Personal Approaches to Electronic Music Hardware Design

A Thesis
Submitted to the Faculty
in partial fulfillment of the requirements for the
degree of

Master of Arts

in

Digital Musics

by

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Hanover, New Hampshire
27th February 2015

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Abstract

This thesis focuses on the influence of open source hardware on the design and manufacture of electronic music instruments and performance systems up to this day. It follows a brief history of electronics and electronic music by and analysis of current practices, and concludes with a series of small projects. These small projects and the case studies were selected to reflect recent and exciting developments in the world of electronic music hardware. In all of those, open source (or one of its previous incarnations) played a significant role.

"he's not a composer, but he's an inventor"

Arnold Schoenberg, on John Cage

Acknowledgments

you know what you did.

Maman, Papa, Laela, Ruben, Mamie, Papi, Grand-pa, Baba, Laurent, Celine, Jonathan, Juliette, Pépé, Mémé, Mamie Jeanine

Becca, Marilla, Hannah, RJ, Yoni, Neko, Anna, Kevin, Gabby, Kelley, Georgie, Oskar, Andrew, Neil, Martin, Eli, Darla, Allison, Bob Gluck, Max August Sky, Kate,

Luke DuBois, Tom Beyer, Langdon Crawford, Agnieszka Roginska, Gus, Teddy, Kate, Sarah,

Jordan Lacey, Philip Samartzis, David Brown, Darrin Verhagen, Michael Graeve, Neil, Vanessa, Jon Sartrom, Robb Drinkwater

The Dartmouth College Digital Musics program, the Dartmouth College Music department, Michael Casey, Aden Evens, Beau, Sam, Andy, Carlos, Shannon, Parag, Angela, Kyle, Victor, Yuri, Jon, Viktor, Katie, Yasser, Jonathan Mullins, Yorke Browne, Kristina Lynch, Kofi Odame, Charles Sullivan, Alexander Hartov, Scott Snyder, Carlos Casas, Theodore Levin, Tom Stoll, Gabriele Vanoni, Ulrike Wegst, Spencer Topel, and the staff of Dartmouth College, the unsung heroes of the steam plant and beyond

Seth Cluett, Jentery Sayers, Nic Collins, Tristan Perich, Tristan Shone, Tara Rodgers, Dan Snazelle, Dan Warner, Martin Howse, Jessica Rylan, Ben Hinz, Louise Hinz, Bonnie Jones, Jon Bellona,

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to anyone who's ever opened a dead walkman

Chapter 1

Introduction

1.1   a custom aesthetic

Music and electronics are c̈omfortably interrelated" [1]. The space within which electronics are conceptualized and developed is defined by the technical means available to the designer and manufacturer. Advances in hardware specifications allow for increasingly sophisticated implementation of analog and digital signal processing techniques, as well as more robust, elegant or inspiring human/machine interfaces.

Audio devices, as a subset of consumer electronics, are bound by those technical limitations. Both corresponding markets see product updates every time a significant subset of those limitations evolve. Beyond those common boundaries, however, audio electronics design and a generalist engineering practice exhibit different approaches to innovation and renewal.

In the 1960's, transistors rendered the dangerous and inefficient vacuum tube obsolete in most devices except for very high frequency circuits and audio amplifiers [2]. The latter case is an early example of inefficient systems being maintained for aesthetic

considerations: vacuum tubes produced specific nonlinearities, internalized as a cultural bias that has perpetuated the relevance of an otherwise antiquated technology [2]. That favoritism is based in subjectivity - some music practitioners prefer solid state amplifiers for an arbitrary subset of qualities the technology offers [3]. Different musical backgrounds and experiences inform the technical choices made in the design of each musician's specific setup. Specifically, they influence which limitations, materialized as imperfections, are acceptable in a personal musical system. Vacuum tubes are only one instance of this phenomena amongst many: discrete transistors, analog synthesizers, low-resolution digital audio, etc.

The task of designing electronic music instruments can not be reduced to a set of performance requirements for a circuit, algorithms, or both. Viewing instruments as optimal machines does not do justice to their potential as catalysts of poetic experiences - interesting results arise when designers explicitly address them as post-optimal objects [4]. Successful instruments must inspire their users, helping them to transform abstractions and intuitions into a concrete sonic output, with limitations often proving inspirational [5, 6]. Don Buchla, in designing his music boxes, Don Buchla describes himself as a builder of instruments rather than of machines - he is consciously addressing a niche market [7]. Nic Collins brings this one step further by coining the term silicon luthier, the craftsperson of electronic music [8]. By intentionally limiting a user base, Buchla and Collins both suggest that electronic music instruments can benefit from a small-scale, custom approach in both the design and manufacturing processes.

This benefit is compounded by the constantly evolving nature of electronic hardware and the digital software it often hosts. Technological advances are not correlated to changes in aesthetics of music: compelling uses of a new instrument are as important as the design of the instrument itself [9]. Designing an instrument for a specific person or use increases its chances of successfully empowering a creative process by addressing

the issues inherent to ubiquitous performance and composition systems today [10, 11].

That particular, personal, small scale, inspiringly imperfect vision of electronic music instrument design materialized in various forms through the 20th century: inventors, 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 [12, 13]. Practitioners meet in FabLabs as much as in their basement shops [14]. Both appear as symptomatic of a similar interest across user-bases: a desire take advantage of emerging technologies to create personal, more inspiring and efficient experiences for themselves and their audiences [15]. 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, w2015). 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, as those still require strong corporate or academic backing.

This ethnography 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 [16]. A more explicit connection is drawn to the people who make audio electronics, whether they are boutique designers or factory workers [17]. Issues arising from a direct transferal of design practices from an engineering based in market economies and cult of performance can be better identified, addressed, and solved for the further development of inspiring interfaces [13, 18–24].

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, and people involved in this process, a more accurate description of these ecosystems of invention can be achieved [25]. 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 selective history of formative practices paralleling the history of modern electronics [26]. Starting with the isolated forefathers of the field and their s̈pirit of invention" [**?**], useful references through to Nic Collins' Handmade Electronic Music [27] will allow us to discuss the 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,

both in terms of general design and in how they apply to musical practices. We will then discuss the current incarnation of this spirit of invention and experimentation, in the greater context of making and sharing cultures. This world of open innovation [19], and, more specifically, open hardware, will allow us to tackle the necessity and opportunity to present one facet of electronic instrument design as that of an ecosystem for invention. In this context, the growth and variety of the ecosystem will appear as almost as burgeoning as its real world analog.

Linking this back to the field of experimental music and physicality, the paper concludes with a set of experiments based on those analyses of existing projects and provides documentation for those who might wish to develop ideas presented here.

1.4   Retrospective

Hacking is pervasive [28]. Open source hardware practices, which share a deep link to hardware hacking [29], 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.

PART I

Past

Chapter 2

A history of experimental electronic systems in the musical arts

...not as descriptive of an act to be later judged in terms of success and failure, but simply as of an act the outcome of which is unknown.

