Wesleyan University

STORES AT THE MALL

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A Survey of Modular Folk

While for many years I avoided the normative synthesizer community, the Eurorack modular standard proliferated, linking a multitude interfaces and philosophies in an infinitely configurable system.[1] Why should I avoid it? One reason was its three-rail power system; I prefer a two rails for the most efficient use of batteries and space.[2] Also, my typical use of wood panels would not port well. Wood insulates the exposed brass nodes of an experimental playing surface. In contrast, Eurorack encourages aluminum face-plates and gendered connectors, continuing a historical philosophy focusing on inputs, outputs, and their correspondence.[3]

A modular panel system offers the designer a single two-dimensional face. Of course, knobs protrude and indicator lights shine, but consider how well modules represent on flat screens; they easily cross the border between physical and virtual.[4] I resist flattening my synthesizers; with multiple control faces, ovoid shapes, or surfaces for physical contact, my instruments accentuate their own physical presence vis a vis the virtual. However, paintings transcends their flat canvas with perspective, or an impression of depth. The challenge of modular design is to afford sonic depth

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1 Eurorack shares mechanical specifications with the international 19-inch rack standard ANSI/EIA-310-D-1992. It also specifies a three-rail power system, of ground and positive and negative twelve volts DC regulated.

2 A two-rail power supply usually supplies nine volts, so it works with both a nine volt battery and a twelve volt external transformer, which it regulates internally. Modern circuit components work at lower potentials, allowing an analog resolution comparable to three-rail systems.

3 Asha Tamirisa is currently working on a critique of the gendered system of synthesizer connectors, and searching for alternative modalities, such as the slider/matrix system on the Arp. Her manifesto for the OpenSignal festival covers these topics as well as sexism in the online synthesizer community.

4 For example, consider Max/MSP, a computer music program, which recently introduced the Beap library of objects imitative of Eurorack modules.

by wide range controls and diverse modulation possibilities.

I set out to characterize the modular synthesizer industry, by participating in two events: the Tokyo Festival of Modular Synthesizers; and Control Voltage Fair, in New York. I had long had a bitter taste from such fairs, because of poor sales at the event, and also an oppressive loudness in the bazaar due to competing demonstrators. For this reason, I wished to participate with an experimental performance mentality. Also, due to the scholarly funding[5], I could adopt a researcher's attitude towards the technology, akin to Georgina Born's ethnography of IRCAM (Born, 1995). I intended to research the aesthetics of booth presentations, and the folklore of technology as object of desire.

Without a finished Eurorack line of my own, I built a concept display, using Japanese washi paper to wrap a cardboard box about the size of a small Eurorack cabinet. Then I rendered my panel layouts as cards affixed to the front of the box. In the competitive and loud sales atmosphere, a silent presentation has an advantage by divesting from sound-making; it scintillates the imagination without wearying the ear.[6]

The Tokyo Festival of Modular occurred on June 7 and 8, 2014. The venue, Super Deluxe, is a mid-size basement club serving cold beer and snacks. Having no raised stage, the "headliners" tables spilled out into the space, littered by many black-

5 Wesleyan University graduate program in Experimental Music funded the research.

6 Two examples of divestment from electronic sound making: Pauline Oliveros' piece “Sound Patterns,” which specifies electronic sounds to be performed by an a cappella chorus; Alvin Lucier's piece “Gentle Fire,” which outlines three steps, of collecting natural sounds, synthesizing them electronically, and finally imagining those processes mentally, thus concluding as a completely imaginary process.

draped merchandise tables. The name "Festival of Modular" implies that it will feature Eurorack modules. However, there were a few standalone type instruments, and my booth, besides its conceptual paper Eurorack, was in this minority.

The sound was overpowering, an extremely loud cacophony of mixed sequences and other blips and bloops. I regret that did not record the sound, for the pain it had caused my ears may have become bliss when re-listening at low volumes on a home stereo. There, I could analyze it and perhaps enjoy it like an atmosphere of ambient frogs on a hot summer night.

The venue provided a powered speaker to each table, where the proprietor would patch and tweak a sonic presentation. I could aurally identify many sequencers.[7] However, an island of idiosyncratic, non-linear and un-striated sound assemblages interested me, so I focused on these four tables and their proprietors. Due to baggage restrictions, each brought only a small suitcase worth of modules. Thus they chose only the most important modules, and a comparative analysis of each distillation proved insightful.

Scott Jaeger resides in Seattle, where he runs "The Harvestman," a series of Eurorack designs that have interesting names and function. For example, the "Piston Honda" is a three-dimensional wave-table synthesizer, but its name suggests more mundane origins; did Scott's Honda Civic inspire a sophisticated synthesis for its emulation? Besides original designs, Scott also offers modules from an esoteric Soviet synthesizer, the Polivoks. Scott worked with the designer Vladimir Kuzmin to

7 There are many sequencer module designs, but they generally accomplish the same thing- repeat a discrete set of arbitrary voltages indefinitely.

bring back the "bizarre, aggressive, and entirely unique character" in Eurorack format. The filter, for example, uses no external capacitors, and relies solely on the non-linear and contingent capacitance inside the silicon components. It seems Scott is skilled at compartmentalizing his business into unique sub-groups with strong identities. Harvestman's aesthetic is uniform in color, with orange knobs over an aluminum background. However, there is a certain pragmatism in the layout, reflecting the idiosyncratic nature of the modules themselves.

All of Harvestman's aluminum face-plates are manufactured in Cincinnati. To some collectors of Eurorack modules, a consistent aluminum appearance is very important, dating back to the earliest day when a single German manufacturer, Doepfer, set the standard. Since I was contemplating alternative face-plate materials, I asked Scott about the aluminum standard. He finds the company in Cincinnati very convenient for aluminum plates, but says that he personally has no problem with alternative materials.

