# Silicon Luthiers: Contemporary Practices In Electronic Music Hardware

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EZRA J. TEBOUL

DARTMOUTH COLLEGE
Hanover, New Hampshire
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*Examining Committee:*

(chair) SPENCER TOPEL, D.M.A.

MICHAEL CASEY, PH.D.

ADEN EVENS, PH.D.

F. JON KULL, PH.D.
Dean of Graduate Studies

# *Abstract*

This thesis focuses on the development of luthiery in contemporary electronic music instruments. Following a definition of the concept of post-optimal objects, a brief history of circuit design and electronic music offers context for an analysis of recent projects, linking open documentation to invention, do it yourself, hacking, bending and self-learning. These projects are further contextualized by a series of interviews with their authors. By working through results and processes, this document exposes how these items can be described post-optimal objects. Through a personalization of the devices, these varied design methods allows individuals to curate more satisfying interactions with their instruments, audiences and professional community.

*”he’s not a composer, but he’s an inventor”*

Arnold Schoenberg, on John Cage

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*to anyone who's ever opened a dead walkman*

# Chapter 1

# Introduction

The present document is concerned with current practices of professional electronic music instrument makers, here referred to as *silicon luthiers* (Collins, 2008). Specifically, it offers a technically literate analysis of modern day hardware in which approaches to circuits and interfaces not following engineering methodologies are intentionally undertaken to offer different and inspiring tools for composition and performance.

This section introduces historical prompts that justify an analysis of musical technology through Dunne's concept of post-optimality (Dunne, 2005). It then details how this point of view can theoretically address some current issues arising in the design fabrication of electronic music instruments. This discussion is finally used to frame the scope, structure and motivations for this thesis.

## 1.1 Toward a Post-Optimal Aesthetic

> ... When's there not a black and white keyboard you get into the knobs and the wires and the interconnections and the timbres, and you get involved in many other aspects of the music, and it's a far more experimental way? It's appealing to fewer people but it's more exciting.
>
> Donald Buchla, in (Pinch, 2001)

Buchla, in designing his "music boxes", describes himself as a builder of instruments rather than machines. The decision not to include a familiar keyboard-format controller in his modular synthesis system was influenced by an appreciation Cage's and Tudor's innovative performances, to whom Buchla sold his first products. He made this choice fully aware of the consequences this might have on his business and popularity (Pinch, 2001, p.44).

Nicolas Collins, student of Tudor, contextualizes the consequences of this type of design philosophy in contemporary electronic music instrument design. Through his book *Handmade Electronic Music*, he encourages users to experiment with electronic hardware in order to be familiar with musical tools not necessarily on a technical basis, but rather, on an experiential basis (Collins, 2006). By offering an experimental approach to electronic music devices, Collins offers a path to becoming a craftsperson of electronic music which does not require a professional engineering background (Collins, 2006, 2008).

In effect, the approaches taken by Buchla and Collins suggest that electronic instruments do not benefit from being reduced to a set of performance requirements for a circuit, algorithms, or both. In their own ways, both practitioners legitimize the claim that electronic music and its musicians can benefit from small-scale, personal approaches in the design and manufacture of instruments. Viewing those devices as

machines which should be optimized for the same metrics as other engineered products (efficiency, reliability, solvability etc.) does not do justice to their unique roles as catalysts of poetic experiences: interesting results arise when designers explicitly address electronic devices as post-optimal objects (Dunne, 2005).

Dunne's concept of post-optimal object is best resumed here by the following quote:

> If user-friendliness characterizes the relationship between people and the optimal electronic object, then user-unfriendliness, a form of gentle provocation, could characterize the post-optimal object.
>
> (Dunne, 2005, p.xviii)

The idea that a physical item can better assist musical functions when it presents some forms of limitations finds precedents in theoretical discussions of electronic music instrument design (Evens, 2005, Rovan, 2009). Engineers implicitly acknowledge this separation between what is theoretically preferable and what is used in practice by offering products based on inefficient, dangerous or unreliable technologies such as vacuum tubes amplifiers or synthesizers (Barbour, 1998, Hamm, 1973).

In explicitly addressing non-standard approaches to instrument design, it is useful to consider Perner-Wilson's kit-of-no-parts framework. In engineering, the kit of parts describes "an approach to designing discrete components that function as modular parts within a coherent system", where these "parts have been optimized for speed, efficiency, and repeatability of assembly" . The kit-of-no-parts approach then encourages users to think of items as the product of a personal craft, where understanding a material down to its components can foster expertise through "skilled use of tools, intimate knowledge of materials" which in turn allow for "more diverse and intelligible results."(Perner-Wilson, 2011)

In discussing the post-optimal aspects of some electronic instruments, this work breaks down designs into three levels, all or some of which can exhibit post-optimal characteristics: the circuit level, the system level, and the interface level.

In effect, post-optimality is already implemented by individuals in the field when they rely on antiquated technologies to inspire new music (Peloušek, 2014), or when they fabricate hardware that enables personal approaches to electronic music composition and performance (Armstrong, 2006, Haslett, 2005).

That personal, inspiringly imperfect vision of electronic music instrument design materialized in various forms through the 20th and 21st century: invention, do-it-yourself (DIY), hacking, circuit bending. Today, this set of historical practices joins back with trends in general hardware design, with movements such as the open source and maker movements (Mellis and Buechley, 2014, Perner-Wilson, 2011). Practitioners meet in FabLabs, which replace the garage and basements of previous generations (Mellis, 2011). Both appear as symptomatic of a similar interest across user-bases: a desire take advantage of emerging technologies to create personal, more inspiring experiences for themselves and their audiences (Hermans, 2014).

The primary goal of this thesis is to contextualize and analyze the work of designers who fit within this vision of audio hardware, aware of precedents but challenging tradition and expectations through inspiring if imperfect uses of electronics.

## 1.2 Motivation

This work exists because of a deep curiosity for the instruments that makes a music electronic, their creators, and their place in today's art world. It hopes to foster future

interdisciplinary research in the field of electronic music hardware and encourage open, experimental devices that blur the line between composition and design.

DIY music instrument communities are based on sharing designs, advice and results. Successful resources document projects from start to end, with more than enough information to tackle any eventual mistake. These attributes find clear parallels in open source hardware design practices, as defined by the open source hardware association (OSHWA). By documenting and contextualizing relevant projects, one can contribute back to both communities. Furthermore, presenting this material in an academic context helps link these practitioners to some of the driving forces behind those emerging technologies. Some of the devices that have encouraged those communities still require strong corporate or academic backing (Arduino, Raspberry Pi).

This survey of design practices in musical technologies should also illustrate an aspect of the interdisciplinary nature of music technology, allowing further comparisons and connections with other designers, trends and fields. By rooting contemporary electronic music practice to the hardware that enables it, a stronger bond to the developing field of sound art is favored (Cluett, 2013). A more explicit connection is drawn to the people who make audio electronics, whether they are boutique designers or factory workers (Rylan, 2015). Issues arising from a direct application of engineering methods based in market economies and cult of performance can be better identified, addressed, and solved for the further development of inspiring interfaces(Christensen et al., 2005, Feldman and Sandborn, 2007, Ghazala, 2004, Hertz and Parikka, 2012, Jackson, 2014, Perner-Wilson, 2011, Riis, 2013, Silver, 2009).

## 1.3 Scope and Structure

This work wishes to contextualize and analyze a selection of audio electronic systems as products of a technological, cultural and social environment. By acknowledging the products, prototypes, tools, people and environments involved in this process, a more accurate description of these ecosystems of invention can be achieved (Vinck and Blanco, 2003). This, in turn, allows for a clearer view of the possibilities and futures for the field of devices for musical expression.

For this clear description to emerge, this document will introduce a cursory history of formative practices paralleling the development of modern electronics (Holmes, 2002). Starting with the isolated forefathers of the field and their "spirit of invention" (Dunn, 2001), useful references through to Collins' *Handmade Electronic Music* will allow a presentation of concepts of component design, system design and interaction design in a musical context. In this discussion, do-it-yourself, hacking and circuit bending are important movements both in terms of general design and musical practices. This thesis then presents the current incarnation of this spirit of invention and experimentation, in the greater context of making and musical cultures. That presentation consists of an analysis of specific projects from the ten years, further contextualized by interviews with their authors. Open innovation made and make electronic instrument design an ecosystem of invention, and this ecosystem is thriving.

PART I

# Past

# Chapter 2

# A History of Post-Optimal Objects in Electronic Music

Great effort goes into making commercial electronics consistent, predictable and uniform regardless of inconsistencies in parts values. The same largely holds for industrially marketed electronic instruments: "one-offs" with unpredictable behaviors or cryptic functions drastically reduce overall adoption of the device, and therefore, their commercial potential (Haslett, 2005, p.5). In this context, the gap between the determinism of product design and the desire for originality of musical performances is bridged by the musician. "Finding your sound" is about finding an instrument and using it effectively.

Making, modifying or otherwise altering electronics is one option to better understand the tools at a musician's disposal and make the most of them. In order to better understand what shaped Buchla's and Collins' work, this chapter draws a brief history of musical electronics that serves as a background for contemporary case-studies presented in the following section.

## 2.1 Electronic Music as Invention

Electronic music was invented before it was composed. Relying on a spirit of curiosity and experimentalism dear to later figures such as Tudor, Collins or Ghazala, pioneers such as C.G. Page, Elisha Gray or Thaddeus Cahill developed electronic musical systems for no reason other than curiosity. As their inventions (galvanic music, the musical telegraph, the Telharmonium) failed to be scientific or financial successes, they abandoned these alleys of research, unaware of their successors' importance (Holmes, 2002, Nasmyth, 1908, Page, 1837).

With electronics still in infancy - no design tradition, few formal structures - blind experimentation was the only option. As design methodologies such as the kit of parts had not been imagined, these devices are not *post-optimal*. However, they do offer a glimpse at electronic music when it was a matter of invention rather than composition.

Two major exceptions were notable for their financial, musical and technical successes: Edison's Phonograph and Termen's Theremin.

Edison was an accomplished inventor and astute investor (Collins, 1998). The phonograph he toured to advertise in 1877 emphasized the intelligibility of the voices it reproduced. Although critics pointed out the impressive but imperfect output from the device, Edison maintained that audiences couldn't accurately distinguish his mechanized reproduction from the natural voice, offering demonstrations tours across the United States (Thompson, 1995). The phonograph is the first example of optimal audio device, one which achieves usability but understates its creative potential (Collins, 1998).

In turn, the Theremin (1920) and its relative financial, but also musical and technical successes presents a significant complement to the phonograph. Just like the Telharmonium, the Theremin can produce some familiar sounds, but with a much simpler device:

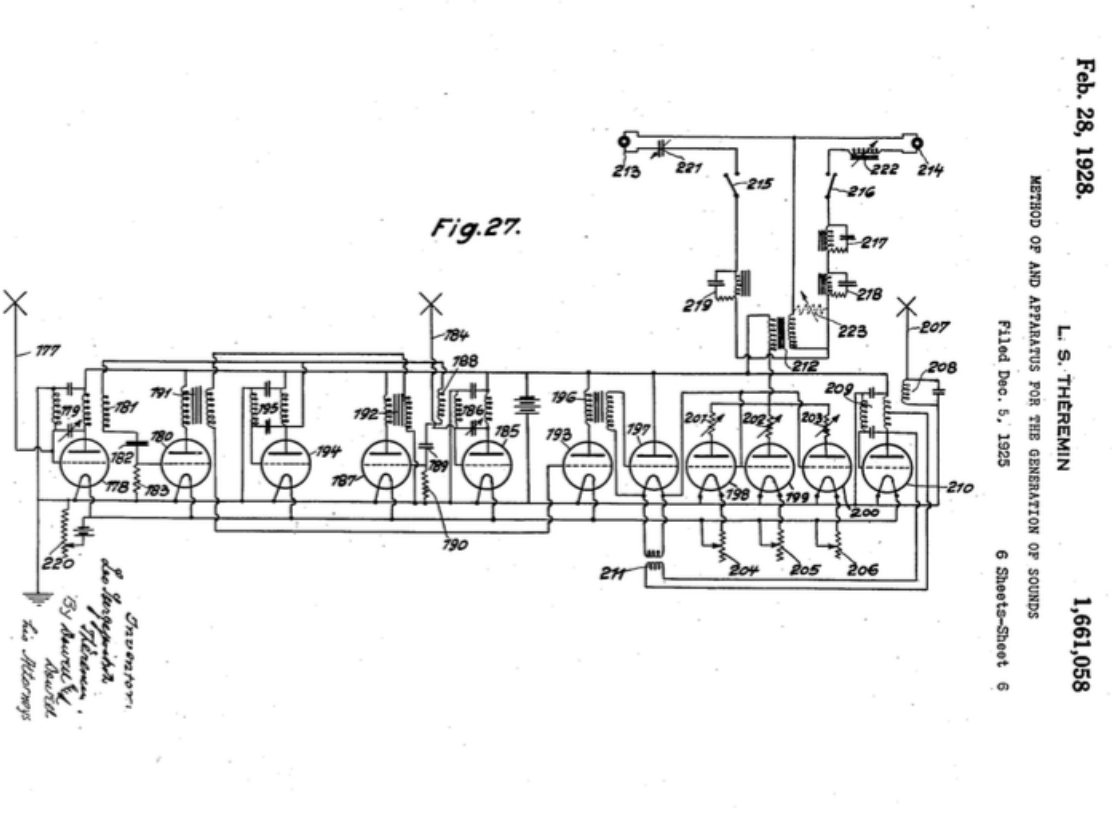



FIGURE 2.1: The Theremin's complete schematic (Theremin, 1928, p.6 of 17)

Compare this with even just one of the Telharmonium's tone generating electromechanical systems:

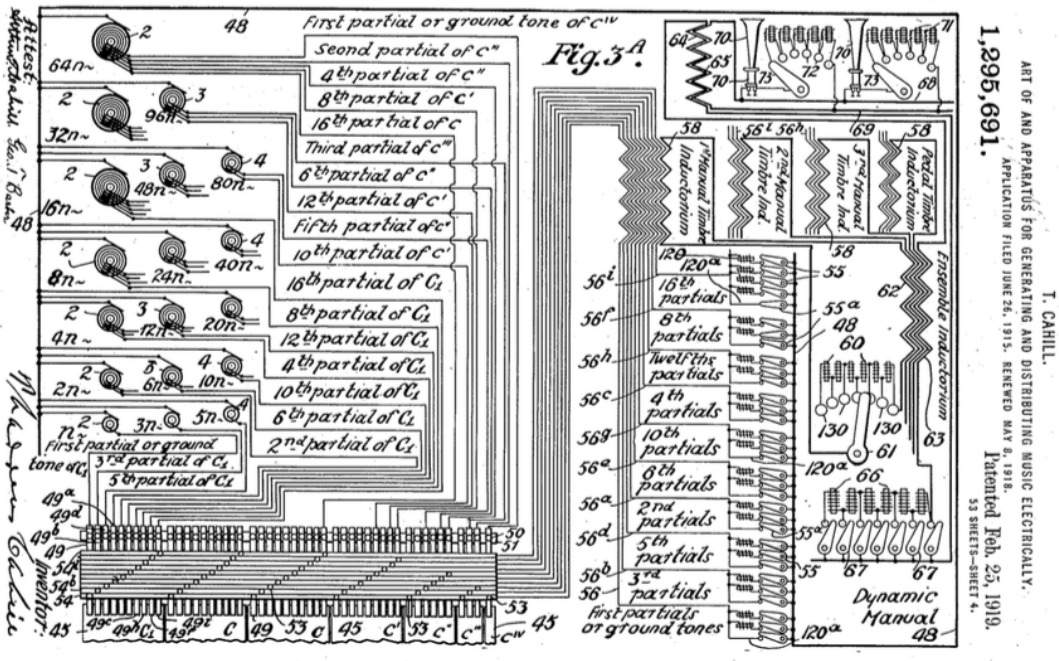



FIGURE 2.2: The Telharmonium's tone generating electro-mechanical circuit (Cahill, 1919, p.4 of 141)

The Theremin's elegant simplicity is related to the hazardous nature of its discovery, best resumed by Kock:

> The early home-made vacuum tube sets, particularly those called "super-heterodyne sets," often possessed the annoying habit of suddenly emitting a loud squeal from the loudspeaker, causing the embarrassed young designer to leap immediately toward the set to readjust the tuning and thereby stop the squeal. In the process of his approaching the set, the nearness of his body introduced a (capacitive) electrical effect which caused the pitch of the squeal to change, going either to a higher-pitched tone or to a lower-pitched one.

(Kock, 1978, p.33)

The theremin, like Gray's musical telegraph, is a by-product of scientific research. However, it comes at a time where its base components are publicly available, backed by population-wide interest in radio technologies and the economic incentive to build electronics from kits. In effect, the theremin embodies a shift in electronic music from

component innovation to systems and interface innovation, which make designs commercially and compositionally viable.

## 2.2 Electronic Music as an Institutional Practice

This shift is, as hinted above, mostly enabled by world-war era research and manufacturing (Holmes, 2002, p.81), especially the vacuum tube triode.

As design methods for vacuum tube-based circuits developed, schematic and tools were thoroughly investigated, optimized and standardized. Building off their industrial successes, institutions served as the breeding ground for most renowned artistic applications of technology: the emergence of the French (ORTF), German (WDR), and Italian (RAI) experimental music studios is directly linked to the increasing popularity of public radio stations. In the U.S., RCA and Columbia University composers collaborated to develop the RCA synthesizer (Holmes, 2002). Max Matthews, after being trained as a Navy radio repairman, found work at Bell Labs with music enthusiast John Pierce, whose fostering would mark the beginning of computer music (Park, 2009).

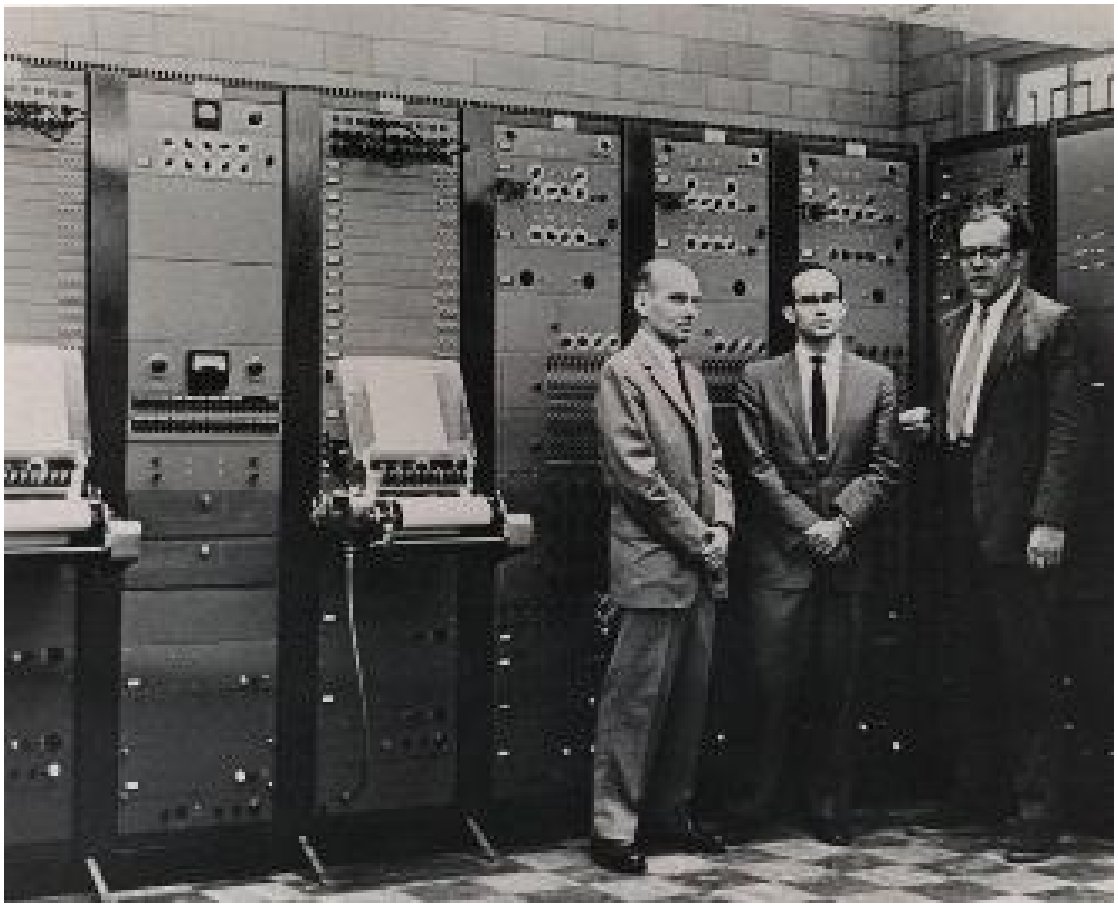


FIGURE 2.3: The RCA Mk.II with Milton Babbitt, Peter Mauzey, Vladimir Ussachevsky, 1958

Those state-funded studios or private research departments constructed a framework for electronic music composition, based on additive / subtractive synthesis techniques and tape editing. But even in those still rigid environments, alternative approaches to instrument design emerged: In Canada, Hugh Le Caine left nuclear physics research to develop the Electronic Sackbut. His device implemented both early version of voltage control and semi-autonomous composition starting in 1945 (Holmes, 2002). The Sackbut's unpredictable response to left-hand controls place its interface squarely in the domain of post-optimal objects.

FIGURE 2.4: The Electronic Sackbut by Hugh LeCaine

In parallel, high costs of manufactured electronics between the world wars kick-starts the birth of do it yourself (DIY) culture. In 1922, a Freshman "masterpiece" radio cost $17 as a kit, while a completed set cost $60. This corresponds to $240 v. $850 in 2014 (B.O.L., 2015, RadioBoulevard, 2015). Accordingly, Radio Shack's first catalog from 1939, contained 80% kits, parts and tools and 20% completed products. A significant number of young engineers growing up with this democratization of technology bring electronic music outside of large institutions. These engineers would echo Le Caine's work, embracing ideals of inconsistent interfaces, intuitive circuit design, and autonomous systems.

One such engineer was Raymond Scott, a professional film composer. He assembled some of the first incarnations of multi-track tape recorders and self-composing synthesizers: his Electronium is described as an instrument that could only be influenced by the user (Holmes, 2002, p.142). "...the Electronium adds to the composer's thoughts, and a duet relationship is set up between man and machine" (Chusid, 1999).

The Electronium "is not played, it is guided"(Darter et al., 1984). Again, a unique approach to interface design places the device within the realm of post-optimal objects.

FIGURE 2.5: The Electronium by Raymond Scott, with Mark Mothersbaugh, its current owner, 1993

Finally, John Cage collaborators Louis and Bébé Barron were arguably the most compelling example of post-optimal musical electronics up to this point. Their use of cybernetics model developed by Norbert Wiener (Wiener, 1965) as basis for musical devices would prove to be yet another early example of a trend, but their hardware implementation was truly unique up to this point: the circuits that Louis built were poorly designed, overdriven and eventually, failed. They would describe the resulting devices as "alive" (Chasalow, 2009). These decaying sound processes would be used as the basis for their composition, which they assembled in a way similar to Schaeffer's concrète process (Dunbar-Hester, 2010).

FIGURE 2.6: Louis and Bébé Barron in the studio

The Barron's devices are perhaps the most compelling proof that personalized musical instruments with post-optimal traits were accessible to those outside of academia and private research.

If the simultaneous rise of vacuum tubes and the theremin allowed electronic music to slowly enter the popular subconscious, it is designers like LeCaine, Scott and the Barron that lead the way in suggesting that hardware wasn't exclusively the domain of the professional engineer. In their design, post-optimal systems and interfaces are a clear, albeit under-documented, thread. This thread comes to full light with the next technological advancement, solid state technologies.

## 2.3 Electronic Music as Living Systems

The development of the silicon transistor, invented in 1947 and commercialized in 1954 (TexasInstruments, 2008), effectively brought down the last barriers for composers to engage directly with the tools that allowed them to make electronic music: price, reliability and safety.

FIGURE 2.7: The first functional transistor, Bell Laboratories, 1947 (replica)

### 2.3.1 Voltage Control

Robert Moog, Donald Buchla and Serge Tcherepnin are all examples of engineers building off their experience with kits and lifelong interests in electronics to fully realize the musical promises of solid-state technologies. The result is an expensive but publicly available package: the modular synthesizer. As those designers were products of institutions (Buchla worked at NASA, Moog at Cornell University, Tcherepnin in Cologne and CalArts), these synthesis systems mirrored the additive and subtractive methodologies developed by the likes of Babbitt, Ussachevsky and LeCaine. However, they did so

in relatively compact formats that allowed for very wide variation and versatility. The parallel with academic computer music is straightforward: unit generators are the equivalents of voltage control oscillators (VC0) and their low frequency equivalents (LFO), ring modulation is multiplication, add/substract units are mixers, etc.

One can see in the commercial modular synthesizer as a first opportunity for the public to "build" personalized systems for popular music. Although modules are limited and costly, the end user is responsible for the final layout of their device.

FIGURE 2.8: The Big Moog Modular System with Klaus Schulze, mid 1970's

Although Moog is not the only manufacturer of modular systems, his choice to pair his devices with the more musically familiar keyboard and some public relations skills make him the bridge between classical tape and electronic composers. What Wendy Carlos sees as the tools of "ugly music" can now be used for "appealing music you could listen to." (Holmes, 2002, p.169) As Carlos fine-tuned her own Moog system,

she eventually went to get a custom version of the system made to her specifications and make electronic music exponentially more popular through her *Switched On Bach* record.

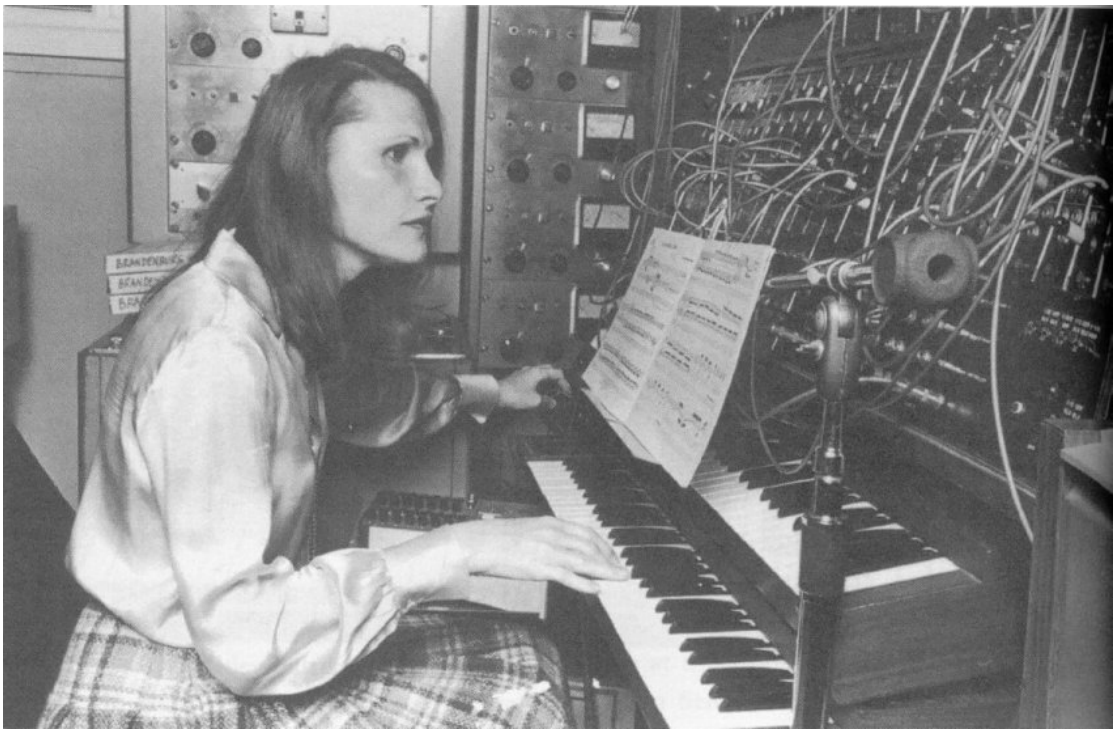


FIGURE 2.9: The Moog 55 system customized for Wendy Carlos

At the opposite end, Buchla viewed himself as a luthier, designer of instruments, rather than the engineer of machines (Pinch, 2001). His decision to develop new methods of interacting with his circuitry rather than relying on pre-existing schemes like Moog's keyboard severely limited his user-base. Nevertheless, Buchla's designs are respected and still popular today: "The Buchla box was designed for musicians who wanted to produce a complex piece of music in real time." (Pinch and Trocco, 2009, p47). If Moog's modular model is the template for much of the additive synthesis audio software and hybrid analog/digital audio hardware today, Buchla's interface and interactive system design work are still being digested and re-used (Rylan, 2015, Snyder and McPherson, 2012) .


FIGURE 2.10: The Arbitrary Function Generator, Buchla's distinctive aleatory module

Ultimately, Pinch concludes: "Designers 'script' or 'configure' ideal users into their machines.(...) Scripts try to contain the agency of users, but users can exert agency, too, and can come up with their own alternative scripts." (Pinch and Trocco, 2009, p.311). The complex interplay between designer and user takes on a significantly different meaning when those two personas belong to the same person. In that sense, being both the designer of the system and the user allows for post-optimal objects to emerge.

As engineers like Moog and Buchla abandoned their institutional positions to develop these modular systems, the American experimental music scene was also enjoying unprecedented exposure. Of interest here is David Tudor, and a major turning point was his performance of Cage's 1961 *Variations II*.

### 2.3.2 Composers Inside Electronics

Preparing the piece, Tudor assembled a complex electronic system which continually produced musical signals. Control on the system was tenuous at best: "You could only hope to influence the instrument" (Nakai, 2014).

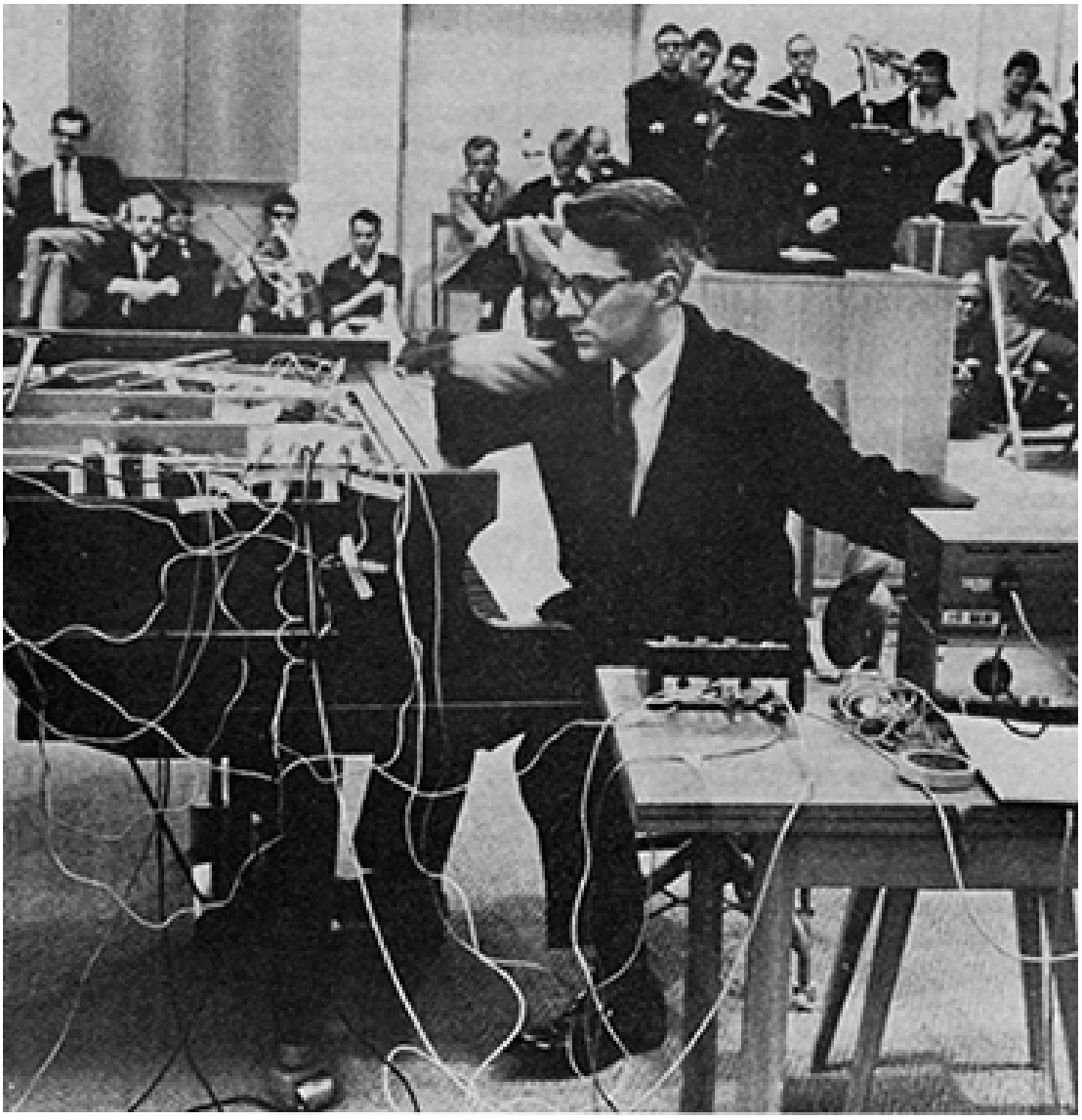


FIGURE 2.11: Variations II, performed by Tudor

Tudor would go on to build a composition career based largely on this premise of live electronics. Reminiscent of Barron's living circuits, Tudor described his work as "composing itself out of its own composite instrumental nature."(Kuivila, 2004, Tudor, year unknown) Tudor's practice of experimental electronic music systems complements Cage's indeterminacy, and this was made possible because of semiconductors (Collins, Appendix A). Transistors and integrated circuits offered the functionality of vacuum tubes without the latter's size, weight, price and high voltage hazards, becoming available and documented as he started using custom electronics (Collins, 2004b). Tudor elaborates:

> Electronic components and circuitry, observed as individual and unique rather than as servomechanisms, more and more reveal their personalities, directly related to the particular musician involved with them. The deeper this process of observation, the more the components seem to require and suggest their own musical ideas, arriving at that point of discovery, always incredible, where music is revealed from "inside," rather than from "outside."

(Nakai, 2014, Tudor, 1976)

Furthermore, Tudor is arguably unique for being the first to so explicitly bridge *poetic* visions of circuits and composition with a complementary approach to musical scores:

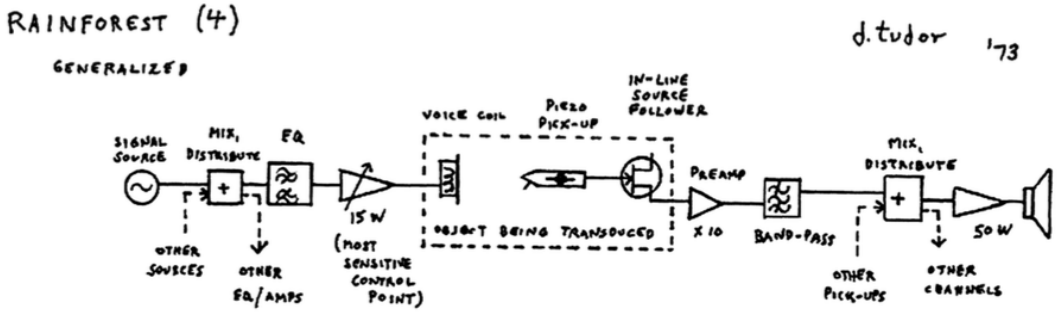



FIGURE 2.12: The score for *Rainforest IV* by David Tudor

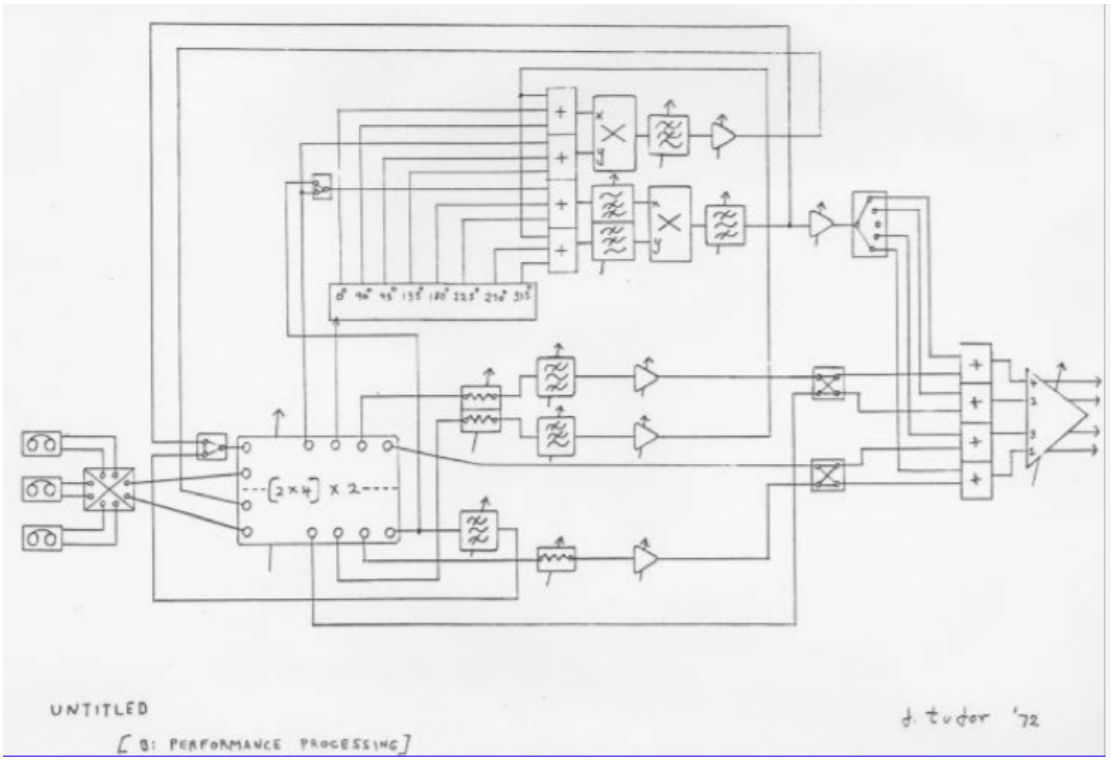



FIGURE 2.13: The score for *Untitled* by David Tudor

These take a formalized practice of abstraction (the circuit schematic), and push it one step further through unusual variations relating to personal interpretations rather than an universal symbology. Graphic scores were by then not an original practice, however, few offered such a clear connection between the musical and physical realities of the compositions.

Both aspects of Tudor's practice can be considered as post-optimal: his circuits behaved as co-composers through complex, unpredictable and sometimes chaotic operations (those systems are still rarely used in standard electrical engineering today), and his schematic-scores challenged the performer to produce personal interpretations of these twice-abstracted symbol combinations.

These innovative methods were largely a collaborative practice. Through collaborations with Gordon Mumma, David Behrman, Hugh Le Caine, or John Fulleman and

thorough personal investigation, he gathered enough experience to masterfully implement one of the first documented uses of chaotic electronics in music (Kuivila, 2004). Some of these collaborations (namely with John Driscoll, Paul DeMarinis, Nicolas Collins, Matt Rogalsky, Ron Kuivila, amongst many) were formalized as *Composers Inside Electronics* (CIE) for the premiere of *Rainforest IV* in 1973. Tudor and his students shaped live electronic music performance (Collins, 2004b, 2006, 2008, 2010, Driscoll and Rogalsky, 2004, Kuivila, 2004, Nakai, 2014). Through the learning, supplying and sharing tools offered online, Tudor's ideals of experimentation and collaboration have come to be more relevant and accessible than ever.

