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Good Vibrations from Electronic Circuits

The Technological Development of the Synthesizer

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1 In the Beginning there Was Ether Music

In one of the first demonstrations of the theremin in London on December 12, 1927, its inventor Leon Theremin not only played classical music accompanied by a piano, he also demonstrated the potential of the instrument to imitate other sounds such as the bleating of sheep, the whimpering of a child or the siren of a factory. The audience didn't know what to make of this demonstration and started to laugh. What the audience didn't realize was that they were witnessing the “ingredients of the synthesizer”. In the words of Theremin's biographer Albert Glinsky: “While the audience tittered, few probably realized that in this bleating and whimpering lay the true crux of the issue. The real significance of the instrument was not in the drippy recital of romantic miniatures they were about to hear. The genuine revolution in this technology was that the raw materials of sound were now exposed and could be molded in every dimension”¹.

The theremin, sometimes called Thereminvox or Etherphone, is probably the only musical instrument played without touching it. The user interface is composed of two electrodes respectively antennas – one for pitch and the other for volume – working with electric capacitance and reacting to the distances and movements of the hands of the performer. As the theremin works without physical contact, it was supposed to give more artistic freedom to the performer. The performances of the theremin led people to believe that the music was coming out of thin air – out of the ether. However, as the lack of physical contact also resulted in no reference point for pitch and no tactile feedback for the performer, the theremin was notoriously hard to learn, and there were only a few versatile players such as Clara Rockmore.

Similar to other early electronic instruments such as the Telharmonium, the Trautonium, and the Ondes Martenot, the theremin never really caught on with musicians. The reasons were plentiful, mainly the high cost of the instruments, the unsuitability of the instruments for many situations where music was performed, and the difficulty of performing the instruments. However, these instruments eventually led to the development of the synthesizer, “the most successful electronic instrument of the twentieth century”². As such the synthesizer stands next to other electric instruments which influenced rock and jazz music in the 20th century such as the electric guitar, the Hammond organ, and the Fender Rhodes electric piano. As the other mentioned instruments are all a hybrid of mechanical and electric mechanisms (e.g. a string electronically amplified in the electric guitar), the synthesizer is the first completely electronic instrument conquering a mass market.

The story of the synthesizer is also the story of one synthesizer in particular – the Minimoog. Although it initially was only built for 10 years until 1981 and only 12.000 units were shipped, the Minimoog set a new standard in the nascent field of electronic music. So much so that the *Buffalo Courier-Express* called it “The Model T Ford of synthesizers”³. The Minimoog is the first synthesizer mentioned in the seminal book *Synth Gems I* and referred to as “the most famous synthesizer in history”⁴. It is the main reason why the synthesizer, today, is mainly seen as a keyboard instrument. As such the Minimoog is included in the book *Classic Keys* next to electrical organs such as the Hammond B-3, the Farfisa Compact or the Vox Continental, electric pianos such as the Fender Rhodes or the Yamaha CP-70B as well as the tape loop-based Mellotron.⁵ As a design object with a wider cultural impact it is also included in the *Vintage & Classic Style Guide* in the category of musical instruments next to the Steinway Grand Piano, the Gibson Les Paul electric guitar, the Marshall valve amplifier, the Hammond organ, and the Roland TR 808 drum computer, among others.⁶

Furthermore, this is not only the story of the synthesizer, but also at least partly the story of the pioneer whose name for a while was synonymous with the word synthesizer: Robert “Bob” Moog. His name was used as a verb – “to moog” – meaning to play the synthesizer and appeared on countless covers for albums with electronic music, e.g. *Moog Plays the Beatles*, *Music to Moog by* or *The Plastic Cow goes Moooooog*.⁷ He was honored with a flagstone on Hollywood’s Rock Walk on Sunset Boulevard in 1985, received the Polar Music Prize from the king of Sweden in 2001 and a Technical Grammy Award from the National Academy of Recording in 2002, and was awarded an Honorary Doctor of Fine Arts degree at the University of the Arts in Philadelphia in 2003.⁸ In a whim of fate, he started his career in musical instruments by building and selling theremins, before he turned his attention to building and selling synthesizers. And although he was never successful in a financial way, he laid the foundation of the synthesizer market as we know it today.

2 Synthesis and Synthesizer

The *Audio Dictionary* defines a synthesizer as “a purely electronic musical instrument which can be used to imitate many conventional instruments. The accuracy of the imitation varies from synthesizer to synthesizer”⁹. This definition sees the synthesizer mainly as an electronic substitute to conventional instruments. However, synthesizers can also create an array of natural sounds and electronic sounds not found in nature. Therefore, another definition for a synthesizer, this time from the *Dictionary of Music Education*, is: “A class of electronic devices that make possible the creation of any sound via electronic synthesis”¹⁰. Since the aim of the

synthesizer usually is to perform music, a synthesizer can also be defined as “a self-contained electronic music system for the generation, modification, and playing of electronically produced sounds”¹¹.

Synthesizers can come in a range of technological sophistication. As the author Michael Chanan observes: “The cheaper, more popular models [of synthesizers] are musically much more limited than the cheapest piano, and have too many automatic controls. The more sophisticated jobs, on the other hand, with proper touch-sensitive keys and multiple banks of programmable oscillators, offer entirely new sonic worlds. They are not a replacement for the piano, but an entirely different instrument, which has had a major effect not only within popular music but in many areas of musical production where dissemination takes place through loudspeakers”¹².

To generate sound a synthesizer applies sound synthesis. Synthesis can be subtractive or additive. While in subtractive synthesis an audio signal from an oscillator is passed through a filter to suppress certain sounds, additive synthesis combines different waves, usually sine waves, to generate a sound. Although additive synthesis sounds more straightforward, subtractive synthesis is easier to implement in electronic circuitry and has thus been used much more often in analog synthesizers.¹³ In digital synthesizers, analog synthesis has been replaced by digital synthesis (e.g. linear frequency modulation as in the Yamaha DX7). This can simply take the form of a digital simulation of analog parameters. So, although analog synthesis has today often been replaced by digital synthesis, analog synthesis is often still the basis for digital synthesizers. An added advantage is that digital synthesis can be combined with digital samples, e.g. of analog instruments.¹⁴

The main signal path of an analog synthesizer goes from the Voltage Controlled Oscillator (VCO) via the Voltage Controlled Filter (VCF) and the Voltage Controlled Amplifier (VCA) to the output where the signal is picked up by a loudspeaker or headphones (see fig. 1). The VCO generates the basic sound, the VCF changes the timbre and the VCA influences the dynamics. The three different components can be influenced by a control voltage. The main controller is a piano-like keyboard; the main standard is the one-volt-per-octave standard.¹⁵

The oscillator generates sounds via different vibrations with characteristic waveforms. Main waveforms of an oscillator are sine wave, triangle wave, sawtooth (or saw) wave, and square (or pulse) wave. While a sine wave has no overtones and thus sounds very plain, the other waveforms resemble different instrument groups in their overtones: A sawtooth wave resembles strings, a square wave sounds like woodwinds and a triangle wave like a flute.¹⁶ Furthermore,

oscillators can be used as noise generators which produce noise meaning “rapid and totally random fluctuations of frequency and amplitude in an oscillator waveform”¹⁷, such as white noise or pink noise. Different oscillators can be combined using a mixer.

