Tampere University of Applied Sciences

Elements of the West Coast Approach to Sound Synthesis

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BACHELOR'S THESIS
October 2019

Media and Arts
Music Production

ABSTRACT

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Tampere University of Applied Sciences
Degree Programme in Media and Arts
Music Production

NIELSEN, HENRI:
Elements of the West Coast Approach to Sound Synthesis

Bachelor's thesis 51 pages, appendices 1 pages
October 2019

The objective of this work was to study the West Coast approach to synthesis, originally developed by Don Buchla. The objective was to find out what the approach is, how it was developed, and how the individual elements of a West Coast synthesizer contribute to the creation of the sound.

The secondary objective of this work was to examine the possibilities of creating the West Coast sound on other systems than those created by Buchla.

The history of the development of the West Coast approach was studied to find out how Buchla's background affected his approach as a synthesizer developer. The development process of the first West Coast synthesizer was also researched, as well as Buchla's influence on the music industry.

The Music Easel, a West Coast synthesizer developed by Buchla, was studied in detail to find out how it works. The documentation of each individual module of the synthesizer was studied to find out what it does and how it affects the overall sound. The use of circuits in synthesizers in general was studied to better understand the functionality of the modules.

The user interface of the synthesizer was also studied to find out how it influences the interaction between the user and the synthesizer. In addition, various software and hardware options for creating West Coast sounds were examined, and their advantages and disadvantages discussed.

It was found that each module on a West Coast synthesizer is important in the creation of the sound. The functionality of the Complex Oscillator and the Lo Pass Gate were considered to be particularly significant. The sequencing options as well as the user interface were considered to have an important role in the creation of the sound alongside the sound sources and effects.

It was also found that there exist viable options for emulating the sound both in the software and the hardware domains.

Key words: synthesizers, sound design, electronic music, buchla

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ABBREVIATIONS AND TERMS

CV	Control Voltage
LFO	Low Frequency Oscillator
VCA	Voltage Controlled Amplifier
VCO	Voltage Controlled Oscillator
FM	Frequency Modulation
Hz	Hertz, Unit of Frequency
VST	Virtual Studio Technology
DAW	Digital Audio Workstation
MIDI	Musical Instruments Digital Interface
UI	User Interface

1 INTRODUCTION

Don Buchla, a synthesizer developer from California, created a synthesizer that was taking advantage of the newly developed voltage control technology in the year 1964.

Coincidentally, he was working at the same time as another developer, Bob Moog, who was operating in the East Coast. They were unaware of each other working on the same idea. (Jenkins 2007, 50.)

The terms West Coast and East Coast synthesis are used to refer to the different approaches both had in their designs.

Both synthesizers were analog, and based around the voltage controlled oscillator, which is an electronic sound source that can play different pitches when it is sent different voltages. (Klein 1982, 43)

Because of the limitations and nature of the analog technology, Bob Moog's and Don Buchla's designs share a lot of similarities. In many cases, the technology dictated the most practical solution to a specific problem.

However, there was still room for both developers to do things differently from each other, both in the functionality of the circuits, as well as the user interfaces. The different design philosophies led to a difference in the sound as well

The East Coast sound established by Moog is very recognizable, and most analog synthesizers even today are based on the East Coast approach. The basic principle is the use of subtractive synthesis, in which the desired tone is essentially carved by filtering a raw waveform to subtract unwanted frequencies (Klein 1982, 17).

The West Coast sound is less known (Holmes 2008, 224). The sound creation is not based around a single principle. Instead, it combines elements of additive synthesis and frequency modulation to create a variety of complex timbres. The resulting sound is often described as organic and lifelike.

2 DEVELOPMENT OF SYNTHESIZERS

Electronic music was already made and explored before the development of synthesizers, but the equipment it was being made with was not primarily designed for making music. Musicians were using and combining various electronic devices to create experimental sounds. (Jenkins 2007, 48.)

The term synthesizer was used for the first time in the year 1896 by the inventor Thaddeus Cahill to describe his instrument called Telharmonium (Holmes 2008, 208).

In his patent from the year 1897 he described that the device was capable of producing sounds electronically, which could be controlled from a keyboard to make music. He also used the word synthesizing to describe the process of combining electronic sounds to make the final sound. (Holmes 2008, 8.)

The Telharmonium already had many of the features of the modern synthesizer, but it was only capable of producing simple tones with limited customization options. It was also large and required a lot of power (Holmes 2008, 8).

The Telharmonium was followed by many other pioneering electronic instruments and inventions.

2.1 Pioneers of the Voltage Controlled Synthesizer

The voltage controlled synthesizer is the synthesizer that eventually became well-known throughout the music industry.

The voltage controlled synthesizer has a sound producing oscillator, which can produce a range of tones when it is sent different voltages (Jenkins 2007, 20). This sets it apart from the earlier synthesizers like the Telharmonium, which had individual sound sources for each tone (Manning 2004, 112).

The first voltage-controlled synthesizer prototype was developed by Hugh Le Caine in the year 1945. The prototype was called the Electronic Sackbut. (Holmes 2008, 171.)

The first complete voltage-controlled synthesizers were developed in America in 1964 by two individual pioneers simultaneously, Bob Moog and Don Buchla (Manning 2004, 113). They were operating at the opposite sides of America, and were unaware of each other when making the initial prototypes. This lead to some differences in their approaches and design. (Manning 2004, 102.)

Both instruments shared a modular design, which allowed the users to rewire connections to change the signal flow of the instrument. This was achieved with electrical cords connecting the modules. (Pinch & Trocco 2004, 41.)

The so called "fixed-architecture" synthesizers were developed later. In those synthesizers, the connections between modules are fixed in place, so that the user cannot change their order. This makes the instruments simpler to learn and use, and is common in modern designs (Jenkins 2007, 16).

Bob Moog was operating on the East Coast of America, while Don Buchla on the West Coast (Manning 2004, 102). The terms "East Coast Synthesis" and "West Coast Synthesis" refer to the differences between the two, which will be explored further in the next chapters.

2.1.1 Background of Bob Moog

Robert "Bob" Moog was born in 1934 and lived his youth in Queens, New York. His dad was an engineer, so he had good access to electrical equipment and knowledge from a young age. His father had an electronics workshop in their family's basement, and there was equipment and parts that Moog could learn to use. He was mostly self-taught, making projects from instructions on electronics magazines. (Pinch & Trocco 2004, 13.)

He studied science, electrical engineering, and eventually achieved a Ph.D. in engineering physics (Holmes 2008, 209).

Eventually Bob Moog came across a new invention, the Theremin, which became a passion for him.

Moog was very interested in the instrument and made his own prototypes at the age of fifteen. He developed them further as a hobby for years, eventually reaching a point where he was able to start selling them commercially on a small scale. This is what originally made him start his own company at the age of nineteen.

2.1.2 Development of the East Coast Synthesizer

Moog went to music industry events to promote his Theremins. In one of those events, he met an experimental musician called Herb Deutsch. (Holmes 2008, 208).

Deutsch introduced Moog to the experimental electronic music scene in New York.That made a good impression on Moog, and he became interested in developing an electronic musical instrument to help the musicians. (Holmes 2008, 209.)

Moog developed his first prototypes based on the wishes of Deutsch, who felt limited with the capabilities of his setup. The main issue with the gear of that time was that it was difficult to create melodies or notes on the equipment not made for music. (Jenkins 2007, 50.)

Moog was able to create a voltage controlled oscillator, which was able to play musical pitches. That formed the foundation for what would later on become his first complete synthesizer. (Holmes 2008, 208.)

Moog attached a keyboard to play the pitches in a musical way. That decision proved to be very successful in the long run, as it made the instrument more relatable to musicians without electronics knowledge. (Pinch & Trocco 2004, 60.)

