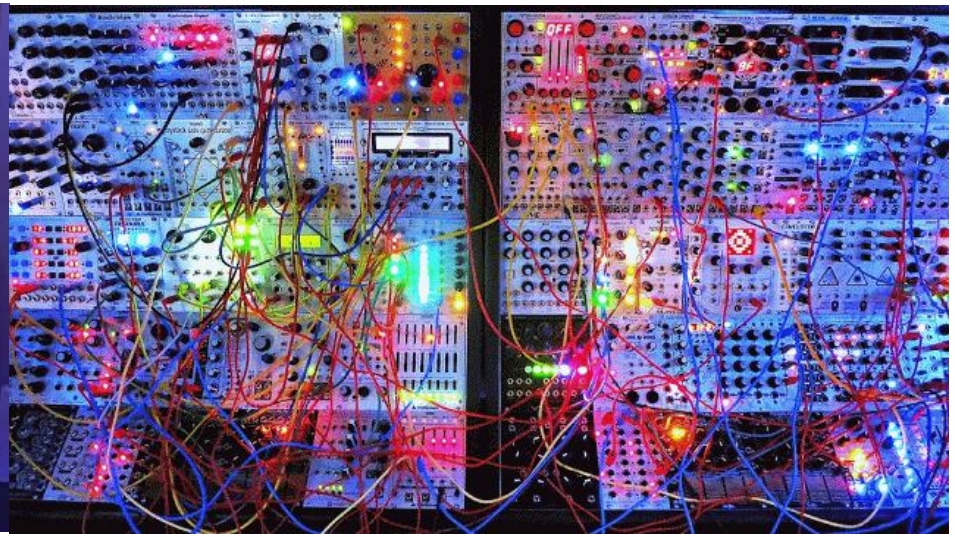
MUSC 4820/5820 Digital Music Techniques 001

Week 9: Sound Synthesis 1 - Additive, Subtractive, Wavetable, & Granular Synthesis



