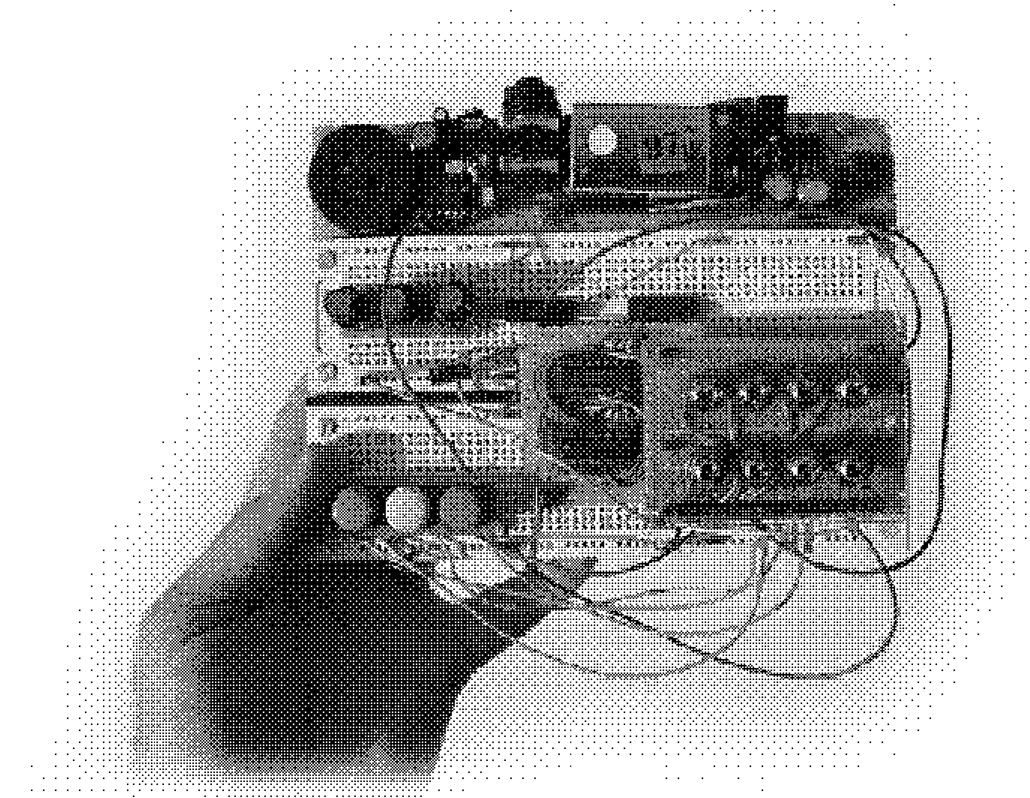
COLLABORATING WITH circuits

music, invention and electricity



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Abstract

This paper is an investigation of the nature of my personal arts practice and how it is impacted by the phenomena of electron flow, ie. using the medium of electricity. A number of work samples will be used to illustrate how the concepts of musical experience I am exploring through my practice manifest themselves in the real world.

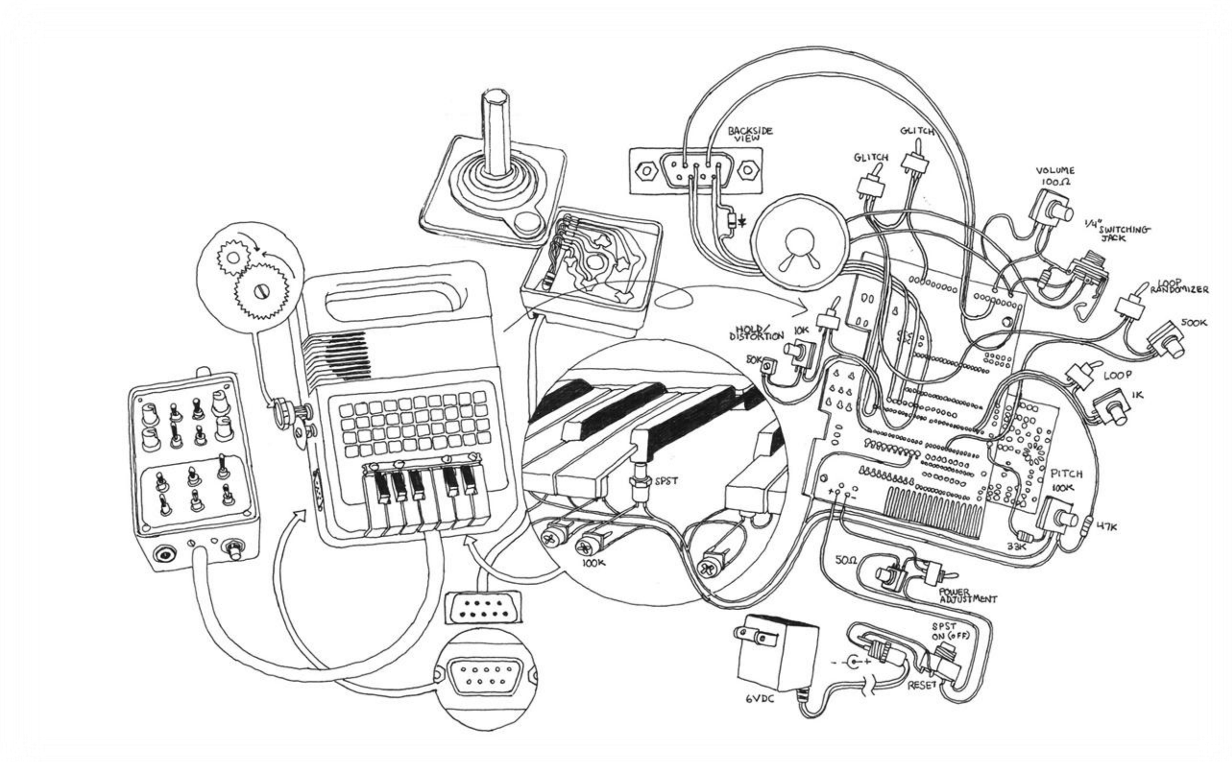

Figure 1. How to turn a Texas Instruments Speak&Spell into a musical instrument. Edwards, 2010.

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Figure 2. My studio. Troy, New York. 2010.

INTRODUCTION

In this paper, several methodologies of creating music will be discussed that challenge its definition. This investigation centers around the behavior of electricity and man's inexplicable compulsion to invent and explore. I will be using the analog modular synthesizer as a reference point throughout.

This is important because:

-As an object, the modular synthesizer is both a physical musical instrument and a tool for exploring sonic behaviors and patterns.

-As a concept it represents the idea of experimental potential which in itself accounts for much of its appeal. These aspects of the modular synthesizer will lead to discussions of form, concept and experience relative to the greater topics of invention and experience.

Consequently, the concept of collaboration will be considered by how this idea can be applied to man's engagement with the phenomena of electron flow.

0.1 Personal Context

Before I address the above stated topics I will first give a personal context for my investigation. I do not consider this material to stand on its own. It is only with a defined context that the value of my investigation can be assessed. In order to establish this I will consider broad topics relative to my intentions followed by more specific contexts relative to the techniques of implementing these intentions.

Figure 3. Performance. Poortgebouw, Rotterdam. 2014

Writing this paper is closely linked to my intention in enrolling in graduate school. It is an exploration in identifying a deeper resounding theme in my work. By identifying this theme I am able to assess impulses and influences which are relevant to my own artistic curiosities. For me, a crucial aspect to making good artwork requires identifying man's sincere intentions and producing honest expressions of that sincerity.

While this research deals heavily with scientific principles and processes, it is not my purpose to advance these fields. I wish to actively use artistic liberties inspired by engineering, physics and philosophy.

0.2 Universal vs. personal truth

Over the past decade I have researched scientific principles, such as the theory of electron flow, alongside a wholly idiosyncratic arts practice. The contrast of these two processes has allowed for a better understanding of the relationship between universal and personal truths while helping me to develop the ability to differentiate between the two.

For example:

-Universal truths are opinions, feelings, and realities shared by the majority of humans. At their extremes, these truths are closely linked to scientific laws and are dictated by our shared biological evolution.

-Personal truths are feelings which may be entirely unique to a singular person. These truths are the product of universal truths combined with our complex personal history.

Naturally these truths intersect, and it is at these points common or local truths begin to form. These are shared among smaller communities and subcultures. I often consider this when performing and try to be mindful of the desires and expectations of my audience relative to their age and gender, coinciding with the spatial awareness of the event and venue of performance.

The search for universal truth

The kind of art that I strive to create and wish to see from others is that which displays the artists sophisticated awareness and respect for universal and personal truths simultaneously. Perhaps it could be said that creative whims are directly connected to an elusive *universal* truth. This truth could be of a scientific or spiritual nature. If this truth can be determined, then one can begin to assess the overall value of the artistic work in exploring it.

However, the origin of *personal* truths can remain hopelessly complex. I began my time at The Institute of Sonology with the belief that learning more about the science behind my interest in music and electricity would shed some light on my desire to uncover more about it. Through the process of admitting the arbitrary nature of many of my personal truths, I have also come to value them for their inexplicable uniqueness. *Personal truth* is a necessary component of what I consider to be important artwork. Artwork is not simply a representation of what we all find appealing. The assertion of personal truth is a necessary component and is at times the only thing distinguishing it as art. For example, photos of space taken by the Hubble telescope may be considered beautiful but they are not art. Van Gogh's painting "starry night" on the other hand is. There is a common truth that the Hubble photos appeal to. We are naturally intrigued by simple patterns which clearly represent vast, complex realities. There is no human expression present therefore, it is not art. Van Gogh appeals to the same truths but includes personal truth as well. We consider the heavens alongside our human desires through his work. *We trust the artist to show us a new form of desire worthy of our consideration.*

0.3 Defining artistic terms

It is not my intention to challenge the readers personal definition of art. Art is naturally a wildly complex topic and one with as many definitions as there are people inclined to give them. My goal is rather to clarify that I have established terms according to my own artistic practice in order to gain a deeper understanding of music and visual art making. The following terms are subjective and debatable but will serve as a framework for this paper.

Art
Including any medium from painting, music, performance, fashion to poetry, etc.

Skill
The extent to which an individual understands and is able to embody universal truths in their work.

Talent
The ability to embody universal truth *as well as* personal truth. With adequate **talent** the artist is able to contrast personal and universal truths in a way that inspires an introspective consideration of these topics in the mind of the viewer. This results in both feelings of comfort and discomfort as we are reassured by what we already know and challenged by what we don’t.

Quality or **integrity**
The degree to which the above is achieved.

Value
An entirely different topic which has to do with the context of an artwork which may give momentum and impact to that work despite the intentions of the artist. A primary as well as a secondary outcome.

Valuation
This on the other hand does not require inspiration which leads to a problematic scenario when value is mistaken for quality and novelty for sincerity.

Sincerity
Absolute acceptance and respect for ones’ own potentially arbitrary personal truths.

Inspiration
The artists compulsion to express sincerity. Not all inspiration leads to good art but all good art must be inspired and therefore must be sincere.

Electron Flow/Electricity
The flow of electrons is an organic process with as much potential for engagement and inspiration as paint, wood, stone or any other traditional medium of artistic expression.

0.4 Ohms Law

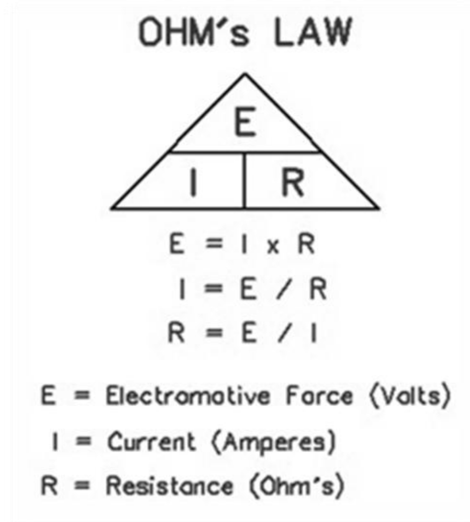

Figure 4. OHM's law triangle illustrates the relationship between voltage, resistance and current.

After continually searching for a universal truth or principle to help define and guide my work, I have settled on a set of mathematical equations called **OHMs** law. It allows me to analyze my process in a manner that renders some valuable results. In terms of artistic practice it represents a method for considering and critiquing my methodology.

Ohms law is a set of equations published in 1835 by German physicist Georg Ohm in his book Die galvanische Kette, mathematisch bearbeitet (tr., The Galvanic Circuit Investigated Mathematically). These equations describe a relationship between three numerical abstractions of force, mass and time relative to the flow of electric charge. These abstractions are called voltage, resistance and current.

1. Voltage is a measure of the **force** driving the flow of electricity.

2. Resistance is a measurement of the degree to which the **mass** that electricity flows through will engage with and impede that flow.

3. Current is a measured amount of charge flow over a given period of **time**.

The relationship between these three factors can be used to understand, describe, and control electricity. Through this process we have found countless ways to use electricity to perform valuable work.

Relative to this paper, there are two primary concepts to use from **OHM**s law.

1. OHMs law presents a method of understanding three dimensional reality (in this case electrical charge flow) using force, mass and time.

2. OHMs law states that these factors are inherently linked. The values of each are meaningless without all three. In essence, they must be considered as a whole.

OHMs law and art

Mathematical abstraction of the physics of electricity gives us a method for talking about discrete variables of the field. Ohms law gives us a method of looking at the interrelatedness of these variables. By drawing *parallels* between art and electricity, I have gained a better understanding of my creative process by borrowing the *objective* approach one takes to designing electronics and applying it to the *subjective* approach of making art.

