Synthesizer

A **synthesizer** (also spelled **synthesiser**)[1] is an electronic musical instrument that generates audio signals. Synthesizers generate audio through methods including subtractive synthesis, additive synthesis, and frequency modulation synthesis. These sounds may be shaped and modulated by components such as filters, envelopes, and low-frequency oscillators. Synthesizers are typically played with keyboards or controlled by sequencers, software, or other instruments, often via MIDI.

Early Minimoog by R.A. Moog Inc. (ca. 1970)

Synthesizer-like instruments emerged in the United States in the mid-20th century with instruments such as the RCA Mark II, which was controlled with punch cards and used hundreds of vacuum tubes. The Moog synthesizer, developed by Robert Moog and first sold in 1964, is credited for pioneering analog synthesis concepts such as voltage-controlled oscillators, envelopes, noise generators, filters, and sequencers. In 1970, the smaller, cheaper Minimoog standardized synthesizers as self-contained instruments with built-in keyboards, compared to the modular synthesizers before it. The first mass-produced synthesizer, the Yamaha DX7, was launched in 1983, popularizing digital synthesis. Software synthesizers now can be embedded on single microchips in any electronic device.

Synthesizers were initially viewed as avant-garde, valued by the 1960s psychedelic and counter-cultural scenes but with little perceived commercial potential. *Switched-On Bach* (1968), a bestselling album of Bach compositions arranged for synthesizer by Wendy Carlos, took synthesizers to the mainstream. They were adopted by electronic acts and pop and rock groups in the 1960s and 1970s, and widely used in 1980s rock. Sampling, introduced with the Fairlight synthesizer in 1979, has influenced all genres of music and had a major influence on the development of electronic and hip hop music. Today, the synthesizer is used in nearly every genre of music, and is considered one of the most important instruments in the music industry. According to *Fact* in 2016, "The synthesizer is as important, and as ubiquitous, in modern music today as the human voice."[2]

Contents

History

Precursors

As electricity became more widely available, the early 20th century saw the invention of electronic musical instruments including the Telharmonium, Trautonium, Ondes Martenot, and theremin.[3] In the late 1930s, the Hammond Organ Company built the Novachord, a large instrument powered by 72 voltage-controlled amplifiers and 146 vacuum tubes.[4] In 1948, the Canadian engineer Hugh Le Caine completed the electronic sackbut, a precursor to voltage-controlled synthesizers, with keyboard sensitivity allowing for vibrato, glissando, and attack control.[3]

In 1957, Harry Olson and Herbert Belar completed the RCA Mark II Sound Synthesizer at the RCA laboratories in Princeton, New Jersey. The instrument read punched paper tape that controlled an analog synthesizer containing 750 vacuum tubes. It was acquired by the Columbia-Princeton Electronic Music Center and used almost exclusively by Milton Babbitt, a composer at Princeton University.[3]

1960s: Early years

The authors of *Analog Days* define "the early years of the synthesizer" as between 1964 and the mid-1970s, beginning with the debut of the Moog synthesizer.[5]:7 Designed by American engineer Robert Moog, the synthesizer was composed of separate modules which created and shaped sounds, connected by patch cords.[6] Moog developed a means of controlling pitch through voltage, the voltage-controlled oscillator.[7] This, along with Moog components such as envelopes, noise generators, filters, and sequencers, became standards in the synthesizer market.[8][5]

Robert Moog with a Moog modular synthesizer. Many of Moog's inventions, such as voltage-controlled oscillators, became standards of synthesizers.