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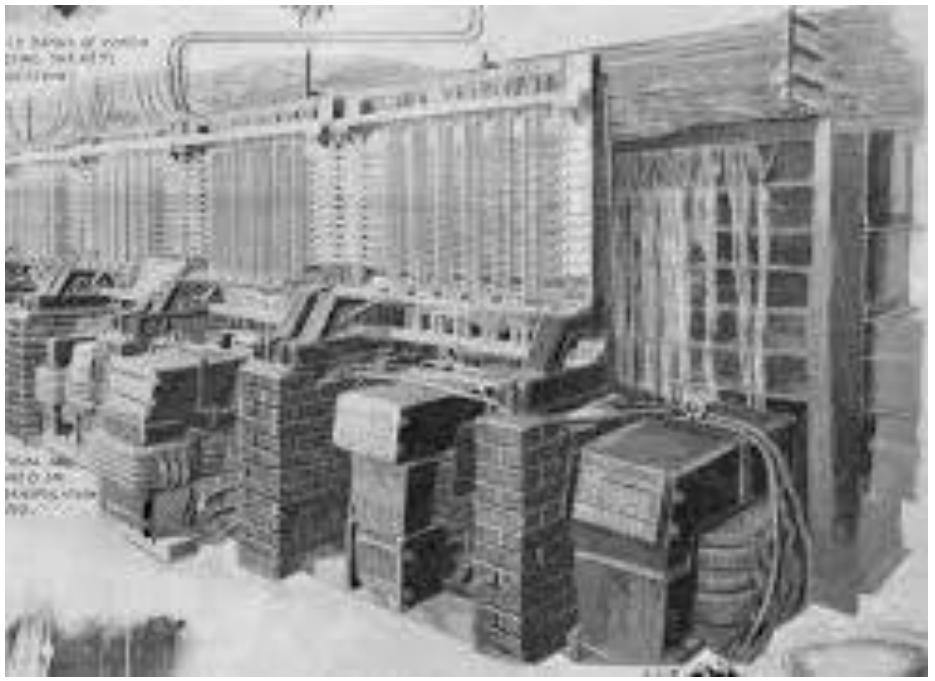
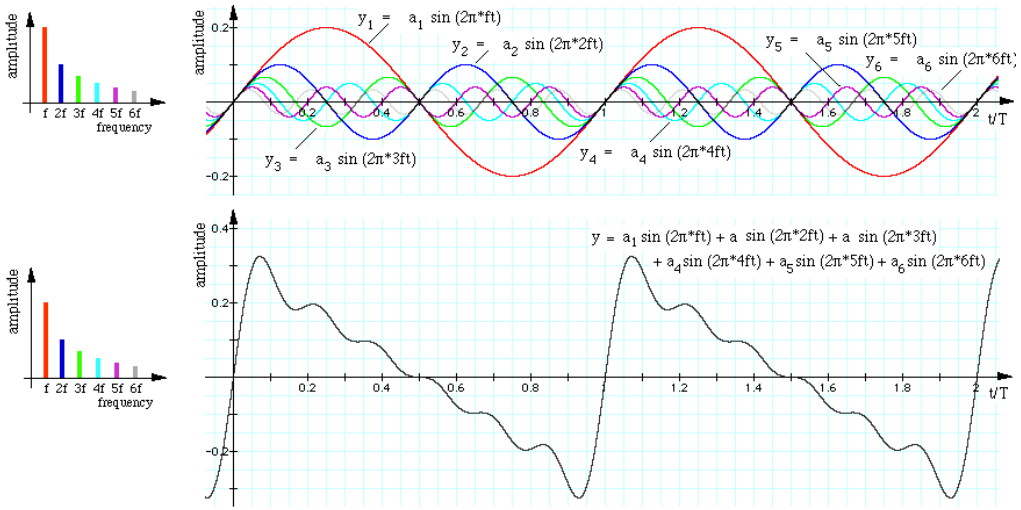
Overview of Sound Synthesis

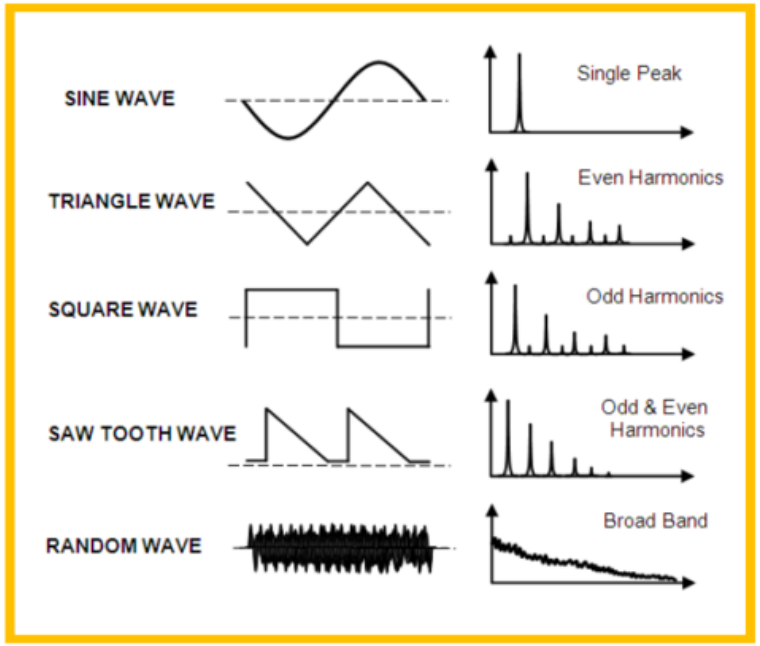
- 1906, “Telharmonium”, the 1st and largest sounds synthesizer
- 1940s, the invention of the stored program electronic digital computer opened the way for the present era
- 1957, Bell Lab, the first experiments in sound synthesis by computer, using a giant IBM 704 computer (MUSIC I program)
- Musical computer programming languages
- 1960s, the first UGen (Unit Generators) Concept was coined by Max Mathews ,using MUSIC III program.
- UGens are signal processing modules like oscillators, filters, and amplifiers – we are still using this concept nowadays
- Time varying and Static synthesis methods: Envelopes, Ugens, and Patches
- Current types of sound synthesis: waveform synthesis; modulation synthesis; physical modeling and formant synthesis; graphic synthesis, stochastic synthesis, spatial synthesis, and many more
- Using software for sounds synthesis in real-time and non-real-time
- Fourier Transfer Theory: Sound analysis and re-synthesis theory (From time domain to frequency domain)



