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SHAPE
(Sound and Habitat Audio Prototyping Environment)

By

Jason Scott Cress

A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Philosophy

in

Music

in the

Graduate Division

of the

University of California, Berkeley

Committee in charge:

Professor Edmund Campion, Chair
Professor Carmine Emanuele Cella
Professor Ken Ueno

Spring 2020

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by

Jason Scott Cress

Abstract

SHAPE (Sound and Habitat Audio Prototyping Environment)

by

Jason Scott Cress

Doctor of Philosophy in Music Composition

University of California, Berkeley

Professor Edmund Campion, Chair

Sound and Habitat Audio Prototyping Environment (*SHAPE*) is a collection of nature-inspired electroacoustic devices created for sound art in public spaces. It is part of an audio feedback research project at the Center for New Music and Audio Technologies (CNMAT). By repurposing discarded electronics and manufactured objects, low-cost materials are used to make interactive sound sculptures and novel music instruments. Subtle gestures and actions by participants change the sound in real time.

The project attempts to question the dichotomy between sound art and common environmental sounds through a zero-waste, collective action framework. With *SHAPE*, natural and artificial materials converge; construction and deconstruction hold equal weight; raw materials reclaim another existence; and sounds from unusual sources expand into fully resonating bodies.

Audio transfer is based on two input types for each device: a piezoelectric contact mic and an electret air mic. These elements combine to sense both vibration in material and pressure waves in the air. Sound energy is then converted into an analog and a digital signal. Both analog and digital electronic environments are highly programmable, allowing for quick on-site prototyping.

Six devices from this project will be highlighted and described in detail. Aside from the PCB fabrication, smartphone, and case construction, all of the e-components for these devices can be easily found in old discarded speaker systems and reused. Proprietary devices such as the iRig are currently being used, but these will be reverse engineered for future open-access integration. Open-source software such as Pure Data and MobMuPlat make any Android or iOS device compatible with this system, thus facilitating second-hand use of virtually all smartphone models. Considering the portability and cost effectiveness of this project, *SHAPE* is particularly adept at facilitating outdoor applications such as sound installations or musical performances.

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INTRODUCTION

The initial idea for the *SHAPE* project came from a requirement to organize the discourse around six different instrumental prototypes I created during 2017–19. This document is in support of those physical instruments which my dissertation comprises. The first device, *Larsen*, was named after the Larsen effect formalized by Søren Absalon Larsen in the early 1900s. This effect is commonly known as audio feedback or “howling.” It occurs acoustically when a sound input sensor, usually a microphone, is in positive feedback configuration with an output, usually a loudspeaker. The result is energy accumulation at the resonant frequencies of the system. Because these frequencies increase in gain exponentially, they require immediate limiting or attenuation before the system becomes damaged.

Many musicians since the 1950s have utilized this effect expressively and dramatically in music. Jimi Hendrix is a famous example from popular culture for having created musical distortion by overdriving his guitar amplifier while in a positive feedback state. David Tudor from the sound art world made interactive sound sculptures by attaching piezoelectric inputs to acoustic resonator objects, effectively making an autonomous feedback network with emergent sonic behaviors.

My research at the Center for New Music and Audio Technologies is influenced by these past practitioners and has mostly focused on building novel instruments which facilitate spontaneous, collective sound art. Interaction, portability, and sonic autonomy are important considerations. Each of these elements implies substantial technical planning and design work. Other principal considerations include cost effectiveness, accessibility, and environmental consciousness. To address all of these abstract considerations, I propose audio feedback as a technical and metaphorical framework for the *SHAPE* project.

Naturally occurring, in essentially all processes, feedback is how sound and other phenomena evolve. It connects the end of a process to the beginning. “Positive feedback” and “negative feedback” are common terms used in many fields, but I use them loosely to describe any phenomenon that is cyclical or responsive to an input.

For example: a genetic trait that is not inherited by an offspring as negative feedback; a favorable (or non-favorable) social media post about a celebrity as positive feedback; or the persistent use of fossil fuels causing climate change as positive/reinforcing feedback. Feedback is a common feature of any interaction, which shapes the characteristics of a singularity over time. In sound, humans perceive singularities as “sound events” or “sound objects.”¹ As a result, it seems reasonable to apply the notion of feedback to these phenomena as well.

Acoustic feedback from an audio system is one way of intentionally generating autonomous probabilistic frequency responses from an electrical system. Pressure waves activated by a circuit can propagate through air or flexible material at many temperatures, thus

1 Brian Kane, “L’Objet Sonore Maintenant: Pierre Schaeffer, sound objects and the phenomenological reduction,” *Organised Sound*, 12(1) (2007): 15-24.

allowing direct physical human interaction. This scenario is substantially different, for example, than representing the pressure waves on a computer and changing the signal through software.

By arranging non-linear physical bodies or filters between an electrical input and output, dynamic and probabilistic changes occur in the overall sound. These changes are based on factors such as inherent acoustic resonance, inherent electrical resonance, distance of the input from the output, impedances or filters in between, and others.

Through experimentation, I have found that analog circuitry is more ideal than programmable digital chips in producing low-latency sound transformation, natural resonance, and subjective vibrancy. To explain this difference would require research at the atomic/electron level which extends beyond the scope of this project. I hypothesize, however, that electron flow through simpler component configurations allows for more saturation, accumulation, and varied distribution of electrons. A hybrid analog/digital system is likely ideal for music engagement. Triggering sound samples and other non-sound outcomes, such as coordinated visuals, etc., make digital software programs worth investigating as a complementary sidechain.

Therefore, by emphasizing the sound of electrons flowing through rudimentary analog circuits, coupling the signal to physical filter objects, and mixing in subtle digital playback of audio samples and visual GUIs, a rich and accessible interactive sound system becomes possible, giving way to new questions.

What if the system could be portable enough to fit in your pocket, simple enough for anyone to build, and cost-effective enough to be installed without theft protection? What if implicit social interaction or tacit knowledge could be leveraged to encourage spontaneous social gatherings around these devices? Could deep-level compositional decisions be made by anyone in a group, even during the flow of group expression? These questions are asked as aspirational objectives in the *SHAPE* project.

Comparisons drawn throughout this paper are meant to connect disparate fields of study and observations across jargons. “Positive feedback” and “negative feedback,” for example, are terms meant to be understood as generalized phenomena and not linked to any one discipline or practice. I will refer to particular fields of study when additional clarification is needed.

CHAPTER 1: AESTHETICS AND PHILOSOPHY OF *SHAPE*

Feedback as a Natural Metaphor

Use of the words “habitat” and “environment” in the *SHAPE* acronym (Sound and Habitat Audio Prototyping Environment) are meant to evoke a broad sense of human interrelatedness with nature and the project’s science-related underpinnings. “Feedback,” a well-known phenomenon in many scientific fields of study, is the primary design principle implied in all *SHAPE* works. By initiating continuous change inside a network, feedback is considered the cause of emergent systemwide characteristics, much like the frequency of an oscillator circuit or repeating pattern of a biological cycle. This phenomenon could be described as a kind of “flow” or “cycle” in any given timescale.

Some examples are described below by comparing natural processes to audio processes. Two natural processes concerning feedback, among others, are well-known in environmental science: fruit ripening and bird flocking. As self-reinforcing phenomena, these processes give rise to collective or cumulative effects, particularly from the perspective of an observer. I liken these natural processes to musical interplay, which is often “greater than the sum of its parts” in group performance. Sound amplification with electroacoustic systems can have similar effects when inherent resonances are explored dynamically.

Fruit Ripening and Feedback

In the example of fruit ripening, a positive feedback loop occurs. It begins with a single fruit which spreads a chemical to all other nearby fruit over days. The cycle is a chain reaction which slows and stops when all fruit in the area are ripened and decay sets in. Apples, specifically, follow a process of synchronization which is contingent on one apple initiating the transference of ethylene. Other nearby apples (and fruits generally) contacted with this airborne chemical begin to ripen rapidly and ethylene accumulates [Fig. 1, left].

The same positive feedback principle could describe an audio system configured in loop (i.e., loudspeaker pointed at microphone). Energy accumulation starts at a single resonant frequency and increases in gain exponentially until attenuated. The result is an acoustic tone [Fig. 1, right].

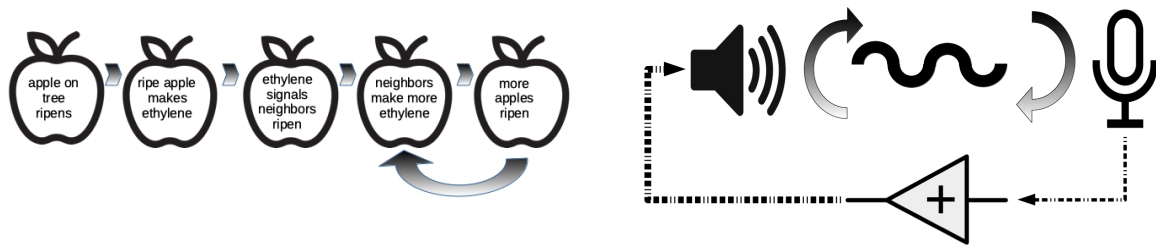


Figure 1. Left: apples ripening in positive feedback loop.² Right: audio feedback loop configuration.

Bird Flocking and Spectromorphology

Flocking birds also create cumulative forms based on individual flight patterns and basic rules [Fig. 2, left]. The rules governing these flight patterns are amalgams of simple individual reactions—small feedback loops—inside the flock. Each bird monitors the flight of its neighbors and responds to them by moving when they move. The ideal number of neighbors to watch for an individual starling is six or seven. This relatively low number of neighbors to monitor enables an individual starling to respond quickly to change and have relative freedom while maintaining group dynamics, called murmurations, amidst general uncertainty³. The result is a beautiful shape-shifting form in the evening sky. What if these relational dynamics could be applied to music improvisation or sound processing?

Pierre Schaeffer coined the term “sound object” in his 1966, *Traité des objets musicaux: essai interdisciplines*. Mostly referring to a listener’s perception of recorded sound within acousmatic contexts, he identifies salient features which begin, transform, and end in a particular order⁴. Much later, with the advent of computation, Schaeffer’s contemporaries go further in describing the “sound object” as a singularity of spectromorphological energy⁵.

2 “Positive and Negative Feedback Loops in Biology,” Albert, Last modified February 17, 2020, <https://www.albert.io/blog/positive-negative-feedback-loops-biology/>

3 George F. Young, Luca Scardovi, Andrea Cavagna, Irene Giardina, Naomi E. Leonard, “Starling Flock Networks Manage Uncertainty in Consensus at Low Cost,” *PLoS Comput Biol* 9(1) (2013): e1002894.

4 Schaeffer, Pierre, *Treatise On Musical Objects: An Essay Across Disciplines* (Oakland: University of California Press, 2017).

5 Denis Smalley, “Spectromorphology: explaining sound-shapes,” *Organized Sound*, 2, no. 2 (1997): 107–26.

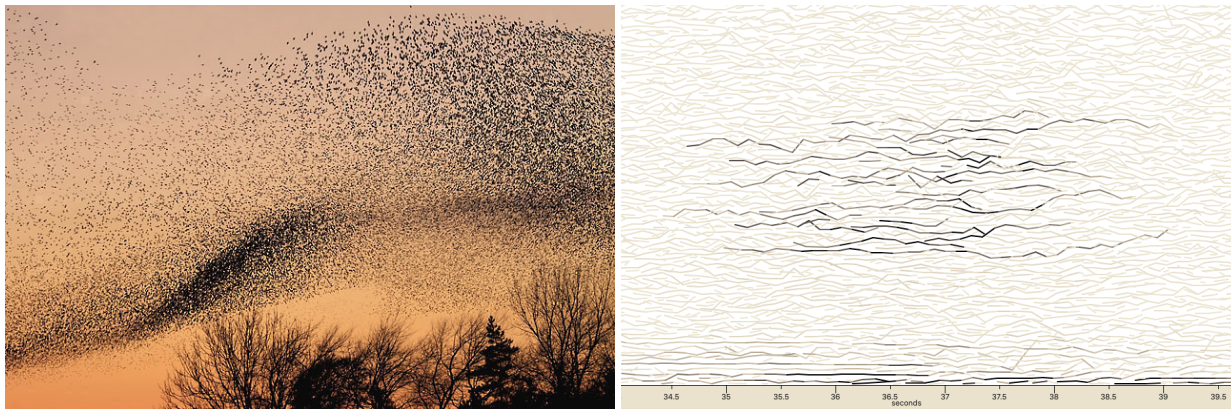


Figure 2. Left: starling flock patterns (murmurations). Image taken from [wikimedia.org](https://www.wikimedia.org). Right: spectral analysis of a cityscape audio sample with free software SPEAR.

Though different in application and context, bird flocking proportions could be used to generate spectral data maps and digital sound objects. In fact, many contemporary sound artists have already used this approach for sound spatialization and spectral transformation. The world and practice of “data sonification” comes to mind, particularly the work of Chris Chafe et al.

Usually, these projects involve real-time digital mapping from a non-sound source to a sound output. Variances in the data stream are represented and output to trigger sounds or transform them in a particular way. High-fidelity precision is often prioritized because research scientists are involved, and data integrity is key for analysis.

The *SHAPE* project is different, however. Precise calculation of spectral/timbral data is not necessarily prioritized, and analog audio is run in tandem with a digital sidechain. This hybrid system is preferred over a purely digital system because it offers more incongruence and unpredictability in timbre. The analog sound seems to “blur” the signal and create an ever-changing sonic texture with little or no effort on my part. Having both systems run in parallel and mixed equally offers both advantages at once. Natural resonance is apparent in the analog, self-reinforcing feedback loop side, while computational strategies are available in the digital environment, such as waveshaping, memory playback, and convolution. Having both technologies available for performance is likely ideal for musical exchange.

Musical “Ecosystems”

As the starling murmurations demonstrate, highly stable and complex forms can result from simple individual actions flowing together in a network. *SHAPE* mimics this phenomenon by situating murmuration-like parameters in a device for human-to-machine and human-to-human sound art. Physical filtering by people and digital processing by computers are used to define the flow of a semi-autonomous sound system which can be influenced by participants. Feedback is the “flow,” and participants’ gestures are the interference or disruption to that flow.

Music-like events in *SHAPE* are based on environmental resonances, human interaction, and simple computer programs. Acoustic resonance provides the immediate sound characteristic

and interactive potential, while the computer provides a memory bank for musical information. As participants interact with a *SHAPE* device, timbral changes occur via acoustic resonance in milliseconds. During this process, the computer identifies salient signal changes which cause more dramatic changes in the sound texture over minutes. Musical events are, therefore, self-generating with probabilistic resonance and contingent upon external forces to activate them at different timescales.

Before an event begins, the system is already producing subtle sounds. If passersby begin to notice the sounds, they can either choose to ignore or engage the device. If they decide to engage, most will attempt to influence the sounds with their hands or physical presence near the device. This change in external force interrupts the inherent resonance feedback flow of the device and causes a shift in the sound texture. It is an interplay of system feedback and human interaction. In other words, resonant objects are like complex oscillators and humans like audio filters.

Sound layering, a staple of most traditional musics, is produced between free agents in *SHAPE* when multiple devices or interfaces are within proximity. Improvisation and probability are the *modus operandi*. Rather than establishing a set of melodic or harmonic “schematics” to be enacted, musical ideas are directly linked to participants’ physical interactions. Therefore, “noise,” or textural complexity, is an integral part of the soundscape.

Traditionally, individual agency and freedom in music is afforded only to virtuoso soloists or highly trained performers, but not so in *SHAPE*. It is hoped that compelling and nuanced music can occur outside of conventional practices when a musically-oriented sound environment is designed effectively and open participation is default. This design practice is meant to encourage passersby from a variety of backgrounds to participate freely while exploring, listening, and influencing a *SHAPE* event.

CHAPTER 2: COMPOSITION AND PROCESS

Learning from Tudor's *Rainforest IV*

In a 1995 interview with Matt Rogalsky, David:

Tudor described *Rainforest* as a piece that 'teaches itself,' ...⁶

Below is an audio routing diagram David Tudor illustrated to describe basic assembly of *Rainforest IV* equipment. It is a visual guide for performers to build their own version of the electronic resonance system [Fig. 3].

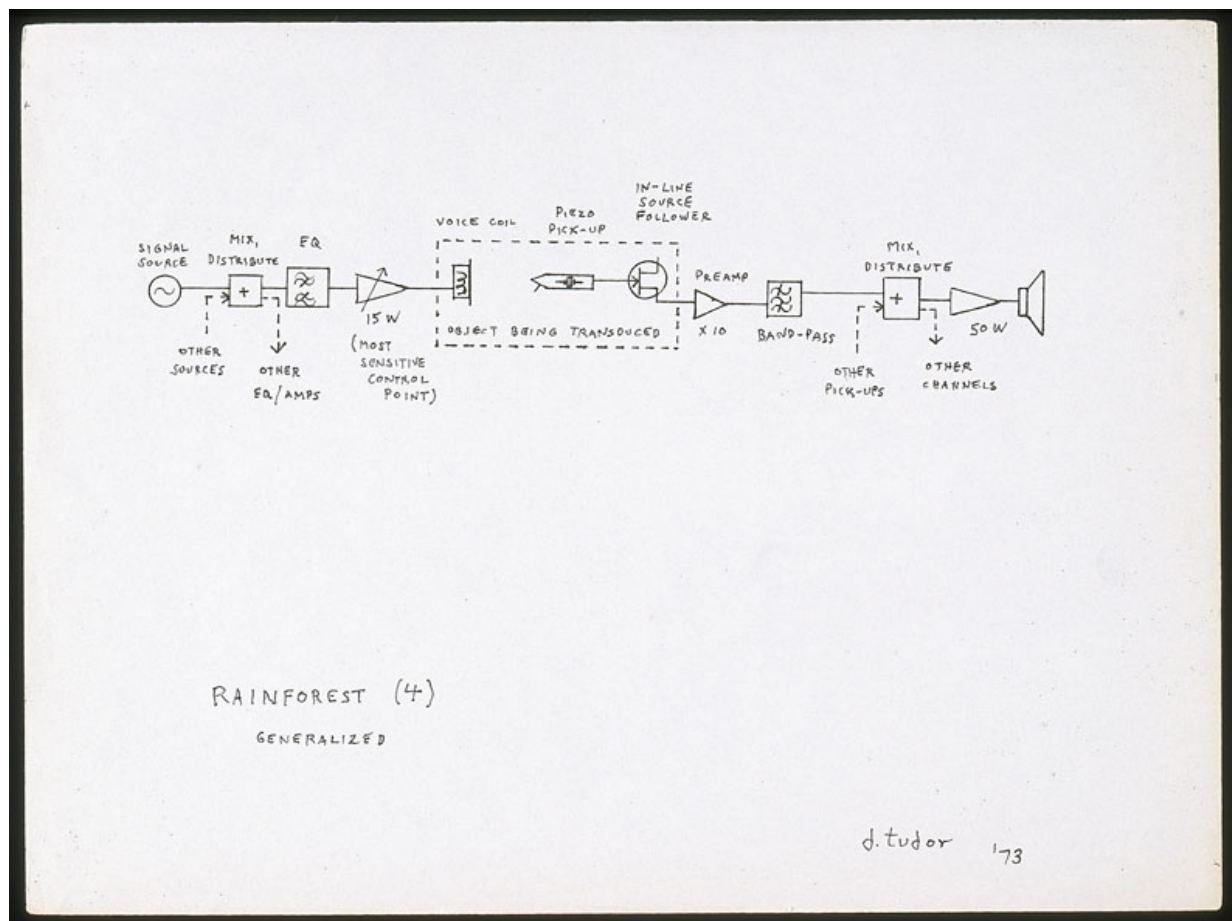


Figure 3. David Tudor's *Rainforest IV* (1973) (© Estate of David Tudor) audio equipment routing diagram. Image taken from davidtudor.org.⁷

⁶ David Tudor, Interview with Matt Rogalsky, 28 March 1995, Tomkins, Cove, NY. Published electronically at <http://www.jaimeoliver.pe/courses/ci/pdf/driscoll-rogalsky-rainforest.pdf>.