Around the same period, American engineer Don Buchla created the Buchla Modular Electronic Music System.[9] Instead of a conventional keyboard, Buchla's system used touchplates which transmitted control voltages depending on finger position and force.[5] However, the Moog's keyboard made it more accessible and marketable to musicians, and keyboards became the standard means of controlling synthesizers.[5] Moog and Buchla initially avoided the word synthesizer for their instruments, as it was associated with the RCA synthesizer; however, by the 1970s, "synthesizer" had become the standard term.[5]

1970s: Market growth

In 1970, Moog launched a cheaper, smaller synthesizer, the Minimoog.[10][11] The Minimoog was the first synthesizer sold in music stores,[5] and was more practical for live performance; it standardized the concept of synthesizers as self-contained instruments with built-in keyboards.[12][13]

After retail stores started selling synthesizers in 1971, other synthesizer companies were established, including ARP in the US and EMS in the UK.[5] ARP's products included the ARP 2600, which folded into a carrying case and had built-in speakers, and the Odyssey, a rival to the Minimoog.[5] The less expensive EMS synthesizers were used by European art rock and progressive rock acts including Brian Eno and Pink Floyd.[5] Designs for synthesizers appeared in the amateur electronics market, such as the "Practical Electronics Sound Synthesiser", published in *Practical Electronics* in 1973.[1] By the mid-1970s, ARP was the world's largest synthesizer manufacturer,[5] though it closed in 1981.[14]

The Minimoog, introduced in 1970, was the first synthesizer sold in music stores.

Early synthesizers were monophonic, meaning they could only play one note at a time. Some of the earliest commercial polyphonic synthesizers were created by American engineer Tom Oberheim,[9] such as the OB-X (1979).[5] In 1978, the American company Sequential Circuits released the Prophet-5, the first fully programmable polyphonic synthesizer.[8]:93 The Prophet-5 used microprocessors for patch memory, allowing users to store sounds.[15] This overcame a major difficulty in previous synthesizers, which required users to adjust cables and knobs to change sounds, with no guarantee of exactly recreating a sound.[5] This facilitated a move from synthesizers creating unpredictable sounds to producing "a standard package of familiar sounds".[5]:385

1980s: Digital technology

The synthesizer market grew dramatically in the 1980s.[8]:57 1982 saw the introduction of MIDI, a standardized means of synchronizing electronic instruments; it remains an industry standard.[16] An influential sampling synthesizer, the Fairlight CMI, was released in 1979,[15] with the ability to record and play back samples at different pitches.[17] Though its high price made it inaccessible to amateurs, it was adopted by high-profile pop musicians including Kate Bush and Peter Gabriel. The success of the Fairlight drove competition, improving sampling technology and lowering prices;[17] early competing samplers included the E-mu Emulator in 1981[17] and the Akai S-series in 1985.[18]

In 1983, Yamaha released the first commercially successful digital synthesizer, the Yamaha DX7.[19] Based on frequency modulation (FM) synthesis developed by Stanford University engineer John Chowning,[20] the DX7 remains one of the bestselling synthesizers in history[19][21] and was the first synthesizer to sell over 100,000 units.[8]:57 It was widely used in 1980s pop music.[22] Compared to the "warm" and "fuzzy" sounds of analog synthesis, the DX7 was characterized by its "harsh", "glassy" and "chilly" sounds.[2]

Digital synthesizers typically contained preset sounds emulating acoustic instruments, with algorithms controlled with menus and buttons.[5] The Synclavier, a digital synthesizer made with FM technology licensed from Yamaha, offered features such as 16-bit sampling and built-in digital recording. With a starting price of $13,000, its use was limited to universities, studios and wealthy artists.[23][24]

The success of the DX7 led to competing digital synthesizers. The Roland D-50 (1987) blended Roland's linear arithmetic algorithm with samples, and was the first mass-produced synthesizer with built-in digital effects such as delay, reverb and chorus.[8]:63 In 1988, the Japanese manufacturer Korg released the M1, a digital synthesizer workstation featuring sampled transients and loops;[25] with over 250,000 units sold, it remains the bestselling synthesizer in history.[25] The advent of digital synthesizers led to a downturn in interest in analog synthesizers.[8]:59

The Yamaha DX7, released in 1983, was the first commercially successful digital synthesizer and was widely used in 1980s pop music.