A prime example of avant-garde, personal electronic music techniques coming to a popular forefront with relatively little technical support comes from the British composer Brian Eno, through his development of the system later known as *Frippertronics*. His process on *Discreet Music* is clearly related to Tudor's:

> If there is any score for the piece, it must be the operational diagram of the particular apparatus I used for its production. (Eno, 1975)

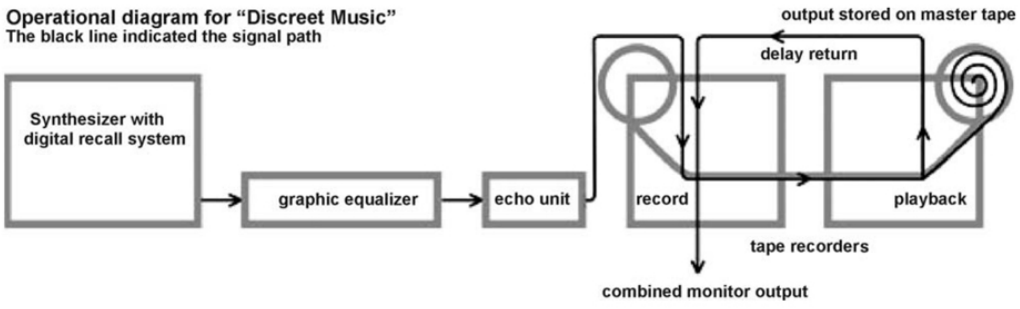



FIGURE 2.14: The Operational Diagram for Discreet Music(Eno, 1975)

In terms of post-optimal approaches, Eno operates between the system and interaction levels. However, Tudor's wish to see personality emerge from circuits is echoed

by Eno's "acceptation of that passive role" which characterizes the first half of *Discreet Music*.

More so than Tudor's various devices, *Frippertronics* serve as the archetype of simple post-optimal electronic music instruments. It illustrates the amount of resources, technical knowledge and musical intuition necessary to make the medium of electronic music one's own. Tudor and Eno, by using diagrams as scores rather than standard staff notation, redefine the notion of musical literacy and expertise.

## 2.4 Electronic Music as Craft: Silicon Luthiers

Academically, the essence of Tudor's successors' would be captured by CIE member Nicolas Collins:

> "The circuit— whether built from scratch, a customized commercial device, or store-bought and scrutinized to death— became the score."

(Collins, 2004b)

*Handmade Electronic Music* was first published in 2006, presenting an extensive amount of information on homemade electronic instruments with insight from years of experience, references and sources. By completing this project, Collins not only proved that blending academic, commercial and hobbyists attitudes could be successful in all three of those areas, but also linked decades of practices in the do-it-yourself electronic music world to the "maker" movement.

Discussing Tudor, Mumma and Kahn, Collins describes the origin of his interest in music hacking, which references the origin of experimental electronics as a legitimate ground for musical composition:

> "I learned from Tudor and Mumma that you did not have to have an engineering degree to build transistorized music circuits. David Tudor's amazing music was based partly on circuits he did not even understand. He liked the sounds they made, and that was enough." - David Berhman (Collins, 2006, p.ix)

In effect, *Handmade Electronic Music* is a manual for the design, manufacture and refinement of post-optimal musical electronics, starting at the component level and working to larger systems. Collins gives an informal list of the "unsung heroes" of this practice: Moog, Buchla, Tcherepnin, but also Tom Oberheim, Alan Pearlman, Craig Anderton and David Cockerell, then followed more recently by Bob Bielecki, Bert Bongers, and Sukandar Katardinata (Collins, 2006, p.211). Those are later named *Silicon Luthiers*: they are, in effect, the master craftsmen of electronic music instruments (Collins, 2008).

Just like Tudor and Lucier helped younger practitioners develop their own hardware based approach, Collins' book encourages an inclusive and intuitive vision of tinkering and experimentation for the arts, and does so through more than a friendly informal tone. The original draft for the book, a compilation of class notes, is freely available for download off of the author's website (Collins, 2004a) . The first result for "handmade electronic music pdf" on most search engines will give a pdf of book.

By tolerating or passively encouraging open access to resources, Collins gives back directly to the community he has helped shape. More than writing the book on hardware hacking for non-engineers, he's an essential force in making open hardware design the self-sustaining cycle it aspires to be through the maker movement. By publishing this through a large company while in a professional academic and musical position, he also lends the weight of a more widely recognizable figure to a movement and methodology that challenges the necessity for those very institutions.

Measuring the influence of this book through simple academic metrics, such as the number of times it is cited in publications following it (Harzing, 2008) yields the following results. "Handmade…" seems to have been referenced in 88 publications. For comparison, Road's "Computer Music Tutorial", published 10 years earlier, returns 1267 citations, the "Art of Electronics" (a standard circuit design text from 1989) returns 3640, and Gharzala's "Circuit Bending" from 2005 returns 45.

When it is cited, "Handmade…" is rarely commented upon directly. It is referred to in surveys of contemporary sound art, music, and music technology practices (Kelly , Ed., Mills et al., 2010, Pigott, 2011, Rodgers, 2010), and as an inspiration in the development of a specific musical controller (Ariza, 2007, Hoadley, 2010, Murphy et al., 2010, Riis, 2013, Valle, 2011).

Overall, the academic impact of the work is fairly confined to the field it wished to solidify (music hardware hacking). Its varied content originated from a set of lecture notes, which have since found their place in other college level classes at other institutions.

On a community level, Collins' impact is difficult to measure objectively. Highly frequented music hardware hacking forums such as Experimentalist Anonymous, DIYstompboxes, freestompboxes.org, and electro-music.com all contain mention and praises for the accessibility and simplicity of "Handmade…", but those explicit references are rare. For comparison, searching for Ray Wilson's popular "music from outer space" do-it-yourself synthesizer website returns between two to three times more results on the same forums. However, as the upcoming case-studies will indicate, Collins' writing has had a long-lasting practical effect on music tinkerers. Further publications prove that although Collins' text is not the only resource available, he has contributed to the development of entire sub-genres of musical expression based entirely on explorations of audio hardware hacking (Ghazala, 2004, Hegarty, 2007, Kelly, 2009).

This history elucidated how Dunne's concept of post-optimality could link seemingly disparate practices in the design and fabrication of musical instruments: first, inventors' curiosity to combine the new medium of electricity with the older purpose of music helped define what metrics the greater engineering community would use to determine optimal objects. Second, the advent of vacuum tubes and solid state technologies empowered growing waves of tinkerers to apply knowledge and research from radio communications and explore possibilities outside of what best practices recommended, slowly offering an alternative to the institutional practice of electronic music. Finally, these post-optimal practices were legitimized by academics in order to further disassociate an engineering backgrounds from the design electronic music instruments.

This leads this discussion to the current state of post-optimal objects in electronic music: what drives practitioners to implement such approaches, and what advantages might they still offer?

# Chapter 3

# Selected Recent Works

This chapter describes a selection of designs from the past few years by makers in electronic music. All of these analyses are based on freely available material, usually online but often referencing printed material. They were selected because they illustrate the variety of incarnations post-optimal design can take in electronic music instruments. They all function using relatively modern semiconductor components, and yet each of them offers an opportunity to identify and justify post-optimal devices in music.

## 3.1 Devi Ever: *Devi Ever FX*

*Devi Ever FX* was initially ran by Devi Ever, who achieved niche notoriety for selling a long list of different distortion pedals before leaving the business to Louise and Ben Hinz. Devi is particularly appreciated in the online pedal DIY scene for her willingness to share audio circuit designs.

The *Improbability Drive* was selected here to both serve as a simple example of the research and analysis methods used in this chapter and offer a first view of how post-optimal design finds its way into musical electronics.

### 3.1.1 The *Improbability Drive* (2011)

Devi Ever FX (under the new Hinz ownership) currently sells 23 different designs of guitar effect pedals (mainly focused around distortions, overdrives or fuzzes), while its "outdated" page names 30 additional discontinued models. As a primer to the upcoming analyses, this subsection presents a introductory project to discuss basic concepts.

The *Improbability Drive*'s circuit was first posted by Devi Ever herself on the freestompboxes forum, which is notorious for its experienced reverse engineering community of musicians and experimenters(freestompboxes, 2012a). Over email, one of the interviewees would express a general disdain for their unethical practice of copying pedals while their designers are still retailing them.

Although the original schematic is no longer available on the discussion thread, it was picked up by Ken Schurer of Infanem (Schurer, 2015), traced, and posted back by user B3ar on digi2t's request.

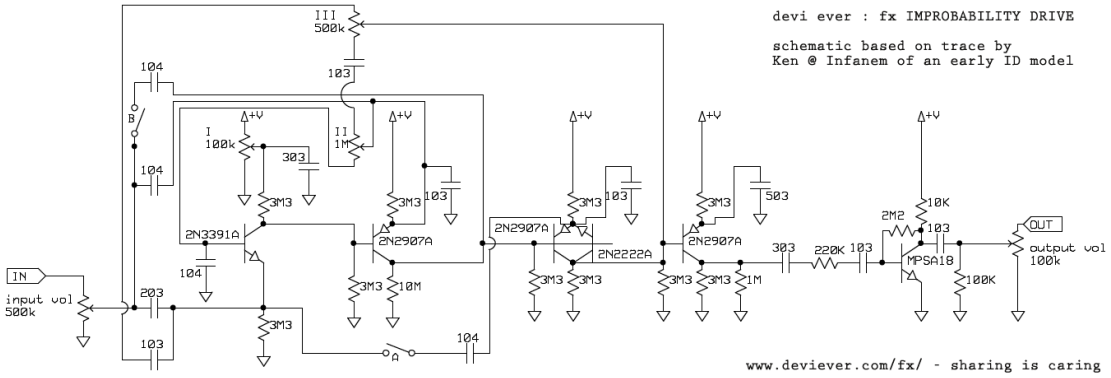



FIGURE 3.1: The Improbability Drive, traced from a second version board, courtesy of Ken Schurer

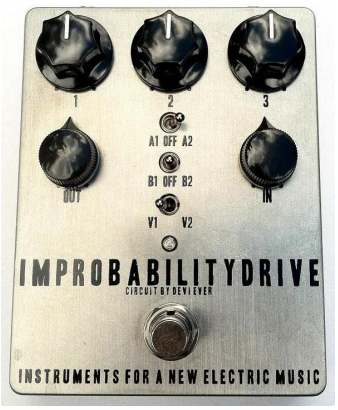



FIGURE 3.2: The Improbability Drive, adapted for commercial production (Schurer, 2015)

Following up on this project, user storyboardist designed a protoboard and circuit board layout and shares it with the rest of the thread. Astrobass and digi2t discuss the finer details of the modifications Schurer might have made to Devi Ever's original design.

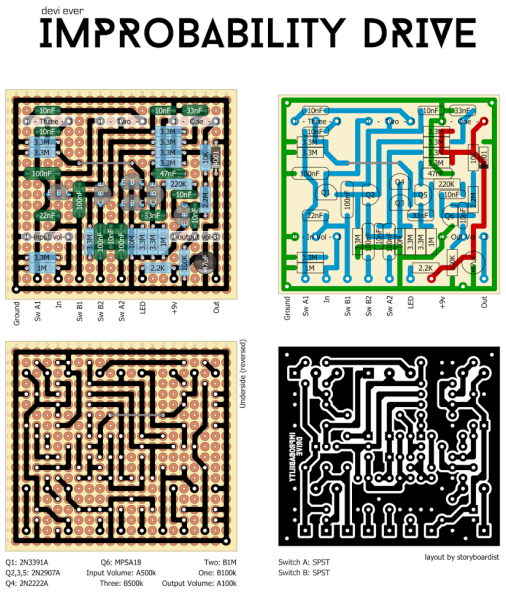



FIGURE 3.3: The Improbability Drive circuit layouts for PCB or prototype board, courtesy of storyboardist

In a couple of pages' worth of discussion, a discrete transistor fuzz circuit was resurrected and made easily implementable by anyone with 15 dollars worth of parts and a few hours of time, for no reason other than users appreciated Ever's original contribution and were willing to entertain another user's delayed interest (freestompboxes, 2012a).

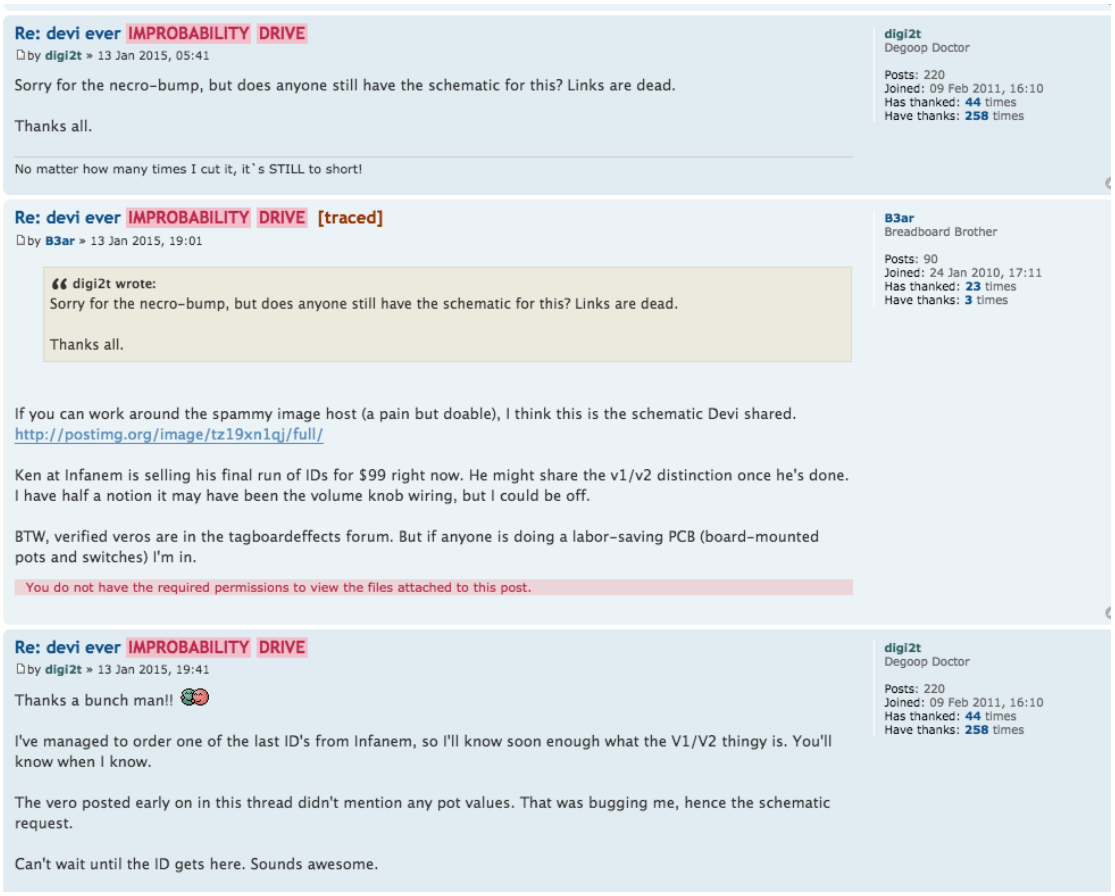



FIGURE 3.4: a screenshot of the Freestompboxes.org page describing the *Improbability Drive* (freestompboxes, 2012a)

Presenting enough information to discuss a circuit design and replicate hardware results (in this case, timbres) is a typical maker practice, and constitutes the main source of content for websites like Hackaday, Instructables and portions of the Make Magazine website (as we'll see in a few sections).

Other threads vary in detail. Some offer in-depth, component level analysis of each circuit, while other describe products so rare that there is barely any information on the topic. Unlike torrenting forums where rare catches are motivated by the concept of ratio bounty, users have little incentives to help other than curiosity and personal satisfaction. This website's audience is a dedicated, eclectic and usually friendly set of musicians and tinkerers united by an interest and a tool for sharing information.

This example shows two things: first, that open approaches in electronic music hardware are still present today, and, second, that those open practices are in effect accessible to anyone with the resources and time to learn how to read a schematic in proximity of a soldering iron. Introductory projects such as this have two other consequences: encouraging the development of more sophisticated, personal projects, and serving as an educational gateway to circuits and notions of electrical engineering, design and fabrication.

## 3.2 Jessica Rylan, *Flower Electronics*

Rylan's circuit design practices is based on both self-taught circuit skills and later rigorous training, either as an employee of Don Buchla's or later as a co-author with chaotic systems researcher J.C. Sprott (Piper and Sprott, 2010). In previous interviews, she expresses the unattractive formatted nature of classical approaches to additive or subtractive modular synthesis, as well as the generally male-centric communities behind it. This dissatisfaction is presented as a motivation for a number of circuit designs and corresponding commercial products (Rodgers, 2010, pp.139-155).

Inspecting devices sold by her company, *Flower Electronics*, over their period of operation (2006-2011) only imprecisely informs one of how this might have been done. Enclosures are still standard guitar pedal cases, albeit with layouts, knobs and banana patch jacks reminiscent of Buchla's designs. The underlying circuits roughly seem to follow modular synthesis architectures. A clear interest in chaotic oscillators is denoted, but even in that case, it seems difficult to break out of the VCO/VCF/VCA modular mold.

In some sense, Rylan's work is at its most compelling when it is presented in the context of her own history and musical practice. The personal synthesizer, started in

2004, is the aptly named tool she developed in this quest of alternative design.

### 3.2.1 The *Personal Synth* (2005)

FIGURE 3.5: Jessica Rylan performing with the personal synth

FIGURE 3.6: The Personal Synth by Jessica Rylan, close up view courtesy of (Rylan, 2011)

A particularly well documented instance of Rylan's work (Rylan, 2011), this device is arguably the work that started Flower Electronics. Later commercial works by Rylan were not presented in such detail.

Rather than paraphrasing the circuit analysis provided by Rylan, this section will comment on the devices originalities and their implications in the context of a hardware practice.

At the heart of the device are two 8038 oscillator chips, in a doubled circuit Rylan derived from Thomas Henry's *Audio Generator* (Rylan, 2011, **?**)

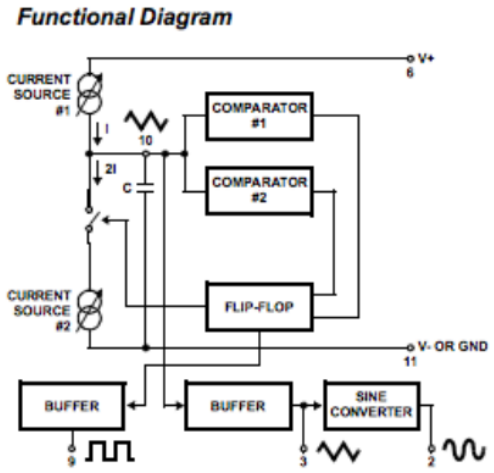



FIGURE 3.7: The 8038 oscillator functional diagram, courtesy of Intersil

Implementing voltage control of the wave-shaping section forms the basis for a versatile and compact device is unique: most timbral forming in analog synthesis takes place in the filter or modulation sections.

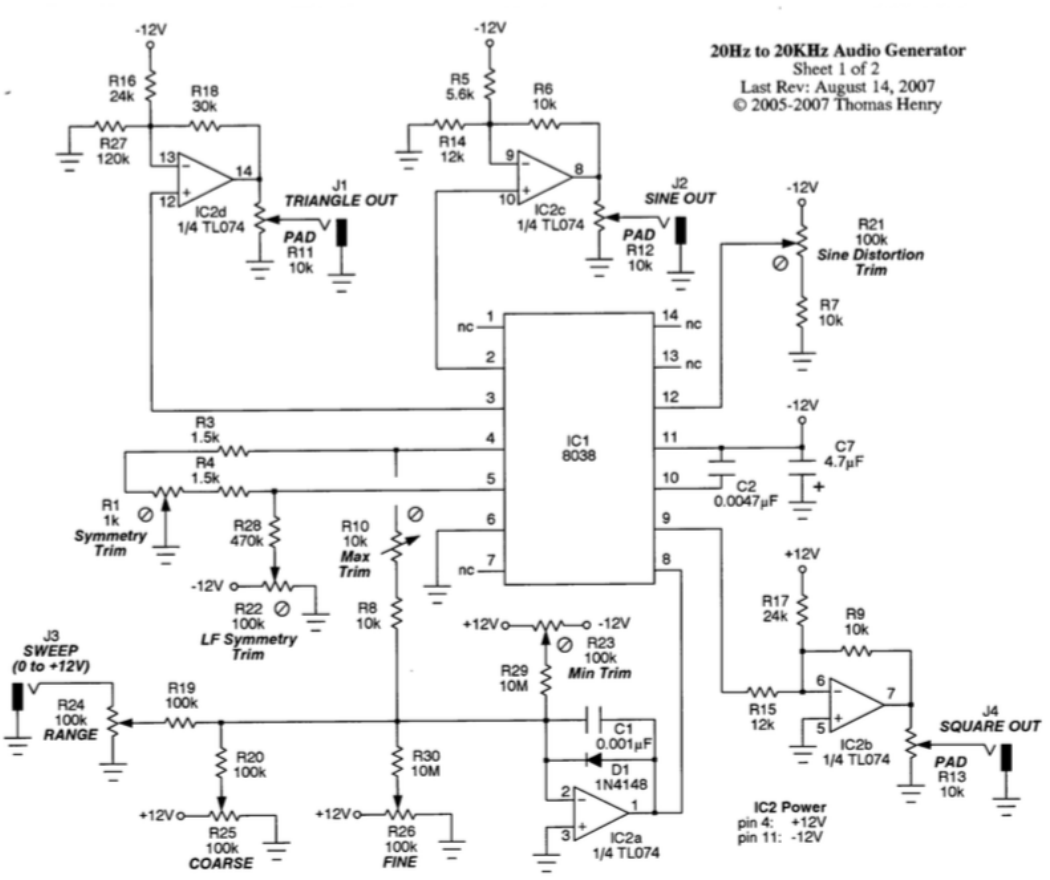



FIGURE 3.8: The original 8038 oscillator schematic by Thomas Henry(Henry, 2010)

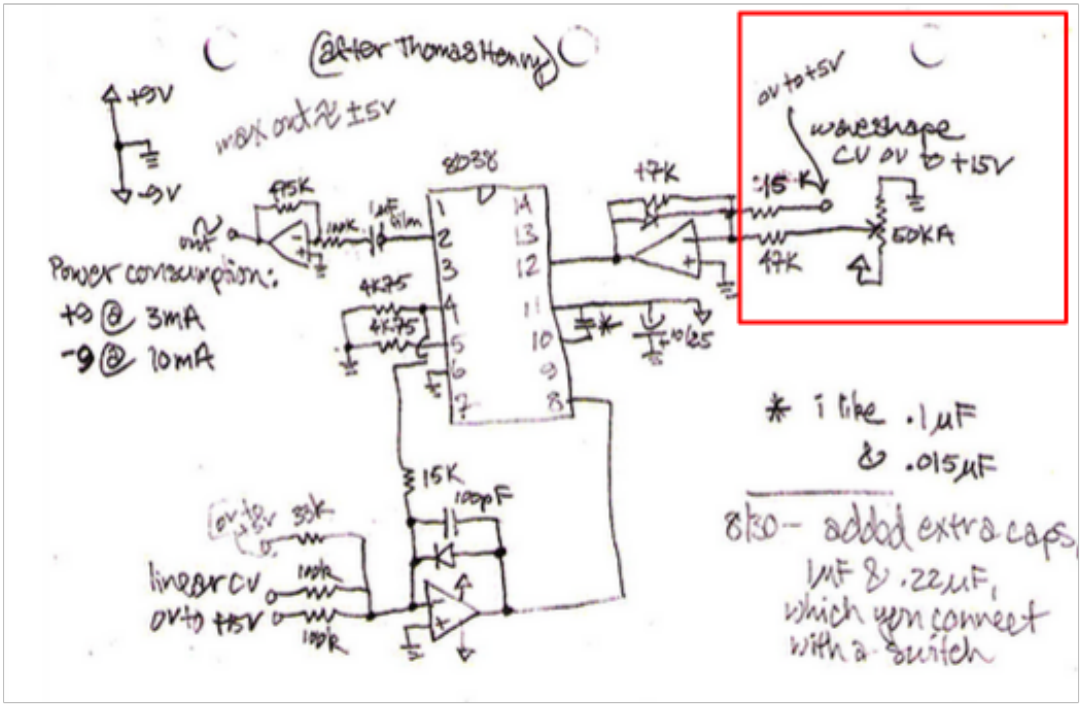



FIGURE 3.9: The *Personal Synth*'s 8038-based oscillator(Rylan, 2011). In red is the voltage controlled wave-shaper

The choice of an 8038 is significant. By no means an antiquated design, the chip has however been discontinued as of writing, with no replacement from the manufacturer. As digital devices implement high quality sampling and the communications / military roots of semiconductor research lose interest in the specificities of chip oscillators, those designs get obsoleted at an increasing rate. Just like Nicolas Collins' 566 circuits, Rylan's 8038 circuit is a worthwhile study, but not necessarily the most practical avenue for the musical tinkerer.

This device is further expanded by a microphone input, in which the preamp produces low frequency oscillations if not turned off. Then, an original VCA implementing an unpredictable flavor of filtering through nonlinear zener diodes:

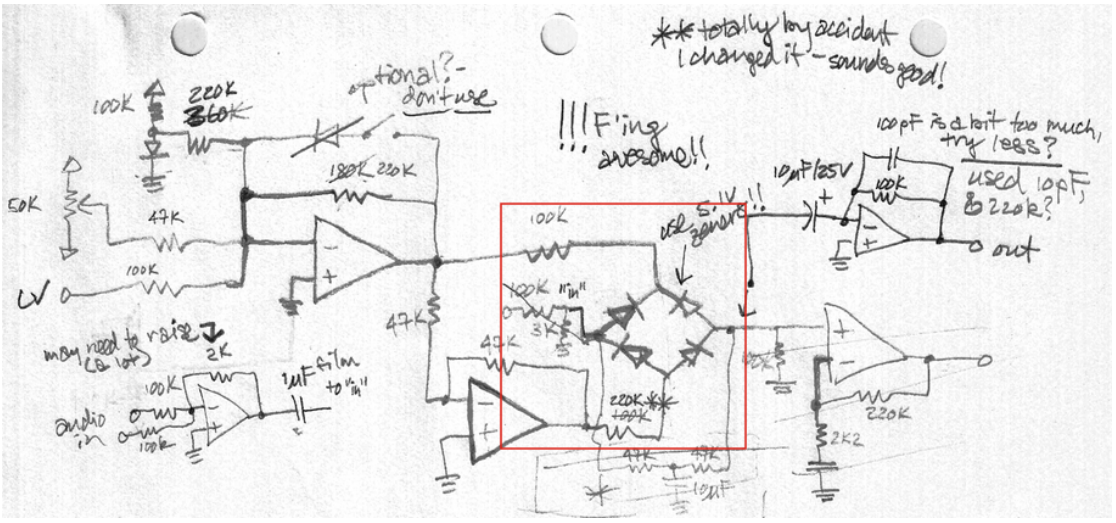



FIGURE 3.10: The *Personal Synth*'s unique zener bridge VCA design. In red is the diode bridge for the VCA (Rylan, 2011)

Rylan explains her reasoning behind this unusual choice of amplifier topology:

> for the other really magic part of the personal synth, I eschewed filters and opted instead for a diode-bridge VCA, implemented with zener diodes. Theoretically the Zener shouldn't really change things (consider how attenuated the audio input it) but as they say, the results speak for themselves.

(Rylan, 2011)

For a high-level view of the device, she offers the following diagram:

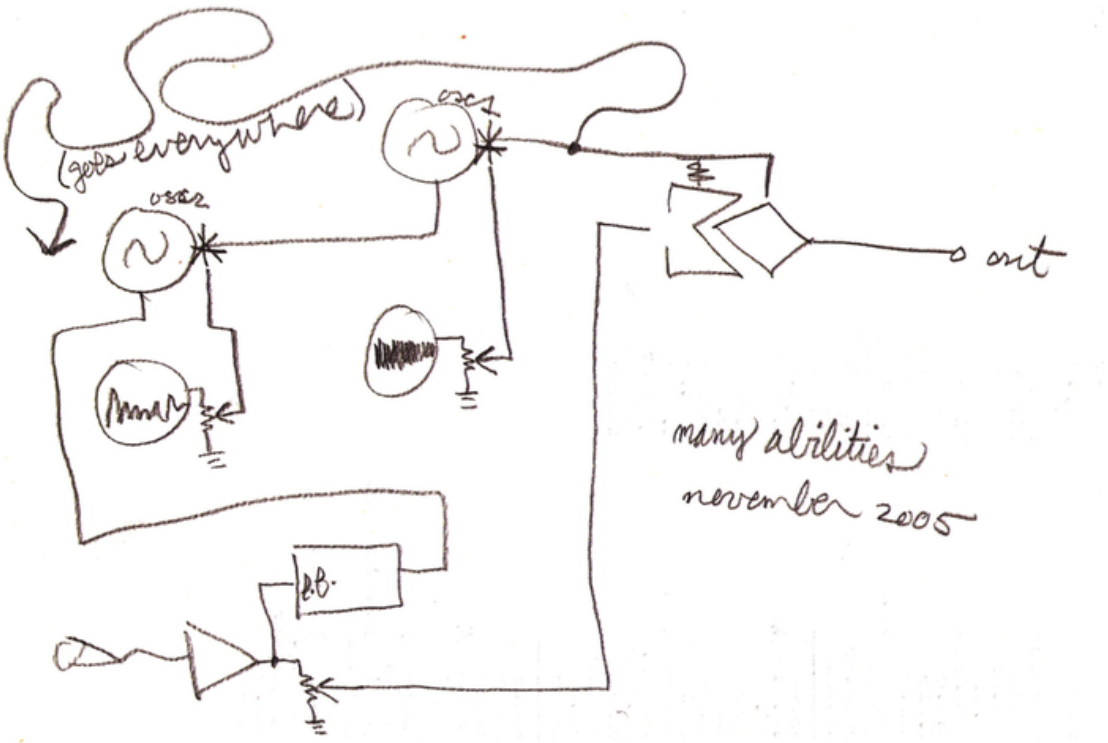



FIGURE 3.11: The functional diagram for the *Personal Synth* (Rylan, 2011)

After some reworking, a typical patch might involve the following clarified signal flow:

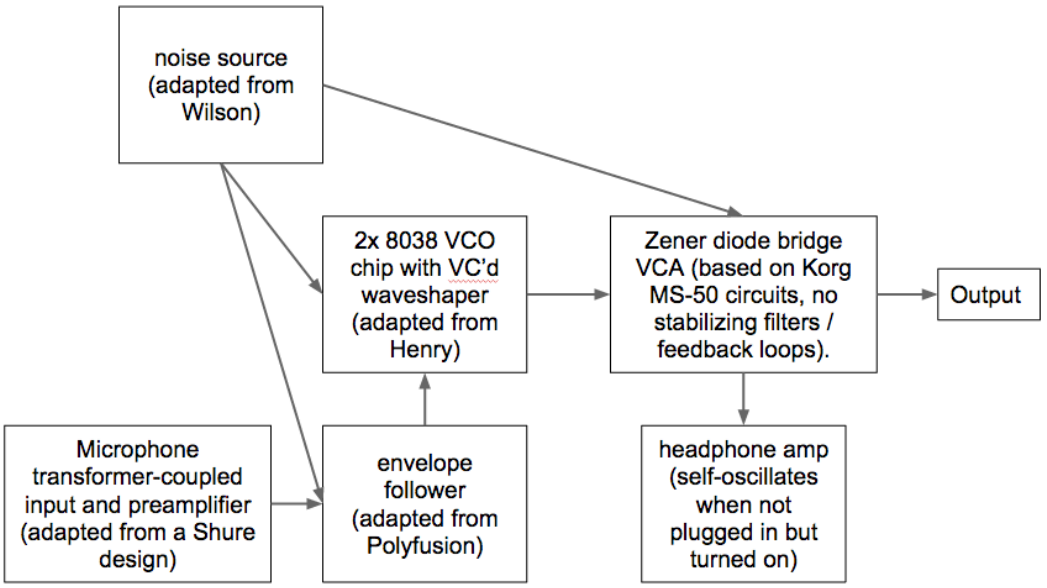



FIGURE 3.12: The adapted functional diagram for the *Personal Synth*

If the Personal Synth is perhaps not a completely new way to think about analog synthesis, it was a new way for Rylan to think about music which prompted the development of successful business. A number of the decisions within the device, such as removing feedback capacitors and protections or including differently nonlinear devices at crucial elements, all constitute instances of post-optimal design, meant to enhance the poetic capacities of the device. This post-optimality and chaotic behavior links Rylan to Tudor's concept of letting electronics speak for themselves.

## 3.3 Ben Hinz: *Dwarfcraft Devices*

> We can make our "1"-"0" decisions into just about anything- a musical note, a test waveform, a measured and displayed value, a video presentation, a clock, a game, an industrial control, a toy, a microcomputer, an art form, a community information access service, or just about anything else you can dream up. All it takes is the right number of logic blocks properly connected to do the job. (Lancaster and Berlin, 1988, pp-7-8)

*Handmade Electronic Music* focuses much of its circuits around the Complementary-Silicon-Metal-Oxide (CMOS) family of integrated circuits. Collins acknowledges inspiration from Lancaster's *CMOS Cookbook*, quoted above. In doing so, both authors recognize how powerful binary information - an its continuous counterpart, the square wave - can be in relatively simple synthesis environments. Older examples abound: the Weird Sound Generator, a typical first synthesis project sold as a kit by Ray Wilson from the *Music From Outer Space* website, relies on interconnected CMOS chips for its synthesis (Wilson, 2015). *Beavis Audio*, an important DIY music website, focuses one of its most interesting blog posts on this family of circuits, naming Collins as an influence (BeavisAudio, 2015).

Although Collins is not the only source of these digital logic sound generators, the publication of his book has had a visible impact on many of the low-part-count synthesis circuits seen today. The following examples exhibit particularly interesting and relevant projects, as Ben Hinz acknowledges that he started making audio electronics based on the Collins book (personal exchange, 2015)

### 3.3.1 The *Robot Devil* (2012)

The Robot Devil is an octave and distortion instrument effect based around two integrated circuits from the 4000 family of CMOS chips, the 4040 clock divider and the 4049 hex inverting buffer. Just like with the *Improbability Drive*, a forum post contains most of the information necessary to analyze the device to the component level (freestompboxes, 2012b).

Similar 4049 circuits are presented in Craig Anderton's classic *Electronic Project for Musicians* (Anderton, 1980, p.173), then updated by in Collins' *Handmade Electronic Music* (Collins, 2006, p.155), with Poss' law as subtitle: *Distortion is Truth*.

As one can see from the forum schematics provided by user *nocentelli*, the *Robot Devil* distortion portion of the circuit appears to be closest to the original Craig Anderton version, rather than Collins' augmented 3 buffer or distortion+fuzz versions:

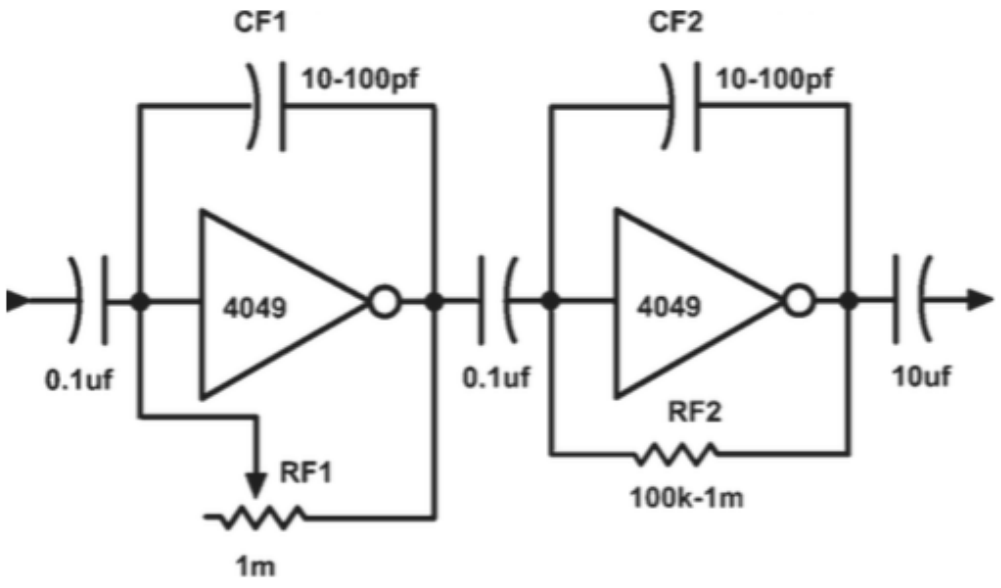



FIGURE 3.13: Two stage distortion schematic by Collins (Collins, 2006, p.155)

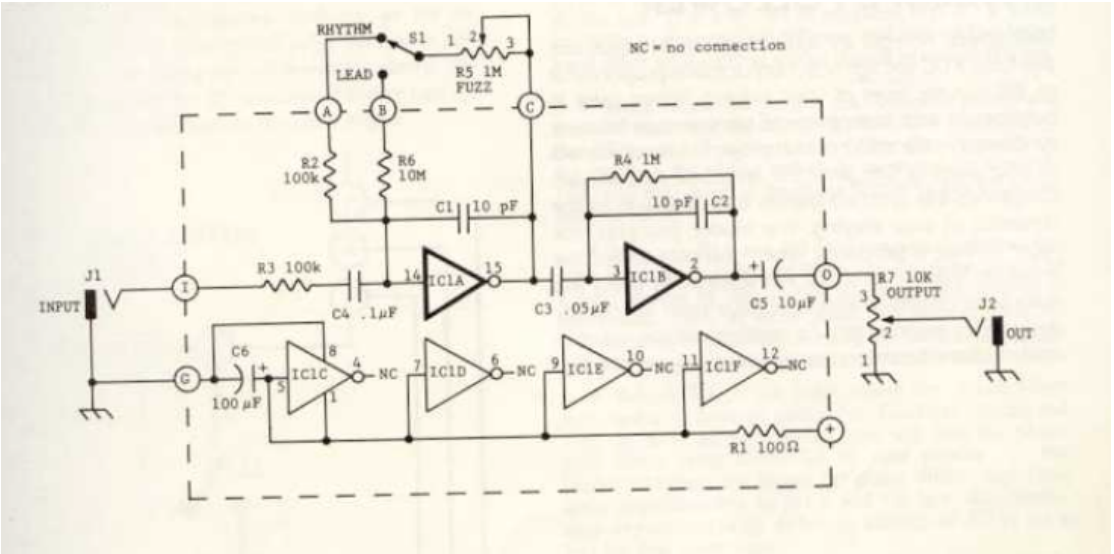



FIGURE 3.14: A "tube sound fuzz schematic" by Anderton (Anderton, 1980, p173)

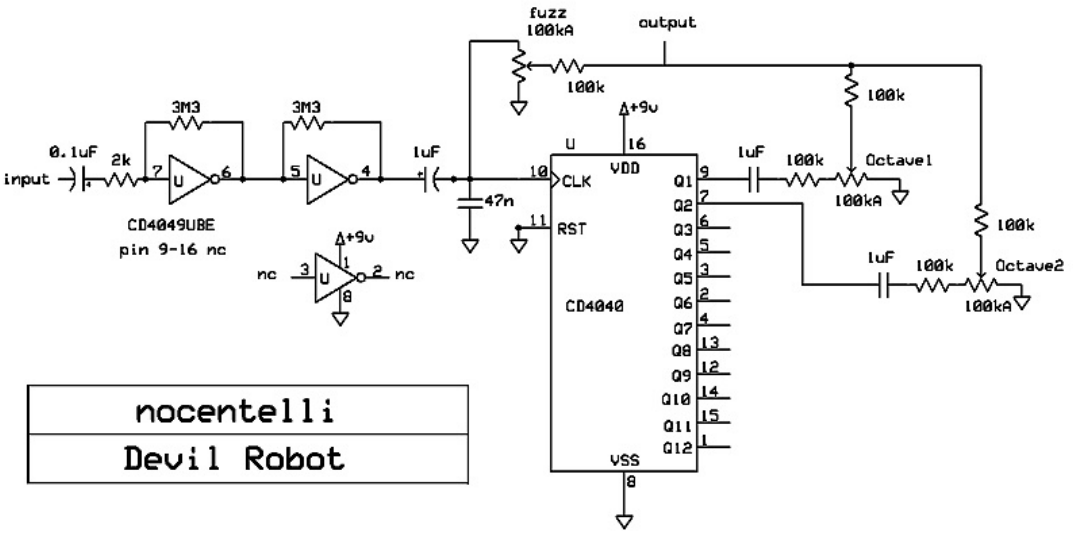



FIGURE 3.15: The *Robot Devil* schematic, as traced by user Nocentelli (freestompboxes, 2012b)

The 4049 circuit is based around using this hex inverter/buffer integrated circuit as a linear amplifier. Since the buffering components are designed around field effect transistors (FETs), overdriving one of the six buffers it contains with another used as an amplifier causes tube-like distortion without having to deal as explicitly with discrete FET circuit design (Nishizawa and Terasaki, 1974).

