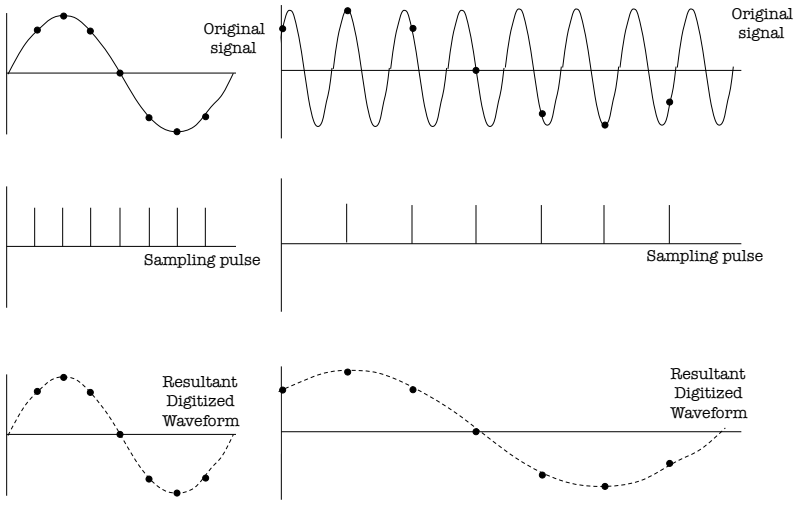
Typical rates:

