Chapter 13. Meeting 13, Interfaces: Modular Synthesizers

13.1. Announcements

- Quiz on Thursday
- Music Technology Case Study Drafts due next Tuesday

  Draft should meet minimum requirements of final paper

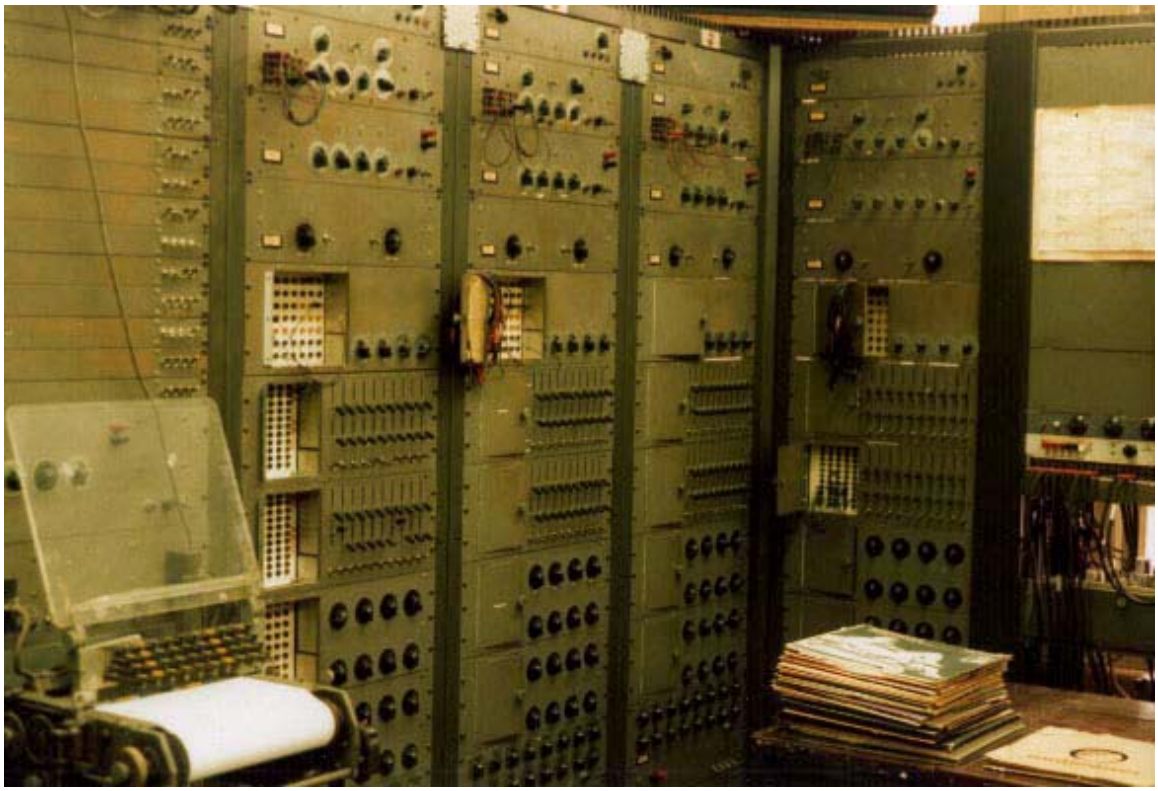
  Contact me with questions or problems
- Today: we will look at modular synthesizers in part through Arturia's virtual instrument emulations. Next Tuesday we will build similar models in PD.

13.2. The Modular Synthesizer: Overview

- The Modular Synthesizer: a collection of voltage-producing components with inputs and outputs freely inter-connected with patch cables
- Semi-modular synthesizers: voltage producing components with a mixture of fixed, switchable, and/or selectable interconnections
- While composers such as Varèse and Stockhausen were synthesizing tones in the 1950s, the synthesizer was not a conceived of as a single hardware entity
- The modular synthesizer was, in part, a consolidation and repackaging of existing technologies
- Voltage control, the flexible automation of parameters, was a (the?) key innovation

13.3. Foundations: RCA Synthesizer

- RCA Synthesizer



Courtesy of Kevin Lightner. Used with permission.

- 1940s-1950s: Harry Olsen and Herbert Belar, working for RCA, explore music machines with vacuum tube and tuning fork oscillators
- 1955: complete Mark I, features 2 voices

  Sine tooth signal from tuning forks converted to square and then sawtooth waveforms (1955, p. 599)

  A variety of AR envelopes possible with "growth and decay" generators (1955, p. 602)

  Timbre control with high and low pass filters with variable cutoff frequencies and a "resonator chain" (1955, p. 605)

- Olson, H. F. and H. Belar. 1955. "Electronic Music Synthesizer." *Journal of the Acoustical Society of America* 27(3): 595-612.

  Perhaps the first description of an instrument as a "synthesizer"

  Two channel, fixed signal flow, controlled by punched paper

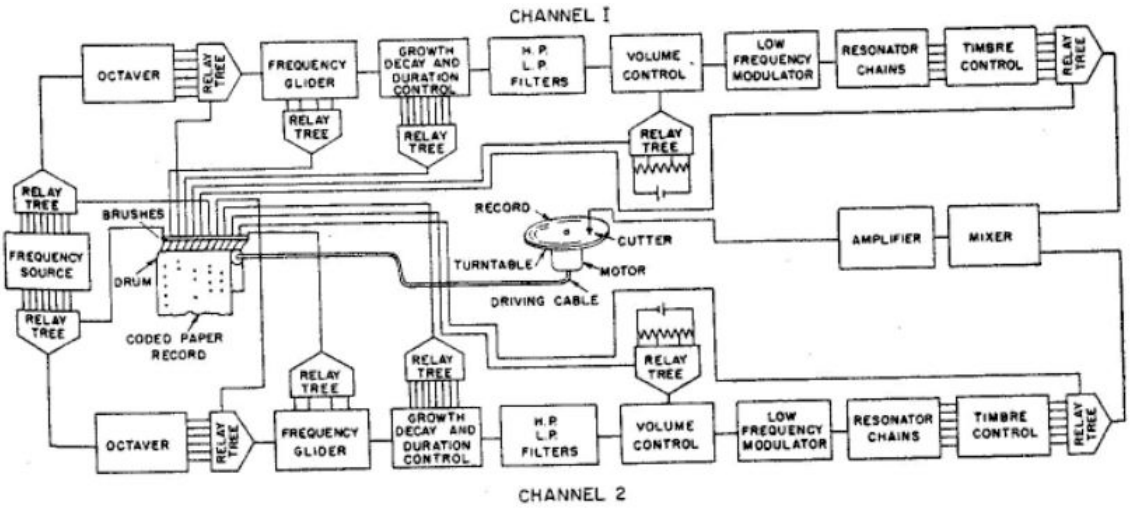
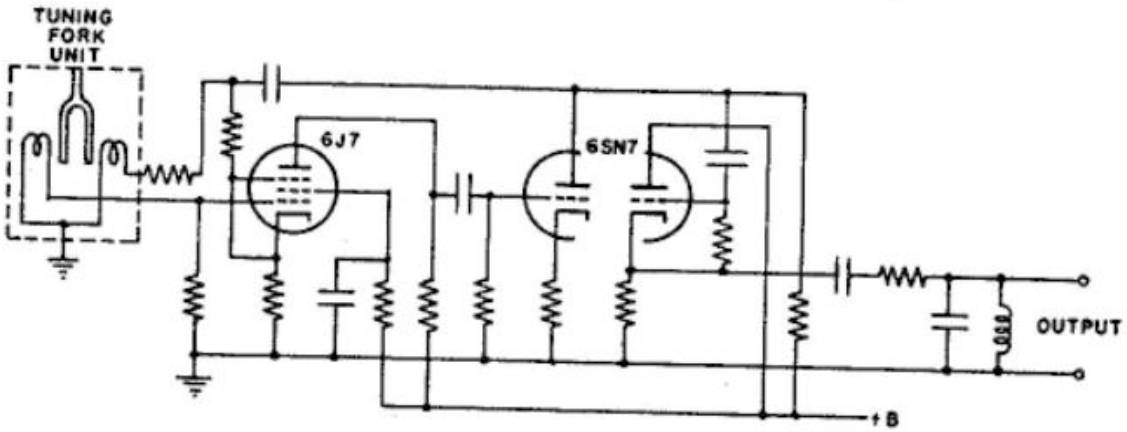


FIG. 2. Schematic diagram of the electronic music synthesizer.