Modular Approaches

In many ways, I view the *SHAPE* project as a continuation of David Tudor’s work, *Rainforest IV*, to the degree that it liberates music to include new types and degrees of interaction by untrained participants. The above diagram is evidence of how a highly conceptual and open-ended approach can produce successful pieces of sound art. Rather than relying on written notation to communicate specific ideas with highly skilled performers, *Rainforest IV* engages performers implicitly without preformed notions of strict interactions or behaviors.

This interactive “openness” enables performance in a wide variety of situations and encourages people to construct their own version of the work by assembling electronic networks with audio cables, amplifiers, filters, voice coils, and pick-ups. The illustration below includes my annotations on Tudor’s routing diagram [Fig. 4]. Delineated are fixed and variable parts of the assembly, which exist inside the flow of an installation event.

7 “Tudor’s Electronics,” David Tudor: Electronics, accessed November 1, 2019, <https://davidtudor.org/Electronics/electronics.html>.

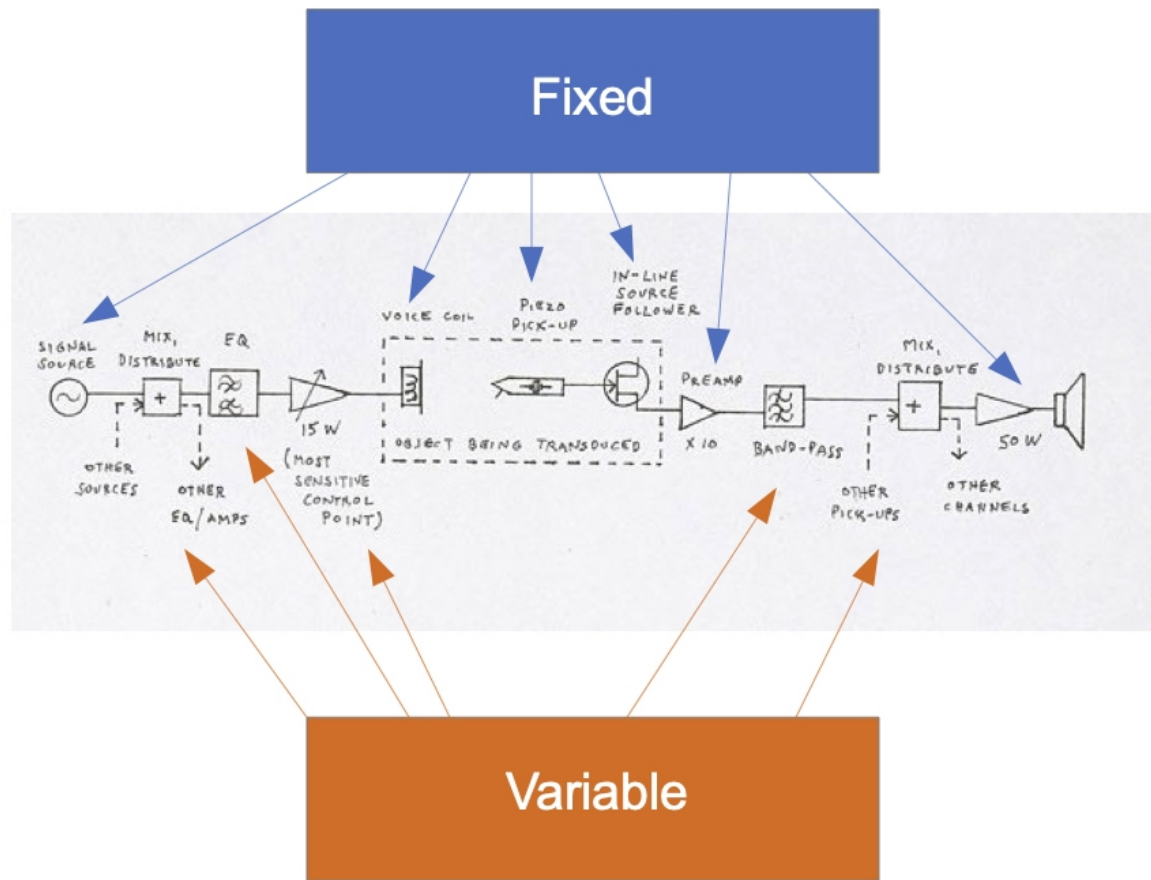


Figure 4. Annotated *Rainforest IV* (1973) (© Estate of David Tudor) audio equipment routing diagram inside an event flow.

Unlike most works of sound art or musical performance, *Rainforest IV* does not assume a completely fixed musical situation beforehand, technologically or musically. This work, instead, flattens the structure of decision-making by granting performers, technicians, passersby, and others permission to construct the work according to their unique preferences and constraints. Tudor's graphic instructions essentially function as a placeholder for future performers to realize their own version of the work. It is flexible, simple, and effective in conveying its potential. Tudor's work, only through a concept sketch, word of mouth, and recollections from collaborators, perpetuates dynamically to this day in art schools and galleries across the United States and Europe.

Key Situational Insights

As more performances and installations of *Rainforest IV* occurred, Tudor is known to have instructed participants to place their ear near a sculpture for listening or feel the vibrations of a resonating object in their hand or against their head. The atmosphere was meant to be

informal, and children were encouraged to participate.⁸ These activities were intended to encourage deeper listening and curiosity in people—a process that could last up to three hours.

Longer duration performances make sense, in part, because the setup time for an installation remains intensive which in turn justifies the long duration required for people to experience novel connections with the sound objects. Also, the technicians who assemble the sound network are integral to the composition and unfolding of the piece. History lessons taken from this work include: 1) explicit instructions are not necessary for dynamic musical interaction; and 2) the process of construction is a satisfying experience in and of itself.

Process as Composition

Since the 1960s, the idea of process as a work unto itself has been prevalent in various fields of study, especially literary pedagogy and visual art. Methods of instruction were coined “process” and “ecomposition,” essentially meaning process in lieu of composition. Later, this idea was adapted by artists such as Felix Gonzalez-Torres. The work *Untitled (USA Today)*, 1990, instructs participants to pick up individual candies from a candy pile, thus transforming the pile dramatically over time⁹. Visitor participation is essential to the work and directly influences its compositional form. This suggests that compositional form in any capacity or art practice could be developed in this way. Music composition, too (particularly like in Tudor’s *Rainforest IV*), could be synonymous with process and participation. I imagine instrument building and improvisatory participation in sound sculpture as similar to designing a musical score or other form of musical organization.

SHAPE depends on process and participation, in fact, within the context of interactive sound. By definition, *SHAPE* works are incomplete and prototypical until a musical flow event emerges with untrained participants. Once flow has occurred, a sound composition can end or continue as people decide. This usually assumes at least one person is active for a duration of approximately three or more minutes, and works rarely have a conclusive ending, as most are familiar with in music. The process of interaction counts *as* or *inside* the flow of a musical composition and flow states are linked together by the process of instrument building.

Musical Automata with Passive E-Components

Similar to (yet substantially unlike) the practice of conventional improvisation, I imagine that instruments have autonomous agency in the process of music-making. Just like a stringed instrument situates certain tones based on the length of string, *SHAPE* situates certain fundamentals based on system resonances. These resonances are activated with simple analog circuits and acoustic feedback. The feedback generates probabilistic tonal shifts which humans can influence.

8 “History of Rainforest IV,” Composers Inside Electronics, accessed November 20, 2019, http://composers-inside-electronics.net/rainforest/rainforest/RAINFOREST_IV.html.

9 Darren Jones, “Galleries Representing Felix Gonzalez-Torres are Editing HIV/AIDS from His Legacy: It Needs to Stop,” accessed November 28, 2019, <https://www.artslant.com/ew/articles/show/47997-galleries-representing-felix-gonzalez-torres-are-editing-hiv-aids-from-his-legacy-it-needs-to-stop>.

Given this ongoing sound generation, cognitive energy usually dedicated to things like percussing an object, blowing into a mouthpiece, or bowing a string is greatly reduced for human participants. In other words, participants have more cognitive space to enjoy and respond to the overall sound rather than both generating energy and shaping that energy. More focus can be placed on group dynamics, global sound characteristics, and individual contributions to the global sound.

SHAPE attempts to leverage these inherent interaction and tonal probabilities at the intersection of instrumental agency and human intention. My hope is that novel compositional structures (both musically and instrumentally) will emerge more often when people are encouraged to explore instrumental group sounds in this way and outside of traditional frameworks. Public sound sculpture or installation, being outdoors and/or in the path of many people, is particularly interesting to apply such ideas.

Building *SHAPE*

Inspired by David Tudor's simple routing diagram for *Rainforest IV*, I decided to draw the most simple concept of what defines a *SHAPE* device; below was my first sketch [Fig. 5].

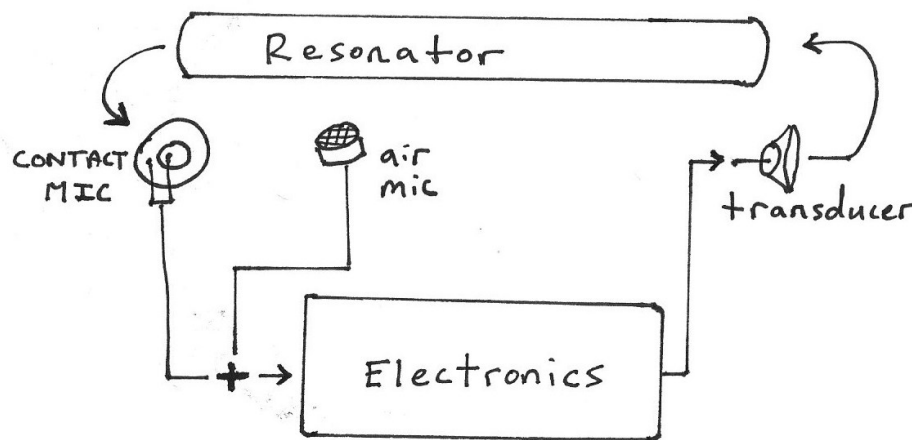


Figure 5. First sketch of electronic feedback archetype for developing *SHAPE*.

This diagram served as a framework for how I thought about building *SHAPE* devices, and helped clarify the basic functionalities of circuits and materials already available in-house.

The main considerations during the initial building process were safety, creative experimentation, and sourcing. Any building phase that became overly complicated was rebuilt in a simpler way. This “two steps forward, one step back” approach helped me think about how others might bypass the barriers that I was encountering. Such barriers included exposed electrification hazards, an ever-growing list of tools needed to test circuits, and costly materials.

Safety

Because working with electrical systems can be a dangerous endeavor, low-voltage/low-fidelity applications are prioritized in the *SHAPE* project. All circuits are built using small batteries and low power components, which mitigate most situations of getting “zapped.” Other safety issues arise too, however. Soldering, for example, poses significant health hazards to people due to toxic fume exposure and hot scalding irons. Breadboarding is the well-known alternative to this, which makes circuit building much safer, faster, and easier.

The advantage of breadboarding is that it enables solderless connection of electronic components with an easy-to-understand grid [Fig. 6, left]. Even though connection between breadboarded components is not as secure as soldered, it does provide a quick way to test simple circuitry and provides sufficiently secure connections for prototyping. Alligator clips are also useful for connecting components solderlessly [Fig. 6, right].

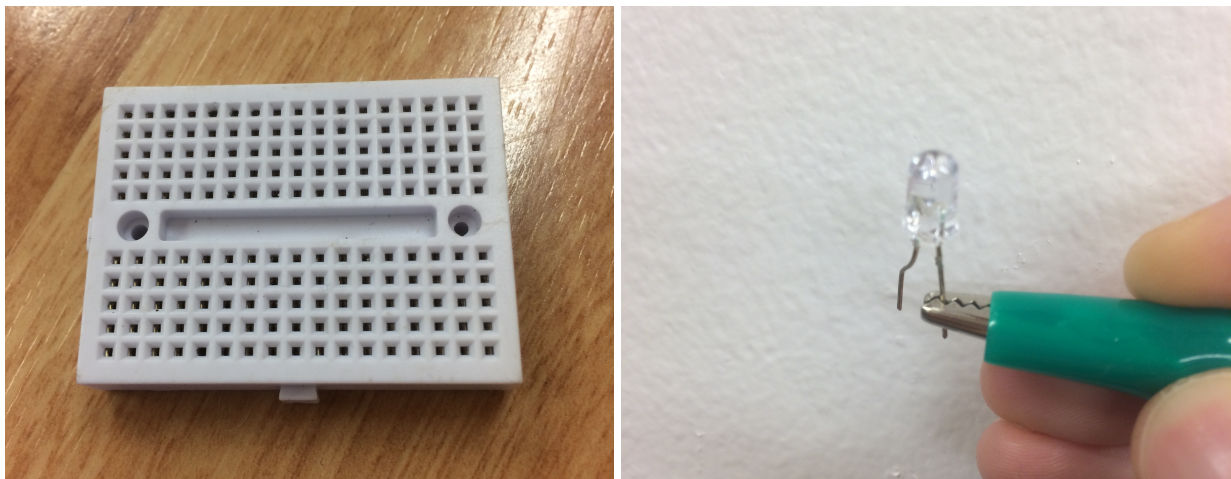


Figure 6. Left: small breadboard grid for connecting components. Right: alligator clip solderlessly connected to LED component “leg.”

Minimizing Toolkits

One of the many barriers that I encountered while building *SHAPE* devices was the seemingly endless list of expensive equipment needed to test and prototype circuitry. I took a mental note of this and actively sought to eliminate the need for expensive equipment like oscilloscopes in the *SHAPE*. The added benefit of reducing my toolkit was a more methodical, simplified, and effective prototyping process. Below is a photo of my reduced electronics toolkit (excluding a solder plunger) [Fig. 7, right].

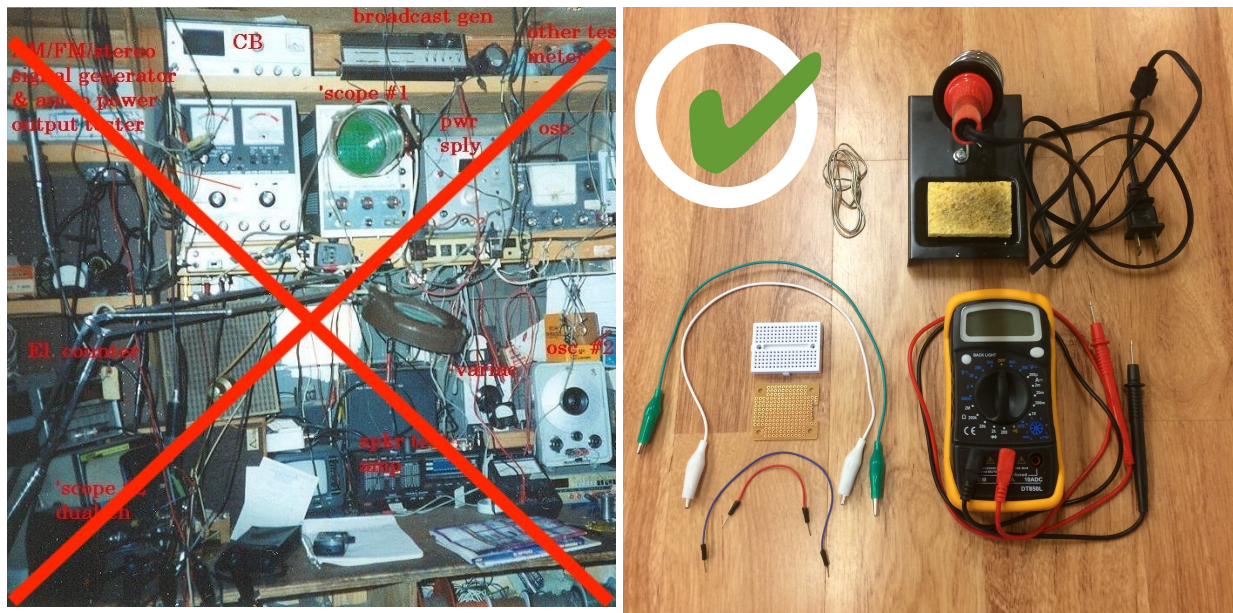


Figure 7. Left: a typical electronics work desk with expensive equipment (image taken from fleischerelectronicsservice.com). Right: simplified electronics toolkit for basic circuitry prototyping and troubleshooting only.