8 K	dark / dull
11 K	↓
22 K	
44.1 K	
48 K	bright / clean

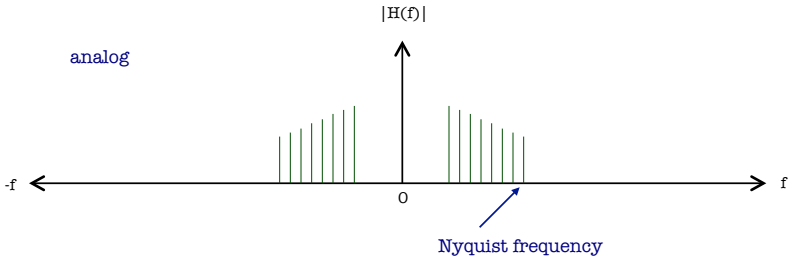


Fletcher & Munson

Foldover in time domain

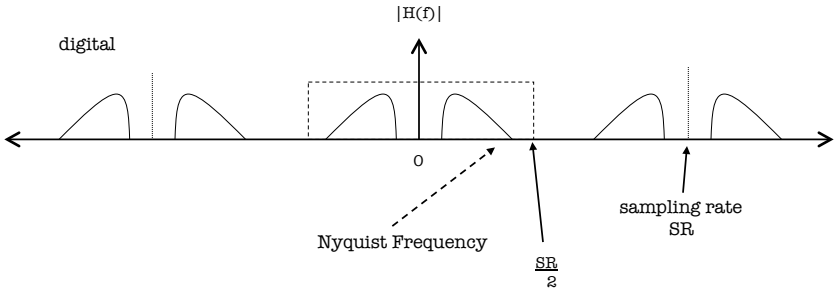


Positive and Negative Frequency

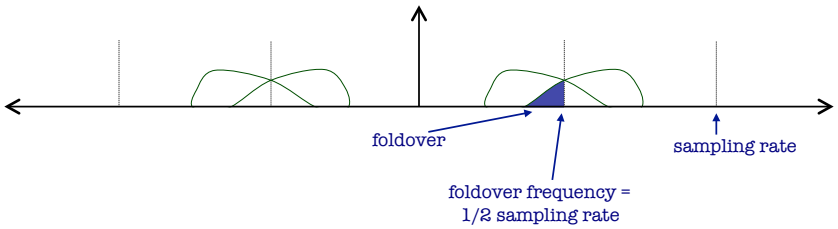


Digital Spectra

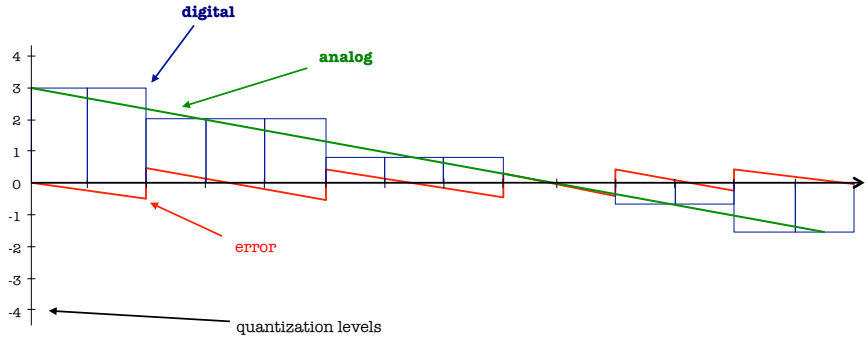
quantization in time



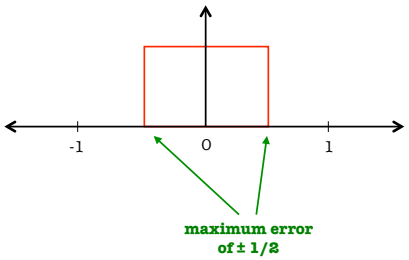
foldover in frequency domain



Quantization in Amplitude



Distribution of Error



Computing S/N

"Ideal"