There are three reasons to use alternative materials in the face-plate: simply to introduce a new color and instant recognition to one's brand; for touch sensitive surfaces that require an insulating substrate; and as a lighter alternative. The particular material I considered, fiberglass circuit board, also diffuses light, giving it a halo. Indicator lights need a drilled hole in aluminum face-plates, making them sharper. I prefer the diffuse alternative because it seems to swell and contract with analog undulations, like an organic form.[8]

8 I learned about light diffusion while working with Baltimore artist Dan Conrad, who makes “light paintings,” illuminated boxes that explore the effect of color perception, like animated Joseph

At another table stood Josh Holley, president of Malekko Heavy Industry, presenting more Eurorack modules. Josh is skilled at networking with other designers, to license and adapt modules for a maximum variety under one roof. In fact, his main business is the Dark Space manufacturing center, offering assembly services to synthesizer designers. Thus his business integrates original designs of his own with outsourced and sub-contracted services.

A glance at the Malekko showcase gives a sense of uniformity, whilst representing many different lines. Fonts, knob style, layout and legend differentiate each line. Layout is important because Eurorack is a small standard, so the multitude of knobs and jacks can feel crowded to users. Malekko represents two main layout styles: those that places knobs and jacks together according to their functional association, and a separation of knobs and jacks into two separate bays.[9]

Another integrative personality, Cyrus Makarechian, represented Muffwiggler.[10] His suitcase sized rack featured modules constructed of different materials: clear plastic, fiberglass, and aluminum. Most modules have a legend to describe their function; those lacking it demanded intuitive skills of the performer. In representing a diverse forum of synthesizer builders, Cyrus seeks sublime new

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Albers paintings. At Total Plastics Incorporated, he schooled me in the variety of diffuser plastics, as well as the correct box depth for diffusion. His brother Tony Conrad, in contrast, used harsh flickering in his own visual work, and I would hypothesize a tension between the direct and diffuse use of light, and extrapolate to the current discussion on aluminum versus fiberglass.

9 Wiard modules segregate knobs on top from patch points below, whereas many other designers choose to integrate knobs and jacks, so that functionality flows smoothly from manual control to patching.

10 Mike McGrath created the namesake of the store, the Muffwiggler forum, devoted to analog synthesizers and synthesis in general. It was a natural outgrowth to start an Internet store, that showcases all the mainstream modules, but according to Cyrus, it also sells the more idiosyncratic and esoteric modules, found by combing through all the accumulated forum discussions.

connections due to the overlapping philosophies.

Across from Cyrus, a Russian named Roman Filipov displayed a small rack of Buchla clones for Eurorack, with his own twist. His table displayed an original Buchla module for reference, with the trademark separation of banana and mini-jacks, for control voltages and audio respectively.[11] There are many opinions on banana plugs versus mini-jacks, and the various systems that represent them, but Buchla synthesizers were the only systems that represented both. It is because of a structuralist viewpoint by Don Buchla, that control voltages, like a conductor, are semiotic, and audio signals are spectral; the two should never mix. Roman's Eurorack incarnations of Buchla modules force the universal mini-jack for all connections, thus re-blurring the distinction between symbol and sound; this move is important for most experimental electronic music, where modulation and meaning are allowed and coerced to trade places at frequency.

Remembering the previous conversation with Scott Jaeger, who had resurrected old Soviet circuits, I asked Roman if the esoteric circuits of his homeland interested him. He replied that he doesn't care; he prefers West Coast California 20th century circuits. In fact, he was to donate his old Soviet schematics to Scott, who was much more interested in reproducing those esoterica. Roman, a Russian, focused on west coast California circuit designs; Scott, a Seattle man, went deep in Russia for weird ideas.

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11 Don Buchla pioneered early modular synthesizers with his Buchla 100 series. Although they are not Eurorack, they do have a three-rail power supply. Banana plugs are a single conductor test cable, usually with colored plastic plugs. Different colors can indicate function. Mini-jacks are a two conductor audio cable with metal jacks; they are the standard connector for Eurorack.

Although Roman felt free to make changes in the Buchla layout, such as the standardizing of mini-jacks, he chose to preserve the sense of uniformity in aluminum, font and blue pin-lines that mark a Buchla's faceplate. Buchlas have pragmatic layout decisions, such as curved arrows for cramming extra functionality, but they appear uniform. Uniformity is important to recognize a brand. How one brand's uniformity works visually with another brand's is an important curatorial decision for the synthesizer collector.

Alfredo Aliaga's Atomosynths can modularize as Eurorack, but he chooses to display them as standalone instruments. The combination of smoked or lime green polycarbonate face-plates and clean etched lines make them attractive.[12] He uses a CNC router to cut face-plates, with a fine, one millimeter bit.[13] I considered doing the same with wood as I do my other pieces. Eurorack production demands higher volume of smaller modules, so I decided against CNC option because it would take too much time.

Tokyo has one indigenous synthesizer store, known as 5G. Like Control in New York, and Analogue Haven in Los Angeles, 5G focuses almost exclusively on Eurorack. It seems the standardized format promises repeat customers in its collectible nature. The contemporary synthesizer shop derives not from the extinct

12 It's like my son, he is addicted to fishing, and we go to the fishing tackle store. Bass is this ultimate fish because it angrily snaps at colorful plastic jelly and plastic lures. The lures combine a hyper-real visual presentation, plus churning, clicking and crunching underwater sounds; the affect on a bass is to trigger an anger response that forces it to strike. Besides the promise of catching fish, a lure hooks a fisherman as well with its hyper-real plastic colors, and most importantly in my own psychology, the sound of a new product as it is un-boxed. For examples of this, refer to Youtube ASMR and un-boxing videos.