1990s–present: Software synthesizers and analog revival

Whereas once synthesizers had filled rooms, they can now be embedded on microchips in any electronic device[5] or run as software.[26] 1997 saw the release of ReBirth by Propellerhead Software and Reality by Seer Systems, the first software synthesizers that could be played in real time via MIDI.[8] In 1999, an update to the music software Cubase allowed users to run software instruments (including synthesizers) as plug-ins, triggering a wave of new software instruments.[27] Propellerhead's Reason, released in 2000, offered an array of recognizable virtual studio equipment.[27]

The market for patchable and modular synthesizers rebounded in the late 1990s.[8]:32 In the 2000s, older analog synthesizers regained popularity, sometimes selling for much more than their original prices.[26] In the 2010s, new, affordable analog synthesizers were introduced by companies including Moog, Korg, Arturia, and Dave Smith Instruments. The renewed interest is credited to the appeal of imperfect "organic" sounds and simpler interfaces, and modern surface-mount technology making analog synthesizers cheaper and faster to manufacture.[26]

Impact

Early synthesizers were viewed as avant-garde, valued by the 1960s psychedelic and counter-cultural scenes for their ability to make new sounds, but with little perceived commercial potential. *Switched-On Bach* (1968), a bestselling album of Bach compositions arranged for Moog synthesizer by Wendy Carlos, demonstrated that synthesizers could be more than "random noise machines",[6] taking them to the mainstream.[5] However, debates were held about the appropriateness of synthesizers in baroque music, and according to the *Guardian* they were quickly abandoned in "serious classical circles".[28]

The Moog was adopted by acts including the Doors, the Grateful Dead, the Rolling Stones, the Beatles, and Keith Emerson.[29] Emerson was the first major rock musician to perform with the

Keyboardist Keith Emerson performing with a Moog synthesizer in 1970

Moog and it became a trademark of his performances, helping take his band Emerson, Lake & Palmer to global stardom; according to *Analog Days*, the likes of Emerson, with his Moog performances, "did for the keyboard what Jimi Hendrix did for the guitar".[5]:200

The portable Minimoog (1970), much smaller than the modular synthesizers before it, made synthesizers more common in live performance.[13] The Minimoog took a place in mainstream black music, most notably in the work of Stevie Wonder,[5] and in jazz, such as the work of Sun Ra.[30] It was also used by electronic artists such as Kraftwerk, who used it on their albums *Autobahn* (1974) and *The Man-Machine* (1978), and later by Tangerine Dream, Klaus Schulze, and Gary Numan.[30] In the late 1970s and the early 1980s, the Micromoog was widely used in the emerging disco genre by artists including Abba and Giorgio Moroder.[30] Some acts felt that using synthesizers to create sounds was "cheating"; Queen wrote in their album liner notes that they did not use them.[31]

Early synthesizers could only play one note at a time, making them suitable for basslines, leads and solos.[30] With the rise of polyphonic synthesizers in the 70s and 80s, "the keyboard in rock once more started to revert to the background, to be used for fills and atmosphere rather than for soloing".[5]:207 Sampling, introduced with the Fairlight synthesizer in 1979, has influenced all genres of music[7] and had a major influence on the development of electronic and hip hop music.[32][33]

In the 1970s, electronic music composers such as Jean Michel Jarre[34] and Isao Tomita[35][36][37] released successful synthesizer-led instrumental albums. This influenced the emergence of synthpop, a subgenre of new wave, from the late 1970s to the early 1980s. The work of German krautrock bands such as Kraftwerk[38] and Tangerine Dream, British acts such as John Foxx, Gary Numan and David Bowie, African-American acts such as George Clinton and Zapp, and Japanese electronic acts such as Yellow Magic Orchestra and Kitaro were influential in the development of the genre.[39] Gary Numan's 1979 hits "Are 'Friends' Electric?" and "Cars" made heavy use of synthesizers.[40][41] OMD's "Enola Gay" (1980) used distinctive electronic percussion and a synthesized melody. Soft Cell used a synthesized melody on their 1981 hit "Tainted Love".[39] Nick Rhodes, keyboardist of Duran Duran, used various synthesizers including the Roland Jupiter-4 and Jupiter-8.[42] Chart hits include Depeche Mode's "Just Can't Get Enough" (1981),[39] the Human League's "Don't You Want Me"[43] and works by Ultravox.[39]

