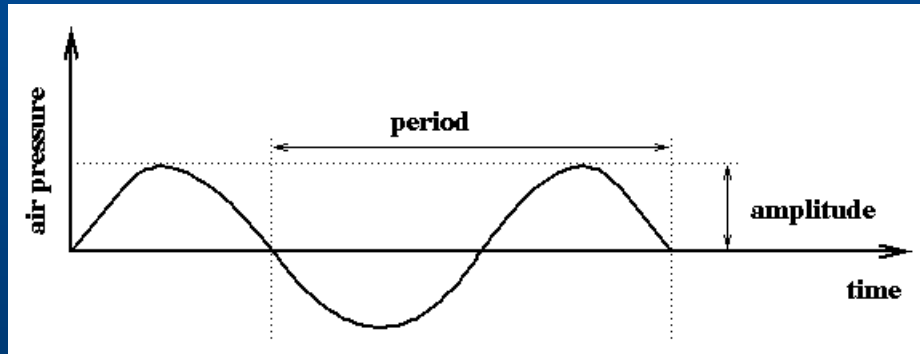


Digital audio

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Sound

Sound is a continuous longitudinal wave that travels through the air
The wave is made up of pressure differences
Sound is detected by measuring the pressure level at a point
The amplitude of a sound is the measure of displacement of the air pressure wave from its mean