13 CNC stands for Computer Navigated Cutter. It employs a three-dimensional motor assembly and a router machine to cut and shape materials according to computer control.

electronics store, a place where dusty and old resistors, chips and transistors are to be bought. Rather, synthesizers have risen from the ashes of compact discs and vinyl records as the currency of the music store. As a reincarnation of such, the synth shop inherits the cultural purchase of of its progenitor, and this explains much of the emphasis on face-plate design for modules. A synth shop will assemble a great library of modules, like a massive record collection, with the added benefit that they have no spines; modules always face out like a record on display. The Tokyo shop, 5G, brought an impressive wall of modular, leveraging their home field advantage to move heavy machinery.

Most Tokyo electronic music is not experimental in nature, but often features club and house drum tracks from the late twentieth century. One would expect such a modular wall to generate compounds of highly esoteric synthesis,[14] but it only pumped out house beats! The Japanese media is a tightly controlled apparatus to appropriate culture including that of the underground and anti-establishment, but it always seems to smooth it over with a sense of taste, including those house beats that marked the heights of its modern economy. Likewise, we can hear this taste applied to synthesizers. In comparison, American synthesizer usage has a diametrical sense of taste, searching for radical or hardcore formations, perhaps due to a media formation of our own?

Other local stores had more subtle flavor. Take Hikari instruments, who arranged a tasteful display of Eurorack compatible cases along with some well-

14 Eurorack users often demonstrate their systems on Youtube. A goal of such home-studio demonstrations seems to be sublime and esoteric sound assemblages.

designed promotional materials. They offer only one module, an eight step sequencer, focusing instead on building nice cabinets from wood and sometimes surplus military or industrial enclosures. This highlights the synthesizer's role as furniture, a sculptural piece and status symbol at home in a culture collection. Recycling old military cases is a nod to various underground noise and punk cultures that use such found objects for music making.

A most enigmatic local maker is known as JMT. The instruments are evidently intended for underground and noise scenes, from their website description, "analog synthesizer noise machine."[15] A prominent feature is the lack of text legends, requiring a good deal of intuition and a period of be-friending to learn their tricks. I am familiar with this design strategy, as I often renounce text as superfluous to the synthesizer; if it is necessary to name a control, I find a way to eliminate that control. JMT synthesizers are not Eurorack, but multi-faceted alternative objects.

Each night at the Tokyo festival featured a headlining performer in the later hours. I was indisposed to stay for these performances, because of my physical and spiritual condition after the synthesizer barrage. However I did observe the preparation rituals of performers before their show. Keith Fullerton Whitman brought a modular system, that he patches ahead of the show, composing and preparing his pieces for seamless execution. The performance thus consists of mixing, tweaking and improvising additional patches. The visual impact of the synthesizer performer is similar to a disc jockey- a singular artist hovering above a horizontal tableau of music

15 http://www.jmtsynth.com/, retrieved April 2015.

devices.[16] The synthesist performer diverges from DJ appearances by allowing a pleasant tangle of colorful and totemic wires to spill from his table, marking it as messier and more configurable than turntables. Note how in the following picture, Keith's wiry and curly beard, in pointing to his patches, makes a connection between the compositional motives dwelling in his skull and their tangled manifestation on the table.

Illustration 1: Keith Fullerton Whitman at Tokyo Festival of Modular

Keith is my friend, and he smiles in this picture. But besides friendship, he has another reason to smile- he received compensation for his performance at the festival.

16 I would say the artist is "un-hunched" because a successful performer maintains a distance from the gear, never obsessing or distracted by it, not hunching over it publicly. One strategy shared with a disc jockey is to dance, or sort of throb half-hunched posed behind the table.

Examining the financial structure of TOFM likens it to larger festivals such as NAMM (National Association of Music Makers), where builders pay to show their wares in a booth, but performers are paid to attract audience. This kind of event assumes that exposure is a boon to the business of presenters, and the fee also compensates the venue for logistics such as tables and amplifiers. The structure establishes a three-way relationship between presenters, performers, and visitors at the event, where presenters are brought closer to the visitors as paying guests, a sort of amalgamated audience. In theory, this “loss of face” by builders brings them sympathetically closer to their desired audience, the visitors who may eventually purchase a synthesizer. Presenters blend creative personality with informative salesperson, as talking mediator between the casual audience and the spectacle of hired performers. Keith is an ideal performer at this venue because of his large collection of modules which he uses effectively, showcasing many different makers. He has high visibility in the virtual and real worlds, and familiarity with the wide array of synthesizer products; he acts as liaison between the audience and the presenters.

Illustration 2: T-Shirts for sale at Tokyo Festival of Modular

There are social layers of representations and loyalties, to one's brand, be it a modular line, a synthesizer shop, a band or a DJ. Merchandise such as stickers, t-shirts, and beer cozies imprint this brand on the protective cases, bodies, and social life of any visitors. The same is true at any event, but synthesizer logo designs are especially viral. Modular panels and their layout take on an extreme sense of self from the colors, knobs, fonts, and lines they use; they are not simply ephemera but become permanent members of a music studio and must represent the owner's taste, be it radical, finely honed, gonzo, techno, etc. Esoteric circuit imagery and schematic symbols provide an unlimited font of design ideas. The recording industry has almost a century's worth of creating graphic images that somehow tantalize and suggest the

invisible heard content within the sleeve. This is the final and most potent influence on synthesizer propaganda at the festival, with the sublimation of physical recordings.

Illustration 3: A Japanese synthesizer band, or synthesizer store?

Three Japanese performers pose proudly at a table of synthesizers, representing their allegiances. Japanese culture emphasizes the photogenic and public appearance of representatives who negotiate a social web at such festivals, and also peripheral business encounters at bars, restaurants and musical events. The taking of photographs, as shown here, propagates brand images as the centerpiece between a table of gear, a smiling face and eclectic haberdashery.