Moog kept developing the instrument further, adding an envelope generator to be able to play notes dynamically, and a filter to be able to shape the frequency of the sound. He was going on iteration after iteration based on feedback from Deutsch and other musicians.

2.1.3 Popularity and Influence of Bob Moog

The Moog synthesizer got a lot of interest, first from the experimental electronic scene and eventually also from the music scene at large.

A big breakthrough moment for the Moog synthesizer was when Wendy Carlos made an album called Switched-on Bach, released in 1968 by Columbia Records. On the album, she played compositions of Bach with the synthesizer. The album sold Platinum. (Jenkins 2007, 51.)

After the release, many "Switched-on" records were released based on the same idea of using the synthesizer to play existing compositions. The popularity of the record gave the synthesizer as an instrument lot of publicity on the media. (Pinch & Trocco 2004, 8.)

Bob Moog recognized the commercial value of adding a keyboard to his synthesizers. He understood that for a traditional musician it would make his modules more approachable. (Pinch & Trocco 2004, 60.)

PICTURE 1. Bob Moog. (Fact Magazine)

2.1.4 Background of Don Buchla

Don Buchla was born in 1937, in Southgate, California. Growing up he played the piano as a hobby and tinkered with electronics projects. He had access to electronics from early on as his father was an air force test pilot. (Pinch & Trocco 2004, 32.)

He studied physics and went on to work in the field after graduating from the university.

Later on, he was employed by NASA to work on a number of projects. Some of his projects included developing a radiation belt to be used by astronauts in space, and even exploring if it was possible to send chimpanzees to Venus. (Pinch & Trocco 2004, 34.)

2.1.5 Development of the West Coast Synthesizer

Buchla was experimenting with tape music and sound related devices on his free time. Eventually he found his way to the San Francisco Tape Center, where experimental musicians were gathering and producing early electronic music.

The technique used was to cut and splice tape recordings manually with a razor and other tools. With this technique, it was possible to change the order of the tape parts, creating new recordings. (Holmes 2008, 125.)

In 1965 Buchla was commissioned to make a synthesizer by two of the members of the Tape Center, Morton Subotnick and Ramon Sender (Holmes 2008, 221).

For controlling the synthesizer, Buchla invented an analog sequencer, which allowed the player to program a looping pattern which would play the notes sequentially. The sequencer made it possible to change the sounds at the same time as the pattern was playing. (Holmes 2008, 222.)

He also included various touch-sensitive plates for playing notes, but did not include a regular keyboard. However, the notes could be played chromatically with the touch-sensitive plates. (Holmes 2008, 223.)

2.1.6 Popularity and Influence of Don Buchla

Don Buchla took part in arranging sound systems and even performing in many events, for example the Acid Tests and the Trips festival (Pinch & Trocco 2004, 94).

He made custom synthesizers for the band Grateful Dead, known for pioneering the psychedelic rock sound. He also designed their famous sound system, which was used to tour across the United States. (Pinch & Trocco 2004, 103.)

Buchla was not particularly interested in the commercial success of his instruments. Instead, he wanted to experiment rather than succeed commercially with his designs (Pinch & Trocco 2004, 50).

Buchla instruments and the West Coast synthesis methods in general have never reached the popularity or commercial success of Moog (Holmes 2008, 224). They are largely unknown to other people than dedicated synthesizer enthusiasts. However, with the increasing interest and affordability of analog synthesizers, new musicians and companies are exploring his designs again.

PICTURE 2. Don Buchla. (Buchla Musical Instruments)

3 STUDYING THE MUSIC EASEL

In order to acquire a deeper understanding of West Coast synthesis, it is useful to study the designs of Don Buchla in detail.

The Music Easel was chosen as the subject of the study. It is a portable, self-contained synthesizer, housed in a case resembling a suitcase. The other designs of Buchla are larger.

PICTURE 3. The Music Easel. (Buchla Musical Instruments)

The Music Easel contains the same types of modules than the larger systems, but on the larger systems there is added functionality and complexity. The aspect of portability has impacted the design, making the modules of the Music Easel focused on the essential features that are required to achieve the sound in a limited space.

While on the larger systems, the individual modules can be swapped in a modular fashion, on the Music Easel the modules are fixed. This setup is called semi-modular, and it was considered good for the study, as the set of modules and way of working is defined by Buchla.

Importantly, despite the portability, the Music Easel still allows the user to freely change the signal flow between the units. Modularity is one of the aspects found on many of Buchla's designs (Jenkins 2007, 50).

The Music Easel was released in the year 1973, and is still in production, even though the company has gone through ownership changes and Don Buchla himself is already deceased.

Many well-known users of Buchla products are also using the unit.

In the following chapters the Music Easel is explored in detail, module by module. It is worth noting that the objective of the study is not to document all of the functionality and technical details of the Music Easel. Instead, the focus is on examining the creative possibilities of the modules, and how their functionality contributes to making the sound.

3.1 Elements of the Sound of a Synthesizer

Before proceeding to the study of the West Coast sound, it is useful to define what elements make the sound of a synthesizer.

A narrow definition would include only the elements that are directly creating or processing the audio coming from the outputs of the synthesizer.

This definition leaves out the controllers, such as a keyboard and various compositional tools like arpeggiators and sequencers, as those are not directly making audio.

However, it can be argued that in many classic synthesizers, these elements are also a part of what is considered their sound.

For example, the bass synthesizer TB-303, produced by Roland in 1982, has a recognizable sound that was making analog synthesizers popular again in 1985 (Jenkins 2007, 195). It has only an oscillator with saw and square waves followed by an envelope and a filter (Jenkins 2007, 195). The architecture is simple, and many synthesizers have these features.

However, what makes the sound of the TB-303 distinguishable and hard to emulate is the combination of the sequencer and the sound engine. The accent and glide functions combined with the filter and envelopes make the patterns created on it sound specific to the TB-303. (Jenkins 2007, 193.)

The sequencers and arpeggiators, as well as keyboards included in synthesizers are compositional tools that can be argued to contribute to the overall sound aesthetic, even though they are not directly making sound.

Another aspect to consider is the user interface of the synthesizer. The elements most easily reachable on the front panel can be more likely to be used often.

For the purpose of this work, the sound of a synthesizer is considered to include all of the built-in compositional tools, sound sources and sound processing tools included on the synthesizer, as well as aspects of the user interface.

3.2 Defining the Standard Features of an Analog Synthesizer

Some of the designs of Buchla on the Music Easel are different from the designs that have become standard in analog synthesizers (Jenkins 2007, 119). In order to understand his designs and the logic behind them, it can be useful to define a set of features that are common in analog synthesizers to have a point of comparison.

