Sound Synthesis

PITCH = THE OSCILLATOR

-All sounds consist of waveforms. The component of a synthesizer that generates waveforms at different pitches is called an oscillator.

-Most synthesizers use a keyboard to determine what pitch the oscillator generates. But guitars, bass, drums, wind instruments and even violins can be used to control the pitch of an oscillator.

-Early synthesizers could generate only one pitch at a time. These instruments were known as monophonic.

-Eventually synthesizers were developed that could generate more than one note at a time, allowing chords to be played. These synthesizers were known as polyphonic.

-All synthesizer oscillators can generate a variety of basic waveforms. These usually include (at the very least):

-**Triangle**:Similar in sound to a sine wave but with some additional odd-numbered harmonics that gives it a hollow-sounding quality.

-**Sawtooth**:A bright and rich waveform that contains all harmonics, which decrease steadily in amplitude. The sawtooth waveform is commonly used to generate bright, brassy sounds.

-**Square**:A hollow-sounding waveform that consists of only odd-numbered harmonics.

-**Pulse**:A square waveform that' s modified so that the positive cycle could be just 10% while the negative cycle is 90%, or vice versa, or anywhere in between. Changing the pulse width modifies the harmonic content of this waveform. Continuous changing of the pulse width is known as Pulse Width Modulation and is a technique used to generate rich string sounds.

-In addition to these basic waveforms, most modern synthesizers have oscillators that can generate an even wider variety of waveforms including some that are based on real-world/sampled sounds.

-Most synthesizers contain two or even three oscillators, each of which can be set to generate different waveforms at different pitches. When more than one oscillator is provided, there is also a means of controlling the volume of each oscillator and therefore the “mix” of the waveforms.

TIMBRE = THE FILTER

-In a synthesizer, a filter is used to screen out some frequencies (or harmonics) while letting others pass through. The filter modifies the raw waveform generated by the oscillator to provide additional control over the harmonic spectrum.

-The filter removes harmonics and this concept is the basis of subtractive synthesis, the most common method of synthesizing sounds and the principle on which all analog synthesizers are based.

There are three common types of filters:

-**Low-Pass**:Low frequencies are allowed to pass while high frequencies are blocked. This is the most common filter type. It preserves the bottom end and controls the overall brightness of the sound.

-**High-Pass**:High frequencies are allowed to pass while low frequencies are blocked. This filter produces a “sizzling” high end without any low frequency content.

-**Band-Pass**:This filter allows only a selected band of frequencies to pass through while all frequencies below or above the selected band are blocked. The band-pass filter is used to “bring out” or accentuate specific harmonics.

-Adding RESONANCE (sometimes alternately called EMPHASIS) in the filter boosts those frequencies around the cutoff frequency. Resonance makes the sound more “synth-like” (ie - Rush: Tom Sawyer synth bass) and is also the major parameter of the classic “wah-wah” or “cry-baby” guitar sound.

AMPLITUDE = THE AMPLIFIER

-The amplifier is the component of a synthesizer that controls the volume of the sound.

-Not just the overall volume, but the volume characteristics of the sound from beginning to end.

-Most musical sounds do not maintain a uniform amplitude from beginning to end. For example, a marimba has a sharp beginning (attack) and yet fades away quickly (release).
An accordion note begins slowly because it takes time for the reed to start vibrating. And a piano note starts quickly and fades out gradually as long as the key is held down, but ends quickly as soon as the key is released.

-The amplifier component of a synthesizer can be used to control the volume characteristics of every note that’s played.

More Synthesizer Components

LFO or LOW FREQUENCY OSCILLATOR

-Most synthesizers include one or more LFO' s or LOW FREQUENCY OSCILLATORS.

-These function just like regular oscillators but in a lower, sub-audible frequency range. A selection of different waveforms can be selected for each LFO.

-The output of an LFO is generally used as a source of modulation.

-When routed to an oscillator, a sine wave LFO creates a vibrato effect.

-When routed to a filter, a sine wave LFO creates a wah-wah sound.

-When routed to an amplifier, a sine wave LFO creates a tremolo sound.

-The overall amount of LFO modulation can be controlled using the modulation wheel, usually locat-ed beside the pitch bend wheel and operated with the left hand during a synthesizer performance.

ENVELOPE GENERATOR or ADSR

An ENVELOPE GENERATOR or ADSR is used as a modulation source to control various synthesizer parameters from the moment each key is pressed.

A = ATTACK TIME: the time it takes to reach maximum value from the moment a key is pressed;

D = DECAY TIME: the time it takes to drop from maximum value to the sustain level;

S = SUSTAIN LEVEL: the level that will be maintained as long as the key is held down;

R = RELEASE TIME: the time it takes to drop from the sustain level to zero after the key is released.

-Most synthesizers provide at least two Envelope Generators: one for the filter and one for the amplifier.

-Depending on the ADSR settings, the filter envelope can be used to create filter sweeps (by modulating the cutoff frequency) and the amplifier envelope can create volume “shapes” to mimic the volume characteristics of a piano (sharp attack, slow decay) or a violin (slow attack, full sustain).

Some synths also offer a third envelope generator which can be routed to control the Oscillator Pitch to simulate, for example, the sharp pitch rise at the very start of a trumpet note.

