

## Bleep Listening

Ezra Teboul

Handmade electronic music can be thought of as the coordinated production of electronic instruments and electronic sound. An exploration of the "music *implicit* in technology,"<sup>1</sup> it requires attention to the electrical properties of materials, to the sonic consequences of those materials' evolving interconnections, and to the creation of situations favorable to the exploration of those evolutions. Therefore, any study of the practice should consider both the assembled and the assembler: who and what share responsibility for the resulting ever-changing communities and artifacts?<sup>2</sup>

The listening associated with hardware hacking focuses on the musical potential of electronics as they operate. This often results in a collapse of the distance that traditionally distinguished the musical score from the instrument: this led Alvin Lucier to consider the viability of the circuit as a score.<sup>3</sup> The practice of hardware hacking has continued to build institutional and popular legitimacy as a method of musical composition and creative work, while embracing a fragmented and shapeshifting type of material production.

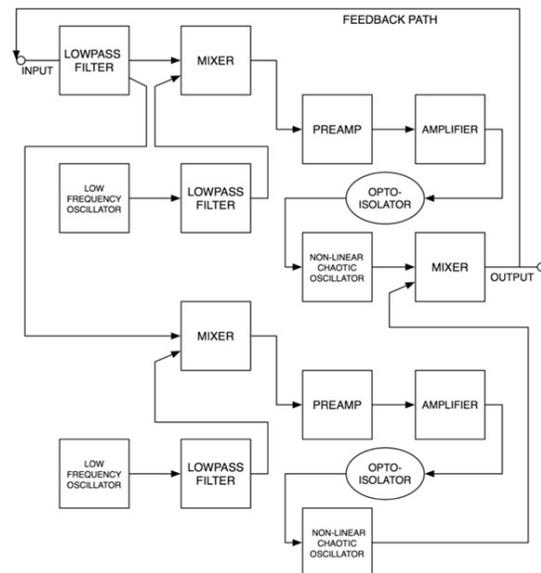
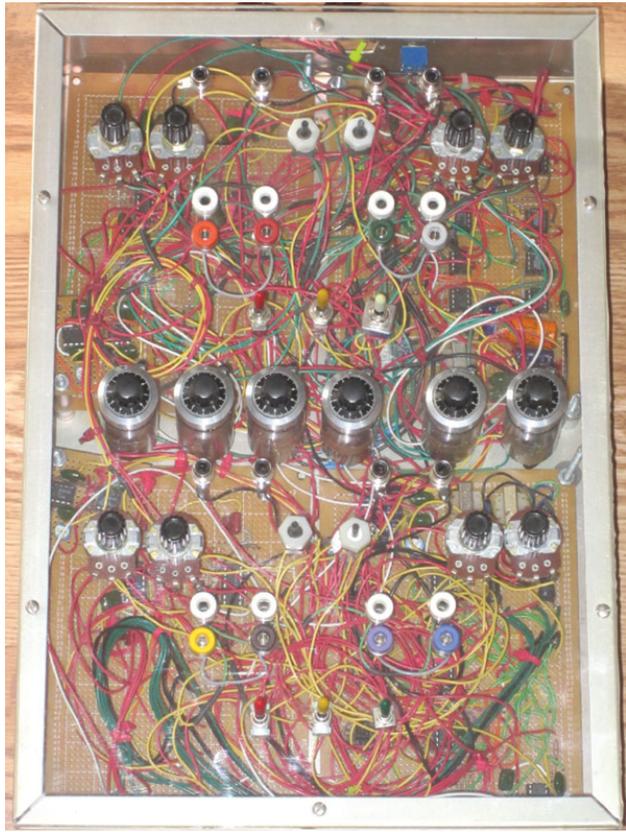
The standardization of electronic components and industrial practices means that most practitioners are linked, consciously or not, to global production processes. This connection is mirrored in global patterns of consumption, and both phenomena are enacted by the unequal, global connecting tissue of the Internet. Since the publication of the earlier editions of this book, a thousand fuzztones have indeed flowered thanks to Tim Berners-Lee;<sup>4</sup> this was quickly replicated ad infinitum for almost every other effect, synthesizer and controller imaginable. Hacking has only gotten easier (*ibid*) -- so much so that each electronic music genre now has its own subculture of fetishizing, criticizing and developing or ignoring technological tools. Larger manufacturers monitor potential markets through the public platforms that propagate these do-it-yourself and do-it-together projects, and respond by producing variations of old, nostalgic favorites on a regular basis - for a premium.<sup>5</sup> This continues the cycle of over-production, cannibalization and adaptation that fostered hacking practice in the first place.

Tara Rodgers reminds us that none of these instruments are made in a vacuum, and that each instance of handmade electronic music is an opportunity to think about how online and off-line resources have led to the development of temporary, erratic, ad-hoc groups.<sup>6</sup> The conditions specific to each project—available parts, information, ideas, individuals—shape the final results. This dynamic process is, however, is not well-documented.<sup>7</sup> Recovering the labor and paths of knowledge in the making of handmade electronic music has become a mission for a number of individuals, online communities and academic subdisciplines, who grapple in different ways with the friction between global technological commodities and small-scale art practices.<sup>8</sup>

*Handmade Electronic Music* did not explicitly ask how hacking communities emerged (it was not a sociological study), but it did offer a peek into the extensive body of work these efforts have produced, from the point of view one of the field's participants. The categories used in the book to distinguish meaningful technological sub-trends—circuit bending, feedback, battery-powered, bands, audiovisual, mechanical, circuits from scratch—reflected the author's experiences and perspective. The inclusion of a variety of new authors in this third edition is an