The study of electricity has introduced me to utilizing a formalized method of problem solving:

1. Identifying a goal
2. Proposing a form of work which will achieve this goal
3. Establishing an energy source to drive that work

This is the most rudimentary way of analyzing a system and is one I find refreshing in the realm of making art. In order to control the energy source it is necessary to analyze force, mass and time relative to that source. This translates into an analysis of how much **energy** passes through a **physical form** in a given period of **time** as a result of the **force** driving that energy.

The energy which drives my art emerges from the contrast of universal and sincere personal truths as previously defined. I consider the force of that energy in terms of what it will physically pass through (eg. a synthesizer) and how that engagement will be experienced over time. The *force* of this energy is my inspired *concept*, the mass that this force will activate is my *medium* which will then be experienced over time by others as they listen to my music or view my visual works. My most basic goal here is to both comfort and challenge myself as well as others.

0.5 Framework

The format of this paper is informed by the method explained above and is therefore broken up into four sections, helping to identify the systems which make up my exploration into musical experience.

The first three chapters will address mass, force and time relative to my artistic practice. I have called these **form**, **concept**, and **experience** respectively. The chapters will be anchored in personal work examples. The final chapter will discuss a topic through using the topics of the previous three.

Since the topics of music and collaboration with electronics will be considered through real applications it is therefore impossible to neglect the other two factors in the process:

1. The form factors of the modular synthesizer cannot be discussed without also considering the concepts that impact that form.

2. The relationships from concept to experience can be seen within and across each chapter and work example. In this way I consider each of the following chapters to be fractalized models.

The context for my investigation and especially the work examples given are informed by personal preference. To some extent it is my intention to consider the topics in a broad and unbiased way, but ultimately these topics will be made real by applying them to work driven by personal preference/style. Therefore, it is as much of a description of myself as it is a description of the musical process.

CHAPTER 1: OBJECT
THE MODULAR SYNTHESIZER

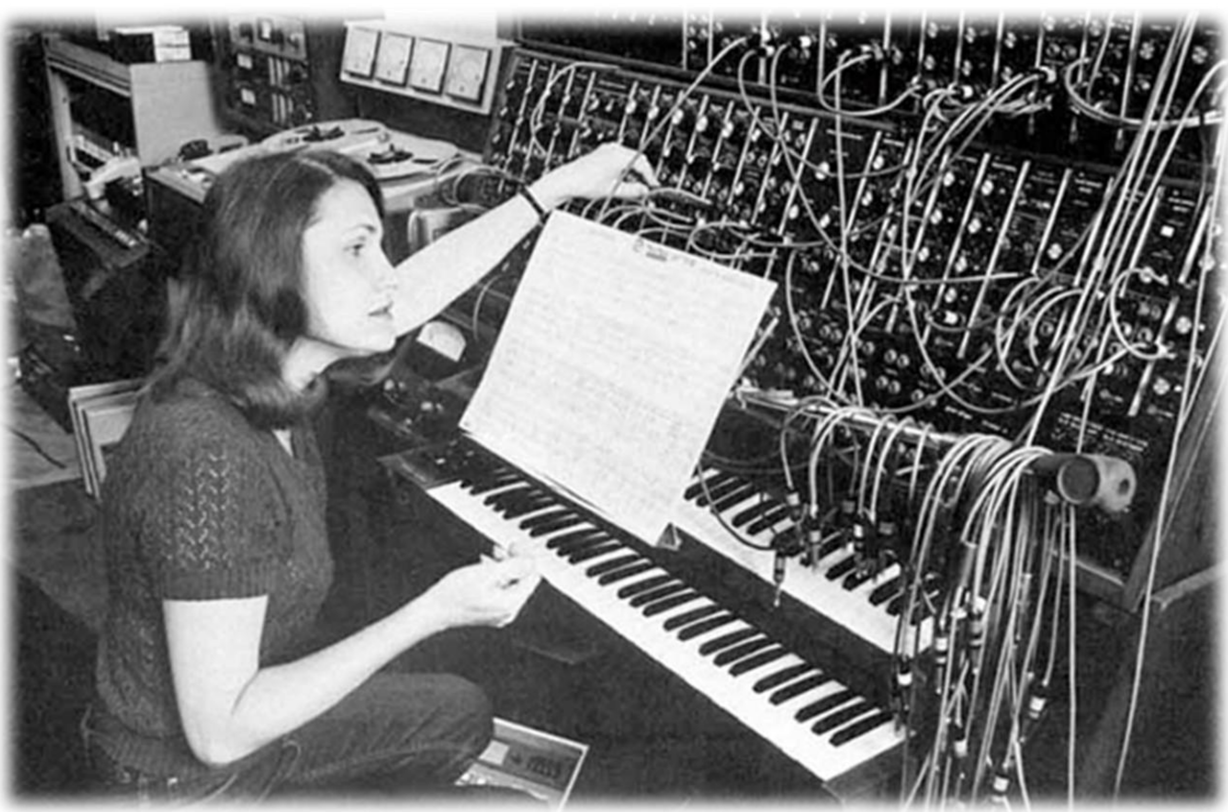

Figure 5. Wendy Carlos studying the soundtrack for Tron at her custom Moog modular synthesizer

1.1 Intro

Figure 6. Compumedic Sciences, Inc Model 6F13 analog computer. Developed for naval training exercises

The Modular synthesizer is a family of musical instruments characterized by the use of patch cables and rotary knobs to manipulate its behavior. To many observers it resembles something closer to a piece of scientific test equipment than a musical instrument. The first modular synthesizers were in fact adapted from analog computers such as the EC-1 designed by American educational electronics company HeathKit in 1960 or the CSI Model 6F13 developed a few years later. The primary difference between the modular synthesizer and the test equipment it is related to is the scale of operation. Different applications call for different levels of accuracy, range and controllability. Test equipment requires most of all accuracy and for the most part a wide frequency range of millions of hertz (cycles per second). Musical instruments call for subtle and flexible controllability.

Figure 7. Test oscillator vs. musical oscillator. The test oscillator (left) is designed for precision and range. Exact values are entered by pushbutton and read on a screen. The musical oscillator (right) allows expressive but relatively imprecise control through rotary controls. Multiple in/out jacks are available for sending signals and receiving modulating voltage signals.

Beside differences of scale these machines are actually very similar. One could view the modular synth as a form of lab equipment suitable for scientific research but calibrated to function within a musical range and context. Making this similarity clear highlights the strength of the modular synth as a tool for discovery and research but also allows it to be applied to subjective musical experience. This tool gives us the ability to create theories and build up complex systems to test these theories, but in the end the greatest importance lies in whether or not it sounds ‘good’, which of course is a personal assertion. That means an output of the system with appealing musical value retains that value even if the user is unable to understand and reproduce that output in a scientifically systematic way.

1.2 Excitation

All musical instruments can be considered as a pairing of exciters and resonators. If we consider the piano as an example it is easy to see that striking the string excites it into resonance. The strings are the resonators, the striking of the strings is the exciter that puts energy into it. In the case of the analog modular synthesizer, one can view the circuits as the resonators and electricity as the exciter. As is the case with the guitar, flute, horn, etc, the properties of the exciter plays an integral part in determining the behavior of the resonance and personality of the instrument. Rather than as a physical phenomena in its own right, this simple dynamic that electricity shares with other exciters seems to be increasingly viewed as a means of imitating or enhancing analog reality.

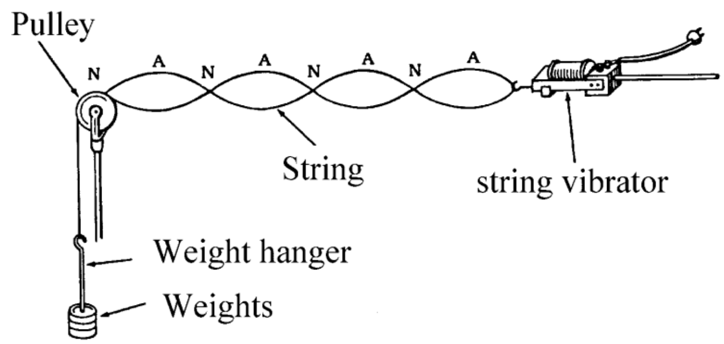

Figure 8. Apparatus used to study the behavior of a string excited into vibration using an electric motor.

Because the modular synthesizer is an electrically powered instrument, it requires no human energy to operate. Unlike acoustic instruments which must be bowed, blown, plucked, strummed, and struck into life, the modular synthesizer is in a state of excitation as long as it receives electrical energy. We have outsourced the exertion of physical energy to the power plant. What we get in return is an instrument unhindered by the limitations of human movement. As a result, we are free of the need to physically exert ourselves and may spend that energy elsewhere within the musical process. It is then “played” by *revealing* rather than creating this excitation. This can be done by a wide range of methods, and as such, a traditional or “correct” method of playing the modular synthesizer has yet to be established. This leaves the musician to decide what the intended role and behavior of the modular synthesizer should be.

1.3 Modularity

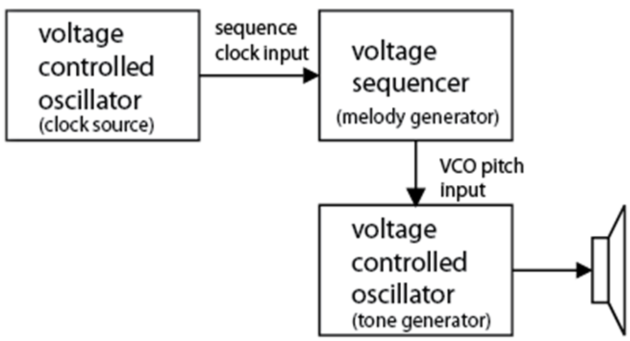

Figure 9. Modular synthesizer flow chart. Shows three modules connected to produce a simple melody.

As the name implies, the modular synthesizer consists of a series of modules each performing specific functions, such as generating audio tones or controlling the volume of a sound source. These modules are connected together to create compound functions that ultimately culminate in the presence of musical structures. For instance, one module may generate a tone while another module generates a stepped pattern which can be used to control the pitch of that tone. A third module could be used to control the rate of the pattern. Through this combination of modules we now have a simple *melody generator*. These modules can be seen as a set of core building blocks, essentially useless on their own, but when combined can be used to build up complex musical structures.

1.4 Modulation

“The key to modular synthesis is modulation, not modules”
-Rob Hordijk

Indeed, there is little value in a single module or collection of individual modules. Their strength lies in their ability to work together to create a *cooperative* system. With acoustic instruments the only realistic means of creating connections between instruments is through human control. We perceive a shared intention among other musicians and apply that through physical engagement with our instrument. Because the modular synthesizer uses electricity as its activator, human engagement is not necessary and connections between discrete modules can be made electrically.

Voltage control

Voltage control has been implemented by adopting a communication protocol which is used to tell modules what to do. Unlike many other electrical communication protocols like midi or OSC, each module hears and speaks the same language of modulating voltage levels. There is no translation of languages or embedded information in control voltage signals. This means that the effect of a control voltage depends entirely on how it is applied and not by some pre-established role.

Many synthesizer manufacturers take steps to complicate this fact by identifying signal “types” and creating misleading distinctions between these types. This is often in the interest of general playability but at the expense of conceptual clarity.

The common types of signals are “gate” and “control voltage”. Many people specify “trigger” and “audio” as additional types of signals, but as these are essentially subclasses of gate and cv signals they will not be discussed here.

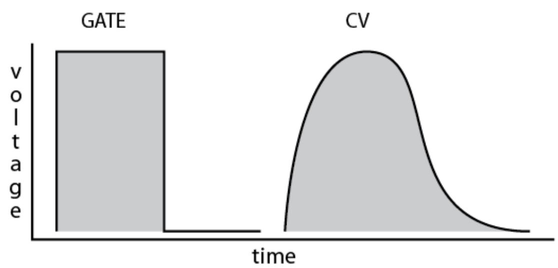

Figure 10. Gate and CV signals

Gate signals are considered as on/off signals and are used to activate something or initiate events. **Control voltage** (hereto referred to as CV) signals are variable voltages that are used to modulate variable parameters such as pitch or volume.
One could say that gates represent time periods like tempo while CVs represent values like notes. Despite these distinctions they are all just varying levels of voltage. There is no reason one can’t use a gate signal to modulate the pitch of an oscillator. As well, a modulating sine wave output of an oscillator can be used to trigger steps in a sequencer or set states in a logic module. *The distinction often has more to do with how a signal is being used rather than the characteristics of the signal itself.* This point gets to the heart of one of the great strengths of voltage control. There are many suggested techniques for signal patching but very few enforced ones. The user is free from the logic of suggested techniques and can abandon them in search of *new, novel, surprising discoveries and functionalities*.

1.5 Expansion

In order to discuss expansion we need to look at the modular synth on a few different levels.

-As an **object** it is a physical musical instrument and a tool for exploring sonic behaviors and patterns.

-As a **concept** it represents the idea of experimental potential which in itself accounts for much of its appeal.

-It has a cultural presence as a globally collaborative, open source and ever growing design movement.

Each of these facets of the modular synthesizer promotes the idea and physical possibility of expansion. Any designer who wishes to add to the modular synthesizer format need only adhere to a few simple rules which primarily specify core parameters like power supply and signal levels. However, In order to realistically integrate these designs into the greater system and gain from that integration, the designer should also understand and adopt an approach to parameter modulation which allows control by external voltages. By complying to these few rules the designer is able to add something unique to a greater system where the most common functions already exist, thus saving the designer from wasting time redesigning circuits.

1.6 Form factor considerations

Figure 11. Various modular synthesizer formats.