Because ready-made or easily made circuits are a priority in the *SHAPE* project, future builders don't have to waste time learning how to use an oscilloscope or other advanced equipment. For example, if a circuit schematic is already tested and applied, other builders will not have to worry about making precise measurements with expensive equipment because they already know that the circuit works and can freely begin building. Troubleshooting, in most situations, is all that is left to do, and it usually only involves continuity, resistance, and voltage testing. Troubleshooting can be done with a basic multimeter, reducing toolkit requirements to only a few units.

Additionally, if builders want to modify circuits, *SHAPE* accounts for this as well. Schematics are expanded to label regions or ranges of a circuit rather than a single specification. This increases expressive opportunities inside the circuit. For example, a voltage range, rather than single voltage, allows builders to manufacture and implement their own batteries or purchase multiple battery types instead of just one. Therefore, future modifications can suit a greater number of unique constraints.

Circuit benders like Reed Ghazala and Nicolas Collins label with ranges. David Tudor indicates “most sensitive control” on the potentiometer icon before the transducer. Flexible labels like this are incredibly helpful for other builders. This is why I wanted to do the same in *SHAPE*.

Internet access is, of course, another extremely useful resource in finding electronics tutorials and guides. In fact, without internet tutorials, many *SHAPE* projects may have been impossible for me to build. This presents another barrier to entry for some, so I plan on giving

away sound modules at future *SHAPE* events. Nicolas Collins' *Handmade Electronic Music* has been helpful as well¹⁰.

Some Experiments

Online circuit diagrams are plentiful, so I found a simple 9V bullhorn circuit diagram online, redesigned it (in Fritzing software), and breadboarded it with an LM386/electret configuration. Then, I built a different 9V LM386 amplifier for piezoelectric contact mic and tested it. Feedback in each case had vastly different sound results, so I was encouraged to experiment more with those circuits except with different outputs (i.e., transducers rather than loudspeakers, etc.).

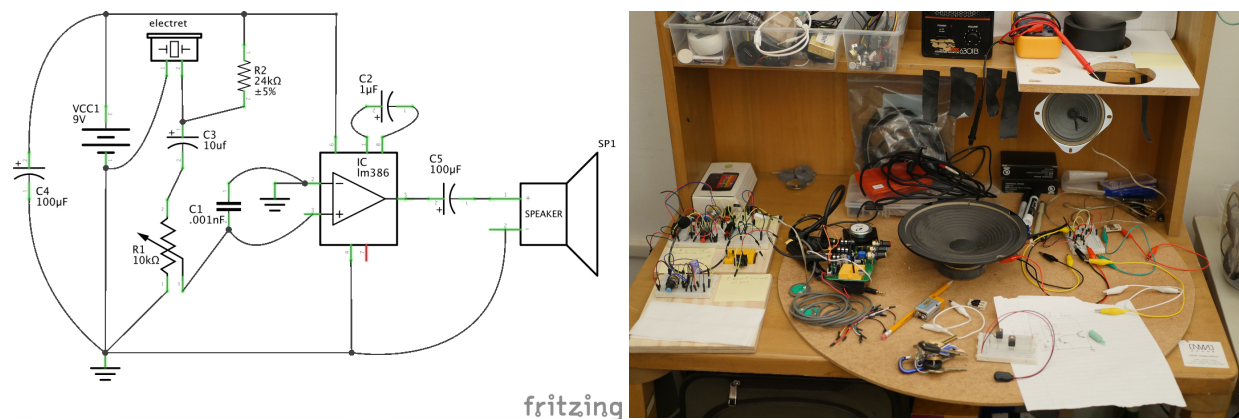


Figure 8. Left: simple LM386 electret amplifier circuit. Right: my work desk for building and testing circuits.

¹⁰ Nicolas Collins, *Handmade Electronic Music* (New York: Taylor & Francis Group, 2014).

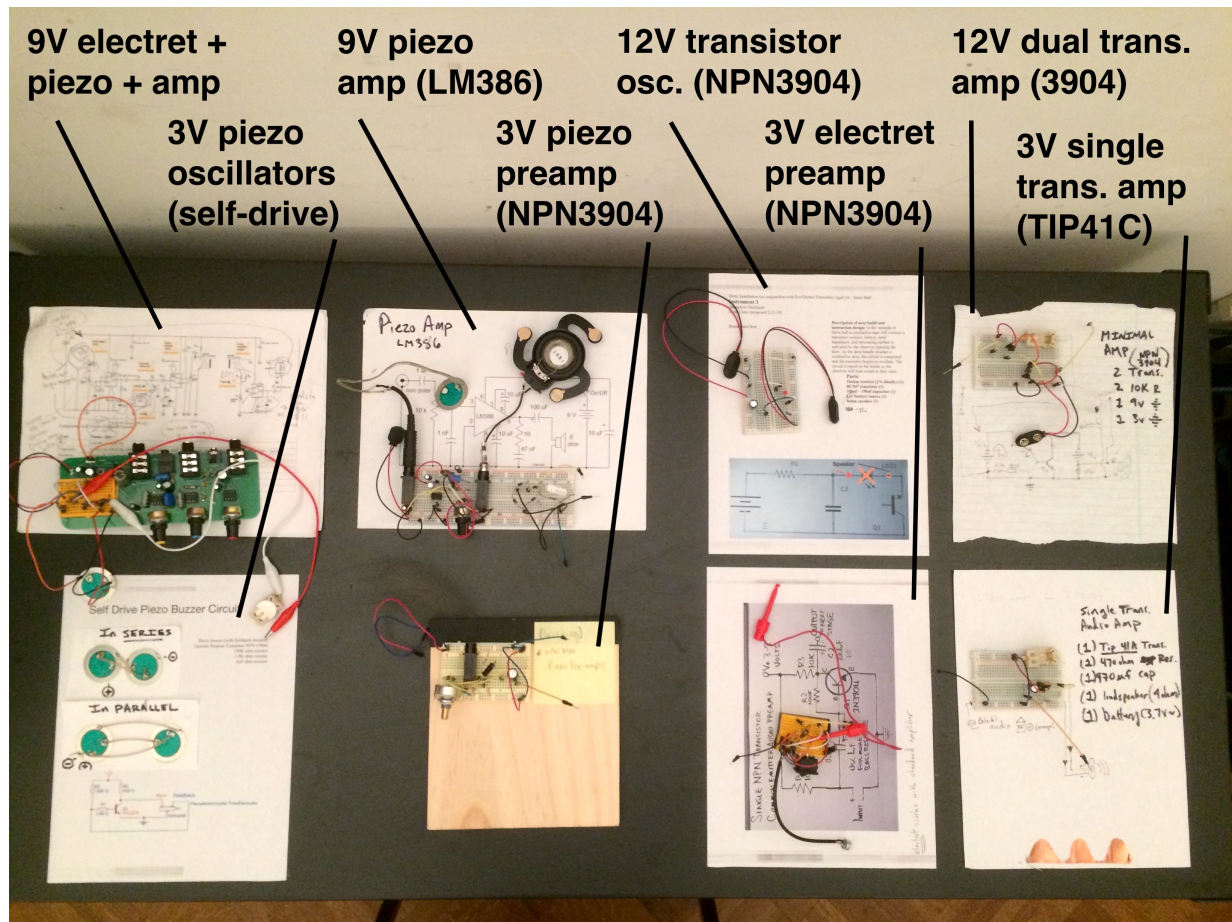


Figure 9. Various amplifier, oscillator, and preamp circuit experiments.

I wasn't satisfied with the proprietary nature of these components, however, and wanted to dig deeper. What if a mechanical/electric oscillator could be built with only household items and a voice coil? Below [Fig. 10, right] is an example of a homemade graphite 3V contact mic to a 3V battery to a transducer. Mechanical feedback occurred when the input physically coupled to the output.

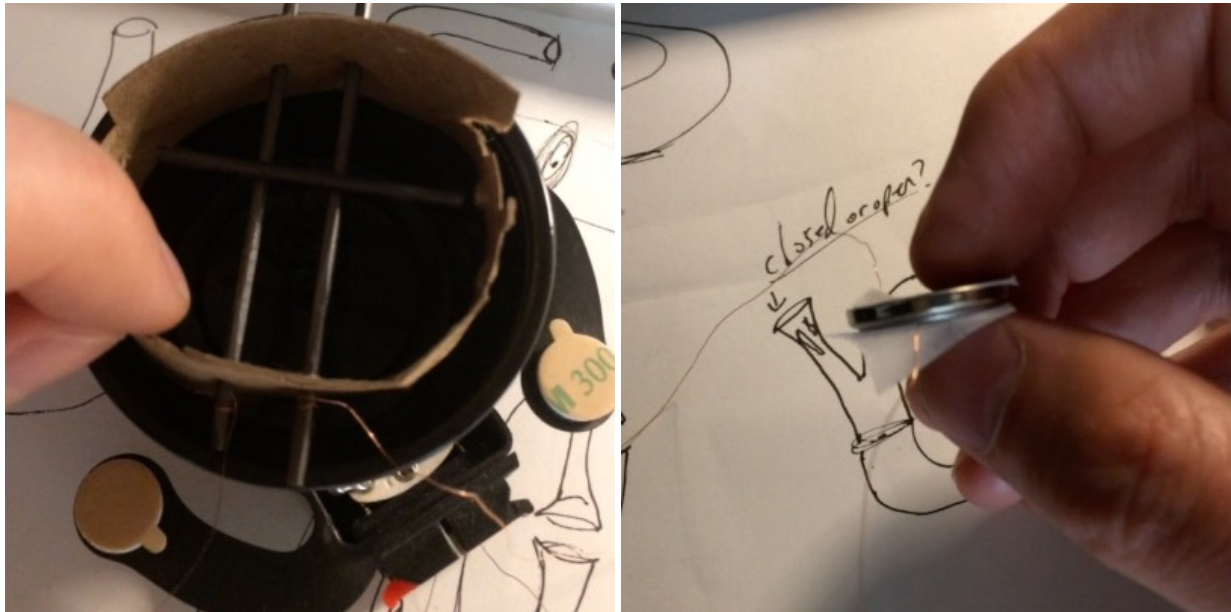


Figure 10. Left: homemade graphite contact mic to transducer. Right: 3V battery connected to circuit.

Encouraged by the basic functioning of these experimental circuits, I began to compile a list of possible non-proprietary electroacoustic application in my mind. I referenced Hannah Perner-Wilson and Leah Buechley's *Kit-of-No-Parts* as a guide¹¹. However, *Kit-of-No-Parts*, being mostly related to crafting, did not fit well for my purposes. It also assumes a degree of access to specialized conductive materials like conductive fabric and adhesives—both of which carry relatively high price points in craft retail shops. Instead, I sought to make practical circuits with truly free and available materials. Below [Fig. 11] are experiments with household items to find their electrical conductivity and resistance.

¹¹ Hannah Perner-Wilson, and Leah Buechley, "Kit-of-No-Parts," MIT Media Lab, accessed January 9, 2020, <http://highlowtech.org/?p=1069>



Figure 11. Left: testing an aluminum can lid for electrical continuity. Middle: testing coffee wire coil. Right: guitar string coil ohm reading.

All of these experiments were conducted in an effort to reduce the overall cost of making *SHAPE* devices. However, after many failed experiments, it became clear that even basic functionality requires e-components that are optimized and reliable. For this reason, I decided to accept proprietary e-components for future prototypes as long as they were either discarded or of low price.

Sourcing and Reusing Old Electronics

Circuit boards and the variety of components contained therein are surprisingly easy to source in almost any area. I found old circuit boards in e-waste bins around businesses, college campuses, and my own personal e-waste. The ubiquity of electronics worldwide is what makes them accessible for reuse. Below [Fig. 12, left] is a picture of my electronics storage bin system. Large bins to the left contain raw materials, smaller bins contain breadboarding/testing projects, and circuits at the bottom show new functional modules.



Figure 12. Left: discarded materials to useful modules. Right: module closeup.

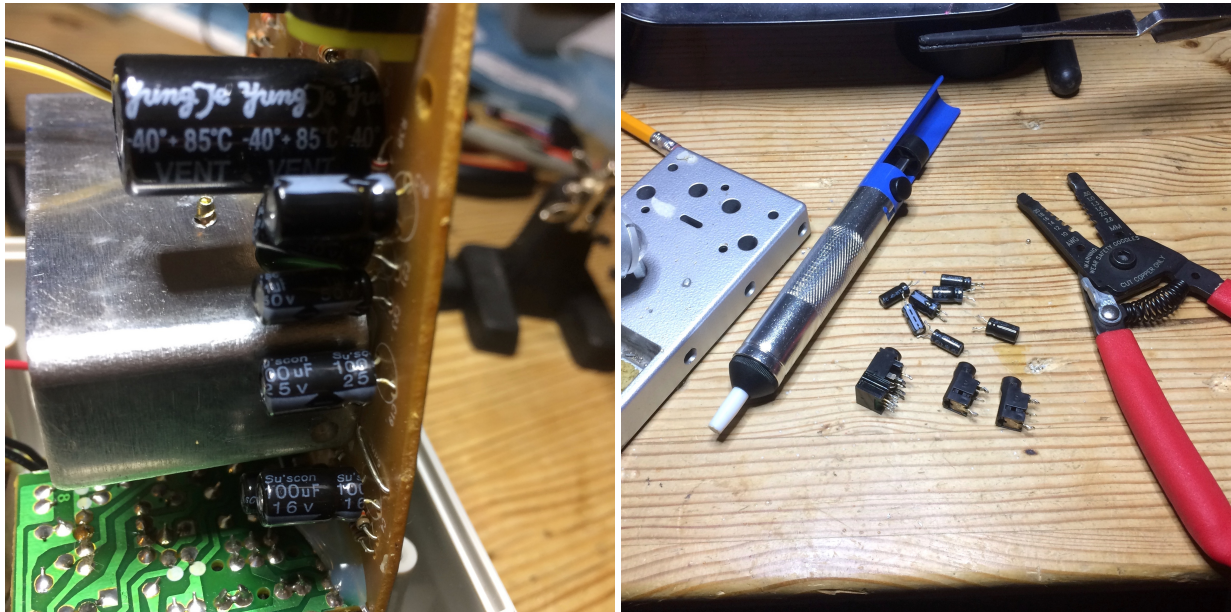


Figure 13. Left: old amplifier circuit board. Right: desoldered and extracted capacitors and audio jacks.

An old amplifier circuit board, which was salvaged from an e-waste bin, can be seen above [Fig. 13]. The capacitors and other components were perfectly functional, and some reintegrated into other circuit designs. Each component was tested for viability before reintegration.

Desoldering components like these involve heating the solder to its melting point with an iron or heat gun and extracting it with a solder plunger. Once all of the solder is removed from a component and circuit board, it can be extracted by hand and made available for use in other circuit boards. This process is tedious but worthwhile if one knows what to look for. All components should be tested with a multimeter before extraction. This will help mitigate future troubleshooting.

CHAPTER 3:
SIX INSTRUMENTS “IN SITU”

BLOOM

BLOOM (2019–present) is a self-drive flower circuit design. It generates resonant frequencies and LED light sequences continuously with feedback [Fig. 14].



Figure 14. BLOOM window oscillator in situ (CNMAT 2019).

It is an example of a semi-autonomous light and sound network that responds dynamically to light and vibration energy. Its repeating pitch fluctuations can be altered when participants change the light exposure with their hand or physical presence. The changes in both light and sound are recognizable and therefore offer a “proto-musical” application. In other words, this device might be viable as an instrument which complements other instruments. It is most likely not a standalone audio environment. Other devices would be necessary to contextualize this device as “musical.”

The distributed network of circular 3-electrode piezoelectric elements functions in a couple of ways. First, the mass of the piezo crystals arranged in parallel combine and slow the overall feedback frequency. Second, the photoresistive elements sense light which changes the resistance characteristics of the circuit. Default sounds are soft glissando-like high frequencies that repeat intermittently and smoothly as the electrons flow through the circuit. LED light sequences appear randomized, but correspond to the electrical characteristics of the transistor, changes in photoresistance, and mechanical sound energy.

Interaction and Installation

Attached to each piezo transducer element is a photoresistor, which functions as an interface. Resistance changes as participants place their hand over the photoresistor elements and subtly influence the sounds and LED sequences [Fig. 15].



Figure 15. *Interaction with hands and photoresistive light sensors.*

Resultant sound novelties such as “pops” and/or more angular sounds occur when a physical presence most likely a person changes the resistance. Light sequences also appear to change when a person has placed their hand over the photoresistors. This indicates that real change in electron flow is occurring.

Circuitry Experiments and Modifications

The distributed circuit design began after I found a simple self-drive buzzer circuit on Hackster.io¹². I modified the circuit by expanding the voltage range, integrating photoresistor and LED elements, and changing the transistor to NPN3904 [Fig. 16]. This modification extended the interactive potential of the circuit by providing more voltage flexibility (i.e., 3-5V), visual/sonic feedback for physical interactions, and more commonly found components such as the NPN3904 transistor. All of these changes represent a design orientation toward more accessibility in construction and function.

¹² Tauno Erik, “Self Drive Piezo Buzzer,” accessed February 5, 2020, <https://www.hackster.io/taunoerik/self-drive-piezo-buzzer-e9786f>.

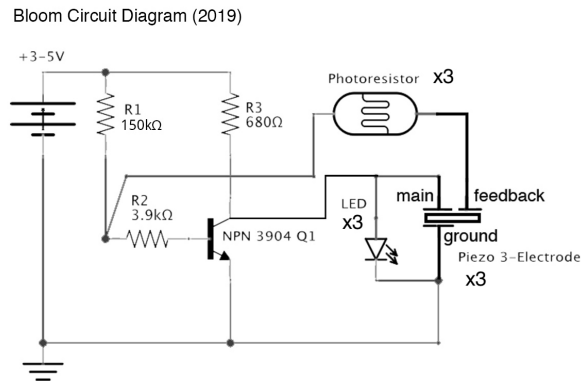


Figure 16. My modified and extended circuit design made with open-source software, Fritzing.

Testing and Breadboarding

Testing and modifying this circuit involved many iterations. The process started with an idea to sonify and illuminate the electron flow of a single transistor. Interaction was considered later, but photoresistors were available in my workspace, so I considered them a potential addition. Interrelated sound and light properties proved possible after connecting the transducer/LED network to the main circuit.