Electromagnetically driven tuning fork oscillators



3 and 4 bit binary parameter specifications

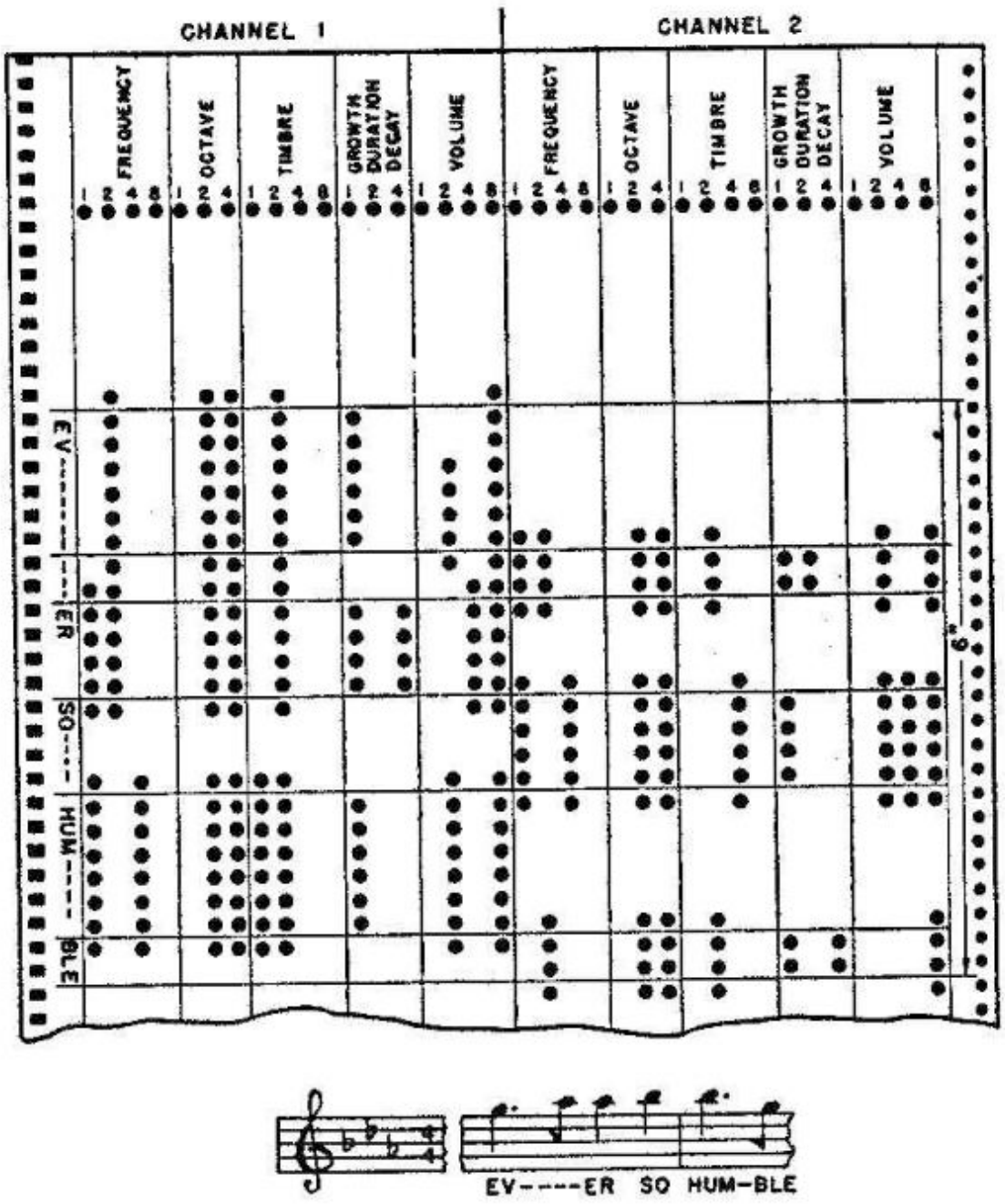


FIG. 27. The punched paper record.

Direct to disk output recording

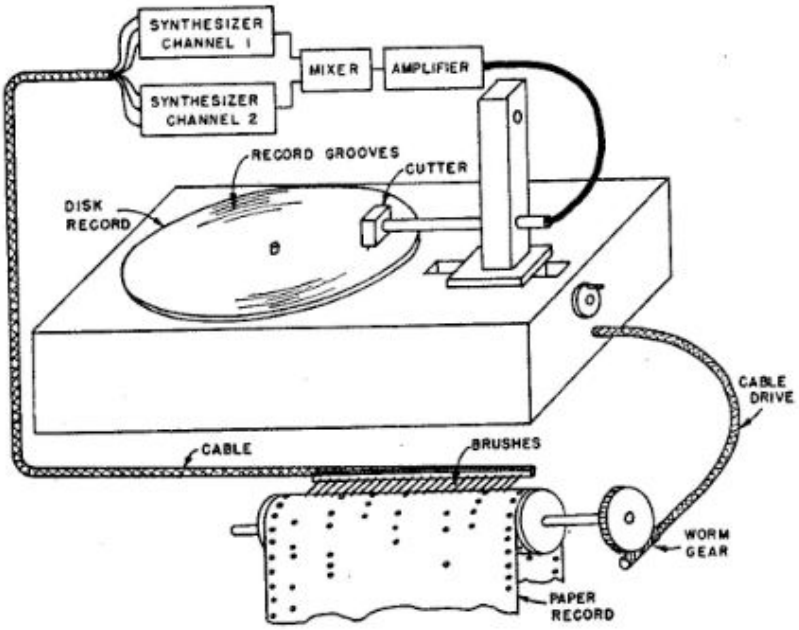
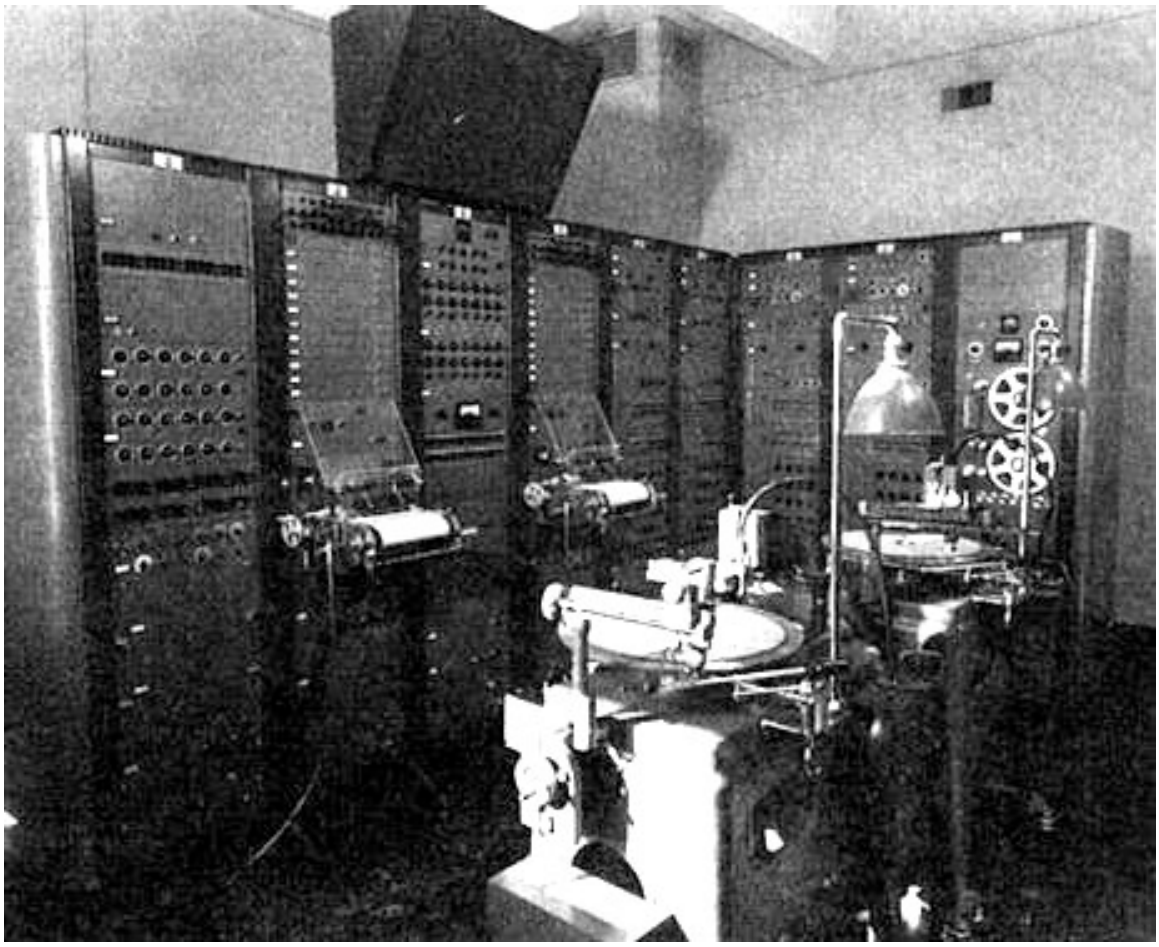