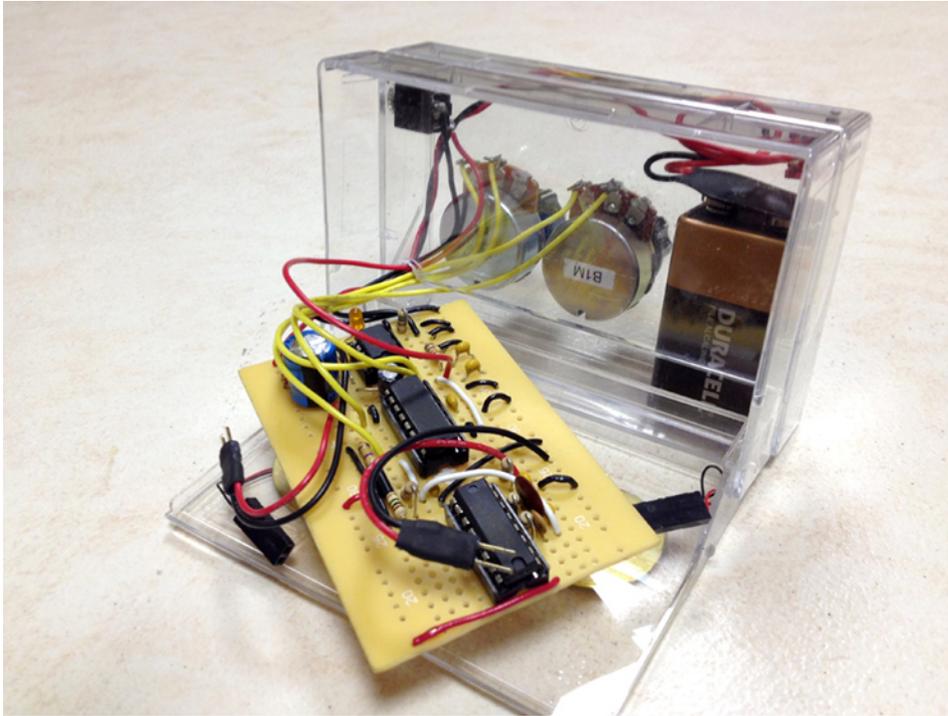
acknowledgement of the breadth of contemporary activity. In this chapter I discuss recent projects, some of which fit Collins's earlier categories, while others require new groupings to accommodate their inspirations and aspirations.<sup>9</sup>

## Chaos



**Figure 1** David Dunn, *Thresholds and Fragile States*. Device and corresponding block diagram for the first half of the circuit (second half is a mirror copy). Images courtesy of the artist.

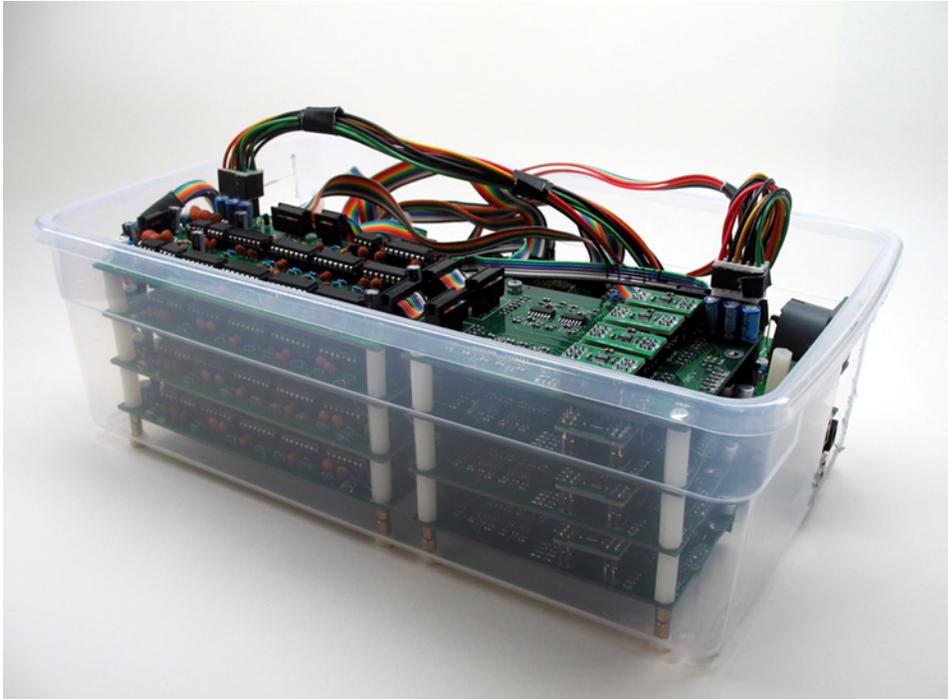
David Dunn is among a number of musicians interested in chaotic behavior in sonic contexts. His *Thresholds and Fragile States* (2010-2011) is a synthesizer built around a network of four chaotic "jerk" oscillators.<sup>10</sup> He was inspired by listening to the "emergent logic" of shifting sonic balances in Louisiana's Atchafalaya basin, and describes the work as "an attempt at understanding pattern formation in natural sound systems."<sup>11</sup> The unpredictable nature of the circuit, which cannot be "controlled" so much as "oriented," is reflective of a longstanding trend in experimental electronic instrument design to foreground rather than minimize chaotic patterns. Dunn works between the scale of his sonic environment and that of his handmade electronic system, listening to both so one can inform his experience of the other. This type of generative electronic system behavior, which Dunn calls "autopoiesis," has precedents in instruments such as in Salvatore Martirano's *Sal-Mar Construction*<sup>12</sup> and David Tudor's feedback network compositions.<sup>13</sup>