On June 21, 2014, I participated in Control Voltage Fair in Brooklyn.[17] Having

17 The specific location was Ten Eyck street, a Hague of the new world, crammed in between an oily river and a bunch of Chinese merchants, it also contained many nose-rings and kindly death

endured the cacophony of the Tokyo Festival of Modular, I swore to go completely silent and conceptual at this event. However, the space was taller and less populated, so there was more room for sound. I found the sonic environment less aggressive, and the open garage door afforded natural light and escaped many slap echoes. At the Harvestworks booth, a video synthesizer silently represented alternative concepts, and other builders used oscilloscopes rather than amplifiers to make the atmosphere quieter.

I set up my conceptual paper synthesizer at a booth, along with a clear sounding demonstration of touch-organs.[18] Next to me was Mark Verbos, of Verbos Electronics. It's wonderful how names work; Mark is not loquacious, but his Buchla adaptations do feature the verbose legend of the origin, with a clean, professional aesthetic. He has repaired many Buchlas,which he remixed as Eurorack adaptations. Like Roman's work, Mark's use mini-plugs solely, shunning the structuralist impulse of banana separation. Also the modules have a strong clean aesthetic, with the classy pin-lines of the original, but a little more strength of color contrast; he uses blocks of black ink next to bare aluminum to help break up the monotony. Mark has a strong sense of brand, and his logo, a black letter V with a red dot, appears on many T-shirts.

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metalists, as well as other fuzzy burlap berets and various accordion toters... Brooklyn, on a cool day, during a "river to river" music festival was a great place to have an open door to a dark warehouse spilling out loud modular sounds. Super Deluxe in Tokyo, as a warm synthetic basement environment against a rainy day, had great spot-lighting and finely tuned decorations. In contrast, the warehouse in Brooklyn had no artificial lighting at all, just skylights and a rusty garage door.

18 Thanks to the festival organizers, Abby and Matt, who offered me a complimentary powered speaker. Due to this generosity and the quieter space, I did in fact participate in the sonic event.

Control, the store in Brooklyn, also has a strong logo. They present many Eurorack brand modules, and have a great showroom that you can come in and play around for hours. They brought shirts, cards and a nice stand of all sorts of modules. Pittsburgh Modular and Make Noise both offered cozies- foam sleeves for cold beverages branded with their own distinct logos.

Meme Antenna, a store in Brooklyn, sells the "Lio&Linn-wood+metal-," a wooden case for Eurorack modules, made in Japan. According to Adachi Tomomi, wooden synthesizers are not viable on the Japanese market.[19] My hypothesis for this disconnect is that the "ki" of wood is an ancient one, used for housing fine clothing, family relics, and of course, ancestral ghosts and natural spirits in shrine usages. Electronic synthesizers, however, associate with ballistics, communication and war. The two resonances are difficult to mix, but over the years the wooden case should become popular.[20]

What is the fate of Eurorack? Musing on all the hubbub over this format, a friend postulated that it will become a big drum machine. I hope not, and I know that modulations are the exit from steadiness. The manifesto of Steady State Fate describes the terminus of modulation as a clearing in the forest of chaotic realms, where predictable striations are the rule again. In fact, the Steady State Fate

19 Adachi Tomomi, an experimental vocal performer, also makes his own electronic instruments in Tupperware.

20 An important Shinto anniversary is the thirty-seventh year after a family members death; this is an important year for according to Shinto, he may now become part of an ancestral spirit, losing individual identity for the sake of a more powerful family entity. Perhaps there is a similar process unfolding in materials for electronics, as wood, metal, plastic, and silicon can be blended more and more. I saw a little bit of wood in Tokyo Festival of Modular, but it only is used to emphasize a certain vintage feel.

presentation is usually such a drum machine.[21]

Had I began as a Eurorack designer, I would not have experimenter with paper circuits, wooden synths, battery power, and alternative intuitive connectors. Surveying current Eurorack festival culture, I learned of the subconscious urges that music marketing encounters- brand name uniformity through legend, layout and logo. Some builders connect to past modules by remixing them- Roman and Mark work with Buchla ideas. Scott, in recovering esoteric Russian circuits, went beyond authenticity and nostalgia to imply a beastly nature to those modules. Scott and Josh both integrated different sub-lines into their business, as a platform for diverse concepts. In the final revision of Mobenthey modules, I applied these ideas, recovering some more esoteric ideas from my distant past in conjunction with newer developments. The festivals highlighted the importance of legend, logo, and layout, which I would not give short shrift in the production run.

Naming Synthesizers

Tara Rodgers cites metaphors in audio-technical discourse as a means to relate humans with nature, machines, the body, and each other. (Rodgers, 2011) In her dissertation, she attempts a feminist reading of the history of synthesis, focusing on two metaphors: sounds as aqueous undulations, and sounds as individuals. I will attempt to build on her history of metaphors for synthesis and extend them into the present and future of the art, as new metaphors are created in the process of naming. I will compare this process to the generative forces in science fiction, where exploring

21 http://www.steadystatefate.com/, Retrieved April 2015.

the consequences of imaginary innovations is what drives the plot structure. Synthesizer history is rich in, for lack of a better word, synthesized names, as new modulation structures are held to be unaccountable to traditional vocabulary. I think Tara Rodger's work on metaphors in the history of synthesizers can help with a tentative analysis of some recent developments. Before continuing, I would like to summarize her readings for historical background.