Piezoelectric crystal elements were soldered together in two main ways: “series” and “parallel.” Each of these configurations behaved differently when connected to the circuit. For this reason, I decided to isolate each configuration on a separate piece of paper [Fig. 17].

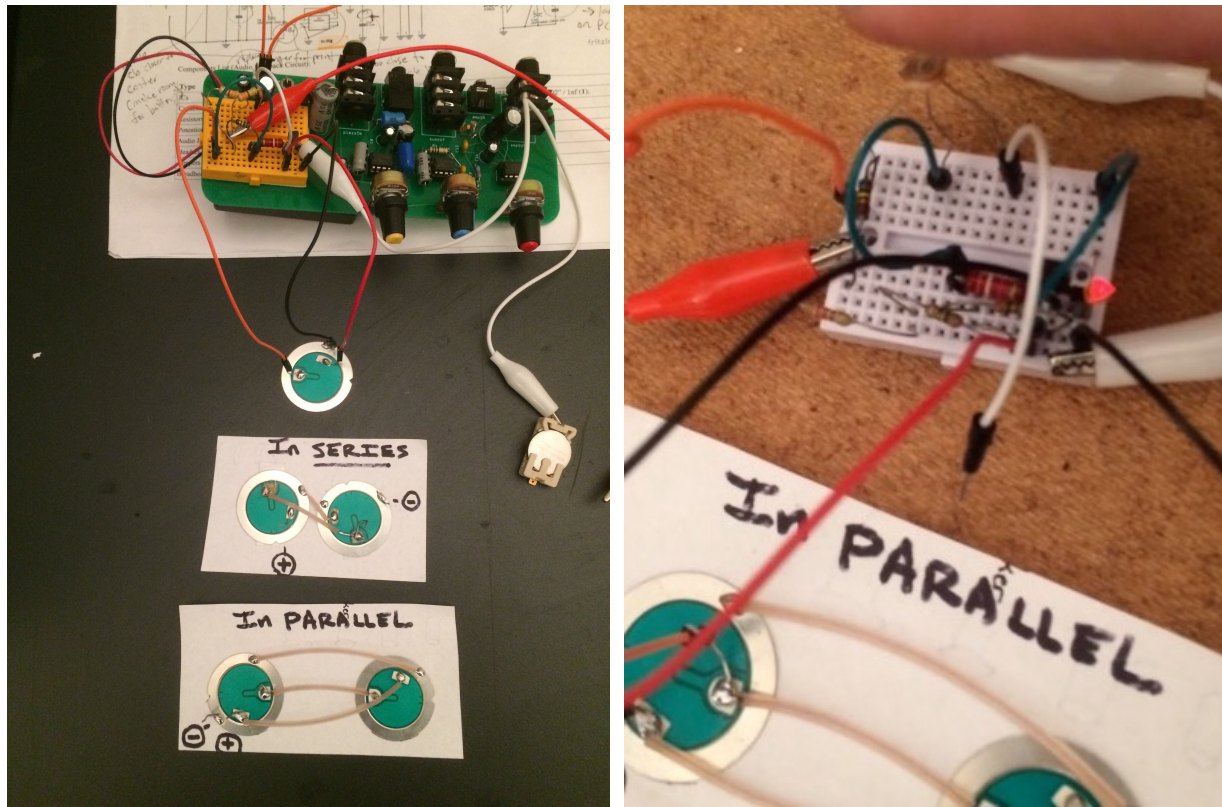


Figure 17. Left: breadboarded circuit with series and parallel transducer configurations. Right: further breadboard testing with added LED and photoresistor elements.

After numerous tests, I found that “double transducer” elements configured in parallel generate lower tones than “double transducer” elements configured in series. My hypothesis was that the crystal mass of each transducer combined (much like battery cells) when in parallel, increasing the size of the electron conduit [Fig. 17].

The simplicity of a piezo buzzer circuit is what drew my interest initially to experiment with its potential. Eigenfrequencies of the feedback circuit were leveraged to produce extraordinary behaviors and expressive opportunities beyond the original “buzzer” design. I like to think of the *BLOOM* circuit as a blueprint for the entire *SHAPE* project. It demonstrates how simple circuits can be expanded into multi-sensory systems and interactive environments. A digital diagram helped me conceive of and iterate the device’s arrangement without spending too much time with physical materials. I was able to build the device in one session [Fig. 18].

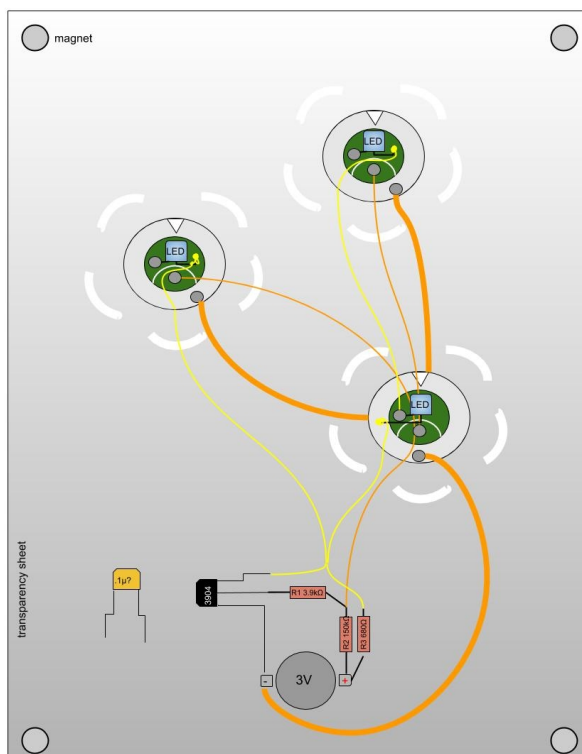


Figure 18. Left: arranging the BLOOM window oscillator digital diagram before building. Right: testing BLOOM circuit with alligator clips to battery.

LARSEN

LARSEN (2017–18) was the first prototype I designed and installed in 2017. It was an outdoor installation at César Chávez Park in Berkeley, CA. No car access was available and the site was quite windy. Installing there was a deliberate test of my equipment’s portability and durability. Setup only took about thirty minutes and I am proud to say that several people engaged with the installation without verbal or text instructions [Fig. 19].



Figure 19. *LARSEN* open cylinder audio waveguide in situ (photo by Jon Yu at César Chávez Park 2017).

How It Works

As I mentioned in the introduction, *LARSEN* derives from the Larsen effect formalized by Søren Absalon Larsen in the early 1900s. The phenomenon could be described as accumulation of inherent audio resonances when in a positive feedback state. In other words, an audio output is facing an input such as a speaker to microphone configuration which results in a high-pitched “howl.”

Far from “howling,” however, this installation situated acoustic feedback such that open pipe cylinders physically filtered emerging frequencies and software managed frequencies digitally. The frequencies were based on factors such as cylinder length and electronic flow. Acoustic energy was distributed evenly by arranging the loudspeaker inside an airtight case above the pipes. This caused pressure waves to be routed inside the pipes and to the microphone. Wave energy split at intersection angles of more than 90 degrees [Fig. 20].

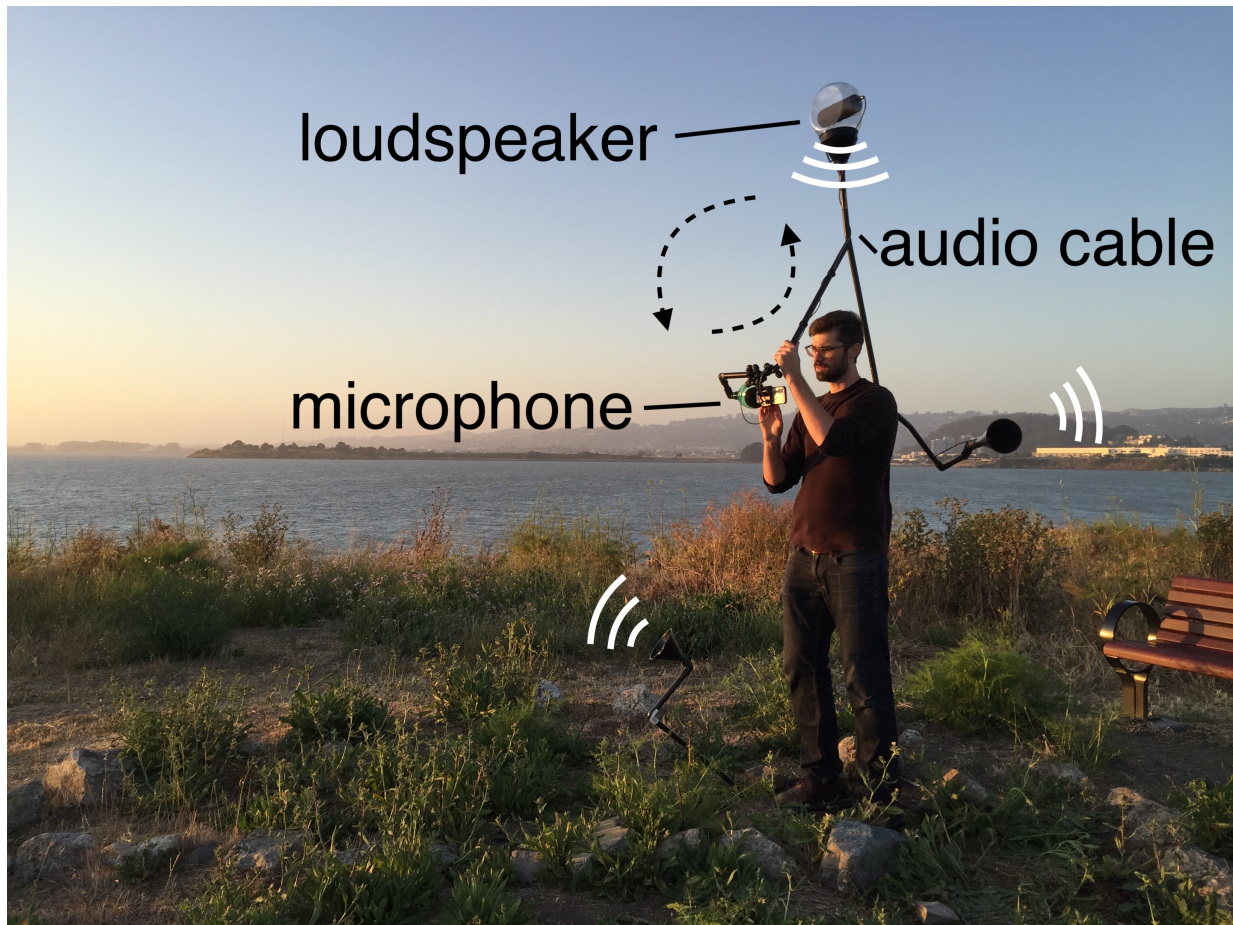


Figure 20. Annotated sound wave propagation in *LARSEN* park installation (photo by Jon Yu).

Interaction

Before building *LARSEN*, I had several criteria in mind for the interaction. First, I wanted to create a situation in which passersby felt guided in the process of appreciating environmental sounds. Second, I didn’t want to use words or dramatic gestures to suggest this. Third, cues should be based on intuition or “tacit knowledge” more than demonstration. Fourth, a temporary unsanctioned space in the park had to be established in order to avoid standardized etiquettes such as those expected in art galleries or concert halls.

The ambiguous visual design of *LARSEN* also avoids the expectation of traditional music. My intention was to encourage participants to focus on present interactions rather than subconsciously reenacting past experiences. I believe that the visual ambiguity of *LARSEN* was, indeed, confirmed after one participant asked me if the apparatus was for photography.

Upon arrival at the site, I constructed the instrument within ten minutes to begin the interaction phase. Immediately, the sound sculpting process started in semi-autonomous fashion, which cued passersby to listen. As people walked by on a nearby path, several stopped to listen for several minutes each. The environmental sounds seemed to be working in tandem with the instrumental tones and noises. During multiple moments, environmental tones from a bird, fog horn, and train harmonized with the instrument's drones. The subtle mix of these two different sound worlds seemed to center participant's awareness on the local sound environment.

After approximately thirty minutes, the sounds became repetitive enough to function as a delineation in the sound sculpting process. I decided to end the session by slowly fading the instrument's tones smoothly into the surrounding natural environment's sounds. Deconstruction of the instrument was quick, as there were less than ten parts and the pipe system was connected with snap joints. Originally, the pipes were designed as a soccer goal frame. The entire instrument could fit into two small tote bags. Careful separation of the hermetically-sealed speaker casing was necessary, but it was fairly easy to deconstruct as well. It was super glued together with a plastic fish bowl, oil funnel, and brass coat hanger [Fig. 21].



Figure 21. Left: soccer goal frame pipes which snap together. Right: fish bowl hermetically sealed loudspeaker casing.

Digital Management of Acoustic Feedback

Pure Data and MobMuPlat are the open-source softwares I used in *LARSEN* to filter feedback energy. The patch managed microphone input with a compressor, limiter, bandpass, and dynamic bandstop notch filter. The notch filter continuously scanned for the most present frequency in the signal and attenuated it in real time. Attenuation speed “ramp” and frequency sampling rate “sampleRate,” for example, were parameterized in the GUI on a smartphone [Fig. 22, right].

The “bandpass” slider represents a frequency spectrum of 100Hz to 3500Hz. Different frequency bands were boosted in gain by the corresponding slider. I used this to focus on different resonances and vibration characteristics of the physical cylinders. The “sampleRate” slider was used to change the attenuation rate in milliseconds. Eigenfrequencies were identified with the [fiddle~] object, thus quickening or slowing the accumulation of different acoustic tones.

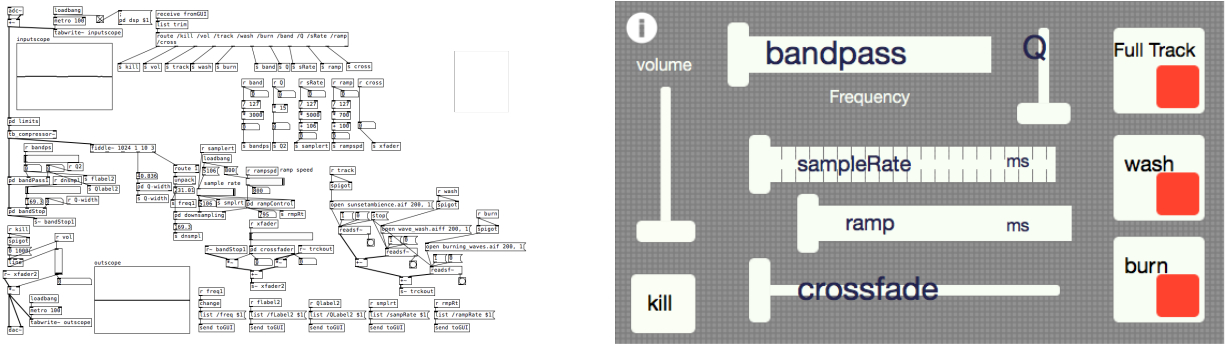


Figure 22. Left: Pure Data patch for processing sound. Right: MobMuPlat GUI interface for demonstrator or participants to influence signal dynamics.

The bandstop filter was not represented on the GUI interface because it ran a Fast Fourier Transform spectrum analyzer independently in the background. Its function was to identify the most present frequency of the signal and limit it with a notch filter. The rate of this limiting or attenuating “ramp” was controllable for humans through the GUI interface and created a music-like distribution pattern of eigenfrequencies [Fig. 23].

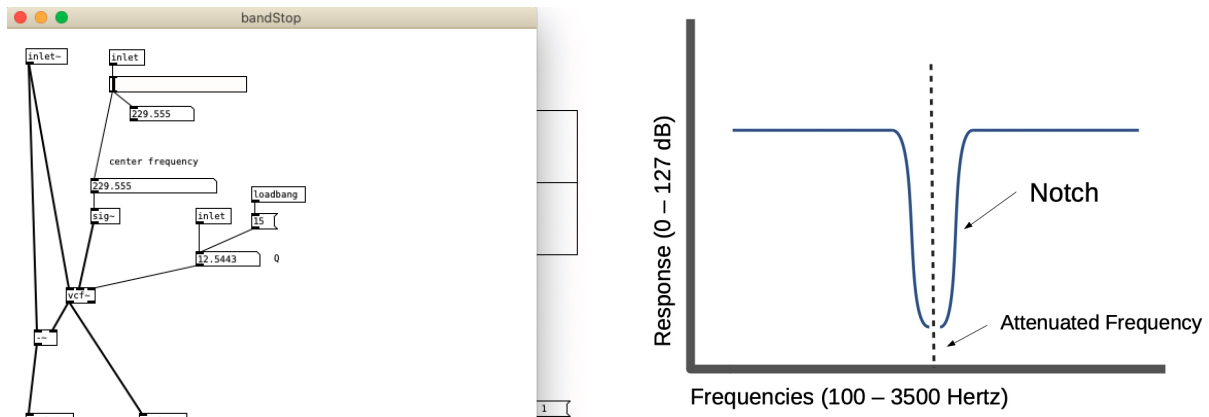


Figure 23. Left: Pure Data patch for dynamic bandstop. Right: notch filter diagram illustrating frequency attenuation.

It is important to mention that the digital software was implemented as a filter rather than a sound generator. I think that this approach produces timbral outcomes closer to physical acoustics. The complexity of acoustic sound—being made up of countless environmental interferences—is what inspires me to explore physical resonance as a form of sound art.

TONE

TONE (2018–19) was an analog audio waveguide with tree-like array of electret microphones arranged above a resonant 4Ω loudspeaker and mounted in an acrylic base [Fig. 24].



Figure 24. *TONE* analog audio waveguide in situ (CNMAT 2019).

Acrylic “leaf” microphone mounts were suspended at the end of each cylindrical “branch.” Acoustic feedback was situated by arranging the loudspeaker upward toward the mic array. As

pressure waves propagated upward from the loudspeaker, sound was filtered through the pipes before arriving at the mic array, thus introducing non-linearities and expressive opportunities.