FIG. 28. Perspective view and schematic diagram of the paper record and the disk recording system of the music synthesizer.

- A first attempt at a rigorous, fixed, and complete parameterization of musical events
- Not a performance instrument

13.4. Foundations: RCA Synthesizer Mark II

- 1957-1959: Columbia University, with Rockefeller Foundation grants, purchases the RCA Synthesizer Mark II and establishes the Columbia-Princeton Electronic Music Centre.
- Mark II features four voices similar to the Mark I, adds a white-noise generator, microphone input, and variable frequency oscillators
- Olson, H. F. and H. Belar, J. Timmens. 1960. "Electronic music synthesis: the Mark II R.C.A. Synthesizer." *Journal of the Acoustical Society of America* 32(3): 311-319.
- RCA Synthesizer disk cutting lathe



- Eventually installed three-track Ampex tape recorders
- Audio: 1955 Demo recording demonstrates dance band synthesis

13.5. Listening: Babbit

- Audio: Milton Babbitt, *Philomel*, 1964

- 12-tone technique applied to pitch and other synthesis parameters
- What is the role of the electronics in the context of the piece?

13.6. Foundations: Buchla

- 1963: 100 Series Modular Electronic Music System

Courtesy of Buchla and Associates. Used with permission.

- 1965: Buchla releases Buchla Box, without a keyboard
- 1970: 200 Series Electric Music Box

Courtesy of Buchla and Associates. Used with permission.

- 1971: 500 Series: First digitally controlled analog synthesizer
- 1972: Music Easel

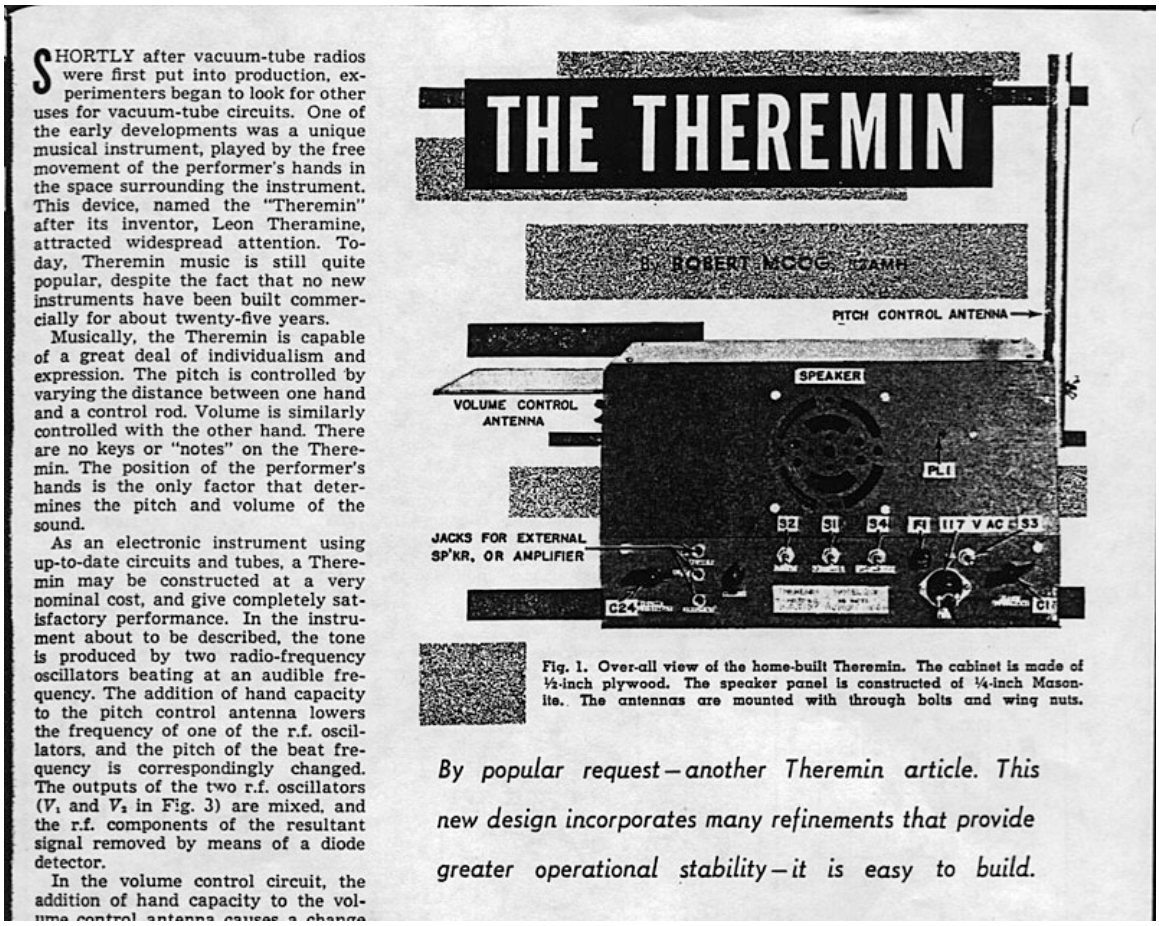
Courtesy of Buchla and Associates. Used with permission.

- 2002: Buchla 200e (19k+)

Courtesy of Buchla and Associates. Used with permission.

13.7. Foundations: Moog

- 1954: Moog publishes article in *Radio and Television News* on how to build a Theremin



THE THEREMIN

By ROBERT MOOG* (ZAMH)

SHORTLY after vacuum-tube radios were first put into production, experimenters began to look for other uses for vacuum-tube circuits. One of the early developments was a unique musical instrument, played by the free movement of the performer's hands in the space surrounding the instrument. This device, named the "Theremin" after its inventor, Leon Theramine, attracted widespread attention. Today, Theremin music is still quite popular, despite the fact that no new instruments have been built commercially for about twenty-five years.

Musically, the Theremin is capable of a great deal of individualism and expression. The pitch is controlled by varying the distance between one hand and a control rod. Volume is similarly controlled with the other hand. There are no keys or "notes" on the Theremin. The position of the performer's hands is the only factor that determines the pitch and volume of the sound.