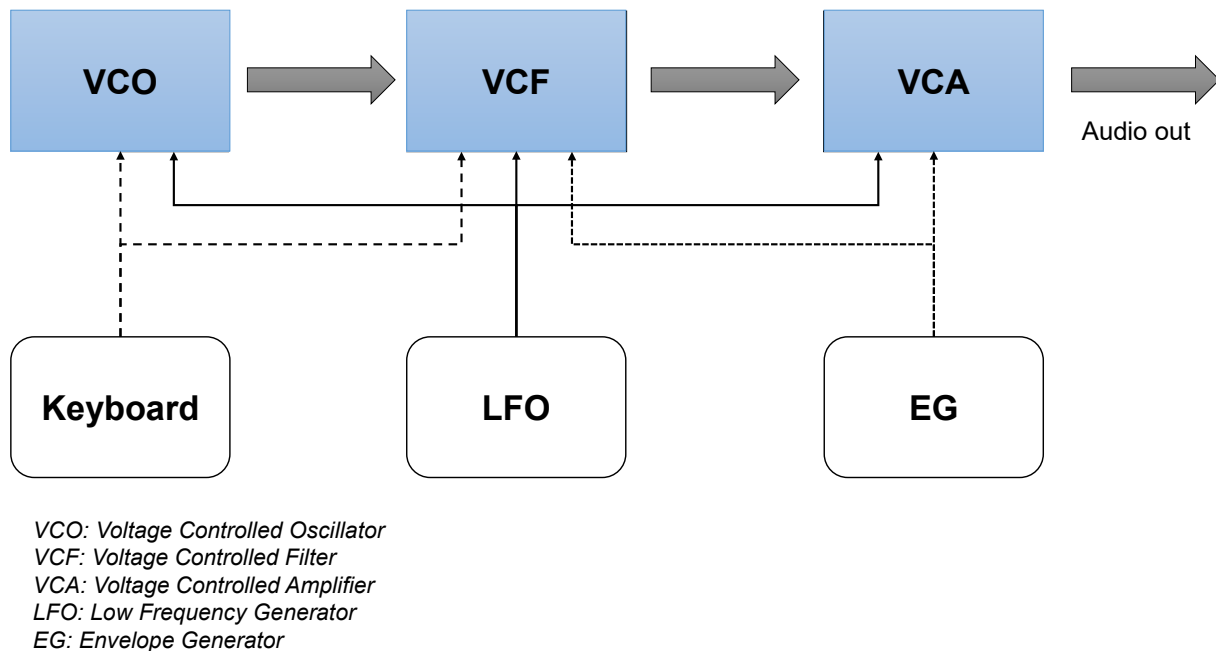


Fig. 1: Schema of an analog synthesizer¹⁸

The Voltage Controlled Filter (VCF) is used to filter out certain frequencies of the sound and is especially used in subtractive synthesis. Main types of filters are the lowpass filter (higher frequencies are filtered out), the highpass filter (lower frequencies are filtered out), and the bandpass filter (higher and lower frequencies are filtered out). Different filters can be combined, e.g. a lowpass and a highpass filter in series create a bandpass filter.¹⁹ The Voltage Controlled Amplifier’s (VCA) function is to “dynamically change a sound’s volume over time”²⁰.

Different instruments such as pianos, flutes or brass have different sound envelopes. The sound or amplitude envelope shapes the amplitude of the sound wave at the beginning, the middle and the end. It is usually described by the four parameters attack, decay, sustain, and release (ADSR) (see fig. 2). They signify the time it takes to go from zero to full amplitude (attack) and then down (decay) to a specific level (sustain), after the key is pressed, as well as the time it takes from the sustain level to zero (release), after the key was released.²¹ The Envelope Generator of a synthesizer gives the sound its distinctive shape by manipulating mainly these four parameters. The Low-Frequency Oscillator (LFO) generates subaudible waves to control certain parameters such as pitch to generate vibrato or trills amongst others.²²

