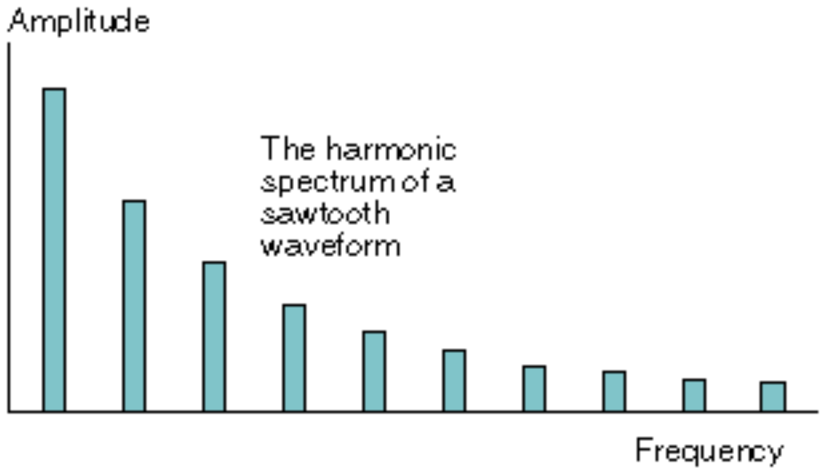
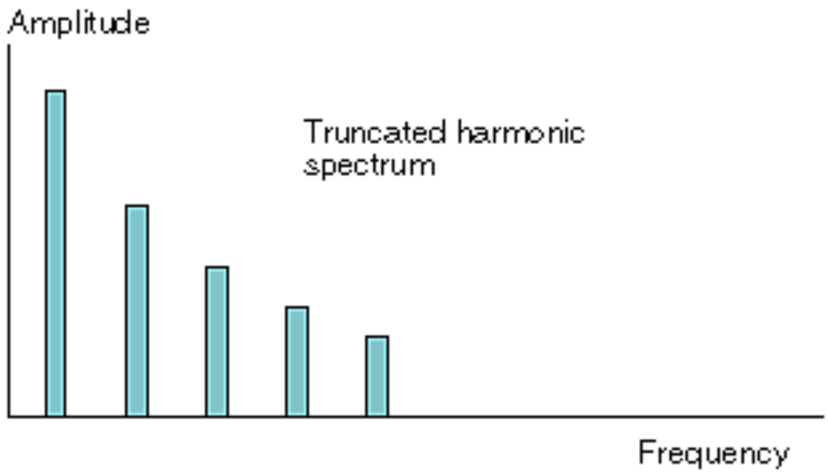
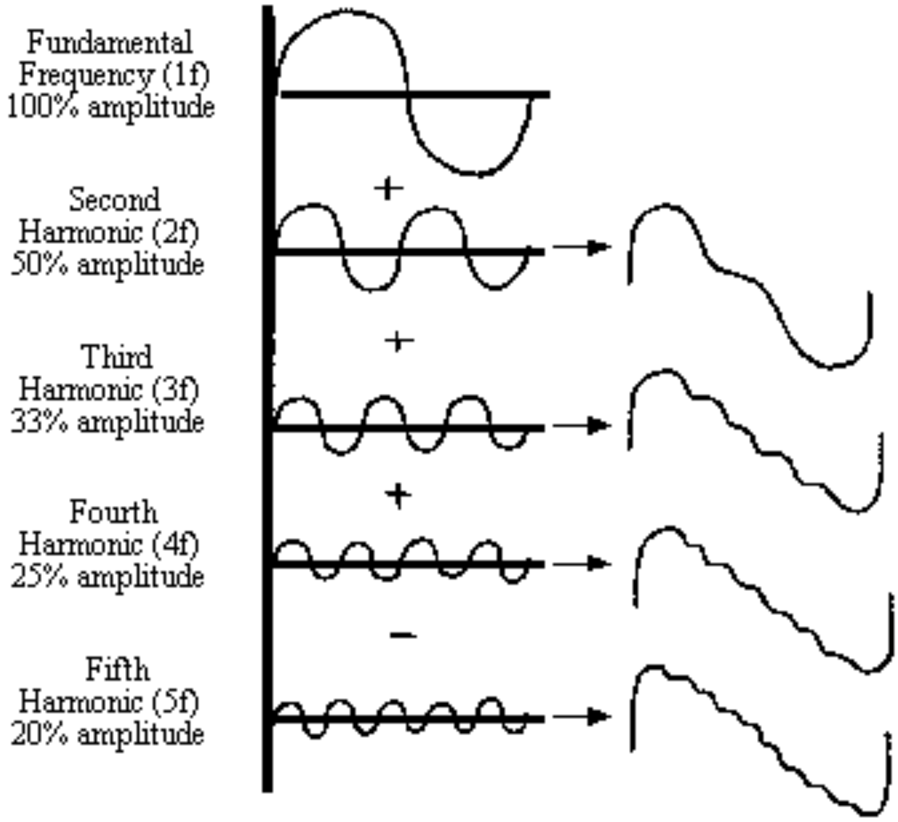
Types of Synthesis