The maritime analogy in synthesis, according to Rodgers' reading, is part of a masculine program to tame the forces of the sea, by constructing machines to generate and ultimately control waves. She points out that at the end of the nineteenth century, a strong European maritime industry existed to support colonial conquests, further bolstering the need to control, or at least understand undulations. This was manifested in Lord Kelvin's "harmonic synthesizer" which attempted to synthesize the motions of the tides, for the purpose of further precision in generating sailing schedules. Kelvin's use of the word "synthesizer" was the first to use it outside of an abstract logical argument and apply it to the "putting together of waves". Strong metaphors, such as the fascination with the power of the ocean and its tides, generate ways of thinking that lead to new technology. Rodgers' work is to associate the ocean with femininity and twentieth century "men of synths" with the colonial urge to tame, and thus metaphors are the "othering force" of power relationships in European, industrial society.

In naming a concept, much is done towards taming it.

Industrial society emphasized the individual over community, and this is the

source of the second metaphor: synthesized sounds as individuals. By individuating sounds into waveforms, a wave with an envelope, they can be charted and controlled as industry does its workers. This needs to take a wave, which has theoretical extension over all of time, and bound or shape it into a discrete time. It also connotes the age old human need to deal with the finiteness of life in the silence of death. The metaphor generates structural complexity in the language of synthesizers, because of the need for not only primitive waves, but also forms, such as the ADSR, "attack decay sustain release" envelope, which allows for the finite existence of a sound, with parameters for the speed and quality of the four parameters.

Some namings lack a name, only using combinations of letters and numbers as a sort of codename. A good example is the Yamaha “DX7,” billed as the first keyboard instrument to solely use FM synthesis. It seems that for a while, successful synthesizers had codenames: Korg had the “M1”, Roland had the “D-50”, “S-50” and “JX-10”, and so on. I’ve always wondered if this phenomenon was a weapons metaphor, seeing that in the milieu of these synths, there was a steady global war between two forces, the AK-47 semi-automatic rifle of the “eastern bloc”, and the M16 machine gun. The military metaphors are a pervasive undertone of all synthesis engines, as Rodgers so aptly pointed out. But there could be a more general, modernist undertone to naming by letter, in that it refrains from colorful analogies and lets the synth speak a universal language of its own. Compare to the stage setting of the HAL9000 computer in Stanley Kubrick’s 1968 film, “2001: A Space Odyssey”, which uses three-letter abbreviations for core functions of the electronic

brain; a universal organizational system is implied with neat building blocks that are aesthetically pleasing and iconic as well. Perhaps the "modernist" trend in synthesizer naming is of a similar stream, suggesting the great power of computing ability behind an abstracted interface.

Three letter abbreviations also have great use in the "traditional" names for most synthesizer modules. Here is a partial list:

- LFO: low frequency oscillator, for modulation of audible carrier waves
- VCO: voltage controlled oscillator, a basic building block of synthesized sound.
- VCF: voltage controlled filter.
- VCA: voltage controlled amplifier.

The "codename" system of naming modules and synthesizers was pervasive for a long while during the 20th century, but as when there is any pervasive system, there is also an equally perverse reaction to it. Using words to name synthesizers, as a reaction to the abstract codename, led to some quite "gonzo" names, as well as serious and profound re-contextualization of the role of the synthesizer. By naming they create a space around the new word, with specific nodes of meaning that would be implied to the reader of science fiction, but also real electronic interpolations between these nodes; a web of meaning modulations is created around the name. I would start with a very subtle modulation of meaning, in the name of Jessica Rylan's synthesizer company, "Flower Electronics". The surface of the name touches on the gender relationship of a female business with the predominantly male world of

synthesizers, especially when cross referenced with Flower Electronics main product, Little Blue Boy. Flower can also be interpreted as a "flowing thing", and this is very appropriate to analog electronics, and still may be within the gendered realm suggested by Tara Rodger's reading of water as feminine metaphor. As opposed to digital technologies, which use symbols and codes, analog circuits see electrons as flowing between components and inside dielectric fields. I myself explored the dialectic of flow versus form in a 2001 proposal for a synthesizer that juxtaposed pulses, or countable digital events, with the smooth forms that are characteristic of analog synthesizers.[22] One further note about flowers is that they bloom, and this too is an analog metaphor. Within certain patches involving feedback amongst diverse operators, a personality develops not unlike the morphology of a plant; there are rhizomes, a thick and fibrous stalk, leaves, and at isolated spots on top, special areas of highly developed color and delicate complexity. Having set a name for the company, Rylan could explore these metaphors as a practice of developing and elucidating their meaning space. From the flower electronics website:

> Her designs are known for their personality stemming from their unconventional use of synthesis blocks; they are not arranged traditionally for monolithic musical goals but using alternative metaphors as a rubric which results in exploration of chaos. The botanical metaphor has a profound role as reaction to cold and sterile names, as it re-introduces organicism into the analog.

Buchla, Serge, and Moog are simply the names of their inventors, serendipitously applied to new technology and invoking an assemblage of strange sounds as if they were science fiction. The exact mechanism of this transference I

22 See the following chapter on the Form-Flow Synthesizer

leave to your imagination, but I would note that on a Music Players forum thread called "Best and Worst Synth Names...", Moog is hailed as one of the supreme names, invoking "phatness", although to use that word such as in "Little Phatty," makes a synth name one of the worst. It seems, rightly so, that drug and party culture analogies make a synth too trashy for a “serious” synthesist. Buchla’s "Source of Uncertainty" module is hailed as a great name, for its lack of synthetic wordage, and depth of meaning. Here, a zen spirituality is invoked in the idea of "Source", a module with no modulation input, purely for generating uncertain energies, almost intersecting the idea of chaos magic, but not quite, for the "Source of Uncertainty" fit neatly into the Buchla structure of ultimate control over synthesized sound. It was the one module that offered "true" random voltages, but as a universal element. Another highly praised name comes from the Serge system, "Universal Slope Generator" likewise has a modernist ring to it. Its universality makes it highly usable, earning praise as one of the most brilliant of the Serge system.