Physical Interaction

Prospects such as air-gapped proximity filtering and intuitive physical interactions were apparent for human interaction. When participants walked around the device, a Helmholtz-like standing wave was produced intermittently in the room. This was a result of acoustic reflectivity and external sound energy. The fundamental frequency derived from the resonance of the glass sphere mounted above the loudspeaker.

Other system frequencies could be activated by focusing energy around a particular microphone “leaf” with one’s hand in close proximity. Higher frequencies were based on cylinder length and electronic flow. Participants could perceive that environmental sounds were immediately transformed and influenced other resultant resonances [Fig. 25].



Figure 25. *TONE installation and interaction (Hertz Hall 2019).*

Circuitry

The *TONE* circuit was a simple 9V LM386 amplifier which was connected to a simple electret NPN3904 preamplifier [Fig. 26]. The electret mic array was configured in parallel rather than in series, which increased the possibility of focused energy on a particular mic element. The amplifier was mounted on the acrylic base of the instrument and connected to the mic preamplifier via conductive tape [Fig. 26].



Figure 26. *Left: TONE amplifier mounted to acrylic base. Right: TONE preamplifier mounted to an acrylic “leaf.”*

Reusing Parts

Before building *TONE*, I was in the process of deconstructing *LARSEN* and decided to reuse many of the parts from *LARSEN*. The acoustic principles foundational to *LARSEN* were mostly first principle physics and wave propagation models which could be applied to a variety of situations. I decided to build *TONE* with the same pipes and open cylinder waveguide principles. The major differences were that I made all of the circuitry myself and reversed the orientation of the loudspeaker/microphone(s) from top-down to bottom-up. Below is a comparison of the two instruments side by side in their construction phase [Fig. 27].



Figure 27. *LARSEN* vs. *TONE* construction layouts (left: top-down, right: bottom-up)

The main differences between these two construction approaches were sculptural and interaction-based. For example, physically balancing an upward-angled sculpture as opposed to downward was more challenging in relation to gravity, but offered more interaction possibilities. One such possibility was a less reflective, more responsive gestural interface.

The downward orientation of *LARSEN*, for example, had to be rerouted sideways to avoid sound reflectivity from the ground. Such reflectivity produces a constant frequency feedback loop with or without human intervention indoors or outdoors. The upward orientation of *TONE*, by contrast, offered more responsiveness to physical interruption because very little reflectivity came from the air above when outdoors. This enabled a more distinct difference in the sound when a person placed their hand near the microphone “leaf” interface. Of course, when *TONE* was situated indoors, the ceiling caused reflectivity from above and made for a less responsive hand-oriented interface.

ARC

ARC (Acoustic Resonance Circuit, 2017–18) was a digitally-managed air and contact mic input, and transducer output. The sounds produced by the instrument were mostly drones based on mixing two different types of signals together amidst system vibration [Fig. 28].



Figure 28. *ARC (Acoustic Resonance Circuit) setup at CNMAT 2018.*

Setup and Configuration

The *ARC* input devices included an electret microphone and a piezoelectric microphone for sensing both environmental sounds and physical vibrations. The output device was a single transducer attached to the resonator object. By configuring the system this way, a non-linear network of interrelated but different inputs was enabled inside a positive feedback loop.

Vibrational feedback was generated by the contact mic/resonator combination and outside sound energy was sensed by the electret air mic. Independently, feedback from the contact mic/resonator functioned like an oscillator and the external sound energy sensed by the electret mic functioned like a standard input. The result was that both eigenfrequencies and external sounds were represented in the overall sound output [Fig. 29].

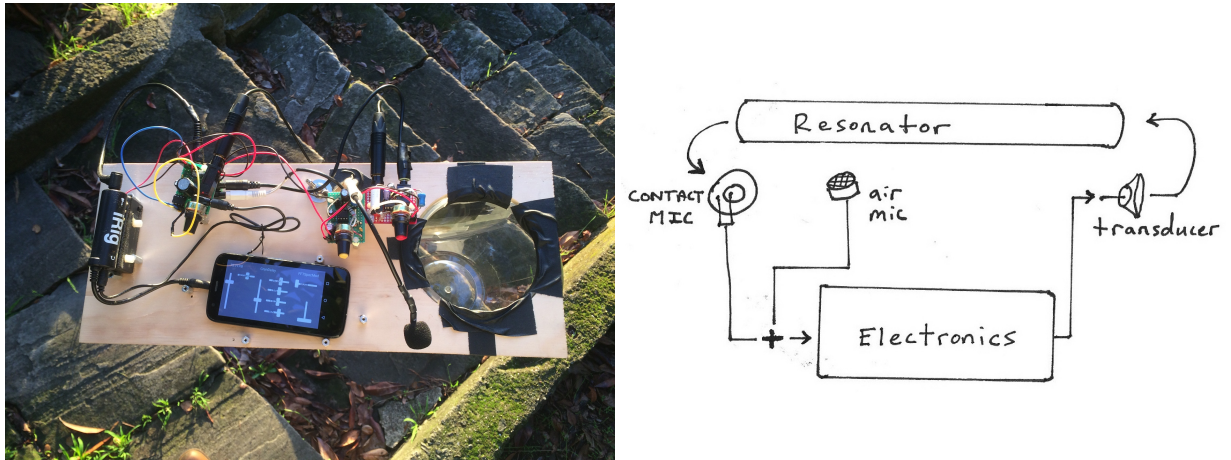


Figure 29. Left: first outdoor ARC installation prototype. Right: archetype sketch for ARC prototype.

While building the first prototype of this device I discovered that both analog and digital processing of the signal was possible while in a feedback state. Analog signals, when mixed together directly, offered characteristic sounds of each passive e-component. Digital management, implemented via the iRig device, offered countless filtering options between the analog inputs and the analog output. Android smartphones with MobMuPlat and PD files pre-installed were used to apply additional effects and other spectrum filters. iOS devices were also tested successfully with this system [Fig. 30].

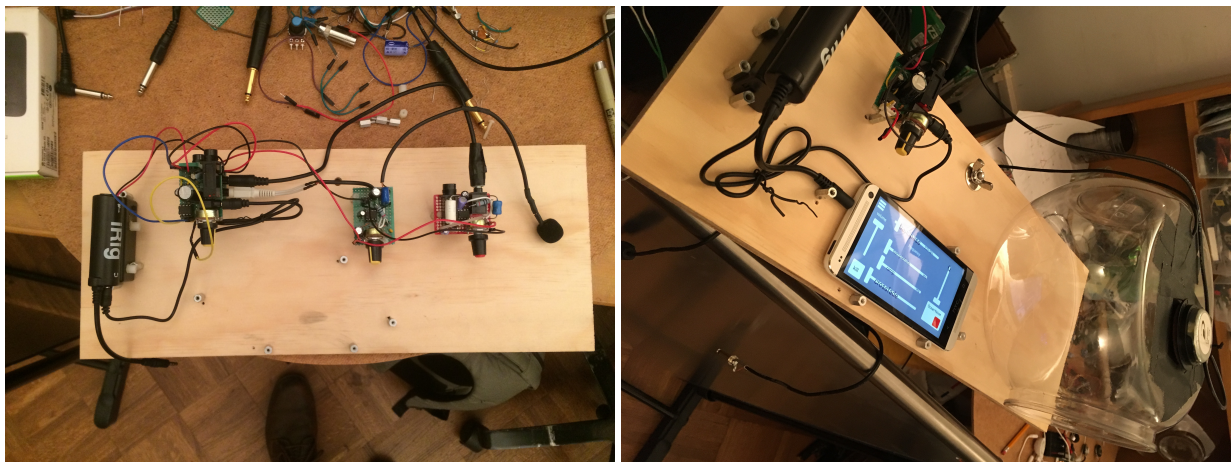


Figure 30. Left: analog circuit configuration. Right: digital circuit configuration.

Circuitry

The main advantage I found for a purely analog system was the low-risk nature of inexpensive parts as compared to a digital smartphone. An analog system could be built in functionally small cases that could fit anywhere and be extremely portable. The digital

smartphone configuration offered memory, sound generation possibilities, and interesting filtering techniques. It also posed the risk of losing an expensive piece of equipment after installation. All of these factors played a part in deciding what circuits to build.

1k Ω 1% resistors were used inline with each analog input signal to function as a passive mixer. Because voltage drop occurs after the resistors, this approach is considered a “hack” to mix signals together. However, I was reasonably satisfied with the sound results, so I moved forward.

The electret input circuit was taken from an old bullhorn diagram (electroniq.net) and the piezoelectric input from a pre-amp circuit (mycircuits9.blogspot.com) for piezo amplifiers. The main output amplifier was the same as the amplifier used in *TONE*. A combination of all three circuits was then made, with the option to integrate the iRig/smartphone extension [Fig. 31].

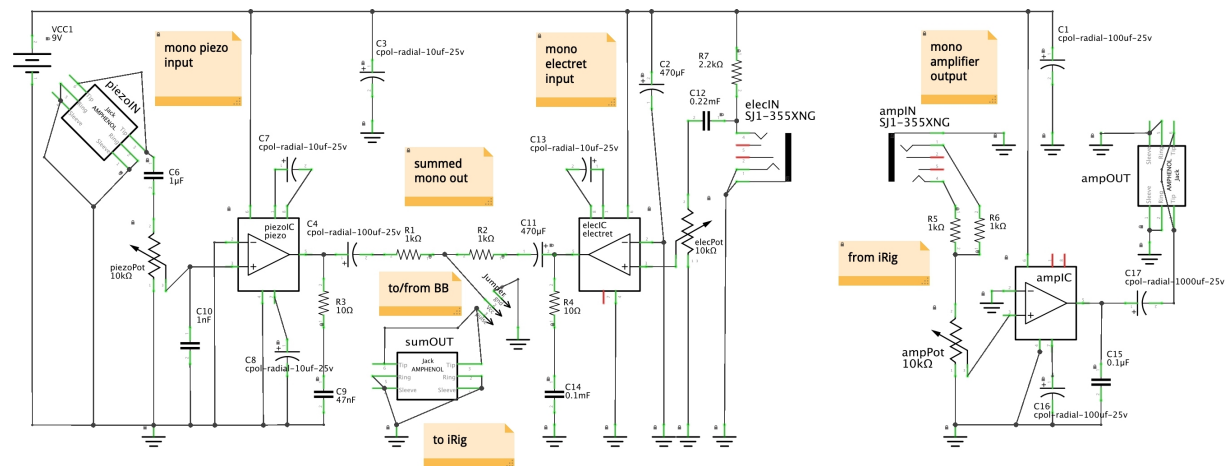


Figure 31. Integrated circuit from the electret preamp, piezo preamp, and output amplifier.

Component List:

Type	Name / Qty.
ICs	LM386 + mounts (3)
Capacitors	1000uf (1); 470uf (2); 100uf (3); 10uf (4); 1uf (1); .22uf “224” (1); .1uf “104” (2); .047uf “473” (1); .001uf “102” / 1nf (1);
Resistors	10ohm (2); 2.2kohm (1); 1kohm (4);
Potentiometers	B10k Linear Pots (3)
Audio Jacks	6.5mm phone jacks (3); 3.5mm phones jacks (2)
Headers	3-pin (1)
Jumpers	female to male jumper wire (2)

Breadboards	Mini-breadboard (1.8"x1.4") (I)
-------------	---------------------------------

Other Iterations

As experimentation went on over the 2018 year, I decided to try an analog-only version of the device. The first prototype was adopted by Professor Ken Ueno for experimentation and installation. Two iterations of the functional feedback circuit were developed. One was set on a wooden board and the other was made out of acrylic. The first iteration stopped working because it had no casing and was damaged. The second traveled better because mounts were included in the design, but ergonomic support for handling was not ideal [Fig. 32].

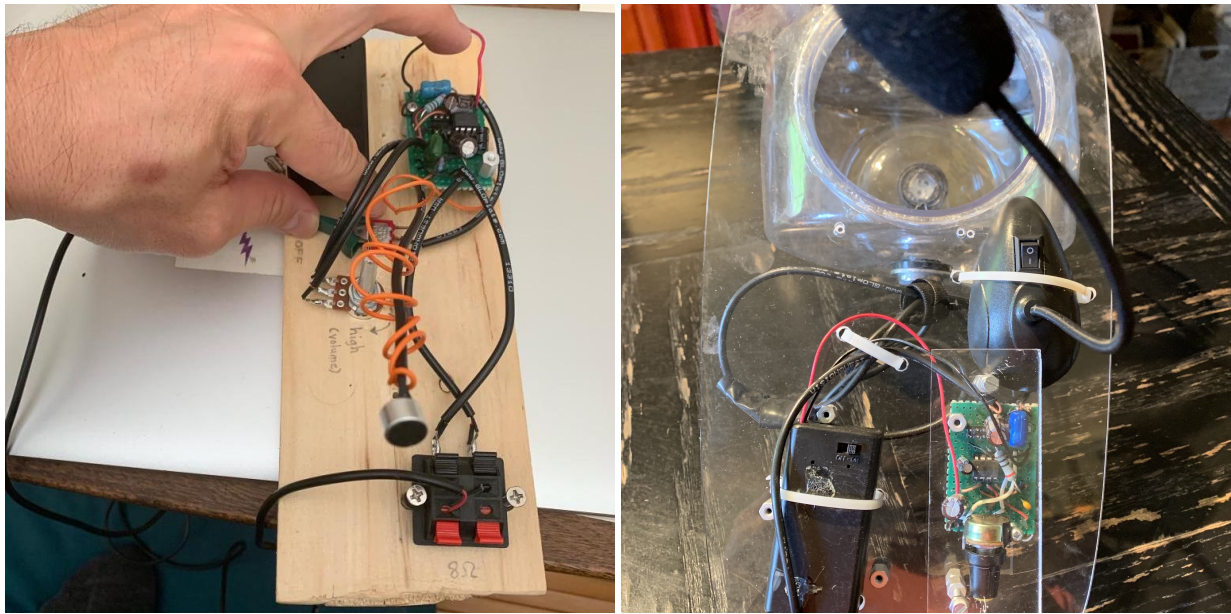


Figure 32. *Left: first ARC prototype for experimentation. Right: acrylic ARC bullhorn circuit.*

In 2019, Professor Ueno tested this device in an art gallery in Hong Kong and performed with it at the EMPAC gallery in Troy, NY. Ken reported that the response of the device was slightly different in various spaces, but in all cases, the potentiometer knob was very sensitive at a particular point at which the device would immediately feedback. Fine tuning the potentiometer knob to a “balanced” state between positive feedback and neutral was challenging [Fig. 33].

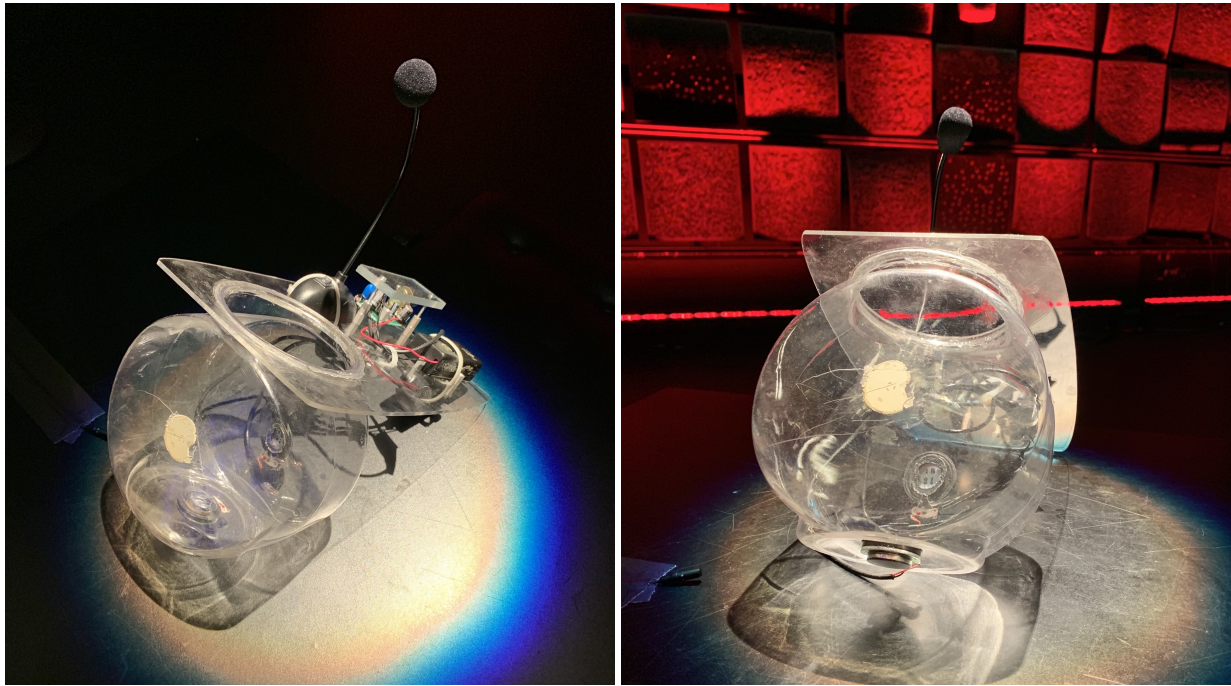


Figure 33. ARC device tested at EMPAC (Experimental Media and Performing Arts Center) gallery in Troy, NY by Ken Ueno (September 2019).

Other prototypes and tests were made which included the digitally-managed version [Fig. 34].