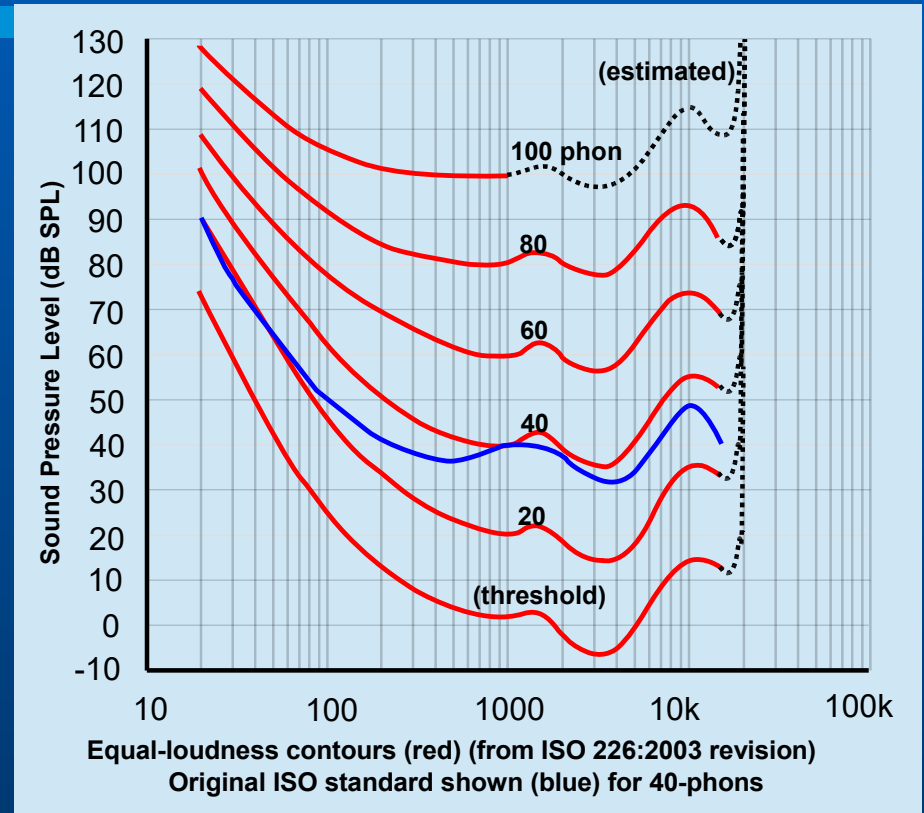


Sound loudness

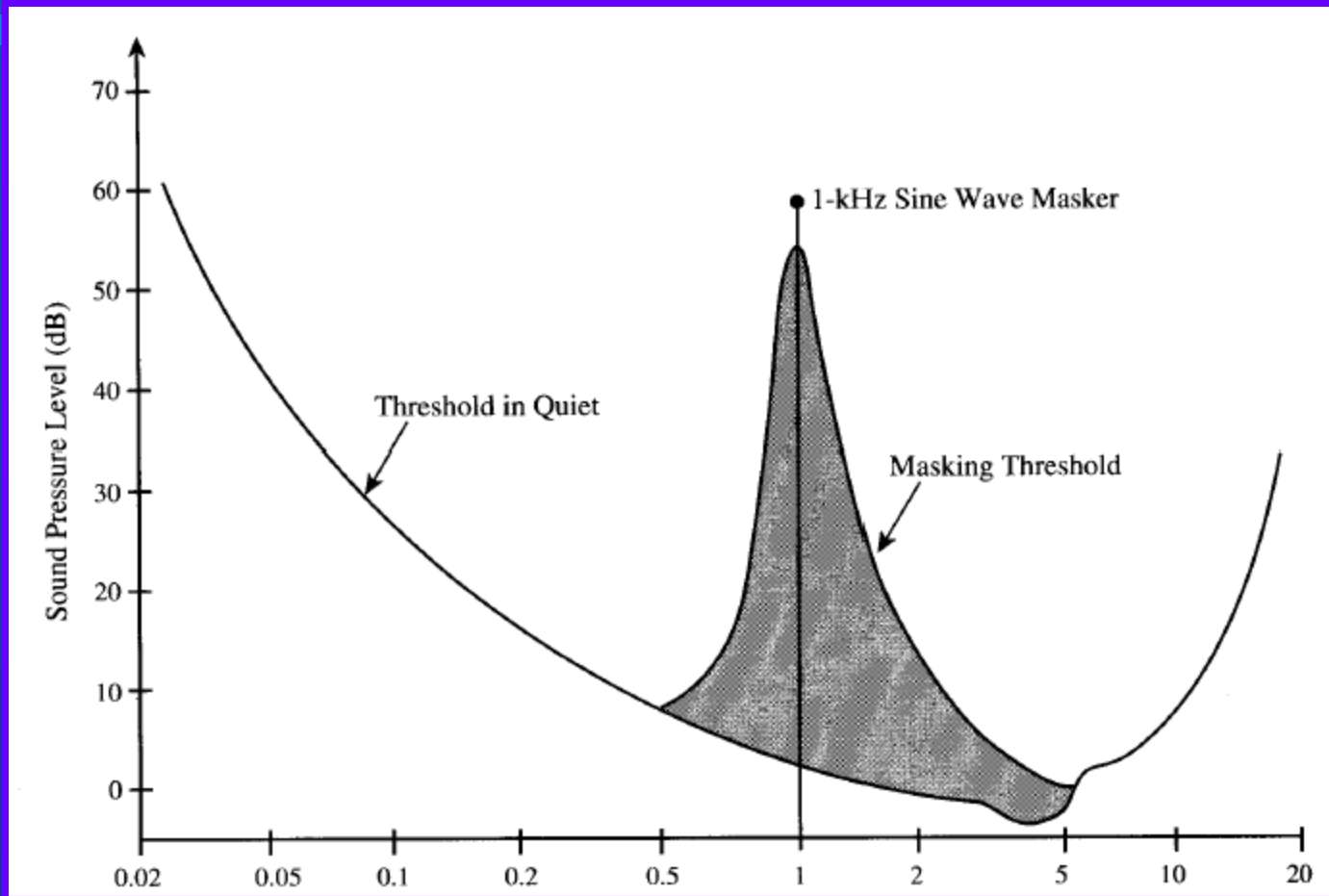
Features : Amplitude, Frequency
Perceptual : Loudness, Pitch

$$10 \log_{10} \frac{I}{I_0} \text{ decibels}$$

Conversation 60 db
Traffic noise 70 db
Threshold of discomfort 120 db



Sound masking



Frequency / pitch

frequency is an absolute measure, **pitch** is generally relative
the degree of highness or lowness of a tone

Pitch and frequency are linked by setting the note A above middle C to exactly 440 Hz.