The History of Synthesizers

-The first synthesizers appeared on the music scene in the mid to late 1960's. These early instruments were essentially a series of independent voltage-controlled modules that were connected together with patch cords to produce a sound.

-Bob Moog is generally credited as being the first to produce synthesizers commercially. The Moog Modular was large, complex, and expensive; but musicians were eager to explore the sonic possibilities of a new breed of musical instrument that created sounds that had never been heard before.

-Some of the early musicians and groups that helped introduced the world to synthesizers were:
Walter Carlos "Switched On Bach" ,The Beatles, Rick Wakeman/Yes, Keith Emerson/Emerson Lake & Palmer - "Lucky Man", Tony Banks/Genesis and many more!

-These early synthesizers used the principle of voltage control to create and control sounds. A keyboard was connected to the main synthesizer; playing notes higher up the keyboard produced a higher voltage which was patched to the oscillators to generate a waveform with a higher pitch.

-These instruments were monophonic: only one note could be played at a time. If the player tried to play more than one note at a time, only the lowest pitch would sound (low note priority).

-Soon other companies such as ARP (America) and Roland and Korg (Japan) started to develop commercial synths. By the early 1970' s, a new breed of compact synths were introduced which had internally-wired signal paths and therefore did not require the use of patch cables. Some popular examples are the Moog Minimoog, Arp Odyssey, Roland SH-101 and Korg MicroKorg.

-By the mid-1970' s the first polyphonic synthesizers were developed. The Moog Polymoog had a separate oscillator for each of it's 71 keys! Tom Oberheim developed the first practical polyphonic synth,the Oberheim 4-voice, which used one keyboard to control 4 separate synth modules and provide 4- voice polyphony.

-Up until this time, each synthesizer “patch” was created one sound at a time. Changing from one sound to another could mean tweaking dozens of knobs, sliders and switches. Dave Smith of Sequential Circuits changed all of this in 1978 when he introduced the Prophet V synthesizer, which used an on-board microprocessor to take a “snapshot” of the settings of all those controls and also provided five note polyphony.

-For the first time players could “program” up to 64 “patches” and switch between sounds instantly.
Soon other programmable synths appeared such as the Oberheim OBX and the Roland Jupiter 8.

-All of these synthesizers used analog technology and subtractive synthesis techniques to generate their sounds.

-By 1980 a brand new class of synthesizer emerged: the digital synthesizer.
These new instruments used computer technology to actually generate the sounds.
One of the first popular digital synthesizers was an instrument from a German company called PPG.
The PPG Wave synthesizer used additive synthesis and later wavetable synthesis to create a range of new sounds unlike any of those produced by its subtractive predecessors.

-Around this same time, yet another class of electronic instruments was being invented: samplers.
These instruments used computer technology to record and digitize a short snippet of real sound.
The recorded sound could be mapped to the keyboard and played at different pitches.
By looping the recorded sample, notes could be played for longer than the original duration of the sampled sound.
The potential for reproducing the sounds of real acoustic instruments and everyday sounds grabbed the attention of musical innovators the world over (Peter Gabriel, Art of Noise, Depeche Mode and Yello come to mind).
Some of the first samplers were the Fairlight CMI ($50K) and the New England Digital Synclavier ($75K).
A little later the Emu Emulator ($10K) and PPG Waveterm ($15K) appeared.

-Despite this explosion of new instruments and sound generation techniques that was being made available, one major problem remained: there was no easy way to connect an instrument from one manufacturer to that of another.

-A number of companies (Oberheim, Roland, PPG) had gone so far as to develop their own proprietary digital interfaces, but it took the leadership of Dave Smith from Sequential Circuits to set up an industry meeting in 1982 and propose a “Universal Musical Interface”.

-This new interface eventually became known as MIDI (Musical Instrument Digital Interface).

-The first MIDI instruments were introduced in 1983 from a variety of manufacurers including Sequential Circuits, Roland and Yamaha. MIDI became a standard instantly and virtually every synthesizer manufacured since 1983 has a MIDI interface.

-In 1983 Yamaha introduced what would prove to be the most popular synthesizer ever produced, the Yamaha DX7, which used FM synthesis (frequency modulation) to produce a pallette of sounds that was very expressive in the hands of a capable player.

-In 1986 Roland introduced the D-50, the first synthesizer to use short recordings of real instruments or “samples” to produce patches that came closer than ever before to re-creating the sounds of real acoustic instruments. A new breed of synthesizer, the sample playback synth, was born.

-Up until this time all synthesizers were capable of producing only one sound at a time. In 1987 Roland upped the ante with the introduction of the Roland MT-32, the first multi-timbral sound module. It was like having eight synthesizers in one box - each of the eight synths

could play a different sound at the same time.
For the first time a single instrument could play a complete orchestration.

-Fast forward to 1997 when everything changed forever (again): computers became powerful enough to permit the introduction of the first software-only synthesizers such as ReBirth from Propellerheads.
-These new “virtual instruments/software based instruments” have allowed developers to introduce new techniques for creating sounds without having to design and manufacture hardware.

-Musicians and composers have benefitted from having literally hundreds of different virtual instuments available to them for much less cost (The Digital Audio Workstation).