Most formats are used only by one or two companies. This makes connecting modules between different companies unnecessarily complicated. At their core all common modular synth modules function the same way. They speak and listen to modulating voltage.

It's possible that some amount of standardization has been invented for commercial reasons. In some cases it is advantageous to discourage compatibility, but for common formats it is apparent that these standards were designed to address quality, flexibility and expense to differing degrees. Design standards are also based on incidental factors such as available materials in the region they emerged from, but for the sake of comparison I will be focusing on more intentional factors.

Figure 12. 5U format module

Quality

The 5U standard was popularly used by MOOG synthesizers and has been adopted by a few other companies such as Cyndustries and MOTM and a handful of independent designers. The layout is simple and clean. All controls are clearly labeled and placed far enough apart so that one can easily access them. ¼" grounded audio jacks and insulated cables are used for signal patching. These jacks and cables are big, sturdy and easy to patch. 5U format modules are known for being clean, precise and reliable. The emphasis is consistently on quality: the quality of the hardware, the quality of the signal and the quality of the circuit. As a result these modules are larger than most protocols and are often more expensive.

Flexibility

Figure 14. Serge synthesizer. Circa 1970.

Some designers like Serge and Buchla adopted their own standards which differ from 5U in many ways but most notably by using lightweight banana connectors for patching rather than the heavy ¼" connectors. The most significant selling points of banana over other connection formats is that the cables can be stacked (see figure 13) allowing the user to connect several cables to a single jack. This seemingly small feature has a profound impact on the functionality of a system. This format places value on flexibility as it puts far more control in the hands of the user and dramatically increases the potential functionality of each module in the system.

Figure 13. Cable for connecting banana jack. Image shows two points where addition cables can be plugged.

Figure 15. Eurorack module produced by ADDAC Synthesizers. This physics based module emulates the behavior of marbles on a table.

Expense

The most popular format today by far is called EuroRack. By no small coincidence a primary design consideration of this standard is low cost. Eurorack is the smallest of all common formats. The 1/4'" jack and 1" knobs of 5U have been switched out for hardware half the size. This format is commonly criticized for difficult playability as a result of cramped control layouts.

The Eurorack protocol has become extremely popular in concert with a resurgence of interest in modular synthesizer performance and design. As the community continues to grow, more and more modules are becoming available to the public. Through this process the market has quickly become saturated with standard modules such as oscillators, amplifiers and filters. As a result there is an increased pressure on engineers to produce unique and unusual modules. There is also the market to support them. Experimental engineers like Dutch artist Gijs Gieskes are able to produce a successful line of extremely unconventional modules such as voltage controlled computer fans and noise generators that utilize lasers and sand filled hourglasses.

My own work with modular synthesis focuses on these similarities and I constantly strive to find ways that obscured connections between a wide range of technologies can be revealed and exploited by other inventive artists (see the photo of my studio in fig.2 on the table of contents page for an example). I have outlined the protocols above to show that there are a number of concerns that go into the design of a modular synthesizer but show that while differences do exist, they remain relatively similar. All formats use patch cables and knobs and communicate by modulating voltage levels.

1.7 Electricity

To simply state that the modular synthesizer is an electrically powered instrument says very little about its behavior. The flow of electricity is a complex topic especially considering the advent of digital electronics which have transformed the phenomena of electron flow into a conceptual domain of logical calculations. Despite these differences between analog and digital processes, both can be used to produce perceptually identical results. This leaves many people asking, "What is the difference"? Answering this question is a paper in itself but I will attempt to outline some important points below. I will start by saying that I make no qualitative judgments about either method. I believe in using whichever one is most appropriate to a given application.

In order to make this distinction one must consider the far reaching implications of each and not just a comparison of singular aspects. The offending approach is often taken when comparing digital to analog methods by assessing the relationship of the two based on audio waveform comparison alone and under specific or ideal circumstances. I choose to consider perceptible stimuli as a product of a specific physical process. Electronic music is the product of physically manipulating a computer. Acoustic music is the product of physically manipulating an acoustic instrument, a piano for instance. A digital simulation of a piano is not a piano. It is a method of manipulating logical data at high speeds in order to render an audible approximation of idealized and expected piano behavior. This is not inherently problematic. There is no incontrovertible reason we should be making sound with pianos rather than computers or vice versa. The problems emerge when people unquestioningly accept the idea that a simulation is the same as what it simulates. The flexibility and ubiquity of digital technology and the industry that gains from the sales of these technologies challenges us with these assertions of authenticity at every turn.

In the following section I will outline some of the defining elements of both methods:

-How each method can produce perceptually identical output
-Why the breadth of the two outputs will never be truly identical.

Analog circuitry produces and responds to infinitely variable levels of voltage and current flow. That is not to say that the circuit can produce and receive infinite energy, but there are *infinite* states between *finite* extremes. The number of states we can see/read are limited only by the resolution of the equipment we use to read it. Analog signals can be controlled and stabilized to usable levels but just beyond our view of that level the signal is always moving. The engineer must determine what scale of stability their application requires and at what scale the instability can be appreciated for the organic behavior it embodies. This says a lot about why analog synthesizers and recordings are credited for having a “richer” or “warmer” sound. It is simply the presence of continual movement at the boundaries of our perception that permeates through the perceptible range. It is also the key to understanding the potential of analog signal feedback where these once imperceptible movements become increasingly more amplified with every cycle of the signal loop. This is especially apparent with analog video feedback where complex patterns emerge from a blank image. These patterns are embodied in the original signal, they need only be magnified and enhanced through chaotic iterations to be perceived.

Figure 16. Analog video feedback

Digital circuits have been designed to ignore subtle fluctuations of voltage levels and produce and receive only two states; on and off. For an example, note the difference between a light dimmer and a light switch: Analog is the dimmer, digital is the switch. When considering electricity as the force that activates a musical instrument it seems pretty obvious that one would prefer a dimmer over a switch, but the rapid overthrow of musical technology by digital circuitry shows us this isn’t true. What digital lacks in variability it more than makes up for in precision and speed. Let’s go back to the light switch analogy. Consider that someone is asking you questions and you can only answer by flipping the light switch. On is yes, off is no. This works for some simple question but is insufficient for most. A more expressive method is required but one is still limited to only using a light switch. Eventually one finds that by turning the light on and off at varying durations, one can start to transmit more complex answers. One can decide with the interviewer on a set of switching patterns that represent different letters and numbers (see figure 17 below). A simple ON/OFF statement has now been transformed into a sophisticated language by introducing the analysis of these states over time.

This is where the analogy begins to break down and the real strength of digital circuitry emerges.

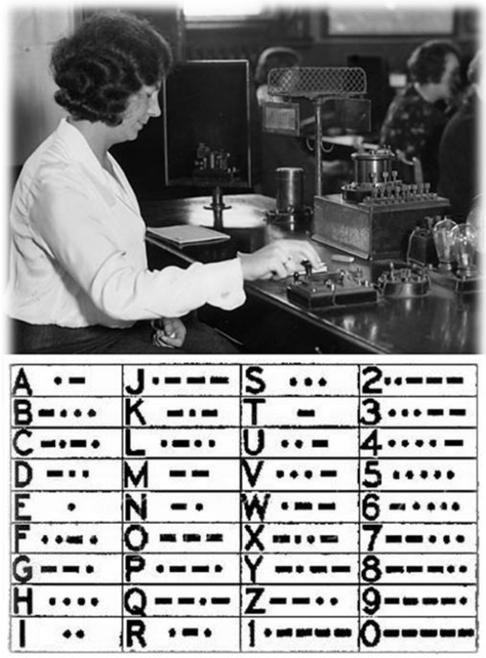

Figure 17. In this image a woman uses a simple on/off pushbutton called a Telegraph to transmit messages over wire electrically. The messages are encoded using a system of dots and dashes called Morse Code. In 1844 the inventor of the Telegraph, Samuel Morse demonstrated the usefulness of his invention to the United States congress by transmitting the message "What hath God wrought" in morse code over a wire from Washington to Baltimore.

Now imagine that the switch can be thrown millions of times a second. Our bodies and the plastic and metal of a light switch won't allow this, but digital circuitry can handle this with ease. At this rate, so much data can be delivered that one can forego representing letters altogether and can instead describe discrete steps of the waveform of a voice saying the answer. When this data is translated through the appropriate hardware (such as a speaker) we perceive that data as a voice. These discrete steps are generated at a rate that tricks our minds into perceiving them as a single sound. This is easier to understand when compared to film. Motion can be represented using a series of still images. When these images are shown one after the other at high speed (commonly 60 times a second) we perceive them as a single moving image rather than many still ones. The same effect works for sound. Digital methods in general work by exploiting the boundaries of our sensory cognition. The stimuli of digital methods which produce sound, light etc are an illusion of analog variation composed of static states.

As the speed of digital processing increases we are able to embed more and more data into a single period of cognition. Let's say this period is 1/60th of a second and we are able to flip the switch 1,000,000 times a second. That means in one cognition period we are able to make more than 16,000 statements. That is so much data that this not only represents a voice giving your answer, but can represent several voices, as well as the appearance of the people producing them. Not only that but because all of this information is based on a finite string of on/off signals (albeit a lot of them) it is possible to record and exactly replicate their sequence.

Simulation

The power of digital technology cannot be understated. It has revolutionized countless aspects of the human experience, but while digital technologies have replaced analog/organic ones something crucial has been sacrificed along the way. As digital technology evolves the physical phenomena that makes it possible is minimized. Man's ability to make faster, more powerful digital circuits is determined largely by the engineers ability to minimize the heat that is naturally produced by the movement of electrons in a conductor. By reducing the physical phenomena of digital circuitry we are able to maximize its purely logical capabilities.

Digital data has no sensually perceptible value. Through the use of digital technology we are able to generate and process data at a volume, rate and level of precision that is absolutely impossible by human means. This data though has no value if we are unable to perceive it. This is where a conflict emerges. The strength of digital processing is based on its ability to transcend physical phenomena but in order for it to be accepted into the human mind it must manifest in a physical form at some point. In order for this to happen, data must first be transformed into a simulation of natural phenomena.

Digital methods may perform very many, very fast operations but they remain finite, at some point in the development of a digital simulation we must accept an estimation of what lies beyond our ability to calculate. Inherent in the acceptance of this estimation is a further acceptance that the inaccessible factors are probably unimportant, that the data we do have is “real enough”. A digitally simulated guitar is not a guitar. The sound it generates is not made by vibrating guitar strings. A simulation of a vibrating string is not a finely wound steel wire stretched over a wooden body. A simulation of a wooden body is not an alignment of wood fibers that have been touched and transformed by atmospheric conditions over months and years. We must stop somewhere and accept an estimation of what lies beyond. In this estimation we are making a finite and logical human decision about the behavior of infinite natural phenomena.

The laws that determine the behavior of each system, physical and simulated, analog and digital are very different and whether we like it or not these laws extend far beyond our ability to perceive them and influence the behavior of the system in ways we are unable to predict. My affinity for analog methodologies and preference over purely digital ones is largely due to the visceral connection I feel with its phenomenological origins. The following work sample is a great example of a physical musical instrument that is engineered to give the user tools to access and explore this point of origin.

1.8 Work sample:
The Hordijk Modular Synthesizer

Figure 18. The Hordijk modular synthesizer. Designed and produced by Rob Hordijk. 2014

Intro

No one has had more impact on my interest in analog modular synthesis than Den Haag based artist and designer Rob Hordijk. His inventions and philosophies have largely shaped my path from novice circuit hacker to inspired modular synthesizer designer. I feel immensely grateful to have had the opportunity to work with Rob over the past few years and learn from his personal experience and wisdom. The following work sample is an instrument that I have watched evolve over the course of our friendship. It represents what I consider to be a superior example of the strengths and potential of analog modular synthesis. Furthermore I consider his methodical and holistic approach to design to be an example to follow in my own work regardless of medium.

I first met Rob in 2005 at an electronic music festival in Los Angeles. He was giving a lecture on analog synthesis and demo-ing some new instruments. I had the chance to use the instrument pictured in fig. 19 called the **Blippoo Box** during our meeting and was both baffled and intrigued. The object itself radiates an aura of quality. From its weight to the feel of the controls there is a sense of decisive exactness and balance. The sounds and behavior of the instrument carry this feeling even further. They are rich, complex, engaging, mysterious and oddly familiar all at once.

Figure 19. Rob's Blippoo box analog noise machine. Feedback loops between simple function blocks create a wide range of complex sonic patterns.

The Blippoo is unlike any instrument I knew of at the time. Instead of controlling pitch and volume as one does with many instruments, the Blippoo is played by discovering and exploring complex behaviors and patterns of sound. This is done by adjusting the knobs on the faceplate. These controls have technical labels that speak to the functionality of the circuit but I have found over time that they are relatively unimportant. The behavior of each control varies based on the settings of the others. This is due to the fact that the sound generating circuitry is a network of interlocked feedback loops. Therefore as one parameter is adjusted it pushes and pulls on other parameters as the loops weave throughout the system. Instead of logically understanding and predicting the effect of a control, the musician is better off observing the effects of their actions and developing idiosyncratic methodologies of play. Despite this confusing behavior of the Blippoo, it gives the impression of being far from random. Instead it seems to be acting on some organic whim which evades human understanding but is logical nonetheless.