[30, p.13]

If experimental music is an act of uncertain consequences, transferring the concept over to engineering appears as counterintuitive. Great effort goes into making commercial electronics consistent, predictable and uniform. The same largely holds for electronic instruments - öne-offswith unpredictable behaviors or cryptic functions drastically reduce the overall adoption of the device, and therefore, their commercial potential [11, 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. Ëinding your sound ïs about finding an instrument and using it effectively.

Making, modifying or otherwise altering electronics is one option for that musician to both better understand the tools at their disposal and make the most of them. Numerous historical precedents for personalized instruments will be presented in the

upcoming chapter, while contemporary instances will be developped in the next. All of them were developed out of a concern for originality, costs, or simple curiosity. Throughout those examples, we'll see how electronic instrument design practices have developed from the example set by the electron pioneers, explored the different levels for experimentation within that space, and how those modern practices converge with contemporary digital technologies, towards an increasingly personalized musical field of expression [15].

2.1 An organology of electronic instruments?

In understanding the development of electronic music instruments, it appears as important to consider at first each of those terms separately. If the development of electronics defined what could be done by artistically-inclined tinkerers, pre-existing instruments and musical traditions shaped what those tinkerers implemented. The influences of acoustic music traditions are still clearly visible on electronic music today, and one could consider the latter as both a continuation and response to the former.

The fabrication of acoustic instruments is a craft. Organology, formalized in 1914 by the Hombostel-Sachs system [31], was an attempt at classifying musical instruments of the time. By considering the mechanical differences between each instruments, the system separated music-making devices into four categories:

- idiophones, or self-supporting vibration systems

- membranophones, with a vibrating membrane

- chordophones, using vibrating strings

- aerophones, relying on vibrating volumes of air

The materials and their geometry clearly define a mechanism, and that mechanism defines the instrument. This is a purely physical parameter space, which takes advantage of the complexities of the real world to develop sophisticated systems.

What separates acoustic and electronic instruments is also what limits organological classification. Indeed, it is difficult to expand to electronic instruments because the physical phenomena behind oscillations (sound) in these instruments is more difficult to categorize. In attempts to modernize organology, electronic instruments are simply designated as electrophones [32]. As Hugill notes, this system does not give justice to categories such as extended acoustic instruments, gestural interfaces, and infra-instruments [33]. It appears difficult to design a robust classification system without shifting from a focus on mechanical engineering to an approach referencing electrical and mechanical systems equally [11].

Electronic music redefined the concept of what an instrument could be and how it could be conceptualized. This discussion focuses on the expanded skillset that comes with the introduction of electro-mechanical hybrids in the matter of creating sound, and exposes some of its consequences.

2.2 Circuit design. innovation at multiple levels: component, system, interaction

The design parameters of electronic instruments is a newer space. It is defined by the electronic components available, which has two consequences for every electronic instrument maker since the rise of publicly available electronics in the nineteen-twenties:

- electronic instrument and their pre-manufactured electronics offer an additional degree of separation from the organic world.

- design plans go from being a representation of the final product to an schematic abstraction. The two offer different liberties in the fabrication process.

The question of experimentalism in electronic music hardware implies the following: to what extent has the standardization of resistors, capacitors and other basic electric building blocks standardized the space of possibilities for electronic music instruments?

To better discuss the world of audio electronics design, let us introduce some basic concepts involved in those processes. The design of instruments includes elements of electrical engineering and product design, both of which can be informed by some musical tradition or system. A completed schematic gives enough information to reproduce a device, often complimented by a bill of materials, a circuit board etching plan, and a diagram for the physical layout of parts. In case of a digital device, some component will be a microcontroller loaded with executable code.

The ubiquity of digital devices today cannot be overstated. This is particularly true in musical devices - the versatility and power of artistic computing is discussed at length by musicians in the upcoming chapters.

Software design offers a rich tradition of experimentalism for audio. Max Mathews acts as the forefather of a long line of extensively-studied composers who either programmed their own instruments, or worked closely with engineers to do so. Those efforts effectively redefined the world of electronic music, and as we'll see excluding digital from a discussion of contemporary audio hardware in music would be as toxic as it would be difficult. Open source originates in software- this thesis wishes to expose the possibilities of interdisciplinary design approaches.

By looking at the role of experimentalism in electronic music hardware, one can get a sense of how hardware can complement the speed of innovation that characterizes

software. Improving physical music devices can take three forms:

- component innovation

- system innovation

- interaction innovation

Historically, electrical engineers have been concerned with those first two points, while the latter is more open to interpretations from various sources. The New Interfaces for Musical Expression (NIME) conference has developed out of a desire to unite efforts in that field. Software affects all three levels, blurring the distinction between component and system while re-labeling the interaction innovation as UX/UI design (user experience/user interface).

Looking at the historical development of those three types of innovation in electronic music and electronics gives us a better sense of where the field is today.

2.3   Electronic music as invention

Before 1915 and the beginning of commercially available vacuum tubes, electronic music relied on a spirit of adventure and experimentalism close to the later works of Tudor, Kuivila, Collins and Ghazala. Dunn's pioneers developed system because they invented or developed interesting forms for the basic components of an electronic circuit (the resistor, the capacitor, the inductor):

C.G. Page   C.G. Page "toyed" with horseshoe magnets, spools of copper wire and batteries - in 1837, he would publish one of the first reports of electronic sound, which he called galvanic music without being able to explain it [34].

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Elisha Gray   Elisha Gray, in 1874, was the first electronic musician to tour his home country. His invention, the musical telegraph, was invented after he realised he could control the pitch of the hum produced by a vibrating metal strip attached to his bathtub while running experiments with his nephew. After touring once with it, he ignored its musical potential and failed when he attempted to use a modified version of the device as an early iteration of what would then become the multiplexer [26].

William Dudell   William Duddell's 1899 "singing arc" offered pitch control for the audible hum of carbon-arc light bulbs. Here again, the musical application was coincidental - he was originally trying to get rid of the unwanted buzzing sound [26, 35].

Thaddeus Cahill   Thaddeus Cahill's Telharmonium, patented in 1896, was the first successful massive undertaking of electronic music hardware. In its full form, the two-hundred ton instrument was a sophisticated electro-mechanical polyphonic instrument, developed and assembled for the sole purpose of entertainment. With Cahill rises the persona of musical inventor as businessman, effectively becoming one of handmade electronic music's earliest father figure [26].

This short list describes only some of the inventors who were much comfortable with raw materials and physical experimentation than most of today's electro-acoustic or digital music community. Interestingly enough, none of the signal generation methods described above (electromagnetic oscillation, RLC-circuit oscillation, spark-gap oscillation, electromechanical oscillation) are common in the following generations of electronic music hardware experiments.

With electronics still in their infancy - no design tradition other than what could be borrowed from acoustic instruments, and few formal structures, experimentation is the only option. By operating in a musically mechanical context, Cahill and his peers

established the baseline for electronic creativity. This is the origin of electronic music, where the promise of the new medium was enough for people to blindly experiment.