In the 1980s, digital synthesizers were widely used in pop music.[22] The Yamaha DX7, released in 1983, became a pop staple, used on songs by A-ha, Kenny Loggins, Kool & the Gang.[2] Its "E PIANO 1" preset became particularly famous,[2] especially for power ballads,[44] and was used by artists including Whitney Houston, Chicago,[44] Prince,[22] Phil Collins, Luther Vandross, Billy Ocean,[2] and Celine Dion.[45] The Roland TB-303 (1981), in conjunction with the Roland TR-808 and TR-909 drum machines, became a foundation of electronic dance music genres such as house and techno when producers acquired cheap second-hand units later in the decade.[46] Korg M1 presets were widely used in 1990s house music, beginning with Madonna's 1990 single "Vogue".[47]

Today, the synthesizer is used in nearly every genre of music.[5]:7 It is considered by the authors of *Analog Days* "the only innovation that can stand alongside the electric guitar as a great new instrument of the age of electricity ... Both led to new forms of music, and both had massive popular appeal."[5]:7 The authors draw a connection to the synthesizer's origins in 1960s psychedelia to the raves and British "second summer of love" of the 1980s and the club scenes of the 1990s and 2000s.[5]:321 According to *Fact* in 2016, "The synthesizer is as important, and as ubiquitous, in modern music today as the human voice."[2] It is one of the most important instruments in the music industry.[39]

Film and television

Synthesizers are common in film and television soundtracks.[5]:273 ARP synthesizers, for example, were used to create sound effects for the 1977 science fiction films *Close Encounters of the Third Kind*[5]:9 and *Star Wars*, including the "voice" of the robot R2-D2.[5]:273 In the 70s and 80s, synthesizers were used in the scores for thrillers and horror films including *A Clockwork Orange* (1971), *Apocalypse Now* (1979), *The Fog* (1980) and *Manhunter* (1986). They were also used to create themes for television shows including *Knight Rider* (1982), *Twin Peaks* (1990) and *Stranger Things* (2016).[48]

Jobs

The rise of the synthesizer led to major changes in music industry jobs, comparable to the earlier arrival of sound in film, which put live musicians accompanying silent films out of work.[49] With its ability to imitate instruments such as strings and horns, the synthesizer threatened the jobs of session musicians. For a period, the Moog was banned from use in commercial work, a restriction negotiated by the American Federation of Musicians (AFM).[5] Robert Moog felt that the AFM had not realized that his instrument had to be studied like any other, and instead imagined that "all the sounds that musicians could make somehow existed in the Moog — all you had to do was push a button that said 'Jascha Heifetz' and out would come the most fantastic violin player".[50]

Musician Walter Sear persuaded the AFM that the synthesizer demanded skill, and the category of "synthesizer player" was accepted into the union; however, players were still subject to "suspicion and hostility" for several years.[5]:149 In 1982, following a tour by Barry Manilow using synthesizers instead of an orchestra, the British Musicians' Union attempted to ban synthesizers, attracting controversy.[51] That decade, a few musicians skilled at programming the popular Yamaha DX7 found employment creating sounds for other acts.[52]

Sound synthesis

Synthesizers generate audio through various forms of analogue and digital synthesis.

In subtractive synthesis, complex waveforms are generated by oscillators and then shaped with filters to remove or boost specific frequencies.