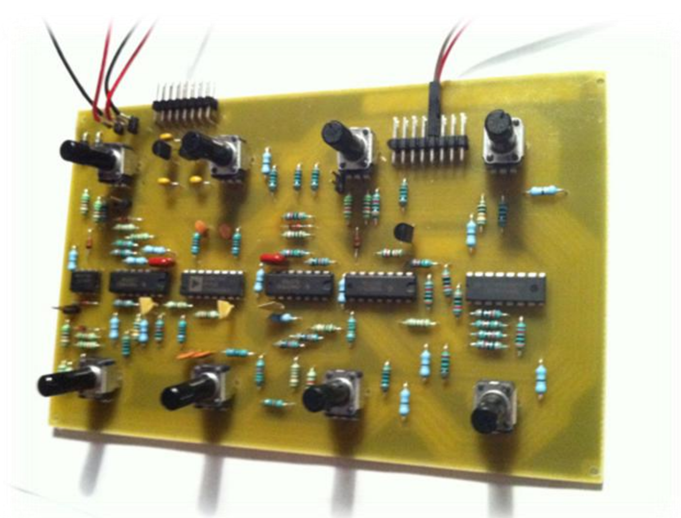

Figure 20. Rob's Benjolin synthesizer. Designed as a kit for DIY synthesizer enthusiasts.

I have since learned how the Blippoo works and have also become familiar with a particular range of sounds which it most often produces. With this growing understanding of the technical behavior of the instrument I have developed an even greater appreciation for the boundaries of human understanding that the Blippoo pushes against. It is an instrument of intuitive simplicity and unimaginable complexity.

The following year I met Rob again at the same festival but in New York City this time. He had a new circuit with him called the Benjolin. Like The Blippoo, the Benjolin utilizes simple analog building blocks and cleverly configured feedback loops to create complex patterns. But unlike the Blippoo it was designed as a kit to be assembled by hobbyists. My only objection to the Blippoo was that it was virtually unattainable to a young, struggling artist like myself. It was truly an object of desire and inspiration but the cost and limited availability made it inaccessible. The Benjolin on the other hand gave me and thousands of others like me access to Rob's unique and sophisticated vision of analog synthesis and instrument design. It does so at an attainable cost and in a format which allows the inventive musician to develop their own instrument.

Figure 21. An expanded, fully modular version of the Benjolin I designed in 2012.

Invention is an integral part of my process. I admire the work of other artists and engineers but what I value most is innovation that I can fold into my own process of exploration and invention. The Benjolin is exactly that. Over the past several years I have worked extensively with his design, building new interfaces and publishing modifications. Not only has it inspired my work as an instrument builder and musician, but it's character has become an increasing part of my artistic identity as I perform with it. This illustrates one of the things I find most exciting about designing musical instruments. The character of the instrument inventor is integrated into the creative spirit and personality of the musician that makes the instrument their own.

Figure 22. My current performance synthesizer uses two modified Benjolins and a voltage controlled tri-color light source.

The Hordijk Modular Synthesizer

Shortly after our meeting in New York, Rob began working on a family of voltage controlled synthesizer modules that has evolved over the past 5 years into a 12 panel suitcase of remarkably unique and powerful modules. Robs methodology of designing and fabricating this instrument has been engineered from the ground up to allow the system to grow and evolve over time as inspiration drives him. In this way I consider this instrument to be a product of his desire to invent as much as his desire to make music.

Electricity

The Hordijk Modular is an instrument based on a deep understanding and respect for the nature of electricity. This phenomena is not a generic energy source used to simply power the instrument. It is its very heart, breath and voice. It is what powers and inspires.
He does not employ this phenomena in order to imitate familiar instruments or sounds, but instead gives the user a means to explore the unique and complex nature of electricity and electro-acoustics. In order to achieve this Rob has employed almost entirely analog circuitry. Despite that I believe that Robs approach to synthesizer design is strictly non-purist and he employs any method that will best achieve his goal of exploring the nature and the complexity of electro-acoustics. It just so happens that analog circuitry is what most often achieves his goal. By employing analog design approaches Rob encourages the user to explore the behavior of electricity, the complex and highly musical potential of signal feedback and to identify one’s own application for them.

Hand craft

The design approach Rob has taken gives him control over every step of the fabrication process. All of the circuits are original designs that he has built and used for several months or in some cases several years. The circuit boards and faceplates are produced in his home as needed. He solders all boards himself and finally puts everything together into a custom built housing. By keeping the process on a hand-made scale Rob is intimately aware of every aspect of the instrument and once a system is fully assembled he can be confident that it is the highest quality possible. He is also able to develop his designs as he goes rather than commit to a single mass produced approach. This project is an ongoing, evolving process of exploration for everyone involved from inventor to user.

Form factor

The module form factor complies with the 5U standard. Two priorities that informed this adoption are quality and playability. The system is designed to be a musical instrument.

As such, the controls should be easily accessible, both visually and physically. The quality of the components should be as high as cost and realistic benefit permits. This quality should contribute to a feeling of integrity that inspires musicians to respect their instruments and drives a desire to express themselves through it.

A layout of 8 knobs and 10 jacks has been adopted on all modules. The impact of this standard extends both ways between designer and user. On one side the consistency contributes to the users' ability to mentally take in a module and assess its features. It also gives a feeling of equal weight between modules and encourages the user to consider each as much as the next.

On the design side the standardized layout presents boundaries. Many great designs are defined by how they work within limited boundaries. It requires Rob to make decisions and compromises. Each decision and compromise he makes imparts a small piece of his personality into the final instrument.

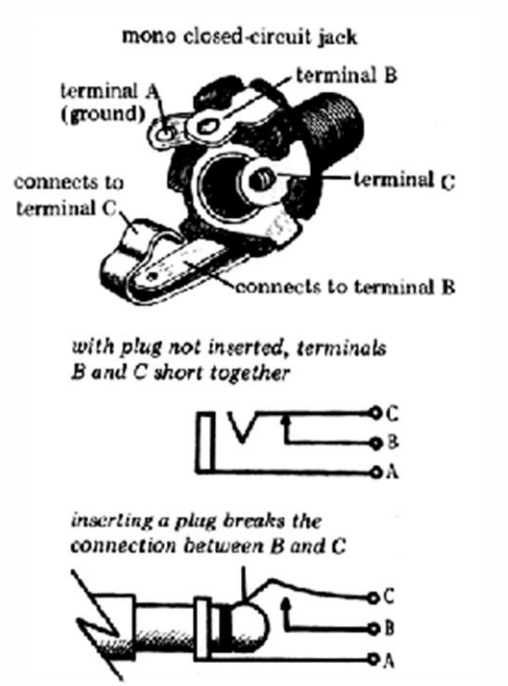

Figure 23 The Hordijk system contains several levels of normalization but in nearly all cases it is overridden when patch cables are plugged into the external modulation input jacks. This action pushes a switch inside the jack that disconnects an internally routed modulation signal and allows the signal from the inserted cable to be used as a modulation source instead

Normalization

Normalization is the interconnection of function blocks (such as filters, oscillators, etc) made behind the control panel 'in the factory'. Normalization is generally implemented to make very common connections by default, thus freeing the user from the burden of patching the same configuration over and over. It is a relatively *uncommon* design technique in modular systems. The idea of modular synthesis is that functions are seen as discrete blocks that can be defined and redefined as unforeseen combinations between functions are discovered by the user. Normalization *challenges* that idea by saying 'some connections are better than others'. It is a bold statement but if the designer has a sophisticated understanding of what better connections are, it can be an effective technique for reigning in the endless possibilities of modular system configuration and presenting the user with a considered range of valuable behaviors. This range of valuable behaviors in turn defines the personality of the instrument. The personality alongside uncompromising build quality is where I consider the greatest value of the Hordijk System to be. He has created a powerful contrast between high quality engineering and unique personal design.

Modules

Each module in this system is a meditation on the nature of electricity, the musical potential of modulation and the strength and character that emerges from the purposeful connection and contrast of discrete function blocks. Inherent in each of these modules and the connected functions they embody is an expression of the artistic vision and spirit of its designer.

Below I have included images and technical information about three modules as a representation of Rob's design approach. No list of features can accurately translate the experience of using these modules and experiencing the results of the philosophy that informed their design. Regardless, I have included this information to help give form to the topics discussed previously.

Rungler

Function Blocks:
-x2 Voltage Controlled Oscillators (VCOs A & B)
-Rungler
- -XOR gate
- -Shift register
- -Digital to analog convertor
- -Integrator

The Rungler module combines 2 voltage controlled oscillators through a voltage processor to create pseudo-random stepped voltage sequences and complex timbre patterns. This module functions as a wide range noise generator and experimental melody sequencer.

Manual control	Input	Output
VCO A		
Frequency		Sine wave
Rungle>freq amount		
Rungle>fluctuation amount		
Freq mod amount	Pitch mod A [VCO2]	
Fluctuation mod amount	Fluctuation mod [VCO2]	
VCO B		
Frequency		Triangle wave
Rungle>freq amount		
Pitch mod amount	Pitch mod B [VCO1]	
Rungler		
mode switch: random/sparse/dense	External clock [VCO 1]	Clock
		XOR
		Stepped
		Smoothed

Dual Envelope Generator

Function Blocks:
-Attack, Decay I, Sustain, Decay II, Release (ADSDR) envelope generator (ENV)
-Attack, Decay (AD) envelope generator (ENV)
-2x Sample & Holds

Manual control	Input	Output
ENV A		
Attack time	Attack time mod	ENV A
Decay I time	Decay time mod	
Sustain level		
Decay II time	Decay II time mod	
Release time	Release time mod	
ENV B		
Mode switch: Free/Gate/Loop		ENV B
Attack time		
Decay time		
Decay time mod amount		
S&H A		
		S&H A
S&H B		
		S&H B
ENV B + S&H B		
	Decay time mod/S&H B sample signal [S&H A]	
ENV A + ENV B + S&H A + S&H B		
	ENV + S&H gate	

The **Dual Env** module holds two voltage controlled envelopes as well as two sample&hold circuits. The first envelope offers manual and voltage control over five stages; attack, decay I, break, decay II and release. This gives an envelope which more closely resembles the energy dissipation of an aucoustic instrument than the traditional ADSR envelopes found in most other synthesizers. The second envelope offers attack and decay as well as a separate control for decay length. This control is normalized to the output of the second sample&hold. A retrigger switch allows this envelope to act as a repeating oscillator.

Triple Voltage Controlled Low Frequency Oscillator (VCLFO)

Function Blocks:
-3x Voltage controlled Oscillators (VCOs A, B & C)

Manual control	Input	Output
VCO A		
Frequency		VCO A sine wave
Freq mod amount	Freq mod A [VCO B]	
Fluctuation mod amount	Fluctuation mod [VCO B]	
VCO B		
Mode switch: free run/sync/hold	Sync/Hold [VCO C]	
Frequency		VCO B triangle wave
Freq mod amount	Freq mod B [VCO C]	VCO B pulse wave
Wave Shape		
VCO C		
Frequency		VCO C triangle wave
Freq mod amount	Freq mod C [VCO C]	VCO C square wave

The **Triple LF-VCO** holds three voltage controlled low frequency oscillators. Each has a unique character and frequency range which are primarily intended to opperate at the subaudio range. Oscillator B has a switch which allows the cycle to be retriggered or sampled&held by oscillator C. The frequency of each can be controlled by external voltage or by normalized connection between all three. This configuration causes the signals to feedback into eachother and create chaotic patterns.

CHAPTER 2: CONCEPT MUSIC AND INVENTION

2.1 Intro

Figure 24. My studio in The Hague. 2014. The array of commercial and hand-made equipment is custom engineered to facilitate invention, integration and expansion.

Music and invention is a far reaching topic and is difficult to address in an isolated way. The first and third chapters address form and experience respectively but the desire to invent plays an important role in each. This determines the evolution of form and defines the driving force behind experience. The work sample in this chapter represents the primary focus of my masters study and will be addressed with considerably more detail.

The process of playing a modular synthesizer is much more than physically manipulating controls and creating sound. It is also a process of imagining, building and observing. For myself and many other musicians, the appeal of playing this instrument in large part lies in the process of exploration and invention. The modular layout of inputs and outputs between modules and the extreme flexibility of signals represents vast configuration potential. This potential begs to be explored. For those who are already predisposed to exploring sound and complex signal architectures this is a naturally appealing interface.

Over the last decade the modular synthesizer market has exploded with several dozen companies and thousands of independent inventors building modules and sharing designs. At the center of this explosion is the “Euro Rack” design protocol. There are many particulars to why this standard is so popular but it’s not necessary to discuss them here. What's more important is that there IS a widely accepted standard. This allows for global collaboration and cumulative design.

We are currently experiencing a worldwide resurgence of interest in analog electronics and modular synthesis which is doing far more than re-hashing retro designs. Online communities and evolved fabrication techniques have brought the second wave of modular synthesizers to entirely new audiences since the 1960's and 1970's when it first appeared. Most importantly, it has been brought to an audience of inventors who are able to express their inventive ingenuity by creating their own designs. Many of these designers have found they can form a lucrative business by selling their designs, realized as physical modules. In most cases the inventor need only sell a few hundred units to justify the effort of design, production and distribution. This represents a very low risk level, meaning even the most unusual ideas can be supported by a small group of customers among the thousands of synthesizer players looking for modules to integrate into their system. This creates an environment that fosters, even encourages experimentation. This spirit impacts participants ranging from those who design modules, to those who collect and make music with them. The manifestation of a desire to discover new things and invent new possibilities permeates through every aspect of the current format of modular synthesis. In many ways I feel this is a desire which the medium was built on 50 years ago. The current level of activity and creative variety was only possible once the medium was freed from its classification as cutting edge technology and allowed to be appropriated.