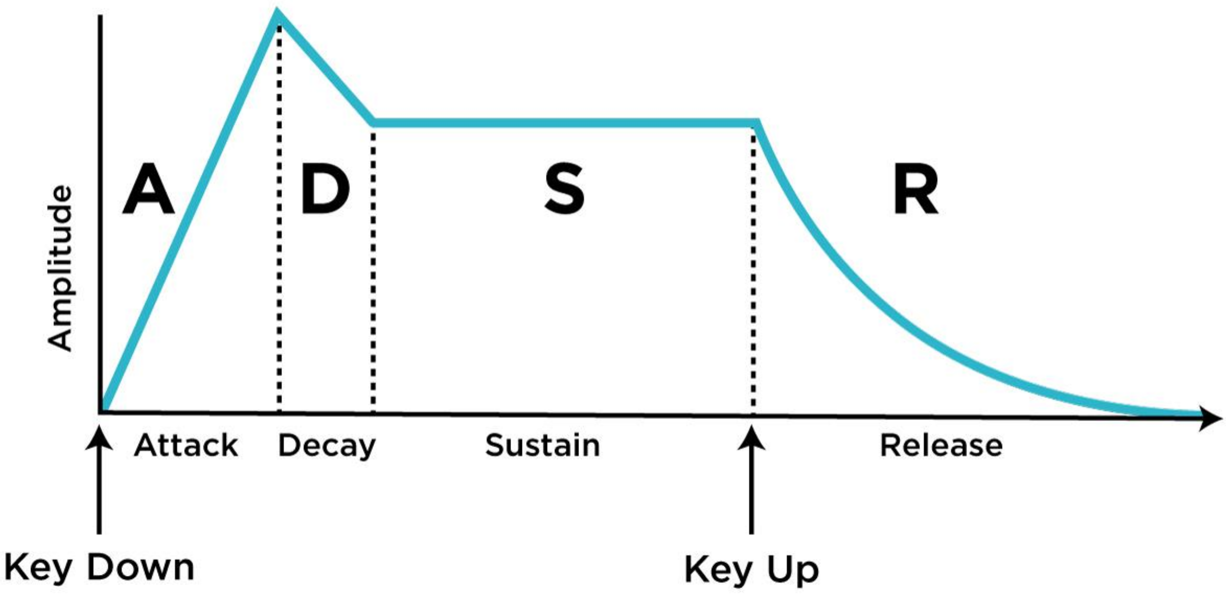
A design that is common in analog synthesizers throughout the industry is often similar to what Bob Moog designed for the Minimoog. It was released in the year 1971, and it was the first synthesizer to be sold in music stores in America (Pinch & Trocco 2004, 8).

PICTURE 4. Minimoog Model D. (Moog)

A common method used in analog synthesis is called Subtractive Synthesis. It is based on the idea that a tonally rich waveform, most typically a square wave or a triangle wave, is created by the oscillator. These waves sound harsh in their raw form, but the filter of the synthesizer is used to subtract the unwanted frequencies from the raw sound, creating the desired tone. (Miller 2007, 250.)

After the filter, the sound is further designed by the Amplifier. The amplifier allows the sound to be played dynamically, so that instead of being at full volume all the time, it can have a fade in and fade out controlled by the user. The fades are controlled by the Envelope, which typically has four stages: Attack, Decay, Sustain and Release. (Cann 2007, 15.)

The Attack defines how long the sound fades in, the Decay defines how long the sound takes to go down to the Sustain level. The Sustain level is the level at which the sound stays as long as the key is pressed. After the key is released, the Release control determines how fast it will drop back to zero volume. (Cann 2007, 15.)



PICTURE 5. ADSR Envelope. (Perfect Circuit)

Buchla's designs differ in some ways from these conventions. His alternative methods are explored in the following chapters.

3.3 Front Panel

While the front panel may look confusing at first, there is a clear logic in how the controls are laid out.

PICTURE 6. The Front Panel of the Music Easel. (Schneidersladen)

The upper half of the front panel is divided into smaller sections, which represent the modules. Each module has a set of controls relevant to the functions it has. (Braakman, Lee & Perrier 2018, 32.)

In the middle, there is a row of sliders. The sliders correspond to the modules on top of them, and are color coded accordingly.

Below the sliders, there is a row of patch points, which are also color coded and relevant to the sliders. Black patch points are inputs and colored ones are outputs. The patch points are used to insert cables to make connections between the modules.

On the lower part, there is the pressure sensitive keyboard and controls for the arpeggiator and other keyboard-related functions.

On the upper left side, there is a dock for inserting custom circuit boards which are used to store patches on the Music Easel.

A good way to understand the logic of the front panel is by looking at it horizontally. The titles on the top indicate the names of the modules, and all of the potentiometers and sliders, as well as patch points, are related to that module. (Braakman, Lee & Perrier 2018, 31.)

Furthermore, the modules can be divided to groups by their functionality. These groups are color coded together.

On the right side from the middle, the modules are related to audio. Here the audio signal is generated by the oscillators, and the modules are focused around the creation of audio signals. These modules include the Complex Oscillator (red) the Modulation Oscillator (blue) and the Lo Pass gate (black).

On the left side from the middle, the modules are related to modulations. The signals generated here are Control Voltages. These signals make no sound of their own. Instead, the signals are used to control other modules. This section also has various sequencing options of the Music Easel. These modules include the Pulser (yellow), the Envelope Generator (orange), the Sequential Voltage Source (blue). (Braakman, Lee & Perrier 2018, 34.)

All of These modules and their inner workings will be studied in the following chapters.

3.3.1 Aspects of the User Interface Design

On a modular synthesizer, the patch cables can physically clutter the interface if the user is creating a complex patch. On the Music Easel, all of the patch points are placed on a single strip under the sliders. This concentrates the cables to one area, which is conveniently under the arms of the user. (Braakman, Lee & Perrier 2018, 5.)

The upper half of the Front Panel, where the sliders, switches and potentiometers are located is completely clear of cables. This makes the Front Panel controls easy to operate even on a complex patch. This aspect of the user interface can be important in a performance situation or another situation where it's important to make changes quickly. (Braakman, Lee & Perrier 2018, 5.)

All of the parameters of the Music Easel are on the front panel, which makes it possible to see the positions of the controls as well as the patch connections. These factors can improve the readability of the user interface.

The Front Panel of the Music Easel is full of bright colors. In addition to giving it a unique look, the color scheme also has a functional purpose in the UI.

The color-coding clarifies which set of functions is controlled by which set of sliders, and the bright colors are easy to distinguish even on a dimly lit environment.

The patch points are also color-coded with the same coloring as the sliders. As the relevant patch points are under the sliders, one can easily see what is being sent where from the colors alone without tracing the cables. (Braakman, Lee & Perrier 2018, 34.)

The sliders which are commonly patched together are located next to each other, allowing the user to connect the adjacent patch points with a small connector instead of a cable, reducing clutter (Braakman, Lee & Perrier 2018, 35).

The interface is using a lot of lights to signal what is happening inside the modules. Some of the lights are blinking to indicate tempo, while others are dimming gradually to indicate modulation depth. The lights are used to indicate values, as the Music Easel has no screen to provide the information to the user.

3.3.2 Physical Interface

The Music Easel as well as Buchla's other synthesizers are physical devices, which give them an element of tactility.

The user can manipulate multiple controls at once or in quick succession, making it possible to perform the changing of sounds in real time.

Buchla's goal was to make the Music Easel an instrument for performance (Strange 2012, 1). He took great care to place the controls in a way that enables the user to reach the most important controls easily in a performance situation (Strange 2012, 16).

For some users, the physicality can also give the user a more personal contact with the instrument, as it occupies a physical space and reacts to the gestures of the user.

The physical control of the oscillators and sound shaping tools can allow the user to essentially play synthesis, eventually being able to express without thinking about the technical process.

3.4 Sound Sources

These modules generate the sound of the Music Easel.

3.4.1 Complex Oscillator

The Complex Oscillator module is the main audio generator of the Music Easel (Braakman, Lee & Perrier 2018, 38). It generates quickly oscillating electronic signals that can be turned to audible soundwaves when amplified.

The frequency of the oscillation determines the pitch of the sound (Klein 1982, 21). The frequency can be controlled by Control Voltages, giving the user the option to control pitches with the Keyboard Module or any other Module capable of generating Control Voltages.

The frequency of the oscillator corresponds to the frequency of the generated soundwave when amplified. For example, the oscillator oscillating at 440 Hz will produce the note of A4. (Klein 1982, 21.)

The frequency can be freely changed directly by a slider on the module, which enables the user to change the frequency to any value between 55 Hz, which corresponds to the note A0 and 1760 Hz, which corresponds to the note A6. This allows the user to tune all the sounds generated by the module to a wide variety of values even outside of the classical tunings. (Strange 2013, 6.)

The Complex Oscillator is capable of producing sine, square and triangle waveforms. These waveforms can be morphed seamlessly from their pure form to a form with a lot of added upper harmonic distortions. (Strange 2013, 8.)