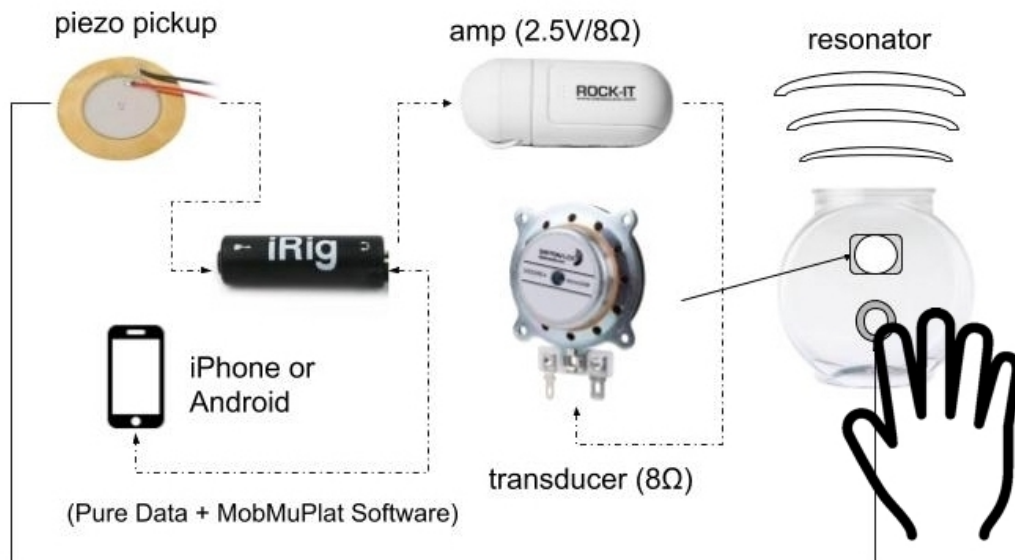


Figure 34. Piezo element situated expressively in a digitally-managed ARC iteration.

I performed in Professor Myra Melford's improvisation class with this device and discovered many promising techniques. The primary technique that I worked with was the piezoelectric contact mic as an expressive element. For example, when the contact mic touched the resonator surface, feedback occurred in the system thus producing tones. These tones could be changed by either moving the contact mic along the surface of the resonator or by changing the angle of the mic [Fig. 35].



Figure 35. *Left: piezo flat on surface. Right: piezo angled on surface.*

The piezoelectric mic functioned like a probe in some cases. Rather than fixed to the resonator such as in Tudor's *Rainforest IV*, the mic is separated and available for a performer to explore an object's resonance. Different frequencies are emphasized in this process.

BULB

BULB (2018–19) was an adjustable resonance chamber connected to an adjustable analog feedback circuit. Multi-phonics from the resonator change as participants move the opening aperture handle and potentiometer knobs [Fig. 36].

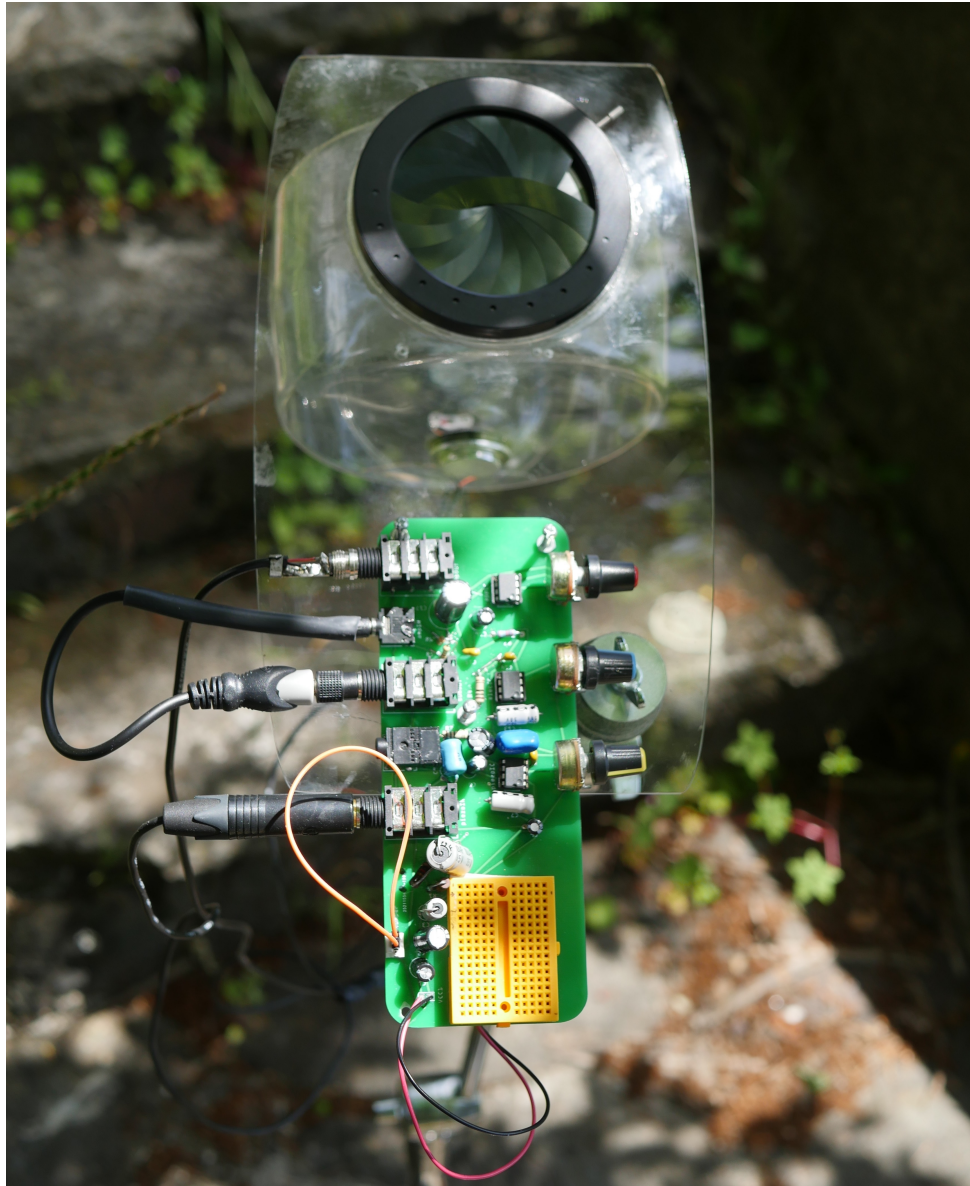


Figure 36. *BULB* installation (CNMAT 2019).

Interaction

When the handle and knobs are turned in various combinations, different multi-phonics are excited inside the resonator cavity [Fig. 37].

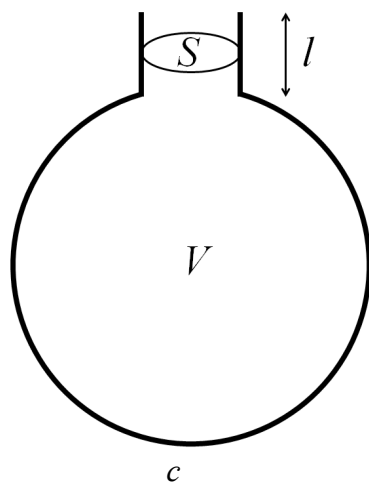


Figure 37. *BULB installation at Hertz Hall (2019)*

I noticed that as participants turned knobs and explored the resonance, enough variety in the sound output was present such that engagement lasted more than thirty seconds and up to about two minutes.

Helmholtz Equation

The first principle math behind the sound output of this system can be explained in the Helmholtz equation pertaining to a spherical chamber. In *BULB*, the metal aperture above the cavity opening changes the dimensions of the chamber “neck,” resulting in different Helmholtz-like frequencies. Sound waves are, of course, subject to more complex discrete scattering functions, but the basic principle is here. The resonant frequency (f) of a classical Helmholtz resonator is determined by its volume (V) and by the length (L) and area (A) of its neck [Fig. 38].



$$= (c \div 2\pi) * \sqrt{(S \div V l)}$$

(circumference) * $2\pi(\pi)$

$\sqrt{\text{(square root of) (S (neck size) } \div \text{ V (volume) } \div \text{ l (neck length))}}$

(frequency)

Figure 38. Left: Helmholtz equation applied to a spherical chamber.¹³ Right: equation breakdown.

As the opening of the chamber is opened and closed continuously, wave scattering occurs, producing multi-phonics when in a positive feedback state. The metal aperture was given to me by a friend in the UCB Physics department. If I did not have access to this, I would have made a rudimentary ‘wave scattering’ object for participants to move around above the opening and produce similar effects [Fig. 39].



Figure 39. Left: sliding aperture closed. Right: sliding aperture slightly open.

Circuitry Experiments

The same circuitry from *ARC* was implemented into *BULB*, except that I sketched the circuit in open software, Fritzing, to create a perforated circuit board (PCB) schematic. The files from this project were sent to Shenzhen, China, for manufacturing. There were unexpected issues

¹³ Kenneth N. Stevens, *Acoustic Phonetics* (Cambridge: MIT Press, 1998), 142.

with the circuit upon testing, which is why I repurposed it as an analog-only circuit board in *BULB*. Originally, the circuit was meant to interface with the iRig and smartphone via jumper headers, but troubleshooting this circuit became laborious, so I routed the analog output back into the analog input to bypass the jumper I/O [Fig. 40].

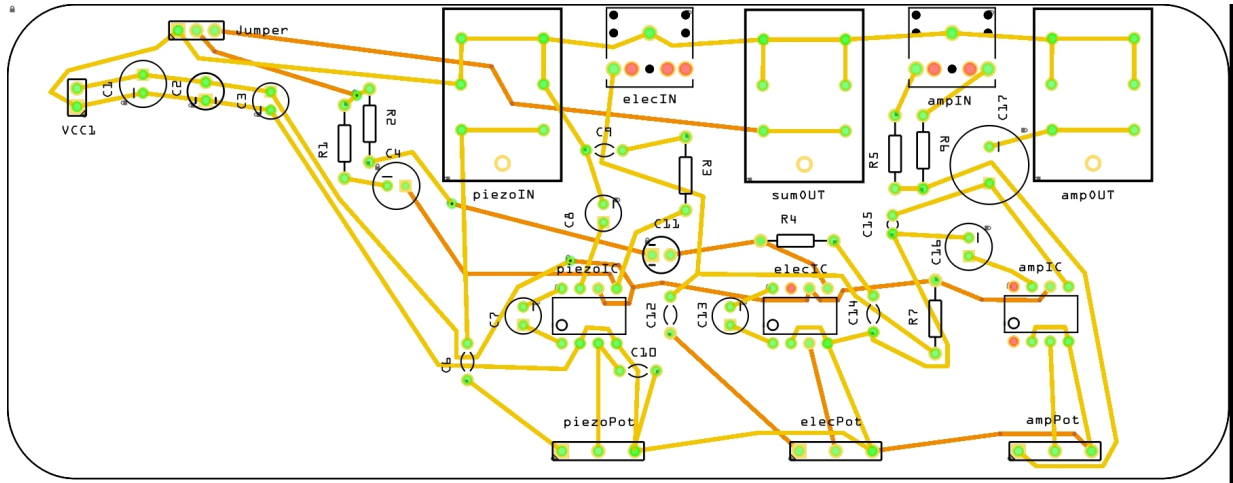


Figure 40. Fritzing PCB design for Gerber files and fabrication.

Reusing the Circuit and Materials

To carry through on the idea of reusing circuitry and objects, I essentially made three different applications from a very similar schematic: *BULB*, *ARC*, and *FLOW*. The circuits and raw materials of each instrument were similar enough to mix and match circuit modules such as the piezo amplifier, preamps, and plastic bowl. *BULB* was the integration of every analog module from *ARC* onto a single PCB.

FLOW

FLOW (2018–19) was an electroacoustic air duct resonator with two inputs [Fig. 41].



Figure 41. *FLOW* air duct resonator and digital interface (Hertz Hall 2019).

Interaction

The circuit modules came from the original *ARC* project and were mounted on an acrylic plate. Similar to *ARC* the interfaces included touchscreen sliders on the smartphone and potentiometer

knobs to control the gain for each respective input (i.e., electret air mic and piezo contact mic) [Fig. 42].



Figure 42. Left: acrylic circuit mounting plate. Right: participants moving sliders and knobs to change the sounds and resonances.

Sourcing Materials and Construction

I found air ducts on the side of the road and decided to turn them into resonators [Fig. 43].



Figure 43. Left: air duct pile on the side of the road. Right: coupling air ducts together as one resonator.

Fitting the air ducts together and mounting the acrylic circuit plate was challenging, but once the main L-bracket was bolted on everything else became simpler to transport and install [Fig. 44].



Figure 44. Left: mounting L-bracket for stand and acrylic plate. Right: measuring, bolting, and cutting the air ducts.

Circuitry

The circuit for *FLOW* is the exact same circuit design as the original *ARC* circuit. In fact, I replicated all of the analog modules verbatim—only the digital interface and software are slightly different. This is the advantage of working with audio feedback as a default setting: every instrument is substantially different, yet the circuitry and programming is basically the same [Fig. 45].

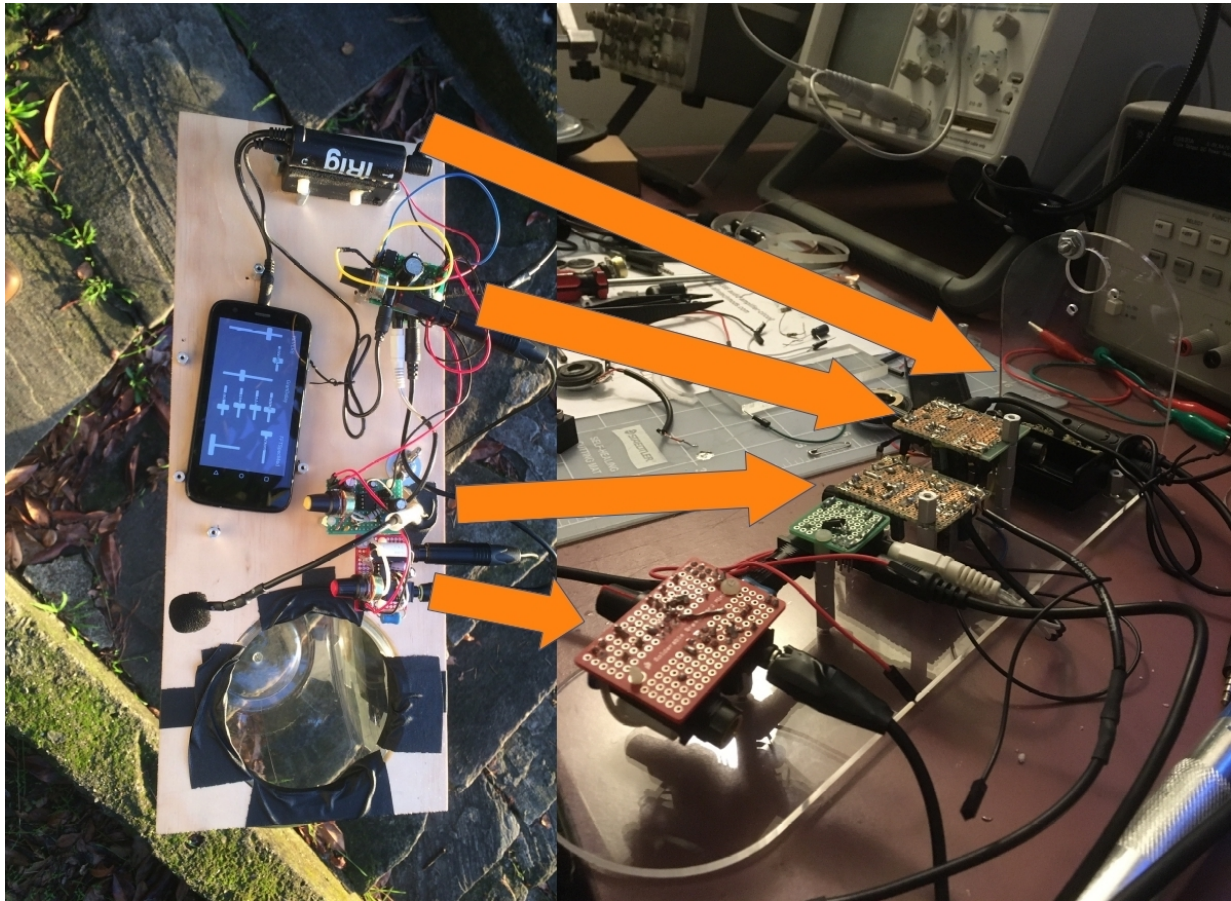


Figure 45. *Transferring audio modules from ARC to FLOW.*

Modularity in this prototyping framework lends to different outcomes without the tedious rethinking of every module and component. Each module had already been worked out by the time I started building *FLOW*. I was tempted to buy electret preamplifier modules from manufacturers like Adafruit and SparkFun, but decided against it. The knowledge and schematics for building these modules can now be published online for many others to access.

Digital Management of Feedback

The unique aspect of *FLOW* versus previous digitally-infused instruments was mostly how I designed the GUI interface. The slider labels ‘LISTEN’ and ‘RESONATE’ [Fig. 46], were polarized to demonstrate the difference between pre-recorded audio and open system resonance. Participants were able to crossfade between these two types of audio seamlessly.

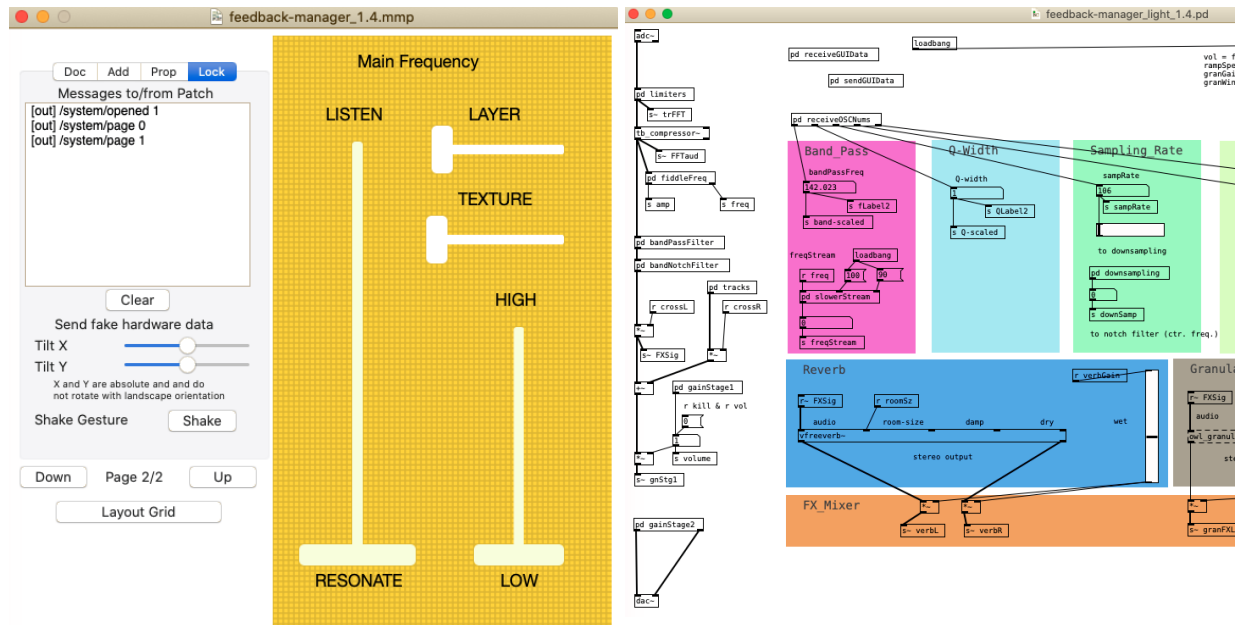


Figure 46. Left: MobMuPlat interface with sliders. Right: Pure Data patch with effects and looped ambient audio track..