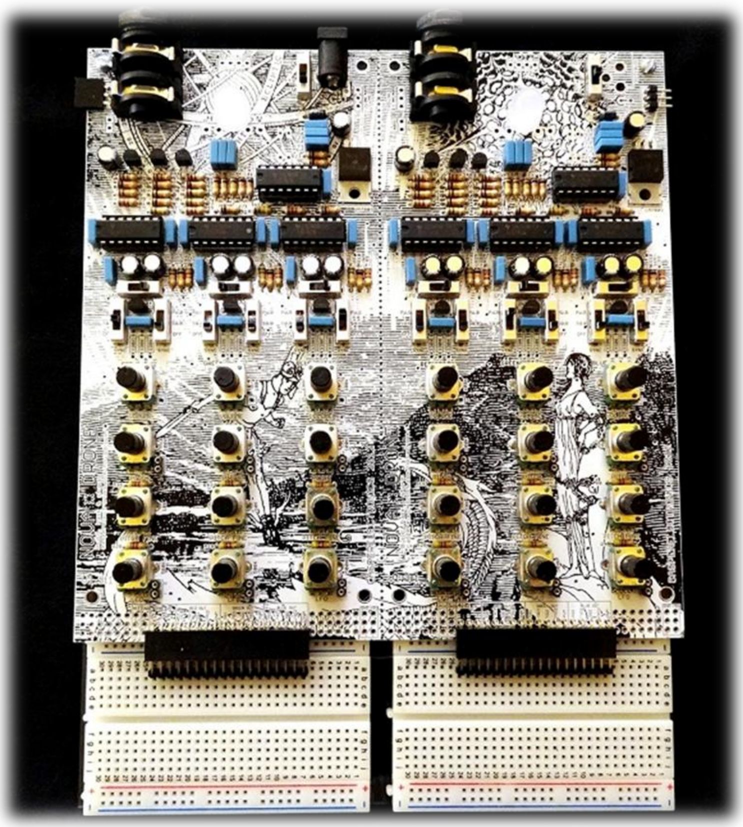

Figure 25. The Nova Drone. I designed this instrument in 2012 as a kit and with a built in breadboard. Both factors encourage the builder and user to engage with not only the instrument but the circuitry itself in a creative and expressive manner.

The spirit of this medium is interconnection and cumulative development. It is a necessary element. Otherwise it would make no sense to have a single module that does only one thing. The value of an envelope generator for instance is only realized when that module has another module to apply an envelope to. So it is only natural that a format based on interconnectivity should gain a great deal by expanding to a social domain where communities share ideas and add to the greater presence of the medium. Like the envelope generator, our ideas are humbly insignificant on their own but immeasurably useful as contributions to the medium.

Ultimately, I value above all else the presence of invention and exploration that emerges from the overlap of science and music; found with modular synthesis.

2.2 Work sample:
The open modular synthesizer

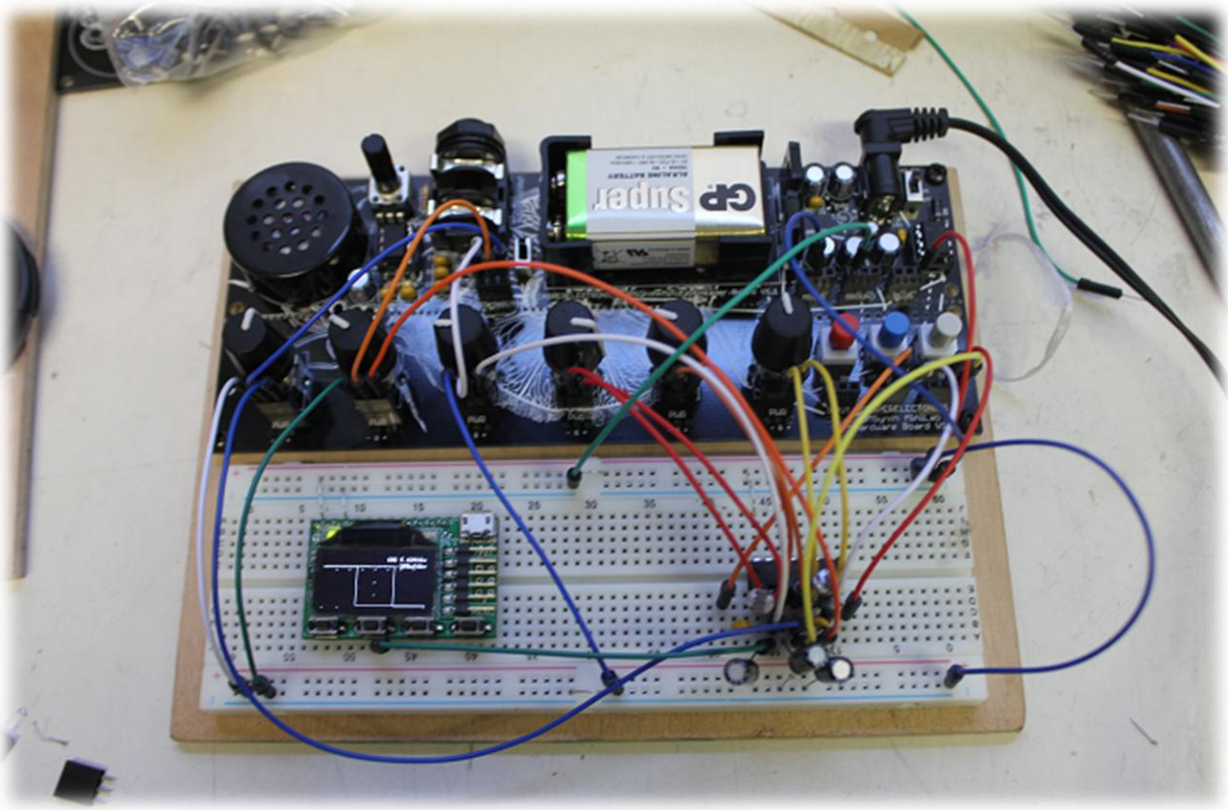

Figure 26. OMSynth MiniLab circuit prototyping and experimentation kit.

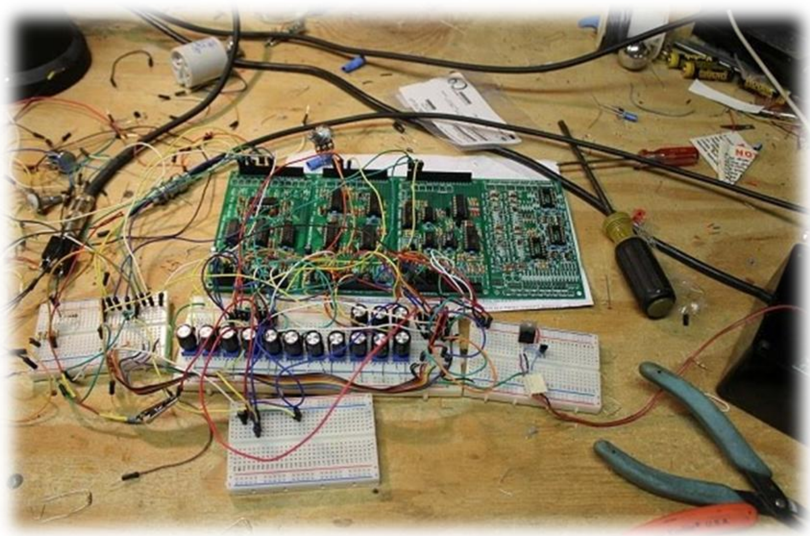

Figure 27. First breadboard based modular synthesis prototype. Inspiration for current OMSynth format. Designed over the summer of 2012.

The open modular synthesizer, or OMS/OMSynth, is a project I began over the summer of 2012. It is centered around a new protocol of physical modular synthesis design and use. It differs from the other popular modular synthesizer formats by catering as much to inventors as it does to musicians. This is achieved by establishing a set of low level function blocks that can be built up to high level musical instruments which allows the user to invent and play and is the premise of modular synthesis in general.
The problem with most modular synthesizer protocols is that the function blocks (modules) they offer are not used to make musical instruments per se. They are used to make modular synthesizers. The design of these modules is too highly developed to allow them to be realistically used in other applications. They are great for building modular synth systems but not appropriate for much else.
OMS presents a format that lets inventors utilize the power of modular design and voltage control in applications and formats of their own choosing.

Concept

OMS is an open source, open application standard of instrument design. One of the core strengths of modular design methods lies in the fact that they are inherently collaborative. The potential of each module increases as it collaborates with another. The greater family of modules is enriched with each additional module. So it only makes sense that the ethos of this entire OMS project should be based around collaboration. That’s why OMS is completely open source. Anyone who can gain from, or give to this project, should be able to do so.

Figure 28. Breadboard based hardware prototypes. Developed in collaboration with American artist Phil Stearns at STEIM. Spring 2013.

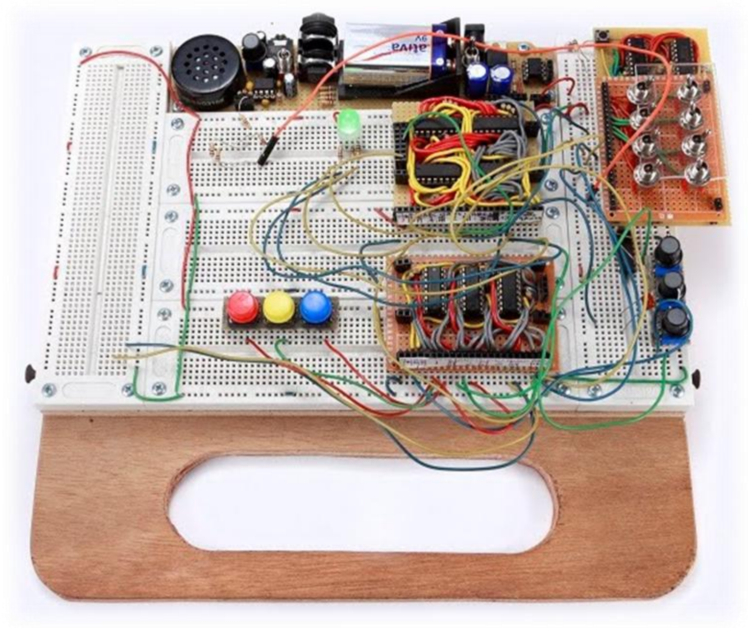

Figure 29. First OMSynth development lab prototype. Designed in collaboration with Phil Stearns at STEIM. 2013.

Object

The physical OMS format is a family of circuit boards and interchangeable hardware boards. The circuits on the boards generate single or small groups of voltage controlled functions. The format of these boards is informed by a set of laws and suggestions.
The laws address the most rudimentary and inflexible aspects of the system which allow for cumulative design and collaboration to take place. The suggestions reflect the general ideals of the OMS project which include collaboration, scalability, expansion and DIY friendly fabrication and use. Following these suggestions makes the design process faster, easier and more compliant with the greater system, but the designer is also free to stray from them as they like.

OMS laws

-Common and flexible power supply. Circuits are powered on +&-12VDC. This is currently the most common power standard in the world of modular synthesis. Modern power regulating technology makes generating stable bipolar power supplies easier and cheaper than ever before.
-Voltage control. Any style of circuit can be used as long as it generates and is controlled by analog voltage levels. Digital circuit can be used but should maintain CV interfacing. Digital communication between circuit boards is possible but only in exceptional cases.
-Scalable fabrication options. Boards are designed to be fabricated using bench top tools but without excluding the potential for industrial techniques to be used.
-Standardized interconnection header. All inputs and outputs are available in one row of points spaced 2.5mm apart. This allows easy connection to breadboards and interchangeable control interface boards.
-Small and cheap boards, lots of expansion options. Boards hold no control hardware but can be easily connected to custom hardware boards via the I/O strip.

OMS suggestions

Circuit design

Circuit design, especially standardized design, is a balance of priorities and compromises. The following suggestions are meant to influence but not dictate this balance. In some cases the unique priorities of the designer may outweigh the following suggestions such as small board size or the use of common parts. The designer is encouraged to follow these suggestions but is not obligated to.

Control

All 'musically useful' variables of a circuit should be voltage controlled whenever possible and/or reasonable to implement.

Cheap and easily found parts

General purpose components and common component values should be used whenever possible.

Safe experimentation

All I/Os should be protected against unsafe levels of voltage and current using simple buffers. This not only protects the circuit from harm but also gives the user a sense of freedom to explore.

Numerous modulation inputs

All voltage inputs should be high impedance connections to the input of a mixer. The user is free to add as many inputs to that mixer as they like.

Outputs

All voltage outputs should be buffered and low impedance. This coupled with the high impedance inputs of other modules means that one output can connect to many inputs.

Circuit board design

The method of board fabrication has a profound impact on the design of the board and even the circuit itself. The fabrication method must address a variety of priorities which include DIY friendly fabrication, small board size, ease of assembly and scalable production volume,

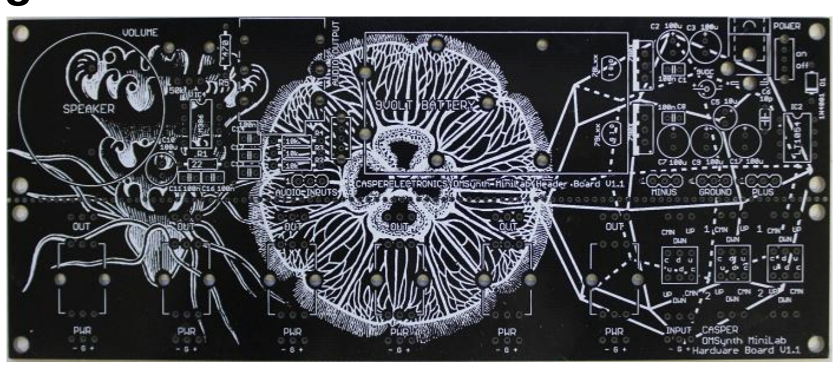

Figure 30. OMSynth MiniLab circuit board. Single sided design and large leads make this board appropriate for home or pro fabrication. Clear labeling of all component numbers and values as well as special instructions such as alternate power regulator configuration makes this board easy to assemble and modify.

meaning the user should be able to produce a single board or many boards without changing the design.