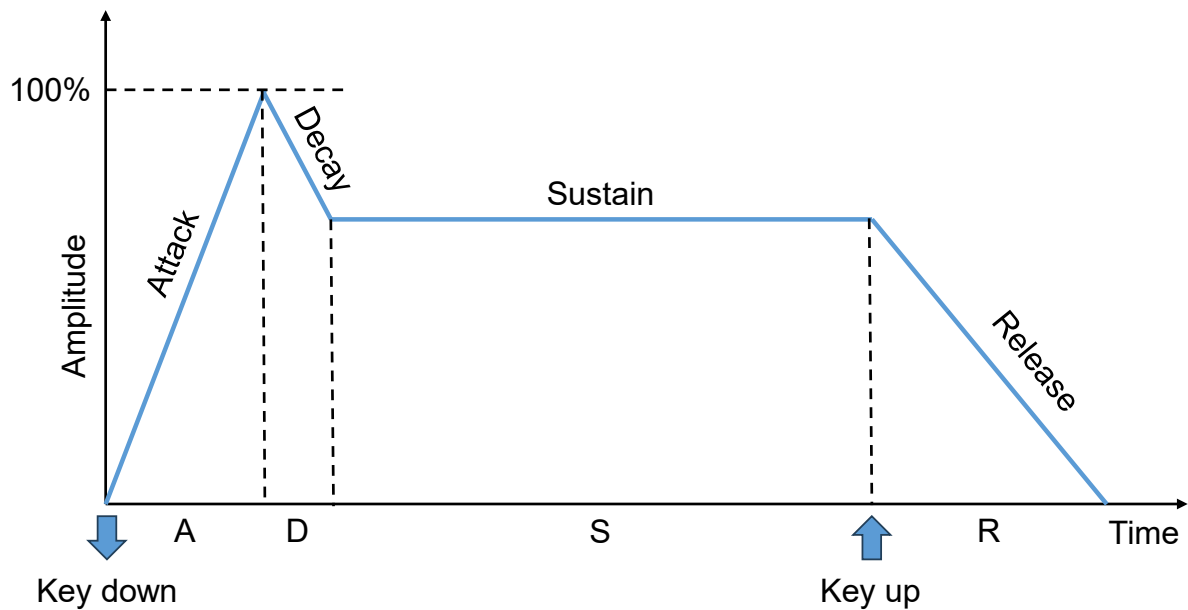


Fig. 2: Four stages of an ADSR amplitude envelope generator²³

To control the various possibilities of sound shaping in a synthesizer, knobs and encoders, faders and sliders as well as buttons and switches are of vital importance, as different parameters such as oscillator waveform or filter settings need to be specified. However, when it comes to playing a note on a synthesizer the main interface is still a keyboard with piano-like keys. Alternatives can be pads, especially for drum sounds, and capacitive touch keys such as on the Buchla Music Easel, but these are rather rare. Additionally, a synthesizer usually has wheels or benders to adjust modulation and for pitch bending which is often used in solos. Alternatives to wheels can be joy sticks or touchstrips.²⁴ As the main user interface for pitch control in the synthesizer is usually a keyboard, the synthesizer is today mainly perceived as a keyboard instrument, but this was not an inevitable development.

3 East Coast versus West Coast

At the conference of the Audio Engineering Society (AES) in 1968 Bob Moog ended his presentation of a technical paper on “Recent Trends in Electronic Music Studio Design” with a preview of the last movement of Bach’s *Brandenburg Concerto No. 3* from the soon to be released album *Switched-On Bach* (usually abbreviated a little tongue in cheek as *S-OB*). *S-OB* was the work of Wendy Carlos painstakingly recording musical pieces by Johann Sebastian Bach with only her modular Moog. She had to use a lot of tape splicing and multi-track recording, as the Moog was monophonic, i.e. only one note could be played at a time, and the oscillators kept drifting out of tune. The record was part of Columbia Masterworks’ campaign

Bach to Rock and launched together with two other records, an accompaniment to a book called *Rock and Other Four Letter Words* and the album *Terry Riley in C* by pioneer minimalist composer Terry Riley. Although the record company didn't do much to promote the album, and Carlos didn't even bother to show up at the record release party, *Switched-On Bach* was the only one of the three albums with a lasting impact.²⁵

By combining classical music with electronic sounds in a very sophisticated manner Wendy Carlos achieved something where others had failed: She made electronic music accessible for the public by combining it with tonal music people could relate to and thus showing for the first time the full potential of the synthesizer as a musical instrument. The album was a huge success. It stayed on top of the Billboard Classical Album charts from 1969 to 1972 and even climbed to number 10 on the US Billboard 200 charts, something unheard of for a classical album. It led to a host of imitation albums, many of dubious quality and with *Switched-On* titles such as *Switched-On Rock*, *Switched-On Bacharach*, *Switched-On Nashville* (country songs) or *Switched-On Santa* (Christmas songs). It also led to a series of albums by Carlos herself in a similar way such as *Switched-On Brandenburgs* and *Switched-On Bach II* (see fig. 3 for the covers of the two *Switched-On Bach* albums featuring a Modular Moog).²⁶ When Bob Moog stepped from the stage at the AES the attending engineers gave a standing ovation to Carlos.



Fig. 3: German versions of the first and second *Switched-On Bach* albums²⁷

The synthesizer was invented simultaneously by Bob Moog in Trumansburg on the East Coast of the United States and by Don Buchla in San Fransisco on the West Coast in 1964. Bob Moog

teamed up with composer Herb Deutsch to develop the Modular Moog. Together they created the VCO, the VCA, the envelope generator (after the ADSR concept of composer Vladimir Ussachevsky and according to legend first realized by a doorbell) and a patented ladder filter which gave the Moog its distinctive sound. As Herb Deutsch commented: “The Moog filter design is as unique to the sound of the synthesizer as the Steinway steel frame is to the piano”.²⁸ Don Buchla developed his Buchla Box for the avantgarde composers of the San Francisco Tape Music Center and invented amongst others the sequencer.

Both the Modular Moog and the Buchla Box were modular synthesizers meaning “these instruments were sold with a basic chassis, or cabinet, filled with a variety of modules selected by the purchase”.²⁹ The different modules had to be patched with cables to connect the different modules and to generate any sound. By feeding back signals this offered an almost limitless possibility of sounds. However, it also made the operation of the synthesizers quite difficult, since it needed to be patched, before it could be played at all. “Creating sounds on the Moog required some basic understanding of audio physics and a lot of trial and error”³⁰. While many synthesizers were custom-made, Bob Moog very soon decided to offer three variants (models I, II and III) of the Modular Moog with a price range from \$2,800 to \$6,200 resulting in some kind of standardization.³¹

Two main functions of a synthesizer are sound design and musical expression or expressiveness. The sound design of early synthesizers served two purposes which were stressed in competitive positioning of different brands, namely the creation of new sounds, and the emulation of acoustic instruments (e.g. piano) or other electric instruments (e.g. Hammond organ).³² At the beginning the focus was on the sound design: “For many [synthesists], the reason why they got excited about the synthesizer in the first place was because of its vast range of sounds”³³.

One of the main problems in sound design of the analog synthesizer was the complexity of the patching procedure. This led to the situation that the few people who owned a synthesizer were often hired by bands or studios for recording sessions. For example, Paul Beaver and Bernie Krause, the West Coast representatives of the Moog company, were frequent guests in the recording studios along the West Coast. The complexity of patching led to a low reproducibility of sounds. One often cited example is a studio session with the Doors in which Paul Beaver was hired to play his Moog. He demonstrated some patches and asked the group which ones they liked, and the band told him to go back a few patches. When he frantically started to repatch and couldn't find what they were looking for, they found out that he couldn't reproduce most

of the sounds he demonstrated. As Ray Manzarek, organist of the Doors, remembers: “And then we realized... he couldn’t *get* back. He couldn’t get back because he had no idea where he had been. He could only go forward, on to the next patch. Ever new, ever forward. You had to stop him as soon as you heard something you liked. He *was* a mad scientist”³⁴. Other modular synthesizers have similar issues. Vince Clarke from the synthpop group Erasure tells a story in the documentary movie *I Dream of Wires* about his Roland-System 100M in which he tries to get a trumpet sound with the help of a dope sheet. After a lot of patching and turning of knobs he arrived at a sound, but to his astonishment “it sounded nothing like a trumpet”³⁵.

