Voltage-Controlled Synthesis

1960's

Early Applications of Analog Synthesis

- 1950's - Begins in Cologne with Herbert Eimert, Stockhausen, etc. at NWDR (Elektronische Musik).
  - Equipment includes – oscillators, noise generators, and signal processors (filters, etc.)
- 1957 RCA Mark II (Columbia- Princeton)
  - Automated synthesis processes by encoding punched holes in paper to activate controls within synthesizer.
  - Huge, integrated system with 1700 vacuum tubes.

New Technology

- Transistors replaced vacuum tubes, resulting in smaller synthesizers
- Voltage Control – the use of a control voltage to regulate the operation of an audio device

  -Resulted in modularity between units

The First Voltage-Controlled Synthesizers

Robert Moog (New York)

- Built the 1st voltage-controlled oscillator and amplifier for composer Herbert Deutsch in 1964.
- Presented “Voltage-Controlled Electronic Music Modules” at AES the same year.
- Released the 1st Moog Synthesizer in 1966.
- Moog synthesizer made famous by pop composer Walter/Wendy Carlos.

Donald Buchla (San Francisco)

- Released the Buchla Electronic Music System in 1966.
- Installed in the San Francisco Tape Music Center.
- Used by composer Morton Subotnick.

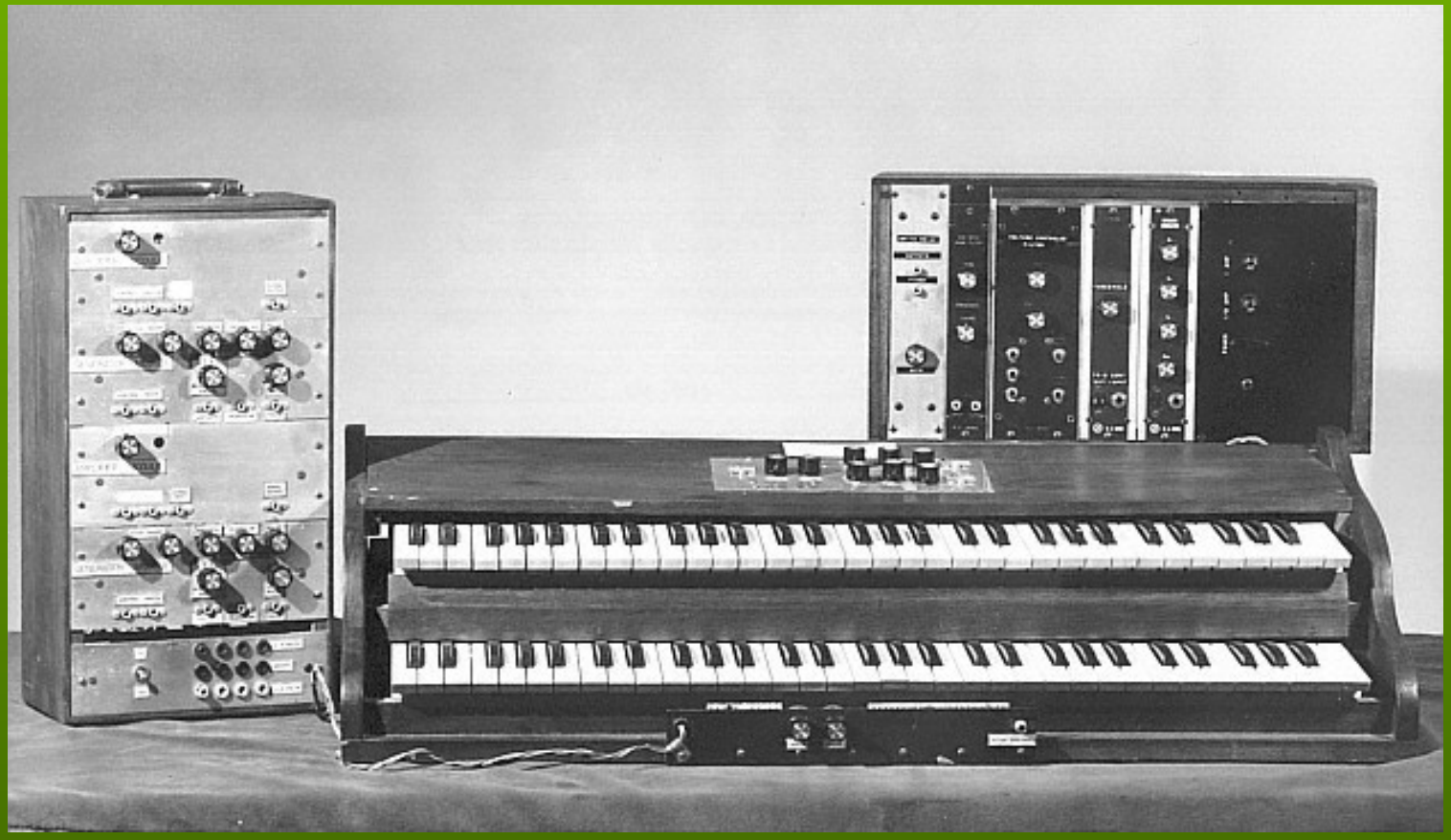
Other Voltage-Controlled Synthesizers

Synket (Rome)

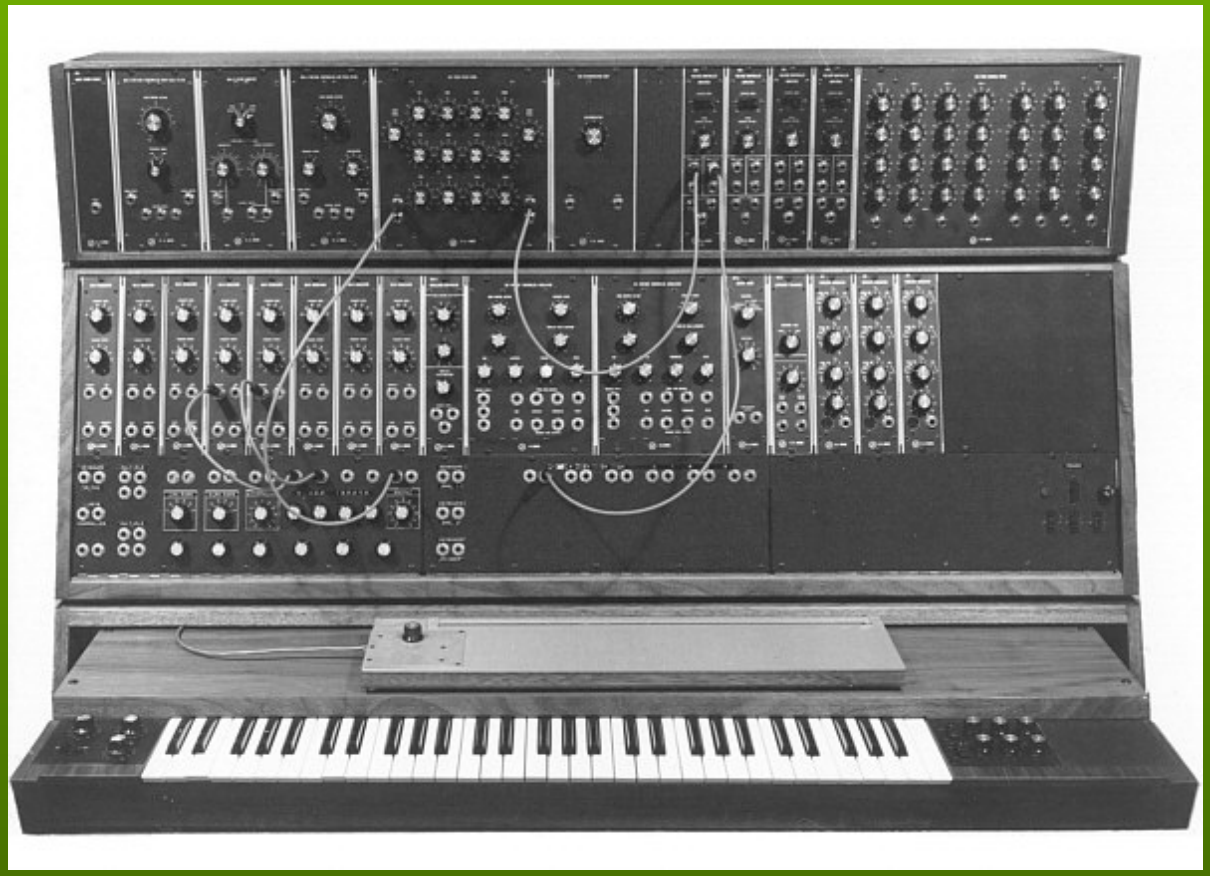
- Small, portable synthesizer created by Paul Ketoff in 1964
- Installed in 1965 at the American Academy in Rome
- Used by American composer John Eaton