Subtractive synthesis is a method of sound synthesis in which harmonics are attenuated by a filter to alter the timbre (tonality) of the sound. Subtractive synthesis is most commonly associated with analog synthesizers of the 1960s and 1970s, in which the harmonics of simple waveforms such as sawtooth, pulse or square waves are attenuated with a voltage-controlled resonant low-pass filter. Many digital, virtual analog and software synthesizers utilise subtractive synthesis, sometimes in conjunction with other methods of sound synthesis. Virtually all analog and virtual analog synthesizers use subtractive synthesis to generate sounds.





Additive synthesis most directly generates sound by adding the output of multiple sine wave generators. This may consist of multiple harmonic or inharmonic *partials* or overtones. Each partial is a sine wave of different frequency and amplitude that swells and decays over time.



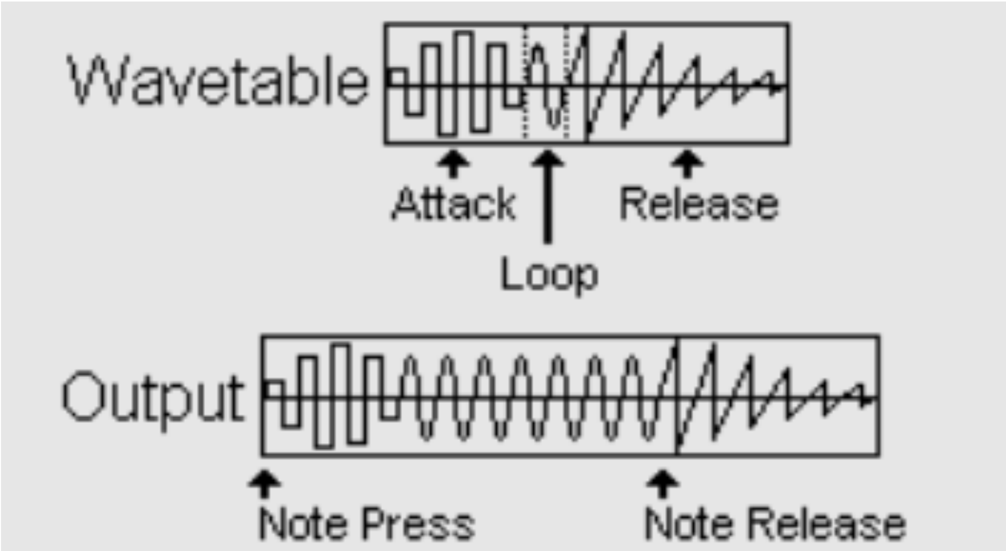
The Making of a Complex Waveform

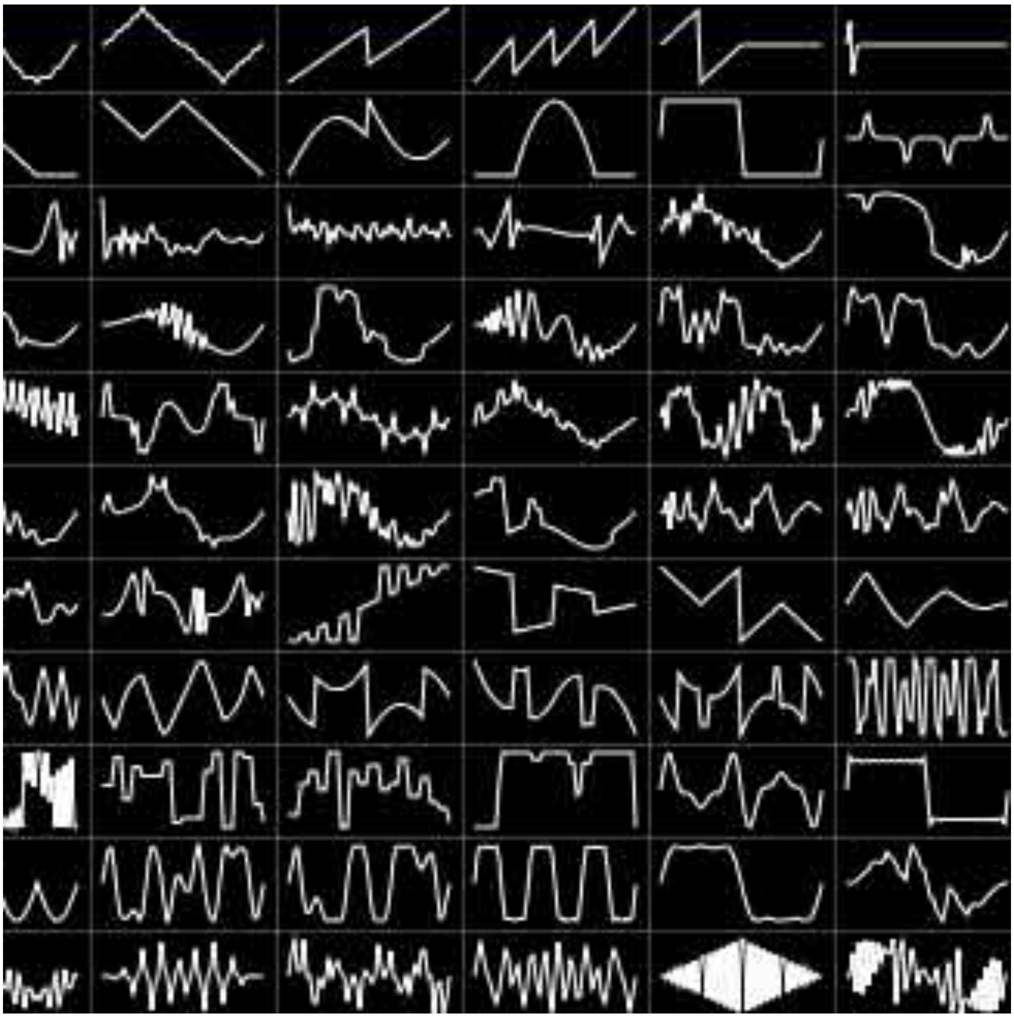
Frequency modulation synthesis (or **FM synthesis**) is a form of audio synthesis where the timbre of a simple waveform (such as a square, triangle, or sawtooth) is changed by modulating its frequency with a modulator frequency that is also in the audio range, resulting in a more complex waveform. The frequency of an oscillator is altered or distorted, "in accordance with the amplitude of a modulating signal."

FM synthesis can create both harmonic and inharmonic sounds. For synthesizing harmonic sounds, the modulating signal must have a harmonic relationship to the original carrier signal. As the amount of frequency modulation increases, the sound grows progressively more complex. Through the use of modulators with frequencies that are non-integer multiples of the carrier signal (i.e. non harmonic), atonal and tonal bell-like and percussive sounds can easily be created.

FM synthesis using analog oscillators may result in pitch instability, however, FM synthesis can also be implemented digitally, the latter proving to be more 'reliable' and is currently seen as standard practice. As a result, digital FM synthesis (using the more frequency-stable phase modulation variant) was the basis of Yamaha's groundbreaking DX7, which brought FM to the forefront of synthesis in the mid-1980s.