From their work in the studio, Paul Beaver and Bernie Krause learned that many musicians referred to the sounds of popular recordings when describing the sounds they were looking for: The sound of The Byrds or the sound of Stevie Wonder. So eventually they limited their repertoire to about 20 to 30 sounds that were popular and easy to patch.³⁶

With regards to musical expression the synthesizer was at first quite different from other musical instruments. Acoustic instruments usually have a fixed sound, and sound changes are achieved through different techniques in playing (e.g. legato or staccato on a piano). The analog synthesizer, however, has a very variable sound generated through patches, but in the beginning nearly no changes through the playing style were possible. The first synthesizers were monophonic, and their keyboards weren’t touch-sensitive. Polyphony, multitimbrality, velocity sensitivity or graded/weighted keys all were later inventions. However, with its wide range of possible sounds it conquered some market niches.

An analysis of early vinyl recordings with the Moog synthesizer shows that the top user types were studios, universities, private musicians, and advertising companies.³⁷ One group of early adopters of the synthesizers were avantgarde electronic composers from the university environment (e.g. *musique concrète* in France, *Elektronische Musik* in Germany or *tape music* in the USA). Herb Deutsch was one of the first users of a Moog in this field, and Vladimir Ussachevsky ordered several Buchla Boxes for his studios. With a background in the Tape Music Center in San Francisco, Don Buchla had a strong focus on this target group.

Another field of early adoption were sound effects for advertising and movies, especially science fiction movies. Composer Eric Siday was an early user of a Moog and made a decent living on designing sound signatures for companies and brands. Likewise, composer Suzanne Ciani used her Buchla synthesizer to create sound logos for many companies especially in the beverage industry earning her the title “queen of soft drinks”³⁸.

Apart from avantgarde composers, the field of rock and pop music was slower to catch on. Psychedelic rock used sound effects for transcendence, e.g. on the Trips Festival in San Francisco a Buchla Box was played, and the Grateful Dead used a Buchla in their performances. The first groups to use the Moog on recordings in mainstream rock and pop include the Byrds, the Doors, and the Monkeys. However, even in this field the synthesizer was perceived more as a gimmick than as a regular musical instrument. Among the main uses in early recordings of the Moog synthesizer, thus, were novelty sounds at the beginning or end of a song as well as background effects beneath the main instrumental track.³⁹

The main difference between the approaches of Moog and Buchla lies in the question, if a synthesizer should have a keyboard as a user interface or not. Moog, early on, worked together with musicians and composers from all kinds of musical genres, whereas Buchla – with his background in the Tape Music Center – worked mainly with avantgarde composers. Thus, for Moog the keyboard soon became a standard feature of his instrument, whereas for Buchla the keyboard was a strong limitation grounding the synthesizer in Western tonality and musical concepts and preventing musicians from exploring its full potential. As one of his sayings goes: "A keyboard is dictatorial"⁴⁰. The notion behind this idea is expressed by electronic music composer Morton Subotnick who released one of the most famous electronic music albums with the Buchla called *Silver Apples on the Moon*: "I said right from the get-go: We don't want a black-and-white keyboard 'cause I knew what that was gonna mean. I got a keyboard, I was gonna produce regular music. That's not what I wanted to do"⁴¹. A similar sentiment is expressed by electronic music composer Suzanne Ciani, an avid Buchla user. In her opinion, the vision of Don Buchla was "very different from what was happening on the East Coast at Moog. I rejected the Moog and adopted Don's vision of these instruments. The problem with the Moog was that it spoke to popular culture very quickly because of the addition of the keyboard. But it meant that the potential of this instrument was lost"⁴². The contrarian approach by Moog is described by Joel Chadabe from the Electronic Music Foundation: "Bob [Moog] was very interested in things that would be successful for commercial musicians. By 'commercial musicians' incidentally I mean musicians that earn their money through music. Most avantgarde composers don't"⁴³.

The keyboard was also important for marketing reasons according to Bob Moog, as it is immediately recognizable and indicates that the machine you are presenting is a musical instrument: "The keyboards were always there, and whenever someone wanted to take a picture, for some reason or other it looks good if you're playing a keyboard. People understand that then

you're making music. You know [without it] you could be tuning in Russia!"⁴⁴. The different approaches of the two pioneers can be described as "stressing uncertainty, idiosyncrasy, the 'wild and wonderful'" in the case of Don Buchla and as "stressing control, reliability, and repeatability" in the case of Bob Moog.⁴⁵ As time revealed, the limitation of the Moog to Western tonality and the keyboard turned out to be its blessing. In the end it can be said: "Most musicians were familiar with keyboards, and hence over time the synthesizer became a keyboard device"⁴⁶. However, there were still some hurdles to overcome to turn the synthesizer into a practical musical instrument for every musician.

4 From Modular to Mini

On August 29 in 1969 New York's Museum of Modern Art staged a concert in its *Jazz in the Garden* summer series which featured an ensemble of Moog synthesizers. It was the first concert in which synthesizers carried the entire performance. For this occasion, four modular Moogs were retrofitted with preset boxes which allowed the performers to switch between seven sounds at the push of a button. The MoMA didn't seem to be too well prepared for such an extravagant event, though: The Moogs and all the other technical equipment were fed by only one electrical outlet. During the last performance by a jazz quartet lead by Chris Swanson a spectator in the packed audience accidentally knocked out the plug out of the socket and abruptly stopped the music in the middle of an especially wild improvisational part. The audience thought that this was part of the plan and responded with roaring applause. As that was also the end of the concert, *Vanity* reported that the tagline for the concert should be: "Socket to me".⁴⁷

The MoMA concert showed that the synthesizer was also an instrument for live performances. However, it also showed its weaknesses: Synthesizers were still rather too big and too complicated to operate for regular musicians in a live setting – apart from being dependable on electricity. This is why live performances by a Moog were still a rare event. One exception was Keith Emerson of the British rock group Emerson, Lake and Palmer who used the modular Moog to play solos at live concerts using a keyboard and a ribbon controller. To make this feasible Emerson used a Moog from the MoMA concert with six presets installed. Still, he faced many problems in setting up the Moog for performances such as the oscillators shifting out of tune when the temperature changed.⁴⁸ And for groups who used regular Moogs there was still the problem of patches: One of the earliest groups to use a Moog in live performances was Mother Mallard who rehearsed in a kind of military-style drill to bring the time for re-patching

between songs down to about five to seven minutes. To distract the audience, they showed classic cartoons during the patching phases between songs.⁴⁹