The gain around each amplifier stage is set by the ratio between the loop resistor, Rf and the input resistor, Ri. In this case, the gain is extremely high (more than 20 000, which means that even a small input signal with distort the output of amplification stages to the extremes of what the power supply can provide before the signal reaches the 4040 divider chip.

The 4040 then acts as an "analog" octave effect. As user *Jonasx24* mentions, the 4020, 4024 and 4040 are all designed to perform similar division roles, taking in square waves of a certain frequency and outputting multiples of that frequency. This is particularly useful in digital circuits, but also in audio: if a distortion circuit can provide

an incoming audio signal with enough higher harmonics to appear as a "square wave" to the divider circuit, it'll produce octave of the incoming signal. In our case, the outputs chosen correspond to the octave down from the input (divide by two) and two octaves down from the input (divide by 4). Looking at the 4040 divider circuit in *Handmade* (Collins, 2006, p.159), we can see how close *nocentelli*'s circuit is to Collins' *Low Rider*:

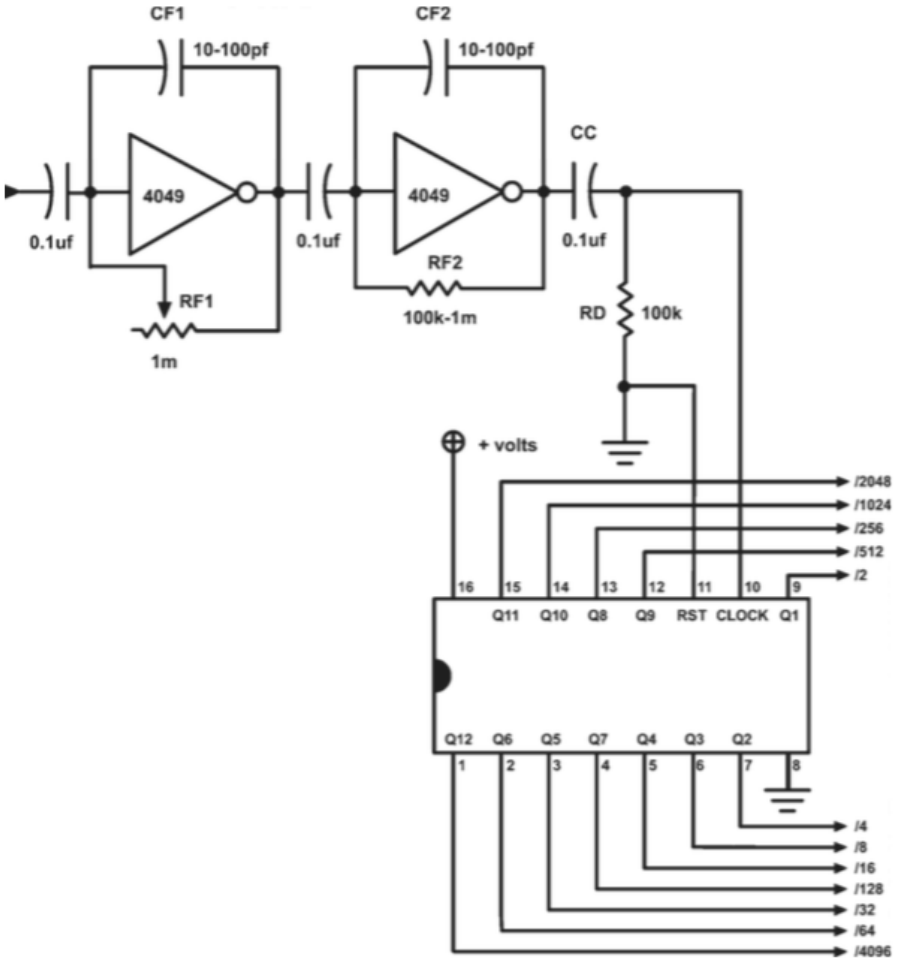



FIGURE 3.16: The *Low Rider* schematic by Collins (Collins, 2006, p.159)

Here, CMOS chips are misused into serving as functional instrument signal processing devices. Similar commercial octave effects such as *Electro-Harmonix*'s *Octave*

*Multiplexer* show that even with low gain, dividers can be used to semi-accurately track and shift octaves for incoming signals.

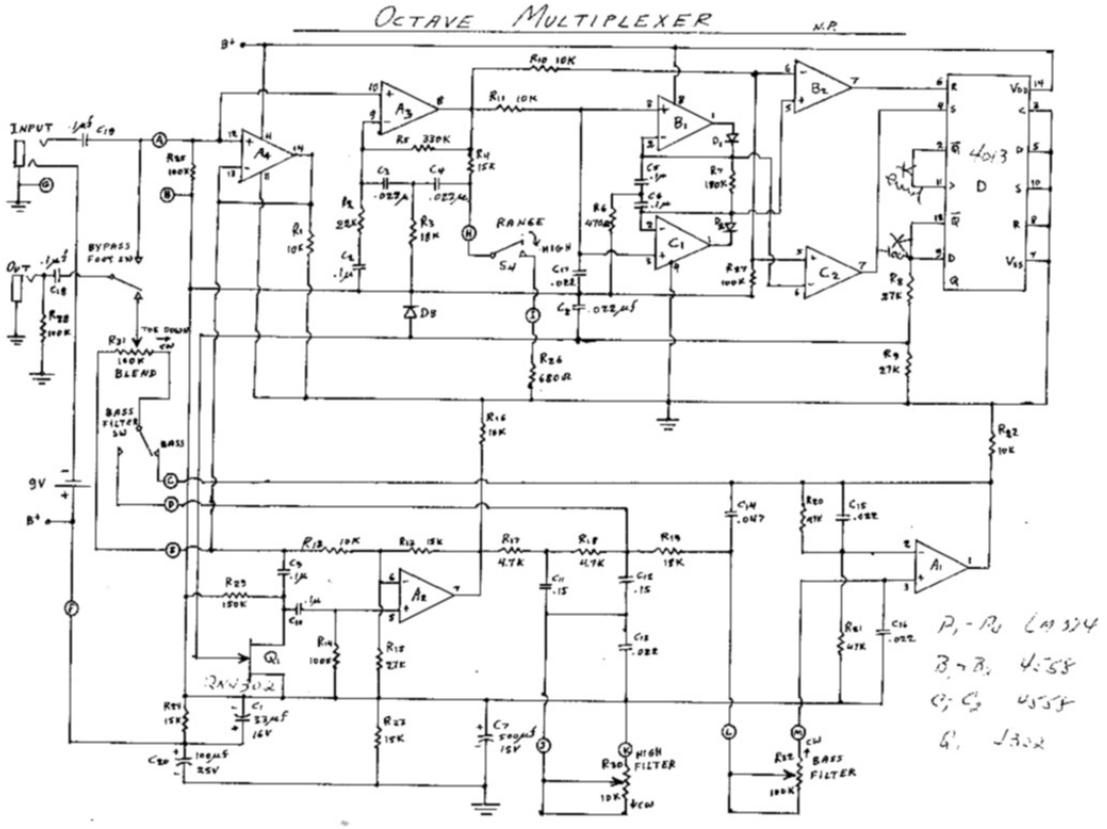



FIGURE 3.17: The *Octave Multiplexer* schematic by *Electro-Harmonix* ()

To resume this device into its main components, a simple annotated version of nocentelli's original schematic suffices:

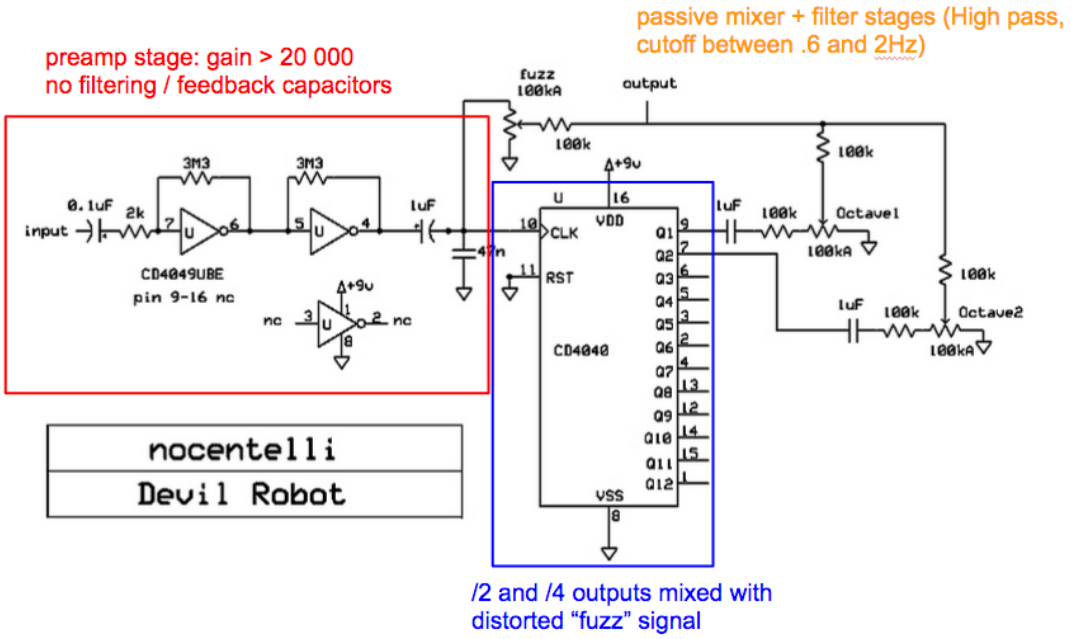



FIGURE 3.18: The annotated version of the*Robot Devil* schematic by *Nocentelli*

Just as in the case of the *improbability drive*, forum users were provided with enough information by the original poster to make the details of the Dwarfcraft design of little practical importance, even if it could have potentially been more refined. As Martin Howse mentions in his interview, proprietary designs often forces creative minds to solve the same problem multiple times. In this case, more than solving a problem, users have assembled a replacement circuit from pre-existing work and experimentation - in short, they've hacked a circuit and made it their own.

In this case, the 4040 chip reacts erratically when the signal decays and upper harmonics come to be of equal amplitude as that of the fundamental for single notes, or when chord components decay less quickly than the chord's root note. In our case, Hinz did took out most of the linearizing and stabilizing components recommended by Anderton and Collins. This is often what makes such effects chaotic and to some, interesting. This is a clear example of a post-optimal device, squarely in the lineage of Collins' practice and teachings.

## 3.4 Taylan Cihan

Taylan Cihan was a Cornell electroacoustic music center graduate student who undertook a variety of electronic music hardware projects (Cihan, 2015b). *Porcupine* was developed using scraps from his previous project, *Vermes*. Cihan was in the process of developing a student space dedicated to the fabrication of electronic hardware for music. Some of the information here was provided by his late advisor and close collaborator Professor Kevin Ernste.

### 3.4.1 *Porcupine* (2013)

> After being stabbed numerous times by the wires sticking out of the device while building it, the name, Porcupine, came out rather naturally. Porcupine, as I would like call, is a concrète box (in reference to musique concrète), combining a built-in analog sound processor with a variety of acoustic sounds that can be generated using the wires. The copper plate and wires are essentially leftover parts from my previous project, Vermes. Instead of throwing it all away, I have decided to recycle them, hence the faint artwork on the surface of the plate, a by-product of my failed very first attempt at making my own PCB.
>
> The sound processor include an analog delay, fuzz distortion, and resonating low-pass filter. A piezo element attached to the copper plate picks up the sound of the wires, which is amplified through a high-gain preamp before sent to the processing unit. An additional 1/4" jack input, which also has its own high-gain preamp, allows the device to be simultenously used as an effects unit to process the external sounds. When the levels, delay time, fuzz gain and filter resonance set to a maximum, the circuit starts to self-oscillate, producing a rich harmonic spectrum.

(Cihan, 2015a)

Taylan Cihan's *Porcupine* is included here because it serves as an elegant example of what experimenters who've grown comfortable with the various components of standard circuits such as those presented in *Handmade Electronic Music* can do. Higher-level combinations of circuits along with unique interfaces are often the logical

next step to making more compelling instruments. In this case, Cihan achieved success by combining semi-standard circuits with an inside-out interface in order to embrace the chaotic experiments from which inspiration came.

Specifically, Cihan's circuit is based on the following building blocks:

> The delay unit is built using a PT2399 Echo Processor IC by Princeton Technologies.
>
> Fuzz distortion is a clone of EHX Muff Fuzz. Schematic from Beavis Audio.
>
> The 4049 Hex Inverter preamp schematic is from Nick Collins' Handmade Electronic Music book (p.187).

(Cihan, 2015a)

FIGURE 3.19: The *Porcupine* by Taylan Cihan, front view

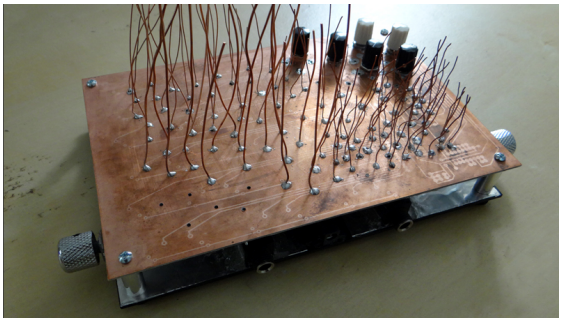
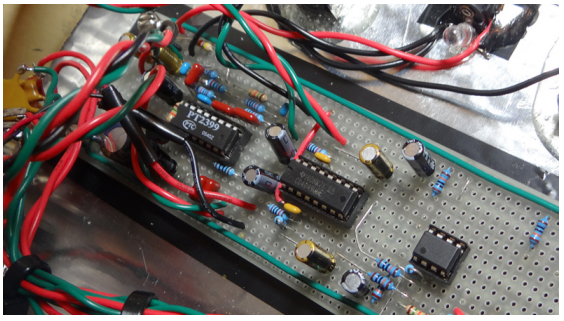


FIGURE 3.20: The *Porcupine* by Taylan Cihan, circuit board view



The circuit board view shows three integrated circuits: a PT2399, a 4049, and a eight pin DIP package IC.

The 4049 is a CMOS Hex Inverter used as a resonating low pass filter, based on one of Nicolas Collins' designs.

FIGURE 3.21: Nicolas Collins' 4049 Low Pass Resonating filter from *Handmade Electronic Music*

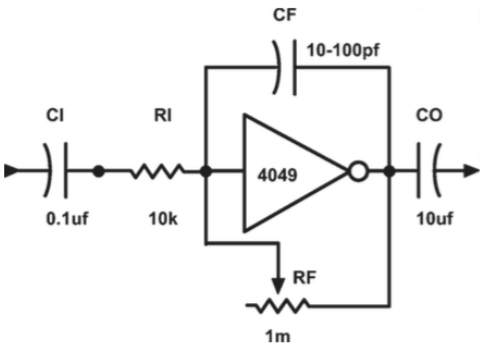
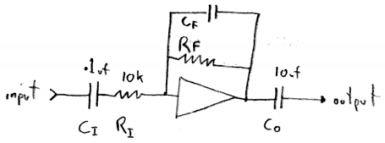



**Figure 23.4** Adding a feedback capacitor.

As detailed in the previous chapter, this circuit and its associated notes are available in the public draft for *Hardware Hacking*.

FIGURE 3.22: Nicolas Collins' 4049 Low Pass Resonating filter from *Hardware Hacking*

1) The CMOS Inverter amplification stage. As with our oscillator circuits, the six sections of the 4049 chip are interchangeable.
2) The input resistor, RI, generally around 10kOhms.
3) The feedback resistor, RF, larger than RI, can be a pot for variable gain.
4) The input capacitor, CI, generally around 0.1uf.
5) The feedback capacitor, CF, usually omitted or very small (10-100pF.)
6) The output capacitor, CO, always around 10uF.

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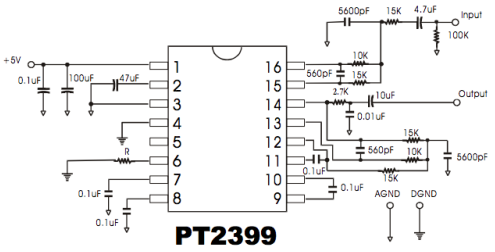
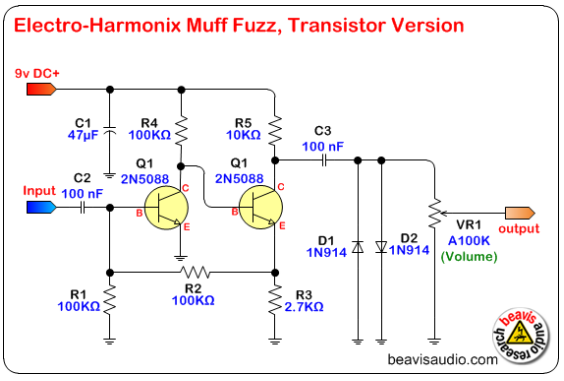
The PT2399, with two electrolytic capactitors, seven mylar capacitors and eight resistors, appears to be a variation on the stock circuit from the PT2399 application note.

FIGURE 3.23: PT2399 stock circuit, from the application note by Princeton Technologies




The Muff fuzz circuit is based on an original Electro-Harmonix design as traced by Beavis Audio (BeavisAudio, 2012) . It is a classic of distortion circuits, a simple and expressive two transistor design which gave Electro Harmonix its reputation. Its parts are common and inexpensive, with various DIY vendors offering kit versions with extremely detailed assembly instructions.

FIGURE 3.24: Beavis Audio Muff Fuzz




The third chip, although illegible in the picture above, is probably an op-amp IC used for the piezo preamp Cihan mentions.

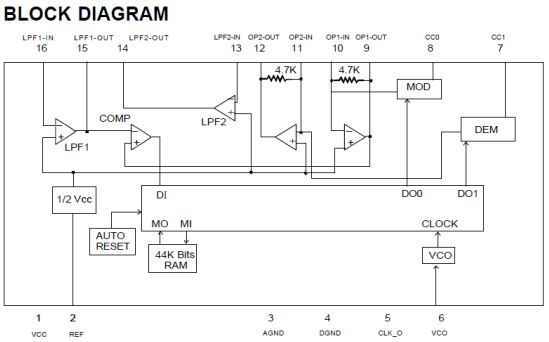
In effect, this combination of circuits and hardware is a versatile, expressive and personal approach to exploring the possibilities of audio circuits. It is simple enough to be understood in two paragraphs, two links and one reference, but the result is arguably greater than the sum of its parts. This is especially due to the nature of the interface,

the ability of the device to both process and generate, and the re-use of materials from a previous project. By exposing the mess of wires and their prickly unfriendliness, Cihan exhibits his appreciation for his medium of choice. This interface design can be considered post-optimal: mild pricks caused from playing with the exposed, sharp wire definitely fit within Dunne's vision of "user-unfriendliness". This unusual, personal approach to developing an electronic instrument would seem inconvenient to anyone looking for a synthesizer, but to anyone else who's tinkered with electronics, the description of the project's genesis and the corresponding result will make perfect sense.

This is where hardware design can ask greater questions in the field of music performance and sound art. The sculptural aspect of the device is indirectly reminiscent of sonic installations by Tudor, Lucier and their aesthetic descendants.*Porcupine*'s ability to both generate and process sounds greatly enhances its potential to be part of a larger, evolving system. By sharing this design, Cihan quietly kept experimental ideals alive. By keeping the information incomplete, he also encouraged exploration and personalization: in effect, Cihan and his peers allow for open musical hardware to go from self-sustaining to self-expanding.

Cihan details the PT2399 delay chip as an analog one. Indeed, the Princeton Technology Corporation datasheet identifies it as an "echo audio processor IC utilizing CMOS technology which is equipped with ADC and DAC, high sampling frequency and an internal memory of 44k." (Corporation) It is a good example of what followed basic logical operators of the 4000 series introduced with the *Robot Devil*.

FIGURE 3.25: The PT2399 internal block diagram from the Princeton datasheet




By combining large numbers of microscopic scale logical operators and connecting those to memories and clocks, CMOS sampling ICs such as this one are possible. The chip is occasionally labeled as analog (sounding convincingly so) by various manufacturers and DIY guides - this suggests that Cihan gathered information from other experimenters online, making him a public participant in the field of open musical hardware design. The next level of complexity in integrated circuits is, arguably, microcontrollers.

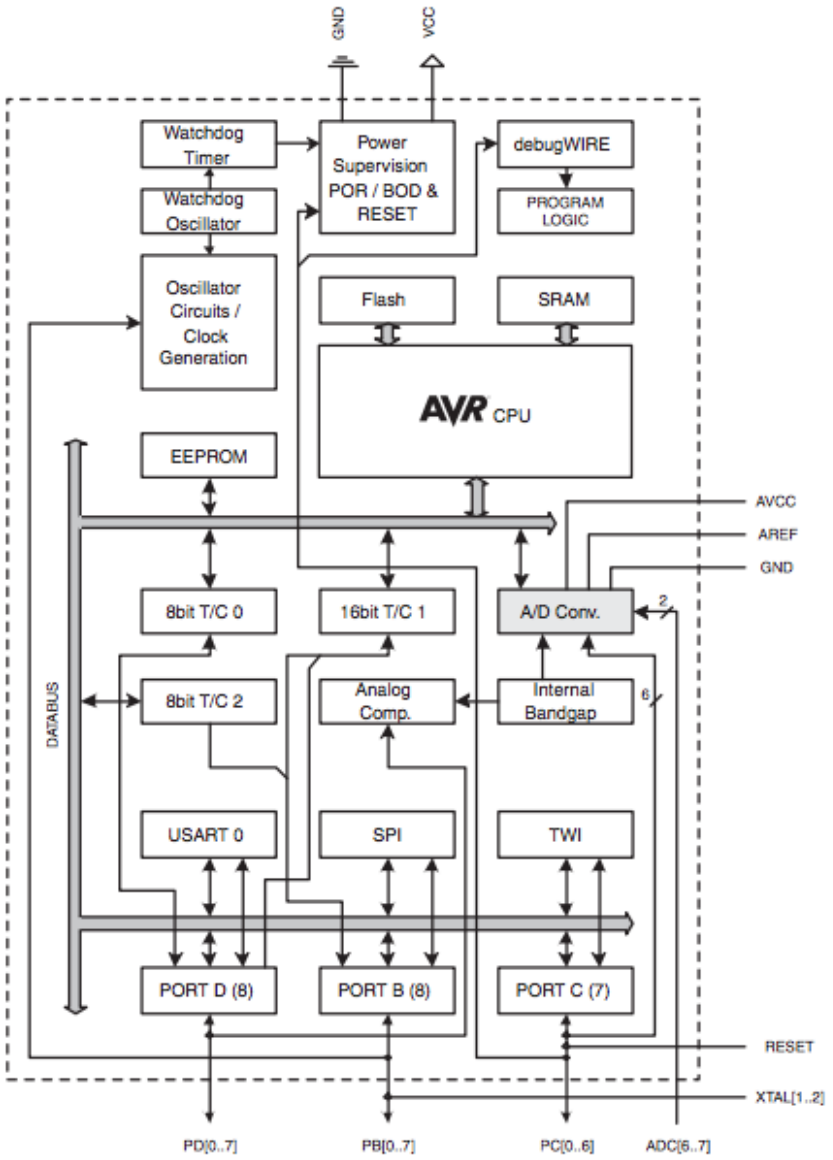
## 3.5 Tristan Shone

The PT2399's main limitation is its relatively small set of applications: generating delayed copies of the input signal within certain limits of amplitude, delay and current draw.

As other subcomponents of computing systems followed in the process of miniaturization, small and accessible systems have become ubiquitous in the arts because of their versatility: microcontrollers. Of particular interest in the arts and this discussion in particular is the Arduino hardware and development environment (Gibb, 2010). The Arduino usually uses an IC from the AVR family:

FIGURE 3.26: The AVR system block diagram for the ATMega328, from Atmel - included in the recent Arduino packages

**Figure 2-1.** Block Diagram




In recent years, the large variety of Arduino packages have had a particularly strong impact on creative computing in sound and installation work. Presenting those here allows a discussion of various custom-made instruments which exhibit innovations at various levels and represent additional visions of post-optimality in electronic music instruments.

Tristan Shone has a musical practice based around microcontrollers and goes under the name *Author and Punisher*.

A mechanical engineer and sculptor, Shone is the musician responsible for this one-man project. He released a first album in 2005, *The Painted Army* (**??**), as he was developing his first set of instruments, the Drone machines. His website's subtitle is "electromechanical destruction since 2004" (Shone, retrieved 2015a).

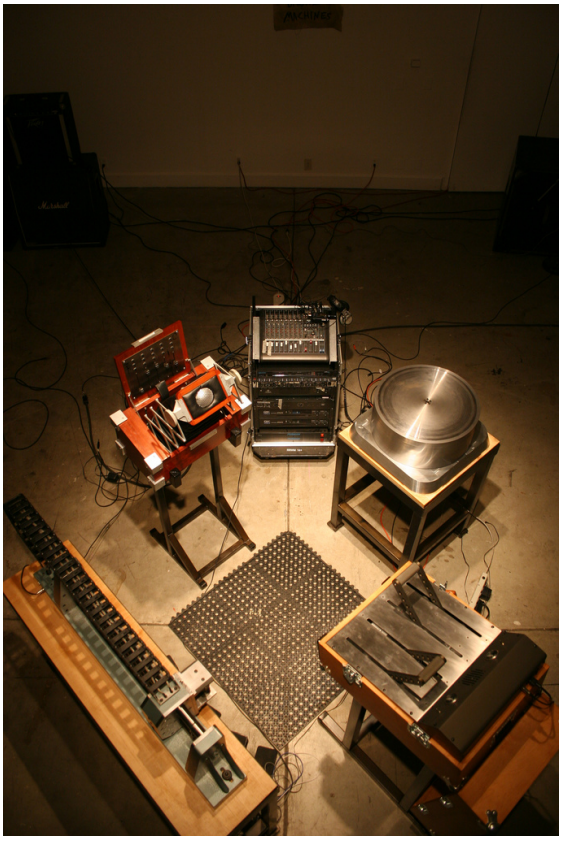


FIGURE 3.27: Tristan Shone's live setup around the release of the *Drone Machines* album, courtesy of Shone

He has since released three more full-lengths relying increasingly on hardware he fabricated, in conjunction with a software sampling and synthesis system built around Ableton Live. Most of his devices have evocative names such as *Linear Actuator*, *Big Knobs* or *Bellows*.

FIGURE 3.28: The *Bellows* instrument, made by Tristan Shone, courtesy of Shone

His experience with sculpture and mechanical engineering are clear, although discussing the matter with him makes it clear that he is ultimately making those because they seem like the best way to perform his music. Although he has grown to try and move away from the visual impact of his setup by collaborating with visual artists, his website still provides the curious with a combination of evocative live shots and technical diagrams.

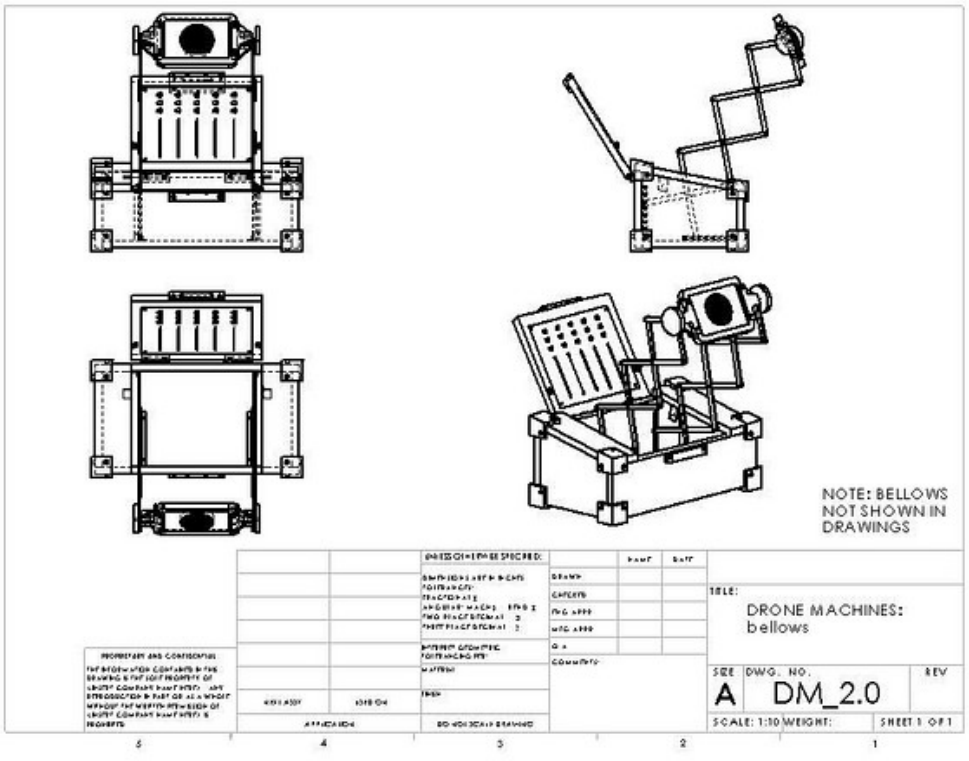



FIGURE 3.29: The technical diagram for the *Bellows* instrument, courtesy of Shone

Most of these electromechanical devices act as controllers: they encode movement into a number using Arduino systems. This information is then fed into a computer, which triggers starts, changes and ends for specific sets of pre-composed sounds.

Shone's microcontrollers system is based on the Arduino environment, which he uses with custom firmware developed by Dimitri Diakopoulos and featured at NIME in 2011 (Diakopoulos, retrieved 2015, Diakopoulos and Kapur, 2011) . This firmware modification turns a specific strands of the Arduino hardware (the Uno, Due and Mega 2560 boards) into a driverless device, enabling it to send MIDI data over USB without any more setup than a commercial USB-MIDI item.

However, Shone's live setup is not just centered on controllers. Shone describes himself as a "lifelong beatboxer" and in this context, he's devised a number of ways

to detect, record and manipulate his voice (Shone, retrieved 2015b). He's currently developing a set of masks (documented on his website are the trachea quad mic, the dither mask, the drone mask and the mute mask), while his previous vocal interface is called the Headgear. That system was the topic of a tutorial written by Shone for the Make Magazine website (Shone, retrieved 2015b), and uses electret microphones.

### 3.5.1 *Headgear* (2011)

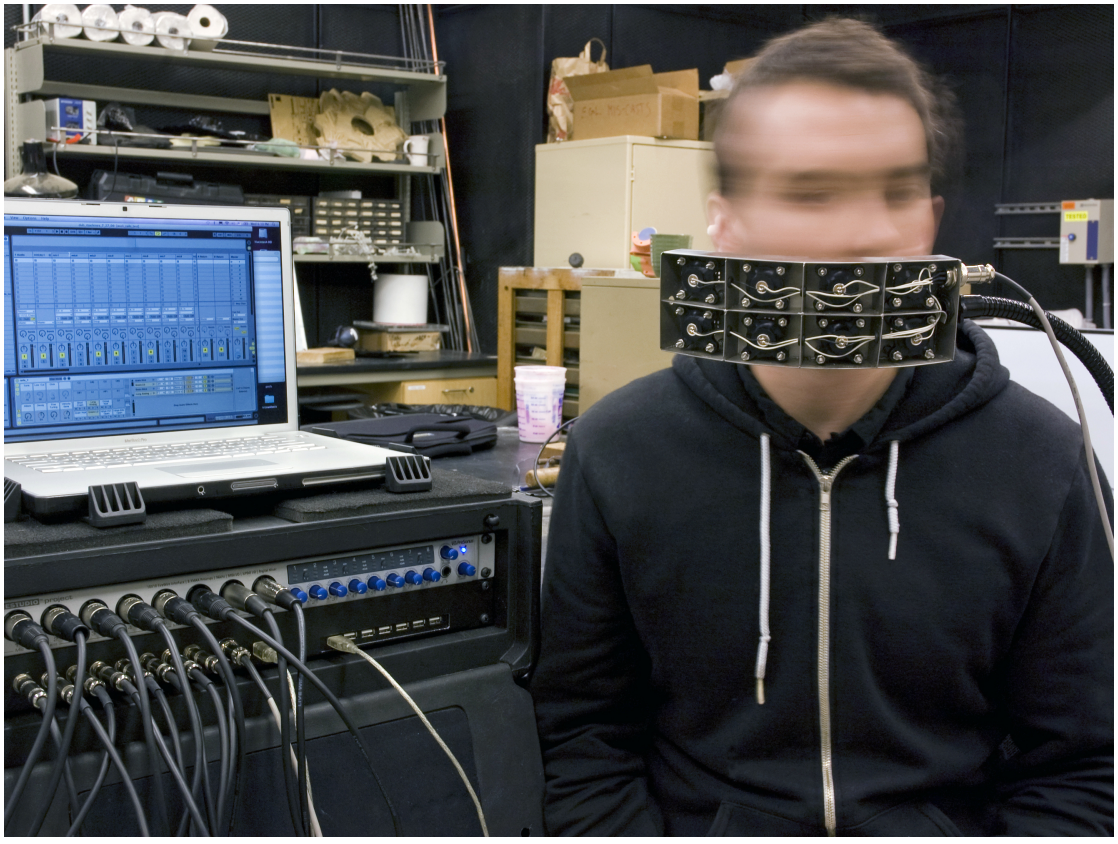


FIGURE 3.30: The Headgear device by Tristan Shone, wired for operation, courtesy of Shone

The circuit accompanying each microphone is simple and straightforward, taking advantage of an Arduino's power supply to power them.

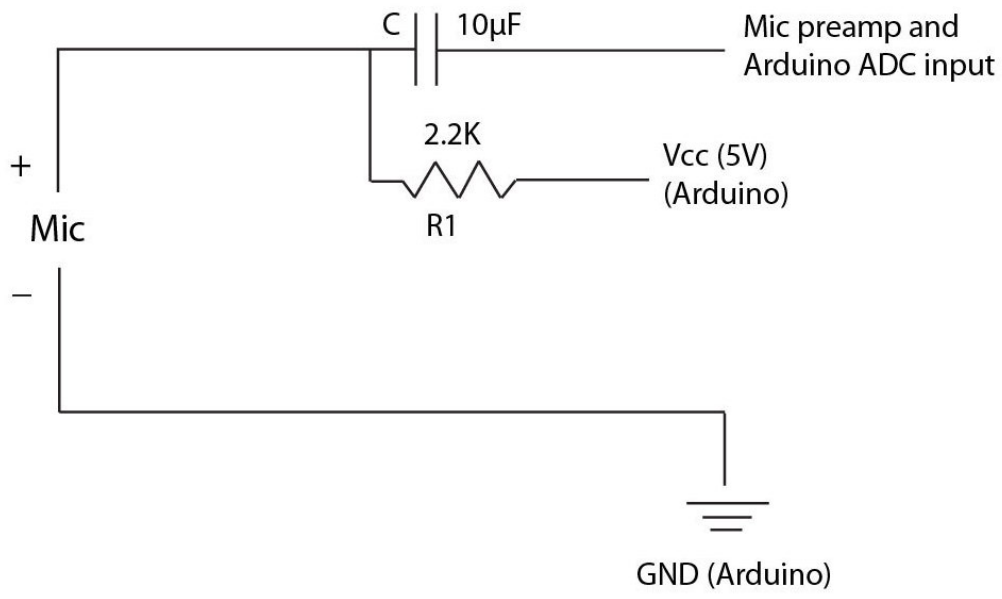



FIGURE 3.31: The schematic for each microphone wiring, from the MAKE article by Tristan Shone

The device fulfills two roles: it can act as a controller through the use of the Arduino system and its MIDI generating code (Shone uses the HIDuino firmware to facilitate this), and also provide sound samples to

We see a trend in the systems being presented here: simple electronics, serving a specific purpose between exploration of a physical process (touching in the case of Cihan's *Porcupine*, voice in the case of Shone). Both represent instances of post-optimal approaches to interfaces through an exploration of the materials they use everyday.

The Headgear is not the main element of Shone's live setup, nor is it necessarily its centerpiece. However, through its dual operating mode, the sharing of its design on public platform such as MAKE magazine, and the relative simplicity of its inner

workings, it serves as a good example of the few things needed by an accomplished fabricator and artist to make a compelling device.

As can be expected in parallel with the rise of microcontrollers as interfaces for turning our environment into a source of control data, recent years have seen a number of initiatives turning accessible, general purpose computing devices into code-based synthesis engines. All these projects are the embodiment of their designer's curiosity, adapted to various degrees of interactivity for performance, composition or commercialization.

## 3.6 Dan Snazelle: Snazzy FX

Dan Snazelle is a recording engineer turned hardware designer. Although his relationship with musical electronics is mostly done through the design of analog electronics, he is one of the first to market an Arduino as the central piece of a synthesizer module. In doing so, Snazelle and his collaborator Darwin Grosse take advantage of the fast-paced communal activity of coding communities and the ability to sell a product even though there is enough information for people to build them from scratch.

### 3.6.1 The *Ardcore* (2011)

The Ardcore is in effect a reprogrammable lo-fidelity oscillator and control voltage generator packaged in a eurorack format and complemented by a set of freely available and editable programs.

This project was developed by Darwin Grosse and Dan Snazelle. Darwin Grosse is a developer at Cycling '74, while Dan Snazelle is the owner and designer at Snazzy

FX. Just like the Porcupine, the Ardcore documentation isn't all neatly packaged in a tutorial form, but a significant amount of information is available for the curious.

At the beginning of this project is Grosse's master's thesis at University of Colorado, Boulder. The document describes the first completed prototype and provides context, code examples, an overview of its possibilities, and detailed documentation of the collaboration process with Dan Snazelle.

Of interest here is the information available to the tinkerer that might be interested in building their own homemade ardcore. Grosse's statement of purpose can be found in Appendix A of his thesis:

> This specification provides the analog modular community with a standardized use of the Arduino microcontrollers system, and will include a large number of example sketches (programs) that accomplish tasks within the modular world. Any Arduino user can utilize these specifications to create modules, control systems or computer interfaces, and will be able to use any programs that others may come up with.