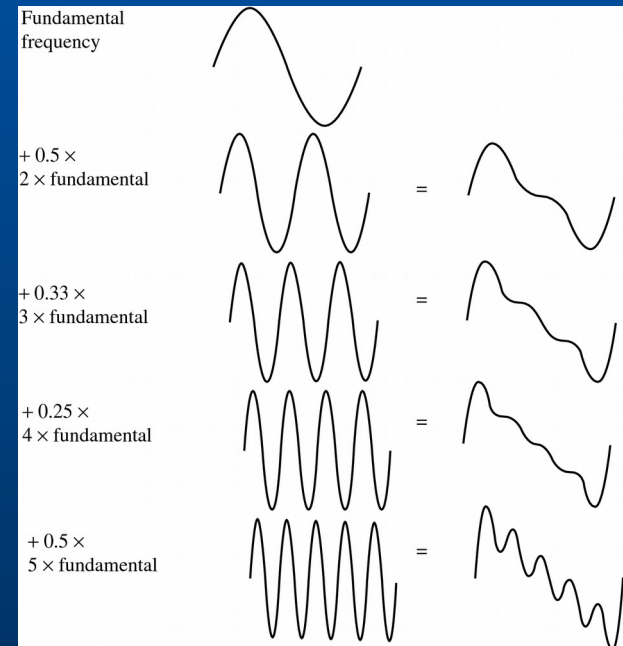
C : do
A : la

Frequency / pitch

An **octave** above that note takes us to another A note. An octave corresponds to *doubling the frequency*. Thus with the middle “A” on a piano (“A4” or “A440”) set to 440 Hz, the next “A” up is at 880 Hz, or one octave above.

$$p = 69 + 12 \times \log_2 \left(\frac{f}{440 \text{ Hz}} \right)$$

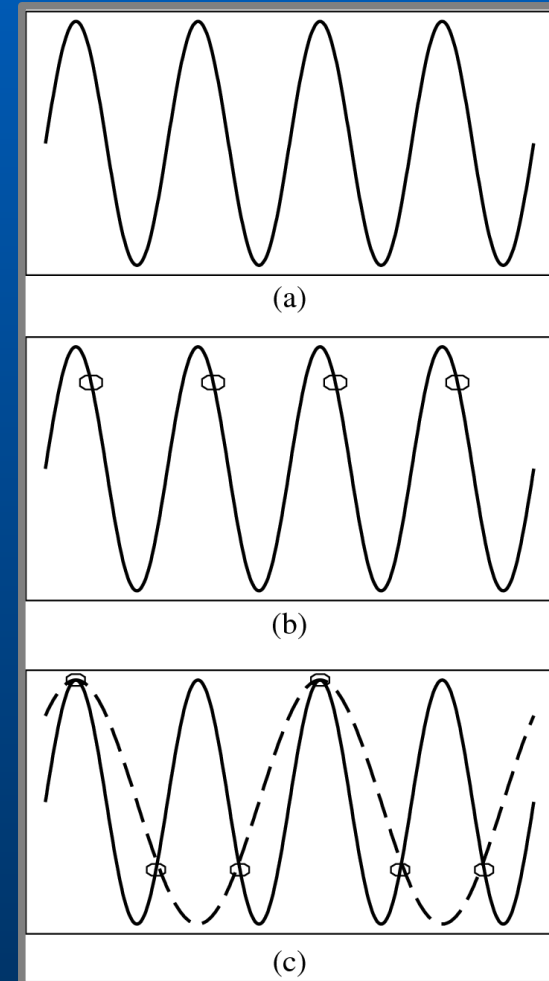
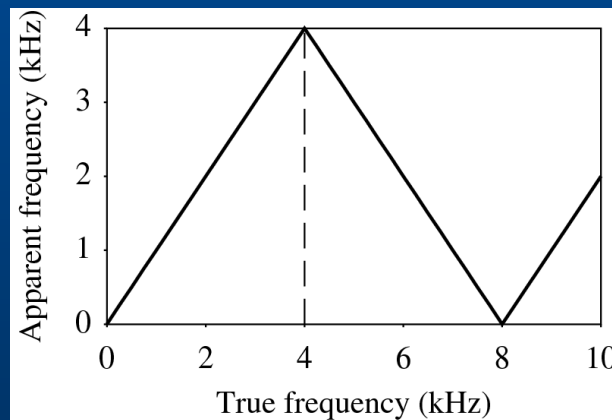
Harmonics: any series of musical tones whose frequencies are integral multiples of the frequency of a fundamental tone