Nonetheless the Moog had the potential to put the keyboard player center stage with a solo on a lead synth sound and as such shift the power relations in a band. As Keyboardist Rick Wakeman put it in an interview with *Entertainment Weekly*: “When it came to solo time, you were either drowned out completely or the band had to embarrassingly drop their volume in order for you to be heard. [...] Then the Moog hit the scene, and here was an instrument with a sound that would cut concrete. Guitarists fell to their knees in fear”⁵⁰. The same was true for the portable Minimoog, the next development of Moog, as David Van Koevering, one of the most active sales people of the Moog company, attests: “The Minimoog could make, because of its sonic energy, it could make the keyboard guy a superstar – a monophonic, piercing electronic sound coming out of four or five ... amplified speaker stacks, could give him some energy and he could compete with the guitar, and he wanted to do that”.⁵¹

However, the development of the Minimoog was not as smooth as it might have seemed. As the market for Modular Moogs was saturated and the company of Moog came into financial trouble due to declining sales, a trend pointed in the direction of a simplified, portable version of a synthesizer which could be sold to amateur musicians and music teachers: “Modulars remained pricy, specialized tools for select professionals. To crack the consumer and educational markets – where the *real* money was – another type of instrument was essential. [...] the synths would have to be smaller, cheaper, and simpler to operate”⁵². However, Bob Moog initially was reluctant to build the Minimoog, as it offered fewer functionality than the Modular Moog and did not meet his high aspirations as a craftsman.

The Minimoog was developed from a first prototype initially called the Min built by Bill Hemsath, one of Moog’s engineers in his Trumansburg factory, from scrap parts. It went through three rounds of prototypes (Models A, B and C) which were all intensively tested by the staff and several musicians, until the final production model (Model D) was created. As Moog protracted the decision to produce the Minimoog, it took a kind of “palace revolution” in which his employees took matters into their own hands and designed the circuit boards for series production, while Moog was on a business trip. After he returned, Moog was at first furious about the mutiny. Eventually though he relented and the Minimoog was introduced at the Audio Engineering Society (AES) meeting in 1970 at a retail price of \$1,495. It was about time, as on the same fair the ARP 2600 and the VCS-3 by EMS, two more compact, simpler and cheaper synthesizers, were also introduced.⁵³

The sentiments of Bob Moog against the Minimoog are described by Michelle Moog-Koussa, Bob Moog’s daughter and Executive Director of the Bob Moog Foundation: “He [Bob Moog] really did have an issue with this decrease in functionality. I hate to say that the Minimoog was a necessary evil, but it was. I think he felt like it was something like that, but I think you know in the end he could see that it served obviously a great purpose”⁵⁴. Later Bob Moog seems to have come to terms with the Minimoog, as he wrote in a book chapter on his most famous synthesizer: “Compared to a modular system, it [the Minimoog] was manageable, non-intimidating, and user-friendly. You couldn’t do much with it, but you could create some basic analog sounds, and – more importantly – you could play the instrument in real time. Remember this was a long time before synthesizers had presets”⁵⁵.

Despite all objections and concerns, the Minimoog was a huge success with professional musicians. One of its success factors was its distinct sound due to its patented ladder-filter which gave the keyboarder more control in a live setting. The bass sound of the Minimoog eventually became one of the signature sounds in pop music.⁵⁶ The functionality to generate sounds was sharply reduced, as instead of patch cords it had the pre-wired signal path of VCO, VCF and VCA which became a standard. Other musical standards, already present in the Modular Moog, such as the one-volt-per-octave standard of Western tonality and the keyboard as a user interface were preserved. The ease of use was reinforced by the easy-to-operate front panel design of the Minimoog (see fig. 4).



Fig. 4: Front panel of a Minimoog⁵⁷

Additionally, the modulation wheel and the pitch wheel which were added late in the design process to the left side of the keyboard and allowed for dramatic solos of the keyboarder. This set-up became a further standard for later synthesizers. However, the main advantages were its reduced size and weight which meant that it was portable as well as its reduced price (retail price of \$1,495). The size differences can be seen from photos of that time, e.g. the photo from the mid-1970s in fig. 5 showing Bob Moog with the Modular Moog and the Minimoog amongst

others. As Rainer Zicke who worked on the Kraftwerk video for *Minimum-Maximum* observed: “Until the development of the mobile *Minimoog*, the *Moog* was an appliance for people with money, time, and space”⁵⁸. However, Minimoogs were still expensive and could only be afforded by rather wealthy people such as Ralf Hütter from the electronic band Kraftwerk. Others had to wait until cheaper Japanese models entered the market such as the miniKorg.