2.4 Electronic music as an institution

In the period following the first world war, the popularization of radio went with the development of hobby electronics. It was more cost-effective to buy a kit and build a radio yourself rather than purchase the completed product. People were not a afraid to open things up (Collins, **??**). 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 (radioblvd.com, w2014; data.bls.gov, w2014).

This was facilitated in the U.S.A. by companies like Radio Shack and Allied Electronics. Both companies, amongst many, sell the parts - resistors, inductors, capacitors, transformers, tubes - and the tools necessary to assemble a variety of consumer audio and radio electronics.

Radio Shack's first catalog (w2014) from 1939, contained 80% kits, parts and tools and 20% completed products. The increasing availability of parts and tools solidified after the second world war, with catalogs like Radio Shack's growing from 1939's 72 pages to 110 in 1946. Heathkit, a major electronics kit focused on high fidelity audio and radio equipment, was founded in 1947. Popular Electronics 1, which compiled articles on those kits and the various technological developments available to the patient home-builder, was published in 1954.

This resulted in a generation of engineers and musicians growing up with electronics, who were both were eager to take advantage of the relatively positive post-war

atmosphere [26]. The father of a certain Robert Moog, whom we will discuss in an upcoming section, was one of the first American amateur radio operators [36, p.12].

Electrical engineering was at that point one of the main research areas in the western world. In that context, the final edition of the Radiotron Designer's Handbook [37] dedicated a third of its 1500 pages to audio electronics. Schematic, tools, methods and designs are optimized, thoroughly investigated and standardized. Institutions serve as the breeding ground for most renowned artistic applications of technology, resulting in the emergence of the French (RTF), German (WDR), and Italian (RAI) experimental music studios, all housed by public radio stations. In the U.S., RCA and Columbia University composers collaborated to develop the RCA synthesizer, closer to the telharmonium in scale than anything in the first half of the 20th century.

Hugh Le Caine   In Canada, Hugh Le Caine's Electronic Sackbut and its concept of voltage-control proved to be an inspiration for the Moog, and a foreshadow of most electronic music systems. His work was developed through a contract with the Canadian National Research Center, he was then employed by University of Toronto and McGill (Montreal) to develop equipment for their studios [26].

Regardless of the motivations of their manufacturers, this first wave of kits and tools empowered the masses. It also placed the 1950's western techno-musical experimentalists in corporations and institutions. Most of the technology used in those musical systems was a byproduct of the war research effort, it seems natural for the first wave of artists and designers to be involved with those organizations [26, p.81].

Two relatively well documented exceptions exist in the U.S:

Raymond Scott   Raymond Scott was a self-taught hobbyist with the additional motivation, funds and time provided by his successful career as a composer of electronic

music for commercials. Having independently developed one of the earliest multi-track tape recorders (7 to 14 tracks), amongst a number of other inventive projects, he would also ultimately receive visits from an impressed Robert Moog. However, he would fail to turn his technological expertise into a successful business [26].

Louis and Bébé Barron   The second exception was Louis and Bébé Barron, a couple who would provide soundtracks for films such as 1956's Forbidden Planet, were innovative in their implementations that they would describe as "they were alive", an interesting parallel with Scott's Electronium. In the tradition of Duddell and Gray, the circuits that Louis built were accidently overdriven and eventually failed. In recording that decaying process, the sounds created by circuits inspired by the work of Norbert Wiener would be used as the basis for their composition, which they assembled in a way similar to Schaeffer's concrète process [38].

Similarly, John Cage's experiments throughout the 50's would incite his collaborator David Tudor to abandon the piano that brought them together in favor of an experimental approach to music through homemade electronics [39?]. Unlike our two previous examples, however, Tudor and Cage would have strong affiliations with academia and indirectly, industry.

As musical systems beneficiated from technological advances developed by the military and major research bodies, fewer people were operating independently with enough success to be documented. Work during the vacuum tube age had undeniable impact: Stockhausen, Schaeffer, Oram, or the Columbia Music Center stand as landmarks in the development of experimental music, arguably solidifying the field as a worthy academic pursuit. However, their efforts were out of the public's possibilities, and often, technical grasp. From a design standpoint, one could describe the ORTF,

RAI and Rundfunk studios, as well as the RCA Mk2 as fitting within Dunne's concept of the optimal machine.

2.5 electronic music as a living system

2.5.1 Tudor and Cage: electronics speak for themselves

Variations II is a 1960 piece by John Cage, "the greatest degree of abstraction of a compositional and notational model that Cage developed over the period from 1958 to 1961." It was extensively studied, then performed in 1961 by David Tudor, for whom Cage effectively wrote the piece. The extent to which the work was internalized by Tudor has led to some to consider him as the piece's co-composer [40]. It included the use of a complex system of signal processing electronics, designed to implement some of Cage's ideals of compositional indeterminacy. "You could only hope to influence the instrument", said Tudor in describing his use of the device [41].

Tudor's debuts are not independent of public or private groups. Fluorescent Sound is commissioned in 1964 by Robert Rauschenberg and sees its sole performance in Stockholm's Moderna Museet. Bandoneon!, his second piece, premiered in 1966's Nine Evenings of Theatre and Engineering. Instigated by Rauschenberg and facilitated by Bell Laboratories, this event gave artists from the american avant-garde a chance to collaborate with some of the world's most productive engineers in New York's Armory building [42]. The collaboration would prove instrumental in fostering the experiments in art and technology (EAT) series.

Reminiscent of Barron's living circuits, Tudor described his second piece as "composing itself out of its own composite instrumental nature." [42, 43]. Tudor, through

various collaborations, develops an affinity for circuits which ultimately make some of the compositional decisions themselves.

Cage had been using "found" electronics in performance since the late 30's, with pieces such as the Imaginary Landscapes series or 1959's Water Walk. Reich's 1965 It's Gonna Rain proved that process-based composition rooted in solely in technology held musical value. Tudor, with his implementation of Variations II, Bandoneon!, and the Rainforest series, legitimizes a compositional approach based explicitly on materiality. "The objects should teach you what it wants to hear", he states after performing Rainforest IV (1973). Cage will echo the statement in 1987 with the following response: "the components, the circuitry is the music, and it comes alive when it is performed" [41].

Tudor was in a unique position of artistic experience and legitimacy that enabled his experiments to become regarded as groundbreaking and foundational (Collins, 2004). Through collaborations with Gordon Mumma, David Behrman, Hugh Le Caine, John Fulleman, and John Driscoll, and thorough personal investigation, he gathered enough experience to masterfully implement one of the first documented uses of chaotic electronics in music [42]. Like Cage, he would not be attached to the idea of considering himself a composer [44]. Tudor is the model for multiple generations of hobbyists, independent scholars and experimenters who situate themselves somewhere between self-taught artistic systems designer and musician.