(Grosse, 2011b)

FIGURE 3.32: The Ardcore's first version circuit board, with an Arduino nano, by Darwin Grosse. Courtesy of Grosse

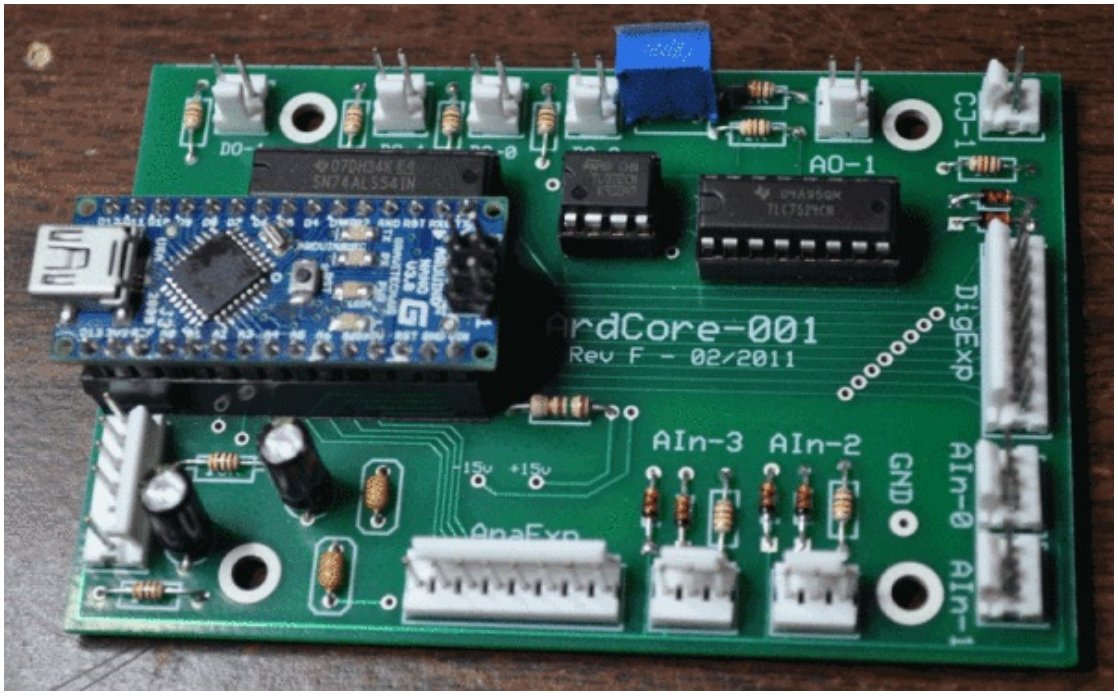


FIGURE 3.33: The Ardcore's first version synthesizer module, by Darwin Grosse, courtesy of Grosse

FIGURE 3.34: The Ardcore's current commercial package, by Snazzy FX, courtesy of Dan Snazelle


Undertaking this project from scratch is somewhat more ambitious than any of the previous case studies. Because the Arduino code is all shared on Github, the software is not an issue, which is in line with the practices of the Arduino community. However, there doesn't seem to be any explicit tutorial or consolidated documentation for copying the hardware. Grosse's thesis details the development and manufacture in much detail, but never explicitly permits copies or provides a full schematic (Grosse, 2011b, pp.21-31).

FIGURE 3.35: The schematic for the DAC section of the Ardcore, based around a TLC7524, courtesy of Grosse

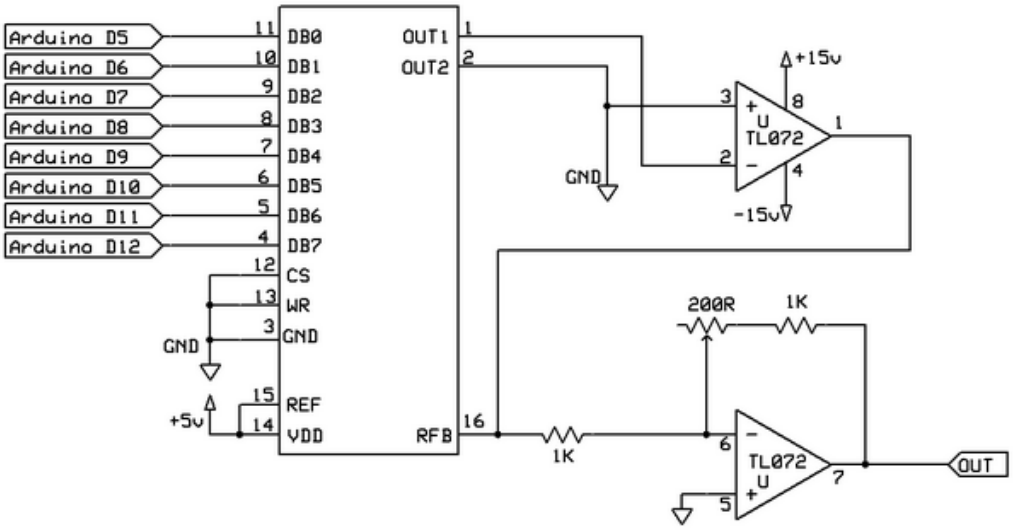
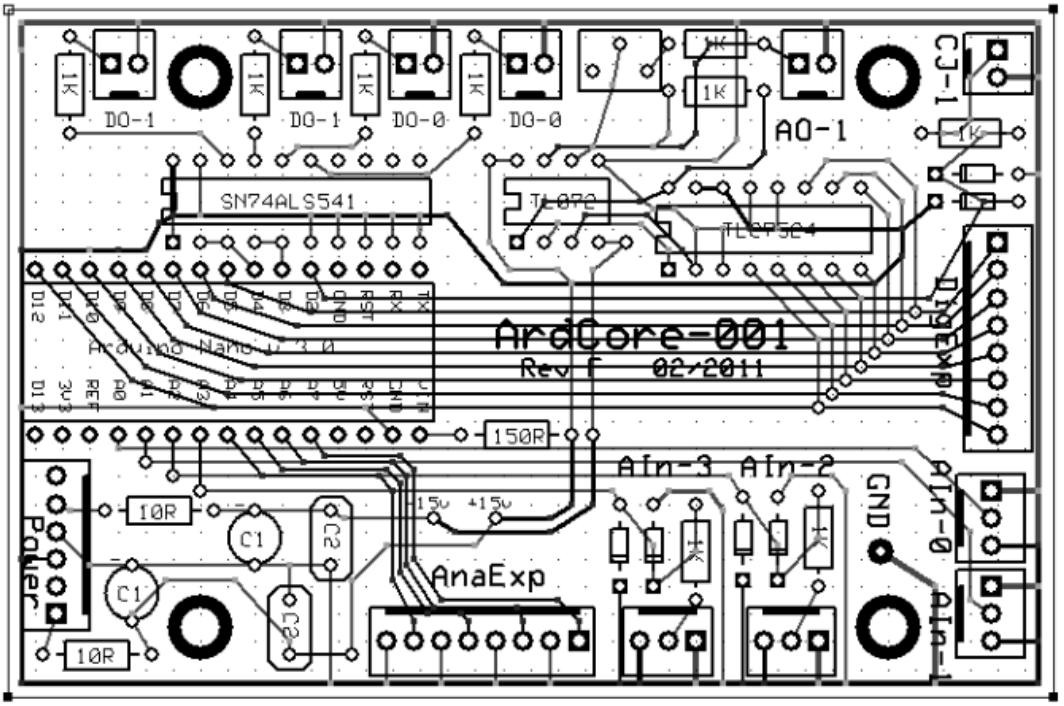



FIGURE 3.36: The circuit board layout for the first version Ardcore, by Darwin Grosse




These documents do go a long way illustrating Grosse's preliminary design. Put

briefly, the clocking input is implemented on a digital pin, while the analog out is done through eight other digital pins being connected to a TLC7524 digital to analog converter (DAC). All the voltage scaling necessary for the circuit to be functional with other devices in the modular environment (Grosse chose the one volt per octave standard) was done through the use of a TL072 op amp circuit with an internal trimpot calibration. The Arduino processor (the Atmel chip documented previously) can now serve as an in/out device for audio signal (albeit sampled at a low resolution of 8 bits) and produce voltages conforming to other manufactured modules.

As Grosse and Snazelle finalized the eurorack version of the module, it becomes clear that the focus is this device's "lo-fi swiss army knife of modular" versatility. The ATmega chip at the center of this design not being meant for audio synthesis or real-time audio signal processing, this system offers plenty of limitations, gentle provocations and user-unfriendliness that qualify it as having post-optimal aspects. Unique to the ardcore, however, is that the two developers contribute actively to various repositories for newt module codes and application, with over sixty options easily available and a theoretically infinite variety of possibilities (Grosse, 2011a, Magnus, 2011).

The Arduino can be viewed as one of the driving force in making and artistic tinkering today (Gibb, 2010). Integrating in a nostalgia medium such as the modular synthesizer system is both beneficial for the life-span of both items and for maintaining the relevancy of a founding technology in electronic music. By placing both their future in the hands of an open enthusiastic community, Grosse and Snazelle arguably guarantee both of their survivals.

## 3.7 Martin Howse

Martin Howse is a British artist residing in Berlin and teaching workshops all over the world. Please refer to appendix A for additional information concerning his background and inspirations.

Although not limited to this framework, Howse's technological experiments often fall within what he calls *psychogeophysics*, which were defined in the anonymous *Psychogeophysics Handbook & Reader*:

> Where does execution (of software) as an act take place and what are the effects of such sitings on the individual? Is there a stark division between the physical and the protocol (between the material and the symbolic), or can these terms be considered as points on a continuum of abstraction? Psychogeophysics attempts to answer these questions using a core methodology based around the pairing of paranoiac detection (parody of scientific practice) and excitation as intervention.

(Anonymous, 2011)

This poetic exploration of technology as a parody of scientific practice appears about as nonsensical as *experimental engineering*, and yet, Howse's work is not without recognition. Discussing Howse's performance work, Douglas Kahn writes:

> When he raised his hand and dug it into the soil, into the earth, a whole new battery of sounds were heard. It was phenomenal. Electricity always seeks a ground; he had grounded electronic music. It was more than a gesture; it was an epiphany.

(Kahn, 2014)

This is another incarnation of what Dunne envisioned as effective post-optimality in design. Howse doesn't appear more as an engineer than musician, teacher, artist or theorist, rather, the easiest way to talk about him is on his own terms: as a psychogeophysicist.

### 3.7.1 The *Dark Interpreters* (2013-ongoing)

The dark interpreters is a series of ARM processor-based synthesizers. They come in three versions, the *Mater Lachrymarum*, the *Mater Suspiriorum*, and the *Mater Tenebraum*. Each correspond to more complex versions of the same basic resampling / granulation synthesis processes, and all are available for purchase from Howse's website (http://www.1010.co.uk/org/darkint.html).

All the files used by Howse to manufacture these circuit boards (schematics, layout, code) are available from his Github repository (Howse, 2012). The hardware documentation is provided in the form of KiCad files, while a collection of C-based ARM code with comments details the functioning of the software. Howse's documentation requires a close look at best. Intentionally making a full understanding of the devices a bit more difficult suggests that post-optimal objects can be achieved through documentation as well.

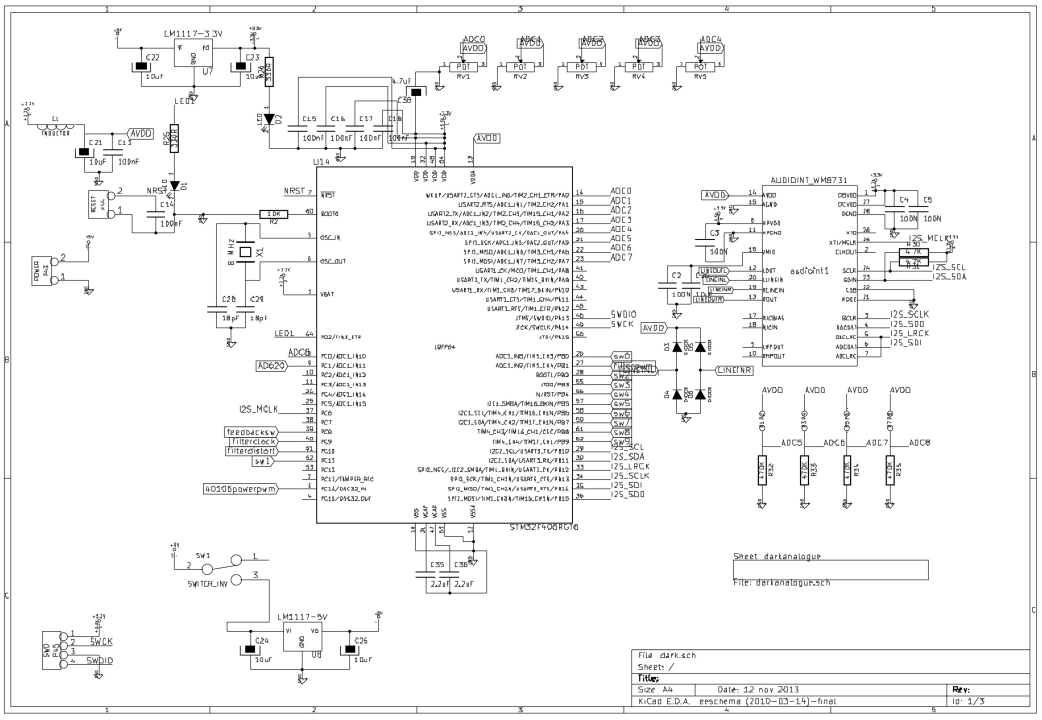



FIGURE 3.37: The schematic for the *Mater Tenebraum*'s analog circuitry, courtesy of Martin Howse

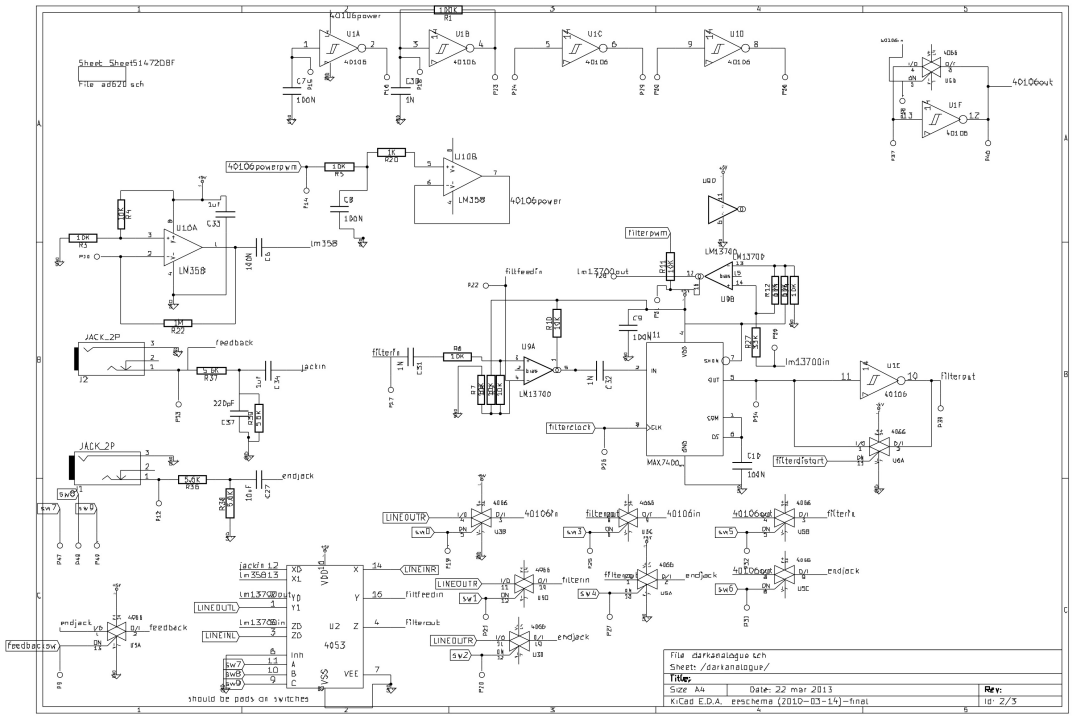



FIGURE 3.38: The schematic for the *Mater Tenebraum*'s digital circuitry cou

The manual provided by Howse details basic operation:

> The Dark Interpreter is modeled as a leaky, overlapping medieval village space within which various plague simulations run, and through which an array of villagers wanders. Audio is processed and/or generated according to the state of the village and the movements of inhabitants. Villagers (grains?) generate changes and are classified according to incoming or outgoing audio (read/write), filter, effects and hardware.
>
> The Dark Interpreter is essentially mode driven, with modes also changing the complexity of operation. Modes are selected by turning knob 5. To set parameters in each mode a finger must be placed on the directions and then settings can be changed with knobs 1,2,3 and 4. Finger pressure/electricity determines speed of the villager's movements or general mode speeds and the selected/fingered direction sets direction.
>
> More advanced modes swap parameters between sets of villagers, allow for fingers to be placed right into code and parameters and finally allow for mirroring which sets selected parameters under the control of a selected mirror (the head/EEG board, the knobs, the fingers or the village itself).

(Howse, 2015)

FIGURE 3.39: The *Mater Tenebraum*, with its copper pad interface and irregular shape. courtesy of Martin Howse

Howse's constant contextualization of technical processes within a narrative framework (here, a plague influencing the interaction of villagers as a model for granular synthesis) is a fairly clear example of what Dunne could have meant by post-optimal devices as catalysts for poetic experiences of technology. Howse's backing in literature and conceptual art seems to guarantee that his technical work is grounded in those very poetic processes.

This vision is however not contradictory with technological acuity. Looking at the source code and schematics shows a thorough understanding from the author of the goal and methods:

```
136 signed char direction[2]={-1,1};
137 u8 wormflag[10]={0,0,0,0,0,0,0,0,0,0};
138 u8 inp;
139 u16 *buf16;
140
141 #define delay()                       do {   \
142     register unsigned int ix;                \
143     for (ix = 0; ix < 1000000; ++ix)            \
144       __asm__ __volatile__ ("nop\n\t":::"memory");      \
145   } while (0)
146
147 #define delayxx()                         do {   \
148     register unsigned int ix;                \
149     for (ix = 0; ix < 1000; ++ix)               \
150       __asm__ __volatile__ ("nop\n\t":::"memory");      \
151   } while (0)
152
153 #ifndef PCSIM
154 extern int16_t audio_buffer[AUDIO_BUFSZ];
155 u8* datagenbuffer = (u8*)0x10000000;
156 #define randi() ((rand()*adc_buffer[9])%4096) // 12 bits
157 //#define randi() (adc_buffer[9]) // 12 bits
158 //#define randi() (rand()%4096)
159 #else //PCSIM
160 #define randi() (rand()%4096)
161 u8* datagenbuffer;
162 extern int16_t* audio_buffer;
163 #endif
164 extern u8 digfilterflag;
165
166 u8 wormdir; // worm direction
167 u8 table[21];
168 u16 sin_data[256];  // sine LUT Array
169
170 u8 exestackpush(u8 exenum, u8* exestack, u8 exetype){
171   if (exenum<MAX_EXE_STACK){
172     exestack[exenum]=exetype;
173     exenum++;
174   }
175   return exenum;
176 }
177
178 u8 exestackpop(u8 exenum){
179   if (exenum>0){
180     exenum--;
181   }
182   return exenum;
183   }
184
185 u16 villagepush(u16 villagepos, u16 start, u16 wrap,u8 effect){
186   if (villagepos<(VILLAGE_SIZE-1)) /// size -2
187     {
188       village_effects[villagepos/2]=effect;
```

FIGURE 3.40: A screenshot of the main.c file embedded in the *Mater Tenebraum* courtesy of Martin Howse.

The main code defines the granular synthesis engine, where each granule is presented as a villager living in a plague-ridden environment.

```
353  SIR:
354
355  4 states 0=suscept/1=infected+days/255=D/-1=recovered?/dead
356
357  #define recovered 129
358  #define dead 255
359  #define susceptible 0
360
361  Iprob = x # probability of transmission
362  Dprob = x # probability of death
363
364  - if dead or recovered then leave as are
365  - if infected (>1) add day until recovered(129) or dprob dead(255)
366  - if susceptible (0) then count surrounds and Iprob to be infected
367
368  [see also more complex models which include: population for each cell,
369  S.I.R pops (4 bits each as 16 bit CA), parameters for radius,movement
370  prob, birth death, virus morbidity, contact infection prob, vectored
371  infect prob, spontaneous infect prob, recovery prob, re-infection prob]
372
373  */
374
375  void SIRinit(struct SIR* unit, u8* cells){
376    unit->probD=cells[0]/32;
377    unit->probI=cells[1]/10;
378    unit->celllen=cells[2];
379    unit->del=0;
380  }
381
382  uint16_t runSIR(uint16_t x, uint16_t delay, u8 *cells, uint8_t howmuch, struct SIR* unit){
383
384    uint16_t y; u8 i=0;
385    if (++unit->del==delay){
386
387    for (i=0;i<howmuch;i++){
388
389      y=x+32768;
390
391      if (cells[x]==129 || cells[x]==255) cells[y]=cells[x]; //dead or recovered
392      //
393      else if (cells[x]==0){
394        // do count of surroundings
395        if ( (cells[x-unit->celllen]>0 && cells[x-unit->celllen]<129) ||
396         (cells[x+unit->celllen]>0 && cells[x+unit->celllen]<129) ||
397         (cells[x-1]>0 && cells[x-1]<129) ||
398         (cells[x+1]>0 && cells[x+1]<129))
399      {
400      if (randi()%100 <= unit->probI) cells[y] = 1;
401        }
402
403        //calc probI
404      }
405      else if (cells[x]>1 && cells[x]<129){
406        if (randi()%100<unit->probD) cells[y]=255; //dead
407        else cells[y]=cells[x]+1;
```

FIGURE 3.41: A screenshot of the CA.C embedded in the *Mater Tenebraum* courtesy of Martin Howse.

A cellular automata algorithm then describes the rules with which these granules interact, multiply and die. The plague is modeled using a classic suspected, infected, recovered (SIR) model.

On the hardware side, one might notice that the 4000 series of CMOS chips is once again present (the 4053 triple multiplexer/demultiplexer, the 4066 quad analog

switch, and the ever-ubiquitous 40106 hex Schmitt trigger). The embedded digital system is based around an ARM Cortex M4 chip that implements 16 bit, 48 kHz digital sampling as a basis for grain generation that can be heavily effected through undersampling.

FIGURE 3.42: The *Mater Tenebraum*, with its copper pad interface and irregular shape. courtesy of Martin Howse

To recapitulate, the *Dark Interpreters* are important in the context of a homemade electronic music because they:

- serve as proof that a designer can effectively blend code and poetics in hardware - illustrate an interpretation of Dunne's *post-optimal* objects through a unique interface and unpredictable use of the body or soil as circuit components - demonstrate that publicly sharing source code and schematics does not necessarily take the mystery and

interest away from the original designer's product - offer another direct link between micro-computing systems and their logical ancestors, the CMOS 4000 series

## 3.8 Sang Wook "Sunny" Nam & Joshua Florian: mastering studio

Sang Wook Nam is a mastering engineer teaching at Dartmouth College and running a mastering studio at the time of this writing (Nam, retrieved 2015). As a mastering engineer, Nam does not manufacture synthesis or signal processing hardware. His connection to music technology is presented here because it serves as a fitting conclusion to our lineup of hardware examples: even in professional, closed source environments, open design methods and its products are important.

In visiting his studio, it appears that most items in his setup fall within standard categories of equipment: channel selectors, equalizers, amplifiers, high quality analog to digital / digital to analog converters, etc. However, it also becomes clear that all of this equipment is custom made to satisfy Nam's trained and precise ear.

FIGURE 3.43: The Jacob's Well mastering desk, courtesy of Sang Wook Nam

Most of this equipment is designed, assembled and tested in collaboration with JCF audio's founder and owner, Joshua Florian (Florian, retrieved 2015a). After Nam and Florian worked together at LA's Mastering Lab, Nam came to value Florian's understanding of what they describe as "yestertech" (Florian, retrieved 2015b): older audio hardware circuit designs, usually discrete semiconductor or tube, that were used in high end recording and mastering studios along with the rise and heyday of major labels. A number of parts in Nam's current setup come from A&R mastering studio, which he purchased when they closed down.

This section does not contain a particular product description. However, the concept of "yestertech" is deeply related to that of post-optimal objects and design methodology in electronic music hardware. As Nam's collaborator Joshua Florian mentions, designs respectful of yestertech use a personal and variable tool to measure success: human hearing. A significant portion of his work is to refine previously successful

audio circuits, occasionally updating them to use new parts or to accommodate for the disappearance of an obsolete component. Engineering methodology is still an important part of the process, considering that many of the highly-respected audio amplifier and filtering designs are from professional or retired aerospace and defense contractors, but this appreciation of older topologies and skepticism towards the latest products, yestertech in effect is an approach to post-optimal audio electronics.

## 3.9 Comments

> My favorite programming language is... solder.
>
> Robert Pease (1940-2011)

One case-study that was considered for this section concerned the performance practice of a small group, Live Objects. They were not included because their point, although crucial, was short: connecting engineering to performance art is more than possible, it can be desirable.

In some of the case-study this chapter does include, the performative aspects of each practitioner's process or use of the devices was clear, but none merge design and musical performance as closely as Live Objects.

The technology they use is largely similar to the above case-studies, using preprogrammed microcontrollers and slowly connecting them to additional parts to derive complex musical structure from circuits small and versatile enough to be assembled as part of a standard-length performance. One of their members is Tristan Perich, who has been garnering recognition for his highly deterministic preprogrammed code-based scores, which specify a performance in ways directly indebted to western musical thinking and notation.

However, in the context of Live Objects, the group members take on a radically different approach, submitting the mechanic precision of digital electronics to the whims and inconsistencies of not just humans, but also of solder, wire, batteries, etc. Acknowledging the very material reality of computing devices *in real time* is still somewhat original: post-optimality shows artistic promise in music beyond simple devices.

To conclude, this section formally analyzed the information openly available to describe a set of devices that shared post-optimal aspects. To better understand the motivations behind these alternative approaches, the upcoming chapter presents discussions with some of the authors of these devices and associated practitioners.

PART II

# Present

# Chapter 4

# Interviews: highlights and analyses

This section presents a set of highlights from interviews with current practitioners, most of which were responsible for the projects in chapter three. The goals of these interviews was to expose underlying motivations behind those projects, identify any underlying trends, and give an experiential account of the electronic instrument design community.

Through their work, these artists and engineers have offered a vision for a fragmented practice united by a common curiosity in the devices that make their music possible. They do not necessarily represent the entire space of possibilities, but rather illustrate that this fragmentation and openness ultimately creates a robust, self-sustaining and multi-faceted space for hardware creation in a musical context.

## 4.1 Methodology

In the process of preparing interviews, five themes around which to organize questions were chosen. Those were the following:

- current place of hardware in their work

- dealing with technical limitations
- their perception of the professional community they might feel part of
- the importance of an ethos in their design work
- engagement with the questions of experimental or avant-garde music

These points were then adapted to fit the preliminary research undertaken for each interviewee. They were complemented when necessary by questions regarding each person's background or specific experience. Four exchanges took place over email (Martin Howse, Louise & Ben Hinz, Bonnie Jones, Jessica Rylan), which was less flexible but offered more time for the responders. The other four took place in person (Nicolas Collins, Sunny Nam, Dan Snazelle) or over the phone (Tristan Shone). All of those interactions happened between November 2014 and March 2015.

The goal was to get an understanding of their current relations to electronic music hardware, how they developed that approach, and where they see it going next. This section details highlights and analyses derived from this body of statements. Rather than inquiring explicitly about conceptual ideas such as post-optimal objects, more practical topics allowed for concepts to emerge by themselves when the interviewee wished to discuss them.

*Please refer to appendix A for full transcripts. Unless explicitly noted, all quotes within a section are from the interviewee for that section.*

## 4.2 Louise and Ben Hinz

Louise and Ben Hinz are self-taught inventors who have professionalized an interest in musical tinkering and are now both professional "silicon luthiers". Interviewing them

was an opportunity to discuss their path and see if any element of their methodology fit within a post-optimal approach to electronic audio hardware.

> We bought about $40 worth of parts, a soldering iron and a book on hardware hacking. He had no background in electronics at all. He just kept reading and trying stuff out until he understood it.

In this learning process (the book they mention was of course (Collins, 2006)), the Hinz would come to develop an appreciation for the unexpected mistake, but also for the power of cleverly-arranged simplicity:

> Some of my early work came from using components incorrectly to get weird sounds that were not available elsewhere, which is still really important to us. We decided a few years ago that if we couldn't do something new and interesting that we loved, we wouldn't do it at all. (...) for the most part I just apply fairly common knowledge in unconventional ways, so I wouldn't really be blowing anyone's hair back.

Their re-use of "common knowledge in unconventional ways" brings up the issue of ownership in audio circuit design. Legally, a copyright only protects the raw schematic circuit representation and does not prevent others from producing minor variations of that schematic or of the circuit it describes. In the United States, legal protection from copies can only be achieved through much more difficultly obtained patents, which most designers rarely attempt to get. Music technology is a rare case in which copyright law effectively encourages copies.

The Hinz' financial success can therefore be attributed to the build quality and variety of their work. Dwarfcraft Devices has recently released their first digital product, the *Pitchgrinder*:

> Digital is the future. It's also the now. Most of the ideas I currently have could only be realized digitally. I think there are tons of great analog circuits, and I will use them forever, but for me I'm much more interested in pursuing digital audio processing. We got started on the Pitchgrinder when I was introduced to Bob Lowe, an engineer here in Eau Claire. I threw a boatload of ideas at him, and we kind of sussed out what was doable from there.

Elaborating on their general design methods, Ben adds that this back and forth between tinkerer and engineer has become an important aspect of their process:

> Usually I ask for EVERYTHING. Then I see how many "Nos" and "Maybes" I get back from our engineers (myself included) and usually I try to figure out at least one of the "Nos" and often times we can cram in a couple "maybes" too. Better to go for it all and whittle it down than start small and realize what you could have done far better after the fucking thing is in stores. The same with recording, actually. "Can I put another drum track on there?" "Hell yeah, I already did 12 guitars, we'll whittle it down later."

Beyond the connection he makes between recording and product design, these statements are relevant because they suggest that post-optimal approaches to audio electronics are complementary to classic engineering methodology rather than contradictory. This is doubly verified when Ben also suggests the relevance of others in their technical work:

> Very important now. Early on, I did all of the designs myself and just paid someone else to lay out the PCB for us. The things we're working on at the moment are collaborative, but mostly they stem from my ideas, and I guide the design process. It's far better to hire someone who has the skills I don't, rather than try to master EVERYTHING, and end up losing my shit in the process. We have one full time "techinical" Henchman in the workshop, and Bob Lowe works in his own shop, on his own time.

In effect, post-optimal approaches to silicon luthiery benefit not only from the variety of electronic parts and materials made available through mass-market product manufacture, but also from that very same manufacturing structure.

## 4.3 Bonnie Jones

Bonnie Jones was of interest to this project because she has performed extensively using a set of live-bended digital delays and an assorted set of complementary systems

(some of which quite Tudor-like in their indeterminacy). Live circuit bending is done by exposing the circuit board of guitar effects and creating momentary shorts within and between devices.

FIGURE 4.1: Bonnie Jones performing with a live circuit bending setup. courtesy of simple geometry records

Furthermore, her experience founding, directing and teaching for Techne (an electronic music hardware summer program for girls (Jones, 2010)) placed her in a privileged position to discuss making and composing as it relates to gender and education.

Let us focus first on Jones' primary instrument, the delay pedal. As she details, an element that is often used to make up a shortcoming of electric instruments — their temporal flatness, the lack of space-related delays — is turned into an instrument by the charged process of turning it upside down and opening it, exposing the circuit board and making it as much of tactile instrument as a "sax, or a violin": live circuit bending can be a valid and respected instance of instrumentation.

Delay pedals are not meant to be opened and played by touching wires to the circuit board as Jones does. In that sense, she exposes an immediate and potentially universal approach to making an electronic object post-optimal. By connecting elements of a circuit within or between devices, she is blurring the lines between system and interface through a component with unique agency: herself. She resumes that exploration as such:

> I like to say that my set up came about like discovering a language written on a cave wall. As a musician I always approached playing as a way to understand the basic structure of that language as well as the process I can use to learn how to communicate with that language. I suppose the word that could be used is an intuitive approach to understanding the technical aspects of my instruments and their musical possibility.

Relating to Tudor's vision of indeterminacy, Jones' approach to unpredictable behaviors is explicitly rooted in practice and expertise. "I appreciate when that instrument has surprises or enables me to create sounds that I wouldn't expect". However, all efforts ultimately need to be justified: "I wouldn't care if something was complex if I didn't like the way it sounded." This practical approach reflects that of Shone, or Snazelle. Introducing context-specific elements or free software tools in her performance allows her to respond to a particular prompt, and possibly to engage more closely with the audience. This emphasis on the responsibility of the author to cater to a public seems specific to a set of performative traditions, with a care for transparency. This is confirmed by her activities with Techne:

> I take the approach where teaching and working with my nonprofit TECHNE is part of the continuum of my entire creative practice. It's been important and freeing to unbox the areas of my life that would seem disparate and try to get around the cause/effect/influence categorization.

The cultural and social connections between audio hardware and communities is once more made explicit. In this case, Jones sees a clear purpose for DIY culture:

> I still see DIY culture as pretty critical. Even in its co-opted and packaged state, being able to make shit with whatever is available to you is pure improvisation. I appreciate that and seek that out. (...) the technological arms race in the arts is tricky. Artist as R&D for technology corporations is a real thing. Subversion is still the place where those other voices can be heard. (...) I still believe that the most radical shifts happen when artists without the benefit of institutional, financial, or technological supports, just make things happen.

The latter point relates to the analysis presented in the historical background section, which showed that electronic music hardware went through cycles of institutionalization and democratization. By explicitly noting the lineage of her practice within this history of self-supporting tinkerers, she appears as a particularly legitimate teacher and mentor.

Jones concludes her answers with the following statement:

> The object has a life – the object pushes you and you push it. You can make things that you do not understand at all and maybe later you figure it out and maybe not. Abstraction and improvisation is about hiding and revealing the self at the same time – because of that it is also about resistance. I care about communication but there are so many ways to communicate and so many languages in which to do that.
>
> I am deeply skeptical and suspicious of what is visible.

Jones' hardware emphasizes post-optimal possibilities within commercialized items, and her teaching expresses a clear appreciation for a strong and supportive community within the arts. However, she is unique through her experience as a writer and installation artist: those activities conferring a unique sense of self on her artistic perspective.

## 4.4 Jessica Rylan

Jessica Rylan was included here for her interest in chaotic / semi autonomous systems in composition. In her discussion with Tara Rodgers, she expressed a disappointment in standard paradigms for audio synthesis, and in the biased communities of the musical electronics field (Rodgers, 2010). She's currently pursuing nano-optics research at Stanford, meaning that her audio hardware design and performances have slowed to a standstill. However, getting a chance to have her elaborate on some of those topics was a good opportunity to discuss some her previous claims and interests.

In her replies, self-limitations such as not using an oscilloscope / multimeter for a year, or picking the circuit based on how its schematic looks rather than how it sounds offer a clear post-optimal alternative to regular product design. Her scientific progression is particularly relevant in understanding this methodology: periods of self-teaching and experimentation followed by intense involvement in academic environments, a period as a employee of Don Buchla's business, and finally a relative abandon of the musical world for doctoral scientific research

She addresses the issue developed by Collins of the engineer which is not the best player of its own designs, saying "I found design to be a really exciting world for discovering sounds I hadn't heard before and didn't know existed, as well as a way to realize sounds I wanted to hear but couldn't find."

Rylan's main implementation in a performance context was the *Personal Synthesizer*, presented in section 3.2.1 as a unusual implementation of circuits, with its unpredictable output making it have post-optimal design characteristics. This, once more, brings us back to the post-optimal concept of musical chaos. Rylan presents chaos as inherently more musically interesting in the analog domain:

> the dynamic range limitation in an analog circuit causes limit cycles in chaotic behavior, but this is a generally good thing for music. Moreover, the many noise sources in analog circuits, which operate over many different time scales, help chaotic analog circuits sound good. That noise is entirely absent in digital instruments, unless it is specifically added in. But the main killer is that even in this day and age, digital "chaos" is rarely real-time. Even a modern laptop only has four FPU's, and they can only do so much. Analog is always real-time, 100% of the time. I'll put it specifically: I have never in my life heard a laptop performer get the beautiful chuffing/breathing sound that I sometimes am lucky enough to find with analog circuits in feedback loops.

Another point that resonates strongly is the relationship between her academic experience and her musical experiments: "the approach to circuit design taught in engineering programs is strictly at odds with the kind of music that the personal synth allowed for." As Collins described in his interviewee (section 4.6), Tudor was uncomfortable with electronics until Mumma gave up on teaching him vacuum tube circuit design and moved to solid state devices. The lesson here seems to be that successfully combining both practices is based mostly on a fragile balance between intuition and curiosity, with both depending on finding the right type of medium. The fantasies that Rylan expresses a few lines later - daydreaming of "having our own fab and making our own transistors," appears as typical of the grandiose ideas that often fuel simpler projects, as well as what we can ultimately hope for from developments in open design and fabrication. She however was probably the most skeptical of the interviewees when it came to discussing the potential of open information on circuits empowering musicians:

> I doubt that designing the instrument yourself necessarily means that relationship is "deeper" somehow, since there are a lot of engineers who are music fans but terrible musicians, and a lot of sound artists who are terrible circuit designers. (...) Of all the people who embark on building electronics specifically for music, very few end up building anything more complicated than a square wave oscillator, and a tiny tiny fraction of those people learn to understand circuits and design their own instruments. Perhaps this sounds elitist but it's just true. It has actually been a source of great sadness for me, because as much as I enjoyed leading hands-on electronics workshops, I ultimately came to question their value. The learning curve in electronics is very difficult.

Her opinion on community is along similar pessimistic lines, addressing the under-discussed issue of gender balance in this field:

> There were only a few people who I ever really discussed circuit design with. It would have been nice to know more people, but it's a very small community and widely dispersed geographically. Also, all men, which definitely effects the social dynamic.

On this final point, the field of electronic music is purely sub-optimal.

Rylan ultimately seems to be one of the best-informed people when it comes to musical applications of engineering concepts. Through that knowledge, she's assembled one of the most compelling example of alternative musical electronics which exhibit a number of post-optimal design decisions matching Dunne's description, however, it also seems to have also justified a clear disinterest in digital implementations of musical chaos, when other interviewees did not have such strong opinions on the matter.

## 4.5 Dan Snazelle

Dan Snazelle was interviewed because of his work with the Ardcore synthesizer module, which effectively brings a tradition of additive and subtractive synthesis with the multipurpose paradigms of more recent microprocessor-based synthesis. As research revealed that this project was a collaboration between Snazelle and Darwin Grosse, the set of questions prepared for Snazelle also attempted to get more information concerning this collaborative, hybrid system in electronic music. It also inquired about the development of a small community around the Ardcore's collaborative and open code base.

Snazelle's initial commercial line marketed in 2007 under the Snazzy FX label consisted of three guitar pedals. This isn't due to a particular interest in the format.

Rather, at his company's beginning, the boutique synthesizer module market was a small one and guitar pedals would be easier to sell without needing significant design changes.

The connection between DIY, guitar electronics, and more standalone synthesis hardware is important, reminiscent of the Hinz' current trajectory. Pedals offer a first, simple practical experience for many musicians, especially those coming from a popular music context rather than an experimental, avant-garde or contemporary classical one. The relatively low complexity means that the high barrier set by engineering described by Jessica Rylan can appear less insurmountable, and successful professional careers can be built around those efforts.

Furthermore, pedals' simplicity can beat that of even the simplest digital circuits. Snazelle is only one of many practitioners who feel like analog operates on a more human and approachable scale, which often results in an intuitive connection to analog-centric systems (even with modular synthesizers becoming increasingly digital). Regardless of the initial or current complexity, his design methodology has remained consistent:

> I guess I try to think on a systems level, with things like that? Same with the Tidal Wave (another module). It might be that there isn't anything new about a filter, or an oscillator, but how you approach it, and how you structure it... and presenting, especially the interface? The musicality of something... I'm very interested in. I've been playing guitar for 29, 30 years. I've been making music my whole life. I was a musician, still am... but I don't approach things from an engineering standpoint, but I ask myself how is this going to function as an instrument, how is someone going to use this in their music?

The circumstances led us to describe his compositional work less than his physical products, but simply being in his office and seeing his collection of instruments is proof of his care for sonic results. The parallels between both processes are obvious to him:

> It's a lot like writing an album (...). I think of Snazzy FX as an art project. It's my art. These (pointing to his products, prototypes, setup) were a statement. (...) the design aspect is really intuitive.