The labeling continuum between these two words was important because I wanted participants to easily understand how to experience the instrument in two different modes. LISTEN represented the instrument as a loudspeaker of prerecorded audio which was looped in four-minute cycles. RESONATE represented the instrument as an oscillator with self-resonating frequencies that emerge from the air duct cylinders. Both of these modes had a distinct ambient or textural quality, implying that resonance could be experienced in different ways.

CHAPTER 4: REFLECTIONS, PROBLEMS, AND FUTURES

Workshops and Experiences

In September 2018, I was invited by Professor Ken Ueno to lead a circuit-building workshop at the City University of Hong Kong. The participating students were mostly from the media/art department, so I thought it would be reasonable to propose a simple bullhorn megaphone circuit as a breadboarding project. Several groups completed the circuit within the first hour of the workshop and began experimenting with acoustic feedback and resonance. The remaining groups were able to complete the circuit on their own with a short tutorial that I put together later. The success of this workshop confirmed to me that building simple circuits could be taught in a relatively short amount of time. By focusing on simple modules rather than large complex systems, makers were enabled and rewarded in a low-stakes step-wise manner. I think the benefits of working this way include a higher degree of novelty during the creative process and a richer tension between aesthetic and practical considerations while building. These experiences have informed my teaching philosophy and provide a basis for future tutorials and circuit designs.

Fluid Prototyping

The more I learn about the prototyping process through building sound sculptures and leading *SHAPE* workshops, the more I am inclined to prioritize design flexibility over robustness and reliability. Making circuits reliable, in my experience, is easier to accomplish than designing truly novel prototypes. Typically, circuit design is focused on optimizing a specific and well-known outcome before very much experimentation has taken place. In my opinion, this approach often misses important design potentials and focuses too much on refinement rather than expressive discovery. Instead, I prefer to prioritize a low-level iterative process that explores simple circuits as expressive instruments.

For example, *BLOOM* was a *SHAPE* device that illuminated the electron flow and interactive potential of a single NPN3904 transistor. When in a feedback state, the flashing LED array visualized inherent saturation properties of the transistor, generating different lighting sequences within the flower-like “buds.” The small box shape of the transistor, with three legs arranged upward, also resembled a flower stem “base.” Effectively, this transistor component functioned as both a probability lighting generator and representational “flower” object.

Interaction opportunities were also included by implementing photoresistors inline and spacing components out on the substrate. This enabled direct hand engagement to change the electrical resistance of the device and resulting light/sound sequences. Aesthetic considerations were also made obvious by spacing out each component and allowing participants to clearly see every detail of construction [Fig. 18].

No full schematics existed for the *BLOOM* device prior to building; the design was intuitive and based on my experience with basic piezo buzzer circuits. Adding LEDs and

photoresistors felt like a natural step beyond the initial buzzer circuit. Function and aesthetics, in this case, were natural byproducts of keeping things simple and trial/error techniques.

Modifying *SHAPE* circuits was often a process of testing and labeling multiple values for each connection point. If a range of values was practical and functional, I labeled that connection point accordingly with minimum and maximum value. For example, the *ARC* design had a potentiometer range between $\sim 1\text{k}\Omega$ and $10\text{k}\Omega$ resistance. Through experimentation, I found that acoustic feedback in the resonance chamber produced vastly different sound outcomes from very small resistance changes in the potentiometer. Thus, I began to view the potentiometer knob as an expressive interface for performance.

So far, connection points of circuits and acoustic properties of found materials are the expressive junctures where I like start with most *SHAPE* devices. The confluence of hardware and function has been inspiring to me as one *SHAPE* device evolves directly and indirectly into another. “Mutations” of these devices seem to occur in both a physical and conceptual way. New hybrids and applications resemble their old prototypes to varying degrees, but only clear acrylic circuit casings and original archetypes link them all.

The Economics of *SHAPE*

Connoted here, “economic,” relates to the market price, setup time, and effective available musicality of a *SHAPE* device. Each type of “cost” connects economic principles with instrument design, sculpture, interaction design, and music composition. My goal is to formalize these ideas and establish a design practice of maximal effectiveness with minimal means.

This philosophy derives from my personal values of utilizing all resources with care and intention. I want to leverage this philosophy for the benefit of others who do not have time to create, but desire to express themselves musically nonetheless. This means considering extra-musical things such as budget constraints and money as part of the art-making process. In other words, money is considered only one factor among many in the *SHAPE* design process and not foundational to the project.

Before conceiving of *SHAPE*, I knew that I wanted to rethink what a budget meant in the context of art-making. Money as a foundational constraint in art practice has always seemed trivial to me. This is why I decided to include time and energy in the budgeting process and prioritize *building* over *buying*. Too often in my experience, emerging artists are confused on this point and are superficially deterred from realizing their authentic work due to monetary constraints. The *SHAPE* project, by contrast, gives permission to artists to think differently in this regard and to view everything around them as a rich resource.

Bypassing Proprietary Circuits

After building the *LARSEN* installation in 2017, I found that consumer electronics were helpful for initial testing but posed significant barriers to creative building. The Android smartphone, UE Boom speaker, and Zoom microphone offered high reliability, programmability, and sophistication, but they could not be modified in interesting ways. I

implemented them conservatively so as to not break them and risk losing costly equipment. Also, the closed nature of these devices reduced my ability to tailor the hardware to the application. In other words, because the hardware was impossible to modify, hardware integration into the waveguide system was awkward and unconvincing. For these reasons and others, the *SHAPE* project is aimed at modularizing amplification and synthesis functions (typically provided by computers) with components that are freely available. My goal is to establish a practical framework for building functional circuitry in a flexible modular way so that expensive proprietary devices are no longer essential to the project.

Outdoor installations, in particular, are vulnerable to theft when proprietary devices are involved. Smartphones, for example, are a well-known commodity that automatically increase the temptation for people to take the device. The cost of money and performance time resulting from a smartphone or laptop theft would be substantial—enough for me to try and find functional alternatives to this technology.

Software obsolescence is another pervading issue that comes with high-profile proprietary computers. Updates are essential for the secure operation of high-profile smartphones or laptops according to most brands. This requirement effectively places complete control of a device's lifecycle in the hands of a single company. Therefore, I prefer to reuse modules/materials from wherever they are free such as waste bins or legitimate second-hand exchanges. By doing so, *SHAPE* circuits can be free from third-party obsolescence, tailored to a single audio task, and integrated seamlessly into a sculptural installation.

Two other advantages of avoiding proprietary devices is that non-proprietary homemade circuits are more visually distinct and ambiguous. Both have artistic advantages. For example, when a participant looks at a homemade circuit, they will notice that each component is situated in a freeform fashion. This is because most of the components have been sourced differently and have been soldered together by hand. Prefabricated circuits, by contrast, are constructed with industrial, mass-producing machines which require complex pre-designed schematics. Thus, I prefer to work with the visual distinctiveness, diverse component source, and freeform arranging of handmade circuitry over prefabricated.

The aesthetic difference between these two kinds of circuits is based on the way they are made. I compare this to the difference between handwriting and digital text rendering. The first evokes a sense of freeform style and the second a more formal style. Each renders the same meaning or function of the text equally but does so in a visually distinct way. Similarly, homemade circuits evoke a more freeform look than prefabricated and represent a less formal approach to circuit design.

Homemade circuits also have the advantage of functional obscurity. This provides the artist with another opportunity. For example, when a participant observes an exposed homemade circuit, no brand or specific interface casing is apparent for them to associate with their past experience. Therefore, the participant will likely wait before passing judgement on the device and maintain an open mind while exploring the device's characteristics. Ambiguity, in this case, provides the artist with an opportunity to astonish participants outside of their typical

consumer experience. It also provides encouragement to other artists who would like to build their own custom devices based on free materials.

Reducing Cost and Time

One way that *SHAPE* devices are designed to facilitate spontaneous group collaboration is by reducing the amount of time it takes to construct a device and by reducing the monetary cost of materials. A reduction in these areas requires persistent questioning of every design choice and clever sourcing practices. My hope is that *SHAPE* designs can be built by anyone with nothing more than a little time and energy to spare.

Realistically, however, *SHAPE* devices featured in this document took many hours of planning and building. Future devices will have to be much easier to realize and simpler to employ. Balancing the degree to which an instrument is pre-constructed and deconstructed will be important. A key approach to solve this is discovering and logging mass-produced waste products that already contain expressive potentials and building on those as instruments. Because industry measurements are standardized, coupling and functioning of these devices is inherently simpler and provides a large-scale opportunity for reducing time spent building.

In chapter one, I proposed the idea that most people are conditioned by our consumer culture to expect instantaneous and intuitive engagement with any technology that they encounter. This expectation can be accounted for and leveraged in *SHAPE* designs as a consistent behavior which requires accommodation.

Reducing the amount of time for production and engagement means simplifying not only the interface of a design, but also the construction of the design itself. Monetary cost must be reduced for general access and replication by others without monetary means. These factors are addressed directly and practically in *SHAPE* designs to increase an instrument's overall expressiveness and usefulness. In other words, I seek to make *SHAPE* designs that are instantly accessible in the construction and engagement process.

Problems and Possible Improvements

The problems described below are both technical and philosophical. I see a need to provide both practical prototypes and environmentally-conscious solutions. By reframing production inside a zero-waste perspective, I hope that makers and DIY artists can work with more intention. I am also interested in resolving practical sound installation problems with technology that is simple and intuitive.

Challenges with Combining Circuits

Mixing and integrating circuit modules are important aspects of *SHAPE*, but they have proved challenging. Different audio input preamplifiers have posed complex loading and mixing problems. To solve this, I established some voltage input/output standards which mostly derive from generic battery and e-component voltage ranges. 3V-5V or 9V VCC and 1V "line-level" outputs are what I work with currently. Signal viability of a module "network" seems to require some basic definitions. Industry e-components are permissible in my mind as long they are freely available, ubiquitous, and simple enough to implement easily.

However, some circuit modules that share voltage VCC are not always compatible and require extensive modification to be combined effectively. Reed Gazala's circuit-bending journal article, *The Folk Music of Chance Electronics: Circuit-Bending the Modern*, has been a helpful resource for finding new audio strategies¹⁴. I am studying methods of voltage testing at different points within complex circuits. My goal is to define a simple method or adapter circuit that can standardize output voltages on each module. This will allow for a custom "plug-and-play" scenario between various modules in future prototypes.

Zero-waste Instruments

Implied in the *SHAPE* project is a goal of leveraging free "end-of-life" materials to support a zero-waste initiative between human-centered ecosystems and musical activity. It is hoped that more diverse musical collaborations will occur in more environments with more people. However, if the technology medium in this project changes to something other than electronic circuits, I would happily adapt, even if the project itself becomes obsolete. My fundamental proposal is a movement toward more collective, in-person interaction with technologies that do not isolate individuals, but instead, provide close connection. Zero-waste, as an environmental and musical concept, might be part of the solution.

If artists rethink how they produce their art and the life cycle of the products they use, perhaps salvaging could become a more popular strategy. The practice of music improvisation, in particular, gives good insight into re-contextualizing something unwanted as beautiful. Miles Davis says:

"It's not the note you play that's the wrong note—it's the note you play afterwards that makes it right or wrong."

This is how I approach instrument design: by re-contextualizing waste products as a productive resource through creative design. In my opinion, who better to think creatively about waste than artists?

By establishing reuse as a fundamental principle, artists looking for ecologically sound ways to practice their art will find philosophical justification in this project and be more inclined to find waste solutions in other areas as well. Each new ecological consideration will build on another. It will work like a cascade, with simple steps leading to major change.

Some practical ways that I apply zero-waste ideas in *SHAPE* music designs include: reusing amplifier circuit components, building solderless circuits, reusing smartphones with PD and MobMuPlat, and focusing on low-power audio circuits rather than high-power/fi. Any combination of these strategies could prove compelling, but the most promising to me so far seems to be reuse of amplifier components. I am using these parts to build electroacoustic air-gapped feedback interfaces.

14 Reed Ghazala, "The Folk Music of Chance Electronics: Circuit-Bending the Modern," *Coconut Leonardo Music Journal*, Vol. 14, (November 2004), 96–104.

Recently, I experimented with the idea of air-gapped electroacoustic feedback by coupling a resonant surface to a voice coil, 9V LM386 amplifier, and electret mic. This configuration generates feedback frequencies which can be filtered by hand, mid-air. Nicolas Collins has provided many similar tactile approaches in his book, *Handmade Electronic Music*, but my prototype provides an air-gapped haptic feedback option¹⁵. Perhaps this simple device could solve problems of cost and sanitation in public sound installations. The technical foundation for this starts by bypassing over-the-counter solutions, making novel mid-air proximity sensors, and directly addressing the difficult logistical and artistic problems that often get in the way of compelling public sound art.

The Importance of Reuse

In addition to profit-seeking companies that impose product obsolescence with little accountability, U.S. corporations and other industrialized countries ship and dump their electronic/manufactured waste on developing countries at an ever-increasing rate. This poses significant health hazards to the residents of those receiving countries and, eventually, to our global environment. Usually, these waste products are not broken down properly at their final destination and end up in landfill or the ocean, contaminating those areas and causing countless toxic ripple effects.¹⁶

15 Nicolas Collins, *Handmade Electronic Music: The Art of Hardware Hacking* (New York: Taylor & Francis Group, 2014), 110.

16 Jim Puckett, "Exporting Harm: The High-Tech Trashing of Asia," accessed November 14, 2019, <https://static1.squarespace.com/static/558f1c27e4b0927589e0edad/t/55d79060e4b0ff44487f306a/1440190560888/BANsExportingHarm-2002.pdf>.



Figure 47. *Computers and electronics piling up in an e-waste facility. Image by INES from Pixabay.com.*

The reuse of old electronics as the basis for artistic production involves an implicit critique of the corporate mentalities that consistently fail to take into account the larger environmental impacts. The *SHAPE* project applies this reuse principle by salvaging, rebuilding, and fixing circuits. Circuit-bending is another approach discussed later. Electronics at the “end-of-life” phase can be useful if viewed as a resource. The *SHAPE* project also presupposes that many constructed prototypes will be broken down and reused as parts for many different installations.

Sharing and Developing Designs

As the worldwide technical platform for networked digital representation becomes ubiquitous and searchable, I assume that *SHAPE* designs will be easier to find online. However, I do not support the current monetization and monopolization practices of such platforms by large companies. For this reason, I prefer sharing *SHAPE* designs and ideas at in-person workshops and events. The development of this project can only be effective if resources are truly open and accessible.

Open-access/Open-source Music

“Open-source” a term used widely since the 1990s is meant to signify anything that is available to be utilized or modified freely without proprietary constraints. This idea and practice started with open software media, but gradually applied to any coordinated group or collective work—an important consideration for me when designing *SHAPE*.

Accessibility of a *SHAPE* device is an ongoing and multifaceted process of considering factors that offer more flexibility to more people. The main accessibility factors in the *SHAPE* design process is fourfold: 1) made from materials widely available; 2) simple circuit design that practically anyone can build; 3) direct physical access to the filtering of sound energy; and 4) simple functional modules that can be integrated into various “quick setup” or “plug-and-play” situations.

I believe barriers to entry, such as software price, advanced programming, audio math, and expensive prototyping materials often suppress creative impulses for many people. Substantial investments of time and energy are required to approach even modest results in most real-time software like Max/MSP, Pure Data, and others. Most people cannot afford the software either.

This is why I am committed to sharing all of my circuit designs freely online at the CNMAT website and making simple, easy-to-understand digital patches in free, open-source software such as Pure Data and MobMuPlat. Detailed tutorials will accompany each patch. I am also committed to moving all of my digital projects to a Linux-based computer by 2021. It is an effort to reclaim how technology is disseminated beyond industry standardization. These strategies and values make the *SHAPE* project more malleable and affordable for more people.

Sharing and Replication

Replication and modification of *SHAPE* instruments are encouraged through uncompromisingly simple schematics, tutorials, and designs. I hope to avoid jargon-heavy instructions and overly complex prototypes as much as possible. In the near future, *SHAPE* circuit schematics and building instructions will be published either on the CNMAT website or on another public-facing website. Other artists will then be able to reference these materials when building their own electroacoustic devices. Currently, only circuit schematics, photos, and descriptions of the work are published on the CNMAT website [Fig. 48].