A common thread in Tudor's work was the spotlighting of electronics customarily hidden during performances, ̈composing inside electronics ̈**??** In trying to take advantage of the sculptural aspects of the instruments through sonification by using contact microphones or transducers, his work also developed a notion of sound art which challenges the distinction between installation and performance [45]. His approach was

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different from Lucier's: where the latter focuses each piece on a specific physical phenomenon, Tudor's work was rarely concerned with minimalist systems [39, 45].

Another manifestation of his originality was his coercion of general-purpose abstraction borrowed from electrical engineering, then adapted for the performance of his pieces and equipment [42]. This repurposed set of abstract notations would blur the line between schematic and score, just like Cardew and Earle Brown proposed the use of abstract art as basis for musical performance. In doing so, his performances became more and more personal - Tudor's oeuvre is "practiced, not preserved" [44]. This "musical practice based on constant modification and innovation" [45] is a direct foreshadowing of the methods which define online do-it-yourself communities active today.

If Tudor defined a practice of experimental electronic music systems that complements Cage's sonic uncertainty, it is largely thanks to semiconductors (Collins, in**??**. Transistors and integrated circuits offered the functionality of vacuum tubes without the latter's size, weight, price and high voltage hazards. These became commercially available and well documented as he started using custom electronics [39], with Texas Instruments selling their first silicon transistor in 1947 (texas instruments, w2014) and integrated circuits (ICs) becoming available in the 1960's.

The easily replaceable, cheaper components would make prototyping musical electronics more accessible, also allowing Tudor to easily enroll help for performances. Starting with 1973's performance of Rainforest IV, his group of collaborators would solidify as the Composers Inside Electronics group (C.I.E., w2014). The group, reformed for Tudor's death in 1996 is still active today. Their approach is resumed by Tudor in 1976:

> 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.

[41, 46]

Tudor's innovative methods and C.I.E.'s ever growing cast have guaranteed the relevance of their work in scholarship of musical hardware leading up to the current decade [8, 27, 39, 41, 42, 45, 47]. 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. As the E.A.T. experiments failed, the public's appreciation and understanding of overwhelmingly complex electronic art fell [48], opening the door to artists who managed to blend adventurous electronics to pop or classical traditions. The relatively smaller scale and ambitions reopened the door to the more recluse experimenters that had not become engineers for Bell Labs or European studios.

2.5.2   The rise of voltage control

With the development of solid state electronics, audio signal synthesis and processing becomes a more manageable endeavor. As Hugh Le Caine intuited and implemented, but failed to popularize, signals could serve both as raw audio signal or as control information for paramaters of that audio signal.

Bob Moog, building off of the experience he accumulated assembling, selling and distributing theremin kits, develops that capability in an expensive but publicly available package: the Moog modular synthesizer. Each module serves a primary function and communicates with other modules using those formatted control voltages. The parallel with 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 a first opportunity for the public to "build" personalized instruments for popular music. Although the number of modules is limited (not to mention the prohibitive cost), the end user is responsible for the final layout of the device. Although Moog is not the only manufacturer of modular systems, the quality of his system, 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." [26, 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.

A number of other musically inclined inventors also developed comparable systems, each with their own specificities. Two American complements to Moog are Serge Tcherepnin, designer of the Serge modular system, and Donald Buchla, responsible for the Buchla synthesizer. The latter is most relevant in our discussion.

As mentioned in the introduction, Buchla viewed himself as a luthier, designer of instruments, rather than the engineer of machines [7]. 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, but the quality of his luthery would ultimately appear as inspiring for circuit designers up to today [17],**??**. "The Buchla box was designed for musicians who wanted to produce a complex piece of music in real time." [36, p47]. If Moog's modular model is the template for much of the additive synthesis audio software and hybrid hardware today, Buchla's interface and interactive system design work are still being digested and re-used [] 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." [36, 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 more varied processes to emerge, as well as a more original set of parameters for those processes. The ease with which tools permit this dual role directly influences the variety of the instrument design ecosystem and its evolution cycles.

2.5.3 Brian Eno: uncontrolled versus unintentional realizations of music

A prime example of avant-garde, personal electronic music techniques coming to a popular forefront with relatively little technical support is the British composer Brian Eno and 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.

[49]

> even though it is correct to say that composing process music does not require electronics, the use of electronic instrumentation often inspires its creation. The very nature of electronic music instruments, old and new, encourages a composer to think in terms of a process, whether that process is a hardwired patch of cables, a virtual patch inside a computer, or the turning of dials to various increments that shape the development of a piece of music. [26, p.237]

If Tudor operated between the component and system levels, Eno is somewhere between system and interaction. 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*.

This record allows us to briefly discuss the role of intentionality in composition with autonomous or semi-autonomous musical systems. If Eno's practice at that time is implicitly linked to Tudor's, he is also explicitly acknowledging the unintentional nature of his process:

> ... having laid down, I realized that the amplifier was set at an extremely low level, and that one channel of the stereo had failed completely. Since I hadn't the energy to get up and improve matters, the record played almost inaudibly. This presented what was for me a new way of hearing music - as part of the ambience of the environment. [49]

He combined this new vision of Satie's *Furniture Music* [50] with an interest for tape-loop based delays dating back to the previous decade, creating the following system:

FIGURE 2.1: Operational Diagram for Discreet music
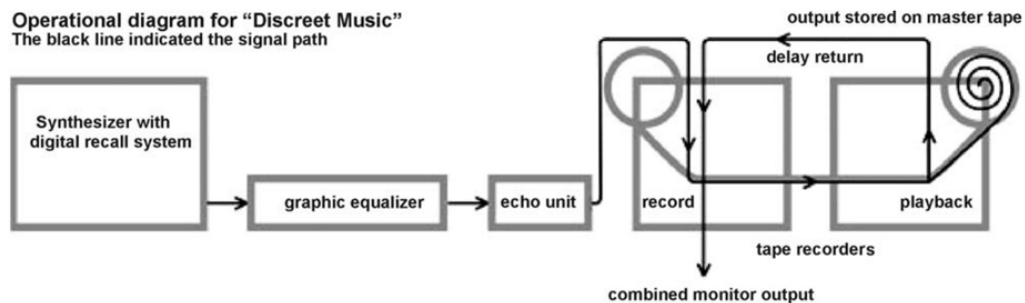
Eno would keep combining this approach to listening with evolved versions of this 1975 system, eventually yielding elements of the *Ambient* series [51–54]. This also developed beyond the studio: if *Discreet Music* was originally intended as a backing track for improvisations by Robert Fripp, the latter would eventually use the system extensively through to this day. *Frippertronics* is both a performance, composition and installation medium, a flexible, adaptive and personalized instrument.

The compelling nature of this release is undeniable. *Discreet Music* holds high value as a prototypical ambient record, an instance of hardware-based process music,

and an example of a semi-autonomous electronic music instrument. If Tudor blurred the line between composition and performance through his interpretation of Cage and subsequent live electronics works, Eno's work develops this further by legitimizing curated unintentionality as a compositional prompt.