As an electronic instrument using up-to-date circuits and tubes, a Theremin may be constructed at a very nominal cost, and give completely satisfactory performance. In the instrument about to be described, the tone is produced by two radio-frequency oscillators beating at an audible frequency. The addition of hand capacity to the pitch control antenna lowers the frequency of one of the r.f. oscillators, and the pitch of the beat frequency is correspondingly changed. The outputs of the two r.f. oscillators (V_1 and V_2 in Fig. 3) are mixed, and the r.f. components of the resultant signal removed by means of a diode detector.

In the volume control circuit, the addition of hand capacity to the volume control antenna causes a change

Fig. 1. Over-all view of the home-built Theremin. The cabinet is made of ½-inch plywood. The speaker panel is constructed of ¼-inch Masonite. The antennas are mounted with through bolts and wing nuts.

By popular request—another Theremin article. This new design incorporates many refinements that provide greater operational stability—it is easy to build.

- 1961: Moog publishes article in *Electronics World* describing his transistor-based Theremin
- 1964: Moog, with composer Deutsch, builds first synthesizer prototype
- 1965: Moog releases 900 series for commercial sales

  Synthesizers used by composers, for advertising, jingles, and in recording studios
- 1966: Moog patents the 904A low/high-pass voltage-controlled filter with 24 dB / octave rolloff and resonance up to self-oscillation

Oct. 28, 1969 R. A. MOOG 3,475,623

ELECTRONIC HIGH-PASS AND LOW-PASS FILTERS EMPLOYING THE BASE TO EMITTER DIODE RESISTANCE OF BIPOLAR TRANSISTORS

Filed Oct. 10, 1966 4 Sheets-Sheet 1

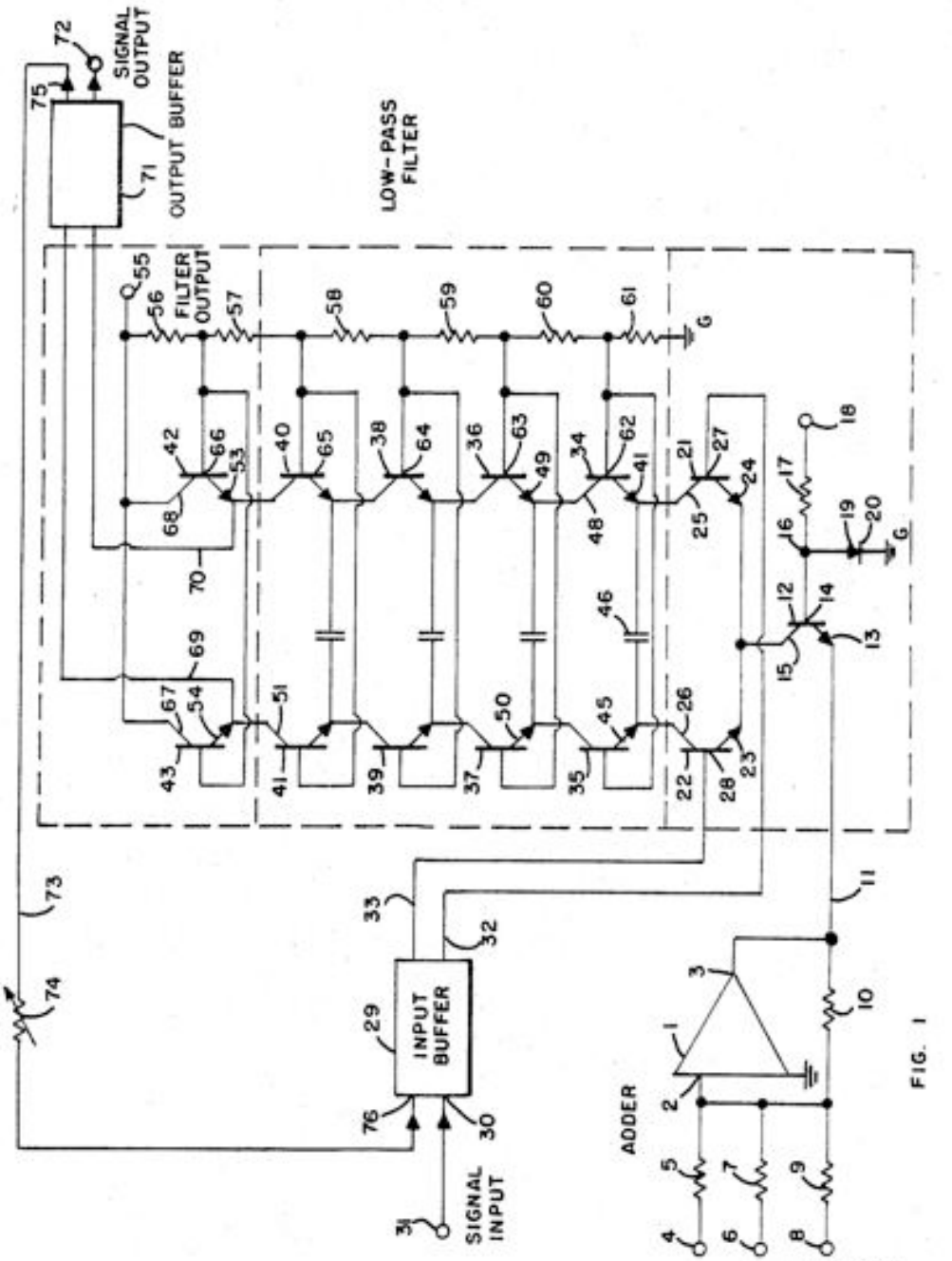
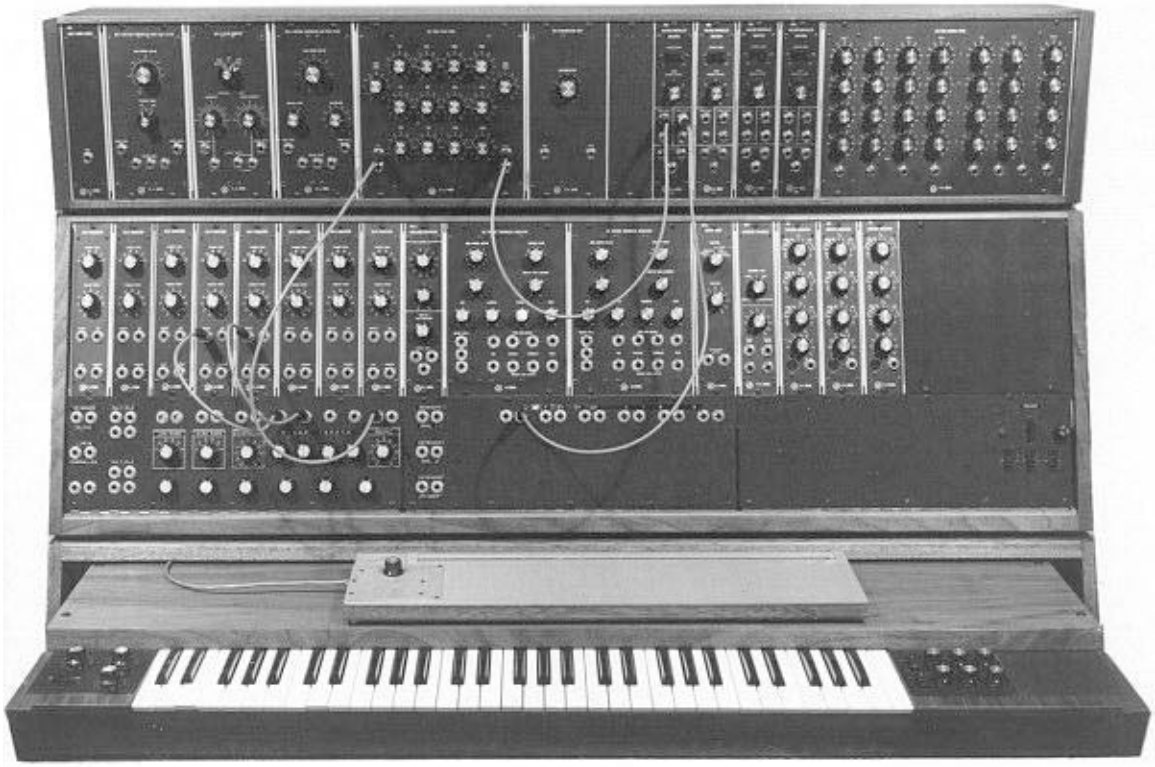


FIG. 1

INVENTOR.
ROBERT A. MOOG
BY Alfred W. Barber
ATTORNEY

- 1967: Moog releases modular systems I, II, and III

Courtesy of Roger Luther (http://www.moogarchives.com). Used with permission.