DIY fabrication
All boards should be designed to be fabricated using a PCB milling machine. If boards can be made single sided without dramatically increasing the size of the board they should be. This lowers milling time and raw board cost and still allows etching based fabrication processes to be used if desired. Regardless of the design, nothing should be included that negates the possibility of industrial fabrication. Milling machine is the ideal, etching if possible and industrial should always be an option.

Hand Assembly
Designs should primarily use through hole components. Surface mount components can be used but should be large enough for hand assembly.

Small boards
Boards should be as small as possible without dramatically compromising functionality and ease of assembly.

Lots of hardware options
The most popular forms of hardware should be available as plug in control boards. All other options can be implemented by the user.

A few notes on PCB fabrication methods:

Home etching- This is the most accessible process as it requires low initial cost and very few special tools to execute. The drawbacks are that there are many steps to the process making it highly prone to error, time consuming and laborious. It also requires the use of dangerous chemicals which necessitate special handling and disposal techniques. The most relevant drawback is that this process is only suitable for making single sided boards.

PCB (printed circuit board) milling machine- The PCB milling machine is a bench top computer controlled mill that can cut and drill custom PCBs. A mill requires maintenance and training to use but when used correctly it can produce highly precise, double sided circuit boards in a matter of minutes at a very low cost. It offers a suitable balance for the DIY synth builder between the ease and accuracy of industrial processes with the small scale and low cost of home fabrication. The drawback of this process is that mills are prohibitively expensive for individual purchase. With the growing popularity of hack and fab labs across every major city in the world this tool has become available for use by members of these labs.

Industrial fabrication- This is by far the easiest process for producing high quality circuit boards in high volume. This process gives the designer access to a number of valuable options such as solder resist layers, board labeling and through hole plating. The combination of these three options makes assembly of these PCBs extremely easy.

Unfortunately, there is a very high initial expense and several week wait time that makes this process unsuitable for low volume fabrication. If the designer has a tested board that they wish to produce in volumes of 20 or more units this is the best option.

CHAPTER 3: EXPERIENCE
NON DURATIONAL MUSIC

Figure 31. Bit Shifter 2012. Video game controllers, touch sensor controlled analog synthesizer, modified video game console, television. Interactive installation on display at Georgia Southern University. This piece puts users in control of two joysticks which allow them to play video games as well as generating complex analog sound fields and interlinked video distortion. The piece plays with the shifting focus of the user as they move between modes of competition, performance and reception.

3.1 Intro

In this section I will be discussing the experience of using the modular synthesizer and how the process naturally lends itself to creating musical experiences that challenge the roles and concepts of music making.

The modular synthesizer does not require human engagement to operate. This was explained in the first chapter. This is due to the fact that it is electrically powered and therefore human excitation of the system is not necessary. Furthermore a communication protocol of voltage control has been implemented to allow modules

within the system to “talk” to each other and create complex networks of control signals or “conversations” between modules.
This allows the musician to engage with the instrument on various levels through a variety of processes.

One process is related to invention and is a conceptually driven physical process where the musician develops ideas or theories of signal architecture and then configures the system to test these theories. This process is often also a product of the physical form of the instrument which presents a wide range of options and subsequent inspiration to the musician.
This is the process of *programming* the instrument. I also call this the **invention** stage.
The next process is one where the parameters within a programmed patch can be manipulated to generate focused musical events. In this process the musicians attention is on timbre and time rather than architecture and concept. I call this **playing** or **performing** on the instrument. Another process which plays an important role in the other two is **listening.** Listening is vital to programming and playing and can also be form of passive engagement which is shared by audience and musician.

When one plays an instrument they are often engaged in a form of feedback loop where their physical actions impact the behavior of the instrument, manifesting as sound heard by the musician who then physically responds, and so on. Programming on the other hand is a conceptual and analytical process. Listening is not necessary during the theoretical phase but is necessary to test and experience the final product. There is a separation between theory and experience. Many musicians favor this method of musical generation where parameters are established prior to activation and then experienced as they play out. This is essentially the process of establishing and experiencing a behavior. It is also a sort of game where predictions are made then tested against an outcome. By placing all of one’s intention into the initial program the musician is able to transition to the role of listener while the music unfolds. This is an interesting and gratifying contrast of roles within a single creative process. It is an especially popular technique in the digital domain and has led to the ubiquity of terms like “generative music” and “algorithmic composition”. The strength and potential risk of this method is that actions derived from a set of initial circumstances don’t always go as intended. This is exciting because it can lead us to unexpected discoveries, and it is also dangerous because the results can end up far outside of the musician’s or anyone else’s definition of interesting music. In the latter case, the value must instead be derived from the concept behind the experience. In order for this to work, an audience must know what that concept is and agree it is worthwhile. Utilization of obscure or novel functions of the system may be enough to satisfy the musician but not the audience who likely knows very little about these functions or the system itself. This can lead to music that is conceptually impenetrable as well as sonically unsatisfying. It can also lead to very clever music that inspires us to reconsider the value of sound once it is given an appropriately stimulating context.

3.2 Exploration

The final process of engagement that I will be talking about involves mutual consideration of concept and timbre and is a combination of listening, programming and playing. I call this process **exploration**. The first step of exploration is to listen to the system while programming it. Once listening is introduced to the process the musician will likely find as they go that the results are not completely as expected. They can then choose to adjust their programming strategy to move toward or away from these results. Before long we have a process that looks a lot like ‘playing’ where there is a feedback loop between sound and action. Exploration invites the musician to program by ear and arrive at illogical results. The process gains from one’s ability to abandon their need to fully understand the logical progression of the system. This need is replaced with an ability to adapt to and work with a sonic experience rather than predict it. At the same time, the musician doesn’t abandon their desire and ability to analyze and control system architecture. They instead allow the goal they are programming toward to evolve as they experience the output of the system. At this point the musician can slip easily into a playing mind set or withdraw enough to analyze the system architecture and formulate a plan. There are no rules to how one moves between these processes. They can start by programming, move into playing, then listen and so on. The skilled musician will be able to engage in several of these processes at the same time.

I argue that the primary strength of the modular synthesizer is the liberty it gives the musician to explore. My ability to embody this strength is how I assess my skill in this field. This defining characteristic is a result of numerous overlapping strengths and limitations. The body of this paper has been presented to identify many of these strengths and give context to my current assertion. The physical format, the pervasive potential for invention through experience, the sonic complexity and novelty. All of these things work in concert to produce experiences that naturally challenge the roles and concepts of music making.

3.3 Non-durational Music

If we look at the movement between these modes (exploration) as a specific technique of using a synthesizer, then we can classify the sonic output generated by this technique as a particular style of music. I call this style **non-durational music**. This title is derived from the lack of a clearly defined or implied duration of the music generated through the process of exploration. It says nothing at all about things like melody or history, only about the way we focus on time, our involvement with the music and our expectations of finality. As the user explores, their focus constantly shifts between playing, inventing and listening, The physical, the conceptual and the experiential. The intention of participant changes with each transition and with it so do their expectations and critique of duration.

It is the engagement of the participant in the totality of exploration that permits these shifts of focus to take place. That is to say this is not a spectator based art form. There is no way to represent this format of music through performance, with film or audio recordings, a written score or even text. It is a multi dimensional process which can only be appreciated by experiencing its multiple dimensions.

If this art form cannot be recorded and represented then the only way to share it with the world is to help the public actively engage in the process of exploration.

The methods I employ in my work involve producing interactive installations and experimental musical instruments. Both of these approaches put tools for inventing, performing and listening in the hands of the public. An extremely important aspect of this is that the participant must take part in deciding how these tools are to be used. This is crucial to the process of invention. At the same time it is my job as the person presenting this experience that I create scenarios in which it is likely that the experience will be had. Giving the user complete free reign will likely lead to too many unintended places. The secret is that the medium subtly directs the user on a path of least resistance to a range of favorable behaviors. When the user arrives at the end of that path they should feel as though it was their own impulse that got them there. For this reason, the instruments and installations I produce have no clearly intended method of use. They do however have particular capabilities that the user can discover and utilize. The variety and contrast of these capabilities are what inspire the user as well as lead them toward certain results. I should mention that I still consider these to be personal artworks and not simply tools designed to effectively perform a task. There is a mindfulness to the greater intention of these tools in their design but also an indulgence in my own personal preference and creative style.

The following is an example of an installation that is designed to help participants experience non-durational music. I submitted this proposal in March 2014 for inclusion in a musical architecture project called Dithyrambalina taking place later this year in New Orleans USA. Some of the material is a bit redundant in the context of this paper but I have left it intact as it helps to illustrate the thought process behind the piece and gives additional context to topics I find consistently important in my work.

3.4 Work sample: Saeluhouse

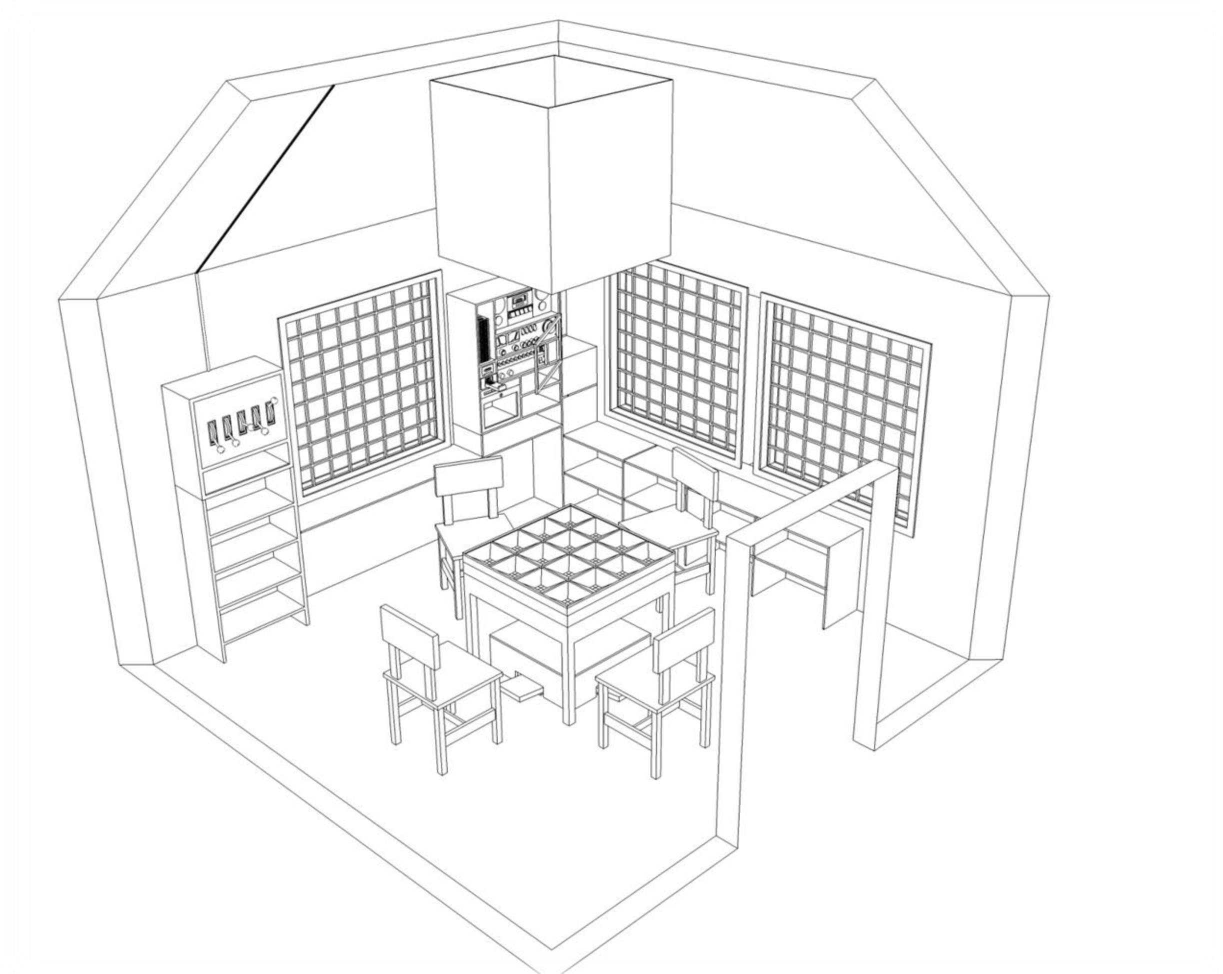

Figure 32. Cutaway of Saeluhouse installation.

Concept

The Saeluhus or “happy house” is a simple structure found across the mountain ranges of Iceland, put in remote locations to aid lost travelers. It offers basic services such as warmth, nourishment and a place to rest. There is an awareness of our common frailty displayed by the very presence of these buildings. Anyone regardless of race, religion, finance, etc may at some point find

Figure 33. Icelandic Saeluhus emergency shelter.

themselves in a losing battle with nature, and the presence of a happy house could save their lives.

But the name “happy house” implies something beyond simply staying alive, humans find happiness beyond their ability to survive. We are driven by an unceasing need to create order and to invent. In this act of invention, we find structure, satisfaction and a particular kind of resounding happiness.