- In subtractive synthesis, complex waveforms are generated by oscillators and then shaped with filters to remove or boost specific frequencies.[8] Subtractive synthesis is characterized as "rich" and "warm".[53]
- In additive synthesis, a large number of waveforms, usually sine waves, are combined into a composite sound.[8][54]
- In frequency modulation (FM) synthesis, waveforms are modulated with the frequency of other waveforms; the resulting complex waveform can, in turn, be used to modulate another, and this another, and so on. FM synthesis can imitate acoustic sounds such as piano, strings and organs.[55] FM synthesis is characterized as "harsh", "glassy" and "chilly".[2]
- Phase distortion synthesis, implemented in Casio CZ synthesizers, is similar to FM synthesis.[54]
- In wavetable synthesis, synthesizers modulate smoothly between digital representations of different waveforms, changing the shape and timbre.[56]
- In sample-based synthesis, instead of sounds being created by synthesizers, samples (digital recordings of sounds) are played back and shaped with components such as filters, envelopes and LFOs.[57]

- In <u>vector synthesis</u>, pioneered by the <u>Prophet VS</u>, users crossfade between different sound sources using controllers such as joysticks.[58]
- In <u>granular synthesis</u>, an audio sample is split into "grains", usually between one hundredth and one tenth of a second in length, which are recombined and played back.[59]
- In <u>physical modelling synthesis</u>, a mathematical model of a physical sound source is created.[60]

Components

Oscillators

<u>Oscillators</u> typically produce waveforms (such as <u>sawtooth</u>, <u>sine</u>, or <u>pulse waves</u>) with different <u>timbres</u>.[8]

Filters

<u>Low-frequency oscillators</u> (LFOs) produce waveforms used to modulate parameters, such as the pitch of oscillators (producing <u>vibrato</u>).[8] <u>Voltage-controlled filters</u> (VCFs) "shape" the sound generated by the oscillators in the frequency domain, often under the control of an envelope or LFO. These are essential to subtractive synthesis. Filters are particularly important in <u>subtractive synthesis</u>, being designed to pass some frequency regions (or "bands") through <u>unattenuated</u> while significantly attenuating ("subtracting") others. The <u>low-pass filter</u> is most frequently used, but <u>band-pass filters</u>, <u>band-reject filters</u> and <u>high-pass filters</u> are also sometimes available.
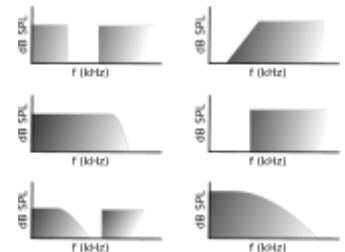

Various filter modes.

The filter may be controlled with a second ADSR envelope. An "envelope modulation" ("env mod") parameter on many synthesizers with filter envelopes determines how much the envelope affects the filter. If turned all the way down, the filter produces a flat sound with no envelope. When turned up the envelope becomes more noticeable, expanding the minimum and maximum range of the filter. The envelope applied on the filter helps the sound designer generating long notes or short notes by moving the parameters up and down such as decay, sustain and finally release. For instance by using a short decay with no sustain, the sound generated is commonly known as a *stab*. Sound designers may prefer shaping the sound with filter instead of volume.

Envelopes

Envelopes control how sounds change over time. They may control parameters such as <u>amplitude</u> (volume), filters (frequencies), or pitch. The most common envelope is the ADSR (attack, decay, sustain, release) envelope:[8]
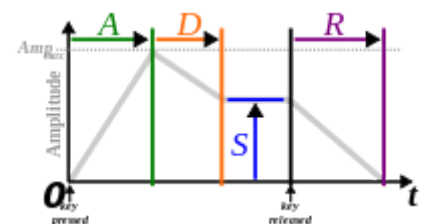
Schematic of ADSR

- **Attack time** is the time taken for initial run-up of level from nil to peak, beginning when the note is triggered.
- **Decay time** is the time taken for the subsequent run down from the attack level to the designated sustain level.

- **Sustain level** is the level during the main sequence of the sound's duration, until the key is released.
- **Release time** is the time taken for the level to decay from the sustain level to zero after the key is released.

Low-frequency oscillators

Low-frequency oscillators (LFOs) generates an electronic signal, usually below 20 Hz. LFO signals create a periodic control signal or sweep, often used in vibrato, tremolo and other effects. In certain genres of electronic music, the LFO signal can control the cutoff frequency of a VCF to make a rhythmic wah-wah sound, or the signature dubstep wobble bass.