Additive Synthesis

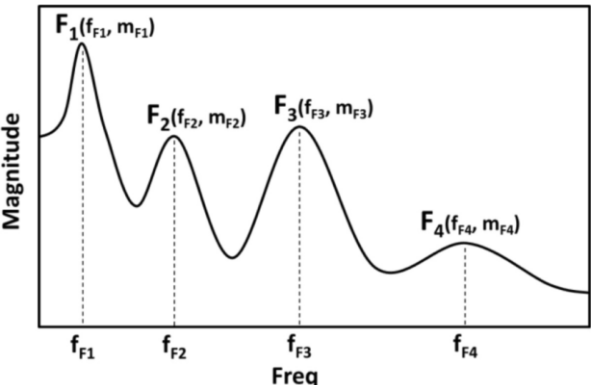
- **Sound Analysis methods to find a sound's key elements :** Short-time Fourier Transform (STFT), Fast Fourier Transform (FFT), and spectrum analysis
- Then, a system combines all the sine waves' frequencies and their proportions varying in time in that particular sound to recreate the original sound –this called resynthesis
- Another good use of Additive synthesis is to add partials through time – this give very subtle sound transformations to enrich the compositional purpose – e.g. evolving pads or drone sounds
- One of the earliest sound synthesis techniques – needs a lot of tone generator, VCAs, Envelopes, and/or LFOs to achieve fine control and manipulation, so it can be very **expensive and inefficient** !!!
- Also, for analog modules, pitch drifting in n oscillator is common, so the **pitch could be lack of accuracy**