$$dB = 20 \log \frac{2^N}{1}$$

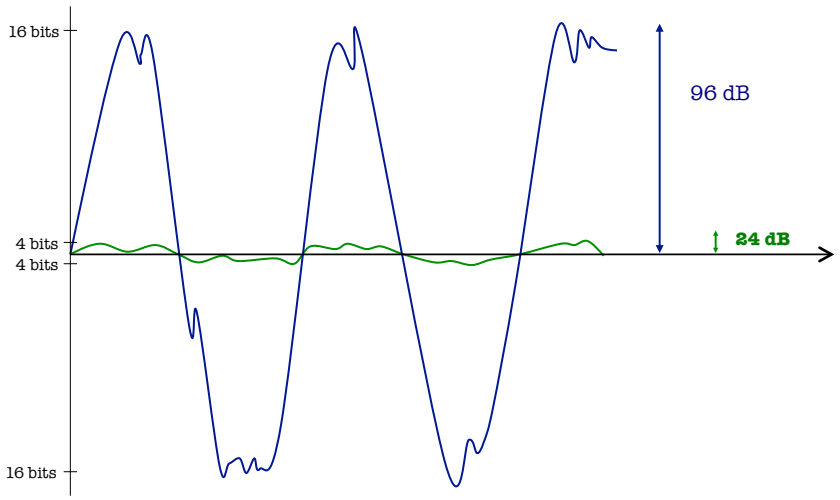
or $$\frac{2^{N-1}}{0.5}$$

6 dB / bit

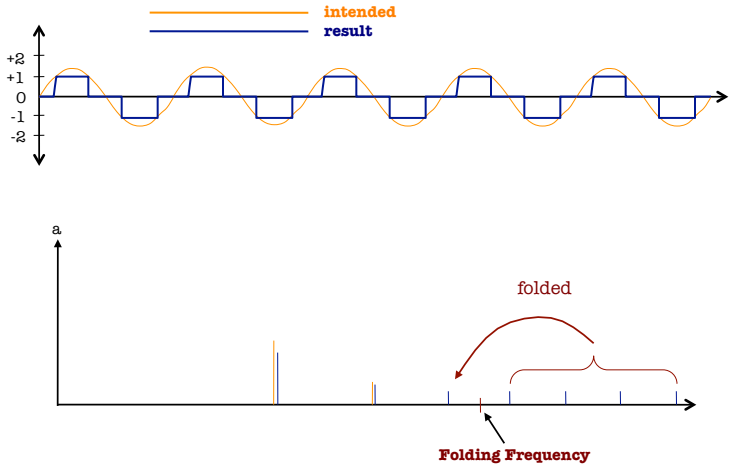
Bit Depth
Example S/N

bits	dB	
2	12	
4	24	
8	48	voice
12	72	
16	96	CD
24	144	proaudio

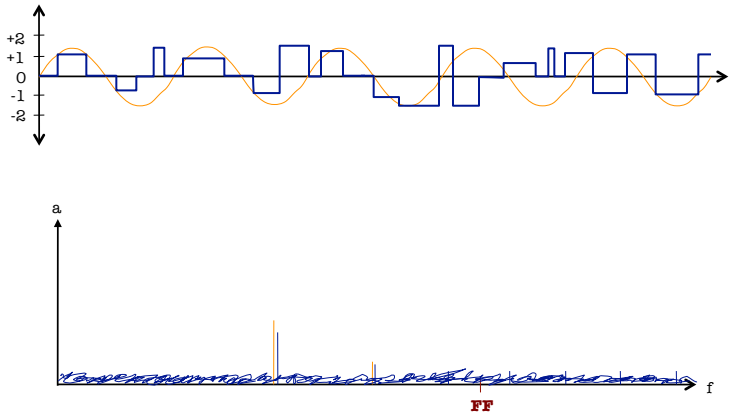
Dynamic Range Problem



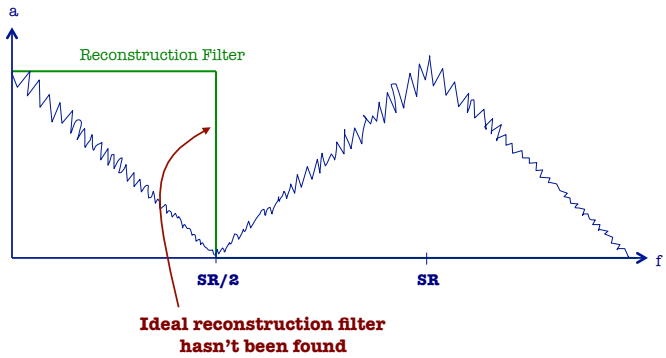
Low-level Signal Problem



Dither



Signal Reconstruction

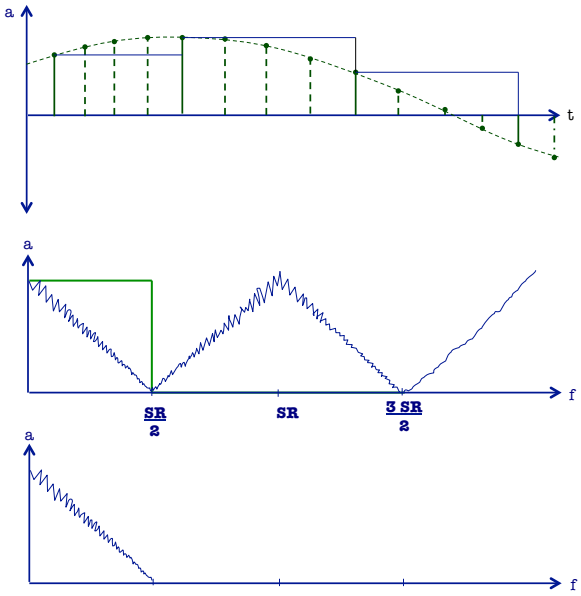


Oversampling Converters

- Multibit oversampling
  convert 44.1 K to
    176.4 K (4x)
    352.8 K (8x)

- 1-bit oversampling
  1 bit at high rate
    sigma-delta
    MASH
  128 x 1-bit =
    8 * 16-bits

Multibit Oversampling



Actual Converters

- Combine oversampling
  first with 1-bit stream
  second

- Resulting noise lower
  4x ⟶ 6dB
  8x ⟶ 12dB

- In computers ground isolation of
  digital noise overwhelms
  everything else!