The upper harmonic distortions are distortions in the waveform which are above and harmonically related to the fundamental frequency of the waveform. Adding harmonic distortions change the timbre of the sound without compromising pitch. (White 2010, 21.)

The upper harmonic distortions are generated in a process called wavefolding. A pure waveform is essentially cut when it peaks and is then folded back to itself, creating more and more folds as the process is repeated (Appendix 1). Each new fold adds another layer of harmonic distortions to the sound (Case 2007, 14).

The Timbre control can be used to mix between the pure wave and the wavefolded harmonically rich version of the sound (Strange 2013, 8). This process is basically the opposite of subtractive synthesis where the harmonically rich waveform is generated first and then reduced by filtering.

The Timbre control is also controllable by Control Voltages. This allows the user to create sounds that change timbre over time, similar to what is possible on a digital Wavetable synthesizer.

The waveforms generated by the Complex Oscillator can be modulated by waveforms created on the Modulation Oscillator.

3.4.2 Modulation Oscillator

The Modulation Oscillator has the same basic operating principle as the Complex Oscillator. However, unlike the Complex Oscillator, it has been designed to reach lower frequencies than the Complex Oscillator.

The module has been designed to be able produce signals that, instead of being audible can be used as a source of modulation for other modules of the instrument (Strange 2013, 8).

The module has the option to select between operating at higher frequencies or lower frequencies.

In the higher frequency operation, the module can be used as a sound source like the Complex Oscillator. It produces signals between 55Hz and 1760Hz, which can be made audible by amplification (Strange 2013, 8). When used like this, the instrument will have two audible oscillators that can be controlled together or independently from each other.

This enables the user to create two-part harmonies or octave effects. Furthermore, the output of the Modulation Oscillator is independent from the Complex Oscillator, so both can be routed through separate channels for mixing and effects.

The low frequency mode produces signals between 17Hz and 55Hz. These frequencies are mostly below the audible range, but can be used as Control Voltages for other modules of the instrument. This mode basically transforms the Modulation Oscillator into a powerful Low Frequency Oscillator.

Both modes of operation have all of the waveform options of the Complex Oscillator, as well as the wave folding capabilities.

Using an oscillator to modulate the frequency of another oscillator creates a range of rich timbres that are hard to attain on other synthesizers. This process is called Frequency Modulation (Chowning & Bristow 1986, 56).

However, it is worth noting that this example of Frequency Modulation not the same as the modern digital FM synthesis. While both are based on the same phenomenon, the modern digital FM takes advantage of the extremely high precision, stability and resource effectiveness of digital oscillators and computing, opening a different set of possibilities (Cann 2007, 104).

3.4.3 Preamp

The Music Easel features a preamp module, which enables the user to connect an external microphone to the instrument. The Preamp is then used to amplify the low-level microphone signal to the higher level appropriate for use when routed through the Music Easel.

The Preamp is able to amplify even contact-microphones, which output extremely low-level signals. Unlike regular microphones, which pick up soundwaves from the air, contact-microphones pick up sound vibrations when connected to surfaces. (Holmes 2008, 184.) These specialized microphones are used to record many acoustic instruments, but also used by sound designers and experimental musicians for electro-acoustic sound design.

PICTURE 7. Contact Microphone. (Phase57)

The Preamp provides another sound source to the Music Easel alongside the Oscillators. It is infinitely versatile in the way it can be utilized. Some examples include connecting an acoustic instrument like a cello and using that instead of an oscillator or connecting a contact microphone attached to a vibrating metal surface and using that as a percussion instrument.

3.5 Effects

These modules modify the audio coming from the Sound Sources.

3.5.1 Dual Lo Pass Gate

Lo Pass Gate combines characteristics of a filter and a gate. For clarification of terms, in this case Gate is referring to the audio effect only, not Gate Control Voltages on voltage controlled modular systems. It is also different from the better-known Noise Gate effect with threshold controls used to remove low level signals from sound sources.

The gate examined here is basically a dynamic volume control, similar to a Voltage Controlled Amplifier. It raises and lowers the amplitude of incoming signals according to Control Voltages it receives. It can receive an envelope signal from another module and let sound through corresponding to that. (Strange 2013, 10.)

However, in addition to functioning as a gate, the Dual Lo Pass Gate is also capable of affecting the frequency content of an incoming signal similarly to a low pass filter (Strange 2013, 10). This combination is particularly effective when generating percussive sounds (Appendix 2).

The Lo Pass Gate is based on the use of light resistive materials, through which the signal is routed. Inside the module there is a small light which shuts down when the Gate is opened. (Braakman, Lee & Perrier 2018, 5.) As it shuts, the resistive material lets the signal through. Because of the properties of the material, a fraction of the sound will leak even as the Gate closes, giving the sounds subtle reverb-like tails. (Braakman, Lee & Perrier 2018, 5.)

The Dual Lo Pass Gate has two effect processors, so it can process two signals simultaneously. Both signals can be routed from any sound source on the Music Easel, for example the Complex Oscillator and Modulator Oscillator (Strange 2013, 10).

The typical use of the Lo Pass Gate is routing envelopes to the control inputs, and then using it as an Amplitude Envelope with some characteristics of a Filter Envelope. However, any Control Voltage can be used to open the gate. The gate can also be kept open with no envelopes or triggers.

On the Music Easel, the analog oscillators are constantly oscillating regardless of triggers received. The Lo Pass Gate can be opened, letting a constant sound through. This allows for the creation of long soundscapes which are not limited by note durations or sequencer loop lengths (Appendix 3).

3.5.2 Spring Reverb

The Spring Reverb is a simple analog device. It has metallic springs suspended from two points inside a metallic enclosure. (Case 2007, 297.) The electric signal to be reverberated is run from one end of the springs to the other. The vibration of the springs blurs the definition of the electric signal, creating an effect which resembles a sound reverberating in a large space. (Case 2007, 297.)

PICTURE 8. A Reverberation Tank with Three Springs. (Amplified Parts)

The properties of the reverberations are defined by the number and length of the springs. The First version of the Music Easel had three springs, but a fourth one was added to later versions, making the sound more spacious. (Braakman, Lee & Perrier 2018, 69.)

The Spring Reverb tank, inside of which the springs are suspended, is housed inside the enclosure of the Music Easel.

The sound of the spring reverb is metallic and not natural sounding in comparison to modern digital reverbs (Case 2007, 297).

However, the Spring Reverb has a sound which is pleasant to some people, and imbues the Music Easel with another layer of personality.

3.6 Controllers

These modules make no sound of their own. Instead they generate a wide variety of Control Voltages, which are used to control the other modules. This includes generation of notes as well as modulation of parameters over time.

3.6.1 Envelope Detector

The Envelope Detector is capable of detecting the amplitude of incoming audio signals. It creates Control Voltages with the same amplitude, essentially turning the contours of the audio into a signal which can be used to control modules and sounds inside the Music Easel. (Strange 2013, 40.)

The module can be used with the Preamp module, so that the signals picked up by the Preamp can be run through the Envelope Detector and turned into Control Voltages. The two modules are very close to each other on the front panel of the Music Easel to allow quick and easy access to the functions of both at the same time. (Strange 2013, 40.)

When the functions of the two modules are combined, an external audio signal can be directly transformed into a Control Voltage, which can then be used to control other modules (Strange 2013, 40).

For example, the created Control Voltage can be used to trigger the opening of the Dual Lo Pass Gate, letting sound from the Oscillators through. When used in this way, the Preamp opens up another dynamic way of playing sounds alongside the pressure sensitive keyboard.

Even a field recording or any other non-musical recording can be used to create long organic Control Voltages, which can introduce some organic modulation to the otherwise electronic signals of the instrument.

The use of the Envelope Detector can be run in parallel to the normal operation of the Preamp, so an audio signal can be routed through the effects and mixer of the Music Easel while at the same time be used to create a Control Voltage (Strange 2013, 40). This can provide a way to blend in the natural sounds with the electronic sounds as the electronic soundscape will react to the ebb and flow of the natural one.