Courtesy of Roger Luther (http://www.moogarchives.com). Used with permission.

901-C OUTPUT STAGE: In conjunction with a 901-B oscillator, this instrument produces two outputs of equal magnitude but opposite sign, of any of the 901-B waveforms. The output is variable, and is used as a control voltage.

$ 45.00

901-D VARIABLE WAVEFORM OUTPUT STAGES; In conjunction with a 901-B oscillator, this instrument produces two outputs of equal magnitude but opposite sign. All of the 901-B waveforms are available and may be mixed in any proportion. In addition, variable clipping is provided to shape the triangular wave. Outputs are used as control voltages.

$ 75.00

902 VOLTAGE-CONTROLLED AMPLIFIER: A universal "variable-gain black box" with balanced, direct-coupled inputs and outputs. In conjunction with control voltage generators such as the 901, 911, 912, or 955, this instrument will perform virtually any amplitude-varying function.

$150.00

902-A BAND PASS FILTER ADAPTOR: Converts a 902 VCA into a voltage-controlled bandpass filter with a three octave range.

$100.00

903-WHITE SOUND SOURCE: Generates white noise over a 1-20,000 cps bandwidth.

$ 60.00

904-VOLTAGE CONTROLLED LOW-PASS HIGH-PASS FILTER: Provides voltage controlled filtering over a seven-octave frequency range. High pass, low pass, and resonant modes are available. The high pass and low pass modes may be combined for broad band-pass or band-reject functions.

$475.00

904-A LOW PASS FILTER: The low pass section of the 904.

$250.00

904-B HIGH PASS FILTER: The high pass section of the 904.

$230.00

October, 1965 Catalog -2-

Courtesy of Roger Luther (http://www.moogarchives.com). Used with permission.

- 1968: Wendy Carlos records *Switched on Bach*

13.8. Concepts: Generators and Modifiers

- Modules are individual signal generating/processing components
- Two basic types of components: generators and modifiers
- Input is from front-panel knobs or voltages
- Output is a voltage

13.9. Concepts: Control and Audio Signals

- Two types of signals (voltages): audio and control signals
- Audio signals:
  - Sounds, alternating (bipolar) voltages in the audio range (faster than 20 to 30 Hz)
  - Voltage range from -3 to 3 volts (or wider)
- Control signals
  - Parameter values, (unipolar) voltages
  - Voltage range from 0 to 5 volts (or up to 15 volts)
  - Used to send control information to other modules
  - Used to provide envelope shapes

13.10. Concepts: Reuse and Interoperability

- Can use output of one module as a signal (audio or control) input to another
- Can use an audio signal (shifted or scaled) as a control signal

13.11. Concepts: Creative Patching

- Developing new signal flows becomes a compositional task
- New signal flows may be timbral adjustments, instrument designs, or compositional procedures
- Patching modules and organizing control voltages becomes an interface

13.12. Synthesizer Components: Generators

- Generators: produce raw signals for further processing
- Oscillators (VCO): sine, square, triangle, sawtooth

Courtesy of Arturia. Used with permissiom.

- Low frequency oscillator (LFO): specialized for slow speeds
- Noise: white and pink

Courtesy of Arturia. Used with permissiom.

- Sample and hold (SAH): sample a generator and transform it into a stepped signal

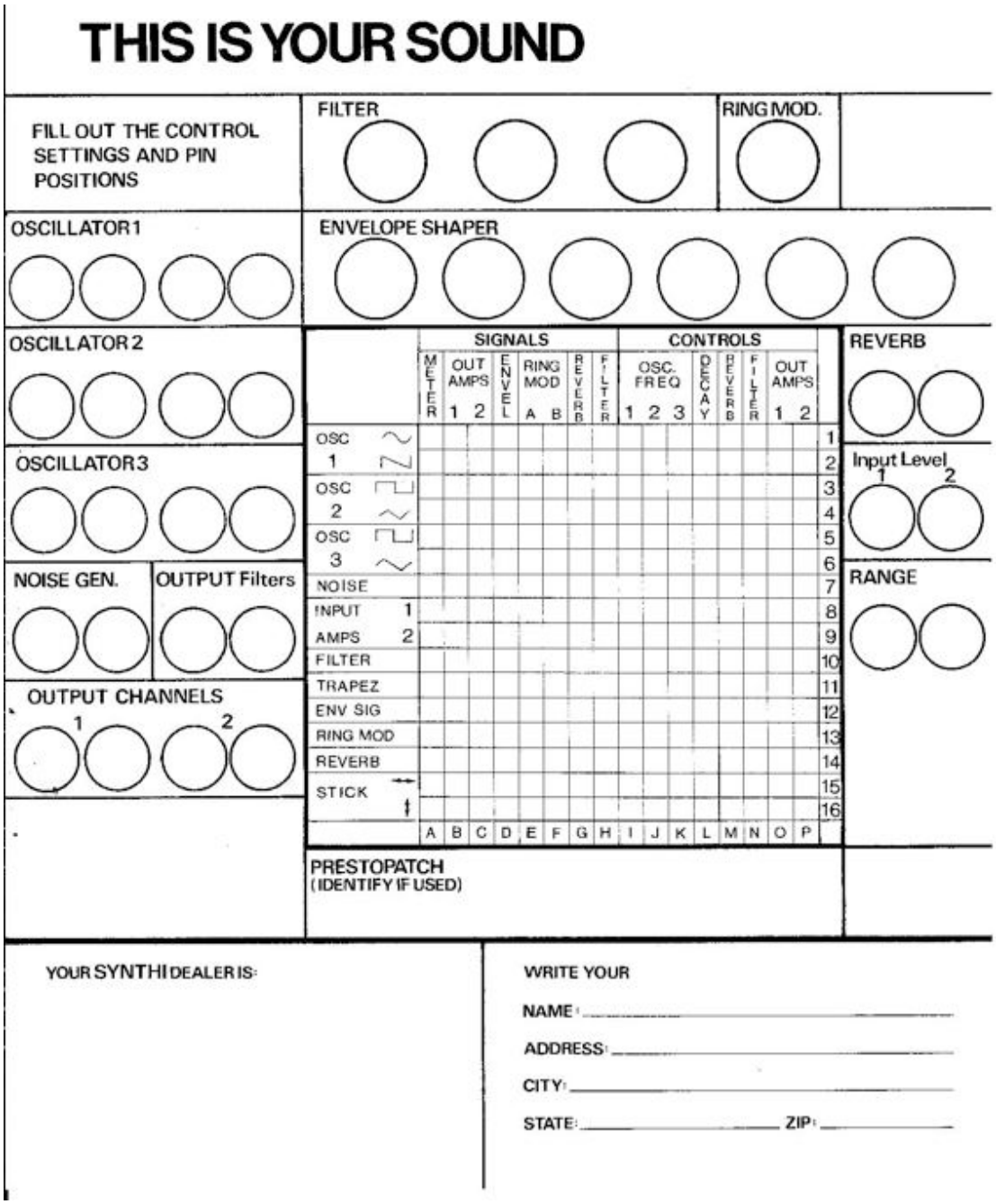
Courtesy of Arturia. Used with permissiom.

