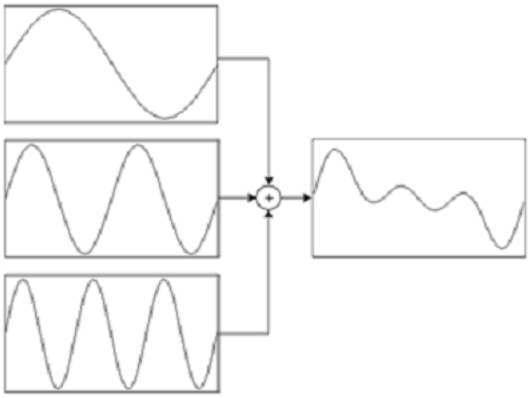
Sound Synthesis in Computer Games **Karen Collins www.gamessound.com**

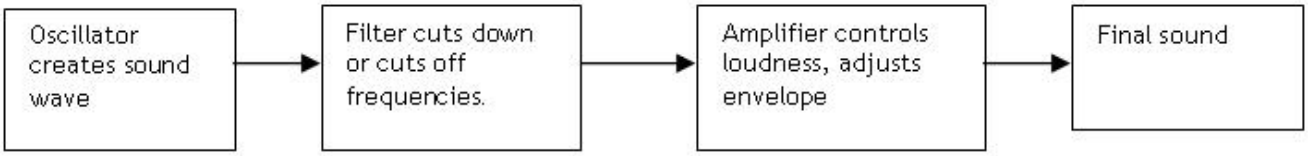
There are ample, excellent discussions in detail of synthesis types on the internet,[1] in journals, and in books on acoustics, computer music, and synthesis, and so on. I will only quickly summarise the main types relevant to video games audio here, then, with a note to their relevance.



Additive synthesis (sometimes referred to as Fourier synthesis, as it is based on Fourier's theorem that all sound waves are made up of sine waves), refers to the creation of a sound wave by adding together simpler sound waves (typically sine waves). Theoretically, additive synthesis was capable of producing any sound, but the sounds of instruments were still difficult to mimic, due to their complexity, in that programming each individual sound was incredibly time-consuming. Additive synthesis chips were popular in the Kawai K5 and K5000 series keyboards, though they never gained much general usage. Atari for a time built an additive synthesis chip known as AMY, in their Atari 65XEM.[2]

Diagram borrowed from Digital Music's Online Course in Additive Synthesis, an excellent resource. http://x.i-dat.org/~csem/UNESCO/4/index.html

Subtractive synthesis starts with a wave form created by an oscillator, and uses a filter to attenuate or subtract specific frequencies and then passes this through an amplifier to control the envelope and amplitude of the final resulting sound. Subtractive synthesis was common in analogue synthesisers, and is often referred to as "analogue synthesis" for this reason. Many arcades and home consoles used subtractive synthesis chips, such as the General Instruments AY-8910 series. The AY-8910 (and derivatives) found its way into a variety of home computers and games consoles including the Sinclair ZX Spectrum, Amstrad CPC, Mattel Intellivision, Atari ST, and Sega Master System.



One of the major sound advances of the 16-bit era was the introduction of **Frequency Modulation (FM) synthesis**. FM synthesis was developed by John Chowning at Stanford University in the early 1970s, and licensed and improved upon by Yamaha, who would use the method for their computer sound chips, as well as the DX series of keyboards. FM uses a modulating (usually sine) wave signal to change the pitch of another wave (known as the carrier). Each FM sound needs at least two signal generators (oscillators), one of which is the carrier wave and one of which is the modulating wave. Many FM chips used four or six oscillators for each sound, or instrument. An oscillator could also be fed back upon itself, modulating its original sound. FM sound chips found their way into many of the early arcade games of the late 1970s and early 1980s, and into most mid-1980s computer sound cards. Compared with PCM or other PSG methods of the 8-bit games era, FM chips were far more flexible, offering a much wider range of timbres and sounds, but still requiring a limited amount of memory. The attributes of FM synthesis were particularly well suited to organ and electric piano sounds, pitched percussion, and plucked instrument sounds, and, as we shall see by the examples below, these instrument sounds dominated those games machines that relied on FM synthesis. Arcades of the 16-bit era typically used one or more FM synthesis chips (the Yamaha YM2151, 2203 and 2612 being the most popular), as well as PCM voice synthesis chips. ADPCM speech chips, a significant advantage over PCM, also made their way into late 1980s coin op machines, such as in the OKI Electric Industry Co.'s OKI 6295 chip, used in *Hit the Ice* (1990 Williams, which used a YM 2203 and two OKI chips, since it had a lot of voice parts, including announcers and crowds), and *Pit Fighter* (1990 Atari, using a YM2151 and an OKI). Other companies, such as Nintendo and Konami, used custom-made chips for their arcade games.