**Figure 2** One of Blonda's Chaos Boxes, built from two clear cassette tape enclosures. Photo courtesy of the artist.

David Kant, a student of Dunn's, has expanded on this tradition of chaotic hardware with a software model of Dunn's circuits for the audio programming language Supercollider.<sup>14</sup> He had earlier built circuits with Madison Heying for their duo, Blonda, including a set of nonlinear feedback circuits based on the 4046 phase-locked loop integrated circuit (see Chapter 23) which exhibited chaotic behaviors. In their iteration of the 4046 circuit, the input and the output of each Chaos Box are routed to piezoelectric discs, both attached to the surface of the enclosures. Blonda performs by manipulating both the control knobs and the boxes themselves—hitting, scrubbing, scraping and otherwise using these enclosures as resonant bodies. In a process not dissimilar to Dunn's use of the Thresholds and Fragile States system, Heying and Kant listen to the patterns that emerge between these electrical and acoustical feedback paths, as mediated by the phase-locked loops, in an attempt to direct the devices roughly down the musical paths they wish to go.<sup>15</sup>

You Nakai's and Michael Johnsen's 2016 paper on David Tudor's *Untitled* (1972) and *Toneburst* (1975) inspired composer Philip White to update an earlier mixer-based feedback system for use in his Feedback Instrument (2017). Drawing on accounts of Tudor's electronics experiments, as well as on his own a decade of experience composing with feedback using traditional mixers, White developed a new hardware and software system that could be controlled digitally. It is not a purely chaotic system, but no-input setups such as those used by White and Tudor produce unstable melodic, rhythmic and timbral patterns that White uses extensively in his solo and collaborative recordings. The Feedback Instrument is built with off-the-shelf electrical components, and subsystems such as the VCAs are adapted from an open source modular synthesizer manufacturer.<sup>16</sup>



**Figure 3** Part of Philip White's Feedback Instrument. The system includes a number of other modules. Photo courtesy of the artist.



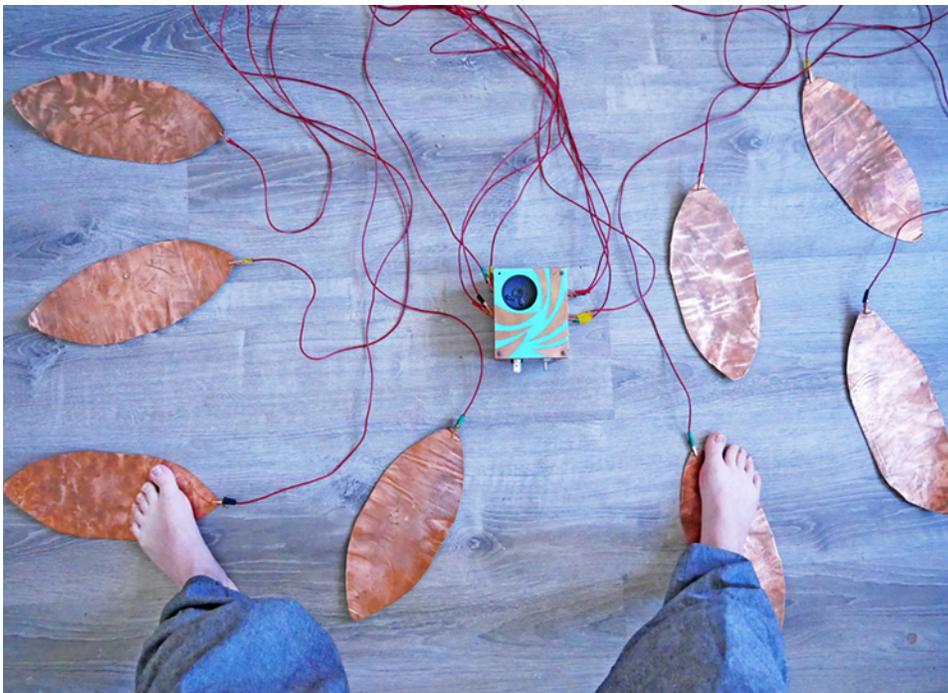
**Figure 4** Bonnie Jones, digital delay pedal setup. Photo credit: Dani Restack.

Bonnie Jones's electronic setup offers her perspective on how one might explore the sonic affordances (if not personalities) of electronics. Jones's improvisations reveal sounds produced throughout the circuit board by removing the back cover, flipping the pedal bottom up, and touching a one-eighth-inch jack to various solder joints on the board. In contrast with Vic Rawlings's exploration of multiple types of pedal circuits (see his video in the "Laying of Hands: section of the Gallery on the website), Jones investigates generations of a specific series of digital delay effects. Each revision of the pedal has a different circuit layout, resulting in different feedback patterns that get piped to the P.A. This is not the way the manufacturer

intended these pedals to be used, and each effect box reacts differently to the harsh feedback treatment, with some components misbehaving or failing over time. Jones's system thus almost hacks itself, much like the self-destructive cybernetic circuits of Louis and Bebe Barrons, which produced the soundtrack for the 1957 film *Forbidden Planet* and overheated themselves into malfunction.<sup>17</sup> Jones states:

Electronic noise makes audible the hidden, the background, the "unwanted." It asks us to be inside of our bodies, to resonate with our surroundings. To be aware of each other, to listen. Our bodies vibrate with its secret messages, its rich complexity. The circuit board becomes a sonic geography, there are known localities, but also unknowable edges, everything is relation and context.<sup>18</sup>

For Jones, electronics serve an ethics of listening, realized in each performance and recording.



**Figure 5** Anastasia Clarke, Cracklepads. Photo courtesy of the artist.

Adapting Michel Waisvisz's classic 1970s Cracklebox circuit, Anastasia Clarke's Cracklepads (2018) take the historic, erratic circuit originally designed for finger control, and opens it to full-body interaction. Clarke's circuit differs from Waisvisz's in a number of ways: it uses an NTE909D IC instead of the original 709, includes eight touch points instead of six (one placed on an empty pin of the 909D, and one on the output of the LM386), and adds a potentiometer after the 386, which unintentionally gave the device the capacity to self-oscillate. As such, it requires its user to touch the instrument to silence it.<sup>19</sup> The interface is novel as well—Clarke drew inspiration from Peter Blasser's "androgynous nodes" to add brass nails in place of the Cracklebox's traditional touch points.<sup>20</sup> She sees these as "neither input nor output, but cross-puts for making any number of unique connections."<sup>21</sup> The design of her instrument includes elements that respond to this concern and affect modes of interaction. In performance, she wires

these rods to large copper petals strewn around the performance space. The result is a full-body instrument that only functions when two or more nodes touch the skin.