The formula of <man's last name> for the system and a modernist or otherwise universal concept as module name was pervasive in the time period known as the good old days of synthesizers. Rodgers debunks this as the true beginning or source of invention, and also for the alternative readings that bring feminism into the history of this time. It seems that subsequent synth names would also reject that monolithic nature of naming. Thus we arrive at the present again, and look at some current synth makers who work with small, handmade batches of idiosyncratic and compellingly chaotic pieces. For the first example I would choose Rob Hordijk, of the Netherlands.

Rob was introduced to me in Cologne by the synth critic Joker Nies, who insisted that we would be good friends by virtue of the similarities of our designs. Rob pulled out a handmade circuit board, with 8 un-labelled knobs, and proceeded to explain the "Benjolin" synthesizer and its underlying "Rungler" engine. Later I brought him to Baltimore to conduct a workshop of building this synthesizer for about ten participants. It was fruitful, I think due to the pataphysical space defined by the synthesizer. It is not a collection of monolithic modules that interact via strict inputs and outputs, but more of an informal and organic relationship between a few simple modules and an abstract "Rungler", that sort of mixes all the flows up and spits out a source of uncertainty derived from them, to be fed back as a persistent modulation. There are knobs that control how much "Rungling" is to be applied to each oscillator or filter. The way it works is by cross referencing the histories of two oscillations and creating an arbitrary digital table of the two, which is then decoded back into the analog realm as a control voltage. The result when included in a feedback loop is a dictionary of paradoxes, negating stability by the constant arbitrary re-evaluation of the "Rungling action". The name is purely imaginary, but it touches on the concept of "Hyper Chaos" as defined by Quentin Masseilloux in his "After Finitude."[23]

The meme of chaos as a sort of random noise conflates all three of these concepts; random, noise, and chaos mean little difference to popular culture but actually are distinct according to the mathematician or even the lowly synthesizer

23 Hecker, Florian, interview with Quentin Meillasoux, 2010.

designer. I will not attempt a full definition of each, but note that chaos can sound like noise, but with more "eddies" or characteristic turbulent patterns in it (both aqueous metaphors), and with a different generating operation involving plain non-chaotic elements in feedback or cross modulation with each other. The idea of hyper-chaos, however, can sound sometimes like noise, and sometimes like plain tones or other linear musics. It is the bifurcation between purely chaotic realms and rather rational fields that marks the idea of hyperchaos. In my own experiments with a chaos knob and in the rungler knob of the Benjolin, hyperchaos indeed is found in the higher range; it is chaos that is beyond chaos. In the Benjolin it sounds like quick flourishes of articulation alternating at unknown intervals with static tonal measures. This use of the rungler circuit was to realize the name of the Benjolin, which Rob describes as "a combination of banjo and violin." Rob came up with the name first and then pursued it by tinkering with various combinations of runglers, oscillators, and filters. Eventually he ended up with something quite suggestive of this conventional reference, by use of the hyperchaos striation between chaotic and plain, but capable of many other modalities which diverge from the original concept by virtue of the abstracted structure of the device. Thus naming is a searching for a foothold and also a key into a multidimensional universe created by the search and implementation of the abstract concept.

Form-Flow Synthesizer

In the early aughts, I submitted a manifesto to minimalist record labels,

including Raster-Noton and Mille Plateaux, in order to ensnare not a record deal but an undefined contract for synthesizer art piece. The labels ignored my manifesto and did not respond to my frequent and pushy email correspondence. I thought I had a chance, as a silent submission, in their tall incoming pile of CD demos. Of course these labels curate content not from the demo pile, but from personal connections, and thus my manifesto indubitably went unread.

The manifesto, now lost, explores the dialectic between form and flow in historical synthesizer interfaces. Perhaps I lost it because this simple binary could not hold the increasing waters of synthesizer concept. Perhaps I lost it because of the pain of rejection by minimal and trendy record labels. I now realize the concept is interesting for how it relates analog synthesizers to radical digital techniques, at the time known as "clicks and cuts."

In digital audio workstations (DAW), the textbook method for compositing sound is to apply short fades at each end so as to not enter or leave digital silence with an audible click; cut audio may have an instantaneous volume difference that manifests such artifacts. Minimalist and materialist perspectives on this phenomenon prefer to leave it un-compensated, as a more primitive operation on the sound, leaving a trace of the tool with a percussive punctus. Further developments include using unnaturally short clips of sound, for more and more frequent click artifacts. The "clicks and cuts" genre of minimal electronic music employs these clicks as its rhythmic layer, and enjoys more silence due to their extremely short , one-sample, duration.

At a CD sampling rate of 44.1 kilohertz, any cut between sounds will manifest a spike of seemingly infinite spectral energy, due to the instantaneous transition between two different levels. A novice at the DAW will quickly learn of this "problem" and usually adopts ameliorating techniques such as microscopic fades, or cutting sound to zero crossings. This notion of the infinite in the click of the clip relates proportionately to the idea of meter as instantaneous, or infinitely short points that mark a metric space. Thus minimal techno is only appropriating the most concise rhythmic operator possible: the click that approaches infinity in its brevity.

Another aspect of minimal electronic music in the early aughts looks to experimental music in the use of sustained electronic tones of simple timbre. Michael Pisaro, working with field recordings, employed faint but steady sine wave tones in his pieces as a framing apparatus; recordings extracted from nature gained borders by the presence of these synthetic tones. Sachiko M decided to only use sine waves because they gave her agency to create her own music; sine waves have indefinite length and thus offer the most flexibility and least pre-defined meaning to the composer. The earliest experimental music by Alvin Lucier also employed sine waves to accomplish simple acoustic tasks, such as resonating objects from a distance or standing waves in a room.