3.6.2 Pulser

This module is designed for creating a variety of analog Control Voltages with pulse like qualities (Strange 2013, 34).

It can create either trigger or gate signals. A trigger signal is a very short ramp-like signal with a sharp transient (Braakman, Lee & Perrier 2018, 50). One trigger is only a few milliseconds long. While the triggers can be used to trigger short events such as percussive hits directly, it is generally more useful when used to activate other modules such as the Envelope Generator for more control.

A gate signal is created when the Pulser is triggered from the Keyboard or the Sequential Voltage Source, and the length of the gate signal is determined by the length of the incoming Control Voltage (Braakman, Lee & Perrier 2018, 50). The amplitude of the created gate signal stays high for as long as the signal is received. This makes it suitable for determining the length of notes.

Trigger and gate signals are sent from the Pulsar to activate events on other modules. The controls on the Pulser allow the user to select which of the control sources are received at any one time. These include the Keyboard, the Sequential Voltage Source and the Pulser itself.

When switched to trigger itself, the Pulser is capable of generating a rhythmic evenly pulsating Control Voltage. The interval of the pulses can be set by a slider, which goes from .002 seconds to 10 seconds (Strange 2013, 34). This string of pulses can be used to trigger rhythmic series of events, for example a continuous bass drum pattern.

To avoid monotony, the tempo of the internal pulse can be modulated by Control Voltages from other modules, increasing the scope of rhythmic possibilities beyond even repetitions (Braakman, Lee & Perrier 2018, 50). The rate of the Pulser can for example be modulated by the pressure applied to the Keyboard.

3.6.3 Envelope Generator

When triggered by the Keyboard, the Pulser or the Sequencer, this module creates a signal which resembles a wave, commonly known as an envelope. It is most commonly used to define the change of amplitude of a sound over time. It can also be used to control other aspects of the sound such as timbre or filtering. In fact, the Envelope can be routed to control any parameter of the Music Easel which can be controlled by Control Voltages (Strange 2013, 28).

On many synthesizers, the envelope is divided to four parts, referred to as Attack, Decay, Sustain and Release. These define the overall shape of the signal over time as the note is held.

Attack represents the time it takes for the signal to go from zero to full amplitude. Decay represents the time it takes for the signal to go from full amplitude to the normal level which is defined by the Sustain parameter. That amplitude stays steady until the gate signal from a keyboard or other source is no longer received, at which point the amplitude will return back to zero in time defined by the Release parameter. (Cann 2007, 15.)

There are some key differences in how the Envelope is shaped in comparison to the regular ADSR Envelope described above. There are individual Sliders for Attack, Sustain and Decay, but the Release parameter has been left out. Despite of the similar names, the ASD stages of the Music Easel do not function in the same way as on the ADSR model. (Braakman, Lee & Perrier 2018, 54.)

The Attack defines the time from zero to full amplitude, as expected, but instead of entering the Decay stage, the Envelope goes directly to the Sustain stage. After the gate is released, the Envelope enters the Decay stage, in which it returns to zero according to the Decay parameter. In this case the Decay functions in place of Release. (Strange 2013, 28.)

3.6.4 Sequential Voltage Source

This module is a sequencer which can be used to create sequences with the length of three, four or five steps (Braakman, Lee & Perrier 2018, 58).

An analog sequencer is a device which will advance through steps one by one when it receives a trigger from another module (Klein 1982, 64). When activated, each step sends out a Control Voltage which can be set for each step individually with a dedicated slider. These signals can be routed to any destination which can receive Control Voltages (Braakman, Lee & Perrier 2018, 58).

It is worth noting that the Sequential Voltage Source has not been designed only or primarily to create melodic lines. It can be very useful in any situation where series of varying voltages are required.

The sequencer can be used to create complex rhythmical patterns when used in combination with the Pulser. For example, the Pulser can trigger the advancement of the sequencer steps, while the values of the steps can simultaneously change the interval of the triggers sent by the Pulser.

3.6.5 Random Voltage Generator

Designed for creating an output of random voltages. Randomized elements are common in West Coast sound design (Braakman, Lee & Perrier 2018, 61), and make it possible to create evolving sounds with chaotic but controllable elements (Appendix 4).

The range of the randomization can be controlled by the user. On lower settings, the signal will be only slightly altered, staying close to the signal that was sent to the module. On higher settings, the signal will be totally different. (Strange 2013, 40.)

The module generates new random values every time it receives a trigger. That values remains unchanged until a new trigger is received, at which point a new value is generated.

Each time a trigger is received, the Random Voltage Generator outputs four individual random values simultaneously. Essentially the module multiplies the incoming signal by four, but each copy is randomized unrelated to each other. However, all of the signals are randomized by the same amount, and on lower settings will stay relatively close to the original value. (Strange 2013, 40.)

As an instrument designer, Buchla was fond of randomness, and the amount of dedicated outputs for the randomized signals demonstrates how important he found them to be (Braakman, Lee & Perrier 2018, 61).

3.6.6 Pressure Sensitive Keyboard

The Model 218 keyboard of the Music Easel is not a keyboard in the common sense. It does not have similar keys to a piano. Instead it features a pressure sensitive metal plate which has been divided into parts which represent the black and white keys of the keyboard, but which do not recess when pressed. The keypresses are detected by the components inside the keyboard and turned into Control Voltages. (Strange 2013, 18.)

PICTURE 9. Model 218 Pressure Sensitive Keyboard. (Schneidersladen)

The keyboard has 29 keys and the signals created by it can be sent to control other modules. To play the key, the Control Voltages can be routed to control the pitch and frequency of the Complex Oscillator and the Modulation Oscillator.

By default, the keyboard sends pitches to the Oscillators which are equally tempered to emulate the piano, and to enable the playing of music from notation. The tuning of the keys can be changed to suit other tunings, and this enables the instrument to be used on a wide variety of musical situations. (Strange 2013, 18.)

3.6.7 Preset Voltage Sources

There is a section on the pressure sensitive surface of the keyboard which does not have any keys in it. Instead it has four pressure sensitive plates, that output Control Voltages based on the force at which they are pressed. The plates can output a continuous signal, and the force applied can be changed over time. (Strange 2013, 22.) The plates have individual Control Voltage outputs on the panel of the instrument, which can be routed to control other modules.

The plates are capable of reaching the full range of control voltages, and all of the plates function completely independent of the keyboard (Braakman, Lee & Perrier 2018, 68).

The Preset Voltage Sources can alternatively be used as transpose controls. In this mode, each of the four plates represent an octave, and when touched instantly transpose the keyboard to their respective octave. It is worth noting that the transposition is not only limited to full octaves, it can also be set to transpose the keyboard to another user definable scale. (Strange 2013, 22).

3.6.8 Arpeggiator

When the Arpeggiator is activated, any notes held on the keyboard will be automatically played in an ascending or random order. The pattern of the arpeggio can be selected by a switch on the front panel. (Jenkins 2007, 40.)

The rate of the playing can be adjusted on the panel as well, and it can go from 50 cycles per minute up to 500 cycles per minute. The rate at which the arpeggio is cycling can be controlled by Control Voltages from other modules. (Braakman, Lee & Perrier 2018, 67.)

The arpeggio will keep cycling between the notes held in the selected pattern and rate until the keys are released (Jenkins 2007, 40).

It might seem strange that an advanced instrument like the Music Easel only features two arpeggiator patterns, but there is a reason for it. The output of the Arpeggiator can be run through other modules to modify the pattern in many ways before being routed to the Oscillators. It can, for example, be run through the Inverter module to turn the ascending pattern into a descending one.

Furthermore, the pattern can be run through any number of modules to modify the pattern even further. The Arpeggiator module itself can also receive Control Voltages at the same time, changing the settings in real time as the pattern is playing. The seeming limitation of the pattern options is just a starting point from which the actual pattern can be built.