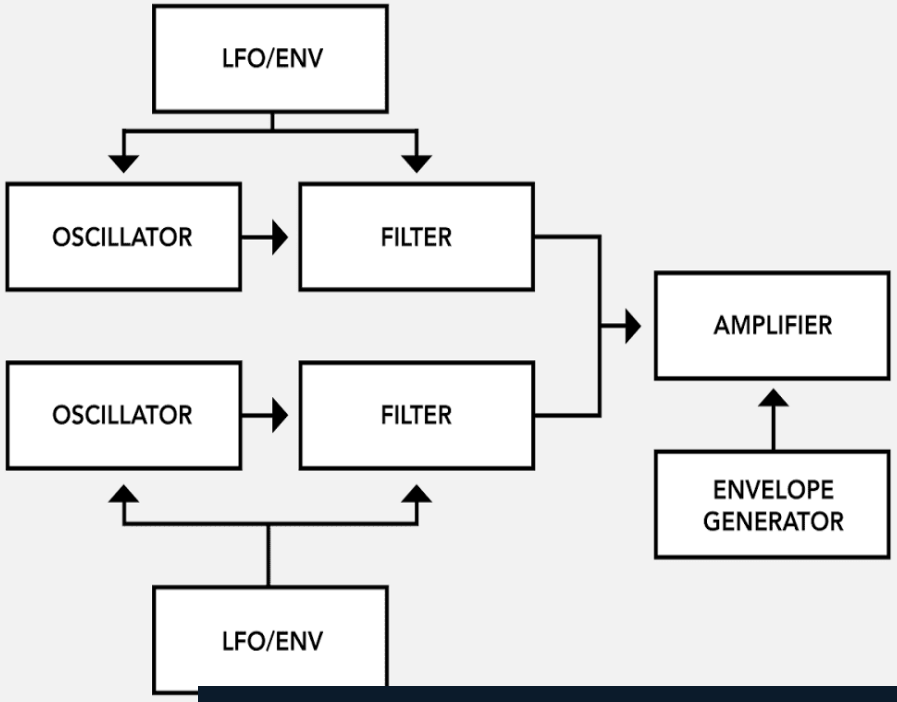


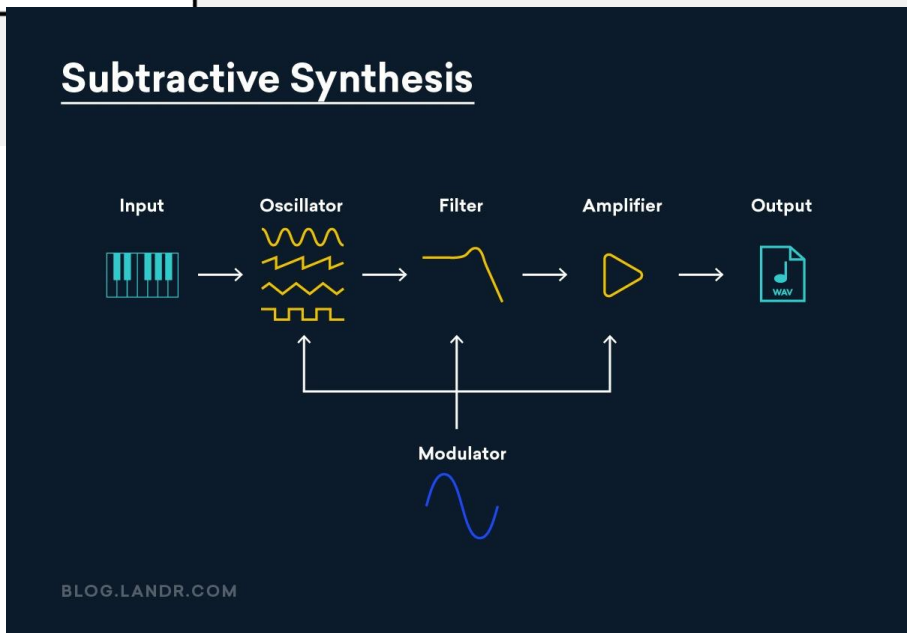


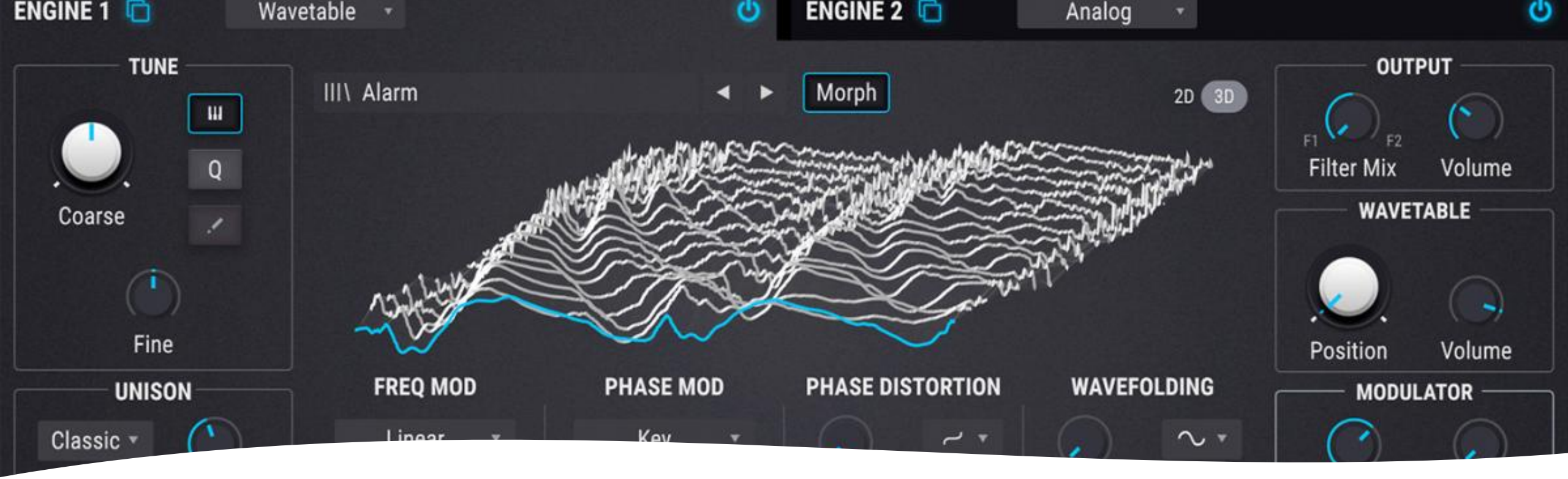
Subtractive Synthesis

- **Sound Analysis methods to find a sound's key elements :** Short-time Fourier Transform (STFT), Fast Fourier Transform (FFT), formant analysis (pitch and amplitude)
- Then, a system usually generates a noise signal to further sculpture the noise with a series of filters - this often is called filter banks and envelopes to recreate the desired sonic results.
- Some of the physical modeling techniques involve subtractive synthesis
- Another good use of Subtractive synthesis is the Vocoder and speech synthesis – e.g. evolving pads or drone sounds (bandpass filters are mostly common for speech synthesis)









Wavetable Synthesis

- **Multiple wavetable synthesis:** wavetable crossfading and wave stacking
- **Wavetable crossfading** creates sounds that mutate from one source to another over time
- **Wavetable Stacking** is a simple and effective variation on additive synthesis. In this method, each sound event results from the addition of several waveforms (typically 4-8 on commercial synthesizer). The difference between wavetable stacking and classical additive synth is that the latter uses only sine waves while wavetable stacking uses complex wave forms.
- There are other more mathematical intensive wavetable synthesis such as Wave Terrain synthesis and time-varying Wave Terrain synthesis that need to calculate orbits and scan terrains, which is widely used in software/digital sound synthesis.

Sample Processing/Manipulation Methods (High-level Organizations for Sonic Grains)

- Editing the audio file length
- Volume level controls and dynamic processors
- Low-fi samplers
- Play back direction
- Pitch shifting and controls
- Looping
- Sample and hold
- Sample slicing and time stretching (granular synthesis)
- Frequency (filtering) and time effects (delay, reverb, chorus, flanging, phasing…) processing; both (Convolution, distortion…)
- Adding voice count (polyphony)
- Use other control voltage sources and modifiers to modulate/modify samples (ADSR, LFOs, and sequencing controls… ☺)
- Spectral control/processing
- MIDI controls (e.g. velocity layers)
- Round-robin switching techniques
- Key switching to change play styles or switch between sample sets
- Scripting (combines concepts of Physical Modeling and Behavioral Modeling with the Multi-Vector/Phase-Synchronous Sample-Morphing technique) e.g. Swam Instruments
- Advance mapping for custom systems
- Combine the above and be creative!!!