### **Electromechanical**

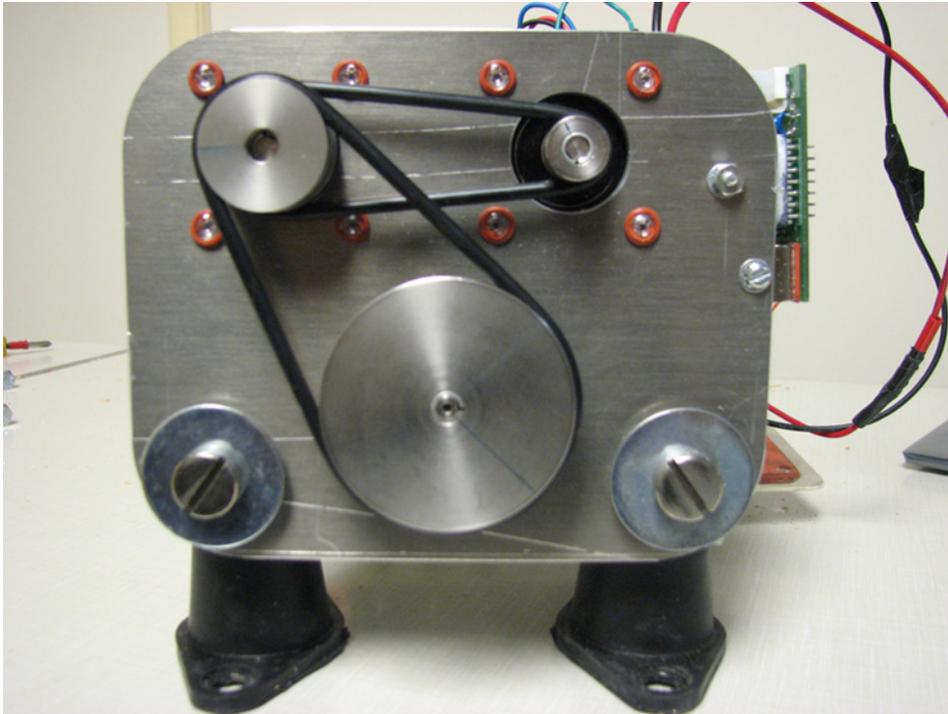
Artists such as Troy Rogers, Scott Barton or Steven Kemper have developed musical automatons—motors, microcontrollers and handmade instruments assembled in digitally-orchestrated ensembles that extend the long tradition of music boxes and player pianos.



**Figure 6** Ragnhild May, *The Flute Player* (2015). Photo courtesy of the artist.

Ragnhild May's electro-mechanical systems, both installed and performed, explore the potential of recorders and air pumps as partially automated instruments. Reminiscent of Maryanne Amacher's psychoacoustic compositions, *The Flute Player* (2015) uses 132 fipple flutes, a vacuum cleaner and five air mattress pumps droning and chaotically generating otoacoustic

phenomena. This offers a brute-force contrast with May's more recent, controlled installation system *School Harmony* (2018), which augments the flutes and air pumps with a microcontroller-automated system to direct the organ pump-bellows and valves to individual flutes of different sizes.



**Figure 7**, Jeff Snyder, Birl Tone Generator. Photo courtesy of the artist.

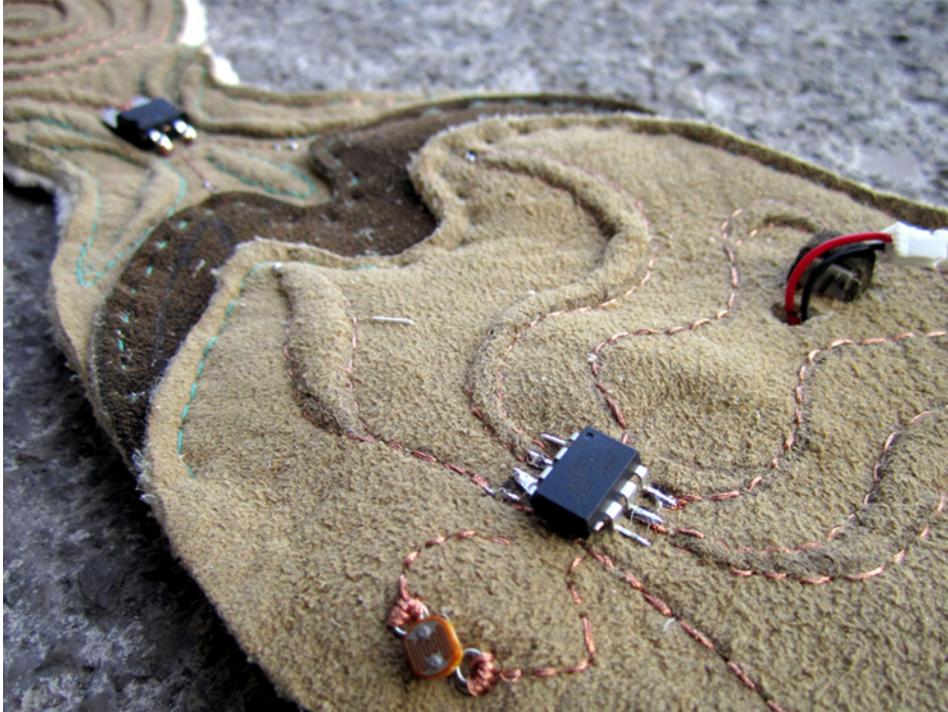
Jeff Snyder's Birl Tone Generators<sup>22</sup> are stepper-motor driven dynamos whose power input is used as an output: as the motor's driveshafts get turned, they produce tones that are used as the basis of a subtractive synthesis system. Pulleys of smaller diameters are used for octaves, which are fed through waveshaper, filter and voltage-controlled amplifier. Thaddeus Cahill's Telharmonium performed additive synthesis and had a constant-speed central drive-shaft for every note and its octaves (see chapter 4), and the Birl Tone Generators are effectively comparable over a century later: electromagnets spinning to generate tones.<sup>23</sup>

### **From Scratch?**

Although most of the projects described here could be considered to have been made "from scratch," some engage with the usually unchallenged substrate of circuits: the components and the printed-circuit-board themselves.

