Electronic Musician
A PRIMEDIA Publication

The Electronic Century Part III: Computers and Analog Synthesizers

Joel Chadabe

Electronic Musician, Apr 1, 2000

The recorder, which became commercially available around 1950, made possible a musical revolution because it allowed composers to record sounds and arrange them into any order. Throughout the 1950s and 1960s, advances in technology led many composers to realize there were sonic possibilities beyond magnetically recorded sounds. For these composers, the goal was to compose sound itself, and computers and analog synthesizers provided the means to do so.

The beginnings of electronic synthesis.

MUSIC FROM COMPUTERS The first computer-generated sound was heard in 1957 at Bell Telephone Laboratories in Murray Hill, New Jersey. Max Mathews had finished writing Music I, the first program to generate sounds with a computer, and used it to play a 17-second composition by a colleague, Newman Guttman. Although the piece didn't win any music awards, it was the first computer music composition and marked the birth of digital sound synthesis.

John Pierce, head of the department in which Mathews worked, was interested in the possibilities of sound synthesis. With Pierce supporting his work, Mathews and his collaborators made continued improvements to the Music I program over the next several years, resulting in a series of programs that came to be known as the Music-N series: Music II (1958), Music III (1960), Music IV (1962), and the last in the series, Music V (1968).

Music V was modular and hierarchical in its structure. The software simulated oscillators, mixers, amplifiers, and other audio modules; each module was referred to as a unit generator. The software oscillators functioned by reading waveforms from numerical tables and outputting streams of numbers that represented those waveforms. Numerical outputs from two software oscillators, for example, could then be added together in a 2-input software mixer. The output from the mixer could in turn be scaled in a software amplifier by multiplying it by a fixed number-increasing its amplitude if the multiplier was more than 1 and decreasing its amplitude if the multiplier was less than 1. In the Music V language, a particular combination of unit generators was called an instrument, a sound was called a note, and a sequence of notes was called a score. The Electronic Century

Additional work in computer music was being done at the Massachusetts Institute of Technology by Ercolino Ferretti, and also at Princeton University by Hubert Howe, Jim Randall, and Godfrey Winham, who introduced some improvements to Music IV. During the first several years, however, developments in computer music were centered at and around Bell Labs. By the mid-1960s, the field began to expand when centers were established at Stanford University, Columbia University, and elsewhere. With sound synthesis becoming an important direction for musical research, the field of computer music continued to grow well into the '70s.

As if to underline the importance of this new technology, the French government established the Institute for Research and Coordination of Acoustics and Music (IRCAM) in Paris in 1977. Jean-Claude Risset (see Fig. 1), who had worked with Max Mathews at Bell Labs in the '60s, was appointed head of IRCAM's computer music department.

EARLY COMPUTER WORKS The computer music research at Bell Labs and other institutions provided the backdrop to the first round of creative musical work with computers. From the beginning, John Pierce and Max Mathews had been eager to make contact with musicians, and in 1961 Pierce hired composer James Tenney to come and work at Bell Labs.

Tenney worked at Bell from 1961 to 1964 and completed several compositions during that period. His first was Analog #1: Noise Study, finished in 1961 and inspired by the random noise patterns he heard in the Holland Tunnel on his daily commute between Manhattan and New Jersey. His interest in randomness at that time included using the computer to make musical decisions as well as to generate sound. In Dialogue (1963), Tenney used various stochastic methods to determine the sequencing of sounds.

Tenney continued to develop his stochastic ideas in Phases (For Edgard Varese) (1963), in which different types of sounds are statistically combined. His techniques resulted in sounds with continually changing textures, similar to a fabric made up of a variety of materials in various shapes and colors.

In 1963, Mathews published an influential article on computer music titled "The Digital Computer as a Musical Instrument" in Science. Jean-Claude Risset, at the time a physics graduate student in France, read the article and became so excited by the potential of computer music that he decided to write his thesis based on research he planned to do at Bell Labs. Risset came to Bell in 1964, began research in timbre, returned to France in 1965, and came back to Bell in 1967. He completed Computer Suite from Little Boy in 1968 and Mutations in 1969. Both compositions contain sounds that could not have been produced by anything but a computer.

Meanwhile, at Stanford University in 1963, John Chowning also came across Max Mathews's Science article and became inspired to study computer science. Chowning visited Bell Labs in the summer of 1964 and left with the punched cards for Music IV. He subsequently established, with David Poole, a laboratory for computer music at Stanford. The lab would eventually become the Center for Computer Research in Music and Acoustics (CCRMA), a major center for computer music research. Chowning later went on to develop frequency modulation (FM) as a method for generating sound. His approach to FM, in fact, was licensed by Yamaha in 1974 and was the basis of sound production in many Yamaha synthesizers through the 1980s.