Throughout history, and across cultures, making music has been a remarkably common act of invention. The creation of music is where I and countless others, find a degree of satisfaction beyond our mere ability to live.

The project I propose is inspired by the “happy house” and is a musical instrument, in a musical room each designed to bring the power of this inventive act to new levels and to new audiences. When a visitor chooses to invest time and attention into the space they will discover an environment as bizarre, complex and expressive as they are. But involvement must be a choice and discovery must be continually possible (and likely) in order to capture the interest of the new user as well as reward the focus of the experienced user. This interaction allows genuine human expression to emerge, which is the essence of music making.

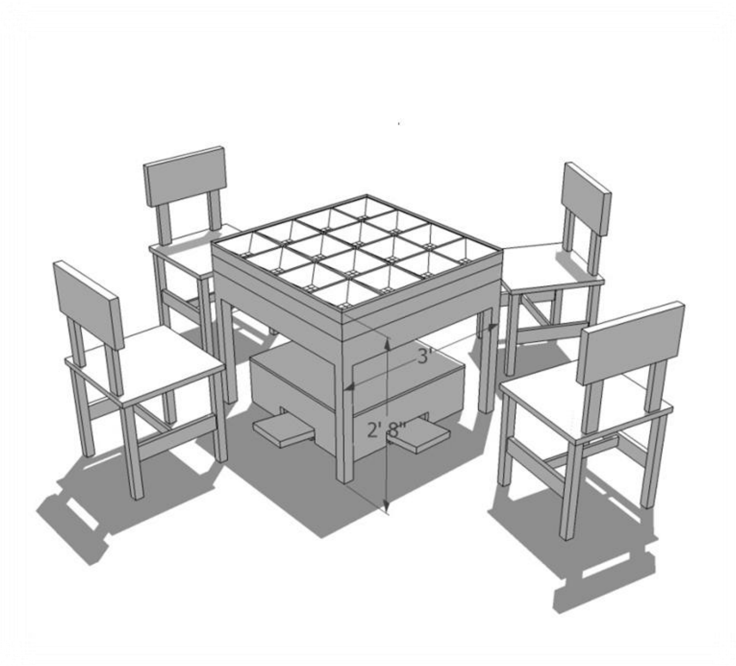

Figure 34. Detail of table

My main goal, above all, is that this piece is fun to use, and I would like the fun to come from something deeper than novel tech tricks or conceptual content. I wish to facilitate the process of making music with others and collectively celebrate our natural desires to learn, invent and share.

Overview

Saeluhouse is a small, free standing building roughly 13’ square and 16’ tall. It should look hand-made and utilitarian but with subtle decorative embellishments.

Inside the room is a small table and 4 chairs. A spot light is tightly focused on the table top. Several large speakers are mounted into the ceiling around the spot light.

Two control boxes sit at eye level on the farthest wall.

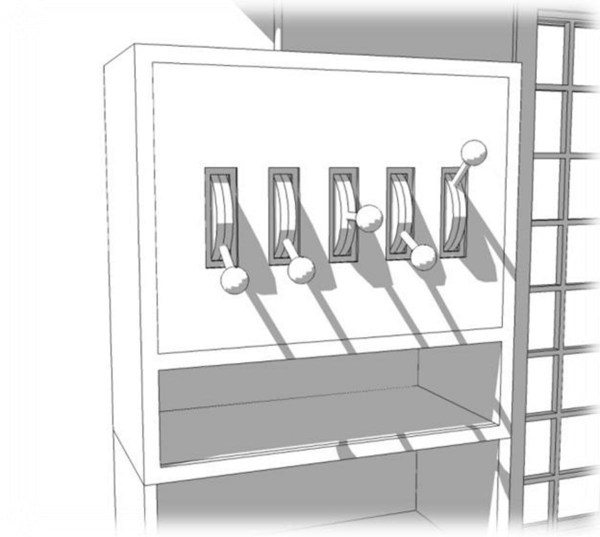

Figure 36. Lighting control levers

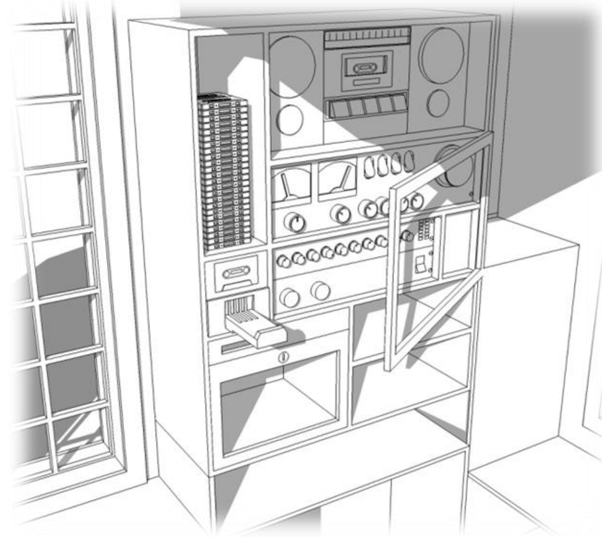

Figure 35. Sound system and coin operated tape dispenser

The box on the right holds a coin operated cassette tape dispenser and a boom box, the box on the left holds several industrial hand levers. The walls are lined with shelves containing books and various supplies, the purpose of which are explained below. Unimposing signage indicates that there are foot pedals beneath the table, which can be stepped on.

Stepping on the pedals activates a complex sound pattern generated by an analog modular synthesizer hidden within the table. The sounds at first seem chaotic and otherworldly. Bringing to mind old sci-fi movies or a robotic rain forest. Like a rainforest, there is in fact a tightly woven order in the chaos, which becomes apparent through prolonged listening.

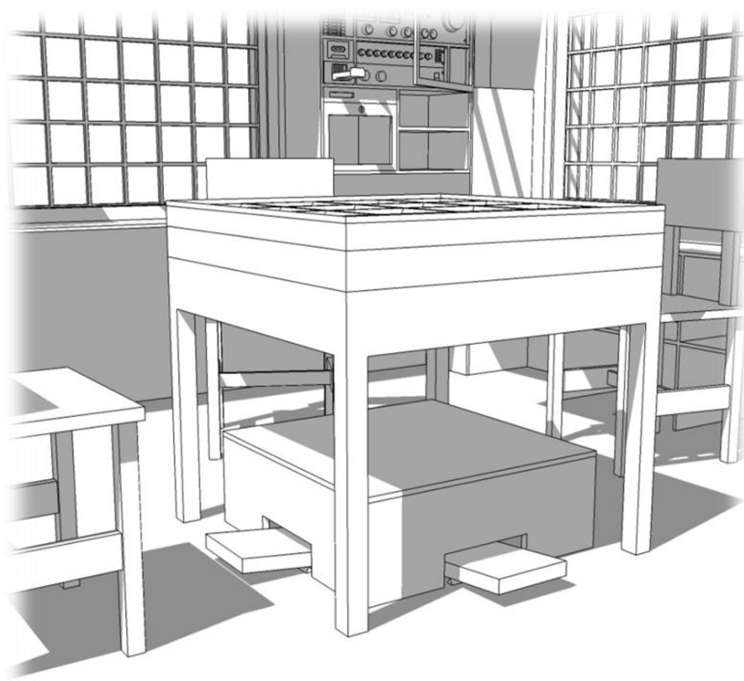

Figure 37. Detail of volume pedals under table.

Placing your hands over the table reveals that the light falling on the surface controls various parameters of the sound. The sound pattern can then be played by carefully

moving your hands over the surface while fading the volume in and out with the foot pedals.
Wild changes in the sound can be triggered through erratic movements while very subtle changes can be made with delicate gestures.

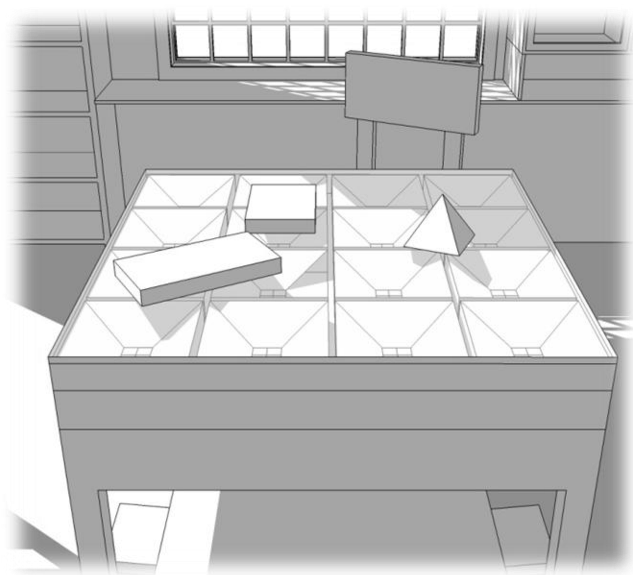

Figure 38. Objects on table obscure light sensors, changing the behavior of the system.

The more adventurous users may begin experimenting by placing objects on the table in order to create and hold different patterns.
This will in effect "program" the sound generator to function in certain ways depending on how many objects there are, their size and translucency and how they are arranged. A search of the room will reveal numerous other light sources such as laser pointers and strobing flashlights which can be experimented with. Even personal items that the user has with them can be used to modulate the sound, like their phone. An interesting use of an item like this would be to experiment with the sounds created by placing their smart phone on the table while playing a movie clip or turning on its strobe light. In order to facilitate this discovery, a QR code would be visible on the table, that when scanned, will open a streaming video that has been made specifically to interact with the table and containing instructions for its use. This will assist the users in realizing additional possibilities that they may not have initially considered.

Moving on…..

If one decides to explore further they will likely find that the big, inviting hand levers to the left of the window temporarily change the behavior of the spotlight when pulled. The light can be dimmed to allow alternate sources to be used such as phones, bike lights, candles etc. And more exciting lighting effects can be activated as well, such as pulsing patterns and sound controlled brightness.
To the right of the window is a coin operated cassette tape dispenser as well as some general audio equipment.

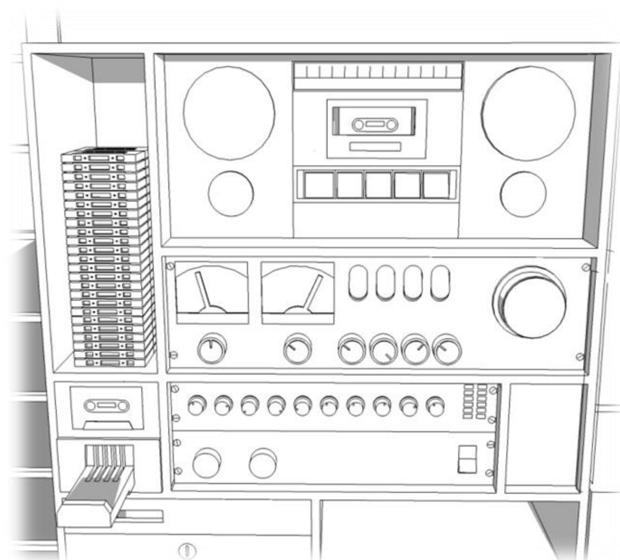

Figure 39. Detail of sound system, boom box and tape dispenser.

The majority of this is locked off from the public. The controls can be made available for maintenance or for special guests.

These tapes can be purchased and placed in a boom box next to the dispenser. Pressing "record" will capture all sound in the room. Pressing play will broadcast any recordings on the tape out to the main sound system. People are free to make recordings and take them home. They are also encouraged to leave them behind for others to listen to, draw on, collaborate with, etc.

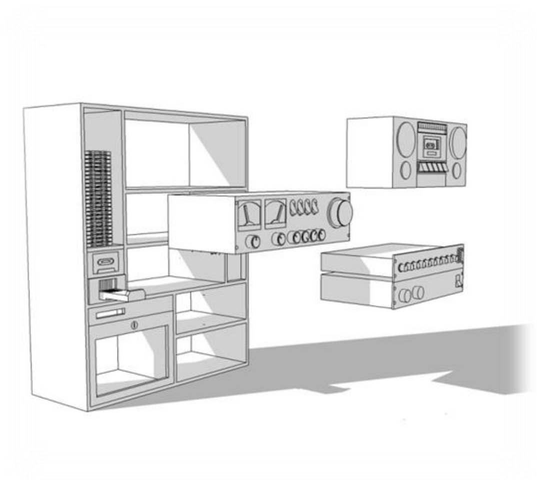

Figure 40. Detail of sound system components.

To aid in this sense of collaborative potential and history, materials for making various forms of documentation have been placed throughout the room. Notebooks, chalk boards, writing implements are all supplied (and restocked if necessary) for visitors to use.

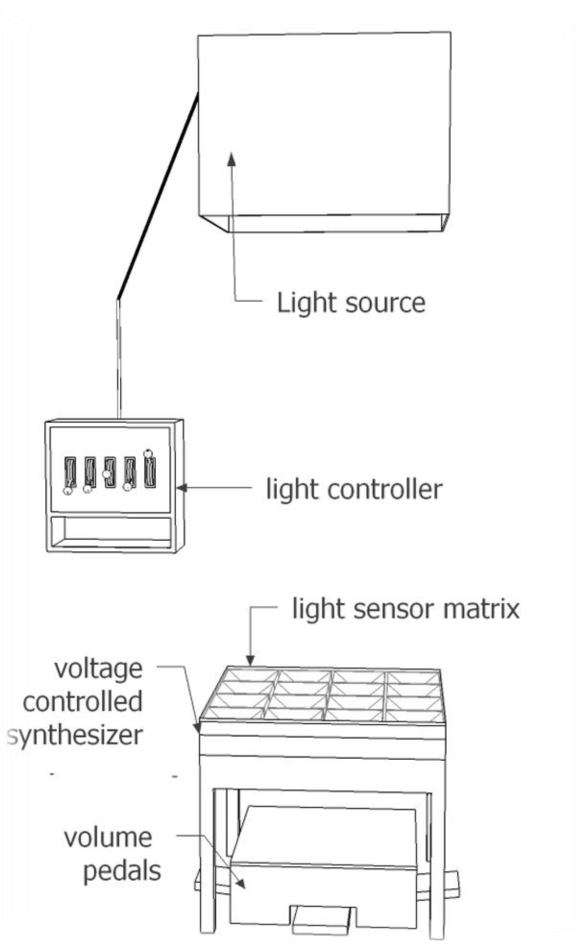

Figure 42. An analog modular synthesizer housed inside the table reacts to the light source above.