13.13. Synthesizer Components: Signal Mixing, Amplifying, and Routing

- Mixers (adding, summing) and amplifiers (scaling, multiplying)
- Voltage controlled amplifier (VCA)
- Mixer with toggles

- Matrix patching and mixing

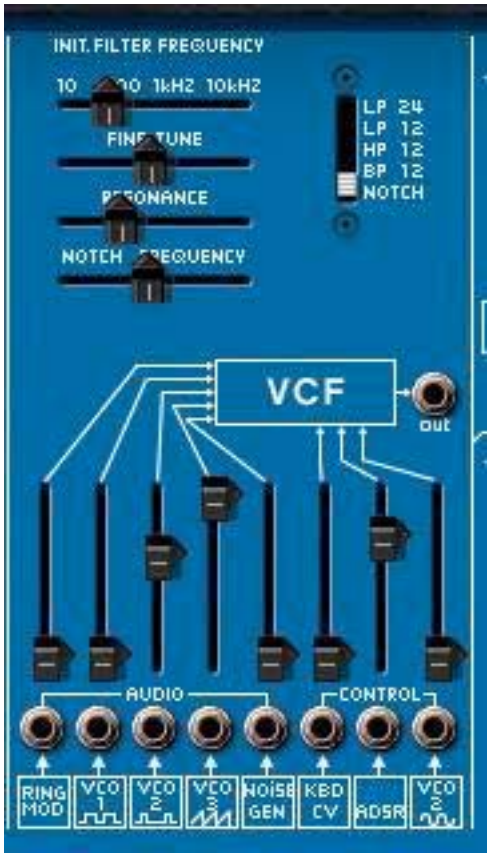
Courtesy of Electronic Music Studios. Used with permission.



Courtesy of Electronic Music Studios. Used with permission.

13.14. Synthesizer Components: Filters

- Boost or cut the amplitude of spectral components, changing the timbre of the sound
- Common varieties: low pass (LPF), high pass (HPF), band pass (BP), notch
- Voltage controlled filter (VCF)



Courtesy of Arturia. Used with permissiom.

13.15. Synthesizer Components: Envelopes

- Unipolar control rate signals used for controlling amplitudes and parameters of other modules (e.g. filter cutoff frequencies)
- Attack, decay, sustain, release (AR, ADS, ADSR)

  ADSR design built by Moog at request of Ussachavesky (Pinch and Trocco 2002, p. 71)

Courtesy of Arturia. Used with permissiom.

Courtesy of Arturia. Used with permissiom.

13.16. Subtractive Synthesis

- Start with a rich, complex tone produced with oscillators and/or noise
- Apply filters to create timbral variation
- Apply amplitude envelopes to shape dynamic amplitude (and filter) contours
- Use modulation of any of these parameters to create dynamic changes, triggered either at the start of each event (by an envelope) or continuously (by an LFO)
- Modulate the modulators!

13.17. Combining and Detuning Oscillators

- Oscillators are commonly grouped in bundles: three 921b oscillators managed by a 921a controller
- Multiple waveform shapes can be used from one oscillator simultaneously
- Driver provides frequency for all oscillators; each oscillator then has tuning to adjust each tone

- Pulse-width and frequency modulation input on driver affect all frequencies
- Three oscillators mixed together, and sent to ADSR. Leftmost ADSR envelope is triggered by keyboard and sent to main outs by default

Courtesy of Arturia. Used with permissiom.

13.18. Applying Filters

- Low pass filtering with cutoff frequency modulation by LFO

- Low pass filtering with cutoff frequency modulation by envelope

Courtesy of Arturia. Used with permissiom.

13.19. Amplitude Modulation and Ring Modulation

- Modulate the amplitude with a waveform moving between -1 and 1 (ring modulation) or 0 and 1 (amplitude modulation)
- Creating tremolo effects: modulator is an LFO at a sub-audio rate (slower than 20 Hz)
- Creating new harmonics: modulation at the audio rate (faster than 20 Hz)
- Using unconventional waveforms may produce interesting effects
- Three oscillators mixed and sent to an amplifier; the amplifier is modulated by sine wave; the output is sent to the ADSR.

Courtesy of Arturia. Used with permissiom.

- Modulate the frequency of the modulator: three oscillators mixed and sent to an amplifier; the amplifier is modulated by sine wave; the rate of this modulation is modulated by another sine wave; the output is sent to the ADSR.

Courtesy of Arturia. Used with permissiom.

13.20. Ring Modulation

- Dedicated ring modulators offer controls for frequency and depth; built in oscillator offers sine wave modulator
- Three oscillators are mixed; the signal is sent to the ring modulator; the signal is sent to the ADSR

Courtesy of Arturia. Used with permissiom.

- Can modulate frequency and/or depth of ring modulation with LFO or envelope

13.21. Vibrato

- Modulate the frequency of an oscillator with a sine wave

- Scale the modulator by an envelope triggered at the start of the event, fading the vibrato in and out

Courtesy of Arturia. Used with permissiom.

13.22. Frequency Modulation

- Modulate the frequency with a sine wave so fast and wide as to create new harmonics

Courtesy of Arturia. Used with permissiom.

- Modulate the modulator

Courtesy of Arturia. Used with permissiom.

13.23. Filtered Noise

- Use a narrow band filter controlled by the keyboard to filter noise

Courtesy of Arturia. Used with permissiom.

13.24. Sample and Hold

- Sample and hold applying noise to frequency modulation

Courtesy of Arturia. Used with permissiom.

13.25. Listening: Carlos

- Graduate student at Columbia during the time of the RCA Mark II Synthesizer
- 1966: Works with Moog to design custom system and produce a Moog demo LP (2008, p. 218)
- 1968: *Switched-on Bach* is the first Platinum-selling classical album

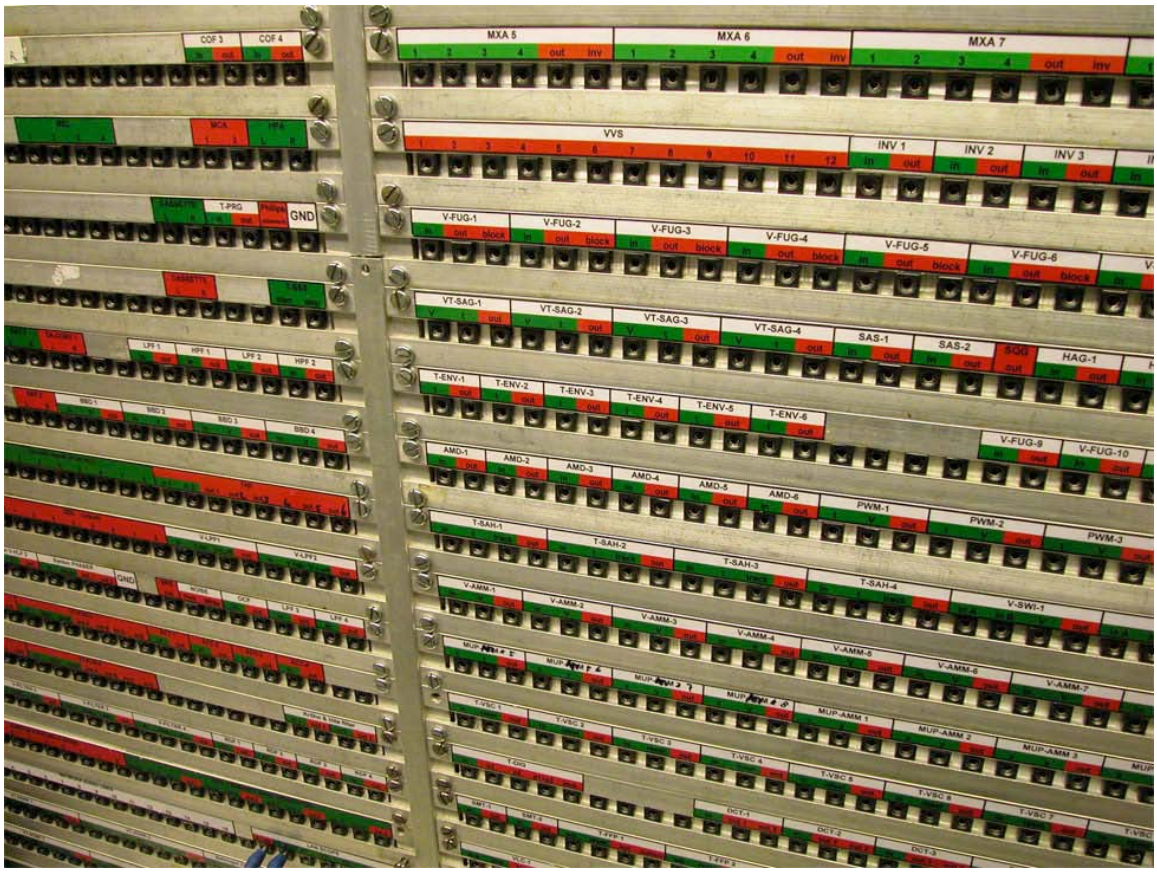
- Performed Bach on a Moog synth, with multi-track recording and layering of parts
- Audio: Wendy Carlos on the production