3.6.9 Inverter

The Inverter is a module that is seemingly simple, but closer inspection of the possibilities reveals a deeper module than meets the eye.

It turns signals it receives upside down. The resulting signal which is output from the module is essentially a mirror image of the sound coming in. The inversion can be applied to any signal (Strange 2013, 32).

One example of the possibilities is taking a melodic sequence and multiplying the signal in two using the Banana Chords of the Music Easel. Now one of the two signals can be routed directly to the outputs while the other can be routed through the Inverter before going to the Outputs. The inverted signal will then become the mirror image of the original melody, creating a basic counterpoint to it.

3.7 Other

These modules enhance the workflow of the Music Easel.

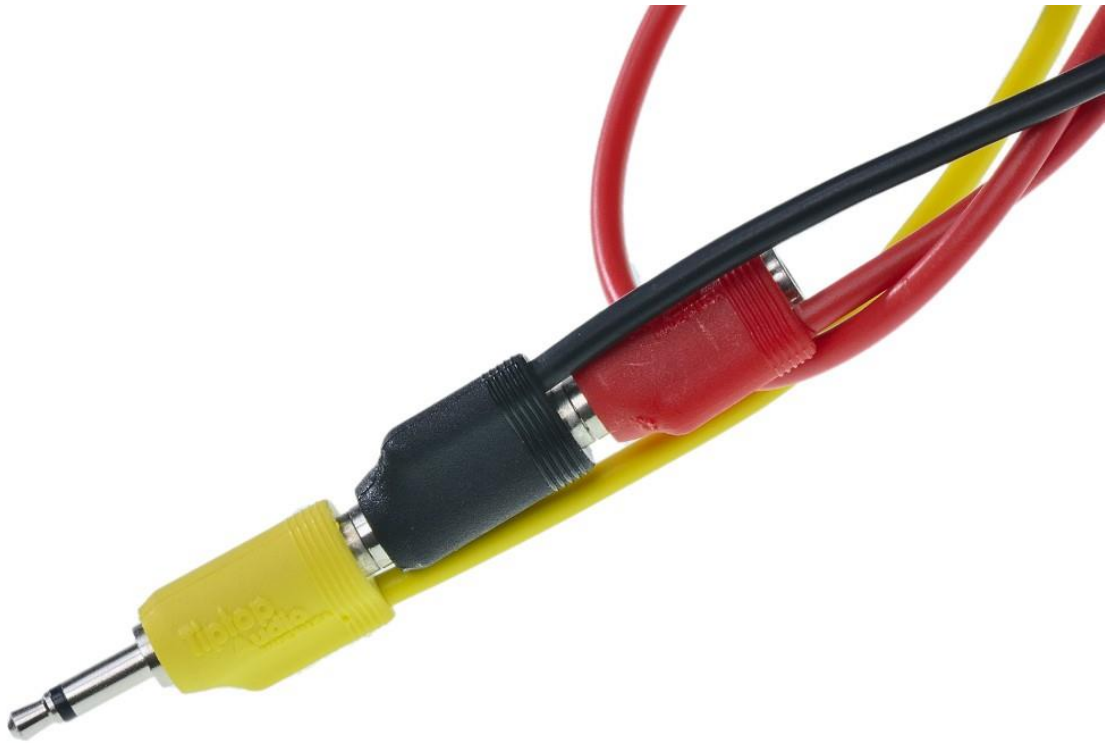
3.7.1 Patch Points

On the Music Easel, patch chords are used to route signals between the modules. The jacks in which the patch chords are plugged are called patch points. Most of these patch points are located on the strip below the sliders. This strip is called the Patch Field.

Having most of the patch points in the same place keeps the front panel tidy and provides the best access to all of the controls even when many patch cables are connected. (Braakman, Lee & Perrier 2018, 67.)

The patch cables used to connect modules are electrical wires which open and close the connections between the circuits inside the modules when connected (Jenkins 2007, 16). On the Music Easel, most of the patch points need to be manually connected by the user and only a few of the most common connections are made inside the instrument.

The patch cables used on the Music Easel have additional plugs on each end, allowing the cables to be stacked on top of each other, to be able to connect multiple cables to one patch point.



PICTURE 10. Stackable Patch Cables. (Tiptop Audio)

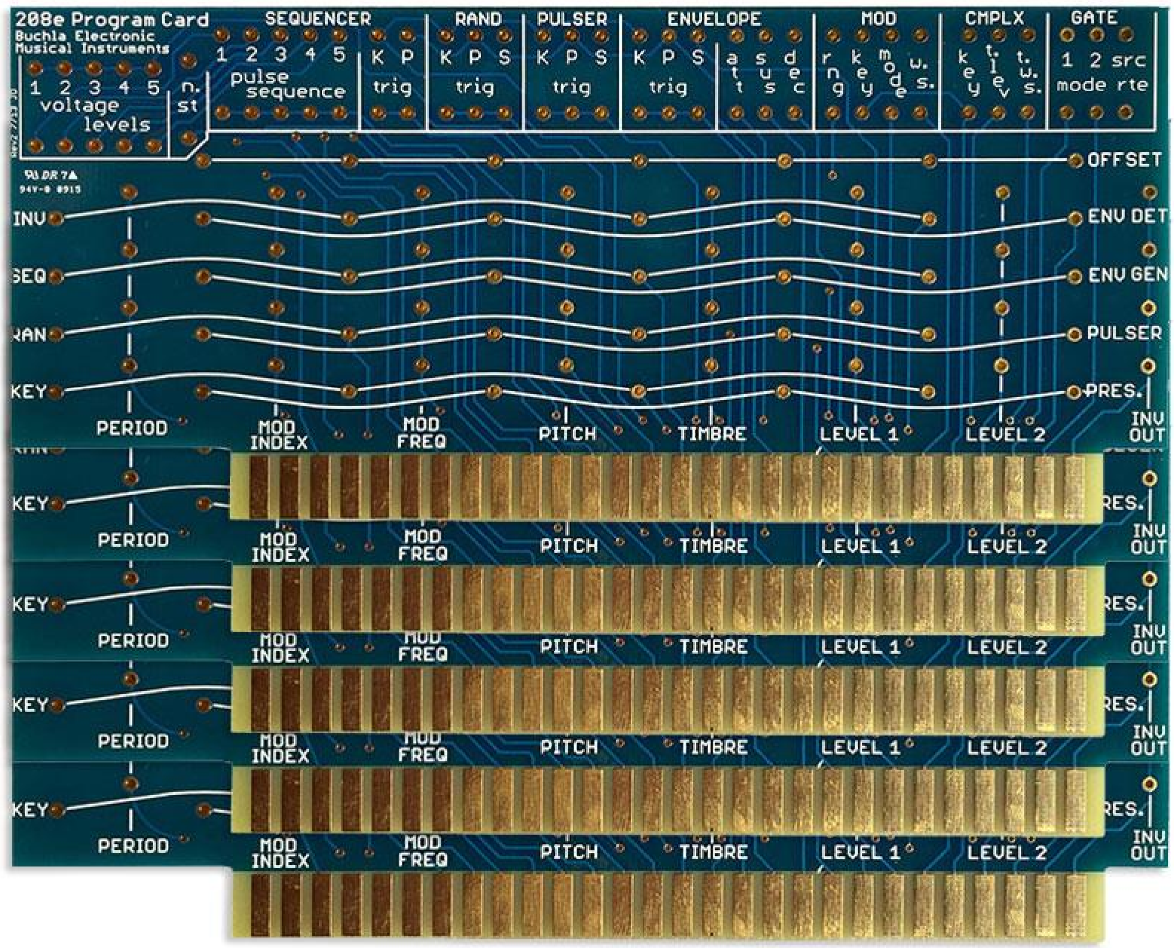
The Patch Points are color coded to make connections easier. Black Patch Points are inputs, which means that they receive signals from other modules. All the colored patch points are outputs. The color corresponds to the section of the Front panel from which the signal is coming from. (Braakman, Lee & Perrier 2018, 34.)