With her *Leathersynths* (2013) Hannah Perner-Wilson investigates the possibility of developing electronic components locally rather than as part of a global market. Reflecting her working environment in Austria, the projects explore a variety of culturally and historically informed possibilities. Some employ a local relief embroidery technique (traditionally used to decorate lederhosen) to create conductive traces between components, as well an embroidered coil that functions as both electromagnet and membrane of a pair of Leatherphones. Other instruments are

knitted with wool from local sheep that is combined with stainless steel fibers to make pressure and stretch sensors (see Chapter 16), or are woven using a Celtic card weaving technique to make multi-conductor ribbon cables with traditional patterns.



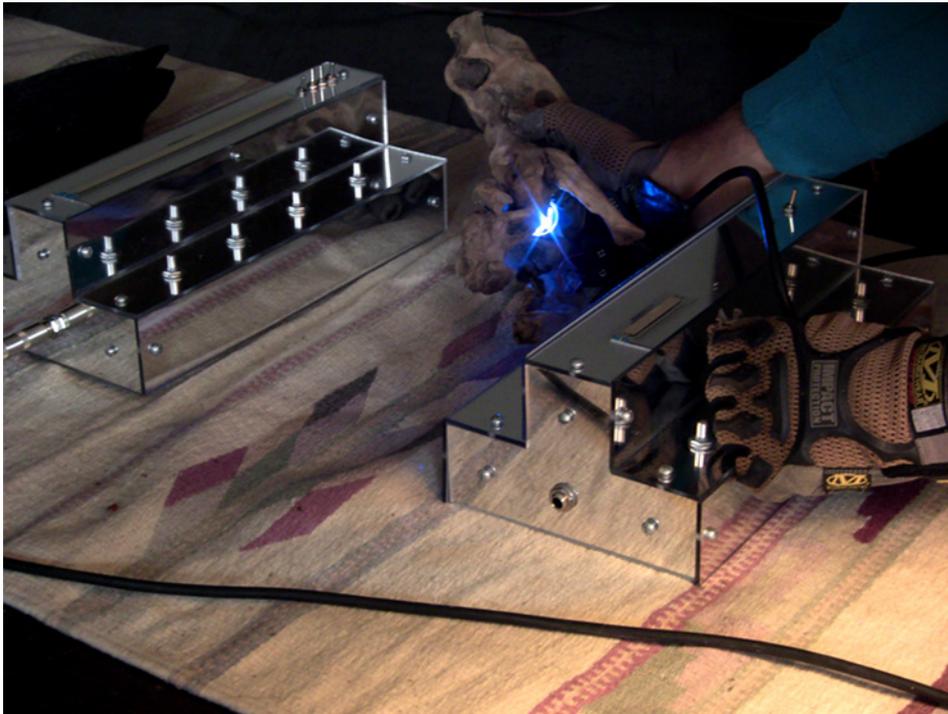
**Figure 8** Hannah Perner-Wilson, Leatherphone. Photo courtesy of the artist.



**Figure 9** Victoria Shen, dB meter earrings. Photo courtesy of the artist.

Victoria Shen and her LED meter earrings extend material exploration in directions suggested by Perner-Wilson, Blasser (see Chapter 26) and Nyler Steiner (Jordan 2015, 44). Shen, who performs under the name Evicshen, worked in the mid-2000s helping Jessica Rylan build chaotic

synthesizers as part of her Flower Electronics brand.<sup>24</sup> Shen has built flexible vinyl-cut circuits that correlate the sound intensity picked up by a microphone to the brightness and color of LEDs. Presented as earrings, these wearable circuits offer visual feedback for and around Shen's sonic performances, indicating when sounds are reaching potentially dangerous levels of volume. Echoing the wearables and soft circuit work of Kat McDermott's Urban Armor series, these handmade experiments offer an alternative basis for the assembly of circuits (clear vinyl) to complement a visual interpretation of sound.