- Audio: Wendy Carlos, Cantata #147, BWV 147, *Switched on Bach*, 1969

- Audio: Wendy Carlos, The Well-Tempered Clavier, Book 1 - Prelude & Fugue #2 In C Minor, BWV 847, *Switched on Bach*, 1969

13.26. Listening: Koenig

- The Institute of Sonology modular synthesizer (BEA-V)



- Explored approaches to automating synthesis parameters based on a single voltage-control pattern, applied and mapped in a variety of ways
- Audio: Gottfried Michele Koenig, *Funktion Grau*, 1969

13.27. Listening: Subotnick

- Audio: Morton Subotnick, *Silver Apples of the Moon*, Parts A and B, 1967

- Composed on a Buchla synthesizer, with the use of a sequencer to organize musical structures (Holmes 2008, p. 224)
- First electronic composition conceived and recorded for release on a commercial recording (Holmes 2008, p. 431)
- How is noise and randomness used in this composition?
- Do we hear sounds performing roles similar to acoustic instruments?

13.28. Listening: Oliveros

- Audio: Pauline Oliveros, "Alien Bog," 1967

- Created on a Buchla Box 100 series synthesizer
- Do we hear sounds performing roles similar to acoustic instruments?

13.29. The ARP 2600

- ARP founded by Alan R. Pearlman and others in 1969
- Released the ARP 2500 modular synthesizer in 1970

- Released the ARP 2600 in 1971

Courtesy of ToneTweakers. Used with permission.

- Semi-modular: fixed collection of modules in each package, and default connections that could be altered with patch cables
- Featured built-in speakers and spring reverb
- ARP was market leader in synthesizers in the 1970s, with 40% of market share
- 1976: ARP releases 16 step sequencer

13.30. The Minimoog

- 1969: Moog receives requests for more compact and portable instrument
- Contained around 300 transistors and took Moog six months to design (Theberge 1997, p. 70)
- Early prototypes

- Introduced in 1970: "a compact, moderately priced electronic music synthesizer designed and built especially for live performance"

introducing...

the mini moog model d

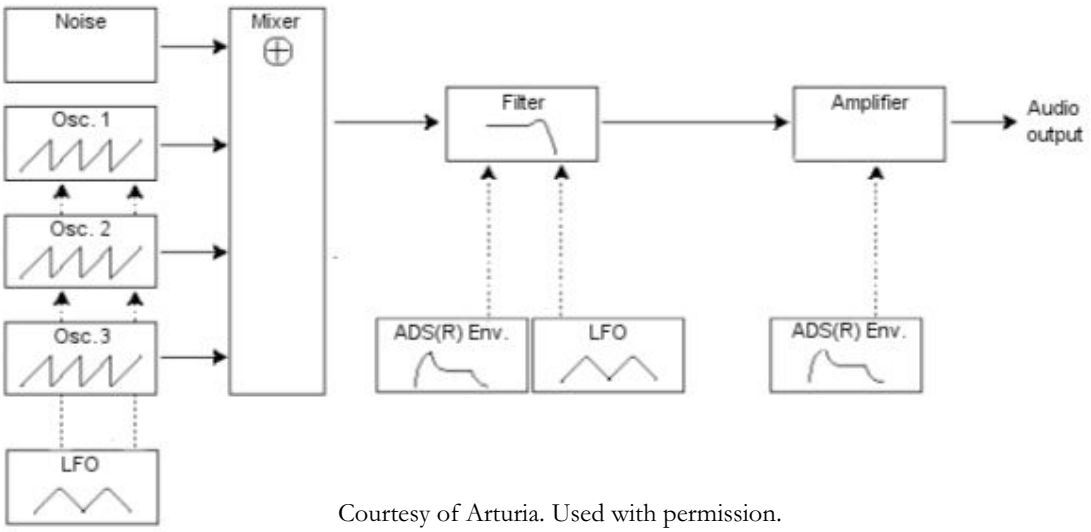
Here it is! A compact, moderately priced electronic music synthesizer designed and built especially for live performance by R. A. Moog, Inc., leading manufacturer of new electronic musical instruments for nearly two decades. The Mini Moog is not merely another sound modifier built to enhance the sound of other instruments, although it can perform this function and many more. It is not another electronic organ with added gimmicks for creating special effects. It is a completely new musical instrument, designed from the bottom up with today's performing musician in mind, and making accessible for the first time a vast range of sound possibilities which had hitherto been available only to experimental composers with an involved knowledge of studio techniques. The Mini Moog incorporates the basic synthesizer functions, so widely in demand by avant-garde, jazz, rock, and pop musicians familiar with the new sounds of electronic music, in an inexpensive, lightweight, portable package designed to be easily set up and played.

The most popular and useful types of sound generators, sound modifiers, and control devices to be found on our large studio model Moog synthesizers are all incorporated in the Mini Moog. Sound generators include three oscillators, producing pitched tones over the entire range of human hearing with several different waveforms, a noise source for producing pitchless sound, and a microphone/accessory amplifier through which sounds from other sources may be introduced into the Mini. Sound modifiers include a wide-range voltage-controlled lowpass filter and a voltage-controlled amplifier, each with its own contour generator. Control devices include a full-size 44-note keyboard and two special slide controllers for touch-sensitive modulation of the tone.

These basic functions make immediately accessible a vast realm of new musical material. Because all component circuits in the Mini Moog are independent of one another, the musician is able to combine them in a variety of ways. Thus rather than being tied down to a limited set of sounds or effects, he is really free to explore all the basic aspects of musical sonority, setting, shaping, and modulating each aspect of the tone color to suit his own tastes. The Mini Moog for the first time places the control of many parameters of sound literally at the fingertips of the creative and imaginative musician.