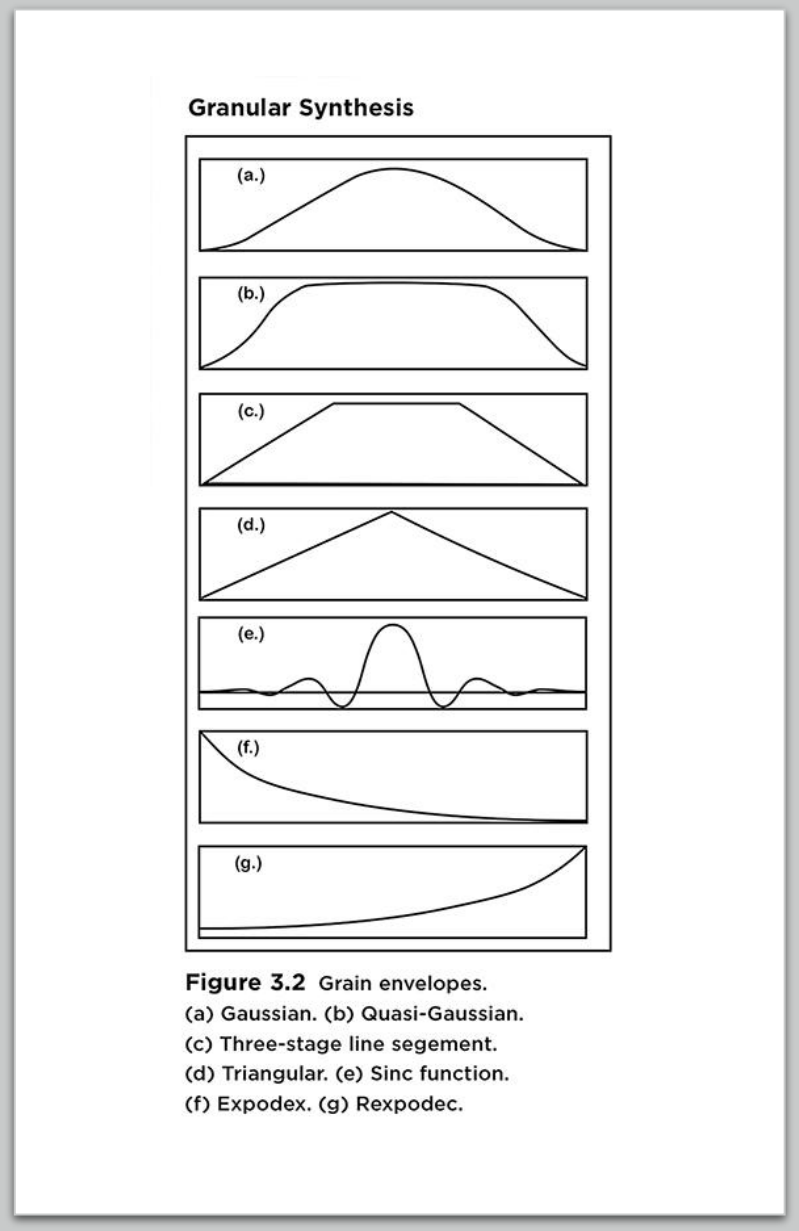


Figure 3.2 Grain envelopes.
(a) Gaussian. (b) Quasi-Gaussian.
(c) Three-stage line segement.
(d) Triangular. (e) Sinc function.
(f) Expodex. (g) Rexpodec.

Granular Synthesis

- **Particle systems and Sonic grains**
- The composer **Iannis Xenakis (1960)** was the first to explicate a compositional theory for grains of sound.
- Then **Curtis Roads** developed the first computer-based implementations of granular synth at UCSD (1974) and MIT (1981).
- Then, a system combines all the sine waves' frequencies and their proportions varying in time in that particular sound to recreate the original sound –this called resynthesis
- Grain Generator (A sinewave oscillator bd ab envelop generator, or simply using samples at a sample/microsound-level) that generate one or more streams of grains with a period between each grain (the speed of the grain-generation determines the pitch or non-pitch)
- Synchronous, Quasi-synchronous, and Asynchronous Granular Synth: Pitch static, pitch varying, and non-pitch granular synths
- High-level granular organizations
- Time granulation of sampled sounds