**Figure 10** Two of MSHR's Nestar instruments, with control glove and LED light controller. Photo courtesy of MSHR.

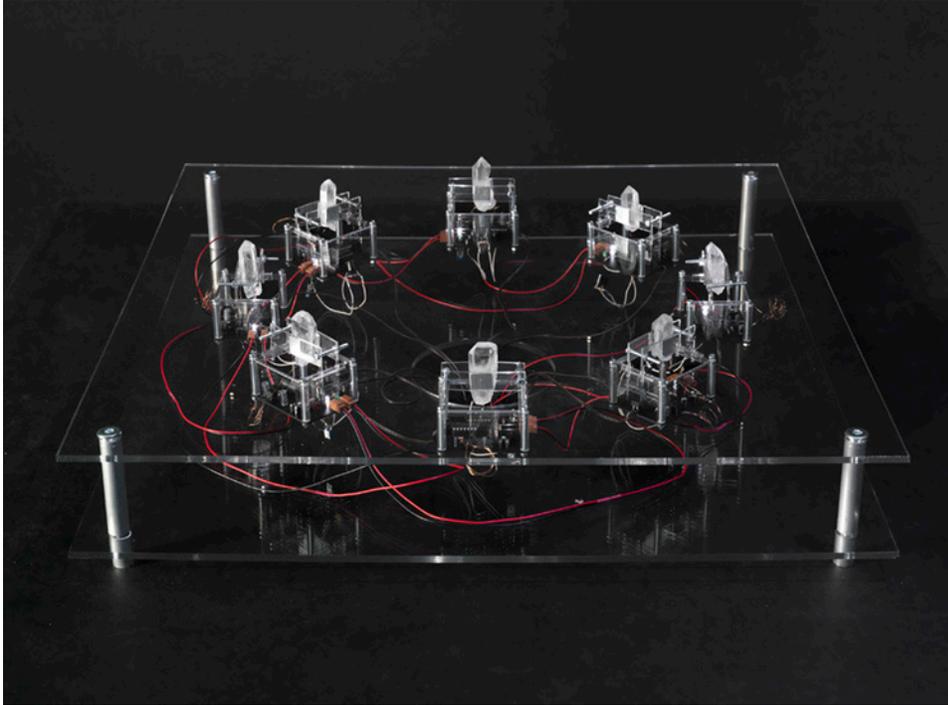
MSHR (Brenna Murphy and Birch Cooper) have developed a number of custom audio-visual electronic instruments for immersive performance ceremonies and installations. The distinctive mirror casing of their devices is a functional decision. These instruments are often light-sensitive: the reflections from one enclosure onto another affect the sound. The Nestar is based on the quad NAND gate CD4093 IC. Each gate is wired as a square wave oscillator whose frequency control can be patched to MSHR's numerous light-sensitive controllers (photocells embedded in translucent plastics of various colors and shapes). A ribbon controller “bleeds” the IC’s power source, which extends the range of timbres and behaviors produced by the oscillators as they begin to operate erratically with low voltages. Performing with multiple Nestars, MSHR use a light organ to produce an array of beams aimed at the photosensitive controllers. They explicitly identify the sculptural aspect of their performance setup, focusing on the use of light filters to affect sound, as an opportunity to interact with signals in a unique controllable way that has shaped their output as musicians.



**Figure 11** Martin Howse performs *Final Session* at Solu in Helsinki, 2019. Photo Credit: Solu Bioarts Society.

Echoing Gustav Metzger's auto-destructive art,<sup>25</sup> and prompted by precedents as varied as the alchemical writings and illuminations of anonymous medieval scribes (detailed in the work of Deborah Harkness, Charlotte Fell Smith and Dame Frances Yates), Bram Stoker's *Dracula*, and the work of media theorist Friedrich Kittler, Martin Howse's performance setups and instruments involve heat and acids to transform materials. Citing Shintaro Miyazaki, Peter Flemming and Bengt Sjolen as contemporaries with similar interests, Howse engages with the composition of the components themselves, often using soil and other pulverized, molten or burnt mediums as electrical components, taking advantage of the fact that numerous familiar substances can conduct, resist or store electricity to some extent. His 2019 performance piece "Final Session" uses "earth, worms, burning matter, temperature sensors, violet laser and minerals" alongside custom electronic systems (for which he open-sources the code and circuit designs), to decode "earth and air signals through un-refined electrochemistry and manipulation of earth-bound electrons, air and light."<sup>26</sup> For Howse these manipulations reveal the processes that lead to the existence of his tools, and in describing his interests he conveys the role of alchemy in shaping his approach to handmade electronic music:

*That which is to be divined in the unfaithful language of replayed temperature change, earthy smoke, dust, glass machines, plant stones, and ear stones are the various past and future depositions, intrusions, compressions, degradations, and gradings of lithic entropy, these everyday deformations of contemporary energy.*<sup>27</sup>

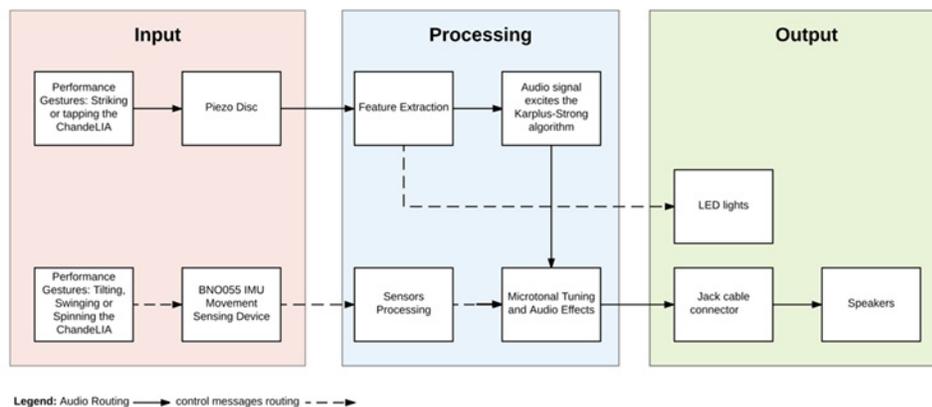


**Figure 12** One of the five subsystems in Ralf Baecker's *Irrational Computing*. Photo credit: Roman März.

Ralf Baecker's *Irrational Computing* (2011) utilizes five interconnected modules based around crystals: silicon, germanium, galena and silicon carbide (all of which are used in microscopic amounts in integrated circuits) as the basis for grotesque, macroscopic mockeries of modern computing systems. Through photoelectric and piezoelectric effects, the crystals convert electricity, light and mechanical vibrations into other forms of energy. Some of these outputs are fed back into a complementary module, creating a complex feedback network. Echoing the concept of the circuit as score as well as the theme of musical chaos, media theorist Ryan Jordan describes Baecker's pieces as having "no musical or compositional intention as such; instead, these works allow the machines, or rather the elements of the machines, to compose themselves."<sup>28</sup>

## Control

While some handmade electronic music has a tendency to engage with the more chaotic suggestions of the materials that surround us, a contrarian subcurrent has focused on the development of controllers for digital music synthesis systems. Working with the increasingly programmable nature of digital audio workstations and other software tools, and relatively ease to use standards, from MIDI to OSC, projects offering assignable knobs, switches and potentiometers have multiplied. A number of these are open source, encouraging the sharing of variations adapted by makers/composers/performers.<sup>29</sup>