Chowning's early compositions Sabelithe (1971) and Turenas (1972) both simulated sounds moving in space. In Stria (1977), Chowning used the Golden Section to determine the spectra of the sounds. The results were otherworldly-magical, strange, icy, and unlike anything that one could imagine coming from an acoustic instrument.

WAITING FOR A SOUND James Tenney, Jean-Claude Risset, and John Chowning were among the first composers to work with computers in the 1960s. Many others followed in the 1970s and 1980s, including Charles Dodge, Barry Vercoe, Jonathan Harvey, Larry Austin, Denis Smalley, and Paul Lansky. Yet compared with composers working with the interactive computer systems of today, these pioneers had a job that was far from easy.

They required technical knowledge, perseverance, patience, and the ability to deal with a lot of frustration. The time frame between specifying a musical idea at the computer and hearing the results, for example, was often measured in days or weeks. A composer would accumulate a Music V creation on a digital tape second by second, day by day. When the composition was finished, the digital tape was normally taken to a particular department at Bell Labs, where it was converted into analog signals and recorded onto an audiotape. This process could take up to two weeks to complete.

A serious problem with this way of working was that composers were not able to hear a work as they created it. Many musicians of the time, including those who were attracted to electronics, did not want to deal with the long turnaround times necessary for generating computer music. Another significant problem was that composers and musicians had to know computer programming.

BIRTH OF THE SYNTHESIZER Analog synthesizers provided a solution. They made possible a new world of sound without the need for programming skills. Synthesizers were also designed for performance and provided an immediacy of response resembling the performance capabilities of traditional musical instruments. Even though synthesizers were based on new technologies, many musicians found them attractive because they had familiar forms and features.

In 1964 three men independently invented analog synthesizers: Robert Moog in Trumansburg, New York; Paul Ketoff in Rome; and Donald Buchla in San Francisco.

That year Robert Moog invited composer Herb Deutsch to visit his studio in Trumansburg. Moog had met Deutsch the year before, heard his music, and decided to follow the composer's suggestion and build electronic music modules. By the time Deutsch arrived for the visit, Moog had created prototypes of two voltage-controlled oscillators. Deutsch played with the devices for a few days; Moog found Deutsch's experiments so musically interesting that he subsequently built a voltage-controlled filter.

Then, by a stroke of luck, Moog was invited that September to the AES Convention in New York City, where he presented a paper called "Electronic Music Modules" and sold his first synthesizer modules to choreographer Alwin Nikolais. By the end of the convention, Moog had entered the synthesizer business (see Fig. 2).

Also in 1964, Paul Ketoff, a sound engineer for RCA Italiana in Rome, approached William O. Smith, who headed the electronic music studio at the city's American Academy, with a proposal to build a small performable synthesizer for the academy's studio. Smith consulted with Otto Luening, John Eaton, and other composers who were in residence at the academy at the time. Smith accepted Ketoff's proposal, and Ketoff delivered his Synket (for Synthesizer Ketoff) synthesizer in early 1965.

Meanwhile, Donald Buchla had begun working with Morton Subotnick and Ramon Sender at the San Francisco Tape Music Center. After designing and building a waveform generator controlled by optical sensors, Buchla conceived of a voltage-controlled synthesizer that incorporated an analog sequencer. Subotnick and Sender requested and received a small grant from the Rockefeller Foundation, and Buchla built the synthesizer and delivered it to the Tape Music Center in the early months of 1965.

Buchla worked closely with Subotnick throughout 1965 to refine the synthesizer, and by the end of the year they had developed what Buchla called the Series 100. In 1966 he formed a company, Buchla and Associates, and began to sell the Electronic Music System (see Fig. 3).

EARLY SYNTH TECHNOLOGY The first round of analog synthesizers were voltage-controlled modular systems-a collection of separate modules, each with a particular audio or control function. The audio modules typically included oscillators, noise generators, filters, and amplifiers.

Sounds were normally generated by subtractive synthesis. With this technique, a composer links oscillators in frequency- or amplitude-modulation configurations to generate complex waveforms, then focuses on elements of the sound within the waveform by using filters to subtract partials.

Typical controllers of the day included envelope generators and keyboards. Buchla employed analog sequencers in his first systems in 1965, and Moog began incorporating them into his systems in 1968.

Analog sequencers are used to generate a series of voltages. The voltage level of each stage in the series is controlled independently by a knob. Each stage is then played in sequence, one after the other, using an oscillator to control the timing. The Moog sequencer, for example, had 24 stages configured in 3 rows of 8.

Sometimes sequencers were used to automate aspects of a performance. But it was far more common to use a keyboard controller to play an analog synthesizer. Voltages generated by the keyboard controlled the frequencies of the oscillators and filters. Every time a key was pressed, the keyboard triggered an envelope generator that normally controlled the filter and amplifier.