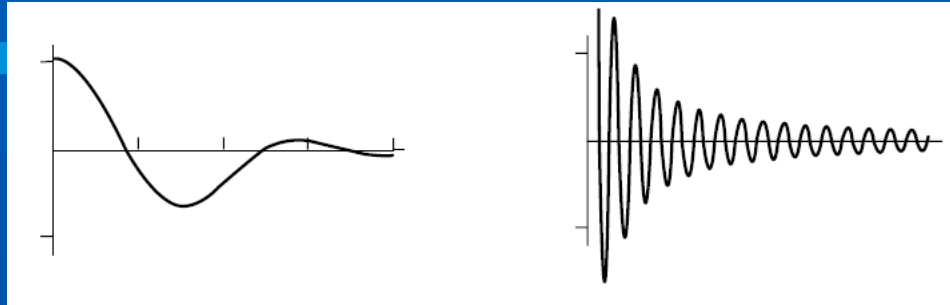
Sampling

The rate of sampling is called the *sampling frequency*
Nyquist rate (twice the maximum frequency content in
the signal)

Anti-aliasing filter



Sampling rate



	Hz
Telephone	8000
Low quality music	22050
miniDV, NICAM	32000
Audio CD, VCD, MP3	44100
Digital TV, DVD, DAT	48000
DVD-Audio, Blu-Ray Disk	96000

Quantization

Linear quantization

Non-linear quantization

Weber's Law says that equally perceived differences have values proportional to absolute levels

μ -law

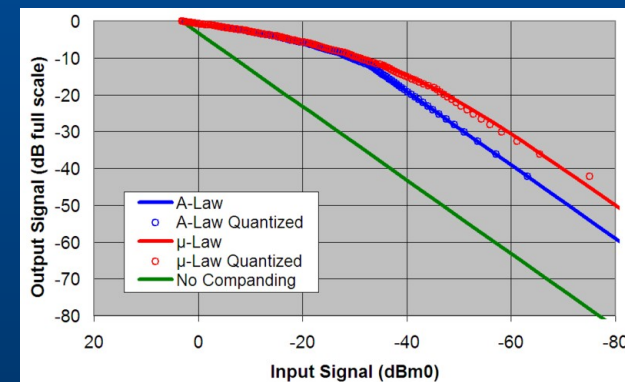
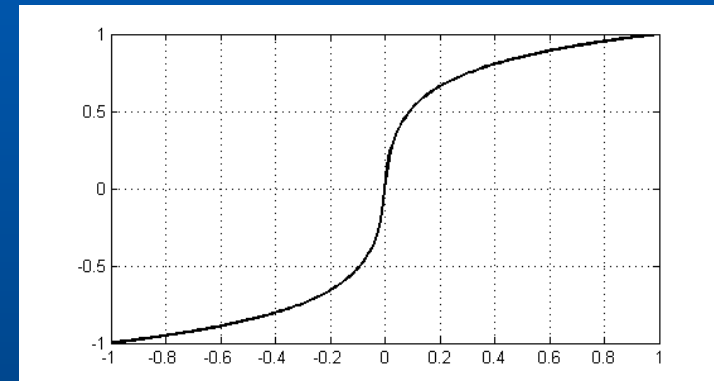
$$F(x) = \text{sgn}(x) \frac{\ln(1 + \mu|x|)}{\ln(1 + \mu)} \quad -1 \leq x \leq 1$$

A-law

$$F(x) = \text{sgn}(x) \begin{cases} \frac{A|x|}{1+\ln(A)}, & |x| < \frac{1}{A} \\ \frac{1+\ln(A|x|)}{1+\ln(A)}, & \frac{1}{A} \leq |x| \leq 1 \end{cases}$$

Quantization noise (roundoff error)