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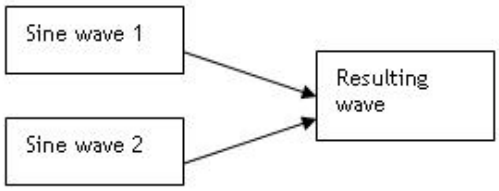
1 Sound on Sound provides an excellent guide to additive synthesis, http://www.soundonsound.com/sos/jun00/articles/synthsec.htm Computer Music's excellent guide on FM synthesis, http://www.computermusic.co.uk/tutorial/fm/fm1.asp. For wavetable synthesis, see www.musicdsp.org/files/Wavetable-101.pdf

2 There is a copy of Amy's specs here: http://www.atarimuseum.com/ahs_archives/archives/pdf/computers/8bits/amy1.pdf



Common FM Sound Chips of the 16-bit Era

Chip and dates commonly used	Systems Using Chip
YM2151 (1984)	Taito, Toaplan and Sega System16. Also found its way into Yamaha DX-series and Korg DS-8 keyboards. YM2151 was Yamaha's first single-chip Fm synthesis chip.
YM2203 (1983-85)	Taito and Capcom arcade chip. Very popular arcade sound chip.
YM2610 (1987-88)	Neogeo and Taito arcade chip. Also used in DX series keyboards and Korg DS-8
YM2413 (1987)	Sega Mark 3 machines, and also some European Sega Master Systems. It supports 9 channels, each of which may play any of 15 pre-defined instruments, or a user-defined sound. In addition, 3 channels can be set for percussion sounds.
YM2612 (1987-88)	Sega Genesis/Megadrive. Similar to those used by AdLib and SoundBlaster sound cards. Channel 6 could be used as PCM sampler (DAC) capable of playing 8-bit PCM sounds. [1]

Wavetable synthesis uses pre-set digital samples of instruments, (usually combined with basic waveforms of subtractive synths). It is therefore much more realistic sounding than FM synthesis, but is much more expensive as it requires the sound card to contain its own RAM or ROM. The Roland MT-32 used a form of wavetable synthesis known as **Linear Arithmetic, or LA synthesis**. Essentially, what the human ear recognises most about any particular sound is the attack transient. LA based synthesisers used this idea to reduce the amount of space required by the sound by combining the attack transients of a sample with simple subtractive synthesis waveforms. This was known as cross modulation. The MT-32 was a MIDI soundcard, capable of 32 simultaneous voices, with 128 pre-set instruments.

Granular synthesis is a relatively new form of synthesis (having begun with the Stochastic Method composers, such as Iannis Xenakis, in the 1970s), which is based on the principle of microsound. Hundreds—perhaps thousands—of small (10-50 millisecond) granules or "grains" of sound are mixed together to create an amorphous soundscape which can be filtered through effects or treated with envelope generators to create sound effects and musical tones. Leonard Paul at the Vancouver Film School is currently working on ways to incorporate granular synthesis techniques into next-generation consoles.

(Footnotes)

1 Technical datasheets, once available by Yamaha's fax-back service, are now found online, though scattered. The datasheet for the 2151, for instance, can be found on : www.ionpool.net/arcade/gottlieb/technical/datasheets/**YM2151**_datasheet.pdf While the YM2203 can be found as a text file onhttp://www.larwe.com/technical/chip_ym2203.html .