The Instrument

The official instrument in this project is pictured to the left. It is most simply played by pressing the pedals and moving your hands over the light sensors.
The sound generator is a voltage controlled modular synthesizer similar to the one pictured below.

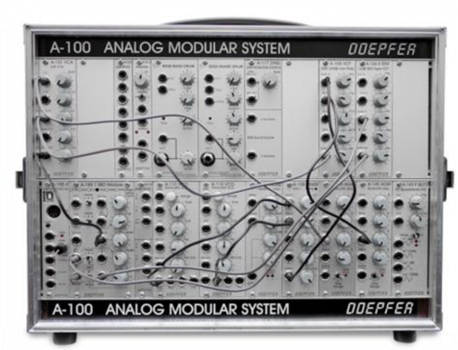

Figure 41. An example of a typical modular synthesizer.

The synthesizer itself will be concealed and its' many different parameters will be controlled by the matrix of light sensors.

LIGHT

While designing this instrument, I have tried to consider the fact that it will be accessed by the public and will function outside my initial expectations. I want to allow people to feel that they are having a unique and expressive experience where their own ideas can exist. Ironically this is not always best achieved by giving individuals lots of choices. A room filled with random objects will not necessarily produce more satisfying musical results than a room containing a drum set and guitar. The system must have clear rules within distinct capabilities and limitations. The user can then bend them if they like but the core rules should always be clear.
For this reason, I chose one simple rule: Changing the light in the room changes the sound.

Within that one rule is a vast range of possibilities; any light source will work. There will be custom room lighting engineered to exploit the capabilities of the sound synthesizer, but any other light source can be used. Each will inspire different behaviors from the instrument and the people playing it. Light is an interface that we all understand, and has as many different permutations as there are people who enter the room. But in any scenario it will be clear: change light, change sound.

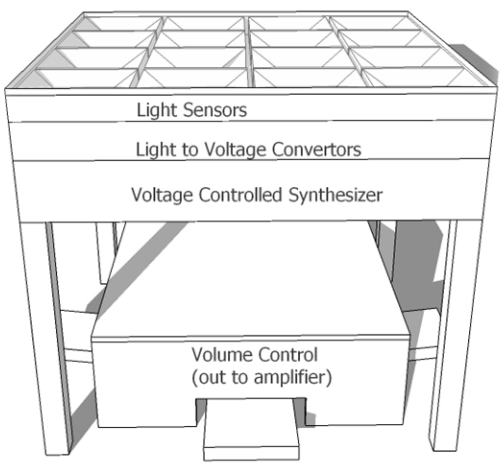

Figure 43. Detail of the table.

How it works

A grid of light sensors are embedded in the surface of the table. Each sensor is connected to a circuit that translates the amount of light it senses into a varying voltage signal. These signals are then used to control the parameters of a voltage-controlled synthesizer.

Voltage controlled synthesizer

Anyone who has seen video feedback has experienced the complex and highly organized chaotic patterns that emerge from an initially blank image. A very similar effect can be achieved in the audio domain as well, using a modular synthesizer. While audio and video feedback are similar in nature, there is a much greater degree of control in the audio domain. Playing this instrument is the act of discovering and controlling feedback loops via its 25 light sensors.
In order for a chaotic feedback generator to function as an instrument, especially one to be used by the public, two things should be considered in the design:

1. It should be easy to generate and manipulate sound; every possible configuration of the parameters should result in a sound.

2. The generation and identification of specific types of sounds is possible but will require imagination and inspiration to achieve mastery.

Applying these considerations to a design results in greater playability. By experimenting and getting to know the system it is possible to create decisive musical events; virtuosity becomes a possibility.

CHAPTER 4: APPLICATION COLLABORATIVE SOUNDSCAPE

4.1 Intro

Collaborative Soundscape is a style and process of music making that puts the previously discussed topics into practice. It is a product of the physicality and functionality of the modular synthesizer. The organic behavior of analog electronics and feedback loops allow for the musician to explore and shift between roles of inventor, performer and audience. Like the work samples of the previous chapters, this chapter addresses a particular way that I am working with the concepts and physicality of the modular synthesizer. Unlike the work samples, I will not be illustrating a finite piece of work but instead will be addressing a philosophy and methodology that is unique to my personal arts practice and gives greater personal context to the topics of this paper.

4.2 Defining terms

Soundscape

A sonic representation of a physical environment.

In the context of this chapter I will define environment very simply as an expansive collection of interconnected systems and behaviors. While many aspects of these systems are difficult to comprehend and predict, particularly the ways in which they interact, there still emerges a character of sound or sonic signature of the greater environment which is relatively predictable.

In this chapter I will be talking about this sonic signature, methods of understanding and recreating its' origin and ultimately how to use this construct in the service of creating musical experience.

Collaboration

Collaboration occurs when two or more systems work together to achieve a single goal. This term implies intentionality; there is a desire to achieve a certain goal driving the systems.

I have used this term twice in this paper paired with, 'collaborating with circuits' and 'collaborative soundscape'. My intention in using this term is to challenge our common perception of the relationship we share with natural phenomena such as electricity. I further intend to highlight that there is a level of communication that can exist between man and circuit that we may not commonly consider and that interfaces such as the analog modular synthesizer can give us access to. By changing one aspect of the definition of collaboration it removes the implication of intentionality and makes the idea much easier to apply to electricity. Let us assume that when the collaboration starts the goal is not fixed.

As the collaborating systems act on their natural tendencies and behaviors they discover and transform a shared goal. The initial intention of a human may be to create music. When this person, which we will call the musician, collaborates with electronics in pursuit of that goal it is possible that the natural behavior of the electronics (which could loosely be considered the intention or goal) may show the musician something unexpected and inspiring. This leads the musician to manipulate the circuitry in order to accentuate or move away from that behavior which manifested as a new behavior and further inspire the musician. This is obviously a form of feedback loop as well as a common method of improvisation, both of which I consider acts of collaboration. This differs from human collaboration in that the emotional drive of the collaborators in a man/machine collaboration is obviously one sided. I have debated the use of this term many times for this reason but feel the idea of gaining inspiration from the nature of electricity justifies a slightly indulgent interpretation of the term.

Sonic signature

The most rudimentary purpose of hearing is to help us assess our surroundings and survive. Through the use of our senses we develop expectations of our environment and ultimately an acceptance of its behavior. This acceptance allows us to check when something is in or out of place and then selectively commit our attention, or else we would be consumed by a need to analyze every aspect of everything around us. When something happens that defies these expectations we are able to transfer our attention back and reassess the scenario. I call this the process of identifying the **sonic signature** of an environment. The signature of a beach is very different than a crowded city street. What one hears and pays attention to depends entirely on the expectations derived from the accepted signature. The sound of a crashing wave would demand little attention on the beach but would be cause for considerable alarm and focused attention if heard in a crowded city street. Similarly the steady murmur of a crowd demands little attention but hearing your own name amongst the voices will. What we hear is impacted largely by what we expect to hear which in turn is informed by the accepted sonic signature of our environment.

4.3 Oscillation and scale

All of the systems in our environment without exception are moving. Wind blows through the branches of a tree causing them to sway and bend, the earth rotates away from the sun, electrons spin from atom to atom. On every scale there is constant movement. When these movements repeat they are classified as vibrations. The regular beating of our hearts is a form of vibration, as is the movement of flowers toward the sun on a daily cycle.

What we perceive as sound results from the vibration of sensors in our ears. When these sensors vibrate back and forth 20 to 20,000 times a second within a certain magnitude range we perceive sound. Therefore it is common to think of sound in purely vibratory terms, especially in a particular range that our ears are sensitive to. What about vibrations that occur above and below this relatively small frequency range or modulating magnitudes that lack a clearly defined vibratory characteristics? Many of these cases may not be considered sound by conventional definitions but impact our sonic environment nonetheless. One cannot deny that the rising and setting of the sun impacts the sonic signature of our environment. In my home town on the east coast of the United States the sound of crickets increases to an overwhelming level every evening during the summer months and fades away as the sun rises each morning. At what point can we say that a repeating movement can no longer be heard?

A term that I find more appropriate than vibration when considering soundscape is **oscillation**. Oscillation is a repeating pattern of magnitude modulation. Oscillations often manifest as mechanical vibration but not necessarily. They can also exist as the modulation of non mechanical magnitudes like light and heat, or on a more conceptual level. This is relevant to consider as I work a great deal with oscillating voltage levels. An oscillating voltage level results from vibrating electrons but is not vibration itself. It is a representation of potential. By talking about oscillation rather than vibration I am able to consider all forms of modulation in an environment that contributes to its sonic signature. Furthermore I am free to consider the impact of oscillation on all scales and not just those we define as audible vibration.

4.4 Circuits as organisms/synthesizers as ecosystems

Figure 44. Screen shot from Walt Disney cartoon Playful Pan. 1930. This scene shows pan playing his flute while mushrooms, flowers, apples and worms dance and sing along.

The flow of electricity is an organic process dictated by natural laws. A circuit designed to perform a specific kind of work can be seen as a collection of natural behaviors that share a goal. In the modular synthesizer a collection of circuits with a shared goal is called a **module**.

Similarly, living organisms can be seen as collections of natural behaviors that collaborate to ensure the survival of the organism. In an ecosystem these internally dictated behaviors are influenced by the other organisms and systems in the environment which they themselves are contributing members. This results in the character and sonic signature of the environment as I discussed above.

Given this similarity I choose to view the modular synthesizer as a programmable ecosystem comprised of interlinking organisms. The organisms have internally established behaviors such as oscillating or filtering audio signals which can be impacted to varying degrees by external behaviors through voltage control. Following this line of thinking it is no great conceptual leap to consider this ecosystem as an environment and the sonic output as a soundscape

This brings me to the key concept of Collaborative Soundscape as a musical process. Unlike the natural world around us, the relationship of the organisms in a modular synthesizer can be modified to serve a single agenda and do so in a musical time domain.

Figure 44 shows a screenshot from a Walt Disney cartoon released in 1930 called Playful Pan. Throughout this scene various aspects of the natural environment dance and sing with a shared musical voice. Of course the natural world doesn't work this way. The clashing, unforgiving struggle of each organism to accomplish its unique goal is characteristic of our natural world.

Collaborative Soundscape is in essence a method of realizing the fanciful vision of the natural world shown in Playful Pan. It gives us the tools to establish an ecosystem of interlinked organisms as well as the ability to determine and modify the origin and degree of those links in real time. We are free to impose a greater intentionality on any of the organisms in the system. At the same time we are also free to behold and gain inspiration from the behavior of the ecosystem. This is where the term **collaborative** is born. As the musician engages with and becomes a part of the ecosystem there is potential that their goals and intentions can be effected by that system. The complexity of an interlinked modular system often renders wildly unexpected and unpredictable results. Attempting to minimize this unpredictability is denying one of the greatest resources this medium has to offer.

CONCLUSION

Throughout this paper I have pursued two primary goals.

1. Exploring the origin of my artistic practice and the context in which I utilize electricity in this process. This exploration is based on a three dimensional ‘real world’ model of analyzing the inseparable nature of force, mass and time relative to my topic. In the context of art I have defined these variables as concept, object and experience.

2. Upsetting common conceptions of electricity as an incidental power source while encouraging a consideration of the organic nature of this phenomena that can be valued as a source of inspiration.

The common disregard for the behavior of electricity is in large part due to the ubiquity of digital technology that serves as a primary representation of application. In the interest of greater speed and increased functionality every attempt is being made to minimize the physical and phenomenological characteristics of electronics.

It is my opinion that this trend is being mirrored in the art world where the importance of form and other inherent phenomena is marginalized in favor of purely conceptual presence. As this imbalance spreads, the natural presence from which we have historically derived our inspiration is being collectively neglected. As a result the presence of sincerity and inspiration has fallen behind our need to produce art and artists are forced to synthesize sincerity in order to deliver concepts.

As an artist, it is my desire to investigate what I feel is a universal compulsion to engage in the act of invention. This act is based in a search for visceral, inexpressible physical/emotional experience and the opportunity to express one’s ability to intelligently engage and deduce. I have found that the combination of music and electricity gives me access to an abundance of these experiences to an extent that will never be exhausted in a single lifetime.

As digital technology steadily integrates into so many aspects of our lives I feel it is important to maintain a connection to the physical phenomena that drives it. I would like to restate that the flow of electrons is in fact an organic process with as much potential for engagement and inspiration as paint, wood, stone or any other traditional medium of artistic expression.

Finally, at the intersection of humans and circuitry, there can exist a shared product of the two which moves, breathes and evolves as the malleable behavior of each reflects off the other’s ingrained and inflexible nature. In this case, nature is the system of electricity creating balance along with man’s drive to find and manipulate balance to make art.

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Figure 45. Pen and ink. Edwards, 2012