More so than Tudor's various devices, *Frippertronics* serve as the archetype of personal electronic music instruments. It illustrates the amount of resources, technical knowledge and musical intuition and sheer luck necessary to make the medium of electronic music one's own.

2.6   Elecronic music as craft

The essence of Tudor's successors' would be academically captured by former C.I.E. member Nic Collins. His Handmade Electronic Music book 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 links decades of practices in the do-it-yourself electronic music world to the "maker" movement, which started to coalesce around a similar time with publications such as "Make" magazine.

The values of this book - concepts of imagining, prototyping, assembling from your home - find a strong precedent in pre-industrial craftsmen and the world of small production [27, 42, 55].

Although Collins' introduction hints at the advantages of this approach in the context of electronic music, the advantages of a craft approach to instrument design and fabrication can be further resumed in the potential for personalization, transparency, and skill-transfer [13]. Conversely, the fascination for Collins' hacking or Ghazala's more

clearly defined circuit-bending can be explained as a desire to fill a need unsatisfied by commercial products [4], a process that has shown its ability to serve as the source for entire sub-genres of the musical arts [4, 56, 57].

> "The circuit— whether built from scratch, a customized commercial device, or store-bought and scrutinized to death— became the score." [39]

Discussing Tudor and 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 [27, p.ix]

2.6.1   the art of hardware hacking

A look at the structure and content of the work reveals six parts: starting, listening, touching, building, looking, and finishing. Those consist of between two and eight chapters, for a total of 30. Each covers a specific theme such as "tape heads: playing credit cards" or "a little power amplifier: cheap and simple", revolving around a few schematics, diagrams, guidelines and suggestions for implementations. Historical background is added when appropriate ("David Tudor and Rainforest", p40; "Circuit Bending", p91. . .).

There are more pictures than schematics, and what should be striking to anyone already familiar with building electronics is that there rarely are any values or names for parts in schematics - another consequence of Tudor irreverently defacing the key document of electrical engineering. Devising 264 pages of electronics for music involving

solely circuits simple enough to describe in a few lines of text appears as a feat in itself. The self-deprecating "keep it stupid" attitude of the introduction rapidly turns into rules number 1 and 2 of hardware hacking, "Fear not!" and "don't take anything apart that plugs into the wall" (p225). In other words, an electromechanical understanding of electronic music is empowering, and you should experiment as long as you do not risk hurting yourself. This hints at another trope of the open hardware movement, mentioned in the introduction: simple, homemade hardware facilitates sharing and learning, thereby encouraging its practice.

> "Finally Tim-Berner's Lee birthed the World Wide Web and a hundred Fuzztones flowered."
>
> [27, p211]

This book can almost serve as an entirely self-contained introduction to electronics in music (falling just short of a soldering iron and a speak & spell). Collins however made sure that it also is aware of the resources that can compliment it through a list of printed hyperlinks that is fairly exhaustive for its time. In that sense, "Handmade..." also relates to more general current practices in open hardware design. Indeed, it is precisely the open sharing platforms allowed by the world wide web that have fostered the communities which collectively comprise the maker movement. The appendices also reflect loosely broad categories of resources important to both practices: previous documented work. Appendix B appears in retrospect as a paper instructables or hackaday, if every project was hosted on a different homepage. Resources for buying parts and tools are listed in appendix C, where the essentials have not changed and already included allelectronics, jameco, and radioshack. Finally, inspiration: appendix E describes the tracks on CD sold with the book and appendix D lists the rules of hardware hacking and the avant-garde.

Before discussing the influence of Collins' book on following publications in related books and articles, it seems important to mention the availability of the book in various digital forms. The original draft for the book, a compilation of class notes, is freely available for download off of the author's website (w2014). The first hit for "handmade electronic music pdf" on most search engines will give a pdf of the 2006 edition of the book of dubious legality, but extremely easy to find nonetheless.

By tolerating or passively encouraging open access to resources, Collins contributes 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 usefulness of those very institutions.

2.6.2   impact:

> "Collins's Handmade Electronic Music details many ways in which human interaction can be built into music and sound making devices."
>
> [**?**]

Measuring the influence of this book through simple academic metrics, such as the number of times it is cited in publications following it [58] yields the following results. "Handmade. . . " seems to have been referenced in 88 publications (google scholar). 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 [59**?**

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–61], and as an inspiration in the development of a specific musical controller [23, 62–65].

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 ("do-it-with-others", diwo, or "do-it-together", dit), 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 results usually number between 5 and 50. As a reference, searching for Ray Wilson's popular "music from outer space" do-it-yourself synthesizer website returns between two to three times more results. Collins' website numbers the quantity of workshops he's given based on the book since 2004 to "dozens", meaning that a significant portion of the sharing could still be happening in-person.

This appears as indicative of the last, and arguably most important point about homemade electronic music instrument design as part of more general arts crafts diy maker movements. They are fueled by personal engagement and, more importantly, passion. In those circumstances, theorizing, documenting and commercializing is not the priority of the majority but rather the duty and privilege of the few who turn their passions into a viable working position. In doing so, they are given the choice of where they wish to place themselves between their aspirations and that of their community.

2.7   re-commercializing diy: the maker movement

The latest iteration of homemade electronics culture, the maker movement, is described as a third industrial revolution (The Economist, w2014). Here, Fab Labs, modelled after MIT's NSF-funded center for bits and atoms, allow the public to benefit from some of the efforts of academia to give fabrication a place in everyone's lives [66, 67]. Through this democratization of invention [67], diy culture expands its reach from sunday inventors and engineers with some free time to a wider audience which could include more and more artists.

Often, compelling uses of rapid prototyping (3D printers, cnc mills and other computer assisted manufacturing techniques) are artistic. D-Shape's large-scale concrete 3D printer is advertised using a sculpture by Andrea Mongante's Shiro Studio (Shiro Studio w2014). Makerbot's frontpage for the replicator displays a picture of the device with a completed red plastic bunny on the extrusion platform - this use falls in the artistic range rather than the utilitarian.

In June 2014, the White House held a maker faire, with president Obama declaring June 18th "National Day of Making" (White House, w2014). Of the 20 projects displayed on the event's website, 9 were artistic (including 2 instruments: a violin and a banana-synthesizer), and most displayed some level of aesthetic concern. If the third industrial revolution is a democratization of invention, is that the place the arts (and specifically, sound devices) will have? Does a modern version of 9 Evenings exist, and if not, what would it look like?

On the sidelines of the maker movement, the technology has changed (shifting to digital or mixed-signal systems) along with its means of delivery. Radio Shack and its ilk have lost most of their importance, with online suppliers like Jameco, Digikey

and Mouser providing large parts catalogs. Specialized marketplaces like sparkfun and seeedstudio occupy more hobbyist-oriented markets. To compare, by 1970, a Radioshack catalog offered one or two pages , or around .5% of the catalog for kits, while thirty pages (20%) are dedicated to parts. In 2002, the last year the company offered catalogs, it contained 25 out of 450 pages of parts, and no kits. The company is currently closing 1100 of its 7000 locations. While this is in no way due solely to the maker movement, Radioshack's slow death or reconversion does mark the end of an era.