Minimal techno appropriated these materials, the click and the standing pure wave, to replace the drum sample and the bass line. I wanted to relate an analog synthesizer to these simple materials. The sine wave survives the translation from digital to analog, but porting the click incites a new re-structuring of one available

operator: the pulse. The digital click lasts only the length of a sample, but since analog has no sample rate, the pulse is an arbitrarily, ideally infinitely, short spike of voltage. In fact analog synthesizers often have pulse systems, but do not audition them, for the same reason that clicks were previously unheard in DAW- they are unlike natural sounds that take time to decay.

In an analog synthesizer, there are generally three types of connection: the signal, like a sine wave it is a sound; the control voltage which specifies pitch or tuning information; and the pulse that governs rhythmic structure. Sequencers take a recurring pulse, either straight or swung, and output a melody in n steps, usually specified by knobs. Other modules to work with pulses include pulse dividers for selecting longer periods. Pulses and their processes form the generic metric framework of the analog synthesizer, but do they have a sound?

The form-flow synthesizer seeks to re-contextualize analog pulses as clicks were in the digital domain, as a signal to be heard. Previously, pulses acted only to trigger more extended bodies of sounds, such as an enveloped oscillation. Now, the electronic pulse is heard as a dry, un-resonated and un-bodied punctus. This sound shares more in common with neuroscience experiments, such as the elementary "listening to a crawfish brain." In that experiment, the crawfish brain is excised from the body, and while the neurons are still electrically alive, they are stimulated by physical touch, and their electric impulses detected with probes. The neuro-impulse's shape is similar to the primitive analog pulse- a single sharp spike of voltage, often in trains, or groups spaced metrically.

The form-flow manifesto posits that these impulses, regulating the rhythm- of thoughts and perception in a brain, of processes and sound generation in a synthesizer- are historically treated as form. Thus, form is macroscopic compositional processes like sequences, loops, or rhythmic patterns that metricize a music. In contrast, flow is gestures and ornamentations not formally represented, but embodied by signals.

Historical analog synthesizers intentionally segregated form from flow. At the time of the original form-flow manifesto, I had personally handled two popular "west-coast-style" synthesizers, the Buchla and the Serge, which influenced my design philosophy. In fact, I was in a band with Don Buchla's son, Ezra Buchla. Furthermore, I was also in a band with Serge Tcherepnin's nephew Stefan Tcherepnin; we all attended Oberlin College and Conservatory at roughly the same time.

A "west-coast-style" synthesizer eschews keyboards such as on a pipe organ or piano, in favor of composition by patching and knob-setting. The idea is that a piano keyboard specifies a multitude of notes, but does little in the way of timbre and the multitude of other parameters an analog synthesizer can accept. According to rumors, Alvin Lucier disposed of the keyboard for Wesleyan's Arp synthesizer for this purpose- worry not about notes but all the other specifics and generalities about sound. So the Buchla and Serge both could interface with a keyboard, but do not require it, and the main trunk of their performance tradition relies on composition by patching with wire. Patching with wire is a great way to build layers and hierarchies

of rhythm and structure, using pulses and control voltages respectively. Finally, the signal generators and processors (oscillator, filter) embody the structure as an audible signal.

My first exposure to the "west-coast-style" came via Ezra Buchla, with whom I formed a band named Mister Kilogram. In that band Ezra played the Buchla 100, a small cabinet of oscillators and filters given to him directly by its maker, his father. This Buchla, one of the earliest, severely limited Ezra's options to simple tone generation, but we enjoyed this contribution, as a framing influence, not unlike the use of sine waves in Pisaro's music. A later solo project by Ezra, called Carmine, used the same small cabinet of oscillators to produce minimal compositions of sustained tones and also dry pulses and crackle, not unlike the digital minimalist clicks. Did these arise from re-purposed pulse circuitry, fed into the audio chain? I know that Ezra did make certain decisions against the intentions of his father on the instrument; there is a network of builder, instrument, and user encapsulated in this one family. The user also makes inventions and builds new connections.

The first page of the "Buchla 100 Series Manual" details the three types of signals- audio signals that are heard, control voltages that determine the "operating characteristics of various modules," and timing pulses that "trigger other events." Furthermore, the manual states that each signal shall use a different connector- audio signals a mini phone plug, control voltages a black banana plug, and pulses a red banana plug. Then it states that two rules must be followed to connect signals: "The path of flow must always be from the outputs of one module to the inputs of other

modules, and the jacks at each end of the connection must be the same. That is audio signals must be connected to audio signals, control voltages to control voltages, and timing pulses to timing pulses."

This is the famous dichotomy between audio and control, epitomized on the Buchla by two physically incompatible connection systems. Don Buchla has stated that this separation maximizes compositional structure by separating it from the filtering and modulating done in audio signals. But it also leaves a situation that asks questions such as, "what do timing pulses sound like?" That is where second generation users like Ezra act to bend the rules, as do the "clicks and cuts" minimal techno composers, drawing stark new sounds directly from the unheard structural tools.

The Serge does not dichotomize audio and control with different connectors, but it still maintains the distinction between the three signals- audio, control, and pulse. I learned about this synthesizer likewise via its creator's nephew, Stefan Tcherepnin, with whom I formed a band known as "The Gongs." The formula of this band was to create an alternative folk music that engaged analog synthesizers and tunings on a visceral level. Using the Serge, Stefan created rhythmic structures using its versatile and highly configurable modules. However, I insisted on building our own rhythm synthesizer, known as "The Man with the Red Steam." The Serge was the main influence in thinking about the control and timing structures for making an analog drum machine.

