Synthesis and Sampling
Synthesis vs. Sampling

• The two primary methods for producing sound with digital electronic instruments.

• **Synthesis**: any method that generates sound “from the ground up” according to some recipe (algorithm).

• **Sampling**: using digitally recorded and stored audio triggered by MIDI messages to generate sound.
Methods of synthesis

• **Additive** (Fourier synthesis) - combines many simple waveforms to create complex sounds
  ▪ Sine waves layered according to overtone series
  ▪ Requires a lot of computational power
    • Telharmonium, Hammond Organ
    • Soft synths – Alchemy, Reason
Methods of synthesis

• **Subtractive** – starts with a harmonically rich sound, filters subtract partials
  – Moog, ARP, Buchla
  – Soft synths - Subtractor

• Types of filters used in synthesis:
  – Low pass (with resonance)
  – High Pass (with resonance)
  – Band pass
  – Notch filter

• Filters may be combined or layered
Filters

• Most basic synth filter = **low-pass filter**
  – Primary parameter is the **cutoff frequency**
  – Frequencies above the cutoff are attenuated on a slope
    • rated in dB/8va (6, 12, 24)
  – **Resonance** - a boost in the frequencies right at the cutoff point
    • turns the filter into an active participant in the sound
Methods of synthesis

• **FM** (Frequency Modulation) - the sound generated by one oscillator (carrier) is modified by another oscillator (modulator).
  – Yamaha DX series, software synths

• Frequency of the modulator affects the timbre of the carrier
Sidebands in FM Synthesis

Sidebands: partials spaced out on either side of the carrier’s fundamental frequency

$\begin{align*}
  f_c &= 440 \text{ Hz} \\
  f_m &= 110 \text{ Hz}
\end{align*}$
Methods of synthesis

• **Wavetable** - starts with one cycle of a waveform stored in memory.
  - To generate a particular frequency the synthesizer repeats the waveform at that frequency
    • e.g. A 440 = the waveform is repeated 440x/sec
  - Drawback: timbre is static from start to end of a note
    • Necessary to use modulated filters and amplifiers
  - Waldorf synths and soft synths
Methods of synthesis

• **Physical modeling** – simulates the acoustic properties of a sound through mathematical formulas
  – Recreates a sound via a computer model of its sonic characteristics
  – Changes to fit the acoustical traits of an instrument up and down its register
  – Yamaha VL series, various software: Logic Sculpture, Tao
Methods of synthesis

• **Granular** – a method by which sounds are broken into tiny bursts of sound called grains
  – Each grain is very short, 5-50 ms
• Grains are arranged in various ways to create different timbres
  – Native Instruments’ Reaktor

**Agon**
Synthesizer Terminology

• **Multitimbral** synthesizers are capable of playing different timbres at the same time.
• **Polyphony** - refers to the number of voices (notes) that can be played simultaneously.
• **Latency** - how long it takes to hear a sound from a software synth after you press a key on the controller.
Sampling

• When a sound is sampled it is essentially recorded digitally

• Sample has 3 distinct meanings:
  – The output of an ADC converter (“measures” an analog sound)
  – A digitized recording of a complete segment of sound
  – The recording of individual notes on an instrument
Sampling

• Notes on a musical instrument are sampled
  – Each sample is **keymapped** to a MIDI note number, e.g. A 440 is mapped to A3 (69)

• Several key numbers may use the same sample, called a **key zone**
  – Sample is played slightly slower/faster to accommodate different pitches
  – Useful for small numbers of semitones

• **Root key** – note that is sampled for the key zone, the note that gets played back without transposition
Sampling

• **Multisampling:** representative notes are recorded throughout the range of an instrument

• **Chromatic sampling:** each note of an instrument is sampled throughout its range
  
  – Easy today because of large hard drives, faster CPUs
Velocity Switching

- Recording different dynamics of a sampled sound
- Different samples are triggered based on the velocity of the incoming midi signal
- Creates a very realistic representation of an instrument’s changing timbres as notes are played with more/less force
Sample Looping

- Used to lengthen the continuous sustain of a sample
  - Mellotron – early sample playback device
    - tape cartridges, 8 second sustain
- Old days:
  - a sample would be looped after a couple of seconds in order to create sustain
- Today:
  - samples are still looped, but cheaper, larger capacity drives allow for much longer loop segments
Sample Loop
Key Switching

• Used in sample playback device to quickly switch between different playing techniques
• Notes outside the range of an instrument are assigned to change articulation
  – i.e. violin sample may have C1-G1 assigned to switch between pizz, arco, marcato, etc.
Key Switching
(Violin Section)

Key switches
[ ]

Sample maps
[ ]
Contemporary Devices

• Samplers
  – Now largely software based
  – Able to load sample libraries or individual samples and edit them

• Sample Players
  – Can playback a sample library but either can’t load new libraries or edit them

• ROMplers
  – Hardware devices that use fixed samples stored in ROM
  – Some can add/change samples by plugging in ROM cards