LFO section of Access Virus C

Arpeggiators

An **arpeggiator** (**arp**) is a feature available on several synthesizers that automatically steps through a sequence of notes based on an input chord, thus creating an arpeggio. The notes can often be transmitted to a MIDI sequencer for recording and further editing. An arpeggiator may have controls for speed, range, and order in which the notes play; upwards, downwards, or in a random order. More advanced arpeggiators allow the user to step through a pre-programmed complex sequence of notes, or play several arpeggios at once. Some allow a pattern sustained after releasing keys: in this way, a sequence of arpeggio patterns may be built up over time by pressing several keys one after the other. Arpeggiators are also commonly found in software sequencers. Some arpeggiators/sequencers expand features into a full phrase sequencer, which allows the user to trigger complex, multi-track blocks of sequenced data from a keyboard or input device, typically synchronized with the tempo of the master clock. Arpeggiators seem to have grown from the accompaniment system used in electronic organs in the mid-1960s to the mid-1970s.[61]

Voltage-controlled amplifiers

Voltage-controlled amplifiers (VCAs) control the volume or gain of the audio signal. VCAs can be modulated by other components, such as LFOs and envelopes.[8] A VCA is a preamp that boosts (amplifies) the electronic signal before passing it on to an external or built-in power amplifier, as well as a means to control its amplitude (volume) using an attenuator. The gain of the VCA is affected by a *control voltage* (CV), coming from an envelope generator, an LFO, the keyboard or some other source.[62]

Controllers

Synthesizers are often controlled with electronic or digital keyboards or MIDI controller keyboards, which may be built into the synthesizer unit or attached via connections such as CV/gate, USB, or MIDI.[8] Keyboards may offer expression such as velocity sensitivity and aftertouch, allowing for more control over the sound.[8] Other controllers include Ribbon controllers, which track the movement of the finger across a touch-sensitive surface; wind controllers, played similarly to woodwind instruments;[8] motion-sensitive controllers similar to video game motion controllers;[8] electronic drum pads, played similarly to the heads of a drum kit;[8] touchplates, which send signals depending on finger position and force;[8] controllers designed for microtonal tunings;[8] touchscreen devices such as tablets and smartphones;[8] and fingerpads.[8]

Clones

Synthesizer clones are unlicensed recreations of previous synthesizers, often marketed as affordable versions of famous musical equipment. Clones are available as physical instruments and software. Companies that have sold software clones include Arturia and Native Instruments. Behringer manufactures equipment modelled on instruments including the Minimoog, Pro-One, and TB-303, and drum machines such as the TR-808. Other synthesizer clones include the MiniMOD (a series of Eurorack modules based on the Minimoog), the Intellijel Atlantis (based on the SH-101), and the x0x Heart (based on the TB-303).[64]

Creating clones of older hardware is legal where the patents have expired.[64] In 1997, Mackie lost their lawsuit against Behringer[65] as copyright law in the United States did not cover their circuit board designs.[64]

The Behringer TD-3 (top) is based on the Roland TB-303 (bottom).[63]

See also

Lists

- List of synthesizers
- List of synthesizer manufacturers

Various synthesizers

- Guitar synthesizer
- Keyboard bass
- Keytar
- Modular synthesizer
- Semi-modular synthesizer
- String synthesizer
- Wind controller

Related instruments & technologies

- Clavioline (Musitron)
- Electronic keyboard
- Musical instrument
- Music workstation
- Sampler
- Speech synthesis
  - Vocaloid

Components & technologies

- Analytic signal
- Envelope detector
- Low-frequency oscillation
- MIDI

Music genres

- Computer music
- Electronic music

Notable works

- *List of compositions for electronic keyboard*

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External links

- Sound Synthesis Theory wikibook
- Principles of Sound Synthesis (http://www.acoustics.salford.ac.uk/acoustics_info/sound_synthesis/?content=index) at Salford University
- Synthesizer Tutorial (https://sites.google.com/site/learning4synthesizer/home)