3.7.2 Stored Program Sound Source

When the Music Easel was created, it was common for synthesizers to not have a patch memory. A patch refers to all the settings of a given sound. A patch memory is the capability of storing and recalling these settings at will. This allows the user to save particularly good sounds for later use or for further refining at a later stage.

On synthesizers without patch memories, the only way for the user to recall sounds was to take notes of the knob and switch positions, and then manually dialing back the same settings as required. On a complex instrument like the Music Easel, it would be practically impossible to be able to get back to the same exact sound as before, because there is so many variables in the patches.

Buchla innovated on patch memory technology when synthesizer technology was still in early stages of development, and digital technology was not yet commonly used. The Music Easel stores patches on physical circuit boards, which are inserted to a dock on the front panel. (Strange 2013, 2.)



PICTURE 11. Stored Program Card. (Buchla Musical Instruments)

On the circuit boards, there are labeled solder points for all the patch points, which can then be connected to each other to represent a patch. When inserted to the dock, these points are connected without patch cords. (Strange 2013, 2.)

Each circuit board can contain one patch at a time, and the amount of patches a user can store is limited to the number of circuit boards they have. This system is severely limited compared to modern synthesizers, but at the time of release it was very advanced, and allowed the user to quickly recall incredibly complex patches. (Strange 2013, 50.)

Later an alternative type of patch board was developed which contains digital technology and can be inserted to the same slot as the circuit boards. It allows the storage of multiple patches and takes the patch system of the Music Easel a step closer to modern systems.

4 EMULATING THE SOUND

One of the objectives of this work is to explore the feasibility of emulating the sound of Buchla's synthesizers on other platforms. The Music Easel is still in production, but it is a premium instrument made by a small business without extensive production facilities. That makes the instrument expensive, even though it is the most affordable of all of the instruments made by Buchla.

As a pioneering designer, Buchla aimed to create instruments that best achieved the potential of his vision for the synthesizer. He was not concerned about reducing the amount or quality of components to make the instruments more affordable. (Pinch & Trocco 2004, 50.)

In the 1960's, synthesizers were so new that they were not yet sold in music stores, and the synthesizers of the time were still often custom made for a customer or academic institution.

Even though the high price of the Buchla instruments might be justified, it still places the Music Easel and other Buchla instruments out of reach of many musicians and studios, even if they would be interested in the approach and sound of Buchla.

Fortunately, in today's market there are many developers of hardware and software that have set out to emulate the sound, or have taken inspiration from the designs of Buchla to produce new instruments with similar principles and sonic capabilities.

4.1 Hardware Emulation

Hardware synthesizers are physical devices dedicated to the production of electronic sound. Hardware synthesizers can be either analog or digital, or hybrid of both.

While direct emulations in the hardware domain are not available, as Buchla instruments are still in production, there are several companies making instruments which have many of the same features, making achieving the West Coast sound possible.

In some cases, these companies have taken Buchla's approach, and developed it even further, aided with new technologies.

Many of these companies are producing hardware in the Eurorack modular format.

Make Noise is a company that is creating modules with the West Coast sound. In addition to their Eurorack-units, they have created a portable analog synthesizer called the 0-coast, which has a Complex Oscillator and is capable of creating West Coast sounds on a budget.

PICTURE 12. Makenoise 0-Coast Synthesizer. (Makenoise)

Another option is Volca Modular by Korg. It is an analog semi-modular system in the size of a VHS-tape. It contains all the essential elements for creating West

Coast sounds at a lower price point than most other options. The unit is also battery powered and small, which make it very portable.

An effective option in the hardware domain is to start building a custom Eurorack case based around the modules of the Music Easel. In the Eurorack market there are many manufacturers who are developing high quality West Coast modules.

This approach has the benefit of allowing the user to decide each module individually to suit their needs. After completing a West Coast voice, the user can also keep expanding the custom modular system further, increasing the sonic capabilities.

4.1.1 Advantages and Disadvantages

Hardware devices have the advantage of being physical, giving the user tactile feedback.

Buchla designed hardware devices, and his designs were made with the tactility in mind. The sliders, switches and dials have been placed in specific ways to guide the user, and to provide instant access to the most important functions.

When compared to software emulations, hardware has the drawback of being significantly more expensive. The cost of parts needed to produce the units and the need to ship them to the customers make them more expensive, while software can be infinitely replicated and sold online.

The modern digital microprocessors are small and affordable, and they have made it possible to incorporate many features at lower costs that would have been significantly more expensive when made completely in the analog domain (Klein 1982, 7).

The prices of new analog components have become cheaper, as production lines and technology have become more effective. Some of the new components available are also more versatile than the older ones, providing more possibilities (Klein 1982, 7).

The new developers are able to base some of their research into the designs and experiments of Buchla and other pioneers, and that also lowers the costs of production of new instruments.

These factors have made it possible to create instruments that have similar features to the Music Easel at lower costs.

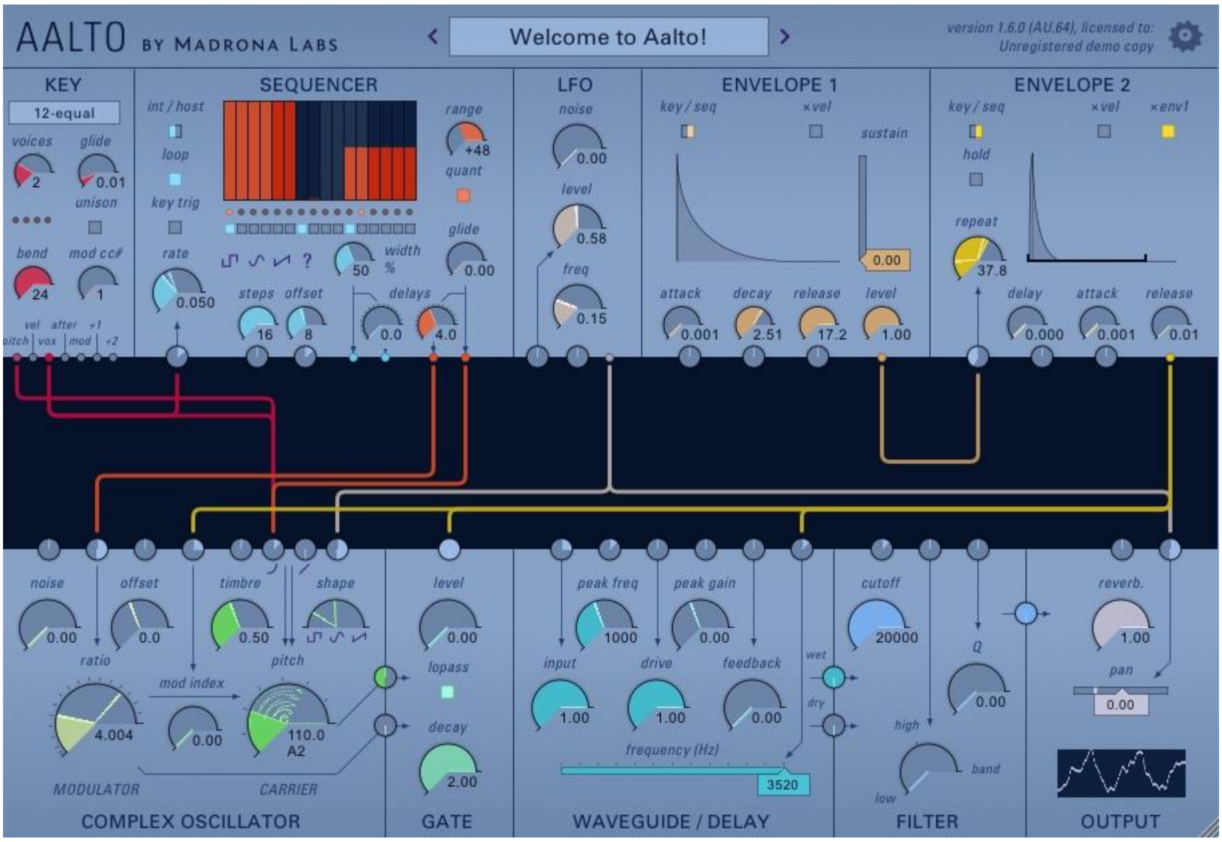
4.2 Software Emulation

In the software domain, several virtual instruments (VST) have been created which either emulate the Music Easel or follow the same principles.