EARLY SYNTHESIZER WORKS The specific design of each synth-the type of keyboard it used, for example-optimized it for a particular musical and performance approach.

The Moog synthesizer was the most traditional of the three early synths because its keyboard resembled a traditional piano keyboard in size and operation. The keys were approximately the same size as those on a piano, and the case was made of wood. As if to verify the traditional functionality of the Moog keyboard, Wendy Carlos used a Moog synthesizer to record Switched-On Bach (1968).

The Synket was a bit less traditional than the Moog and much more compact and portable. Its keyboard was smaller than that of a normal piano, and each key could be wiggled sideways to bend the pitch. Pianist and composer John Eaton immediately saw its potential and began using the Synket as a performance instrument. In 1965 Eaton composed Songs for RPB, for soprano, piano, and Synket. In April of that year, in what was possibly the first public performance using a synthesizer, Eaton accompanied soprano Michiko Hirayama in a concert at the American Academy in Rome. This author had the particular distinction of turning pages at that concert.

The Buchla modular system was the least traditional of the three synthesizers. Its keyboard was made up of a series of fixed-position capacitance-sensitive metal strips, each of which generated a voltage when touched. Morton Subotnick, who had played a role in the Buchla synth's design, used it extensively.

In 1966 Subotnick relocated to New York City, where Nonesuch Records commissioned him to create a series of works specifically for release as recordings. He had brought a Buchla synthesizer with him and used it to compose Silver Apples of the Moon, the first of the series, in 1967. The Wild Bull and Touch followed in 1968 and 1969, respectively.

Subotnick's approach to composing music was unconventional in that he did not play his creations using a keyboard but instead automated most of the detail with the sequencers. In these compositions, Subotnick functioned more as a conductor, "cueing" the sequencers from moment to moment, turning them on or off, changing connections, and pushing buttons.

TOWARD MAJOR SUCCESS Because it had been commissioned specifically to appear on recordings sold by a commercial record company, Subotnick's work crossed the line from art music to commercial music. In fact, much of the synthesizer-created music of the day became popular. Wendy Carlos's Switched-On Bach became the hit of 1969 and one of the best-selling classical music recordings ever.

After hearing Chris Swanson, Robert Moog, and others perform a jazz concert in 1969 at the Museum of Modern Art in New York City, Keith Emerson bought a small Moog modular system and used it for the hit song "Lucky Man" on the album Emerson, Lake, and Palmer. Eric Siday also used a Moog synthesizer to compose a theme for CBS.

Demand from musicians, in what was clearly a growing market, led to a large number of companies being formed and new products being developed. Peter Zinovieff (see Fig. 4) formed EMS Ltd. in London, for example, and with David Cockerell and Tristram Cary produced the VCS-3, among other synthesizers and devices. Robert Moog, Bill Hemsath, and others developed the portable Minimoog, the first commercially successful synthesizer. Alan R. Pearlman formed ARP Instruments near Boston and produced the modular Model 2500, followed by the integrated and portable Model 2600. Tom Oberheim founded Oberheim Electronics and designed the Four Voice, the first polyphonic synthesizer on the market. Dave Smith formed Sequential Circuits and developed the Prophet-5, an analog synthesizer with digital controls.

Many other companies and products came and went. The '70s saw the market for electronic musical instruments expand, accompanied by the feeling that they would have a profound impact on the way musicians thought of sound and music. It was a very exciting time.

Joel Chadabe, composer and author of Electric Sound, is president of the Electronic Music Foundation. He can be reached at chadabe@emf.org.

Several excellent resources offer more information on synthesizers and computer music technology. Here are some recommended books:

The Computer Music Tutorial (MIT Press, 1996), by Curtis Roads, provides in-depth coverage of the technology of computer music.

Electric Sound (Prentice Hall, 1996), by Joel Chadabe, discusses developments in electronic music throughout the 20th century, with excellent coverage of early computer and analog synthesis.

Keyfax Omnibus Edition (MixBooks, 1996), by Julian Colbeck, has a wealth of information on commercially produced synthesizers.

Here are a few recommended recordings to supplement your reading:

John Chowning (Wergo) highlights the composer's early computer music works.

Columbia-Princeton Electronic Music Center 1961-1973 (New World) includes Charles Dodge's Earth's Magnetic Field.

Jean-Claude Risset (INA-GRM) includes Mutations, composed at Bell Labs, as well as Inharmonique and Sud, composed later.

Jean-Claude Risset (Wergo) features Computer Suite from Little Boy, as well as Sud and other compositions for computer sound and acoustic instruments.

Morton Subotnick (Wergo) includes Silver Apples of the Moon and The Wild Bull.

James Tenney: Selected Works 1961-1969 (Artifact) features the compositions that Tenney finished at Bell Labs.

These and other interesting items are available from CDeMusic at www.cdemusic.org.