**Figure 13** Functional diagram for Lia Mice's ChandelLIA instrument. Image courtesy of the artist.

Lia Mice's ChandelLIA (2018) is a chandelier augmented with a piezo microphone and an orientation sensor, wired to a Bela open source digital signal processing device (McPherson et al 2016), which adds low-latency audio inputs and outputs to a Beaglebone small Linux computer, as well as the ability to interface with various sensors. The signal from the piezo triggers a Karplus-Strong algorithm, connecting the chandelier to a digital, real-time model of a vibrating string that runs on the Bela-Beaglebone package.<sup>30</sup> Various musical parameters of this algorithm are controlled, also in real time, by the orientation sensor in the chandelier. Musical behaviors are then achieved by moving, flipping, tapping and touching the chandelier.



**Figure 14** Asha Tamirisa, Matrixharp. Photo courtesy of the artist.

Asha Tamirisa's Matrixharp (2015) is a hardware interface that utilizes a grid of stretch sensors and capacitive sensors to make patch connections and modulate parameters of digital synthesis. This interface and its corresponding software explore the potential of no-plug controllers, inspired by matrix interfaces of the ARP2500 and the EMS Putney. Matrixharp is motivated by a desire to move beyond the gendered and directional connectors of most electronic music hardware.<sup>31</sup> In it, patch connections are “felt” throughout the system through the tension of the

stretch sensors, resisting the localized logic of modular hardware. In accordance with the idea that all hardware hacking has political meaning (see Kori and Novak, this volume), the Matrixharp joins a growing set of handmade electronic music devices in which political explicitly influence design and, as a result, musical performance.



**Figure 15** Quran Karriem and Rebecca Uliasz playing with the Synthball. Photo courtesy of the artists.

Quran Karriem and Rebecca Uliasz's Synthball developed as part of a wider intermedia project involving dancers, graphic artists and historical research directed by Thomas DeFrantz. It "includes three-dimensional accelerometer data, a gyroscope to measure changes in rotational orientation, [and] a magnetometer to measure gravitational fields."<sup>32</sup> The streamed data controls a digital audio/visual synthesis system that can only be partially controlled: humans are not machine-like in their catching and throwing. The Synthball reminds electronic musicians that the motions such as throwing or bouncing a ball—so much more limited in precision than "knob twiddling"<sup>33</sup>—have affordances worth exploring.<sup>34</sup>

### **There still is no conclusion<sup>35</sup>**

There are as many visions of electronic music's future as there are instrument makers and designers. If no particular project from the last decade has emerged as the "next big thing" that Collins hypothesized in the second edition of *Handmade Electronic Music* (see "The Future Was Then" on the website), the categories and projects discussed above hint at shifts in nature of available materials and conceptual trends. From electro-musical chaos to technologically-mediated semblances of control, and across vibratory mediums, hacking remains a diverse and active mode of composition, responding to local cultural and political contexts. This is clear from my own partial perspective, but also many global case studies and longitudinal analyses (see in this book the essays by Curci et al., Van Gelder and Kelly, or Kori and Novak, as well as writing by Dal Farra, Flood, Gordon, Lerner).<sup>36</sup> Given the role that handmade electronic music has come to play in the construction of communities, we can see how important it is to document both the making process and the conditions that enable it, as such documentation can foster

further projects and extend awareness of shared values and of the systems of power inevitably at play.

Hardware is just where the hacking begins.

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<sup>1</sup> Collins, Nicolas. 2007. "Live Electronic Music." In *The Cambridge Companion To Electronic Music*, 45. Cambridge: Cambridge University Press.

<sup>2</sup>For a detailed theory of contemporary musical practices as inherently collaborative, see Georgina Born's relational model of musicology (Born 2010).

<sup>3</sup> Lucier, Alvin. 1998. "Origins of a Form: Acoustical Exploration, Science and Incessancy." *Leonardo Music Journal*, 5–11. We can expand the concept here to include all sorts of technical abstractions, from computer code to layout diagrams and interface designs, as they have since all been used to explicitly or implicitly prescribe and describe musical works to various extents.

<sup>4</sup> See Collins 2009. *Handmade Electronic Music: The Art of Hardware Hacking*. Second. New York and London: Routledge, p 297.

<sup>5</sup>The current fuzz pedal market is a good example.

<sup>6</sup> Rodgers, Tara. 2015. "Cultivating Activist Lives in Sound." *Leonardo Music Journal* 25: 79–83.

<sup>7</sup> The philosopher of technology Gilbert Simondon would call that process *individuation* Simondon, Gilbert. 1958. *Du Mode d'existence Des Objets Techniques*. Paris: Aubier.

<sup>8</sup> There are too many examples to list but see, for example, Holzer, Derek. 2010a. "Schematic as Score: Uses and Abuses of the (in) Deterministic Possibilities of Sound Technology." In *Vague Terrain 19*, edited by Derek Holzer.

<https://web.archive.org/web/20131124040627/http://vagueterrain.net/journal19>, the circuit tracing subforums on freestompboxes.org, or the growing field of media archaeology: Parikka, Jussi. 2011. "Operative Media Archaeology: Wolfgang Ernst's Materialist Media Diagrammatics." *Theory, Culture & Society* 28 (5): 52–74; Striegl, Libi, and Lori Emerson. 2019. "Anarchive as Technique in the Media Archaeology Lab Building a One Laptop Per Child Mesh Network." *International Journal of Digital Humanities*, April.

<https://doi.org/10.1007/s42803-019-00005-9>.

<sup>9</sup> Non-hierarchical electronic instrument taxonomies offer the advantage that they can be expanded to match the self-labeling of these disparate practitioners and ad-hoc communities. See Magnusson, Thor. 2017. "Musical Organics: A Heterarchical Approach to Digital Organology." *Journal of New Music Research* 46 (3): 286–303.