Tonus/ARP and EMS Ltd. (British Rivals for Moog and Buchla created in the late 1960s)

Moog's First Synthesizer



Buchla's Modular Synthesizer III



Typical Analog Synthesizer

- Modules – collection of individual, electrically compatible components. Each is dedicated to a specific function such as signal generation, amplification, filtering, gating, or control voltage generation.
- Inputs and outputs of modules are connected to each other with patch chords.
- Voltage is controlled externally with dials or sliders (potentiometers).
- Patch – a particular combination of modules, cabling, and parameter settings.

Functions of Modules

All Modules do at least one of the three

- Signal Sources – provides oscillation or noise.
- Signal Modifiers – directly modifies the amplitude, spectrum, or other attribute of signal.
- Control Voltage Sources – applied to other modules in patch.

Signal Sources

VCO – voltage-controlled oscillator

- Contains dials for coarse and fine adjustments to frequency.
- Selection of common waveforms
  - sine - fundamental only
  - sawtooth - 1/n, odd and even partials, bright tone
  - triangle - $1/n^2$, only odd partials, mellow tone
  - pulse or square – 1/n, only odd partials, hollow tone

Noise Generators

- Generates white or pink noise (separate outputs or a switch)
  - White noise - equal distribution in all frequency bands
  - Pink noise - greater distribution in lower frequency bands

Interfaces for External Sources

- Microphones, tape recorder, etc. – some synthesizers include microphone preamplification modules

Signal Modifiers

- VCA – voltage-controlled amplifier
  - Modifies the amplitude (intensity) of audio signal.
    - At least 2 inputs (for audio signal and control voltage) and one output.
    - Usually, VCAs attenuate rather than amplify.
    - Usually controlled by an envelope generator.
- Mixer –
  - Module that combines audio signals from different sources.
    - Usually 4 audio inputs can be mixed to one audio output. Dials to adjust level of each input are provided
    - Can be used to combine a fundamental with additional sine waves, each with independent amplitude. (additive synthesis)

VCF – voltage-control filter

- shapes timbre by boosting or attenuating amplitude of frequencies within a range.
  - cutoff frequency – frequency at which filter begins to attenuate frequencies, set with dial.
  - filter slope (roll-off) – attenuation curve, from 0 to full attenuation (about 60 dB)
  - low-pass filter – filters frequencies above cutoff
  - high-pass filter – filters frequencies below cutoff
  - band-pass filter – filters frequencies above and below cutoff
  - bandwidth – distance between 2 cutoff frequencies of a band-pass filter
  - band-reject filter (notch filter) – filters frequencies between 2 cutoff frequencies
  - center frequency – frequency at center of band-width

VCF Applications

- Band-pass and band-reject filters are patched together from low and high pass filters.
- Part of the signal from a low-pass filter can be fed via an internal path back into the input. This recirculation causes a resonance peak for any frequencies near the cutoff. The sharpness of this resonance peak is called the Q of the filter and can be set with a dial. (Used for shimmery effects).
- Control voltage can be used to change the effect of a filter over time.