Wavetable synthesis is a sound synthesis technique that employs arbitrary periodic waveforms in the production of musical tones or notes. The technique was developed by Wolfgang Palm of PPG in the late 1970s [1] and published in 1979,[2] and has since been used as the primary synthesis method in synthesizers built by PPG and Waldorf Music and as an auxiliary synthesis method by Sequential Circuits, Ensoniq, Korg, Access and Dave Smith Instruments among others.
Wavetable synthesis is fundamentally based on periodic reproduction of an arbitrary, single-cycle waveform.[5] In wavetable synthesis, some method is employed to vary or modulate the waveform definition or waveshape. With 1 degree of modulation, this waveform is one dimension of a two-dimensional array. Moving along the other dimension of the array selects different waveforms. A means of interpolating (by scaling and mixing) between adjacent waveforms allows for smooth transition from one selected waveform to the next. If adjacent waveforms contain subtly different harmonics (in magnitude and phase), the table can be swept, dynamically and smoothly changing the timbre of the tone produced. If the adjacent waves however, have radically different harmonic structures, an audible stepping will be heard and artifacts will be present due to the rapid change in harmonic content. Sweeping the wavetable is usually performed by use of an LFO or a ramp with the start position and direction of sweep being specified by the modulation parameters, and the LFO or ramp speed controlling the rate of the harmonic change.





Granular synthesis is a basic sound synthesis method that operates on the microsound time scale. It is based on the same

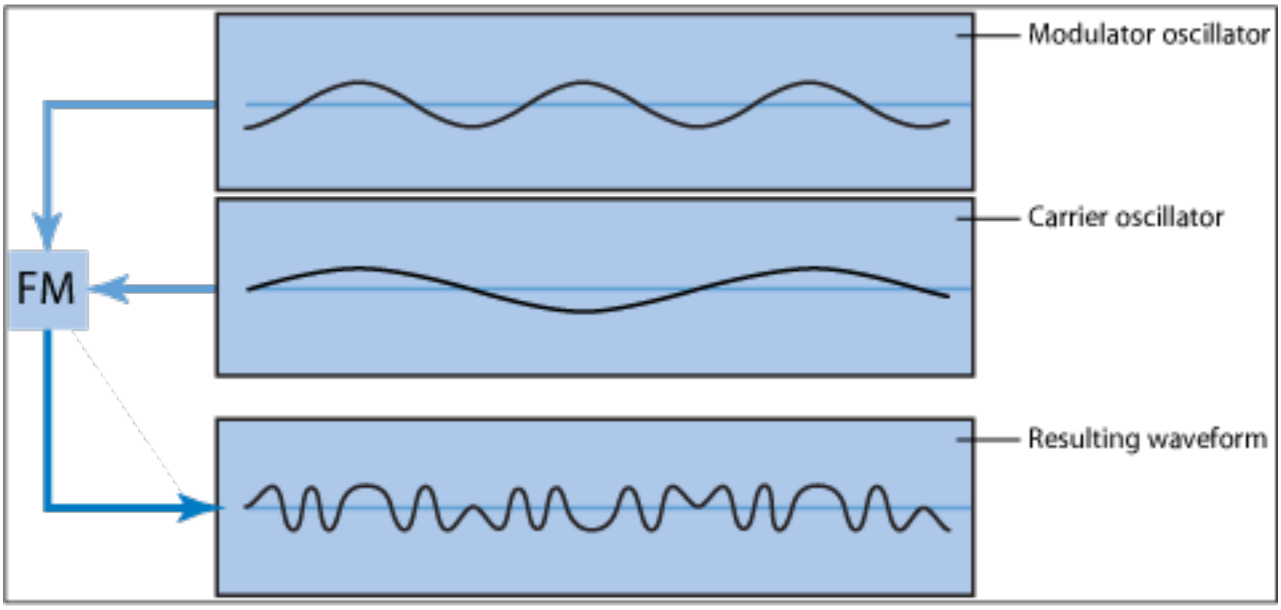
principle as sampling. However, the samples are not played back conventionally, but are instead split into small pieces of around 1 to 50 ms. These small pieces are called **grains**. Multiple grains may be layered on top of each other, and may play at different speeds, phases, volume, and frequency, among other parameters. At low speeds of playback, the result is a kind of soundscape, often described as a cloud, that is manipulatable in a manner unlike that for natural sound sampling or other synthesis techniques. At high speeds, the result is heard as a note or notes of a novel timbre. By varying the waveform, envelope, duration, spatial position, and density of the grains, many different sounds can be produced.
Both have been used for musical purposes: as sound effects, raw material for further processing by other synthesis or digital signal processing effects, or as complete musical works in their own right. Conventional effects that can be achieved include amplitude modulation and time stretching. More experimentally, stereo or multichannel scattering, random reordering, disintegration and morphing are possible.