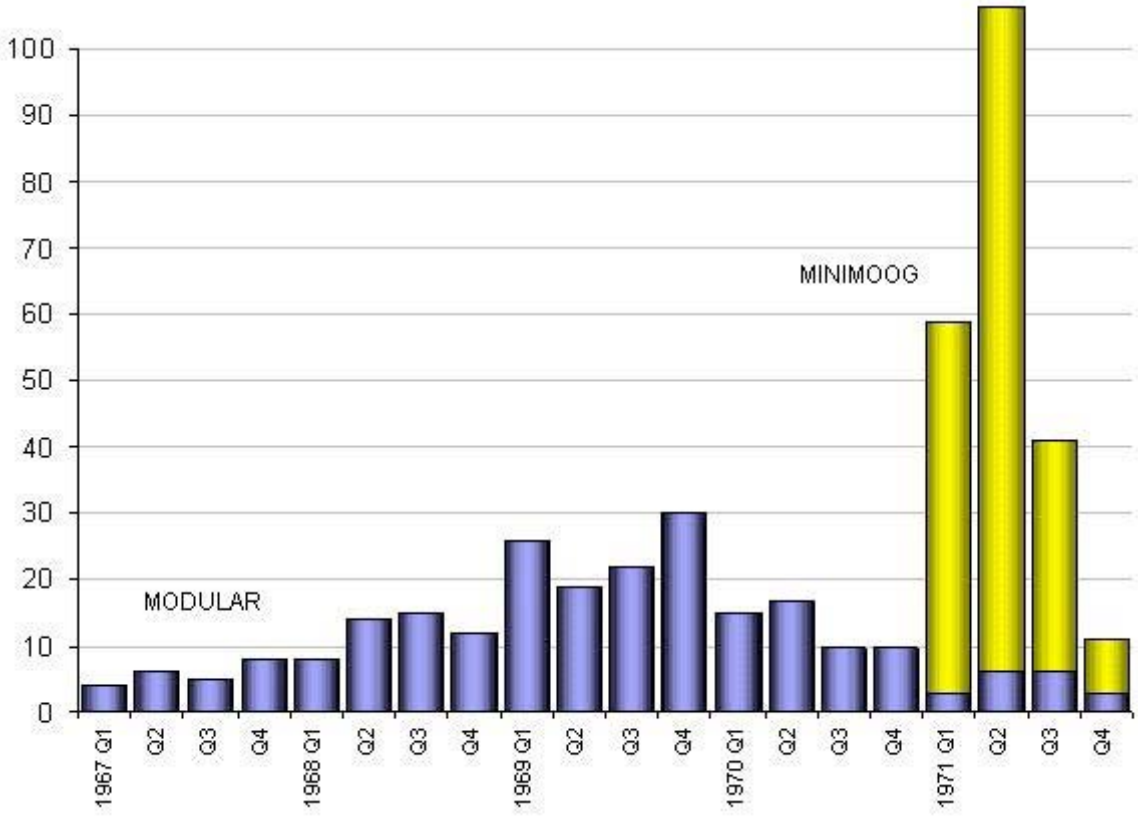
R. A. MOOG, INC., TRUMANSBURG, NEW YORK 14886 PHONE (607) 387-6101

- Simplified abstraction of subtractive synthesis



Courtesy of Arturia. Used with permission.

- Sales were much greater than modular systems



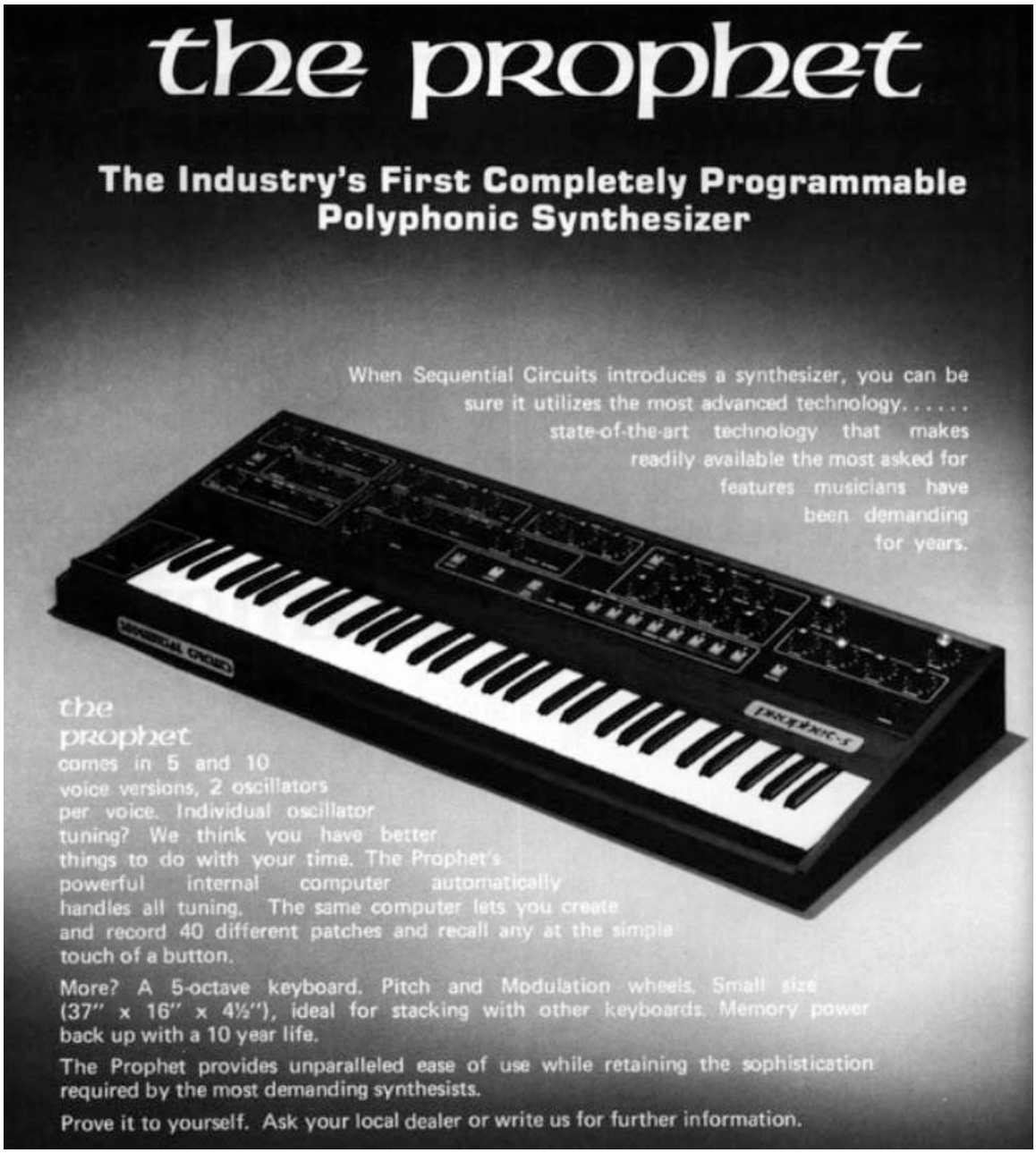
Courtesy of Roger Luther (http://www.moogarchives.com). Used with permission.

- 1972 to 1981: main production models distributed

13.31. The Sequential Circuits Prophet 5

- 1978: Dave Smith and others start company out of Smith's garage
- 1978: Sequential Circuits releases Prophet-5

Courtesy of Arturia. Used with permission.



- Described as "5 Minimoogs in one box"
- Original prices between $4000 and $5000
- A digital-analog hybrid: interface provides data to a "microcomputer system which in tern 'programs' the voices." (1982 Operation Manual)
- First synthesizer to permit storing and recalling presets
- "... several months after the introduction of the Prophet-5 in 1978, the service department at Sequential Circuits began to notice that most of the instruments returned to the factory for repairs still had the factory preset programs in their memory banks. They thus assumed that the majority of users, 80 percent or more, were not actually programming at all but were relying almost exclusively on the presets." (Theberge 1997, p. 75)
- Led to the development of a preset- or patch-making industry
- Prophet VS released in 1986 and 1987: permitted cross-fading between waveforms and free assignment within modulation matrix

13.32. Reading: Pinch and Trocco

- Pinch, T. and F. Trocco. 2002. "The Social Construction of the Early Electronic Music Synthesizer." In *Music and Technology in the Twentieth Century*. H. Braun, ed. Baltimore: The Johns Hopkins University Press. 67-83.

- How did the availability of cheap transistors in the 1960s influence the development of the synthesizer?

- Pinch and Trocco quote Moog describing a particular pose favored in product photographs: what was this pose, and why was it desirable?

- What ideas about the early synthesizer reached closure by the early 1970s?

- What relevant social groups participated in the development of the early synthesizer?

21M.380 Music and Technology (Contemporary History and Aesthetics)
Fall 2009