<sup>10</sup> In physics, "jerk" is the third derivative of displacement with respect to time, which can also be thought of as the time-derivative of acceleration (Spratt, Julien Clinton. 2011. "A New Chaotic Jerk Circuit." *IEEE Transactions on Circuits and Systems II: Express Briefs* 58 (4): 240–243). Incidentally, Spratt co-authored paper on these type of chaotic oscillator circuits with Jessica Rylan-Piper, mentioned below: Piper, Jessica Rylan, and Julien Clinton Spratt. 2010. "Simple Autonomous Chaotic Circuits." *Circuits and Systems II: Express Briefs, IEEE Transactions On* 57 (9): 730–34.

<sup>11</sup> See Dunn, David. 2011. "Thresholds and Fragile States." Unpublished Score.

<sup>12</sup> Cuervo, Adriana P. 2011. "Preserving the Electroacoustic Music Legacy: A Case Study of the Sal-Mar Construction at the University of Illinois." *Notes*, 33–47. Franco, Sergio. 1974.

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“Hardware Design of a Real-Time Musical System.” Urbana-Champaign: University of Illinois. PhD Thesis.

<sup>13</sup> Nakai, You. 2016. “On the Instrumental Natures of David Tudor’s Music.” New York University. PhD Thesis.

<sup>14</sup> Kant, David. 2017. “Thresholds and Fragile States by David Dunn.”

<http://www.davidkant.com/thresholds/index.html>.

<sup>15</sup> Kant, David, and Madison Heying. 2018. “Blonda.” February 23, 2018.

<sup>16</sup> White, Philip. 2018a. “Feedback Instrument (Pt 1).” <http://prwhite.net/instrument-pt1/>.

———. 2018b. “Feedback Instrument (Pt 2).” <http://prwhite.net/feedback-instrument-pt-2/>.

Gillet, Emilie. 2019. “Veils.” [https://mutable-instruments.net/modules/veils/open\\_source/](https://mutable-instruments.net/modules/veils/open_source/).

<sup>17</sup> Greenwald, Ted. 1986. “The Self-Destructing Modules Behind Revolutionary 1956 Soundtrack of Forbidden Planet.” *Keyboard Magazine*, February 1986.

<sup>18</sup> email exchange with the author, Nov. 8, 2018.

<sup>19</sup> Clarke, Anastasia. 2018. “Self/Work: Performing Attention in an Exploration System.” Master's Thesis, Mills College, 53.

<sup>20</sup> Blasser, Peter. 2015. “Stores at the Mall.” Wesleyan University. Master's Thesis, 32, 67

<sup>21</sup> Clarke 2018, 53

<sup>22</sup> Snyder, Jeff. “Birl Tone Generator - Close Up of Prototype.” <https://vimeo.com/15472241>;

“Research.” 2010. <http://www.scattershot.org/research.htm>.

<sup>23</sup> Cahill, Thaddeus. 1897. Art of and apparatus for generating and distributing music electrically. US Patents Office.

<sup>24</sup> Rylan had herself worked with synth designer Donald Buchla prior to starting Flower Electronics.

<sup>25</sup> Metzger, Gustav. 1969. “Automata in History.” *Studio International*. Wilson, Andrew. 2008.

“Gustav Metzger’s Auto-Destructive/Auto-Creative Art: An Art of Manifesto, 1959–1969.”

*Third Text* 22 (2): 177–94. <https://doi.org/10.1080/09528820802012844>.

<sup>26</sup> Howse, Martin. 2019. “The Final Session.” <http://www.1010.co.uk/org/final.html>.

<sup>27</sup> Ibid

<sup>28</sup> Jordan, Ryan. 2015. “DIY Electronics: Revealing the Material Systems of Computation.”

*Leonardo Music Journal* 25 (25): 44.

<sup>29</sup> See for example Chang, Kevin. 2019. “Pd Knobs.” Sonoclast: Electronic Instruments for Music. <http://sonoclast.com/products/pd-knobs/>;

or the 16n in Crabtree, Brian, Sean Hellfritsch,

Tom Armitage, and Brendon Cassidy. 2017. “16n.” <https://16n-faderbank.github.io/>.

<sup>30</sup> Sullivan, Charles R. 1990. “Extending the Karplus-Strong Algorithm to Synthesize Electric Guitar Timbres with Distortion and Feedback.” *Computer Music Journal* 14 (3): 26–37.

<sup>31</sup> Blasser 2015, 1

<sup>32</sup> Karriem, Quran and Rebecca Uliasz. 2017. “Synthball.”

<http://qurankarriem.com/portfolio/synthball/>.

<sup>33</sup> Paradinas, Mike and Richard D. James. *Expert Knob Twiddlers*. Replex, 1996. Record released under the name "Mike and Rich".

<sup>34</sup> Evens, Aden. 2005. *Sound Ideas: Music, Machines, and Experience*. University of Minnesota Press:160, Rován, Joseph “Butch.” 2009. “Living on the Edge: Alternate Controllers and the

Obstinate Interface.” *Mapping Landscapes for Performance as Research: Scholarly Acts and Creative Cartographies*.

<sup>35</sup> Collins 2009: 294

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<sup>36</sup> Dal Farra, Ricardo. 2006. "Something Lost, Something Hidden, Something Found: Electroacoustic Music by Latin American Composers." *Organised Sound* 11 (2): 131–142; Flood, Lauren. 2016. "Building and Becoming: DIY Music Technology in New York and Berlin." Columbia University. PhD Thesis; Gordon, Theodore Barker. 2018. "Bay Area Experimentalism: Music and Technology in the Long 1960s." University of Chicago; Lerner, Martín Matus. 2019. "Latin American NIMes: Electronic Musical Instruments and Experimental Sound Devices in the Twentieth Century." In *Proceedings of the International Conference on New Interfaces for Musical Expression*.