$$\frac{S}{N_q} \approx 20 \log_{10}(2^M) = 6.0206M \text{ dB}$$



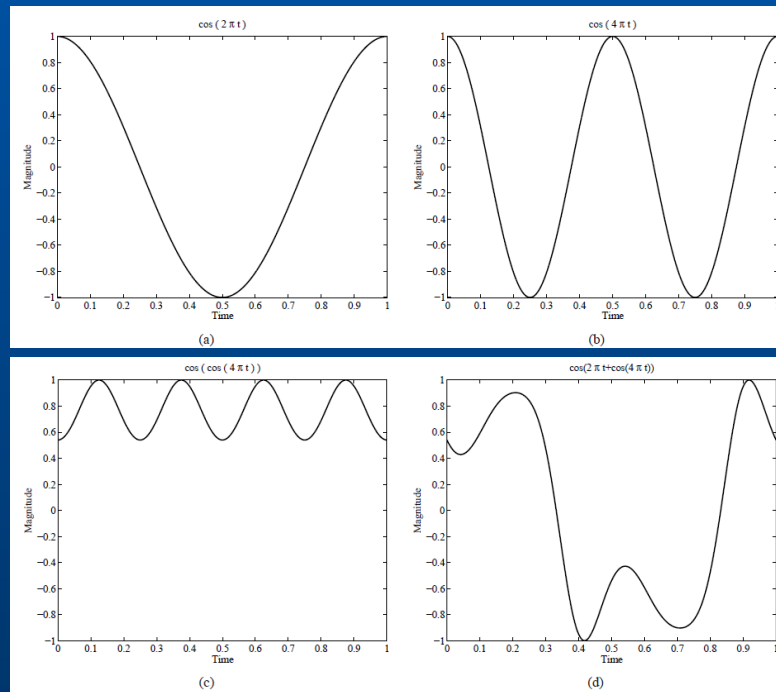
Audio digitization

	Frequency band (Hz)	Sampling rate (kHz)	bits/sample	kbits/sec
Telephone (G.711)	200-3400	8	8	64
Wide-band speech	50-7000	16	8	128
Middle-band audio	10-11000	24	16	384
CD quality music	10-22000	48	16	768

Synthetic sound

Frequency modulation

$$x(t) = A(t) \cos[\omega_c \pi t + I(t) \cos(\omega_m \pi t + \phi_m) + \phi_c]$$



Music Instrument Digital Interface (MIDI)

MIDI is a scripting language
it codes “events” that stand for the production of sounds

MIDI is a standard adopted by the electronic music industry for controlling devices, such as synthesizers and sound cards, that produce music

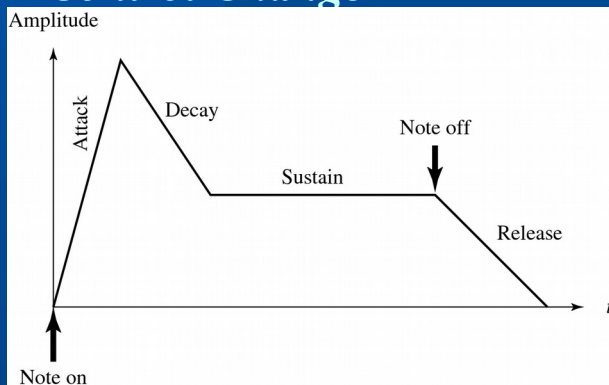
The MIDI standard is supported by most synthesizers

Computers must have a special MIDI interface
incorporated into most sound cards

MIDI messages

Channel Voice Messages

- *Note On / Note Off / Velocity*
- *Aftersustain (pressure)*
- *Pitch Bend*
- *Program Change*
- *Control Change*



Channel Mode Messages

16 channels

Channel 10 : 47 Drum stored sounds

Description

Reset all controllers

Local control

All notes off

Omni mode off

Omni mode on

Mono mode on (Poly mode off)

Poly mode on (Mono mode off)

MIDI system messages

- **System Common Messages**
- **System Real Time Messages**
- **System Exclusive Messages**

System Common Message

MIDI Timing Code

Song Position Pointer

Song Select

Tune Request

EOX (terminator)

System Real-Time Message

Timing Clock

Start Sequence

Continue Sequence

Stop Sequence

Active Sensing

System Reset

MIDI Instrument Patch Map

PIANO

- 1 Acoustic Grand
- 2 Bright Acoustic
- 3 Electric Grand
- 4 Honky-Tonk
- 5 Electric Piano 1
- 6 Electric Piano 2
- 7 Harpsichord
- 8 Clavinet

ORGAN

- 17 Drawbar Organ
- 18 Percussive Organ
- 19 Rock Organ
- 20 Church Organ
- 21 Reed Organ
- 22 Accoridan
- 23 Harmonica
- 24 Tango Accordion