The virtual instruments are plug-ins that need to be opened inside a host audio program (Digital Audio Workstation).

The Arturia V Buchla Music Easel is a licensed direct emulation of the Music Easel. The software interface it has is similar to that of the front panel of the Music Easel. All of the names of the modules and their functions are closely replicated on the emulation.

The Madrona Labs Aalto is a virtual instrument inspired by the Music Easel, but not a direct emulation. However, it features a Complex Oscillator, Lo Pass Filter and other essential features for achieving the West Coast sound. The code of the oscillators and filters have been written in a way that introduces random imperfections to their sound, emulating the behavior of analog circuits.



PICTURE 13. Madrona Labs Aalto VST. (Madrona Labs)

4.2.1 Advantages and Disadvantages

Working in the digital domain provides some significant benefits for the user, but has drawbacks as well.

One of the biggest benefits is polyphony. The original Music Easel is not polyphonic, and producing a polyphonic version of it would be expensive due to the price of the analog components.

In the digital domain, increasing polyphony multiplies the processing power required to run the virtual instrument. However, modern computers have so much processing power that doing so is not a problem for most systems. In the digital domain, the price of components is not a factor.

For this reason, many emulations include the option to turn on polyphony as required. This allows the musician to play chords on the instrument. For the most accurate emulation of the original instrument it is not recommended, but as an option it can be very useful.

Another benefit is the ability to have multiple instances of the virtual instrument open at the same time. This way multiple different parts can be played simultaneously. While one Music Easel is capable of creating a complete soundscape, having multiple instances as an option can prove to be valuable as well.

Having the virtual instrument inside the Digital Audio Workstation provides additional benefits. It can be made to follow the host tempo, and parameters of the instrument can be automated inside the host program for accurate control over time.

The host program can also store and instantly recall all notes and settings of the virtual instrument inside a project. This can make it more practical to incorporate the sound of the Music Easel into an extended project with other audio elements and instruments as well.

A major drawback is the lack of physicality of the virtual instruments. The user has to use a mouse to change the controls, giving access to only one parameter at a time.

There is also no possibility of intentional misuse of the instrument for experimental sound creation. On the physical unit, this could mean plugging patch cables half-way or shaking the unit to resonate the springs of the reverb tank.

It is possible to map some of the controls to a physical controller to get access to more parameters, but the user has to come up with the control scheme and user interface themselves.

4.3 Approximating the West Coast Sound on Other Systems

The hardware and software designed to emulate the sound of Buchla instruments often have modules and functions specific for achieving the West Coast sound. These include Complex Oscillators with wavefolding, Lo Pass filters for shaping the sound and various sequencers or arpeggiators with capabilities for creating generative sequences.

If no emulator is available, or if the user prefers to work on another synthesizer, it is important to understand the inner workings of the Bucha instruments in detail to be able to approximate the sounds as well as possible.

Importantly, the system has to be flexible enough to make the approximation possible. It is probably best to work with a professional virtual instrument designed for complex sound design tasks.

To approximate the sound of a complex oscillator, an oscillator pair of a frequency modulation synthesizer can approximate the basic operation of a complex oscillator.

In this case the oscillator pair is programmed so that the frequency of the second oscillator will modulate the frequency of the first oscillator. Any additional oscillator pairs can be turned off. This can yield sonic results that resemble the sound of a complex oscillator.

Additionally, a low frequency oscillator can be set to add a subtle modulation to the oscillator frequencies, to approximate the slight tune drift characteristic of analog oscillators. This can add an organic element to the sound, which is important in Buchla instruments.

Alternatively, a wavetable synthesizer with custom user wavetables can be used to approximate the sound of a complex oscillator. In this case the wavetable is made from a recording of a real complex oscillator.

The filter should be set up in a way that filters less frequencies the higher the amplitude of the incoming sound is, to approximate the very basic sound of the lo pass filter.

It is also important to have access to a flexible sequencer, preferably in combination with a full-featured arpeggiator. On Buchla systems, a lot of randomization is used in the sequencing (Braakman, Lee & Perrier 2018, 61). On the sequencer used, all of the randomization options should be explored to find the correct settings for achieving generative soundscapes.

On the keyboard, aftertouch and modulation wheel should be assigned to parameters of the synthesizer to approximate the capabilities of the touch keyboard. If the user has access to a MIDI-controller with encoders or faders, these should be mapped to parameters on the synthesizer, to have as much tactile control as possible.

While these methods will probably not sound good enough on their own, they might provide a good first step in achieving a good approximation. However, it is best to use an emulation or a Buchla inspired West Coast synthesizer system whenever possible, as the inner workings of these systems are very intricate and hard to recreate.

5 DISCUSSION

The West Coast approach to synthesis is not based on a single principle or technical function. Each individual module on a West Coast synthesizer, as well as the user interface, plays an important role in creating the end result.

The modules that have a major impact, as well as designs most different from other synthesizers, are the Complex Oscillator and the Lo Pass Gate. These modules have unique functionality, which is instrumental in creating the West Coast sound, and are particularly hard to recreate on other systems.

The West Coast approach is not limited to audio elements, but also includes the interaction between the user and the synthesizer. The elements of the interface are designed to allow sound creation in a physical way, with intuitive hands on control of the synthesis process.

The use of a pressure sensitive keyboard instead of a traditional piano keyboard is an important aspect of the West Coast approach, and one of the defining design decisions of Don Buchla.

An important element of the West Coast approach is the use of sequencing. The West Coast sequencing options make extensive use of randomization, both in the notation, as well as on the sound synthesis process.

Other than Buchla designed systems with the West Coast approach exist in both hardware and software domains. These systems feature the Complex Oscillator, the Lo Pass Filter and other West Coast modules, as well as design considerations that allow the user to work with the West Coast approach.

For the best results, it is recommended to use these West Coast specific options whenever possible. While recreating the West Coast sound is possible to some extent on other systems, it is difficult to approximate all of the intricacies of the West Coast modules without extensive knowledge and effort.

For the most authentic results in the software domain, Arturia offers a licensed high-quality emulation of the Music Easel. When using software, it is important to consider the physical aspect that is by default lacking on virtual solutions. It is possible and recommended to use MIDI-controllers to map parameters of the software to add an element of tactility to the synthesis process.

In the hardware domain, a custom Eurorack system is the logical choice, as there are many manufacturers who are offering high-quality West Coast modules. An efficient approach to building a complete West Coast voice is to acquire a similar set of modules than that on the Music Easel.

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APPENDICES

Appendix 1. Complex Oscillator Wavefolding

Audio File:

https://soundcloud.com/hnielsen/complex-oscillator-wavefolding/s-LCWTs

Appendix 2. Percussion Sounds

Audio File:

https://soundcloud.com/hnielsen/percussion-sounds/s-CFkcA

Appendix 3. Ambiences

Audio File:

https://soundcloud.com/hnielsen/ambences/s-1rBn9

Appendix 4. Randomized Sequences and Modulations

Audio File:

https://soundcloud.com/hnielsen/randomized-sequences-and/s-q5Bd0