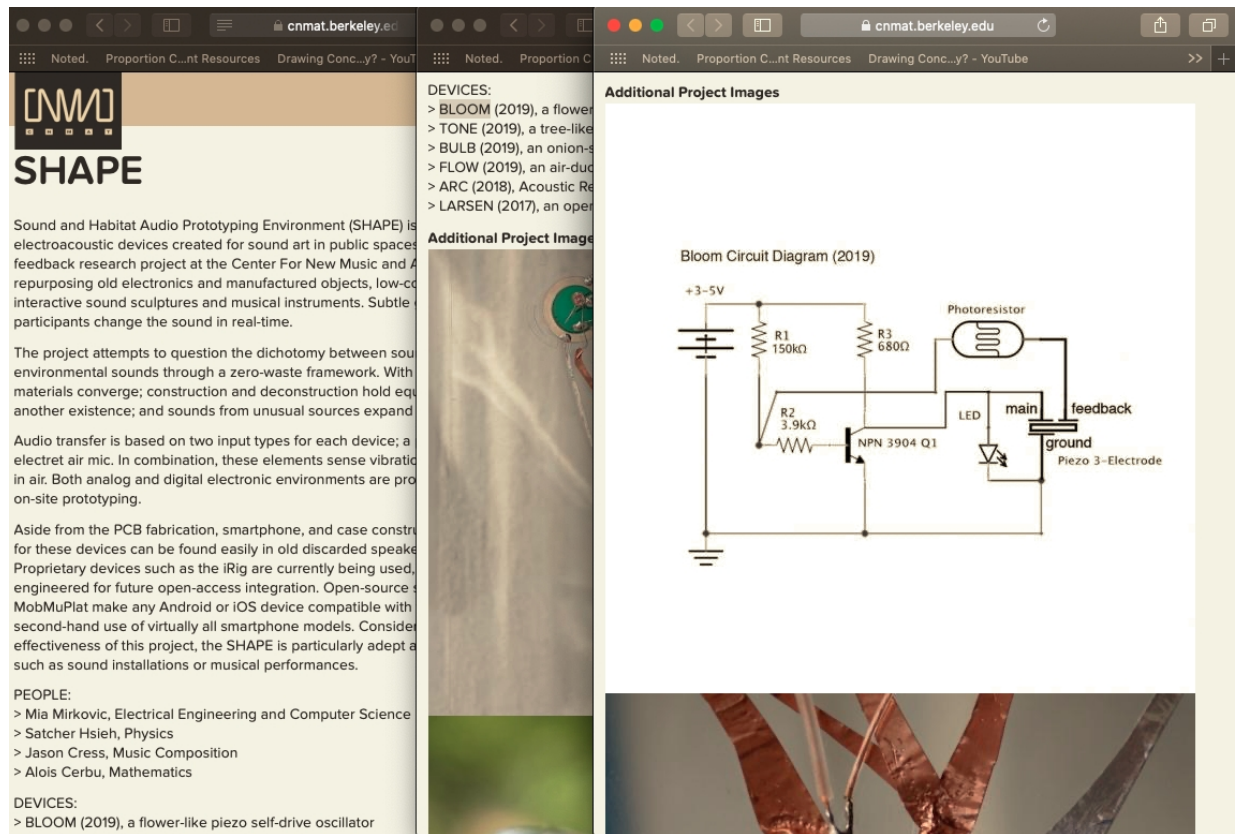


Figure 48. CNMAT website featuring SHAPE device, BLOOM.

The prospect of finding one of these designs someday in another artists' work is exciting to me. I hope that others find this work helpful so that more iterations can be tested and implemented. The ongoing and open-ended nature of this project positions it in contrast to current market practices which usually require products to be fixed and legally closed. Licensing, therefore, is an important consideration for SHAPE given its open-access and non-commercial leanings.

Creative Commons Licensing

Sharing and distributing circuit diagrams, assembly guides, sourcing ideas, and other relevant resources outside the University of California, Berkeley will be licensed with a "no rights reserved" CC0 license by Creative Commons. Though not completely recognized in all global jurisdictions, the CC0 public-domain license is a recognized way that creators can open their work to the public immediately with no crediting required. This is different, for example, than a traditional public domain license, which requires a long copyright expiry period before a work becomes officially public.

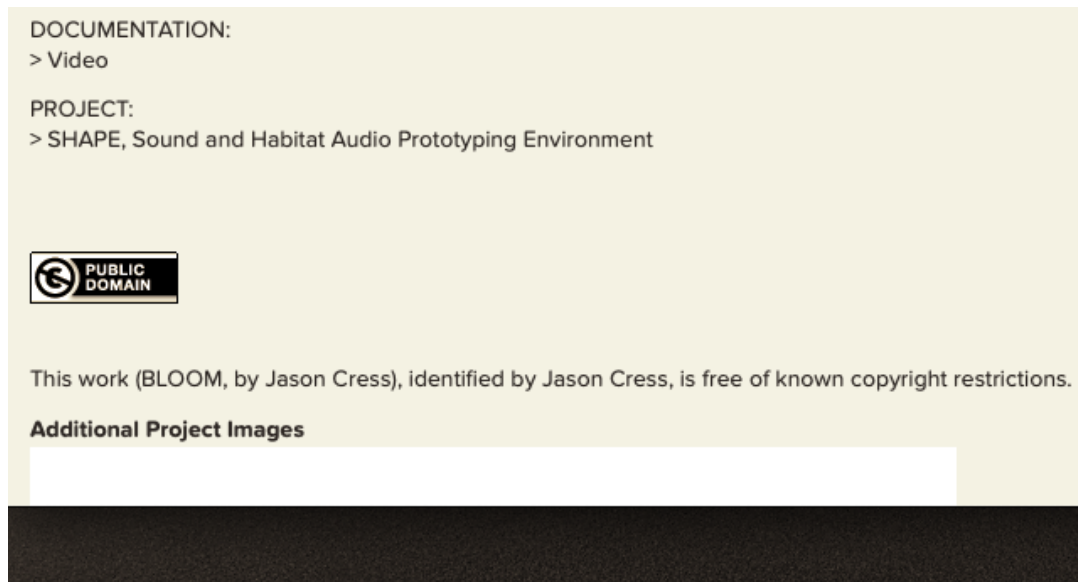


Figure 49. Creative Commons 'CC0' public domain license.

Decentralized distribution of *SHAPE* designs and supporting materials is desirable for maximizing the flow of ideas and bypassing the incessant commercial logic of our current moment. I believe that music and sound art can demonstrate alternative forms of human organizing which are more dynamic and fluid, perhaps like the starling murmurations mentioned in chapter one. The *SHAPE* event is, therefore, intended not to stem from just one person, but many. Sharing designs, events, gatherings, and sound art I hope will flow freely.

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APPENDIX
SHAPE Devices (6 of 6)



BLOOM



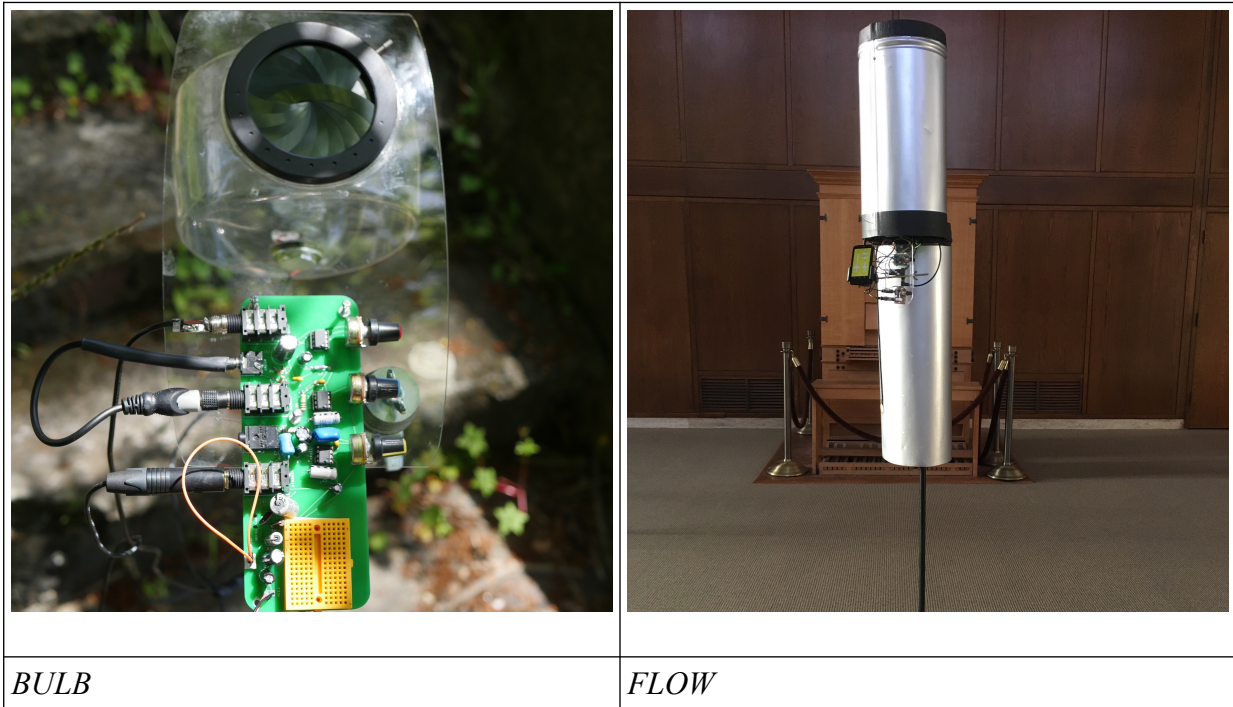
LARSEN



TONE



ARC



Basic *SHAPE* Step-by-step Guide

Below are step-by-step instructions for setting up a functional *SHAPE* device that includes analog input and digital processing. The analog input is an iRig which connects to the audio jack of a smartphone. The iRig functions as an audio input for many types of devices, such as piezoelectric contact mics, electric guitars, etc. The smartphone GUI interface is made with MobMuPlat software by Daniel Inglesia; it offers touchscreen knobs, toggles, sliders, and more for touchscreen interaction. Digital audio processing is done with the graphical programming software, Pure Data. PD offers free community resources from developers, patch libraries, and countless possibilities for sound transformation within a digital context. For individuals who do not have Internet access, these resources are available online through searches at a public library or an internet café. The following procedure outlines how to build a *SHAPE* device within a reasonable timeframe.

1. Download the current version of MobMuPlat to your smartphone device from your phone's app store—it should be free of cost.
2. Download the MobMuPlat Editor from the Github site published by Daniel Inglesia (<https://github.com/monkeyswarm/MobMuPlatEditor>). Only the terminal bash commands are provided as a means for “cloning” or “downloading” the instructions from the GitHub repository, but Inglesia's personal website also provides helpful links for downloading and editing resources (danieliglesia.com/mobmuplat/). Install the MobMuPlat Editor on your laptop or desktop computer. This will be the environment by which to edit and design your digital GUI interface in the MobMuPlat Editor [Fig. 50].

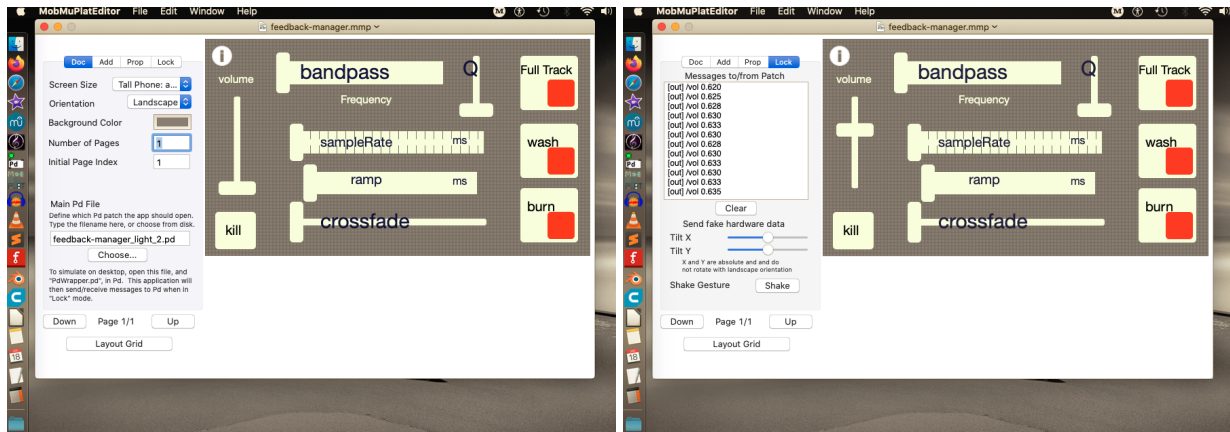


Figure 50. Left: MobMuPlat Editor with GUI interface design. Right: MobMuPlat Editor in 'Lock' mode.

3. Open the PD sound patch (e.g., “feedback-manager_light_2.pd”) and “PDWrapper.pd” file to port MobMuPlat and PD [Fig. 51].

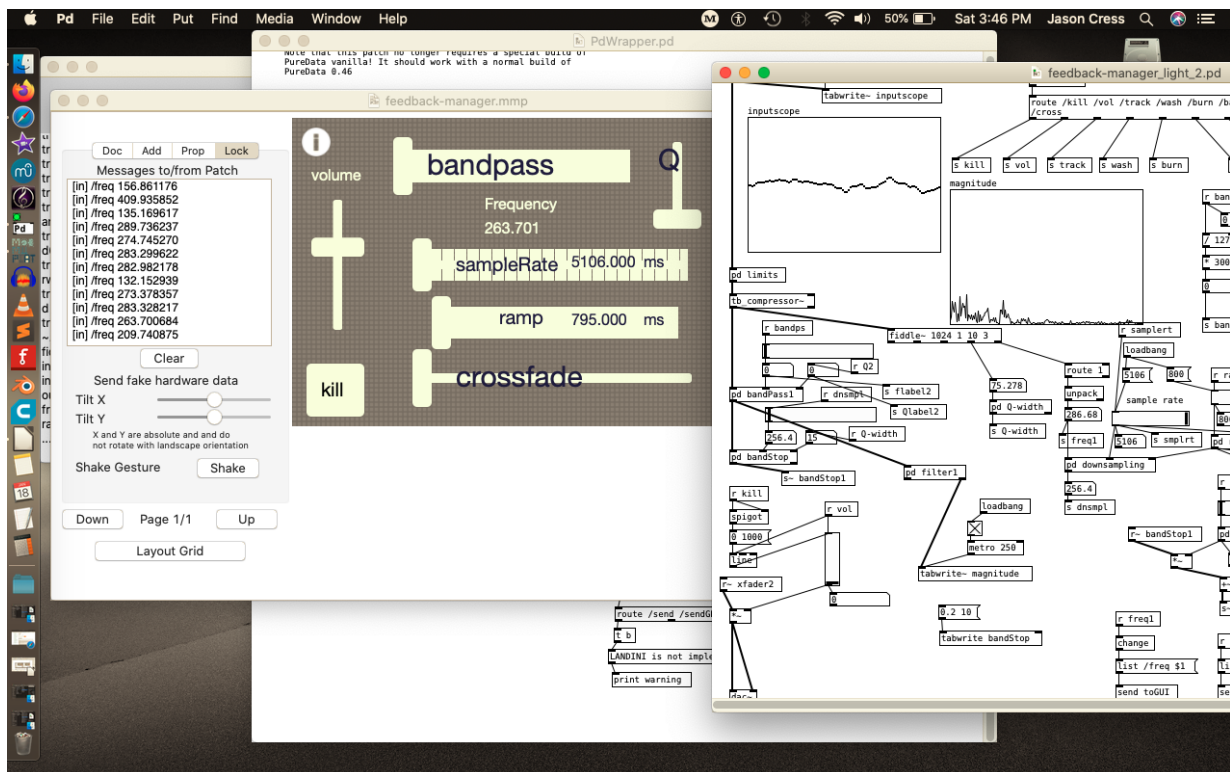


Figure 51. Port PD and MobMuPlat Editor with PD Wrapper file and PD patch.

4. Program these environments however you like. I often configure the audio patch in a recursive network with compressors, limiters, and dynamic frequency attenuators to manage electroacoustic feedback.
5. Follow text instructions on Inglesia's website for more troubleshooting of MobMuPlat Editor (<http://danieliglesia.com/mobmuplat/>).
6. Download the MobMuPlat app onto your mobile smartphone device. This can be found in any of the iOS or Android applications store for free.
7. Upload your .mmp and .pd files to your smartphone via iTunes for iOS or Android File Transfer for Android.
8. Open and test your .mmp file which should be inside the MobMuPlat app documents folder upon startup.
9. Connect the hardware devices together (e.g., iRig device to smartphone audio jack) [Fig. 52].



Figure 52. Left: Plug 1/8" TRSM phone jack into smartphone audio jack. Right: Diagram for entire instrument connection scheme.

10. Test and prototype the system as you like. So far, I have successfully tested iOS and Android smartphone devices with good results. Latency is an issue with any digital sound processor, but the digital processor can be bypassed if only analog modules are used [Fig. 53].

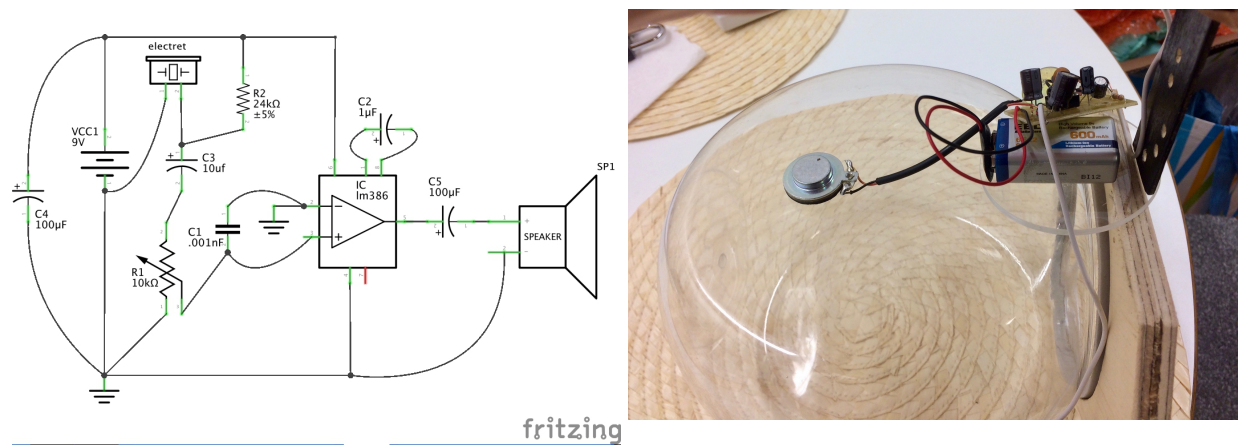


Figure 53. Left: Analog electret LM386 amplifier circuit. Right: ARC analog feedback design.

11. Share your work in any helpful way that is available to you.

A comprehensive list of software you will need:

- Pure Data (vanilla)
- MobMuPlat Editor (latest version)
- MobMuPlat (latest version)
- iTunes or Android File Transfer apps (latest version)
- Custom Pure Data file (digital audio processing)