CHROMATIC PERCUSSION

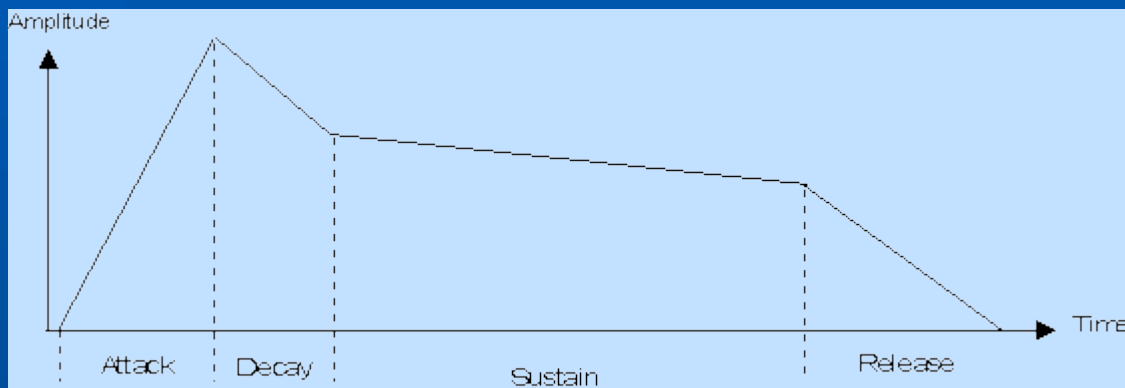
- 9 Celesta
- 10 Glockenspiel
- 11 Music Box
- 12 Vibraphone
- 13 Marimba
- 14 Xylophone
- 15 Tubular Bells
- 16 Dulcimer

GUITAR

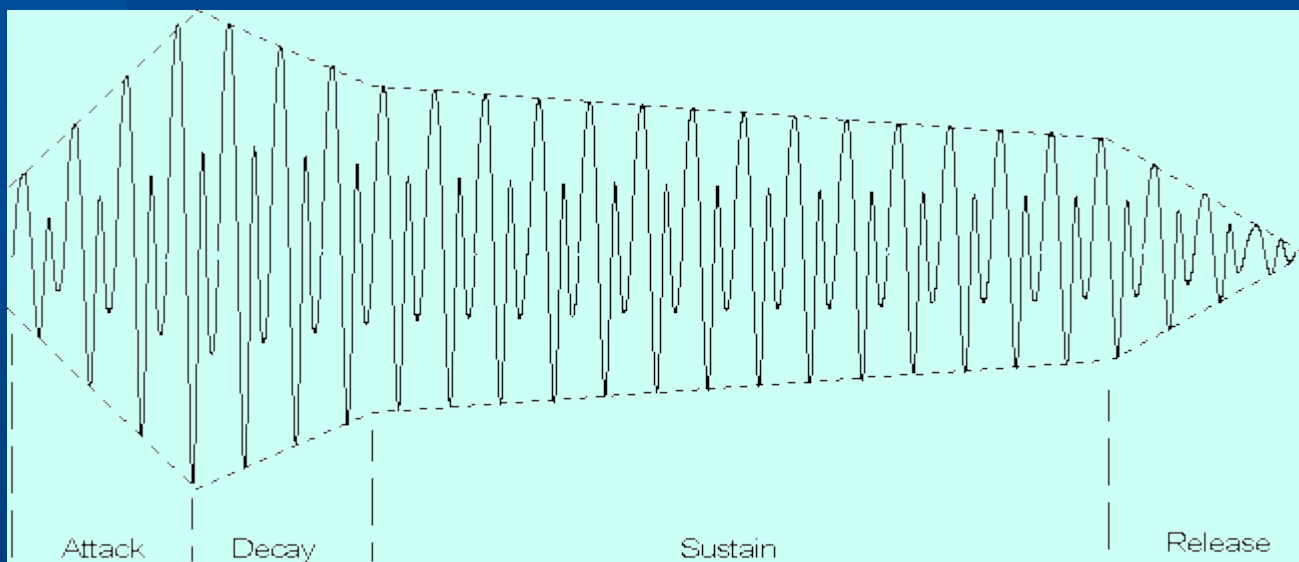
- 25 Nylon String Guitar
- 26 Steel String Guitar
- 27 Electric Jazz Guitar
- 28 Electric Clean Guitar
- 29 Electric Muted Guitar
- 30 Overdriven Guitar
- 31 Distortion Guitar
- 32 Guitar Harmonics