The rise of accessible embedded systems (arduino, maple boards, raspberry pi, beagleboards. . .) and availability of relatively free music software (pure data, chuck, csound, supercollider. . .) leaves music hardware often reduced to the role of place holder for more malleable software. This comes with its own set of design principles (user experience / user interface design), resulting in versatile controllers meant to be used with a computer (monome, linnstrument). With wearable circuits comes the ability to turn most of anything into a controller using the plethora of sensors available to today's tinkerer.

Regardless of objective efficiency and versatility, interest in analog sound generation and old-fashioned interfaces is commonplace in electronic music [27]. The range of possibilities for musical expression has become significantly more fragmented. Each approach, whether it is controllerism, hacking or analog traditionalism is being pushed to their extremes. In exchange for this splintering, online resources provide better documentation than ever before.

The main academic platform for music hardware after 2002 is NIME, which shares all proceedings freely. Amateurs find more informal information on a collection of public or semi-private forums (diyaudio, electro-music forum), databases from some type of digital format of designs (hylander), and repositories ran by benevolent individuals that sometimes also try to run small businesses (music from outer space,

ken stone).

Most general hardware hacking websites (hackaday, instructables, arduino projects site) contain a significant number of audio hardware projects (hackaday audio, instructables audio, arduino audio forum). It could be said the tools and knowledge necessary for audio hardware designs are more accessible to anyone with an internet connection and the time to teach themselves electronics and programming. In addition, academia is heavily advertising the potential of open source design and manufacturing tools. However, there is very little organized measure or monitoring of the reach of these technologies. Do they truly beneficiate learners and beginners, or do they simply empower some artists and scientists already working on similar projects? Do they only reach people in higher education or with a higher education, or do they attract mostly people already interested in open access technologies?

The following sections cover two methods of inquiry for these questions. First, a series of interviews with various point of views in the art and technology world allow us to get some relevant snapshots of current practices. Secondly, responses to those projects and adaptations are devised and documented. An analysis of the process and the efforts undertaken to share those designed follows.

Chapter 3

Selected Recent Works

3.1 Tristan Shone: Author and Punisher

3.2 Sangwook Sunny Nam

3.3 Louise and Ben Hinz, Devi Ever FX and Dwarfcraft Devices

3.4 Nic Collins

3.5 Bonnie Jones, Techne

3.6 Jessica Rylan, Flower Electronics

3.7 Martin Howse

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3.8 Dan Snazelle, Sanzzy FX

PART II

Present

Chapter 4

Interviews: highlights and analyses

4.1 Interviews: methodology and highlights

4.1.1 Tristan Shone: Author and Punisher

highlights

analysis

4.1.2 Sangwook Sunny Nam

highlights

analysis

4.1.3   Louise & Ben Hinz, Devi Ever FX and Dwarfcraft Devices

highlights

analysis

4.1.4   Nic Collins

highlights

analysis

4.1.5   Bonnie Jones, Techne

highlights

analysis

4.1.6   Jessica Rylan, Flower Electronics

highlights

analysis

4.1.7   Martin Howse

highlights

analysis

4.1.8   Dan Snazelle, Sanzzy FX

highlights

analysis

4.2   Greater context

4.3   trends?

Chapter 5

Expriments

5.1 designing an open source, hybrid and personal framework for signal experimentation: an introduction

5.2 sketches

5.3 drafts

5.4 rehearsals

5.5 results

5.6 to-do

Chapter 6

Future: Conclusion

Conclusion here

PART III

Appendices

Appendix A

Interview Transcripts

A.1   transcript for interview with Sang Wook Sunny Nam

1. How did you first get interested in audio technology? What was its part in your learning process as a mastering engineer?

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.

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

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...

So you've listened to ceramic vs. tantalum capacitors... 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?

Have you done double blind A-B test for all of those variants?

Yes.

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...

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

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

2. What do you think of your current setup? Is there still work to be done, or are you happy with it?

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.

3. 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?

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...

Do you share any of this documentation?

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.

4. Do any of the people you contract for this equipment end up sharing the work they've done through collaborating with you?

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...

5. 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?

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.

Is it an active circuit? 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.

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

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. What order filter are you using for your mastering work? 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.

6. You've worked with Josh as your go to engineer?

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 ÿestertech... 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... Do you know any other hardware engineers you'd put on the same level? 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.

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?

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.

7. Is there one specific item that illustrates this process well in your studio?

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.

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.

You use only switches and resistor networks, no potentiometers, no faders?

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

Do you do that?

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... Those types of switches were used solely on my console. Volume controls are also only resistive networks. Do you try to minimize the amount of wiring in the overall studio? Yes. All hand wired, short. There's still a lot...

Is it all point to point soldering?

Yeah.

So no ceramic boards or circuit boards?

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

Do you ever take a look at the inside?

Yeah, every three months I'll open it and clean all the contacts. Do you ever appreciate that wiring as a work of art in itself? 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.

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

No. I'm not good at the smaller things.

8. How do you know if/when a particular piece of gear is finished? (25min52sec)

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.

9. To what extent do you participate in online audio-enthusiast communities and what role do they play in selecting your equipment, if any?

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...

10. Do you measure the performance of your gear electrically, and if yes, what importance do those measurements have?

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 ding̈then the decay is going on. We can still hear decay all the way down on a good amplifier. The 990 goes ẅiuuuu- ss!...b̈ecause 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.

Do you look mostly at THD (total harmonic distortion) measurements for this?

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.

11. What is most important in your work process?

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. This DAW has this function, that 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.

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? 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.

Do you know anyone who has built their own mastering studio from scratch?

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.

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

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

That's too much for one person?

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 Tristan Shone of Author and Punisher

TS: 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.

ET: can you develop your background a little bit more?

TS: 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 Chicksemihay. 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.

ET: where did you go for your art program?

TS: I went to UCSD. Which is also where that guy Chris Chicksemihay 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.

ET: were you familiar with all of RPI's experimental music aspect?

TS: 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...

ET: Can you talk a little about the connection between metalworking and metal music? There's something very physical about both (12:25)

A.3   transcript for interview with Nicolas Collins

(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):

NC: ... In some concert halls, they have devices to jam cellphones. 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 cellphones 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.

ET: Have you ever read the Pirate's Dilemna? 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.

NC: There's so much interest in what's called s̈ilence 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 millenia, 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...

ET: 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...

NC: I'm old, yes. But I'm still alive.

ET: and you wrote the book!

NC: fine... I did do that.

ET: So what's the current place of hardware in what you do today?

NC: ... (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 fine 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.

ET: and a summary of that is in your paper about early microcomputers in your practice?