Additive Synthesis

Additive synthesis could be considered the reverse approach to subtractive synthesis. See the beginning of this appendix, including the discussion about all sounds being a sum of various sine tones and harmonics, for background information to provide insight into additive synthesis.
In essence, you start out with nothing and then build up a sound by combining multiple sine waves of differing levels and frequencies. As more sine waves are combined, they begin to generate additional harmonics. In most additive synthesizers, each set of sine waves is viewed and used much like an oscillator.
Depending on the sophistication of the additive synthesizer you are using, you will be provided with individual envelope control over each sine wave, or you will be limited to envelope control over groups of sine waves—one envelope per sound and its harmonics, or all odd or all even harmonics, for example.
Logic Studio doesn't offer a true additive synthesizer, but aspects of the additive synthesis approach are used in the EVB3 and all other drawbar organs. In the EVB3, you start off with a basic tone and add harmonics to it, to build up a richer sound. The level relationships between the fundamental tone and each harmonic are determined by how far you pull each drawbar out. Because there's no envelope control over each harmonic, however, the EVB3 is limited to organ emulations.

Frequency Modulation (FM) Synthesis

Put simply, FM synthesis involves the use of a modulator oscillator and a sine wave carrier oscillator. The modulator oscillator modulates the frequency of the carrier oscillator within the audio range, thus producing new harmonics. These harmonics are known as sidebands.



Typically, FM synthesizers don’t incorporate a filter. You can generate some subtractive synthesizer style sounds with FM synthesis, but it is difficult to recreate the sound of a resonant subtractive synthesizer filter with this method. FM synthesis is extremely good, however, at creating sounds that are difficult to achieve with subtractive synthesizers—sounds such as bell timbres, metallic tones, and the tine tones of electric pianos. Another strength of FM synthesis is punchy bass and synthetic brass sounds.

Logic Studio includes a simple FM synthesizer, the EFM1. Although it is minimalist, it is capable of producing many of the classic FM sounds made famous by Yamaha’s DX series of synthesizers (the DX7, sold from 1983 to 1986, remains the most commercially successful professional-level hardware synthesizer ever made).

The ES2 also features some FM techniques that allow you to modulate one oscillator with another. You can use these FM techniques to partially bridge the gap between the very digital sound of FM synthesis and the fat analog sound that the ES2 is noted for.

Wavetable Synthesis

Wavetable synthesis uses a number of different single-cycle waveforms, laid out in what is known as a wavetable.

Playing a note on the keyboard triggers a predetermined sequence of waves. In general, this is not a stepped transition but rather a smooth blend from one waveform into another, resulting in a constantly evolving waveform. Multiple wavetables can also be used

simultaneously—either played one after the other, or blended together—resulting in more harmonically complex waveforms.
A single wavetable can emulate filter cutoff with a series of bright, less bright, then dull-sounding waveforms played in sequence—which resembles a reduction of the filter cutoff frequency in a subtractive synthesizer.
Wavetable synthesis isn't particularly successful at emulating acoustic instruments. It is, however, extremely successful at producing constantly evolving sounds; harsh and metallic, or bell-like sounds; punchy basses; and other digital tones.
Wavetable synthesis was championed by the PPG and Waldorf instruments. The ES2 also includes wavetable facilities.

Granular Synthesis

The basic premise behind granular synthesis is that a sound can be broken down into tiny particles, or grains. These sampled grains—usually no more than 10 to 50 ms long—can then be reorganized, or combined with grains from other sounds, to create new timbres.
In many respects, this is much like wavetable synthesis, but it works on a much finer scale. As you might expect, this method is ideal for creating constantly evolving sounds and truly unique tones.
The downside is that granular synthesis is extremely processor-intensive, and it wasn't possible to do it in real time until relatively recently. For this reason, it has remained largely ignored by all but a few in academic institutions. Today's computers, however, have sufficient processing power to make this synthesis method a practicality, and there are a number of commercial products now available.