Control Voltage Sources

Envelope generators

- contour of voltage which is usually applied to the control input of a VCA
  - Used to shape amplitude envelope of a sound. Requires trigger from trigger-generator module, keyboard, or push-button on envelope generator itself. Requires gate voltage to determine duration of envelope.
  - 4 stages of contour – attack, initial decay, sustain, release (ADSR) – 4 dials used to set these.
  - Can be used to control the pitch of a VCO, or the cutoff frequency of a VCF.

Keyboard

- provides a sustained voltage, a trigger voltage, and a gate voltage. (attack, sustain, release)
  - often patched to the control voltage input of a VCO to control frequency. Buchla's synthesizers avoided keyboards because they often limit exploration.
  - Keyboards of early analog synthesizers were monophonic (usually the lowest note struck got priority). Later, polyphonic keyboards were designed which could provide up to 8 independent voltages which could be patched to several different VCOs or other modules.
  - Keyboard tracking – Patching the output from a keyboard to the inputs of a VCF and a VCO changes the cutoff frequency and fundamental at the same time, thus waveform remains constant.

LFO

- low frequency oscillators below the range of human hearing
  - control voltage. Can be used to produce vibrato when connected to a VCO or tremolo when connected to a VCA.
  - When patched to VCO, amplitude of LFO determines amount frequency is raised and lowered, and the rate of vibrato is determined by frequency of LFO. (freq. modulation)
  - When patched to VCA, amplitude of LFO determines amount of attenuation of amplitude, and the frequency of LFO determines the rate of tremolo. (amp. modulation)
  - Many LFOs have a dial for delay time to control onset of modulation.

VCO (As Control Voltage Source)

- Amplitude Modulation – If VCO (freq. >30 Hz.) is patched to the control voltage input of a VCA which is passing an audio signal, then sidebands appear. Each frequency in audio signal will produce two sidebands:

  fc+fm=upper sideband

  fc-fm= lower sideband

  carrier frequency - audible frequency

  modulator frequency - frequency used to modulate audible frequency.

- Ring Modulation - special application of amplitude modulation which results in sidebands with no carrier frequencies.

VCO (As Control Voltage Source Con't)

- Frequency Modulation – If VCO (freq. >30 Hz.) is patched to the control voltage input of another VCO, then we hear sidebands instead of vibrato.
  - Modulation index- ▲*fc/fm=modulation index.* Sidebands heard will be 2 more than the modulation index.
  - Increasing the amplitude of the modulator increases the deviation of the carrier frequency (modulation index is higher), thus more sidebands.
  - Increasing the frequency of the modulator decreases the modulation index, thus fewer sidebands.
  - If *fc* and *fm* are related by a simple ratio, then sidebands approximate overtone series. Thus, FM can be used as an form of additive synthesis.

Sequencer

- Module which can produce a programmed series of discrete control voltages.
  - Pulse generator functions as a sequencer clock – advancing sequencer from one stage to the next.
  - Clock's speed can be controlled through sequencer's voltage control input.

Ribbon controller

- Module which produces a control voltage proportionate to the point along its length at which the ribbon is pressed.
  - Can produce a smooth envelope for VCO, VCF, or VCA.

X-Y controller – "joystick"

- Can produce 2 control voltages.

Touch-sensitive plate

- Can produce up to 4 control voltages.

  1)Position left to right 2) position top to bottom

  3) pressure applied to plate 4)area of plate which is covered.

Envelope follower

- Produces a control voltage with a contour proportional to the amplitude of an external signal.
- Usually a microphone or tape player controls this.

Sample-and-hold unit

- Input signal is sampled from time to time and level of input voltage is held until the next sample.
- Continuous input voltage can be converted to a series of discreet voltage levels.
- Random input such as white or pink noise will produce random series.

Control Voltage Attenuators

- Can be set to reduce voltage by a constant amount.
  - For example, if you set the dial to midpoint, all voltages are cut in half. Often this is connected to the output of a keyboard to achieve quarter tones.

Control Voltage Inverters –

- Inverts voltage (highest voltage switched to lowest and vice versa).

Musical Examples

Morton Subotnick

Silver Apples of the Moon

– created in 1967 with a Buchla Synthesizer

Wendy Carlos

Switched on Bach

– Created in 1968 with a Moog Synthesizer