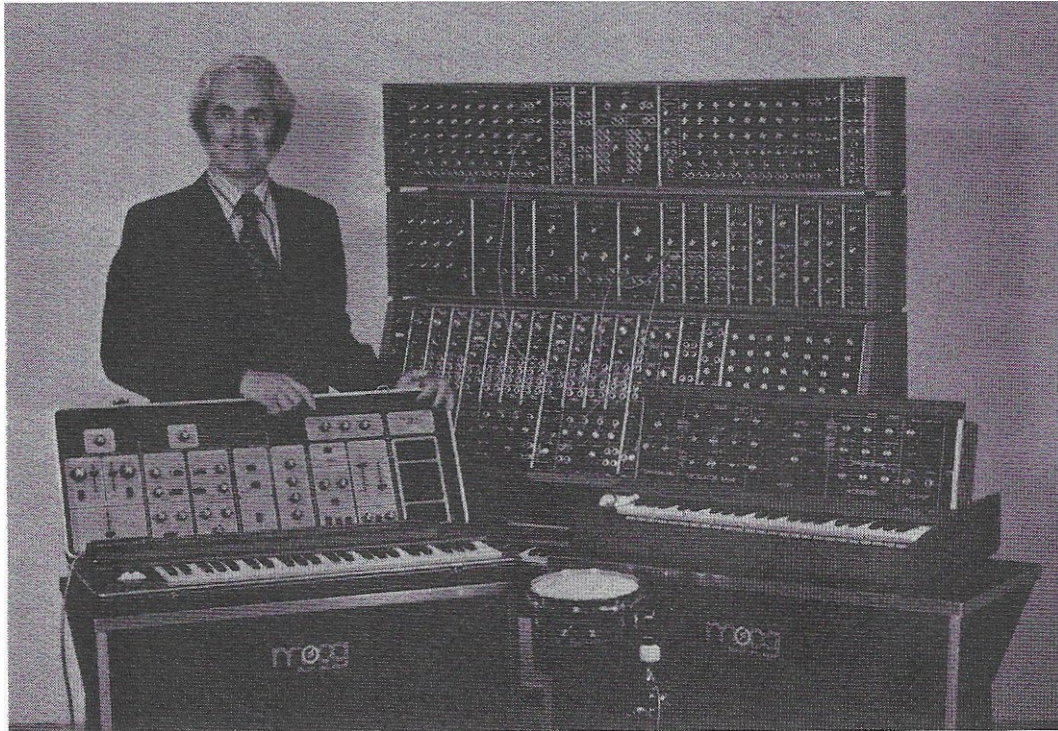


Fig. 5: Bob Moog with the Minimoog (on the right), a Modular Moog (in the back) and other Moog products⁵⁹

Avid users of Moog’s modular systems were taken a bit aback by the reduced functionality. In the words of Moog’s West Coast representative Bernie Krause: “I mean it [the Minimoog] was lighter and as you get older you wanna carry less stuff. But other than that, it wasn’t nearly as versatile as the large one [the Modular Moog]”⁶⁰. However, even in its reduced functionality, the sound of the Minimoog did not fail to impress many musicians and in some cases even its name giver, as in the story of Don Preston who played Minimoog for Frank Zappa and the Mothers of Invention: “I did a solo on one of Mother’s albums and Paul Beaver played it for Bob Moog, and he listened to it and he said, ‘That’s impossible, you can’t do that on a Minimoog’”⁶¹.

There was, however, one final hurdle to success. The market for the Minimoog had to be invented and the instrument had to be established in the music retail business, as the synthesizer was a product in need of explanation: “Until then, nobody had thought of a synthesizer as an

off-the-shelf musical instrument – least of all, music dealers. The Minimoog was compact, but it still didn't look like anything you'd see in a retail music shop. Customers couldn't just turn it on and casually patter over the keyboard to try it out; the instrument would be mute until a salesperson walked them through all the stages of sound production to hear something they could make sense of. And the instrument wasn't cheap: for a keyboard that only played one note at a time, it could be difficult to convince people they were getting their money's worth".⁶²

5 From Analog to Digital

The early programmable synthesizers – such as the RCA Mark I (1955) and the RCA Mark II (1958) – were based on vacuum tubes (see fig. 6). Due to their weight and size, they were firmly installed in a room and, thus, immobile. Only with the introduction of solid-state technology did the size of the synthesizer allow for a movement of the synthesizer, but they were still far from portable, and only after the introduction of the voltage control a market for synthesizers was emerging. The first synthesizers with a commercial impact were, as described, the Moog Modular Synthesizer and the Buchla 100 Modular Music Box, both developed in 1964. Other examples in this category of studio models were the ARP 2500 and the EMS Synthi 100. The Minimoog (1970) can be considered the first commercially successful portable synthesizer. It came with a 44-key monophonic keyboard already including a pitch wheel and a modulation wheel both of which became a quasi-standard in the design of synthesizers. Competitors include the ARP 2600 and from Japan the miniKORG and the Roland SH-1000. Eventually Buchla also introduced a portable synthesizer with the Buchla Music Easel (1972). It did not have a black-and-white keyboard, however it had a 2.5-octave touch plate keyboard. After a brief interlude of duophonic synthesizers which could play two notes at a time synthesizers became polyphonic allowing musicians to play chords of three notes and more. Examples of analog polyphonic synthesizers are the Polymoog (1975), the Roland Jupiter (1978) and the Korg Polysix (1981).⁶³

Analog polyphonic synthesizers were hard to develop and expensive to build, as every key would eventually have to have its own chain of VCO, VCF and VCA. That is the reason why polyphonic synthesizers only took off after the sound synthesis became digitalized. After an interlude of analog synthesizers with microprocessor control (the first being the Prophet-5) the digitalization was also used in the generation of sound by simulating oscillators or including samples. The first fully digital synthesizers such as the Synclavier (1975) by New England Digital or the Fairlight CMI (1979), however, were still too expensive for amateur musicians.⁶⁴ Only with the miniaturization of transistors forecasted by Gordon Moore in the law which bears his name and the associated reduction in price did the synthesizer conquer the mainstream

market. This led to a convergence of the computer and synthesizer technology, as “To a large degree, synthesizers and samplers can now be regarded as nothing less than personal computers whose operating systems and input/output circuitry have been optimized for musical purposes”⁶⁵.