NC: Yes - that's the paper on semiconducting. 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 thinking of the consequences. You couldn't really do anything. My mantra's 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 play their isntruments 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 he started

writing articles for the experimental musical instruments journal. And there was always a little cult of this stop. Always this buzz in the air about the speak and spell. I had a speak and 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 oh Ï'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 casette 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. Those two ... 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.

ET: people realized the speak and spell used microcontrollers.

NC: 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 built 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 mics, 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 Šalvage" - it's on youtube - where you try to revive a disfunctional or broken circuit by essentially injecting voltages into an unpowered board and basically 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 sarts 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 softwares that improvise. George has been working litterally 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 comformability - 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 complimentary behavior.

ET: The other person I'm interviewing tomorrow is Dan Snazelle. Are you familiar with his Ardcore module?

NC: Yup, that's right. 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.

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

NC: No, I think there's 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 (26:18) from the 70's that lent itself beautifully to running on batteries. That was a critical technological bridge.

For most people, 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. My guys who started the first laptop orchestra at Princeton are now doing iPhone orchestras 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.

ET: Dan Iglesias made a nice wrapper for LibPD called mobmuplat...

NC: 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 developping 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.

ET: Is there anything you're curious to see implemented?

NC: 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. Kristina 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.

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

NC: 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 piece called something like just because you can, should you", and it's a reaction against the diy community. 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 a 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 who 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?

ET: 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 electronics, 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 objectlively thought his electronics were producing compelling compositions...

NC: It's complicated. He had this reputation as a virtuso 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 leeched 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 coincides with the getty papers. That's where you'll see a nice overview of the different periods...

ET:Do you know about the Little Bits kits?

NC: I was at Moogfest, the guy from Little Bits gave a talk...

ET: Korg has a series of synthesizer based ones...

NC: I've seen a number of those things developed over the years... Radioshack 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'd 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. Ï'm not going to use unless I make it myself" or Ï'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 book shelf, 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 an 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 carburator works...

ET: which is what HAM radio tests are today...

NC: True. Trevor Pinch edited a really nice companion to sound studies. There's an Oxford one and a Cambridge one, he did one of those. There's a really beautiful thing 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, ëmpowering". 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.

ET: 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?

NC: 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 äre these bent or hacked?" So I ask him what the difference is and he says öh, 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 öh boy 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 boom 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.

ET: 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.

NC: 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 chsen 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.

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

NC: 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 Doto Lim and Ballon & 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 (56:37) 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.

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

NC: 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?

ET: Throwing back to the notion of presets we were discussing earlier.

NC: 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 imprivisation. 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 o 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 Ï'm a video artist" Ï'm a sculptor"... they say Ï'm an artist". And then öh yeah 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! Let's try to get through all of them.

ET: Is personalization of electronic music instruments just a set of decisions concerning which limitations are acceptable?

NC: 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 Ï'm a violinist" or Ï'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, an 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 öh my god not another electric guitar"... well they do, but not in the same way they say öh, a wahwah pedal...?" or ä vocoder?". If you wall 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.

ET: 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?

NC: 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 piezoelectric cristals, 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 english design students who decided to build a toaster from scratch to see how the industry actually worked. Hammer pennies to draw wire and everything like that. It's an exercice 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 exception, 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.

ET: 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 seflearners?

NC: 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.

ET: Who is this book, and more generally devices like arduino and tinkering practices empowering the most?

NC: 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 amazaing. 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...

ET: Where do you see the successors of your book?

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

ET: you might be your own successor.

NC: I hope not, I'm really dragging my heels on this one. There was I think the exploratorium came out with a 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 percetion, 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 book-able subject, and it's one that does tie in a strong academic community.

ET: so do you see this beeing more a book than online resources?

NC: I think it's going to take both forms. The textbook market is still strong, whether its paper or an ebook. It's going to be book-ish. My next thing is going to be a cookbook. I wanted to flip the tables and contribute designs in multiple categories. Instead of an oscillator circuit, it'll be an oscillator circui 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 couple 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.

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

NC: In the sense that I could never get a job with a legitimate designer- All my stuff is directed towards these bizzare applications that I had, and my test... the buddy I'm staying with, the guitarist Robert Goss from Band of Susans... In exchange for staying at his house, 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 doctrined. 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 a bout rogue procedure, it is abut 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 you're 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 Davd Tudor, you'll watch a 40 second recording of Rainforest by a three year old with a camera in his hand.

ET: Is there an engineer's music? Do engineers come to your talks?

NC: 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 litteraly 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.

ET: Do you think creating instruments and creating music are converging practices?

NC: 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-cagean composers about being treated seriously as composers. Most of them very much disliked the word improvisation. They used things like öpen music" or open form score.

ET: In the same sense that Cage disliked the term experimental?

NC: Not quite, he disliked improvisation for other reasons. Those musicians didnt mind improvisation, but they wanted to be thought of as composers, not improvisers. My generation comes around and says ẅho 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. It existed as an array of cheap hardware

samplers in the 80s... live radio sampling, very successful piece. I made a software 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 ÿou 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.4   transcript for interview with Dan Snazelle of Snazzy FX

A.5   email exchange transcript for John Bellona

1 - your approach to hardware/software combinations seems really practical, but my sense is you still explore the capabilities of each framework or medium. Do you look

up to any artist or engineer that might have done that particularly well as a template for your own work?

When I first got into electronics, guitar pedals, digital music I loved engineer/-producers. Dave Fridmann. Nigel Godrich. Tom Dowd. Later on, I was exposed to acousmatic composer Scott Wyatt, who applies a lot of engineering concepts to music that just make his music sounds really crisp and his trajectories are very clear. The sound is very important. This fact is essential for me to remember especially when having to consider gesture and technology in the same sphere. Its easy to undercut sound because you run out of time working on the other components, but sound is why I'm doing all the other things in the first place. So why undercut the reason I'm here? While I am continually exposed to new works that I love (John Cage Four2 (SATB), David Behrman On The Other Ocean), I attempt to come back to the sound as helping to define the work. I will make decisions to support an idea or concept, but the resultant sound should always work with my ears. I hope this makes sense?

2 - one of the interesting challenges of teaching electronic music to me is the variety of interests and experiences within a given student body. How do you feel hardware and software facilitate that catering to individual personalities? Is one (hard or software) favored over the other at the academic level?