This approach to the materiality of sound making appears as a bridge between commercial but small scale businesses and installation work. From the circuits to the enclosure design, Snazelle emphasized his concerned with the interaction between his products and their users, hoping to make his clients "think about making music differently".

> I wanted to go as far as I could. In ten years, I hope the stuff I'm doing will be even more toward that weird goal of making these systems that are designed to do that weird stuff.

The vagueness of *weird stuff* was both confusing and fitting - Snazelle, with his chaotic oscillators and the Ardcore, is not the most prolific eurorack manufacturer but one of the most adventurous ones. He isn't selling his version of classic modules, but is really trying to develop the items he wishes were available. Stepping back, he resumes an overall vision as such:

> I'm not determining every event, point A to point B... I'm going to turn it on, and set something up, and something's going to come out. If you do it right, or if you do it wrong, it can keep going and going. Those unexpected possibilities, for a musician, that's gold. (...) Especially something like the chaotic attractors. It's an organic system. It's happening on the circuit board. It's not a simulation. I feel like there's an insect in the room, it's really neat to me.

Agency and control are once more essential to this discussion of custom and original musical hardware. As these case studies and interviews contextualize each other, we can see that the spectrum of practices they represent offer a nebulous array of answers, but that all of these relate in some way to Dunne's concept of slight "user-unfriendliness" catalyzing poetic experiences of technology. Snazelle's system and interface design shows post-optimal traits, with clear references to Tudor's original intentions.

Just as with Tudor or the Hinz, this workflow is not contradictory with working with a professional signal processing engineer like Darwin Grosse. He describes the collaborative process from his end of the project:

> I spent a whole year on the ardcore. It was really exciting, it's a really great system. It makes me really happy when people write for it. People have done some amazing things. It was the right thing, it made sense, and I got excited. There was no drive for a digital product. It's open source - other music AVR systems were closed source. So I got excited and made it work. And the responses are good! It was a really neat project.

Returning once again to the social element of audio electronics through a discussion of the community surrounding the open source code for the Ardcore, Snazelle discusses both his customer base and fellow fabricators. He is grateful for the help and support both have provided, while stating that resources have never been more numerous and available for young designers. To conclude, he does address some of the stereotypical associations some make with his system of choice, the modular synthesizer:

> I always tell people, don't be scared of my stuff!

Snazelle seems to be a good example of professional in the synthesizer side silicon luthiery: friendly, interested in rigorously approaching "weird" ideas and developing sonically unique tools that often exhibit post-optimal circuits or interfaces. Most importantly, although he is not a professional teacher or workshop leader, he seemed truly genuine about his inclusive, inviting attitude towards technology.

## 4.6 Nicolas Collins

Considering Collins' past writings and his influence on the overall nature of this present work, an interview felt warranted as it could contextualize his current place in the world

of audio hardware and his relation to our underlying thread of post-optimality beyond the connections already found in his book in chapter 2. This section presents some of the unique insights he offered.

> There's so much interest in what's called "silence studies" in the last ten years. This is cyclical. There's a Cage / Rauschenberg moment in the 60's, then it came back with a vengeance. It took so long for Cage's ideas... not to be accepted, but rather internalized. For example, people from many aesthetics could view silence as a positive element, rather than as the absence of something. It hit something, at the turn of the millennium, when all these people realized you could carve things out of all those negative spaces.

When discussing the general place of electronics in a musical context today, one of Collins' striking comments is that the different cycles of tinkering in music, whether they are called inventors, hackers, circuit benders or makers, are all expressions of a cyclical and persistent interest within a musical fringe.

Consider the other related cycles and developments in new music the sound professor has witnessed over the years: first, with Cage and Tudor's concepts and teachings garnering full recognition in waves much after their respective deaths. Second, his long-lasting interest in musical applications of microcontrollers, whose latest incarnation is the ubiquitous Arduino hardware and development platform:

> The most important one was the sort of parallel growth of limits in the open source community and the Arduino. People had been making Arduino type things since the 80's... STEIM made this beautiful sensorlab thing - but it was $3000! Completely insane. So the combination of the affordability of the Arduino and the open source nature of doing programs on it and the fact that they had provided this glue between the physical world and your laptop meant that it was like the peace accord in Belfast. Suddenly catholics and protestants could talk to each other - over the top, but I think a lot of orthodoxy broke down at that point.
>
> — people realized the Speak Spell used microcontrollers?
>
> — That's what I tried to tell these guys. Every single toy they use is a sample-playback computer.

In effect, this allows us to pinpoint the beginning of an aforementioned convergence of analog and digital electronics, resulting in todays pragmatic approach hybrid electronic approach chosen by the Hinz, Shone or Howse. This meeting of conceptual ideas based in musical thought and practical, accessible tools such as the Arduino creates the unique environment for the work presented in this thesis. Collins then elaborated on where he sees this technological agnosticism going, first within his own practice:

> "what I would say is at the moment, it's the chaotic aspects, the instability of circuits that are coming to a full forward in the stuff I'm doing."

Collins is living proof of the connection between Tudor's ideals of letting electronic speak for themselves and the underlying post-optimal trend in contemporary work suggested in chapter one. Improvised electronic performance by Collins such as *Royal Touch* or *In Memoriam Michael Waisvisz* involve the use of unpredictable electronics, which again match Dunne's description of the post-optimal as an embracement of user-unfriendliness.

However, Collins' brand of post-optimality goes beyond systems and interfaces. Indeed, he sees direct continuations of the post-optimal tinkering methodologies presented in his book throughout the world:

> I see this sort of arc, which is best represented in Korea. There's an awesome scene in Seoul. It's Dotolim and Balloon Needle project. Otomo Yoshihide comes to Seoul, and it's like this catalyst for this sort of noise. And you see this evolution: lets start a band, then lets add the effects, then it gets noisier and noisier, and then they say lets disconnect the instruments and use only the effects. You go from Otomo to Japan Noise... then you get to the point where they say lets open up the effects, lets see what's inside, lets do a piece with just the one transistor we pulled out from the pedal... let's just do something with dirty contacts. It's this funny kind of arc that's represented very well in the Korean scene.

He also mentions that his practice presents its most compelling results when undertaken as a social experiment relying on the endless variations arising in human collaboration:

> I got interested in the group dynamics of hardware based stuff, where you don't control things as accurately as... god forbid, a guitar, in your hand. 25 electric guitars in a room, it'd be a very different experience. I got interested in the noise world. The sound world of... disreputable electronics. Electronics that you weren't sure were working correctly, or that you knew was damaged but still interested in the sounds it could make. So I did a piece called "Salvage" - it's on youtube – where six people try to revive a dysfunctional or broken circuit by injecting voltages into an unpowered circuit board and using it as timing components for oscillators. So you get a very complex oscillator with a high degree of chaos in it. And it goes through a set of complex evolutions as more people start joining.

Yet, Collins is aware of the limitations inherent to hacking practices. Our conversation covered the issues of presets, which make mass-market items sonically recognizable, but also how low-level electronic sound can also be devoid of larger musical purpose:

> "There's something pretty dreary about concerts at Circuit Bending festivals. It often seems like the music might be an afterthought. There's nothing wrong with being a luthier. There are people whose tradition is building great instruments. It can be Stradivarius, it can be Trimpin, it can be the engineers that are behind the cracklebox, it can be Bob Moog, but they're not necessarily the people to whom you want to listen to records by."

This divide between engineer and musician, illustrated by the relatively small number of people who are both able to build their instruments and play them expertly is a concern dating back to the early days of electronic music pioneer and is still being dealt with today.

## 4.7 Tristan Shone

Shone's background as a self-taught musician, mechanical engineer and sculptor offered a chance to discuss exactly those difficulties in combining engineering and musical practices on equally expert levels. Questions focused on his Arduino-based controllers and instruments, the influence of his professional work on his art, and his approach to design and open source.

Shone has extensively benefited from both open and closed-source music technology. His devices rely heavily on the Arduino platform and the custom HIDuino firmware, released with an open license. However, his sampling and synthesis engines are mostly contained within the commercial software Ableton Live. The simplicity of his hardware isn't due to any particular ideological belief: he is aware and respectful of music hackers, but simply doesn't believe his experiments with purely audio circuits to have been as interesting to him as his current approach:

> It's the difference for me between some of the metal guitar distortions that you can buy or the electronic bass tones that you can get that I was much more interested in. They hit you in the chest much harder. That was something I could do on the laptop, and I could make one interface that could control any sound I wanted. So I gave up on the analog purity pretty early on.

His vision of homemade electronic music then focuses around a set of alternative controllers with extremely unique interfaces, some of which are presented in the previous chapter. The development of those often centers around a deep connection to the materials and tools he uses everyday as a mechanical engineer:

> in my mind there's just very simple things: a shaft of really shiny hardened bearing steel, maybe a piece of brass self lubricating as it slides on there... I want to be able to feel the interaction between those two materials. Being able to make that connection between those two things is all I want from an instrument.

The motivation behind making such items is a result of his training and musical interest. Ultimately, Shone's focus is his musical output:

> I'm just trying to make music. I have no purist aspect, other than playing everything live. Anything I have to do for that is ok. If I have to get funding from the North Korean dictatorship, I'd do it.

Those devices are unequivocally unique to Shone, with the interfaces arguably constituting an instance of post-optimal musical devices. His work proves that even working with a rigorously engineer-centric methodology, products can be responsible for inspiring accidents that encourage a post-optimal, technology empowered poetic expression:

> There's something exact about what I do, but what I like the most is the accidents and the free form nature of what I'm doing. I use the engineering to achieve the goals I want for my music.

As a specific example, he offers the following comment on the Headgear device analyzed in the previous chapter:

> I can control a bass synth by just rumbling my throat. It's amazing, you can control the subwoofers just with your throat. I never really choose. I mute and unmute those channels quite often as things develop. I think it's nice when it gets beyond formulaic. Sometimes you don't even know exactly how a sound happened. That's why I like music and art a bit more than engineering sometimes, I could be doing something terrible to the sound system but having it sound great.

Furthermore, Shone is deeply aware of the theatrical nature of performing with those devices. This leads him to both justify the validity of his designs:

> A lot of people when they look at my machines they say ooooh, you just did that for looks. No, you can ask me about any component on what I did and why I did it. It all has function. That, to me, is getting back to what metal and heavy music actually really is.

Just as Shone is pragmatic about his hybrid use of hardware and software, or open and closed source technology, he is thankful to the specific people that have helped him, but does not identify as part of a larger community or feel a duty to share all of his work with a greater public. He presents his few steps in that direction (a *Make Magazine* article for the Headgear device, college courses, etc.) as circumstantial rather than formative or inspiring, remaining dedicated to his primary interest in composition. Even amongst engineers, the musically-inclined makers are sensitive to being inspired by unpredictable behaviors from their instruments, which can arise from even the most accurately designed systems.

## 4.8 Martin Howse

Beyond the Dark Interpreters presented in the previous chapter, Martin Howse's work with electronic music hardware is very original, open source yet cryptic. A collaboration with Shintaro Miyazaki as Algorhythmics produced a purely hardware device called the *Detektor*, which transduces radio-frequencies into audible signals to build "an online database of electromagnetic field recordings, where collaborators can upload individual recordings of their environments."(Miyazaki et al., 2010).

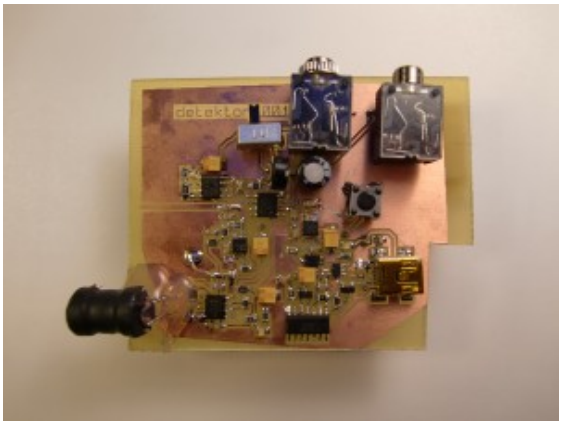



FIGURE 4.2: The Detektor system, courtesy of detektor.org

His *Earthcodes* project attempts to boot computer off of telluric noise by planting part of the motherboard straight into soil (Whitelaw, 2013).

FIGURE 4.3: The Earthboot board, courtesy of (Whitelaw, 2013)

Performances are extremely tactile and hybrid, blending digital electronics, analog electronics and organic matter.

FIGURE 4.4: Martin Howse performing with soil, chemicals, various electronics. Courtesy of Arté Télévision.


He was interviewed in order to better appreciate the intentions behind some of these unusual design and performance practices, keeping in mind themes of post-optimality, levels of innovation in electronic music devices, and community.

> I hardly ever use electronic instruments other than those I have built myself and some of these I have had huge problems in trying to reduce the complexity — this has been the hardest work, how to map a vast mind-set of connections and processes to a simple interface. Working with materials presents a simpler interface.

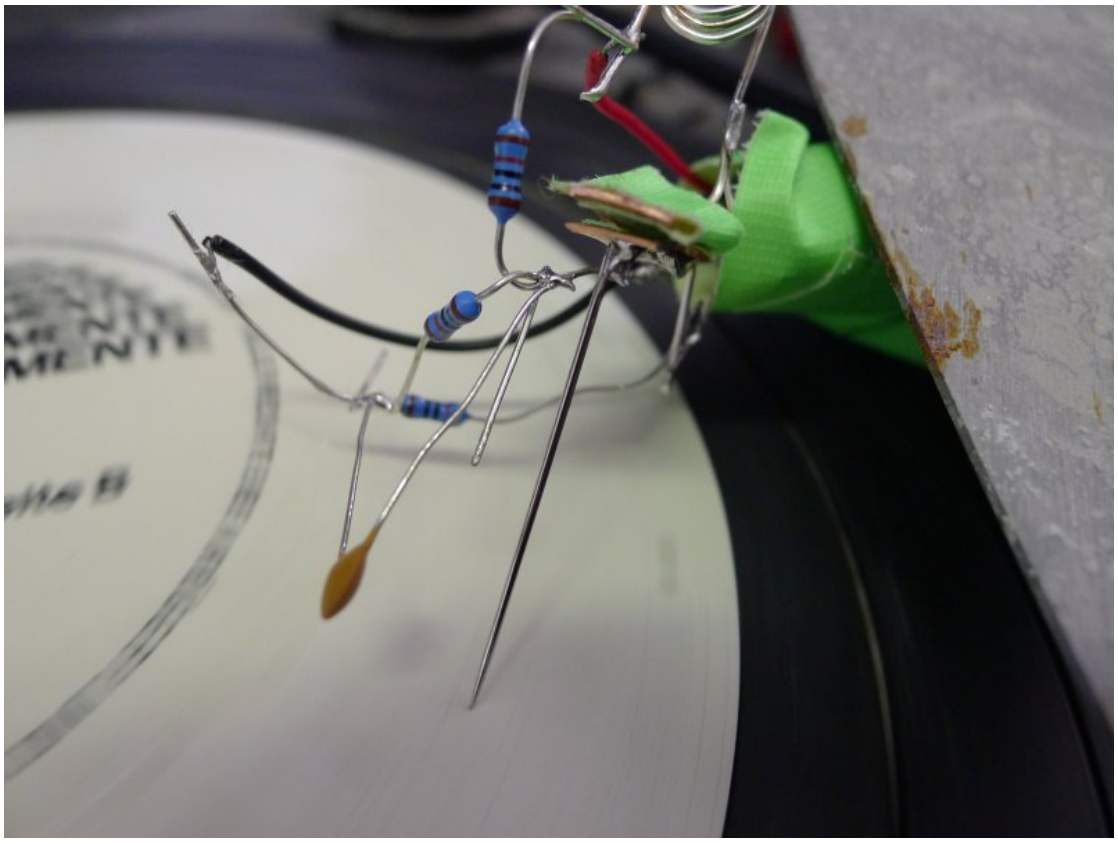
His answer to problems of complex electronics is to go through a contact with raw materials, an approach particularly reminiscent of Perner-Wilson's *Kit-of-No-Parts*.

> the approach is very much a revealing, either through re-working materials towards technology (for example, performances using earth as an active, electrochemical, biologic material), or dissecting and almost dissolving (in chemical sense) digital technology (in workshops), or devising software which examines its own material conditions

Post-optimality is omnipresent in Howse's work: at the component level, through the use of organic or soft, unstable materials such as soil, acids and fungus (Howse,

2012). At the systems level, this is noticeable by his attempts to boot operating systems using noise as sections of code (the earthcode project) or his circuit combining turntable needle and FM radio.

FIGURE 4.5: The FM needle, a hybrid of turntable needle and FM transmitter. courtesy of 1010.co.uk



At the interface level, post-optimality is objectified in his irregular set of copper contacts in the dark interpreters series (see subsection 3.7.1). Their goal is to present a tangible surface for machine languages: "I wanted the user to literally put their fingers into the code, to run the code over their skin"

In these processes, the importance of teaching as a method for inspiration and self-learning parallels the ideas discussed with Collins: these are projects he teaches in workshops, devices he sells, or are part of a performance routine. It is important

to note Howse' unique background in literature, video art and teaching, which heavily permeates his technical practices:

> I began working mostly within video and conceptual art and realized that technology was an important material concern for me; teaching as in workshops is a way of generating new ideas for myself and others.

Once again, post-optimal devices find a social dimension.

Howse's designs were previously qualified as both open source and cryptic, and this is relevant to a discussion of post-optimal design methods. Schematics, codes and poetic presentations of his work are all available online. All were developed using open source software. However, through his use of software such as KiCad (an open source and fully free alternative to professional computer circuit design software) and a personal set of code formatting rules, much of Howse's documentation offers a slight user-unfriendliness also described in section 3.7.1 which clearly encourage learning. This is done in a matter similar to that described by Kevin Ernste when discussing Cihan's *Porcupine* device: provide just enough information to allow attempts at reproduction, but with enough uncertainty to prevent fully accurate duplication (see section 3.4.1).

Collins and Rylan both expressed concerns with the difficulty of "real" engineering and the rarity of compelling performances from electronic music hardware makers. Howse appears to address both concerns: he is perhaps the best user of his own designs, but also seems successful enough with them to be making second runs of completed devices. Post-optimality permeates every single of his endeavors, hinting towards a tongue-in-cheek look at musical engineering that nevertheless must be contextualized with his wide-ranging technical skills.

## 4.9 Sang Wook "Sunny" Nam and Joshua Florian

Sunny and Josh both operate in a very niche market of "highest-end" audio. Their businesses are built upon a reputation for the absolute highest standards of performance, and their investment in such a reputation directly correlates with their continued success. Although a reader will find technical information in their interview transcripts, it seemed most important to include comments on their responses here because they address greater cultural contexts for some important concepts of audio technology in our discussion of open design.

Effectively, Sunny and Josh are both secretive about the details of their work. As Sunny explains, he's spent countless hours and invested a significant amount of capital into designing a studio that is not only unique, but also objectively one of the best listening rooms in North America. In parallel, Josh's design for Sunny are entirely custom, fine-tuned affairs that they collaborate on to optimize until both of their standards for quality audio are satisfied."The concepts are most important", he'll say, explaining why he thinks product schematics shouldn't be made available in most cases.

Their time spent together at the Mastering Lab in Los Angeles makes them share a similar language and respect for what they call "yestertech", a term coined by their supervisor there. In some interesting regards, this interest and respect is the cultural bridge between high end commercial audio and the concept of open design previous chapters experimentally defined.

An informal definition of yestertech according to Josh and Sunny would probably follow these lines: a collection of devices and their associated designs and histories that were designed for the specific purposes of sounding as good as possible, often site or context specific, manufactured in small numbers if ever in mass, and often pre-dating

the commercial boom of digital audio. In that sense, the golden years of yestertech surround the two two world wars, perhaps extending to the mid seventies.

Going back to our historical description of making in electronic music, one might see a correlation between this period and the rise of kit-raised electronics engineers. This is largely confirmed by Josh's personal experience, as he describes his teachers being mostly from that generation and milieu. Those personalities came out of research institutions or large businesses (often aerospace, defense or both) and brought with them a academic and company cultures that largely subsides in todays major label recording and mastering world. That institutionalized vision of electric music largely fueled the development of the music industry until the eighties.

Interestingly, Josh acknowledges that this model largely relied on a mentor-based system of information-sharing. Arguing that this is an inherently pre-internet practice is out of the scope of this thesis, however, denying the rise of self-taught experimenters following the Tudor model (aware of larger trends but faithful to self-contained aesthetic aspirations) would be short-sighted.

Drawing a caricature, a first glance would offer a convenient spectrum of practices: on one end, the blissfully unaware of circuit theory bender and chaotic noise musician, and the professional, mentored, traditionalist engineer on the other. Their obvious and common interest in yestertech shows how inconsistent a classification of practitioners (let alone practices) would be if it followed this spectrum. Roland just announced its first series of eurorack modules(Team), bringing the institution to a market founded and mostly kept alive by quirky revivalists (see appendix A-3 for a more in depth description of that evolution). Ray Wilson, online DIY synthesizer guru recently released a book on analog systems through Maker Media Inc., owned by major publisher O'Reilly media (Wilson, 2013). Technological comebacks or extended lives as cultural phenomenas are at this point commonplace in audio (tube amps, analog synths,

vinyl, cassettes, AlNiCo magnets...): yestertech is, if not half the game of audio equipment design, a binding point for most communities.

Dan Snazelle, in describing his work as entirely original, is compelled to make a significant addendum: "analog electronics are rarely entirely new". In the current context, where chip-tune motivates people to make the most of intentionally limited 8 bit systems and bases entire synthesis schemes off of Commodore 64 SID ICs, it seems almost natural to extend yestertech to *any pre-existing audio equipment that's existed long enough to see a few generations of production and hacking*, thereby maintaining the relevance of the term.

## 4.10 Overview

Various post-optimal practices have been identified at various levels of the electronics design and manufacturing chain. These practices recur explicitly in connection to the boundary between analog and digital technologies, and implicitly through an underlying connection to chaotic or unpredictable systems. Those systems are usually centered on electronics, except in Collins', Jones' and Howse's case where they also find an extended basis in the social aspects of their sound experiments through tutorials, classes and open documentation. Paraphrasing Joe Paradiso's statement that hacking is pervasive, post-optimality could be described as a latent characteristic of hardware-based musical practices.

# Chapter 5

# Conclusion

## 5.1 Summary

The previous chapters have made explicit the prevalence and promise of post-optimal objects within the practices of contemporary silicon luthiers. Furthermore, it post-optimality could be thought of in some cases as a latent characteristic of any musical technology, which could be exposed through hacking, bending or repurposing.

A clear progression from financial and scientific insecurity in electronic music research is visible, as today practitioners with varied levels of qualification make a living as musicians, business owners, teachers and artists.

A number of those identify a long-lasting interest in the promises of those unpredictable, post-optimal chaotic systems, possibly as a counterpart to the surgical and consistent responses of highly engineered audio tools. The social aspect of the practice is also non negligible, with a number of connections being made through Collins' publication and practice, other workshops, histories, and archived material.

Perhaps most usefully, this thesis illustrates that incomplete or very informal records of past and current hardware work can be studied to derive functional approximations and complete analyses of electronic music devices. Snazelle's claim that designers have access to much more than he did even just a decade ago appears to be accurate.

No common motivation was clearly identified in trying to understand why exactly people still tackle hardware design issues when much of these systems could be simulated entirely in software. Paraphrasing Collins, there simply is a tendency for a fringe of the musical population to appreciate the materiality of the tools that allow make their art possible, and the variety of specific motivations give each device a better chance to be unique and innovative.

In 1950, Lester Paul's radio program explained his peculiar guitar playing sounds with a device, the *Les Paulverizer*. Paul, as a noted enthusiast for innovative uses of technology in music, described this machine as one which could enable him to use "one guitar, and make it sound like six". The Les Paulverizer, in reality, was a farce. Its result was fabricated through the use of multiple tape machines and playback speed manipulations ahead of time, then synchronized with Paul's movements on stage.

Living with the lie of the Paulverizer, its author eventually developed a system that could implement some of its fabled capacities in real time. The *real* Les Paulverizer was in effect a foreshadowing of controllers: knobs and switches made available to the musician to send controls offstage and trigger various effects(Kane, 2014).

Brian Kane makes clear that Paul's style and reputation relied largely on technological innovations such as the Les Paulverizer. Arguably, Paul was successful in playing with this subterfuge, letting it run until it led to popular success and ultimately motivated very real technical innovation.

All their efforts and devices were also quite real, but the example of the Les Paulverizer reminds designers that documentation is much harder when your invention isn't real, but also ultimately that the result is all that matters.

## 5.2 On the Importance of Open Design Practices

Hacking is pervasive (Paradiso et al., 2008). Open source hardware practices, which share a deep link to hardware hacking (Williams et al., 2012), are the bridge between longstanding methods in electronic music instrument designs and innovations in the field of accessible invention and fabrication. Through the work undertaken in this project and the writing that came out of it, it was most important to convey that making instruments could be as deeply personal and creative as composition, with endless inspiring parallels, an activity no longer reserved to academics or professionals. The goal isn't to create perfect products, rather, it is to produce something you are happy to use for musical purposes, regardless of its hypothetical shortcomings. In an age where the White House organizes its on *Maker Faire* and half of the documented projects are artistic (White House, w2014), this work will not be alone.

## 5.3 A note on diversity in audio electronics and this thesis

This project hoped to address some cultural and social aspects of open hardware design in a musical context: it appears as important to acknowledge the implicit biases present in this process. Most of the people listed here are from the northeastern United States, and arguably all of them have been operating within a western art world. Three of the ten interviewees are women.

There are therefore clear biases. Future work should include a more thorough effort to seek out and include minorities.

## 5.4 Perspectives

As the manufacture of circuit boards, surface mount electronics and increasingly powerful microcontrollers become available to the public, a number of new possibilities become available to designers of electronic music instruments. These engineering developments always offer an opportunity to think about how these tools are meant to be use in a musical context, but also a chance to think of how they can be repurposed as part of post-optimal and musical object, system or activity. This thesis suggests that explicitly acknowledging the creative potential of unpredictability through craft in electronic music instrument and identifying latent opportunities for post-optimal approaches in product design holds both scientific and compositional promise. As experiments develop and are materialized in an ever-greater variety of devices, further scholarship on this topic is necessary for the documentation and continued development of electronic music.

PART III

# Appendices

# Appendix A

# Interview Transcripts

These are the full transcripts of the interviews undertaken as part of this thesis. The raw transcripts have been formatted and lightly edited for easier browsing. They are arranged in the order in which replies were received.

## A.1 Transcript for interview with Sang Wook "Sunny" Nam

The interview was conducted in person in the Digital Musics building at Dartmouth College on October 14th, 2014.

**Ezra Teboul**: How did you first get interested in audio technology? What was its part in your learning process as a mastering engineer?

**Sangwook Nam**: I went to mastering in 2000. There were no resources to learn mastering, but there were books and photos about studios in the US - I was in Korea - and there were tools that known as applicable to mastering. So I used these, mostly digital items like compressors. Plugins were just born by then, so we didn't use them. So we had digital hardware, like waves from swissland (?), and more things from Germany.

After I went to the west coast at the Mastering Lab, they had a completely different concept of the gear they used. I had to learn everything all over again. They're still quite different from regular studios, in those they use mostly off-the-shelf gear. But I had to learn the history of all the recording equipment, because a lot of our designs were based on work from the 60's. I learned how they worked, how they were designed, how to fix and improve them. They're in a smaller form factor now.

**Ezra Teboul**: Do you hold the distinction between discrete transistor circuits and IC circuits as being important in this context?

**Sangwook Nam**: Yes - discrete, tubes... transformers, resistors... every part is important. They've all changed, become smaller. The overall quality of the parts and the circuits they're in have been in some sense compromised. I learned how the new technologies, how those smaller form factors damaged the sound of the equipment, and

how to keep away from them, all that sort of stuff. What parts I need, how to evaluate them, where to source them...

**Ezra Teboul**: So you've listened to ceramic vs. tantalum capacitors...

**Sangwook Nam**: Right. That's easy. But polyester vs polystyrene? What type of polyester? What type of structure? Even with the same structure, what company makes a better polysterene or polyester condenser?

**Ezra Teboul**: Have you done double blind A-B test for all of those variants?

**Sangwook Nam**: Yes.

**Ezra Teboul**: When did you do those tests?

I didn't have any need to do those while working at the mastering lab because my mentor had already done all the listening tests. Wires, switches, volumes, everything. When I left the company, I did it all again myself, because he didn't tell me all of his results. I had seen a few, I knew some of them, but most of them aren't available in the market. In those cases, I had to find old stock from somewhere, and if I didn't find those, I had to find an alternative. So I go on Ebay to look for old parts - from american to russian military to european parts... I went through, bought samples, listened to everything...

**Ezra Teboul**: Iv́e had to do similar work in the past, and it always seemed like a fun aspect of projects.

**Sangwook Nam**: It's a fun part, if you're a student. But if you're spending money and time, it becomes more of a problem...

**Ezra Teboul**: What do you think of your current setup? Is there still work to be done, or are you happy with it?

**Sangwook Nam**: I'm fairly happy with it. I have some equipment in my mind I'd like to build, still... but my clients are very happy with the outcomes, and I have quite a bit of freedom to do what I need with it, so I'm pretty happy with it.

**Ezra Teboul**: The fabrication of your custom equipment involves contractors and engineers - most of it isn't built by you. How much do you document this collaborative process?

**Sangwook Nam**: Well they submit all the schematics and that sort of stuff to me, so I have the final result and a sketch of the design. I also keep all the email correspondence, some notes I take when I evaluate the products...

**Ezra Teboul**: Do you share any of this documentation?

**Sangwook Nam**: Oh no. It's a very time and money consuming process. Very good polystyrene condensers cost 200 piece. If I'm testing a stereo pair, I'm spending 400 just for those. Unfortunately, they didn't sound good - so I end up spending 5 to 7 grand just on capacitors. So anybody can do it, but, you know - it's my money and time, and it's really hard for me to share that for free.

**Ezra Teboul**: Do any of the people you contract for this equipment end up sharing the work they've done through collaborating with you?

**Sangwook Nam**: The designer and builder of my equipment (Josh Florian - JCF audio) is my close friend, and he's pretty secretive of the information he gets from me. He doesn't use it in his own work or other commissions. Also, its very expensive for mass product, those parts are hard to get...

**Ezra Teboul**: You've mentioned that learning the equipment was a big part of your education. I'm guessing the other part was training your brain listen to what you want to do, what you need to do with a recording when it comes in your hands. For

most projects, what's the technical vs. the mental?

**Sangwook Nam**: Psychological understanding of what the gear does... will take weeks, months, years. These pieces of equipment I've been using are quite different from modern EQs, compressor... if you've learned how to use commercial standards, you'll have to learn to adapt to mine. I'm using shelf eqs, so I don't have any Q control, any peak curves.

**Ezra Teboul**: Is it an active circuit?

**Sangwook Nam**: No, it's all passive. There's only one amplifier at the end. With the parametric EQ most people are used to, it's really easy to go to the frequency you want and take it out, or add something... but you have to be very creative to make something peak- like with a shelf eq. Also the bands are very limited. You need 2 shelf bands to approximate the behavior of one band of parametric EQ, and I have four shelf bands. So I have a very specific strategy to play with the balance of sounds. Also, because those are very wide EQs, you have to get used to that. It's like using nothing but primary colors to paint an image. If you have 48 colors, you just pick up the right one and paint with it, but this is completely different. So I had to learn to adapt my process to these mechanisms, which are very simple but very hard to use for some complex behaviors that more standard equipment can do easily.

**Ezra Teboul**: Does having a say in the way those items are designed probably helps make it easier for you to use them?

**Sangwook Nam**: Yes, that's true. Also, certain EQs have some things that they can do better than others. There's two types of filters: LC and RC. LC means you have to use an inductor. If use that, there's a resonance, so you can get a little bit of a peak curve out of it. Also there's the specific sound of the inductor, which will color the output - it might sound a bit more aggressive, or euphonic... so you have to know what

this EQ would sound like on a particular sound.

**Ezra Teboul**: What order filter are you using for your mastering work?

**Sangwook Nam**: Because it's all passive, I'm using all 6db/octave first order filters. If you want to do 2nd order, you get more parts: more distortion, more non-linearities, more noise. 6dB/oct is more than enough for most cases.

Most EQ slopes in DAWs can get much higher very fast, with 24 or 48 dB per octave being common.

Yes, 24, 48, butterworth... those are common. If I have to do anything that drastic, I can do it in the digital domain, or I can ask for it to be fixed at the mixing stage. If you want to do that at the mastering level, it's a fairly significant problem, so you don't want to do that... That's what's less harmful.

**Ezra Teboul**: You've worked with Josh as your go to engineer?

**Sangwook Nam**: He was assistant engineer when he started at the mastering lab. He found at that his interest was in electronics rather than recordings. He's also a great drummer. So he learned a lot from our resident tech back there, what he calls "yestertech"... tube electronics, discrete, power supply, grounding schemes, all sort of stuff. Then he developed all the new stuff out of that and became the owner of his company that makes great products...

**Ezra Teboul**: Do you know any other hardware engineers you'd put on the same level?

**Sangwook Nam**: One of the resident techs went independent thirteen years ago. He's not making any mass-marketed products, but he'll do commissions. His name is Steve Hazleton, in Tennessee. He's another guy that I can go to if Josh is not available. The other people... people who make mass products for consumers had to deal with all

the safety issues and regulations that can be problematic for some people. They put a lot of stuff in their designs that ultimately compromise the quality of their work... so I wouldn't call them.

**Ezra Teboul**: You made it seem like there was a back and forth between you and the designer to get these electronics together, starting with your query for a specific item or modification. Does this process go both ways, and do you listen to some of their recommendations for mastering equipment?

**Sangwook Nam**: Yes. The equipment that I have... When Josh first listened to what I wanted, the equipment I needed and the topologies I wanted to use, we had to improvise a little bit, which I wanted to do. There's definitely an interplay. He developed a couple of things I didn't think of, and sometimes I'll suggest something he had not considered. That's always going on.

**Ezra Teboul**: Is there one specific item that illustrates this process well in your studio?

**Sangwook Nam**: The monitor panel is all custom made. I wanted to listen to what's coming in, and what's coming out. What's coming from the DAW, and compare everything. I told him I wanted those things, so he'll develop a schematic, and explain how each volume is controlled, how to implement mono... how to make those three inputs independent, how to make the panel that has the less contacts. The more connections, the more contacts. Even though we're using very good switches, you'll lose some details. That sort of thing can be more specific points developed by him... ultimately, we decided on three contacts and he built it.

**Sangwook Nam**: The compressor is another example. I wanted a low pass filter on the side chain so it doesn't see the big bottom end when it compresses it. Since we were using 4 channel switchers, he said we could make it a variable filter, so I decided

on four values. 100 Hz, 200 Hz, something else, 400 Hz... That sort of process.

**Ezra Teboul**: You use only switches and resistor networks, no potentiometers, no faders?

**Sangwook Nam**: Yes. No faders. Only switches. You can also use relays, or cheaper switches, or any VCA type OPM for switches...

**Ezra Teboul**: Do you do that?

**Sangwook Nam**: No, but it's a possibility. But all these alternatives make you lose a lot of low-level detail, so I avoid it. Also the materials of the contact, and their structure... the one I'm using has two contacts. It's military grade silver contacts - gold has a specific sound that's not very useful. So does the copper... Everything has a different sound, and silver is my favorite. It's an expensive switch. It's double sided, so a one pole, twelve out... just one wafer is 60-70... and you have to order thousands of them. The price is just... **Sangwook Nam**: Those types of switches were used solely on my console. Volume controls are also only resistive networks.

**Ezra Teboul**: Do you try to minimize the amount of wiring in the overall studio?

**Sangwook Nam**: Yes. All hand wired, short. There's still a lot...

**Ezra Teboul**: Is it all point to point soldering?

**Sangwook Nam**: Yeah.

**Ezra Teboul**: So no ceramic boards or circuit boards?

**Sangwook Nam**: Well, some of the equipment, like EQs... is built with circuit boards. But the console is entirely point to point.

**Ezra Teboul**: Do you ever take a look at the inside?

**Sangwook Nam**: Yeah, every three months I'll open it and clean all the contacts.

**Ezra Teboul**: Do you ever appreciate that wiring as a work of art in itself?

**Sangwook Nam**: Yes. Fortunately I bought the remnants of A&M mastering... the founders of that studio were working at the mastering lab and built the console for A&M studios... So they had all the parts I wanted. And A&M's philosophy was really similar to the mastering lab's so I was very happy to get that. I had all the good switches, and an already made point to point console. We had to adapt a couple of things, but most of the work was already done. Josh had to do a lot of wiring, but still...

Wiring all those switches... I can't do it. Somehow Josh can do really fast.

**Ezra Teboul**: Would you ever take out a soldering iron and fix something yourself if it needed it?

**Sangwook Nam**: No. I'm not good at the smaller things.

**Ezra Teboul**: How do you know if/when a particular piece of gear is finished? (25min52sec)

**Sangwook Nam**: We'll discuss the topology. For amplifiers, for example, I usually avoid op-amp designs. Even with discrete op-amp based circuits like the 2520 or 990, those use a lot of feedback, and I don't like the sound of either. So we were talking about discrete amps, like a quad or two push-pulls topology? The shelf EQ has a loss of around 21 dB, so will those circuits have enough gain? He'll build a prototype and we can try it and listen to it. He'll make a test board that has a 21dB loss to test it with, I'll listen to it for a few days, send it back with comments...

After he is done the designs, I listen to for a week or two for anything active. Sometimes he makes a mistake and process stretches a bit, but usually it's just one trip and... done. At one point, in the very first stage, he sent around 4 different amplifiers

with variations for me to try, so I picked my favorite and refined that design. I don't want to overuse one amplifier, because even though they're very transparent, it still has its own sound. I don't want to add the same topology multiple times, otherwise those characteristics compound. So if we need another amplifier, say in the compressor, I'll use a different topology - maybe tubes, or solid state topology.

**Ezra Teboul**: To what extent do you participate in online audio-enthusiast communities and what role do they play in selecting your equipment, if any?

**Sangwook Nam**: Human ears can get off-road really quickly. Ears work as comparators. You'll listen to one thing, then another thing, and always compare. If you hear a very bright tune, then a well balanced tune, the balanced one will seem dull. It's very easy to loose objectivity in listening. I had to find a few people that know how to listen to low-levels, to electronics... This is what I usually say: listen to the quality, instead of the quantity. One dB of EQ is the same if you look at the quantity, but every unit has a different sound. People have to pay attention to that, and I haven't found many that do, so I always ask them for a second opinion if I need one. One of them is Bill Schnay, in L.A., and he has a very high resolution recording studio. I listened to capacitors there to pick the ones that sounded the best: we tracked drums in the live room straight into the switch with a very high resolution microphone, and I'll listen to a capacitor with the lowest capacitance to get a sense of what it'll do. He was sitting next to me and helping me, making sure we remained objective. Having a second opinion is really important.

But, online... no. I go there, to find out what the next product is and what people think about it. But the ultimate decision is always with your ear. The people who are lurking... active on those websites... if you're busy, you don't have time to do that. What they're saying is so not true...

**Ezra Teboul**: Do you measure the performance of your gear electrically, and if yes, what importance do those measurements have?

**Sangwook Nam**: I do. Good sounding gear has to measure well, but the opposite is not true. Like the 990, it measures well but I don't like the sound. When Jensen first made it, we tried it at the mastering lab, we had a very big live sound at MGM - now it's Sony, back then it was MGM - we put fast instruments like tambourine or any percussion 40 ft. away from the microphone, and rung the bell, or the tambourine. The tails of the sounds decrease, the microphones record that, then we listen to that through high resolution amplifiers that we know with the same gain and it what it does is d̈inǵ then the decay is going on. We can still hear decay all the way down on a good amplifier. The 990 goes ẅiuuuu- ss!...́ because of the internal feedback. For measurements' sake, you cut out the low level detail, and they think it's noise, and the feedback system cuts it out. But there's still information in that. So measurements isn't a guarantee, but you still need very low distortion measurements to sound good.