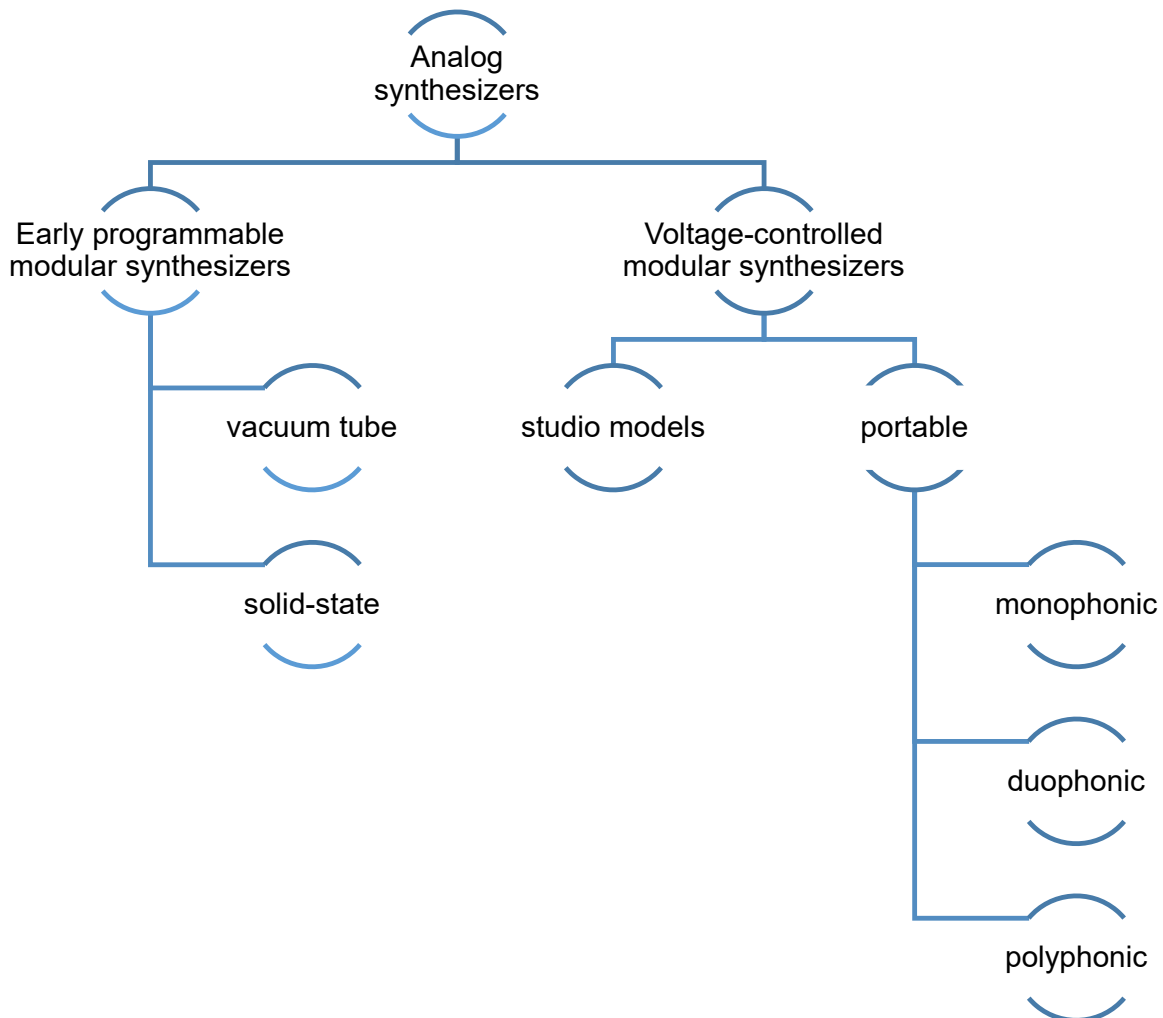


Fig. 6: Evolution of analog synthesizers⁶⁶

The first successful digital synthesizer was the Yamaha DX7 which sold 200.000 units in three years (as compared to 12.000 units the Minimoog sold over his whole 10-year lifetime).⁶⁷ Its electric piano sound has been used repeatedly during the 1980s and can be considered another cult sound of pop music.⁶⁸ Later cheap alternatives by Japanese companies further enhanced the market for synthesizers. For example, the Japanese company Casio sold 15 million of its instruments within a decade in the 1980s.⁶⁹ By this time the synthesizer was firmly established as a keyboard instrument in rock and pop music. The broad distribution of synthesizers also led to own musical forms such as synth pop and electronic dance music (EDM).

Over the entire development of the synthesizer the complexity of the sound design was reduced. While the modular synthesizers used patch cables, the first analog portable models were pre-wired and used knobs or sliders to specify a sound. Sound settings could be remembered with sound charts on which settings could be “stored” in written form. When the synthesizers turned digital, memory banks to store sounds were added rendering sound charts obsolete. Eventually synthesizers came with a certain number of preset sounds selected at the push of a button or through a menu screen. The number of preset sounds eventually became a reason to buy a certain synthesizer model. Moreover, digitalization also offered other forms of synthesis (e.g. additive synthesis) adding to the variety in sounds.

Although most of the synthesizers came with the possibility to alter and manipulate existing sounds, it is estimated that the vast majority of its users did not make use of this feature. For example, many instruments of the Prophet-5 returned for service had the factory preset sounds in their memory banks.⁷⁰ A similar story is told about the Yamaha DX7.⁷¹ Many keyboarders seem to have been content with the existing sounds and only used slight adjustments, e.g. via the modulation wheel. On the other hand, this led to a demand in prefabricated sounds and opened the door for a small industry of suppliers distributing their sounds via external storage devices such as memory cards.⁷²

Musical expression was increased by duophonic synthesizers where two keys can be played simultaneously and later with polyphonic synthesizers to play full chords by pressing three or more keys simultaneously. Furthermore, it was increased by the development of touch-sensitive keyboards, e.g. velocity sensitivity, to allow for different playing styles. Another critical element was the pitch wheel which allowed the keyboarder to play solos in a similar style as guitarists.

Although the overall trend of synthesizers pointed in the direction of more digitalization, there was in part of the music industry a reversal. Due to a revival of analog sounds in the 1990s, many musicians started to buy and use old analog equipment to get the typical analog sound in their recordings. Vintage synthesizers fetched record sums in music stores and on Internet platforms. The trend even prompted Moog to reissue the Minimoog Model D as a modernized version in 2016 and again in 2022, after a temporary scarcity of crucial components.⁷³ It currently sells for about €6,000 in Germany.

The Minimoog also lives on in the digital world as a virtual clone in the Arturia V Collection called the Mini V. It can be played as a standalone version or integrated as an audio plugin into

all established Digital Audio Workstations (DAW) such as Cubase, Logic Pro or Pro Tools, e.g. via the VST format. The Mini V has the same outer design as the Minimoog but comes with more than 500 presets (some of them polyphonic) and added functionality at a price of \$199. The overall design and the front panel are virtually the same as in the physical Minimoog (see fig. 7). Even the modular Moog lives on in the virtual world as the Modular V with virtual patch cords as a skeuomorphism to show the different patches.⁷⁴