Software is a pedagogical conundrum. Teaching concepts is essential to cutting across technologies, but then there is just the ability to work with software in general that requires the technical. I've taught both ways, and with both, each cater. Here are a two examples of success and failure (rambling) I've taught Photoshop as an in-depth technical course. (http://deecerecords.com/artd360/) I've seen previous instructors teach art concepts through the software, which didn't quite satisfy the entire student body (students from product design, architecture, painting, journalism, printmaking, sculpture...). I think it was important, for me, to ask why are students taking this

course? And how is the course offered in the catalog? By teaching the nitty gritty of how-to inside Photoshop, I witnessed non-technical students able to understand how to work with a digital technology and make work they were happy with, discovering solutions on their own. I also witnessed more tech-savvy student jump over the differences in Illustrator or other graphic/image software since they learned to understand what they were looking for. I was happy with the results in this, even though I was getting really into the how-to of a specific software. On the flip, I've taught Processing as an in-depth technical course (this listing is when I taught the lab that still included Flash http://deecerecords.com/artd252/processing), and I completely failed at it. While programming can be for everyone, the way it is taught will definitely cater to particular personalities. The lab I taught Processing in used to be Flash animation, but we slowly switched over to Processing only since the application of programming became more important than the industry need for Flash savvy designers (and Processing is free). For anyone who hasn't learned a programming language, and isn't into the idea of it, the challenge can be, at times, overwhelming. You don't need a lot of programming to do interesting work, but perhaps that was my fallacy in teaching the course that first time. I thought people had to know array manipulation and Objects, but one doesn't. This one should have been more exploratory and project-based. The software battles rage on... pure Data vs. Max/MSP. Processing vs. Flash vs. openFramework vs. Arduino. RTcmix vs. cSound vs SuperCollider. Logic vs. GarageBand. ProTools vs. Logic. GarageBand vs. Reaper.

Do you have students buy a software? Or do you use open source? Do you teach how to use the software? Or do you ask larger questions that use the software to answer them? Do you use software that is for Mac or Windows? (I consider anyone using Linux as being independent and technical)

Certain software hide concepts that are necessary to understanding both the analog

and digital domains, and for this type of reason I stay away. GarageBand is a huge no-no for me because the software doesn't allow students to understand how signal flow works. Dynamics and Effects processing are applied in the same way in this software, but that's not the case in 95% of other digital DAWs and 100% of the analog world. FX processing requires busses, and dynamics processing is placed in line. Is the software free? yes. Is it already installed on every Mac and on every lab machine? yes. Should we use it? No... People will also teach and use what they know. I've seen undergrads taking a RTcmix course, and I've heard gripes about learning an outdated software. I think any software is fine, so long as you either address the needs of the students or are extremely clear about the course will be about (conceptual vs. technical, etc.)

3 - Do you feel like academia / institutionalized art is representative of the overall community (or even just your community) that operates between art and engineering?

Do you feel like academia / institutionalized art is representative of the overall community (or even just your community) that operates between art and engineering? I've found that collaboration is a necessity if we want to elevate our capacity to work with multiple disciplines (art, music, engineering, architecture, dance, to name a few) and to create exciting work. We almost no longer can do it all on our own because of the knowledge required. If we can prepare students to ask questions, reach out to others, and establish collaborative relationships, everyone will benefit. This type of learning also extends outside of the classroom into real-world problem solving, and helps situate the necessity of art in the eyes of an administration who may perceive music as only being an acoustic instrument one plays to become cultured in Classical/Art. (yes, capitals here) Electronic music has similarities with today's community because of the artistic and interdisciplinary process that is involved even if the the end results may sound much different than a listener's expectation from a piece.

4 - what's your community like? What's the place of sharing at the local / international level there?

I've really enjoyed the Kyma community, which is a small niche in the larger world of electronic music. I enjoy the community because it's comprised of academics, sound designers (film and video games), musicians, composers, video artists, and more. Everyone is very humble and open to exploration, collaboration, and dialogue. While I completely understand that the hardware locks out many practitioners, the community contains many individuals with whom I want to have artistic conversations with.

With regard to academia, I see my work and process paralleling that of art and digital music departments than traditional composition. This probably has to do more with the ideas of exploration, collaboration, questioning, and openness. I've also learned quite a bit from working with Harmonic Laboratory, the art collective I am part of. Working between disciplines informs how I approach a project, the connections I see and want to explore, the type of vocabulary I use, and the work I create. Collaborating with Harmonic Lab has allowed a work to take shape rather than to oppressively mold the container.

A.6   email exchange transcript for Martin Howse

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? Is your interdisciplinary practice (art, technology, teaching) means to achieving a unique goal, or different ways to express thoughts and interests? What level of complexity do you look for in your electronic instruments? how do you approach the use of new devices in your setup? how have proprietary designs, tools, and planned obsolescence affected your work? What have the responses to the detektor and dark

interpreter devices been? they are both hardware/software combinations. is that a practical decision? how important are other practitioners in the development of that work? how has teaching affected your creative interests? in your experience, who does open source / affordable hardware empower the most in the arts? Is there any recent technical development you're particularly excited about? what is your current professional community? Do you feel close to it? How close do you feel to avant-garde or experimental music traditions? How has your awareness of those traditions influenced your hardware or text-based work?

A.7 email exchange transcript for Jessica Rylan

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? what is the current place of hardware design in your practice? what parallels do you draw between technical processes and other disciplines or hobbies? 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? 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? The personal synth seems to be a good example of what can happen when the artist/engineer personas merge: unique m̈achinstruments.̈ 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? What would electronic music be life if

every one of them had their version of the personal synth? When designing audio hardware, how do you approach challenges and limitations? How have proprietary designs / tools and planned obsolescence affected your practice? 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? How important have other people been in the technical development of your practice? 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? What is your current professional community like ? To what extent do you identify with a tradition of use, re-use, misuse or subversion of technology for the arts? Do you feel compelled to help people with the same design questions you had when you started? How has musical training influenced your instruments and musical practice? Do you perform with anything other than your own instruments? How fluid is the transition from circuit design work to music?

A.8   email exchange transcript for Bonnie Jones

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? what parallels do you draw between technical processes (like assembling that setup) and other disciplines or hobbies? What level of complexity and indeterminacy do you look for in your electronic instruments? how do you approach the use of new devices in your setup? how have proprietary designs, tools, and planned obsolescence affected your work? how important are other practitioners in the development of that work? how

has teaching audio electronics affected your creative interests? in your experience, who does open source / affordable hardware empower the most in the arts? Is there any recent technical development you're particularly excited about? what is your current professional community? Do you feel close to it? do you identify with hacking / bending / re-use / misuse of technology for the arts? How close do you feel to avant-garde or experimental music traditions? How has your awareness of those traditions influenced your hardware or text-based work?

A.9   email exchange transcript for Louise and Ben Hinz of Dwarfcraft and Devi Ever FX

what are your musical interests and training? do you see any parallels between designing a circuit and playing guitar? 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? the Pitch Grinder is your first commercially available digital product (unless I missed something in the Devi website / history). How was that foray into software / hardware combinations, and what prompted you to do that? how traditionalist is your customer base? Does that conflict with your musical interests? 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? modules also put you one step closer to experimental / avant garde / contemporary classical music. Any opinions? how do you approach limitations in hardware design? have proprietary tools / designs and planned obsolescence influenced your work? Conversely, have you shared any of your designs / tricks / magic? how important have other people been in the technical aspect of your work? do you have any opinions or thoughts on your professional community? have you helped

beginners with design question like Devi did for you? are there any philosophies or beliefs that seem important to you as you do this work?

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