MIDI Synthesizer

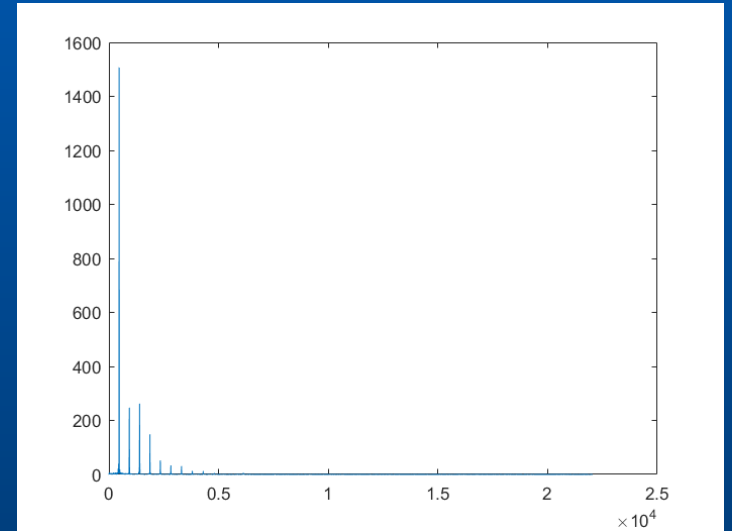
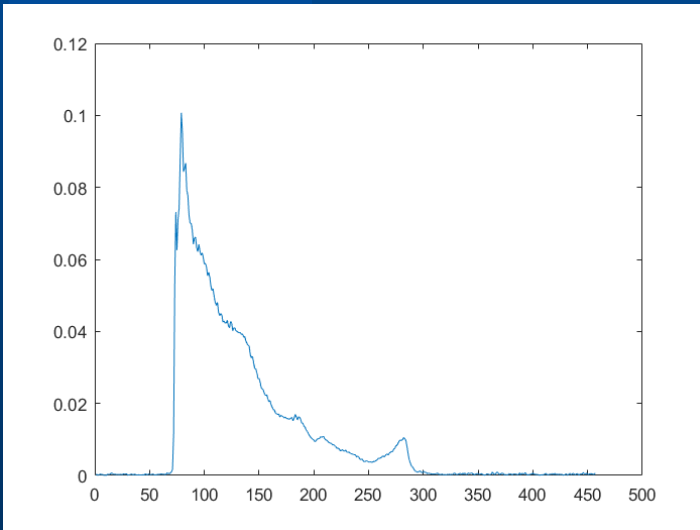
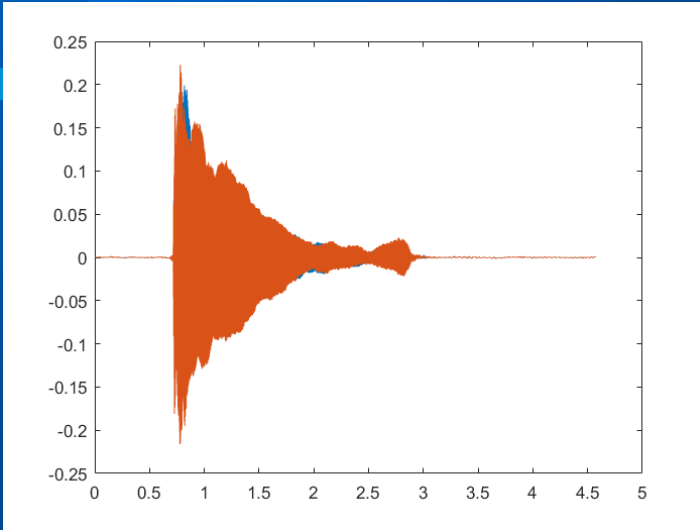
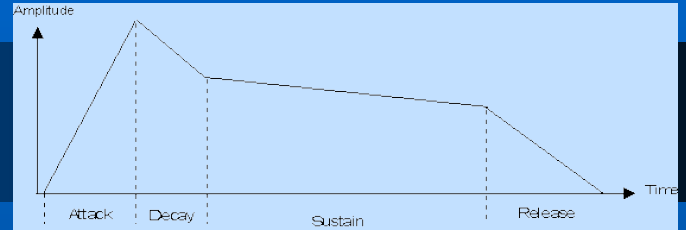
Wavetable



Amplitude
envelope



Assignment 3



Spring 2018

Amplitude envelope