**Ezra Teboul**: Do you look mostly at THD (total harmonic distortion) measurements for this?

**Sangwook Nam**: The problem with THD and some of those measurements is that they're done using sine waves. What's the easiest thing to measure? Sine waves. What do sine waves have to do with music? Not much. That's another problem of measurement. This can be a good measure of what the amplifier does, but it can't be all of it. You have favorite topologies of discrete transistor circuits and tube circuits. Do you want to talk about that a bit more? There's not too much... I like less parts. If I can do with two push pull transistors or tube, I'll use that. If I need more gain, I'll need a stronger design... Tube can be very euphonic, with low distortion, but mostly so at low wattage. Their problem is when they need more power. But if you think about the music, everything is a few watts at most. Drums, or fortissimo would draw a lot of

current and require more wattage. But most of the time you're drawing 1, 2, 3, 4 watts. So tubes are great for listening, but not necessarily when you're mixing or mastering those strong transients. Have you ever considered an hybrid, adaptive amplifier that distributes the load between a single ended vacuum tube amp and a push-pull transistor amp based on the dynamic range of a piece? I'm not a real designer, so I don't know what that involves. You'd probably need a lot of interfacing between the two sides? I don't know... I have used a tube push-pull amp, and it was really good.

**Ezra Teboul**: What is most important in your work process?

**Sangwook Nam**: At the end all that matters is the sound you're getting. It's hard to be objective if you know certain things about your equipment. Forget what it is, listen to what it does and what it can do, where the limits are. It's very bad to have all this technical knowledge without having the listening abilities. I can see a lot of people with that problem, especially on websites. They understand how things work, what's new, but they don't listen.

A funny thing: one guy asked what the best DAW was, and a thousand replies were added on that thread. T̈his DAW has this function, ïhat one has another, but over those thousand replies, no one talked about their sound. That's the current situation of the engineers, and it's really bad. They read the articles and they know the technology... but no listening.

Dither - lots of guys talk about dither. Lots of dithers available. But in my ear, most times dither doesn't work well. For example, if you're using four plugins on one stream, all of those are going to add dithers. If they're using high frequency-boosted dither, even if it's inaudible in one plugin, if you have for or five you can hear that sound and it affects the music. So I tell them to turn of the dither... and they say öh no, truncation of errors... no...̈. All this information about technology is influencing the

way people hear music, and the new technology is always better... In some areas, that might be true, but in music it's not always true. In my opinion, and the history of music says that too, 50-50 is very generous numbers for new technologies. I'd say 20-80. I'd wait 2-3 years after something came out, and trying it in my studio before having an opinion on a particular item. OS, or Pro Tools updates... all sorts of stuff.

**Ezra Teboul**: In the end, what makes your studio special? You've spent a lot of time listening to everything, and that's why people hire you?

**Sangwook Nam**: Mastering is special, because in a recording studio you have 48 or so channels to control your quality. If there's a bit of loss in one channel, the consequences aren't always serious. In my studio, my hands are tied to two channels. If I don't use those two channels better than other mastering engineers, I have a big problem to start with.

After that, even if you have a great equalizer, if you play the music wrong, you're doomed. The first thing I can say than my studio can do better than any other studio is play two channels. My DA converter uses a very specific topology different from any other mastering business. It doesn't have any digital filters. You need digital filters to do oversampling - I don't do oversampling in my deck. I don't have digital filters. I have a special process that fixes oversampling and digital filtering that was done during the recording.

So that's the most important part for me. How to play two channels right. In a musical way.

**Ezra Teboul**: Do you know anyone who has built their own mastering studio from scratch?

**Sangwook Nam**: All this? Yes, Bernie Grunman. A&M... which is gone now... the Mastering Lab. So Bernie, Mastering Lab and me would be the three... All the

others... I don't know anybody else.

**Ezra Teboul**: No one who wasn't a professional in the first place is doing this from scratch.

**Sangwook Nam**: Right. Also, you need to have a tech to build all this, understand the topologies and how to use them.

**Ezra Teboul**: That's too much for one person?

**Sangwook Nam**: And too expensive. All the young engineers who build the gear don't have deeper knowledge of yestertech. Everything I see today has remnants of a 2520 or a 990. Some people work with the quad-type amp. But those three represent most of the designs. So it's a pretty limited knowledge base. Now if you have the resources to look for more original things, you have a lot more to work with. The encyclopedia of audio - the first edition, from the 50's. That's the real treasure.

## A.2 Transcript for interview with Nicolas Collins

The interview was conducted in person at the Native Bean in New York City on February 7th, 2015. The transcript was edited by Nicolas Collins before being included here.

(conversation informally starts on a discussion of headphones, earmuff padding, and the suggestion that the two recordings of the chat will be used with one out of phase to create a composition):

**Nicolas Collins**: ... In some concert halls, they have devices to jam cell phones. This is known. I've seen a handful of references to circuits that do this. this isn't like building a nuclear centrifuge, anyone should be able to do it. The only tricky thing is working at such high frequencies that cell phones operate at. It's not as easy as building a fuzztone - the level at which I work.So I see a couple of versions of this, small ones not powerful enough to fill a whole hall, but I love the idea of carrying something the size of an iphone that creates a black hole around, wherever you go, so that in a 3 meter circumference everyone's cellphone's stop working.

**Ezra Teboul**: Have you ever read the Pirate's Dilemma? It opens with a discussion of the ethical implications of using those ipod radio-emitters for your car. They could jam a frequency not only in your car, but in a 2-3 vehicle radius around you.

**Nicolas Collins**: There's so much interest in what's called "silence studies" in the last ten years. This is cyclical. There's a Cage / Rauschenberg moment in the 60's, then it came back with a vengeance... It took so long for Cage's ideas... not to be accepted, but rather internalized. For example, people from many aesthetics could view silence as a positive element, rather than as the absence of something. It hit something, at the turn of the millennium, when all these people realized you could carve things out of

all those negative spaces... and in some fields this had been accepted for a long time. Graphic design... It's one of those things that follows a zeitgeist or a pattern or a cycle... That idea comes up a lot in hacking. That idea of injecting something or removing something...

**Ezra Teboul**: I'd like to try and go through a few questions, hopefully we can develop that as we go along those. I wanted to start with something basic. I'm interested in contemporary practices in electronic music hardware design, trying to link the first electronic music instruments with DIY and Tudorian electronic music and today's open source movements. You're in a great position, where you've had a chance to work with Tudor but also see taken advantage of contemporary technologies...

**Nicolas Collins**: I'm old, yes. But I'm still alive.

**Ezra Teboul**: and you wrote the book!

**Nicolas Collins**: fine... I did do that.

**Ezra Teboul**: So what's the current place of hardware in what you do today?

**Nicolas Collins**: ... (pause) you know... because of my age... the arc of my material resources are a little different... from yours, from those of my mentors. I'm from a particular generation. My first work was based on hardware because when I was 17 and wanted to do this there was no computer. It was the epoch of mainframe computers. You would not get access to those as a young person, and even then they were an offline, non real time thing, and from the very beginning I was interested in real time music production and performance. So the alternative was synthesis. This was the era of synthesis. However, synthesizers were also impossible to afford. None of these technologies were what you'd call personal. Ownable.

But it was at that moment that integrated circuits went from being extremely functional building blocks, transistors out of which you'd design a whole circuit... to... more modular things, that could do more things out of the box. The most critical chip was a signetics 566, which was an oscillator on a chip. 8 pins, you hook up a very small number of components and you'd get a couple of waveforms. It was designed for touchtone telephones, which is the only reason it existed, because that had a huge market. And across the board, you'll find people from my generation and a bit older for whom that was the first thing they've ever worked with. Because who doesn't want an oscillator?

So... my entry to electronic sound was hardware. But by the end of the 70's, microcomputers emerged. It was pre-apple, industrial computers. It was sort of like large Arduinos, right? And it was a lot like working with Arduinos. So composers from my generation, who are now say between 55 and 70, really dove into the computer stuff early on, and by the mid 80's it was sort of a no brainer. You could get so much done. The biggest drawback was that you couldn't really do internal audio processing on a personal computer until the 90's. But there was so much available in terms of MIDI controllers and everything, and I basically since 1979 kept two parallel tracks of doing these circuit based things and computer based things, because the fact of the matter was I wasn't terribly interested in the sounds of synthesizers... so I had to find other roots.

**Ezra Teboul**: and a summary of that is in your paper about early microcomputers in your practice?

**Nicolas Collins**: Yes - that's the paper on Semiconducting (Collins, 2012). It's the idea that certain technologies have natural strengths. from my standpoint. And most composers think of orchestration as a decision, rather, than say writing for violas the rest of your life. So for me, switching back and forth between technologies was no different from switching back and forth between instruments.

But I have to say, as the decades passed, it was obvious that the computer was becoming the more powerful, more versatile tool, and if I wasn't willing to spend the time being a brilliant analog engineer - I was always self taught - there was much more possibility and much more openness and much more of a community for a sort of open source in the software domain, rather than the hardware domain. But I kept a hand in the hardware all throughout this time. If you look at the few records I've done over time, there's all these oddball instruments. Hybrids of electric and mechanical things. Sometimes maybe guitars, live sampling systems... It was all a mishmosh. What happened, what changed for me was that the end of the 90's, I started teaching in art school. It was this moment where you may be able to identify more clearly... I call it the digital hangover. The computer had become so powerful that people were just knocking back shots without think- ing of the consequences. You couldn't really do anything. My mantra has always been control-x / control-v. It's the world's most powerful tool! You can cut a term paper, you can cut audio, you can cut video, you can design a website. It's the world's most amazing pencil. But as I discovered, from the art school context,

Art students are peculiar in the sense that every single one of them, even if now they do exclusively digital, they all started drawing. There is not an artist in the world that didn't scribble, even if now they use a mouse. And that seems to be really ingrained in visual artists, this desire to do things with their hands. We think of that as a musician's thing - musicians are about the tactile. But I think that musicians don't play their instruments 24 hours a day. They have a nice life+work separation. Artists are always fiddling with something.

It was those students who pushed me to do the class, and it was this generation of hungover... from digital overindulgence... that led to the rise of Circuit Bending. Because the Circuit Bending movement went back to the early 90's, when Reed Ghazala started writing articles for the Experimental Musical Instruments journal (Instruments,

2015) . And there was always a little cult of this stop. Always this buzz in the air about the Speak  Spell. I had a Speak & Spell in 1979 that I hacked. this is pretty basic stuff. But he took off at the end of the 90's, with this sort of anti-computer backlash. For a while people were waking up one morning and saying "I'm never programming again". And for a while it was like that, a real split between the circuit bending people and the computer music people, and they basically had nothing to do with each other. Circuit Bending people were militant about their anti-computer stance. Porta-studios came back with a vengeance, the cassette was a real format... It was almost like a Luddism. But then... a few things happened. The most important one was the sort of parallel growth of limits in the open source community and the Arduino. People had been making Arduino type things since the 80's... STEIM made this beautiful Sensorlab thing - but it was $3000! Completely insane. So the combination of the affordability of the Arduino and the open source nature of doing programs on it and the fact that they had provided this glue between the physical world and your laptop meant that it was like the peace accord in Belfast. Suddenly catholics and protestants could talk to each other - over the top, but I think a lot of orthodoxy broke down at that point.

**Ezra Teboul**: people realized the Speak and Spell used microcontrollers.

**Nicolas Collins**: That's what I tried to tell these guys. Every single toy they use is a sample- playback computer. I did a workshop with the other Nick Collins, in Mexico, some years back. There was so much confusion about the two of us. He's a Supercollider maven, and the organizers could not figure out these two dudes were two different people, so they billed these multiple workshops with Nic(k) Collins, with no indication of which was which - there were 2 or 3 of them. And of course everyone came to all of them and they didn't know what they were going to get. We decided we would simply do the workshop together and every hour we'd switch between software and hardware. It worked! It was clearly the threshold point. Everyone was equally

comfortable working in the two modes, which was a big change. Where does that gets us?

It gets us where we are today. Coming into teaching late I'm much better at making the distinction between my life and my job than I was when I was a grad student. But I can't deny that teaching, not only in Chicago but also these countless workshops have fed back into my own practice. I got interested in one very specific thing at the beginning which is that when I would do a workshop I would have 25 kids sitting around a table with little amps and speakers working on kind of similar projects or technologies at the same time. Everyone would be working with contact microphones, or making their first oscillator. But it was this great orchestral electronic sound, that wasn't mixed down to a P.A.... it's also in the same general region, but uncoordinated. Now for a guy who's background is in deep Minimalism... I started opening up to a chaos... the things you can get with a large number of human beings that you can't get with a line of code - unless you're really really clever - and I'm not, I write relatively simplistic code. So I got interested in the group dynamics of hardware based stuff, where you don't control things as accurately as... god forbid, a guitar, in your hand. 25 electric guitars in a room, it'd be a very different experience. I got interested in the noise world. The sound world of... disreputable electronics. Electronics that you weren't sure were working correctly, or that you knew was damaged but still interested in the sounds it could make. So I did a piece called "Salvage" - it's on youtube – where six people try to revive a dysfunctional or broken circuit by injecting voltages into an unpowered circuit board and using it as timing components for oscillators. So you get a very complex oscillator with a high degree of chaos in it. And it goes through a set of complex evolutions as more people start joining. There's a very simple instruction set. The idea is that it starts out relatively cause and effect-y, because there's only one person doing this, but by the time you get up to 6 you get this sort of density of decision making that's very difficult to think about

being done with a computer.

That being said, you know George Lewis made these really beautiful programs that improvise. George has been working since about 1980 on program that improvise. And because he is such a great improviser, he's someone you should pay attention to. The basic idea's always been that the computer listens to the player, and responds as if it is a player. The reason I mention this is because instead of creating a standard algorithm for what its improvisation should be.... (to the best of my knowledge, and you'll have to confirm this with him, what he's actually done) is that he's written different routines that embody different improvisers that he knows. So that in his computer he has multiple different personalities that behave differently in response to the same data.

Now if I was smarter I would try to do something like that. Computer program that instead of having 6 people doing something I have one person do it, and then five "people" to play along. At the same time, I always have a lot of warm bodies in this workshop and this one way to harness the energy. I've spawned a couple of solo pieces of from that. What I'm trying to do is harness the apparent chaos and conformability - seemingly incompatible - of some analog circuits - but use software as a way to get rid of the the sort of monophonic property that most circuit performances have. To create some sort of complementary behavior.

Do you want a précis? A short version? I've carried parallel practices in hardware and software for years and years and years. They've always worked together but what I would say is at the moment, it's the chaotic aspects, the instability of circuits that are coming to a full forward in the stuff I'm doing.

**Ezra Teboul**: So has there been any one device or project that has created a noticeable shift in your work?

**Nicolas Collins**: No, I think there've been multiple ones. David Tudor used to

talk about how he never understood tubes, and then Gordon Mumma tried to teach him how tubes worked, and they tried to build a tube amplifier, and tried three times, finally giving up. It wasn't until the transistor came around that he was comfortable making circuits.

For others of us it was the integrate circuits. I'm lousy with transistors, but ICs are a piece of cake. The more complete building blocks are great. My whole book is predicated on this CMOS logic circuitry from the 70's that lent itself beautifully to running on batteries. That was a critical technological bridge.

For most people, it was the advent of midi and pc with reasonable userbase, so that software could be made by people other than yourself. In the 80's, the conflation between the music industry and the computer industry was critical for a lot of people. It didn't matter so much for me, a lot of my stuff had backed off from the computer, but for the community at large...

Then when computers actually got fast enough to do real time audio processing. So when Max went from being a MIDI generator language to control synthesizers to having an MSP component that allowed you to do direct sound manipulation, that was a big deal.

And I think... I don't do a lot of stuff with Arduino at the moment, but I know that that has been the next big step, because it's solved the problem of connecting the computer world to the physical world. Foundations like STEIM had been working since the mid 80's to make that work, spending billions of dollars on artists residencies and research. And suddenly, this Olivetti guy shows up and $25 later, you got it all worked out. So you know, open source and Arduino would have been the next big step. And I suspect that this is going to be very important. One of the guys who started the first laptop orchestra at Princeton is now doing an iPhone orchestra at Stanford. Ge Wang

and Perry Cook... they had a very conspicuous laptop orchestra, and when Ge gets out to Stanford, he ups the ante and starts a phone orchestra.

**Ezra Teboul**: Dan Iglesias made a nice wrapper for LibPD called Mobmuplat...

**Nicolas Collins**: Oh right, that's why the name is familiar. It makes a lot of sense, there's still a lot of people who don't want to use their computer on stage. They just like the idea of wrapping it up in a smaller package. A point was made to me that people are developing apps much faster than people are developing full feature software for larger platforms. For every major rev of Ableton or Max you have a million new apps that allow you to test all these areas of work.

**Ezra Teboul**: Is there anything you're curious to see implemented?

**Nicolas Collins**: I would be interested in - and I think some people have done this - but I'm very interested in sort of the electromagnetic spectrum that we have around us. Christina Kubisch does these really beautiful EM sound walks, and I do all these things with coils in my workshops where you pick up the sound of your iphone... but I've always been curious what the wifi traffic sounds like. Make a really simple receiver in that bandwidth, with a frequency shift to bring it all down - not to steal the information, I couldn't care less what people are doing - but to hear if there's any rhythmic quality to the community that's working in that spirit.

**Ezra Teboul**: there's somewhat of a visual equivalent that's been done, with some code sniffing all the image content being downloaded for people's web pages and attempting to recreate an approximate mosaic of the overall network's image consumption.

**Nicolas Collins**: and I've seen demonstrations of some of these slightly suspect softwares that allow you to look at wifi traffic on a network. clearly it can be done. It's just that there's some difference between extracting the data, and my desire is so much

simpler - what is the sound of all those things going back? You do have to do a little of stuff, because even when there's no data there's still a constant carrier, so you have to get rid of the droniness...

It's an interesting point. There's this essay called "Yes We Can. But Should We?", and it's a reaction against the DIY community (Arieff, 2014). There's just a sense that its creating so many things? do you need to be making all these things? The downside of this world you're looking at is it leads to a preponderance of things. It has environmental impacts. Recycling software is much better than throwing out a circuit with a battery in it. It's a question of resources. Then there's the moral aspect, the psychological aspect of hoarding, with being object-oriented. If you've talked to people in bending communities, very often the instrument remain in the forefront of musical practices. There's something pretty dreary about concerts at Circuit Bending festivals. It often seems like the music might be an afterthought. There's nothing wrong with being a luthier. There are people whose tradition is building great instruments. It can be Stradivarius, it can be Trimpin, it can be the engineers that are behind the Cracklebox, it can be Bob Moog, but they're not necessarily the people to whom you want to listen to records by. So I think that there is a need to be clear about that. From Tudor's generation down, there's an air of tension. Am I going to be taken seriously as a composer, if I make this thing? Am I going to be taken for an artisan?

**Ezra Teboul**: That's one of the things that's fascinating to me about Tudor. He comes from this very respected musical standpoint, but embraces the experimental electron- ics, live electronics practice, and he's taken very seriously. But that seems to be mostly because of where he's coming from. Not necessarily because people objectively thought his electronics were producing compelling compositions...

**Nicolas Collins**: It's complicated. He had this reputation as a virtuoso pianist, and then the artistry was elevated in his role as the interpreter, the realizer of these

Cage pieces, whose scores had to essentially be translated for performance. That act of conversion, he elevated to this high art, which very few people have reached since. After that came the creation of these electronic instruments in service of the cage scores, and after that came David Tudor as composer. It was too many talents that leached stuff along the line... there was a smaller vocabulary left to describe it, so to speak. I'm very conscious - I've known the guy from the early rainforest period - I'm very conscious of the fact that it's only after his death that the composer aspect of him began to be treated seriously, in terms of the the written stuff... There's that issue of the Leonardo Music Journal called "Composers Inside Electronics", which coincided with a symposium marking the donation of his archive to the Getty in LA (Collins , Ed.). That's where you'll see a nice overview of the different periods...

Ezra Teboul: Do you know about the Little Bits kits?

**Nicolas Collins**: Yes

**Ezra Teboul**: Korg has a series of synthesizer based ones...

**Nicolas Collins**: I've seen a number of those things developed over the years... Radio Shack even tried a few times to make some of those lego-y things to teach electronics. Since my kids were really into lego, I tried to show them that, the Mindstorm things too... But my kids never latched on to that, and I never invested much time into using these for artistic experimentation... I think it's all quite good - here's my take, getting back to this idea of because you can do it, should you - we all tend to loathe ourselves and the group we represent, so I'm always very conscious about promoting ourselves and the ideas... I have this weird reputation as the hardware guy. If you read about me 15 years, I'd have this weird reputation as the computer guy. These things change. But am I weary of people setting camps."I'm not going to use unless I make it myself" or"I'm not going to use it unless it's linux" or that kind of statement... but I do

think that one of the great virtues of learning to program or learning to work with hardware is that we get a better understanding of the technologies that our lives are ruled by, across all domains. My father's generation was one that tinkered. He was a college professor, for christ's sake. He'd build a bookshelf, not go to ikea - we didn't have ikea back then. If the car fucked up, he'd try to fix, whether or not he actually could. It was assumed you would open the hood and check the oil, and make sure the cables weren't frayed, and you' try to second guess your mechanic.

I tell people how the first time I was in Europe in the mid 70's, I was in Germany and I saw that all the driving schools has these models of cars, cutaway models of car with this cross-section of the transmission and everything! Like the visible

fish. I learned later that to get a driver's license in Germany at that time, you had to answer questions on the written test about how a car works. Not just what this sign means, but also explain how a carburetor works...

**Ezra Teboul**: which is what HAM radio tests are today...

**Nicolas Collins**: True. Trevor Pinch edited a really nice companion to sound studies (Pinch and Bijsterveld, 2011) . It includes a really beautiful essay on German... in Germany in the 30's, there was this emphasis on diagnostic listening. You would be taught to listen to the engine of the car to pinpoint defects. My father's generation, they'd be taught to replace the tap washer when it would drip. The idea was that the technology was open. Even if you didn't understand what was happening, people would open the hood. People do not open the hood anymore. One of the things that happens in my workshops that is ultimately the best takeaway, is that there's always someone that comes up and mentions that dreadful word, "empowering". They may never touch a circuit again, they may have done this because they thought it'd be fun, or because their boyfriend was doing it or something like that, but they say it was the first time ever

opening a radio or this or that. It's the first time they'd ever touch their part.

**Ezra Teboul**: Do you feel like there's more than intuitive connections between this long- standing practice of opening things up for music and the more recent open-source movement?

**Nicolas Collins**: I think it's very unlikely that an obscure music fringe had an influence... I do think that there are certain social trends or zeitgeist that have a long nose, rather than a long tail. A long nose, where you sort or see these signs of a build up. Take something like the Arduino, which has a very strong presence in the DIY community now - it's a very good universal tool. As I say, you can look at proto-Arduinos that have been produced since the late 80s, but it had to hit a

certain price point. Just like circuit bending took off because there was a shift in cultural consciousness, there was a broader acceptance that you didn't need to know what you're doing. My generation, even though we were terrible engineers, we really tried to understand what we were doing. The only reason we would do something interesting is because we didn't [understand what we were doing], but we tried really hard. When the benders came around, the whole idea was "don't tell me how this work". I have this quote in my book, one of the first things that happened: I was setting up on a little table for one of the workshops and this mountain man comes up and asks "are these bent or hacked?" So I ask him what the difference is and he says "oh, um, bending means you have no idea what you're doing when you open it up, and hacking means you have a little bit of an idea." Then I thought, from an ecclesiastical standpoint, that's kind of interesting. So we had that ground shift, and it was the same thing with programming. I remember when we first started with microcontrollers it was like "this is going to be hard, we have to learn how to do this, we have to learn how to do that". And my students discovered that no, all you have to say is I want to control the speed of a motor, all you have to do is search motor speed control Arduino, you get a chunk

of code, you cut and paste. So that is amazing.

I think there is still an issue, which could potentially be called a problem, which is what we might call the preset idea. When the DX7 came out, it had such an amazing timbral palette, compared to most other things. 98% of the users never got beyond the presets on the front panel. There were many, and they were very rich. Except they were finite in number, and after a while you could pick them out in pop songs. The algorithm for FM synthesis has a certain sound to it, but some people did remarkable stuff to it, really differentiated it from the presets on the front panel. The problem with bending is that in a way it's a bit like presets. In other words, we are now on the speak and spell preset or the Casio preset - and you can identify them. With the cut and paste approach to code, it can lead to something similar, which is that module of code, which you didn't end up tweaking very much because it did a good job... now something like motor speed control is pretty utilitarian, but there are other aspects. But you look at other languages, Supercollider, Max MSP - those are very open as to what they can do. But both languages, Max in particular, come with all these modules, these objects, that are very powerful but also quite recognizable. There was a period of several years where I could identify a max patch just by hearing it. It mostly had to with the sample playback stuff that Max did very easily. It was another boon to people who were starting out, but it was a sort of presetting.

So this is potentially a danger with the app market. It takes a very powerful programming environment, and it generates one patch, so to speak. If you develop it yourself, you'll spend some time tweaking this and that, then you can use it in 3 or 4 different pieces and it's adapted. When its an app, it sort of sits there begging you to use it and have it be your instrument.

**Ezra Teboul**: For me there's sort of two origins for presets: the community at large, the programmers - those are the tutorials, example patches that are built in and

the cycling 74 website - then there's the patch your friend made next to you. I think the distinction is important and interesting, for how those two communities work together. How do both communities influence your work? How important have other people been in the development of your work.

**Nicolas Collins**: It's a mix. Statistically, the students of the workshops have been more influential than known individuals. With one or two exceptions. In the early days of the workshop, I had this vocabulary of techniques that were chosen because they were relatively easy to do, inexpensive, and most importantly they did things that computers couldn't do easily. I wasn't trying to do stuff... I was trying to match a market need. It wasn't a Moog synthesizer and it wasn't a computer. Along the way, the assortment of project and the tweaking and tuning of them was very much influenced by the feedback I'd get from people. The other thing is, people suggested stuff. There was this guy, John Bowers. A computer science professor, and he's also done really interesting low end electronic stuff. He was the one who showed me this business of the making a speaker into an oscillator with just a battery. He called it the victorian synthesizer. He brought it up when we were doing a workshop on loudspeakers and all the things you could do with them. Now this is a standard part of the workshop I do - it teaches you so many things, you can get it going instantly... But I look around and... I sort of see what people are doing. It feeds back in. But my general instinct is that I get more from general feedback from the participants.

**Ezra Teboul**: so this is the side of the community that you feel is more influential than your peers?

**Nicolas Collins**: yeah... maybe just because there's so many more of them... maybe it's because they're younger, and they have a keener insight into what's changing. I'm always looking for the next thing. Starting about 5 years ago, I saw this interesting, incredibly low level electronics. I see this sort of arc, which is best represented in

Korea. There's an awesome scene in Seoul. It's Dotolim and Balloon & Needle project. Otomo Yoshihide comes to Seoul, and it's like this catalyst for this sort of noise. And you see this evolution: lets start a band, then lets add the effects, then it gets noisier and noisier, and then they say lets disconnect the instruments and use only the effects. You go from Otomo to Japan Noise... then you get to the point where they say lets open up the effects, lets see what's inside, lets do a piece with just the one transistor we pulled out from the pedal... let's just do something with dirty contacts. It's this funny kind of arc that's represented very well in the Korean scene. I've seen this post- effect pedal stuff happen. It's really interesting.

**Ezra Teboul**: How do approach limitations in your work? Have proprietary tools and designs or planned obsolescence affected you?

**Nicolas Collins**: The notion that if you pick up an object, whether its a violin or a chip, it has certain limitations built in to it, that would impose a method for using them?

**Ezra Teboul**: Throwing back to the notion of presets we were discussing earlier.

**Nicolas Collins**: That might be why, as I say... I for one try to avoid defining myself by a medium... like computer music or hardware hacking or chamber music or improvisation. I'm sure there are people who are happy being in such a niche. I like string quartets or I like piano music or I write for Jazz bands... But my personal interest is to seek out different resources and work within the confine of those. If you look at my background, there he was with Lucier, sort of experimental music, electronic scene in the 70's, then in NY in the 80's, working with improvisers and downtown bands, then in Europe in the 90's, working with chamber ensembles, now in Chicago, in the boondocks, teaching at an arts school, and he's created this whole cult of workshop based hardware practice. Each one of those has provided its own benefits and limitations. But I think that's something that's ubiquitous to art practice. I don't think it has

to do with a time... it's always been the case. I'm only saying this because in art school I'm very conscious of the fact that these days you have very few students who define themselves in terms of medium. Few people say "I'm a video artist", "I'm a sculptor"... they say"I'm an artist". And then " I also do some video and some other stuff and I draw and I've done a print edition". The only people that define themselves by medium these days are painters. Painters still do that. And not all of them, but that's where you get the highest concentration of self-identified students within a medium. Next question!

**Ezra Teboul**: Is personalization of electronic music instruments just a set of decisions con- cerning which limitations are acceptable?

**Nicolas Collins**: Yeah... I think people sometimes have different ways of defining what's an instrument. But from the classical era to the the rock and roll era people said "I'm a violinist" or "I'm a pianist". The conductor was the oddball, but people who made music defined themselves in terms of their instruments. What happens is now, post-electric guitar, the instrument has expanded. Is an electric guitar just a string and a neck? or does it have an amp ? How do you relate to the amp? Oh, you use a pedal. Is it a fuzz, and overdrive? Suddenly you're performing in this network of technologies. Then as I said with my Korean friends you disconnect the guitar, you only play the pedals... there's the transition. I think that it's more difficult now to localize yourself as an instrumentalist. Then you fall into this thing of realizing that an electric guitar is an incredibly versatile instrument. It's been used in so many styles of music. Nobody ever says "oh my god not another electric guitar"... well they do, but not in the same way they say "oh, a wah-wah pedal...?" or "a vocoder?". If you call yourself a wah-wah pedal-er, it seems... much more limited. And maybe it's that preset thing again. It's got such a limited range, it doesn't cross that threshold of expressiveness. That being said you have people that have made a point of working within that. People like Toshi Nakamura and the no input mixing scene. Some of that is incredibly limited... or

Sachiko M's early stuff with samplers, where she only played with sine waves, the test tone in her sampler.

**Ezra Teboul**: Hannah Perner Wilson's MIT master's thesis discussed making basic components from scratch. She defines the advantages of such a practice as the opportunity for personalization, a better chance for transparency, and the importance of skill transfer. Any thoughts on this?

**Nicolas Collins**: I'm doing an advance hacking course this year, so I'm in that right now. We're doing sophisticated designs, but also stuff like baking our own piezo-electric crystals, so we're going in both directions. We're doing stuff by making various parts with kitchen chemicals. It's very good in terms of understanding the material however usually what you make is not as good as what you can get commercially. So it's much more of a learning experience than something that makes sense from a product standpoint. If you haven't, you should read a book called The Toaster Project, by an english design student named Thomas Thwaites who decided to build a toaster from scratch to see how the industry actually worked (Thwaites, 2011). Hammer pennies to draw wire and everything like that. It's an exercise in how the economy of scale works these days. You can do beautiful performance things where you draw and use the graphite as part of a circuit... I've had students who've done this, I have students who've done etching and used the scrapings of the burring on the metal as a conductor for a sound performance. In some cases it makes for a very beautiful performance medium, but I think with very few exceptions, to build these as substitute for commercial ones doesn't make much sense. Build a wearable circuit because you want to interact with it, not because you want to put a wool resistor inside your Moog ladder filter.

**Ezra Teboul**: Going back to the community aspect a little bit, who do you feel like Handmade Electronic Music has influenced the most: artists or engineers, academics or self-learners?

**Nicolas Collins**: Fortunately for my publisher, all of the above. I thought they were crazy to put the book out when they took it. But... because I didn't think any academic would buy it. and it was an academic press. But I knew that there was nothing on the market for this sort of grassroots community, and all the people who were asking me to do workshops could buy it. And then I could stop doing workshops - well, its fanned the flame of workshops, but I think it was very well timed because there was always a need for a practical guide for the community of builders. But the viral history of experimental music that's in it and all those sidebars - there's 150 artists referenced in that book. That made it incredibly attractive for academics. It was being used in music schools, in art schools, it seems to have had a really widespread impact than I thought it would. More power to the book.

**Ezra Teboul**: Who is this book, and more generally devices like Arduino and tinkering practices empowering the most?

**Nicolas Collins**: I think the biggest change is for non-academics. That's the impact of the web. There's a very large base of people who do not need the base of the academic environment for their education. The web is for a lot of things bad, and its use as a formal educational tool is I think deeply flawed, but as an informal tool, its amazing. When I was learning circuitry, you'd get a xerox of a xerox of xerox of a circuit that got from Tudor to your hands through 5 other people. Some stuff might have as well come from the soviet union. Now, even before people spoke of open source, the early web was about people giving away information for free. I think that was critical. I'd like to see statistics - I'm guessing more Arduinos are sold to freelance artists and tinkerers than to universities for the arts and technology...

**Ezra Teboul**: Where do you see the successors of your book?

**Nicolas Collins**: I've really been waiting for another book to come out. I'm working on my own other book.

**Ezra Teboul**: you might be your own successor.

**Nicolas Collins**: I hope not, I'm really dragging my heels on this one. There was the exploratorium book last year. I haven't seen it yet but it's supposed to be quite nice. Sort of stuff with conductive ink, pushing new materials. Make magazine comes in and out of the periphery of my perception, but i don't know if they've gotten into anything major in terms of that market. They pay a lot of attention toward Arduino, Raspberry Pi, Beagleboard... That's where the main area of attention for books is right now. It's a more bookable subject, and it's one that does tie in a strong academic community.

**Ezra Teboul**: so do you see this being more a book than online resources?

**Nicolas Collins**: I think it's going to take both forms. The textbook market is still strong, whether it's paper or an ebook. It's going to be bookish. My next thing is going to be a cookbook. I wanted to flip the tables and have lots of hackers contribute designs in multiple categories, instead of just me. Instead of an oscillator circuit, it'll be an oscillator circuit "by Ezra". Then you'll give reasons why you did it the way you did it, instead of just giving out stock designs. That'll be coupled with analytical essays about the DIY movement from a sociological standpoint, and interviews with or essays by major figures in the scene, to give it a little weight.

**Ezra Teboul**: In that sense, how has a knowledge of avant-garde traditions oriented your hardware work?

**Nicolas Collins**: In the sense that I could never get a job with a legitimate designer- All my stuff is directed towards these bizarre applications that I had. The buddy I'm staying with, the guitarist Robert Poss from Band of Susans, in exchange for staying in his studio, I always bring him some circuit or I repair something. He was the one who

steered me in more practical directions - so I've been doing this basically since we were in college. I'm hyper-specialized in all of my skills. My composition skills, my playing skills, my hardware skills, my computer skills... I'm not a generalist in any way. But I've been doing these things for long enough that I can squeeze them in a direction that serves a more general public. I will say that one of things that was really important for me in the book was making it ideologically neutral. I wanted to be able to have a techno producer and a circuit bender and a sculptor sitting side by side not feeling like anyone of them was being doctrines. Now, as you go through the book, and the workshop, the level of the sort of the notion of experimentalism as a neutral topic becomes very high. It's not about rogue procedure, it is about finding your own path through it. the point is although you can see that as an avant-garde trait, most people realize it is applicable in whatever field they are in. The techno producer needs to get a better drum sample that separates him out from the other people and maybe this contact mic is the solution. The sculptor knows nothing about music, but realizes that this malfunctioning circuit that buzzes works well with whatever she's working on at the moment. It's a non-threatening form of experimentalism. When you listen to the book's audio tracks, clearly they come from an experimental vein, not a piece of pop music on there. I'm sure most people don't listen to those. The videos are different, because they're so goofy, they're like having your own youtube channel. Even if you don't like cats, you'll look at the little funny kitten video. Even if you don't like David Tudor, you'll watch a 40 second recording of Rainforest by a three year old with a camera in his hand.

**Ezra Teboul**: Is there an engineer's music? Do engineers come to your talks?

**Nicolas Collins**: I once had an engineer come to a workshop I did. He was the least competent person in the workshop, I was flabbergasted. When I knew he was an engineer, he said, "but this is the first time I've ever touched an electronic component. I got a BSEE using CAD systems, I've designed a digital signal processor, it's the first

time I've soldered". There used to be an engineer's music. In the day of synthesizers... Most of this is stuff you'd never hear. It was literally made by the engineers. In computer music in particular there are people that are much more technicians than composers, but it's a fine, fuzzier distinction. I think in a way you can look at the music that comes out of circuit bending as, if not engineer's music, luthier's music. If Bob Moog made a record, would that be an engineer's music or a luthier's music.

**Ezra Teboul**: Do you think creating instruments and creating music are converging practices?

**Nicolas Collins**: Well, yes! That's the thing... there's not so much written on it... but back in the 70s as I was saying, there's this real nervousness on the part of post-Cage composers about being treated seriously as composers. Most of them very much disliked the word improvisation. They used things like "open music" or open form score.

**Ezra Teboul**: In the same sense that Cage disliked the term experimental?

**Nicolas Collins**: Not quite, he disliked improvisation but advocated for experimentalism. Those musicians didn't mind improvisation, but they wanted to be thought of as composers, not improvisers. My generation comes around and says "who cares, we can do all this stuff. It's not so critical". But I was very aware that it was replaced by the question of are you an instrument maker or a composer, when you make a circuit? Tudor's thing was composing inside electronics. You build the circuit that is the piece. He was very adamant about that. But those of us who worked with him, we had our doubts. Did I build an instrument, or have I built a piece. That was critical.

The same exists when you write a software patch. You can do things in Max and Supercollider that you think are a composition, then you eventually realize it's more like an instrument, I could give this to somebody else and they'd make a new composition

with it.

I have this one piece, “Devil’s Music” (Collins, 2009a,b). It existed as an array of cheap hardware samplers in the 80s... live radio sampling, very successful piece. I made a soft- ware version at the end of the 90s, and started distributing and having performances of the piece. With DJs doing it on their laptops, sometime with me sometimes without. Although it was really an instrument, it was so limited in terms of what it did that no matter who ran the piece, no matter what their aesthetic was when they decided to play it and pick their samples, it always sounded like “Devil’s Music”. You could always tell it was that composition. It was like wow, there I succeeded... but that was the exception to the rule.

That idea of are you an instrument maker, or a composer, or a performer... And you didn’t even the whole can of worms that is Sound Art. Let’s not go there.

Western Culture has these sort of strange distinctions: composer, musicians, interpreters, improvisers... there’s a lot of culture when honestly it doesn’t matter. You build the flute with the reed at the bank of the river because you’re bored watching the sheep, and you play something based on what your grandmother used to sing. When I was at Wesleyan, there was a guy studying Gamelan, and he said “you can listen to a piece of music from 1500 and a piece of gamelan music from 1950, and you can’t tell the difference between the two of them.” This was during the heyday of Cagieanisms. There’s no idea of innovation there like we have. That’s a different western thing.

## A.3 Transcript for interview with Dan Snazelle

This interview was conducted in person in Queens, NY on February 8th, 2015.

**Ezra Teboul**: Would you like to introduce yourself?

**Dan Snazelle**: I'm Dan Snazelle, I run Snazzy FX.

**Ezra Teboul**: What's your design background?

**Dan Snazelle**: I'm self taught, with the aid of forums, lots of books. You can see I collect those. The typical starting point for a lot of people is Electronotes. I bought the whole package early on. I was an audio engineer, working freelance all over manhattan and the burroughs. I would just put up an ad, once a week, and there was a list 2 pages long of all the things I could do. Paid the bills for a few years, but it was really hard work because you'd get two hours in one burrough, then 2 hours in Staten Island, and everyone wants to do it right after work. Long story short, I rebought the Prophet 600 i used when I was a kid, and I wanted a nice poly - this was 2007 - but I realized that with my current job, and having kids, I would never be able to save up for something more than that. and that really upset me.