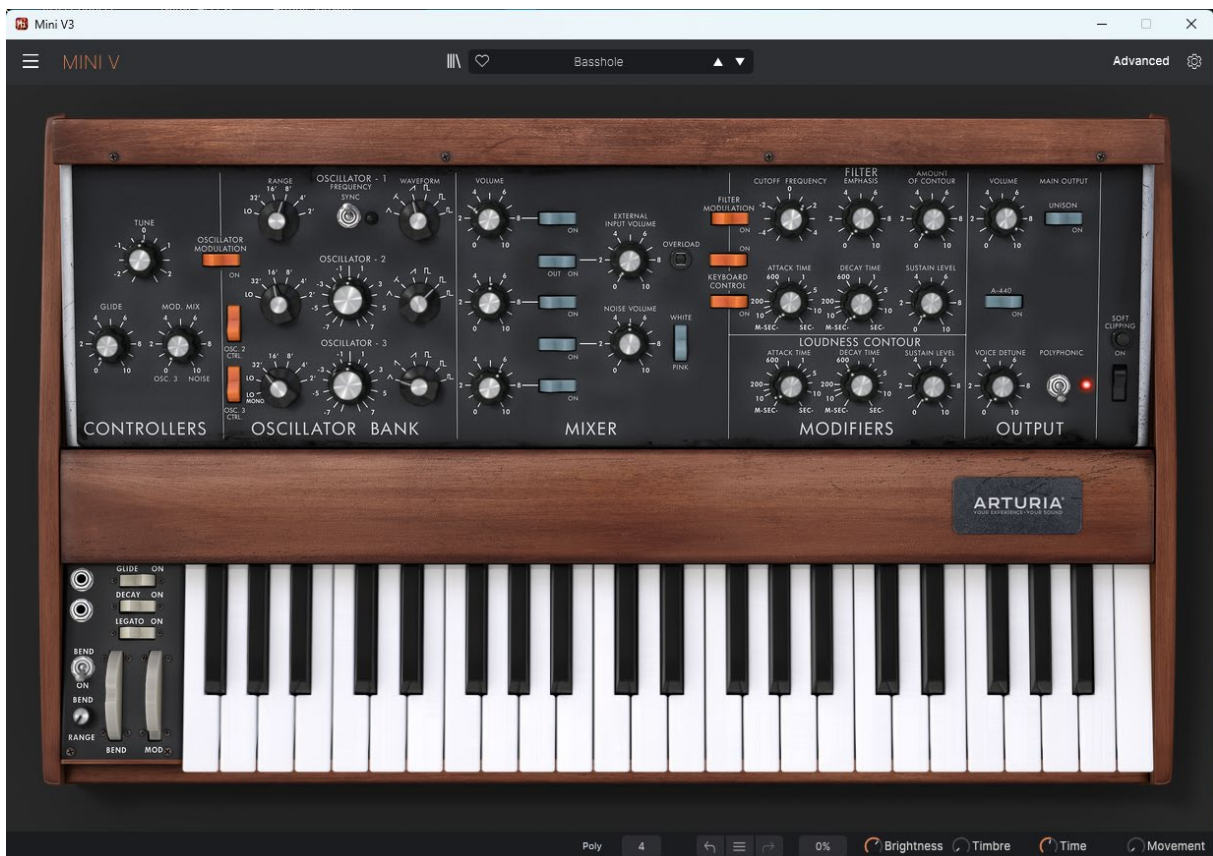


Fig. 7: Screenshot of the Mini V of the Arturia V Collection⁷⁵

The digitalization of synthesizers was part of a larger trend of digitalization in music production in which sound design gained more and more importance but shifted from musician to producer. One result of this trend is the “producer as composer” in which the music studio becomes the place where not only the sound is shaped, but also the music is composed. This trend is driven by the distribution of Digital Audio Workstations (DAW) for recording and shifts more and more decisions about the song from the musicians to the producer. Another aspect of this trend is a shift from the “illusion of reality” where the producer tried to mimic real music performances to the “reality of illusion” in which the producer works in a “virtual world in which everything is possible”⁷⁶. This gives the listeners auditory impressions which they cannot have in the real world – a phenomenon the music psychologist Daniel J. Levitin calls

“hyperrealities”⁷⁷. The whole trend leads to a development where the perfect sound becomes detached from the real and is associated more and more with the represented and the virtual.⁷⁸ This is, however, stuff for another story.

6 Technological Dimensions and Tensions

A technology is usually defined as knowledge about a means-end relationship which is embodied in technical artifacts such as a synthesizer. The technological development takes the form of a technological lifecycle with a beginning and an end as well as a certain trajectory. For example, the performance of a technology often takes a trajectory in an S-shaped form: At the beginning the development of a technology is slow with only small increases of performance. Then the development gathers pace with substantial increases in performance. At the end, when the physical limit of a technology is reached, technological development slows down again. Sometimes old technologies can be resurrected, for example the revival of analog synthesizers or the recently increased sales in vinyl records to distribute music.

Usually, a product contains several key technologies. For example, the Minimoog included solid-state circuitry and voltage-controlled keys amongst others. That means, that several technological developments can overlap when seen from the product level. Successful technology innovation requires a company to predict the development of the technologies in a product as accurately as possible. A method to forecast the technological development is to determine the key high-level technology dimensions of the product and to figure out the trajectories on these dimensions. For reasons of feasibility the number of dimensions should be between three and six.⁷⁹ Those dimensions can, of course, also be used to track technological developments in hindsight as a historical case.

A creative product such as the synthesizer in the 1960s usually underlies three different tensions⁸⁰:

- The creative product needs a typical design so that customers can recognize what it is. However, it also needs a challenging design for people to recognize that it is original and unconventional. The inherent tension is described by the general design rule of the famous industrial designer Raymond Loewi: “MAYA – Most Advanced, Yet Acceptable”⁸¹. If the design serves as a template for an entire industry, it is typically called a “dominant design”⁸².

- Another tension of the creative product is between compatibility and unconventionality. The product needs to be compatible with the living conditions of the user – be they technical, cultural or socio-economic. Otherwise, it is incompatible with the user's needs and wants. At the same time the product needs to be to some extent unconventional, as a conventional product does not offer any new and useful possibilities.
- The third tension is between simplicity and completeness. The product needs to be easy to understand and easy to use, and at the same time it needs to offer the full functionality demanded by the user. Too much functionality results in overengineering with an overload of features confusing potential users; too few functions result in oversimplicity and reduced application possibilities limiting the range of potential users.

The synthesizer seemed to have served many of these requirements, as the vibrations of its oscillators turned into the proverbial “Good Vibrations” which determined the mood of the 1970s. Therefore, it is fitting that “Good Vibrations” is the inscription on the tombstone of Bob Moog who died in 2005 from a brain tumor.⁸³ And it is likewise fitting that *Good Vibrations* is also the title of a song by the Beach Boys from their 1970 album of the same name in which the group used a theremin. With this motto the life of Bob Moog turned full circle and ended with a hint not only to the synthesizer, but also to the theremin – the instrument with which he started his business and which he still cherished and built.

With regard to the development of synthesizers and the Moog synthesizers in particular, there are the following questions:

- What were the different strategies that Moog and Buchla followed in their development of modular synthesizers? What were their targeted early adopters?
- What are the technological dimensions in the development of the synthesizer? And what where the trajectories in these dimensions?
- What features of the Minimoog do you consider as part of the dominant design which can be found in later generations of (analog) synthesizers?
- How can the development of the synthesizer be explained with regard to the tensions of creative products?

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