My family had gone out of town for a week, so I went to an electronics store and got $200 worth of parts. Found a schematic online, learned to read it, soldered it up, it worked. It's actually this thing (pulls out cookie tin with collection of controls and wires spewing out), it's got all these lovely pots on. It worked. You can even see the lovely inside (typical first project wire insanity).

I just kept building little synth things. over time, I made this (points at older modular synth rack under the desk). It's not really any format... closer to frac? I just started building my own stuff. This is really ugly (still pointing at the modular rack,

missing a few modules and dusty with hand painted labels) but it still works to this day.

**Ezra Teboul**: When did the shift to making synths for other people happen?

**Dan Snazelle**: The Audio Arc. There's videos of it online. It's huge. It's 19 inches accross by maybe 6 units tall. 60 controls on it. All because of this guy Charles Lindsey, who later helped me out with Snazzy FX. I had played a show in Brooklyn, and he'd seen the things I built - in plastic tubs or whatever. One of my friends knew him and told me that he wanted to commission me for a custom thing. I'd never sold anything before, I was just doing it for fun. But I said, yeah ok that's cool, what do you want?

So we drew up this little box. It turned into this massive thing that took a year to finish. I was building it in my bedroom, my wife was pregnant with my second child. She kept saying that if it wasn't done by the time he arrived, the thing would be going to the trash. She was angry, because it was in our bedroom. But when that was done, Charlie got that - it still works today. Really neat synth. It doesn't need any cables, but it has lots of patching through rotaries and stuff. He plays electric cello, does a lot with found and ambient sounds. He's also a really great photographer. He wanted to do a lot of different things. The Mini Arc (picks up half-finished pedal from the floor), it was one of my first pedals. It does pitch to CV kind of stuff, a tracker. It tracks very fast. He wanted that, he wanted it to be able to filter things... He wanted a lot. What I worked out for the tracking - someone saw it at his house one day and said oh we should get this guy to start a company! That guy was never involved, but one thing led to another, long story. Charlie came to me and said why don't you start a company? I was still mainly making music. A lot of music. Always been a musician. But what I was doing with studio work was never really going to go anywhere or be different. Working here and there. I worked hard and I like it, but it wasn't art. With this (picks up the mini arc) - there were three boxes (collects all the enclosures from various places around him) -

they're huge, and very heavy. If you look at how big the board is, it's large...

Everything with those is on purpose. The layouts are not grids. Everything about them is thought out. The colors are bright, that one glows in the dark. That took forever to get them to make it right. Saying it can't be done. These were everything I wanted to do, in a box. I did it. I figured, if I'm going to make a company, I'm going to have it be what I wanted to buy. I never had much money. If I was going to buy something, it would have to be perfect.

**Ezra Teboul**: Do you still use these first pedals in your music?

**Dan Snazelle**: Of Course! Certainly. I still own one of each. Two are in the shop, the first one works. It's funny, I get emails everyday from people who want to buy them. They've been sold out for years. I'm coming out with a tiny version of this one (points to the purple one). The Wow and Flutter is a eurorack module - right here (points at the module). But I'm bringing out 2-3 stompboxes this spring. One of them, the divine hammer - the prototype is right here (points at enclosure)... But anyways, I had these, and I'd been doing synth stuff, in bands... starting a company would just be easier with pedals. Euro [short for the modular synthesizer format name Eurorack] was not a household name like today.

This one has CV out, this one has CV in, this one you can play a guitar into it. If you take the sync out, you can drive your VCO. It's pretty neat. So I sort of fell into having a company. I had to catch up really quickly. Look at the insides (of the first, big pedal, which he's holding). There's a lot of circuitry involved. 3-4 boards. Imagine doing that (the Audio Arc) if you've only been doing electronics for a year... You either do it or you fail. You catch up, you learn as you go along, as much as you can.

By the time I got to the pedals, it was still a ton of work, but I knew where I was going. This one (the yellow pedal) is based on that (pointing at the audio arc). Hence

the name. The pedal has the tracking circuit from the audio arc.

**Ezra Teboul**: How much of your circuits are your own designs?

**Dan Snazelle**: I don't make clones.

**Ezra Teboul**: So 100% of your designs are yours?

**Dan Snazelle**: Analog electronics today are rarely entirely new. You're always dealing with the same blocks and fundamentals. When I design something, I try to make something new - that's really important to me. The Tracer city (one of the Snazzy FX products) is *just* a filter box. It's filter with CV, etc. but I try to do it in my own way. I guess I try to think on a systems level, with things like that? Same with the Tidal Wave (another module). It might be that there isn't anything new about a filter, or an oscillator, but how you approach it, and how you structure it... and presenting, especially the interface? The musicality of something... I'm very interested in. I've been playing guitar for 29, 30 years. I've been making music my whole life. I was a musician, still am... but I don't approach things from an engineering standpoint, but I ask myself how is this going to function as an instrument, how is someone going to use this in their music? Early on, that meant how am I going to use it? With the audio arc, I wondered how Charlie was going to use it. Thinking of the end goal is important. Coming up with a panel first. Things like specs, or signal to noise ratios, little details like that? I don't want to sound bad, but I want it to be used to make music.

**Ezra Teboul**: Did you ever read the Buchla interviews where he discusses the difference between instruments and tools?

**Dan Snazelle**: No... it's a topic I talked about yesterday. People seem to say that Moogs are more musical because they have a keyboard. I'm not trying to start a debate. At NAAM, something I heard a lot, just with modulars in general, is that these are those mad scientist toys. Or people come up and say I bet you annoy the neighbours with

these! Because it doesn't look like a keyboard, or a tuba, or a guitar... it has to make a racket. You can make beautiful music with these. You can also make horrible music. It's whatever you want. With the stompboxes, whatever I'm involved in, I want to know the heritage, and I have a lot of respect for the old stuff, to try and meet some of the older people, especially while I still can, that's really important. But those guys were looking forward. They weren't saying well the hammond organ did this, so lets take this... they were really looking to how we're going to use these instruments. very open ended. It still can be very open ended, nothing has to be set in stone. I'm not really a digital guy, but the Ardcore did allow me to explore some other areas, with Darwin. I think it's neat how digital is utilized right now. I'm more an analog guy, and I'll stay in this direction, because there's so many areas to explore.

**Ezra Teboul**: In relation to that, you mostly have analog hardware?

**Dan Snazelle**: Yes. Digital, especially the ardcore, when I saw what Darwing was doing with it, I thought it'd be great to bring this power to people. However, it still ultimately spits out analog.

But sometimes the distinction between analog and digital is clear, like with a wavetable oscillator. Or even menus. Functions. For me, I have the most to offer in analog. That's why I got into this. I'm not knocking digital. Some of the stuff out there is great. But I got into this because I wanted more analog in my life. There's a real attraction because to me, it's more intuitive, I know more what's going on. Especially something like the chaotic attractors. It's an organic system. It's happening on the circuit board. It's not a simulation. I feel like there's an insect in the room, it's really neat to me.

I like the magic of electronics. I know its not Magic, but I like the aura of it. When I was a kid I used to play with these radioshack kits, that had a bunch of springs.

They'd come with a manual with a 100 projects that said connect this wire to this thing. It was electronic blocks, and you'd make a bird sound, or a motorcycle sound. As a kid, that blew my mind! Connect wires, and get something. I like that, still. Anyways. More of an analog person.

Out of all the people selling digital synthesis products, you're the first one to try and incorporate the Arduino in a commercial eurorack format. It makes sense to me that you and Darwin Grosse, who's part of Cycling 74, would be responsible for that. What's the place of digital as control and lo-fi synthesis tools?

The Ardcore is a system. I learned C from Darwin's original sketchs. He'd made 15-20, well documented. I bought a book or two on C and Arduino or AVR. He said I could help him debug these, study the comments, copy and paste... a lot of the functions are already laid out. I spent a whole year on the ardcore. It was really exciting, it's a really great system. It makes me really happy when people write for it. People have done some amazing things. It was the right thing, it made sense, and I got excited. There was no drive for a digital product. It's open source - other music AVR systems were closed source. So I got excited and made it work. And the responses are good! It was a really neat project.

It was also a real *project*. Trying to do something that's new or exciting.

**Ezra Teboul**: What are the parallels between your roles as artist, engineer and designer?

**Dan Snazelle**: I've been making music for 30 years. Synths, for maybe 10? Snazzy FX started around 6 years ago. Not that long. The parallels are strong though. It's a lot like writing an album - as an album. These days, songs are more individual pieces. But when you thing about album, and you'd think about how to approach it as a whole... I used to be in this band called Building. Everything we did was not conceptual

art, but it was really thought out, from the sounds to how the listener would take it in. I played guitar, bass, string and horn arrangements... most of the music. I don't have a classical background, but I had my weird way: write everything on guitar, then sit with the string players. I would write everything with a 4 track. That's the advanced technology we had when I was a freshman. That kind of thinking about things, pouring over every little detail, how your audience is going to be impacted by it, that's exactly how I think about design.

I think of Snazzy FX as an art project. It's my art. These (points to his products) were a statement. The original website was very conceptual. I want everything to fit and work as a statement. We have a section online called allies - it's stuff we think is cool, and I think that's sort of how I approach the products too. The thing that makes me most excited, and that makes me know I'm doing my job, is when people write to me and say "this product is making write music differently" or "I'm thinking about music differently because of this thing". In that respect its a lot like writing music. The design aspect too is really intuitive. Spending months and months researching and looking into an area and then pouring that all out at the breadboard or the simulators. Writing the product.

**Ezra Teboul**: Do you use simulators?

**Dan Snazelle**: Not so much. There's a couple realtime ones for the ipad that are fun when you're on the subway. The wavefolder - the Tidal Wave, my own design - came about in icircuit... it's a java app. I haven't messed around with SPICE too much. I don't put that much time in the simulators. They're still novelty to me. When I designed that wavefolder, I got really excited, printed the circuit from the simulator, said "this is going to make design so much faster!". But that's not what happened. I took that to the breadboard, and it worked like it was supposed to. But because it was on a screen, and I couldn't really interact with it, once on the breadboard so many other things happened

and I spent almost a year on that thing. Became a lot more than a wavefolder.

But I know a lot of people have used them. I'm still very hands on, breadboard kind of person though. I like being at the bench. I always listen, I always have a speaker on. That's the problem with simulators, at least the ones I use. You can't listen. If you hear it, you're putting a sine wave through it and you hear how it changes, but you're not actually making music with it.

**Ezra Teboul**: What do you think of the distinction between musician and engineer or fabricator in cases where the design of an instrument is integral to the development of a musical piece?

**Dan Snazelle**: I kind of view it as a different medium. In high school I really like video, and then synthesizers... you find different mediums and then as you're presented more technology you try different things. Sculpture, painting, pen and ink... having these tools at my disposal is just another way to explore and create. I'm in a position where it ended up as a company, but in my mind I'm a company that makes sense to me and I believe in. I probably would be just as happy getting grants and doing research in an academic environment and doing stuff for art shows. It just sort of happened one way.

**Ezra Teboul**: You're making analog, real-time systems for composition of performances. That comes with a history and expectations, limitations... how aware of these are you?

**Dan Snazelle**: I guess the ardcore is a good example. You have limitations from the 8 bit DAC. How fast can we get this chip to go? I'm really happy how the routine for the DAC came out. Even for the drums, it sounds really good for 8 bit. But in general, analog - or pure analog - yes, the rails are +/-12V, no high voltages, but... there's a wide wide range of stuff to do there, and I don't feel too limited. Sometimes parts, especially

through-hole parts, things get obsoleted all the time. In the past I've seen more than a handful of parts I've used are no longer available. I use SMT for manufacturing but I use through-hole for design and prototyping. It can be a little scary. Analog isn't going anywhere, it's always going to be needed to transfer the digital to the analog world... but if the part doesn't sell enough, they get rid of it. That's one limitation. In analog, you never know what's going to be taken off the market. When I started making synths I wasn't really set on a format, I just cut a piece of metal and sticking it in a rack. I think some of my old modules are +/- 15V. But anyway, for me modular is such a great format. It's so open and encouraging experimentation. My original thinking was that you could really put stuff out there that's different. Whether or not that's true is something you can debate, but I think it is. It also wasn't such a sure thing back then. There was MakeNoise and there was Harvestman and there was Bubblesound... some americans manufacturers. But now it's everyday, I just saw someone released 13 modules. It's crazy how many companies are jumping into it now.

**Ezra Teboul**: What do you think of Synthrotek selling everything as a kit?

**Dan Snazelle**: I actually stayed in a house with him at NAAM. Kits were one of the ways... well not the whole kit, but I used to get circuit boards from ken stone, and electromusic, ian fritz, people like that. 4ms sells kits too. I think kits are great for people who want to get involved. not everybody wants to learn how to go all the way, but they also want to be involved in soldering and making stuff. It's great. I'm actually thinking about getting some to build with my kids. I wouldn't want to be making kits though, I'm so disorganized - putting little parts in bags sounds like a nightmare.

Ian seems like he has a thriving business, and he's doing a service to people... they seem to be reasonably priced, too.

**Ezra Teboul**: They are! I think that's one of their great things. What do you think

about the fact they share all their schematics and designs? Is that something you would do if you didn't have to bag all the parts for kits?

**Dan Snazelle**: Yes and no, it depends on the project. Some of the things I've spent a year developing, no. I'm being honest. People don't put that in the equation. If you've spent a lot of time on these things, not opening a book and taking things straight out of it, you're developing things. I've thought about putting the miniarc out as a kit, or as something... I've wanted to post a few more schematics. I've put a few over the years. The problem for me is all my schematics are hand drawn, and even if the schematic can be useful to somebody, if its hand made, people will complain, and that made me think "nevermind...". So yes and no. I know Ian Fritz wasn't too happy at one point because he designed a new type of through zero filter, and shared the schematic, and somebody turned it around and made it into a product. Wasn't happy. Another Eurorack company started selling it, and luckily the community sort of policed that. People said hey this isn't cool, why are you doing this? But especially now, when Euro's getting so darn competitive, it actually feels competitive! It's amazing, it always had this real community feel to it, but a lot of bigger companies are jumping in, and a lot more of potentially people looking over each other's shoulders.

But most of us in the community we share stuff all the time. We trade part sources, help with designs. Mark Verbos is one of my good friends, and David runs bubblesound, and he's staying here... there's a lot of helping. I don't know if that's going to change as the market evolves. NAAM was weird this year.

**Ezra Teboul**: Too many people?

**Dan Snazelle**: not even that. just a lot of big companies getting in. Dave Smith, Sequential Circuits, there's talk that more and more people are jumping in, and those people aren't going to be in it just for the love. They're going to be in to make money.

You'd be amazed to see how many of us don't approach this with a money first attitude. I just want to pay my bills and make cool suff. My products are not designed to sell a million units, obviously...

**Ezra Teboul**: How have proprietary tools and designs affected your work? (35:49)

**Dan Snazelle**: Probably not too much. The audio arc, for example, had an SSM40 filter chip in it. That's a filter chip you cannot get anymore. It's hard to find. Schematics aren't available... the patent is, but not the schematic. So that was case were going from the hobby level, one at a time, to manufacturing, you do have to make those choices. It hasn't been much of an issue for me, I usually try to go as discrete as possible. Maybe not always the transistor level, but I would never make a product that uses an all in one chip. Even if it means more parts, if you can do it with some that are going to be around for 20 years, you're much better off.

But you know, I think this is something that the internet has changed for so many people. If you talk to engineers from the old days, they'll tell you information was scarce. But that was good, it made them come up with solution they couldn't have had otherwise. I think that when everything is available, we assume that to be the case, and then you find out "oh they're not going to share the schematic, what am I going to do?" that can actually be the best blessing possible, because you have to come with a different solution. Most of what you need to find, you will find. There's not really any specfic reason why you need to know exactly why I do something in a box. You can find most of the general stuff out there. I think that people starting electronics nowadays have it real good. It seems like more and more people are even starting out doing hobby stuff with SMT. and if you do that, you're in great shape because mot things are still available in that format.

But the short answer is it didn't affect me.

**Ezra Teboul**: You talked about planned obsolescence, how does that work within your designs?

**Dan Snazelle**: Euro is made to last a long time. That's what's specific about this market, and stompboxes too. We're nto building this stuff the break. It's meant to last a long time. A lot of the newer laws in Europe about how something is supposed to be recycled (38:58) are interesting because we don't see these as things to just be thrown out. If you look at vintage synthesizers, right here, there are three that are really old. '79, '82, early 80s, late 70s, they all still work. With the exception of my sequential circuits, which does use oscillator chips, you could open them and repair them. The Yamaha, half of that thing is metal, it'll take a beating. I want my stuff to be life that. I want kids 20 years from now collecting it.

**Ezra Teboul**: opening it up, fixing a part.

**Dan Snazelle**: yes, exactly. And as I make these, that's something I've become more aware of. Making sure that parts are going to be around. And most of my associates who make stuff make it really well too.

**Ezra Teboul**: Could SMT be viewed as a hinderance for people trying to open up your products in the future and fix or mod it?

**Dan Snazelle**: it's a hindrance for me! I mean, yes and no. That's one of the thing about this planned obsolescence thing, large companies have made the assumption that since it's so small and tiny no one is going to fix it anyways. It'll just get thrown out. But I see SMT more and more, and even in kits. Turn the board over and all the parts are right there.

Anything anyone has to do is send the thing to me. That's the first thing. Not that many of them come back for repairs, they don't break that often. When they do, they could take it to a friend who knew electronics to repair it. I think it's not more of an

issue than it would be with...

**Ezra Teboul**: Through hole components?

**Dan Snazelle**: Even if this was through hole, they wouldn't be able to know what was doing what... they'd still have to ask me. On the whole, there's a lot more people that are willing to find that stuff out. There's more kit people and nerds in Euro than there are in any other market place or industry. I sort of assume they'll figure it out. I still deal with repairs, even on these.

**Ezra Teboul**: How important have other people been in the development of modules?

**Dan Snazelle**: The first thing is the forums. I mentioned electro-music. I wasn't so into muffwiggler back then, but it's great for people now. That sort of community, to learn about electronics, or even part sourcing, there's a forum called the mostly modular trade association, the mmta. It's for dealers and manufacturers to trade information. That wasn't there when I started, but it's a resource now.

Back then, it was also Dave, who runs bubblesound, and Mark Verbos, who runs verbos sound, they were local. He heard about a company, then I would hear about it. Everybody was pretty forthcoming. Bill from WMD, he'd say "oh you guys have extra of these, yeah we can sell you some of those". So there was a good exchange. I never felt like anyone would refuse me anything. It was hard in the beginning though. Finding someone to do PCB stuffing, contract manufacturing... That's probably easier now. I had to learn the hard way on some stuff...

There's more Euro centric manufacturers now. I don't mean people designing the boards, I mean people stuffing the boards, testing them.

**Ezra Teboul**: you get your modules stuffed and tested?

**Dan Snazelle**: I get the boards populated. I have kids, I don't want my house to be a factory. I'm also the type of person that feels like I don't need to have my hand in the manufacturing at all times. I'm much happier about design than I am about soldering 100 boards. And the community was really helpful in that process. There weren't as many dealers, but Sean from Analogue Haven was extremely helpful with a lot of people. The community has been exceptional, a lot of people helping each other out.

**Ezra Teboul**: how is it today? do you teach newcomers how to get boards stuffed and finding distributors?

**Dan Snazelle**: Just last summer, a new company was making the transition to euro, and they got my number, so gave them my sources and said "yeah, go here for metal, there for this, try this guy". I'm not sure I would share that with larger companies. Control, the dealership? Is a perfect example. It's a hub. You're there to buy something, but you'll run into another designer, or someone who just bought your module, or they'll tell you "someone was just asking about you", it's great!

When I do a talk there, everyone brings beer or has beer, it's really nice. I love that I know my dealers on a first name basis. I've made a lot of good friends, and I want to encourage that as much as I can. I think things will change. But it's been great. The spirit I was treated with in the beginning with some of older guys like Ian Fritz and others from my generation - I want to keep that going. But I'm also really busy, so I do what I can.

**Ezra Teboul**: Do you feel like there are multiple levels of community? I feel like there's the greater online platforms, people who speak the same language as you, then there's the friends and the people close to you...

**Dan Snazelle**: There might even be more than three levels. When I go to NAAM,

or knobcon, or even CVfair, we have our own thing here every year. Those are people I see once or twice a year. Dan from 4ms, or Scott from harvestman... excited to see them, there's a bond there. And then there's the local community, people who I see a lot. My company attracts people like this... there's a level of education from people in arts and people in science that are reaching out to me and saying "look, here's what I'm doing, your stuff is relevant". You could call that people in the scholar community, or people in the crazy art community, but they're reaching out to me, sometimes for no other reason than establishing contact. That's really nice. It's not just where to get knobs, or how to fix that, it's about talking about ideas.

**Ezra Teboul**: How was working with Darwin from C'74?

**Dan Snazelle**: It was great. We're still in touch a good amount. He interviewed me for his podcast. He was going to write a manual for the telephone game, because he noticed I was just sending text files to people. He said maybe I'll make you one. He gets one of every module, we still talk and I see him at NAAM sometimes, he's awesome. It was really fun working with him. I like this exchange of ideas, as I'm a bit of a hermit. I'm a family man, I work all the time, I don't have a lot of time to go out and socialize. When I do get to exchange ideas, it's important. Ideas are where the products come from. What takes the most time is working through the conceptual parts. That's why I get so many books.

**Ezra Teboul**: how close do you feel to avant garde or experimental music?

**Dan Snazelle**: Do I like weird avant garde music? Yes. Is that the question?

**Ezra Teboul**: Rather, how close do you feel to the people in that milieu?

**Dan Snazelle**: I have mixed feelings about this. Some of the music I make is extremely poppy. Not sugarcoated, but it's songwriting. Structure, melodies, etc. But then I've also done a lot of experimental. But I don't tend more towards one or the other,

I think that my initial work with modular encouraged me more to go in the experimental direction, because I like how free form and in the moment it could be. The people who do whacky stuff was a big base of people using this stuff and encouraging it, but I think that one of the problems there is it obscures the fact that other people can use too.

That's why I try to champion both. Obviously my stuff is pretty weird. A lot of people make the mistake that you can't do anything else with a modular. That not true, I've used it live, the telephone game was developed working with a live drummer. Trying to do something that could improvised structure stuff with multiple melody lines that were related. I love experimental music, and I encourage it. The stuff I make so that it's powerful for all types of music. Euro's at a point right now where because there's so many manufacturers and dealers, it won't continue with just people doing experimental stuff. The most important thing right now to keep developping it is to tell everyone hat they can use it. It's like clay, you can use Eurorack for anything. People see wires everywhere and they think this is a mad scientist thing.

**Ezra Teboul**: You were mentioning Nicolas Collins. How close do you feel to circuit benders and reusing electronics? I think this really speaks to that openness in synthesizer making...

**Dan Snazelle**: I feel close to it in that that's where I got my start. There's multiple levels of circuit bending: some people don't want to know what's happening in their electronics. They don't want to know what's going on. I'm different. I want to learn and understand as much about electronics as I can. I love that stuff. At the same time, his book is a great example of trying to open this field up to anyone. I think that in the very beginning.

**Dan Snazelle**: I also made stuff like Crackleboxes (picks it up). The battery might be dead (box turns on, makes sounds). This is in the middle. You've gotta solder

it, look at a schematic, etc. but it approaches a lot of the circuit bent sound. For me, modular became so exciting because of generative stuff, because of the organic system of modules that can create music on its own. You can guide it, or it guides you, but there's an interaction going on. I'm not determining every event, point A to point B... I'm going to turn it on, and set something up, and something's going to come out. If you do it right, or if you do it wrong, it can keep going and going. Those unexpected possibilities, for a musician, that's gold. Having things you can improvise on, on be inspired by, or have it be going in the background, as part of your environment, that's what's exciting to me. I didn't get that so much with bending stuff.

but bending did have the excitement of getting your hands dirty and learning a bit, and jumping into it. Some people are perfectly happy with that, that's great.

I wanted to go as far as I could. In ten years, I hope the stuff I'm doing will be even more toward that weird goal of making these systems that are designed to do that weird stuff. That's not to say you can't use them for any other thing. The telephone game module, if you haven't spent time with it, I works great with the chaotic modules. that's my sequencer. You have some control over how it comes out, but it can do 4-5 melodic lines at once and works great with chaos.

**Ezra Teboul**: Have you been doing more custom or comission works?

**Dan Snazelle**: Yes, I have one right here! This is a new attractor I discovered, using an inductor. And I'm making something for someone up in Berkley, as well. A chaos thing. This first divine hammer is for a customer. So yes. I don't have much time, but I do do it. I've been getting these custom made wooden boxes, from a friend... I have some customers who seem like they buy everything I'll make. Sometimes I just have to pay rent. Right now, I'm just waiting for the Tidal Wave module to ship, until it does, there's no money coming in, and money needs to come in. So that's a chance

to make something custom for someone. I'll contact a few people, and usually they'll say yeah, sure, how much is it? That's great, it gives me a chance to try things. This is one of my goals for the next year, I don't know if I'll have time for it, but I want to do smaller runs, maybe 20 instead of 200. I'll be able to do stuff that's more out there, and will appeal to a specific type of person but not everybody.

If I can pull it off and get the manufacturing right, it'll be great. It's a lot more work. When I make something custom, I'm very perfectionist, it's never a rapid process. I feel bad - this custom divine hammer has had 4 circuit boards in it. I'll make it, say no this isn't right... email the guy and say sorry... it's going to take a while longer.

The custom stuff is fun. There's way more ideas than time to get the stuff out. I have a lot of stacked up ideas, hopefully in the next couple of year this stuff will start coming out.

**Ezra Teboul**: any last comments?

**Dan Snazelle**: I always tell people, don't be scare of my stuff!

## A.4 Transcript for interview with Tristan Shone

This interview was conducted over the phone on February 13th, 2015.

**Tristan Shone**: I've gone full circle: engineering, punk bands, metal bands, back to art school, away from engineering, did some rough and tumble sculpture that was not very satisfying, then I came back into music because it's much more natural for me and I've become a musician at heart. Back to doing engineering to make the money and balance off the touring. Everything's just kind of a big clusterfuck right now, trying to manage a musical endeavor, with trying to get back to really doing instrument design.So much of my life is taken up by booking and promotion, running a business as a band but also balance new design and art grants... there's a lot of logistical crap that seems to take most of my time. Which is maybe not as interesting for your thesis.

**Ezra Teboul**: can you develop your background a little bit more?

**Tristan Shone**: I don't really have any composition experience, other than I'm a trained piano player, and I learned to play guitar, so I could play in metal bands. That's where I came out of college, interested in Robotics and control systems. That's what I did as an undergrad at RPI in Troy NY. I was playing in thrash metal and apocalyptic doom bands from the mid / late 90s, neurosis, melvins, godflesh... also some drum and bass, electronics... while being in my classes, and working on stuff like electric cars, at RPI, I was helping with that, and assisting some professors and learning mechatronics... I think I realized I didn't want to go to grad school for engineering because... I really liked the gadgets and I liked mechanical engineering, and I loved theory of control systems and robotics but it was a bit too much. Not as interesting as physically making things work. I liked machining and fabrication, so I went and got a job in a clean room. This was during the telecom boom, around 2000. You could make a good salary out

of school. So I said screw it and went to design these automated systems for testing MEMS - micro electro mechanical systems. Semiconductor based machines. Other people would etch these out of silicon, and craft these little machine that would basically switch fiber optic lights. I would make these setups with x-y-z mechanisms that would test them... It was a bit dry. Being in the clean room after being in a college band and touring... College life to working in a clean room with really high level scientists was not really my thing. I did a few years of it, switching around to a few different companies, and playing in a band in town that never really went anywhere but also... I found some companies I liked to work for. There was also a professor at RPI I worked for, an art professor called Chris Csikszentmihályi. He's a media artist, he was at MIT's media lab, and I sort of helped him while he was there designin some parts for his installations, travelling with him a couple of times. I went to Finland, met a lot of people in the media art world, kind of introduced me to what you could do with sculpture and mechanical sculpture, microcontrollers before the Arduino... They're easy to use now, you don't have to compile 70 files and set environmental variables on your computer... we were using those... devices that he had developed while at MIT. That's most of my engineering before grad school. Going back was as much a decision for my carreer, wanting to work with art, as it was wanting to leave corporate america and having nothing to do with it.

**Ezra Teboul**: where did you go for your art program?

**Tristan Shone**: I went to UCSD. Which is also where that guy Chris Csikszentmihályi went, one of the guys in the Yes Men was there. Who else was there... Barbara Kruger, Jean Pierre Gorin... Lev Manovich... Good professors, and a very tech oriented school. That's where I work today, in the neuroscience department. We do imaging microscopy, and I work on all the automation, with a bunch of biologists and physicists who come up with ways of doing things.

**Ezra Teboul**: were you familiar with all of RPI's experimental music aspect?

**Tristan Shone**: Yeah, I was somewhat involved in that. That professor I worked for was in that... I think that the music department was pretty small at that time. Then they built that giant building, EMPAC. I'm in touch with some people there, we tried to get a performance there, and it never happened...

**Ezra Teboul**: Can you talk a little about the connection between metalworking and metal music? There's something very physical about both processes...

**Tristan Shone**: At the beginning, when I was building... there's different angles. I started building speakers in grad school with a friend of mine who was coming from rave culture. I was playing metal and buying these kind of guitar center amps, heads, speakers... you buy this keyboard, then this stupid little piece of shit... clamp-on thing for your keyboard stand... thin wall metal that's been welded, and it breaks... I just got to this point where I realized that all... anything you buy at guitar center or musician's friend is a piece of shit. Any pedal you'd buy was a piece of junk. I started to replace... just simple things, like if I needed a sustain pedal, I would go to an army navy store and just buy one that actually had gears in it you could oil, instead of having a plastic rack and pinion gear. That was the main component, that was the weakes link. Everything like that, I decided that I would just make myself. I had three year of time where I was just going to be in the welding shop. So I got rid of my Mesa Boogie Dual Rectifier head, cause its got that tread plate face on, but to me the aluminum tread plate was just fake-strong. That's the way I looked at it. It was basically just a way for metal dudes, who drive big trucks that are actually plastic to look tough. I said oh, I can actually apply the research lab mentality and make stuff out of real materials. It just so happens that I'm into metal and we'd listen to drum and bass because the guy I was working with was a big dubstep and drum and bass guy, in 2004. There was just something about making things... none of that steampunk mentality, where you would make something

with the appearance that it was something that it wasn't, and also not adding... A lot of people when they look at my machines they say ooooh, you just did that for looks. No, you can ask me about any component on what I did and why I did it. It all has function. That, to me, getting back to metal and heavy music actually really is. I also think that there's an issue with some of this stuff... you still have to write songs, and write music, and there's a point in time where you just have to... I started getting ahead of myself, building too much stuff and not actually learning how to play them properly and really having a connection with the materials afterwards. That's where I'm at now, just trying to compose.

**Ezra Teboul**: An interesting thing you've mentioned is the variety of technologies you've delt with: vacuum tube amps, solid state microcontrollers, your laptop as main synthesis engine... Is it about being practical for you?

**Tristan Shone**: that's a point of contention. In the art world, the tendency is towards analog electronics, because people want to make something that makes sound, the thing that you're moving is rubbing on something else... you plug it in, and it doesn't need a computer. For a lot of people, that's purity. I think that's why people like modular synthesizers. And for me, I agree. But at the same time, the most important thing for me, when I was conceptualizing these instruments, was that I was making something that felt right, that was the one to one connection with the sound. What does this bass sound sound like, how does it feel in your hand. With the small experiments with analog circuitry I did, making some of those circuits myself, I just wasn't getting what I wanted. I really wanted something... the sounds coming off of my laptop, I can sample something, tweak it...It's the difference for me between some of the metal guitar distortions that you can buy or the electronic bass tones that you can get that I was much more interested in. They hit you in the chest much harder. That was something I could do on the laptop, and I could make one interface that could control any sound I wanted.

So I gave up on the analog purity pretty early on.

**Ezra Teboul**: The result is what matters.

**Tristan Shone**: Yeah. I have seen... most of the time when I see people do stuff with modular synths now, it's a lot of bleep blops. It doesn't necessarily have the... there's a lot of experimentation while you're coming up with sounds, and that fine, it is what it is.

**Ezra Teboul**: Last week I interviewed Dan Snazelle from Snazzy FX, which is a company that sells eurorack modules. One of their products is the ardcore, which is a multipurpose module with an Arduino in it. He worked with Darwin Grosse from Cycling '74 to design the best way to use a microcontroller platform in a module, with a USB connector on the front panel for people to upload their sketches. They have a small online community to share the various uses and implementations people come up with. That seems to be where the two niches meet?

**Tristan Shone**: Yeah...

**Ezra Teboul**: For a genre as irreverent as noise and metal, there seems to be not that much experimentation with the medium.

**Tristan Shone**: Being involved in this kind of industrial world... although in the last few years I have been getting into more of a music industry than I have in the past, working with musically inclined people at theaters and clubs, you have to trim down your setup, be on stage the second out of four bands. My desire is to have everything giant, welded, setup that's as strong as it could possibly be. I've had to make sacrifices to be able to fold something up. So I have to buy some of that crap every once in a while, and that pisses me off. But for something like industrial, the genre is a total farce. I've played some of these festivals. it's dudes in leather, that isn't even real leather, and they're playing instruments that are just the most plastic thing you've ever seen and it's

all premade beats, and they're mostly pressing play. There's nothing industrial about that at all. There's nothing primal about it. And maybe we just need to redefine a new genre for something that actually takes effort and is composed live and has bring some emotion back in it. And I do see some people doing this now in the noise genre... but anyway. I'm sorry, I only talk shit about the industrial genre because it's so new to me, I was never a fan of it, now to be a little bit involved in it, it's a very frustrating world. It's so fashion based... so much drama, just seems so far from what down to earth music is for me. Being involved in the music industry is very frustrating. With respect to the machines: I'm really interested in textures, and materials. I have so many ideas for new instruments, but they're so expensive and I'm recording and traveling... hopefully this summer I'll be able to work on a few. But really in my mind there's just very simple things: a shaft of really shiny hardened bearing steel, maybe a piece of brass self lubricating as it slides on there... I want to be able to feel the interaction between those two materials. Being able to make that connection between those two things is all I want from an instrument. But then you know, of course, I've got to encode the motion, and fit it inside a case, and make it light enough to take overseas. So you start with this interaction of materials for a motion and it expands out into whats possible. That can be a big thing: traveling, having plugs...

One of the biggest problems for me recently is reliability. USB cables are a big problem. Wireless connections, or using industrial connectors helps make sure they withstand the test of time.

**Ezra Teboul**: Have you considered some wireless Arduino platforms?

**Tristan Shone**: I've done some wireless shield, I guess I haven't done bluetooth...

**Ezra Teboul**: One thing that I thought about when you were talking about industrial music is noise music communities. One example is the community described

in Japanoise, perhaps it complements what you saw in that community? They take all cheaper pieces of gear, blow it out, misuse it... There's a little bit of the original spirit of the noise and industrial genres in that... do you feel closer to them than to the festival industrial crowd?

**Tristan Shone**: You mean hackers ?

**Ezra Teboul**: by extension, I think. Hackers, circuit benders. People who try to go beyond what is bought.

**Tristan Shone**: I definitely don't feel like a hacker. I definitely appreciate the risk that they put into what they do... not everyone's going to design their own shit. I can't expect everyone to fabricate their own stuff. That's when hacking comes around, you don't necessarily have to know electronics, you just need to be creative. I really appreciate that. There's also so much risk! You're making a one of kind object that's going to be up on stage as part of a festival, and you don't have a backup. No nice rack in the back where your tech can plug the duplicate in if the other one fail.

There's a lot of risk involved, I don't feel like a hacker. I think the scene I relato to the most is this metal/stoner/doom, jut on a note of that, there's a real sense of respect of quality, craft amps made with baltic birch, better speaker drivers, discussion on how to get the best tube amp, and they understand how it works. I just know people in Portland designing their own pedals, really crafting this fine. There's this simplicity in the design (27:34). I wouldn't say I want to go back into that world of guitar, but everything's played live, there's improvisation... That's where I'm coming from. The controllerism, sequencing, grids in Ableton... I have a few sequences I play every once in a while but that world, there's not a lot of room for failure. It's all synced up, you play combinations... doesn't have the motion or the power some of the live rock stuff has.

When I think about what I'm doing, people think oh it's robotic, futuristic. To me its not futuristic, it's very organic. I'm basically trying to be a one man band that plays live music. I'm trying to play electronic music efficiently, live, without sequences. That's the whole reason I built this stuff. It wasn't because I wanted to be robocop on stage... Maybe I should've made it less flashy. I like stainless steel and aluminum. You'd be surprised the number of people who want me to make this stuff more visually ridiculous. I don't want to. "oh you should have this spider thing that comes around". And it's tempting, I could be more popular, find some stupid tv show... but in the end I want someone to stand in the back of the room and not even see what I'm doing and say oh this is good music.

You see the gimmicks that people do. I already feel too gimmicky as it is.

**Ezra Teboul**: can you talk a bit about the development of your drone machines, then the dub machines?

**Tristan Shone**: the dub machines, and now I'm making these masks. The drone machines were the first ones. They were about simple rotations; force feedback. Making sounds that would be couple with rotational or linear motion that were heavy sounds that followed the profile of the weight versus... momentum? If you spin the disc that I have with a rotary encoder, and you slow it down with your hand you have this natural decceleration. If you plotted the speed over time you could see, because of the weight, you have a sound profile that's very natural. If it were plastic you'd have more of a linear pattern. If speed is pitch, plastic would be "eeeeeooooo" versus the heavy steel is "heeeeeewooooooooooooo". Or I can keep the speed, since is has a nice bearing in there, at a constant velocity, to keep the pitch going... I call them drone machines because they made much slower, drony music. The album was one thing, but when I would do it live at festivals, it'd be much more droney and more improvised.

But the big problem with those is that they're really heavy. I couldn't take them anywhere. I couldn't go overseas. I also wanted to play faster music, so I came up with this setup where each machine had to be 50 pounds, with their case, for flights, so that changed things from being steel to aluminum, and then I didn't use ball bearings, I'd use teflon coated linear shafts, which aren't quite as nice but work well and are super light. Things like that. Spending a lot of time on which case to buy. That was a much more compact design, and I could just sit at a chair with everything around me and move my limbs. Then the masks... I found I used my voice as my main music making device because it always available to me. My hands are doing things. The head mic is just constanly developing into different things. I can use it as more of a midi controller, blow into different mics and trigger, but lately I've just been using it as if I scream in the middle of it different parts combine. I'm basically just using this one big mic with different effects. Then the new machines, which are these masks, are still in development honestly. Much more meant for acoustic settings, in a gallery with no amplification. They seal my face and I can do things with my voice using them. A tremolo, opening and closing the valves... I have this throat mic, essentially a world war 2 communication they'd use in tanks - you can speak very quietly and you'd hear it. It works great! I use it all the time. That thing is on my neck the whole show. I have effects with it and I control the bass tones...

**Ezra Teboul**: Is there a clear divide between using the mic as a controller versus a source of sounds?

**Tristan Shone**: Actual audio vs midi? If you couple them together, for example I run my throat audio with some effects, then I can pick up the pitch of that and control a synth with it. So I can control a bass synth by just rumbling my throat. It's amazing, you can control the subwoofers just with your throat. I never really choose. I mute and unmute those channels quite often as things develop. I think it's nice when it gets

beyond formulaic. Sometimes you don't even know exactly how a sound happened. That's why I like music and art a bit more than engineering sometimes, I could be doing something terrible to the sound system but having it sound great - now I need to figure out why its terrible and how to fix that without losing the sound...

**Ezra Teboul**: I did want to develop the composition aspect of your work. How does the engineering and music processes work together? Is it an exchange between both?

**Tristan Shone**: There's a sound, in my head. For example this mask I'm working on, I've been composing these songs that I am using them on, and I had all of them in my head when I went to write them. But then when I went to record them, they weren't as palatable as I'd hoped. So the people who helped produce the album wouldn't include them. It was just too harsh. I thought it would combine better, but it doesn't. It's much more organic. So I'm working through the limitations... The way my body's working with the solenoids, the valves, the air pistons... they're slamming into my face, which is something I didn't expect... It's really harsh and I can't play the pieces I wanted to, so I'm re-writing those. And that's a nice accident, because this whole process is taking longer but it'll have a better effect.

The limitations of what you do, design, what you think it's going to feel like and what actually happens when you play it, those are dfferent realities.

There's different rhythms. Tonal ideas I'll have as I'm walking around designing things in the machine shop... when I go to work, then I'm at home, constantly thinking about that and what it should sound like. I don't really write the songs until the machines are done.

**Ezra Teboul**: Do composing and designing instrument ever become part of one more unified process?

**Tristan Shone**: I definitely think I'm more a musician and an artist. There's something exact about what I do, but what I like the most is the accidents and the free form nature of what I'm doing. I use the engineering to achieve the goals I want for my music. I'm not making products, I'm not trying to think about having other people play this. It's come up before, the idea of me making products and things like that, I tried... thought about it... it takes the fun out of it for me, to go to conferences and show people. Market stuff, take that weird quality that you put in your instrument that you only understand and make that adaptable for someone else's interest. It doesn't seem interesting to me. I had one instrument, the idea was that I was grabbing onto someone else's ears and screaming into their face. So if I grabbed on to the microphone, that's it meant to me, to use that instrument. How do you make that marketable? A product? There's a weird connection to your instruments that makes you feel powerful, for yourself. I think it's much more art at this point, not product. Engineering is product.

**Ezra Teboul**: Buchla described himself as a designer of instruments for a niche market, rather than a builder of tools.

**Tristan Shone**: Also, there's just no money in musical instruments. My time is better spent making stuff for me to play. If someone steals it and does a shitty plastic product, that's fine...

**Ezra Teboul**: How important is the engineering side of your community? I've seen videos where you work with CAD-CAM tools, which are infamous for their proprietary nature. In parallel, the DIY analog synth world is very much about sharing ideas to make good sounds. Do you feel like you're part of any larger effort?

**Tristan Shone**: I don't feel like I'm in a community. I have had people help me, anything I need to do in Arduino, ableton, max for live... I couldn't do it without forums and calarts students, or friends I have who do similar stuff. So I need that

world. But at the same time I use solidworks, I use it at work, I'm not going to go use some open source equivalent just because it's free, or because I want to build that community. I just don't have... I've tried teaching, I've given workshops on how to do this stuff, i'm not too good at it. It's just not one of my goals. It's hard enough using this weird combination of tools and getting a grip on it. Getting access to CNC machines is extremely hard, I can't be picky. I bought a cnc router to make speakers, redid the controller on it, the motors, built a vacuum table... good experience, but I sold it for about what it cost me, I'd rather have a cnc mill at this point. I value that community, because we wouldn't be able to do what we do without it.

I know there are free cad tools, but I'm good at solidworks and I get it for free from my work. There's also some elements of software for live that I'm very weary of, and I do spend money on ableton, not really using pd... some of the people that tour a lot, like myself, have to be able to rely on their equipment. Even Max for Live, I've completely removed from my setup because it crashes. A lot of people use it, its great for development. I have some very useful things I've written on it, but it just doesn't work live for me. The amount its crashed... The people who use pd for live... they say how can you use ableton, etc. You go play 25 shows in a row, with your pd setup. I'd like to see it work.

**Ezra Teboul**: It's a big obstacle in making live electronic music cheaper and easier for everyone. The free things isn't always reliable.

**Tristan Shone**: I'm just trying to make music. I have no purist aspect, other than playing everything live. Anything I have to do for that is ok. If I have to get funding from the North Korean dictatorship, I'd do it. I'd take corporate sponsorship, too. I've done it with Lenovo.

**Ezra Teboul**: You've mentioned you've done some teaching... do you also help people with projects if they're similar with your work?

**Tristan Shone**: I taught a class at UCSD, on music theory and production, more on the software side. That was fun, teaching people how to make beats. I've done workshops on 3D fabrication... Anyone sending me an email asking what do you use, as long as I'm not giving away secrets on how I get my sounds, I'll help people get the Arduino setup going, the HIDUINO stuff, most of my stuff comes from other people.

**Ezra Teboul**: Hiduino?

**Tristan Shone**: it's an alternate firmware for the Arduino, it turns an UNO into a USB class compliant piece of hardware that's recognized by Ableton. I don't need USB to serial conversion.

There's definitely people doing much more complicated technical things. I don't do any sequencing, I don't use any drum machines. I just hit the drums, live. It's basically like there is a button for each drum. Sometime I'll loop something, that I've played live, play over it for a few bars...

It's simple stuff. The key of what I find valuable in what i do is just making physical devices that feel good, that are strong, and that just have good interface designs in my opinion.

**Ezra Teboul**: Do you document this process for yourself?

**Tristan Shone**: I comment my code and save that... The code isn't long or complicated, and it's not necessarily that good, so I don't want people to give me shit and read it and use it... But I have put up some stuff through Make Magazine and Wire that's available, for some things... People could email. I haven't had that happen much, probably because there are the people out there that I got it from, so readily available

- making a midi controller with your Arduino, it's simple. There are other devices like the raspberry Pi, the Beaglebone... I'm interested in using them, I just haven't had the need yet. One element of what we do now in the live setup is I'm working with a video artist who uses VDMX, which is a semi open source software for programming lights and video, we take all my audio and midi and we send it out to him in the back at the front of house. He has my sounds directly control the sounds and the video. That's nice, it's very live, he has a hand in it as well...

**Ezra Teboul**: what's the name of the person you collaborate with?

**Tristan Shone**: Will Michaelson - he goes under the alias cutmod. You'll see it on youtube. He's way more on the psychedelic side, for his stuff. But when we work together... you'll see in the videos.

**Ezra Teboul**: does it complement your performative elements? Or are you trying to obscure your instruments, even if they're sculptural?

**Tristan Shone**: We started by having cameras on my stuff, projecting that. The instruments are interesting to people, but for me they're instruments. Like I'm playing a guitar, or the synthesizer. Showing off the instruments is ok, but it only works for so long. Then it becomes the whole thing, the gimmicky instruments. I wanted to go past that, just good music. The ideas and the motions, the abstract behind what I'm playing are images of life. Film, ideas... they don't necessarily have anything to do with tech. How long do I want to geek out on the tech? Right now that's probably the most successfull thing I can do, shoving the tech down their mouths, but there's so much more to it for me. None of my songs are about anything technica, or mech. e. or robotic, or futuristic. Doom, apocalypse, death of the planet...

**Ezra Teboul**: it sounds great.

**Tristan Shone**: I know that's what a lot of people just like. they come out for one show, then they say they were hoping for more electro " I listen to Skrillex"...

## A.5 Email exchange transcript for Louise and Ben Hinz

This interview was conducted over email. Replies were received on March 5th, 2015.

**Ezra Teboul**: Would you like to start by briefly introducing how you worked your way to musical electronics?

**Louise Hinz**: Ben (aen) really wanted to be able to use effects pedals in his own music but we were broke back then (around 2005 or 2006) and couldn't afford to buy them. At that time, there were just a few boutique builders and Devi turned out to be really supportive and helpful.

We bought about $40 worth of parts, a soldering iron and a book on hardware hacking. He had no background in electronics at all (I think he was working delivering pizza or some other shit job). He just kept reading and trying stuff out until he understood it.

Devi was the one who recommended our pedals to our first few dealers and she was instrumental in answering questions about design and marketing in the beginning. We officially started Dwarfcraft Devices in 2007 in our basement, with Ben building at night when our kids were sleeping.

Now we work with two other engineers to get pedals out a bit faster that will push the boundaries (they do the PCB layouts and digital programming).

**Ezra Teboul**: what are your musical interests and training?

**Ben Hinz**: Louise was trained in classical and jazz in high school and college, playing the upright bass. I'm self taught, which goes a long way to explain my "style." We're both sort of "bass heads" interest-wise, which is why we really focus on all our gear sounding good with low-end instruments. It's a very important part of a band for

us. In my case an otherwise great band will be written off if the bass isn't there. But we aren't narrow in our musical interests.

**Ezra Teboul**: do you see any parallels between designing a circuit and playing guitar?

**Ben Hinz**: Not really. One is a task with an end goal and a required outcome. Playing music is freedom, love, and life.

**Ezra Teboul**: both of the companies you're involved with are popular in the pedal market. What made you go from basement experimenters to a business, and how did that influence your circuit design work?

**Ben Hinz**: I was in need of new sounds, and I didn't have money to buy any pedals, so I began experimenting with modifying really cheap gear, but soon after I learned some basic building blocks of audio electronics and started down my own path. Some friends online heard the terrible demos I made and I sold a few that way. Analogue Haven and 9Volt (from Japan), where the first dealers to buy our stuff.

Some of my early work came from using components incorrectly to get weird sounds that were not available elsewhere, which is still really important to us. We decided a few years ago that if we couldn't do something new and interesting that we loved, we wouldn't do it at all.

**Ezra Teboul**: The Pitch Grinder is your first commercially available digital product. How was that foray into software / hardware combinations, and what prompted you to do that?

**Ben Hinz**: Digital is the future. It's also the now. Most of the ideas I currently have could only be realized digitally. I think there are tons of great analog circuits, and I will use them forever, but for me I'm much more interested in pursuing digital audio

processing. We got started on the Pitchgrinder when I was introduced to Bob Lowe, an engineer here in Eau Claire. I threw a boatload of ideas at him, and we kind of sussed out what was doable from there.

**Ezra Teboul**: how traditionalist is your customer base?

**Ben Hinz**: I don't think, on the whole, our customers are very traditional. I'm sure we sell some of our more "normal" stuff to more "normal" people here and there, but most of our customers are on the fringe. When we asked for song submissions a while back there was a ton of stoner/doom tracks, some noise, and some really trashy, noisy pop stuff.

**Ezra Teboul**: Does that conflict with your musical interests?

**Ben Hinz**: Not really. We are pretty eclectic at the shop. Sometimes all I want is Tom Petty, some days it's Roni Size, some days it's Monolake. The older I get, the less genre specific I get. I try not to rule anything out before hearing it. One of our henchman has us listen to the new releases every day. Like, all of them. Usually we just talk shit on everything, but it got me up to speed with FKA Twigs, which is not categorized in a genre I usually look into.

**Ezra Teboul**: Dan Snazelle was mentioning that Eurorack has become more popular than when he started Snazzy FX. How did you come to start selling modules, and was it a significant shift from pedals?

**Ben Hinz**: I have wanted to do modules forever, I was just kind of waiting to make some time to learn how! I really love that instrument/system, so I'm just glad to be a little part of the Machine.

There is a pretty exclusive attitude, and some really picky motherfuckers in that scene, much more than the rock type circles I tend to run in. So I'm making an "Intro

to modular synthesis" video series, to make other folks' entry easier than mine. Lots of it is beautifully complex, but I would much rather the scene be more inclusive and welcoming.

**Ezra Teboul**: modules also put you one step closer to experimental / avant garde /contemporary classical music. Any opinions?

**Ben Hinz**: I don't agree that any one instrumentation gets you closer to experimentation or avant garde. I think that is a cop out. Any instrument, especially one as open ended as the modular, does not put you in a genre or make you better at one thing than another. That is just humans being lazy and categorizing shit. Frankly, I'm better at that avant garde stuff when I use guitar gear.

**Ezra Teboul**: how do you approach limitations in hardware design?

**Ben Hinz**: Ugh, good question. Usually I ask for EVERYTHING. Then I see how many "Nos" and "Maybes" I get back from our engineers (myself included) and usually I try to figure out at least one of the "Nos" and often times we can cram in a couple "maybes" too. Better to go for it all and whittle it down than start small and realize what you could have done far better after the fucking thing is in stores. The same with recording, actually. "Can I put another drum track on there?" "Hell yeah, I already did 12 guitars, we'll whittle it down later."

**Ezra Teboul**: have proprietary tools / designs and planned obsolescence influenced your work?

**Ben Hinz**: Well, now that we can see some of our through hole components going out of production I'm pushing SMD builds from here on out, for the most part. We also have to figure out replacement parts for a few things coming up and redoing the boards for them. Not fun! Other than that, we just have to keep replacing our phones and computers, I guess.

We really aren't into the old, vintage parts mojo BS, so most of that misses us completely.

**Ezra Teboul**: Conversely, have you shared any of your designs / tricks / magic?

**Ben Hinz**: Not really, for the most part I just apply fairly common knowledge in unconventional ways, so I wouldn't really be blowing anyone's hair back. There isn't any magic here, just hard work and some weird brains working together. Some of our schematics are online, but to my knowledge, none of them are correct.

**Ezra Teboul**: how important have other people been in the technical aspect of your work?

**Ben Hinz**: Very important now. Early on, I did all of the designs myself and just paid someone else to lay out the PCB for us. The things we're working on at the moment are collaborative, but mostly they stem from my ideas, and I guide the design process. It's far better to hire someone who has the skills I don't, rather than try to master EVERYTHING, and end up losing my shit in the process. We have one full time "techinical" Henchman in the workshop, and Bob Lowe works in his own shop, on his own time.

**Ezra Teboul**: do you have any opinions or thoughts on your professional community?

**Ben Hinz**: Pretty much everybody I've met in the industry has been top shelf. Once you're in it, I feel like if you haven't got too bad of a mental disorder you can identify with everybody else in the trenches.

**Ezra Teboul**: have you helped beginners with design question like Devi did for you?

**Ben Hinz**: I don't recall going to Devi for design questions until I was trying to

build her stuff, which can be really confusing the first couple times. We asked her a LOT of business questions, though. She helped with finding dealers, pricing, finding the best prices on LEDs, boring stuff like that.

I don't recall really giving out any information on that subject either, other than "Oh yeah, that Pitchgrinder runs on a big PIC chip. You should try that!" Just some general shop talk here and there. We also recommend websites and a few books for people to research on their own. We don't really have time to train people in how to build and design. I also kind of hate when people ask questions that are easily searchable on the great wide internet.

**Ezra Teboul**: are there any philosophies or beliefs that seem important to you as you do this work?

**Ben Hinz**: "Pedal and Steer" and "Don't Scream, Do Something." "Pedal and Steer" comes from when we were teaching our kids to ride a bike. But it really applies to any task. (Pedal) put in the work. The raw energy. (Steer) Keep your eyes open and direct that energy. "Don't scream, Do something" also comes from raising the kids. When there's a problem, kids can seem to shut down and cry about it, and in their own way, plenty of adults do that, too. But usually, you need to shut the fuck up, pedal and steer. Of course those are the easiest and hardest things in the world, depending on the day.

## A.6 Email exchange transcript for Bonnie Jones

This interview was conducted over email. Replies were received on March 15th, 2015.

**Ezra Teboul**: Could you start by describing a little bit your delay  mic setup for performance  composition? How did it come to be, and how is it important in your work today?

**Bonnie Jones**: My current set up varies but usually I have the following possibilities:

3-4 delay pedals fed input to output and played by touching the back of the pedal with an instrument cable plugged into my mixing desk.

Samples bank accessed from a computer using a freeware theater cueing program Telephone pick up microphones used for electromagnetic sounds from computer or mixer Sometimes an assortment of antique or regular microphones for different "voices".

Transducers "exciters" for sending sounds into stationary objects that I usually find in the space – cardboard boxes, metal or plastic bowls, etc.

Two different types of contact microphones one is a regular cheap piezo and one is a higher quality piezo that is embedded in a block of wood to create an amplified surface.

Old Radio Shack (RIP) cassette tape recorder Shortwave radio – used for radio sampling and also for playing the digital delay pedals through.

The delay pedal is still one of my primary performance instruments – meaning if I had to play a gig with just one element of my set up – it would almost always be at least

one pedal. I could say that it's the one part of my set up that feels closest to a traditional instrument like a sax, or a violin or something. Though the other elements in a way create a larger modular instrument – the pedals do have a singularity and for the most part allow me a complete range of musical expression in any given music situation.

**Ezra Teboul**: What parallels do you draw between technical processes (like assembling that setup) and other disciplines or hobbies?

**Bonnie Jones**: I like to say that my set up came about like discovering a language written on a cave wall. As a musician I always approached playing as a way to understand the basic structure of that language as well as the process I can use to learn how to communicate with that language. I suppose the word that could be used is an intuitive approach to understanding the technical aspects of my instruments and their musical possibility.

In that way my instrument sometimes feels like a poem. My first creative discipline was writing, so I draw a lot of parallels there both in the instrument and also in my compositional ideas. I've always been really interested in what happens when the words speak for themselves in a poem, when they do things that you can't foresee, when one word placed next to another word become something that you can't determine. My goal then was to recognize that thing and then try to understand that thing. With my musical set up it's similar to that, I put different elements in tension with each other and they end up revealing to me a bit of their language.

**Ezra Teboul**: What level of complexity and indeterminacy do you look for in your electronic instruments?

**Bonnie Jones**: I like when an instrument is indeterminate but there is also a desire to be able to play something – so yes while the pedals have a certain level of indeterminacy – playing them for over a decade has really allowed me to understand

many of the ways to produce specific sounds. As for complexity – I use tools for the sounds they make vs the nature of their construction or code. I like getting to know an electronic instrument, and I appreciate when that instrument has some surprises or enables me to create and discover sounds that I wouldn't expect – but I wouldn't care if something was complex if I didn't like the way it sounded.

**Ezra Teboul**: How do you approach the use of new devices in your setup?

**Bonnie Jones**: I just throw them in the mix and see how they play. Sometimes I will introduce a new device, or object (rocks, bells, lights, etc.) without thinking about how I will use it in the concert, but including it on the table almost as a way for it to instruct me on how it might be used in the performance. I like having things on the table that aren't used – I like bringing outside objects to see what they might do when I'm in the middle of set, how I might decide to bring them into the music.

**Ezra Teboul**: How have proprietary designs, tools, and planned obsolescence affected your work?

**Bonnie Jones**: It's harder for me to get pedals with the kinds of circuit boards that make for good bending – design of these boards has really minimized the elements leaving much of the board sort of blank.

I usually work with freeware/shareware software and they are usually unsophisticated so I haven't yet run into the problem where my software doesn't do what I need for performance or requires any expensive upgrades etc. For performance I try to stay away from anything that might crash or misfire or require proprietary software. I had an experience in Oslo where right before a concert my computer stopped working. The entire piece was based on having these samples I had carefully composed to be used alongside live electronics. Because I was using all freeware and easily downloadable software, I was able to just switch to another computer and set it up for the performance.

It wasn't perfect of course but it was easier than other situations where the work is more dependent on expensive software etc.

**Ezra Teboul**: How has teaching audio electronics affected your creative interests?

**Bonnie Jones**: I take the approach where teaching and working with my nonprofit TECHNE is part of the continuum of my entire creative practice. It's been important and freeing to unbox the areas of my life that would seem disparate and try to get around the cause/effect/influence categorization. This isn't exactly what you're asking but I do think these days it's important to democratize aspects of what a creative life actually looks like. That said, I spend a lot more time these days putting my creative process into shareable language so that I can transfer that knowledge to students. It's tricky to explain how to do intuitive electronic music exploration. I never had to quantify it before and now I approach my practice with a different layer of explication always in the background. This has made me more interested in writing about music.

**Ezra Teboul**: In your experience, who does open source / affordable hardware empower the most in the arts?

**Bonnie Jones**: Easy access to free tools and cheap hardware plays a key role in bringing in new ideas and new perspectives from less visible artists. I love a lot of the art that is being created today, but sometimes I feel like it lacks imagination – it seems to come from a specific perspective/position and I am invested in finding ways to open that up. I still see DIY culture as pretty critical. Even in its co-opted and packaged state, being able to make shit with whatever is available to you is pure improvisation. I appreciate that and seek that out. Sure, as we get older and our art develops we want our vision to expand – and that requires more support – but we know that support gets doled out in strategic ways and often with strings visible and invisible. I still believe that the most radical shifts happen when artists without the benefit of institutional, financial, or

technological supports, just make things happen.

**Ezra Teboul**: Is there any recent technical development you're particularly excited about?

**Bonnie Jones**: I'm intrigued by ambisonics though I know very little about it aside from the lecture I went to in Stockholm at EMS.

**Ezra Teboul**: What is your current professional community? Do you feel close to it?

**Bonnie Jones**: I work with a lot of different writers, artists and musicians in the US, Europe, Asia, and elsewhere and it's amazing to be connected to so many different minds. Recently I've been drawn to working with activists and social /racial justice groups – I feel like that's closing an important loop for my own selfhood and art.

**Ezra Teboul**: Do you identify with hacking / bending / re-use / misuse of technology for the arts?

**Bonnie Jones**: Definitely – the technological arms race in the arts is tricky. Artist as R&D for technology corporations is a real thing. Subversion is still the place where those other voices can be heard.

**Ezra Teboul**: How close do you feel to avant-garde or experimental music traditions?

**Bonnie Jones**: A tricky question because even though I didn't study music in undergrad, my creative education outside of academia is still driven by an awareness of and direct influence from those historical canons – specifically the electronic musicians of the 50/60s, John Cage etal. My creative trajectory from an outsider's perspective would appear to be very linked to those musicians and artists, however I begin to feel more alienated from this history.The question I have these days is what does it mean to

be in dialogue with these artists? What's the relevance of these questions for someone like me – and by that I mean a women of color? And in a more critical way are the questions these artists were asking so specific to a person's race, privilege, and class that they will naturally exclude so many other vital questions. I'm a 37 year old artist who has been working with electronic music for decades and am still interested in finding historical role models who are asking questions that seem to relate to who I am, where I am, and my experience of the world. If we believe that we are not influenced by our artistic education we are lying to ourselves, if we believe our artistic education is the truth about value, relevancy and validity in art we are lying to ourselves.

**Ezra Teboul**: How has your awareness of those traditions influenced your hardware or text-based work?

**Bonnie Jones**: These things are important to me at this point – they may or may not be traced to historical art/philosophical antecedents "discovered" by the artists I've read about in art history books. The object has a life – the object pushes you and you push it. You can make things that you do not understand at all and maybe later you figure it out and maybe not Abstraction and improvisation is about hiding and revealing the self at the same time – because of that it is also about resistance I care about communication but there are so many ways to communicate and so many languages in which to do that.

I am deeply skeptical and suspicious of what is visible.

## A.7 Email exchange transcript for Martin Howse

This interview was conducted over email. Replies were received on March 18th, 2015.

**Ezra Teboul**: Could you start by describing a little bit your approach to installation / performance hardware? How did it come to be? What's the place of physical items in your work today?

**Martin Howse**: I think that my approach comes from an obsession with the material basis of digital and communications technology - an awareness that these are energetic processes which may be blackboxed, abstracted or plain invisible but which have a strange, dynamic materiality which cna be played with and investigated through hardware. So the approach is very much a revealing, either through re-working materials towards technology (for example, performances using earth as an active, electrochemical, biologic material), or dissecting and almost dissolving (in chemical sense) digital technology (in workshops), or devising software which examines its own material conditions (for example, Island2 installation). This approach perhaps came to be from early experiences with DIY computers in the 1980s, building bits and pieces, and programming in a very direct way (instruction by instruction, looking up operational codes in tables and writing these by hand before they would be input on a simple keypad). I have always been obsessed with this peculier place where code operates in the world, this strange, hidden place where something happens which can then become or is physical and audible. So physical items are very much present in my work today, self-made electronics and material combinations.

**Ezra Teboul**: Is your interdisciplinary practice (art, technology, teaching) meansto achieving a unique goal, or different ways to express thoughts and interests?

**Martin Howse**: These are different ways to express my interests; I don't think it

would be possible to enter into these conceptual concerns within one practice or discipline - for example I began working mostly within video and conceptual art and realized that technology was an important material concern for me; teaching as in workshops is a way of generating new ideas for myself and others.

**Ezra Teboul**: What level of complexity do you look for in your electronic instruments?

**Martin Howse**: I hardly ever use electronic instruments other than those I have built myself and some of these I have had huge problems in trying to reduce the complexity - this has been the hardest work, how to map a vast mind-set of connections and processes to a simple interface. Working with materials presents a simpler interface.

**Ezra Teboul**: how do you approach the use of new devices in your setup?

**Martin Howse**: I would say that new devices are suggested by the setup - the materials and concerns force new ways of thinking or doing things - for example, I started working with modulating sound in light very physically and from here I've been looking at crystal modulations of light, and devices which could bend or twist light.

**Ezra Teboul**: how have proprietary designs, tools, and planned obsolescence affected your work?

**Martin Howse**: Proprietary designs and tools have made things harder on a practical level. People share interesting things created using proprietary tools, under proprietary licenses and this clamps down knowledge and approached to certain problems. It feels stupid to limit aesthetic potentials and equally force people to re-invent. On the other hand, most proprietary work is not so interesting aesthetically, just through the mindset subscribed to. Planned obsolescence forces me to upgrade and waste time.

**Ezra Teboul**: What have the responses to the detektor and dark interpreter devices been?

**Martin Howse**: The detektor and dark interpreter are quite different devices, but the response to both has been interesting - a few people don't really understand the thinking behind them or how they worlk, but most have been very appreciative. I like the idea of these potentially mas produced devices as art works, as spreading some ideas and ways of working like a virus. I think they work in this way rather than as practical instruments.

**Ezra Teboul**: they are both hardware/software combinations. is that a practical decision?

**Martin Howse**: The detektor is purely hardware, so no software as it more or less directly translated electromagnetics into audio across two wideband frequency ranges. The Dark Interpreter is both as it is really close to this exploration of the material base and tangibility of code or software - I wanted the user to literally put their fingers into the code, to run the code over their skin.

**Ezra Teboul**: how important are other practitioners in the development of that work?

**Martin Howse**: The detektor is more based on others work, practically and also in development with Shintaro Miyazaki. There's also a whole community of artists and tinkerers working in that area so it is pretty important to look and work with others. For the Dark Interpreter this is pretty much a personal work and struggle!

**Ezra Teboul**: how has teaching affected your creative interests?

**Martin Howse**: A lot of the phenomena I work with, electromagnetics and say radioactivity have grown out of teaching and workshops; again, generating and sharing

ideas, growing interests.

**Ezra Teboul**: in your experience, who does open source / affordable hardware empower the most in the arts?

**Martin Howse**: I'm not so sure about empowering (particularly within the arts) as I'm uncertain hardware or software platforms really do this; rather the general approach is important. I think there are not so many artists empowered by open sources.

**Ezra Teboul**: Is there any recent technical development you're particularly excited about?

**Martin Howse**: I'm attracted to what could be achieved in a DIY sense within quantum computing. I'm more interested in what becomes accessible from within technical developments - I need to be able to make these technologies, to play with them.

**Ezra Teboul**: what is your current professional community? Do you feel close to it?

**Martin Howse**: I guess my community is within new media art, crossing into sound art, and the noise or glitch scene. So it's a bit of a spread-spectrum community. I feel close to other artists working in a very direct way with technology (say Peter Flemming in Canada, Bengt Sjolen, Ralf Baecker, a long list of others), and synth makers like Peter Blasser, although I wouldn't call that a community as is very diverse and spread out.

**Ezra Teboul**: How close do you feel to avant-garde or experimental music traditions?

**Martin Howse**: I feel closer to avant-garde literature than avant-garde or experimental music. I don't feel so rooted in a tradition of experimental music although I enjoy listening to work from within say musique concrete tradition; it's not something

I relate to so easily outside a live or living context.

**Ezra Teboul**: How has your awareness of those traditions influenced your hardware or text-based work?

**Martin Howse**: Literature has a stronger influence on both sets of work. I like to think of how literature can influence and change hardware - how this could become a new way of working with what seems very engineered or given as to how it should be used. That's the challenge, for example with the Dark Interpreter and other synths how to say insert the influence of Edgar Allen Poe directly into the software and hardware.

## A.8 Email exchange transcript for Jessica Rylan

This interview was conducted over email. Replies were received on March 24th, 2015.

**Ezra Teboul**: could you start with a brief description of your hardware and music backgrounds, what you are doing today and the important steps in getting to that point?

**Jessica Rylan**: I had some formal musical training as a child, particularly singing in a classical children's choir, but also playing piano and flute. I started listening to experimental electronic music in middle school. I decided to start building synthesizers when I was 22, in 1996. I taught myself electronics, reading every book on synthesizers I could find at the library, Electronotes magazine, and various internet resources. It took me about about eight years of self-study to learn to design my own circuits that worked well. I ran a small synthesizer business between 2006 and 2012 (currently it's on hiatus). Over that time I sold around 500 synthesizers. I went back to school to do a bachelor's in engineering in 2006, and started a PhD program in engineering in 2010. I'm currently finishing my PhD and I'm not very active in the music world right now.

**Ezra Teboul**: what is the current place of hardware design in your practice?

**Jessica Rylan**: Not doing any right now.

**Ezra Teboul**: what parallels do you draw between technical processes and other disciplines or hobbies?

**Jessica Rylan**: When I'm interested in something, I get very interested in it. Right now I'm into powerlifting.

**Ezra Teboul**: In what way does scientific research trickle down to influencing your electronics and the music you make with them? Would you say there are parallels between the processes?

**Jessica Rylan**: During the period of time when I was designing circuits, I tried to incorporate a scientific approach into my design work. However, I used this strategy alongside other strategies including intuition, limitation challenges (for a year I didn't use an oscilloscope or a digital meter), and making design decisions visually (either based on what the components looked like, or how the schematic looked aesthetically). However, I didn't have a good basis of science until the end of the period when I was designing circuits. I went back to school for engineering in 2006, and while the circuits courses I took weren't helpful at all for my circuit design, the math and physics classes I took were. In 2010 I published a scientific paper about chaotic circuits. It was very personally rewarding to me to have learned enough math at that point to study the chaotic systems I loved so much formally. I had spent many years listening to and otherwise studying chaos without any formal background. That certainly motivated the formal part, but unfortunately you can't learn differential equations purely through intuition.

**Ezra Teboul**: Are you familiar with Hannah Perner Wilson's kit of no parts? As part of her Master's Thesis at MIT, she devised this set of objects that could be built using some homemade elements - conductive ink to turn seashells into speakers, conductive thread to make electronics in wearables, etc. Would you consider using these methods for electronic music?

**Jessica Rylan**: Not familiar with her work. Sounds really interesting!

**Ezra Teboul**: The personal synth seems to be a good example of what can happen when the artist/engineer personas merge: unique "machinstruments". You've described it as offering unexpected possibilities - a device with which you have an emotional relationship. To what extent do you feel like other electronic musician make a setup their own?

**Jessica Rylan**: For a period of time I was really interested in one-off instruments

like that. I kept a picture of Jon Eaton with the synkett on my design notebook for a few years, though I never actually heard a recording of that instrument. It's a bit different, because while he was the only one who played that instrument, he didn't build it himself. I was also very interested in reading about Gordon Mumma's designs, since he was a musician who built special-purpose instruments. Certainly many musicians develop a deeply intimate relationship with their instrument over a period of years. I doubt that designing the instrument yourself necessarily means that relationship is "deeper" somehow, since there are a lot of engineers who are music fans but terrible musicians, and a lot of sound artists who are terrible circuit designers. For me personally, I found design to be a really exciting world for discovering sounds I hadn't heard before and didn't know existed, as well as a way to realize sounds I wanted to hear but couldn't find.

**Ezra Teboul**: What would electronic music be like if every one had their version of the personal synth?

**Jessica Rylan**: It's not really an answerable question. Of all the people who embark on building electronics specifically for music, very few end up building anything more complicated than a square wave oscillator, and a tiny tiny fraction of those people learn to understand circuits and design their own instruments. Perhaps this sounds elitist but it's just true. It has actually been a source of great sadness for me, because as much as I enjoyed leading hands-on electronics workshops, I ultimately came to question their value. The learning curve in electronics is very difficult. And the approach to circuit design taught in engineering programs is strictly at odds with the kind of music that the personal synth allowed for. Sorry if I'm misinterpreting your question, and sorry if this sounds bitter!

**Ezra Teboul**: When designing audio hardware, how do you approach challenges and limitations?

**Jessica Rylan**: I welcome constraints! Constraints are what makes choosing one thing over another possible. Otherwise everything is equal and there's no reason to have made any one choice over another. I have no interest in purely arbitrary art like that.

**Ezra Teboul**: How have proprietary designs / tools and planned obsolescence affected your practice?

**Jessica Rylan**: This was actually a very frustrating issue with both Little Boy Blue and the Jealous Heart. One of the transistors I relied on for LBB was discontinued, and the quality declined as the part reached end-of-life. I had to buy a New-Old-Stock box from a semiconductor reseller for a 5x markup in order to build the last 75 LBB's. For the JH, I got a great deal on a lot of discontinued OTA (operational transconductance amplifier) chips that I used for the core of the circuit. There is a replacement part available, but at 5x the cost I paid for the original batch.

But I also love rare obsolescent things, and I have a fairly sizable collection of weird semiconductors from the 60's-80's that I hope to use for one-off instruments some day. Also, my boyfriend has clean-room experience making transistors from his undergrad degree, and we sometimes daydream about setting up our own fab and making our own transistors. That would be really cool!

**Ezra Teboul**: You've questioned the scientific approach to sound in favor of embracing a more chaotic, unpredictable method. How do you reconcile that with the limitations of analog electronics, and how does your current music setup reflect that?

Analog is strictly 100% superior to digital when it comes to chaos. There is no question in anyone's mind about that, unless a person is misinformed, or doesn't know what chaos is. There is potentially a limitation in dynamic range, but not a single human ever is interested in listening to music with greater than 30 dB dynamic range, maybe 40 if they're really extreme. I've certainly seen laptop guys use more than that, but

that's not about music, just them trying to punish people. Anyway that's a tangent. I meant to say, the dynamic range limitation in an analog circuit causes limit cycles in chaotic behavior, but this is a generally good thing for music. Moreover, the many noise sources in analog circuits, which operate over many different time scales, help chaotic analog circuits sound good. That noise is entirely absent in digital instruments, unless it is specifically added in. But the main killer is that even in this day and age, digital "chaos" is rarely real-time. Even a modern laptop only has four FPU's, and they can only do so much. Analog is always real-time, 100% of the time.

I'll put it specifically: I have never in my life heard a laptop performer get the beautiful chuffing/breathing sound that I sometimes am lucky enough to find with analog circuits in feedback loops. Digital still doesn't have the bandwidth, and it's still too slow. I love high-performance computing and use it every day in my scientific work (my research group runs jobs on the fifth biggest computer in the world, at Texas Supercomputing Center), but computer music still sounds terrible! To me, anyway.

**Ezra Teboul**: How important have other people been in the technical development of your practice?

**Jessica Rylan**: There were only a few people who I ever really discussed circuit design with. It would have been nice to know more people, but it's a very small community and widely dispersed geographically. Also, all men, which definitely effects the social dynamic.

**Ezra Teboul**: You've described your interest in electronics as coming from a very personal place, from your grandfather and popular electronics found in your old house. How has that personal connection evolved and influenced your design work? Has anyone taken the place of those sources of inspiration?

**Jessica Rylan**: Don Buchla has been a huge inspiration for me and I'm very

grateful for the two summers I got to work with him. I'm also grateful that I got to meet Bob Moog (very briefly) a few months before he passed away. Also, Pauline Oliveros has been a huge inspiration, in the way she has lived her life with no compromises, in her fearless exploration of what's possible, and in her genuine kindness and giving spirit.

**Ezra Teboul**: What is your current professional community like ?

**Jessica Rylan**: I currently am finishing a PhD in nano-optics, and haven't been doing any circuit design or building/selling synthesizers. The current milieu I'm in is very different in a lot of ways. I am surrounded by scientists, most of whom have little to know interest in art. If they do like art, they like the kind of art people tell you is great in grade school - Mozart, or Monet. I enjoy talking about science, but I do get very alienated being surrounded by this kind of insular, hubristic belief in hyper-rationality and disdain for emotion/intuition/chaos.

My current work is optical design and analysis work using computer simulations and math. Some things I design are fabricated by other people, using semiconductor process technology (the same machines/techniques used to make computer chips), but I'm not involved directly in the process of building or testing these objects. They require very specialized equipment (because of the size scale - nanometer size). One of the things I enjoyed about electronics, or specifically electronics technology circa 1965-1985, is that it's on the correct size scale for human interaction. To me, using modern surface-mount electronic parts isn't as interesting, and the nano-optics stuff is even less interesting since it's another five orders of magnitude smaller. I like thinking about those tiny things, but zero interest in working with them.

As far as the "professional" world of electronic music, I went to a symposium about modular synthesizers at Rensselaer Polytechnic Institute a few summers ago. The

most shocking thing to me about it is that it wasn't until half-way through the second day that anyone was able to name the reality that the synth world appears to be at least as, if not more, male-dominated now than it was in the 60's. A well-meaning but completely hapless "cultural anthropologist" from Harvard failed to notice in her "cultural ethnographic study" of DIY synth culture in NYC that the participants were 100% men? It's really disillusioning. I asked everyone: where is the Pauline Oliveros, Suzanne Ciani, Eliane Radigue, Bebe Barron etc etc of today? When these women are so central to the history of electronic music, why has the modular synthesizer become a total bro fest? Everyone (all the guys there) got really defensive. What ev.

**Ezra Teboul**: To what extent do you identify with a tradition of use, re-use, misuse or subversion of technology for the arts?

**Jessica Rylan**: I think it's kind of tacky, some of the synthesizer player press releases I've read recently where they brag about their "deliberate misuse" of technology, like this is a new thing. First of all, reality check: Electronics development only happened for one reason, and one reason only: war. (For example, see The Art of the Motor, or Image and Logic.) And all this "subversion" is just an immature fanatasy about being a rebel. Remember: Stockhausen serves imperialism! (Book by Cornelius Cardew, in case you're not familiar.) So any non-war use (or certainly, any non-Military-Industrial complex use) is "misuse", but we certainly don't think of our use of computers to conduct this interview as "misuse". Another thing to think about, is who came up with these "rules" anyway? Was it the sexist academic composer guys of the 1960's? Or the modern synth-collector guys who are posting on a forum called "Muffwiggler" but are "baffled" that there aren't more women using synthesizers? Meanwhile they're swapping Eurorack modules as if they were baseball cards. I mean, give me a fucking break.

Anyway to directly address your question, Ron Kuivila who teaches at Wesleyan

once told me about a specific feedback patch he picked up from David Tudor. Between that and trying to recreate some sounds I heard Thomas Lehn make one time, I abandoned every "rule" I had read about synthesizers. We also can't leave out Pauline Oliveros, who recorded One of Four live in a studio with electronics test equipment that nobody else had used that way before (as far as anyone knew). She certainly wasn't following the "rules" of the classic tape music studios. In my opinion, whoever is making the "rules" is usually wrong in this case, and they're probably trying to protect their ego or their academic position. But I think bragging about rebelling is really just the other side of the same coin.

**Ezra Teboul**: Do you feel compelled to help people with the same design questions you had when you started?

**Jessica Rylan**: When people get in touch with me with reasonable questions and it's clear they are serious, it's always a pleasure to respond to them.

**Ezra Teboul**: How has musical training influenced your instruments and musical practice?

**Jessica Rylan**: I listen to a lot of very formulaic music for pleasure (metalcore, tween-marketed screamo-light, contemporary Christian, etc). Between that and the small amount of formal training I had, it seems important to make music that doesn't follow any of those rules.

**Ezra Teboul**: Do you perform with anything other than your own instruments?

**Jessica Rylan**: I haven't in quite a while, unless you consider the amplifier-/speaker part of the instrument, which one probably should. I've only used a home-built amp in performance a few times, but it was really cool. I would love to again. But I think in the future I will probably play music with electronics other people built. It can be really fun!

**Ezra Teboul**: How fluid is the transition from circuit design work to music?

**Jessica Rylan**: To me, they always felt very closely related, if not in fact the same thing. That is certainly not true for everyone though! The kind of intuitive music that I like is at odds with a scientific mindset. You have to be able to compartmentalize your intellect to successfully work like that. That's not to say that more scientific approaches to instrument design can't have good results - they certainly can! Though, those kind of instruments tend to lend themselves to a more "traditional" music that I'm personally not as interested in.

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