The 1978 Serge manual outlines the same three types of signals: control

voltages (actually broken into two categories, DC and bipolar), audio signals, and trigger pulses. According to the manual, "DC Control and Bipolar Control provide a 'how much' control to vary the amplitude, frequency, rate, or other voltage-controlled parameters within the synthesizer. Trigger Pulses are used as a 'when' or 'how long' signal to produce timing pulses and to activate or de-activate other functions for a controlled length of time. The Audio Signals are 'what' signals which are usually the electrical oscillations which can be directly transformed into sound.

The three types are the same as in the Buchla, but instead of different connectors that segregate signals, the Serge employs different colors of the same banana type connector; control voltages are blue, audio signals are black, and trigger pulses are red. Without mentioning the Buchla by name, but an obvious reference, the manual points out the cross-compatibility of these signals:

> One of the notable features of the Serge system is that only one type of patch cord is used. This is in contrast with a number of synthesizer systems which use different types of patch cords to handle the various signals. The advantage of a one patch cord system is that it allows signals to be used wherever useful, for example, using control voltages as audio signals. This is often done in the Serge system, especially since most modules have extremely wide ranges with overlapping audio and sub-audio ranges of frequencies.

The idea that control voltages, audio signals, and timing pulses could intermingle and become one another is the most radical and useful concept introduced by "west-coast-style" synthesizers. In contrast with earlier synthesizers, which had relatively static functions and fixed ranges, these synthesizers offer wide ranges, achieved by the immense dynamics of transistor-based voltage control. Due to this

wide range, a triangle wave could sound easily sound as a pitch or become a rhythmic undulation, crossing the haptic-tonal divide in the audio cortex, where rhythmic perception becomes pitch perception. Furthermore, it could become ultrasonic or so low a frequency that it affects the most gradual limits of perception.

The separation of three signal types listens only to the audio signal, which embodies the other two types- timing pulse for rhythm, and control voltage for pitch. As an embodiment, it carries all the other signals and modulations that formed it, like organs; its basic pitch is a fast vibration, its envelope is a triggered attack and decay, and its timbre is little trills and ornaments on its basic waveform. This model of thinking of synthesized sounds, as individual bodies surrounded by the space of silence, is helpful in most compositional contexts. As the intended use of the synthesizer, to create these bodies, it also begs the question, are the other signals not alive?

The Serge attempts to bring all the signals to the same importance by giving them compatible connectors. But the modules still have an intended use, according to the tripartite model, of timing structures, control flows, and signal embodiments. The Serge encodes these intentions as colors on its aluminum face- red, blue, and black. So it is the user's act of re-purposing signals that makes them actually mingle. This is what I noticed in the inheritors of Buchla and Serge- a willingness to use alternative interpretations of the standard model of synthesis. This is the next-generational context which inspired the form-flow synthesizer.

The form-flow synthesizer seeks to explode the fixed organs- timing, pitch,

timbre- of the embodied signal and instead create a synthesizer without organs. Like Deleuze's "Body without Organs," the fixed functions of the historical synthesizer become temporary and contingent, neither input nor output, nor inside or outside. The outside of the embodied signal- manifesting its internal rhythms and pitch signifiers- can convolute such that its structural pulsing, its internal form, becomes heard within the flow of the music.

Cast of Characters

Over the years, I've coined many names. I started with the need to encapsulate descriptive phrases into tight words that describe an analog concept. Such early names included the following:

- *Nabra*, an analog brain, or an assemblage of modules connected together.
- *Toucharce*, a musical instrument responding to touch.
- *Shinth*, a synthesizer made from shit, for circuit-benders who find their raw materials in the trash.
- *Rolz*, a circuit formed by simple sub-components in a closed loop.
- *Sandrodes*, androgynous circuit nodes formed by an intersection of inputs and outputs.

However flowery they sound, these words are practical; they describe specific concepts that I would encounter frequently in my design work. For truly fanciful names I turned my mind away from circuits completely and coined poetic names for my business and instruments. For example:

- *Ambrazier* was an primitive 8-bit digital delay and analog synthesizer.
- The *srine* and *tranoe* built on the concept of that synthesizer.
- *Din datin dudero* was a thesis-piece about composing and performing intuitively with *sandrodes*.
- *Fourses* and *Fyrall* were smaller encapsulations of the *din datin dudero* that I sold as kits.
- *Sidrassi, sidrazzi,* and *sidrax* is a lineage of electronic organs, triggered by pressure on their surface, that explore noise and pure tones surrounded by silence.
- Likewise, *tetrazzi* and *tetrax* are a similar lineage of organs.
- The names of my businesses, *Ciat-Lonbarde, Shbobo, Ieaskul F. Mobenthey,* and *Tocante* all come from a drawing titled "at the mall."

Nabra

In late 2014, I concertized using two older instruments, and in the process of their excavation, I cleaned, repaired and documented them. Early in my career making synthesizers, I was much more interested in the spectacle of the instrument. These instruments manifest a physical performativity, embedding circuits in a textile garment and also a tapestry. I developed the tapestry form of synthesizer out of a distaste for hunching over tables of gear, to perform standing and transform the ritual of patching into a sort of dance. Likewise, the coat synthesizer induces a standing performance, but not a dance; as envelopment of the body, the coat necessitates

closed movements epitomized by the notion of tweaking. There is not open space between patcher and synthesizer as with a tapestry. To introduce these performance modalities, I will start with a low level description of the instruments and conclude with a narrative of the long-term relationship I've had with them.

Harry Partch built his own instruments not only to realize his radical Just Intoned music theory, but also for the physical presence of the large instruments; musicians both intoned them and danced between them, extending musical gestures to pedestrian movements in space. I wanted to capture this form of spectacle in the *Nabra*, of 2000, that hangs on a wall. It is a tapestry of stiff canvas, painted with house paint in the abstract expressionist technique of Jackson Pollock. 52 modular circuit boards face out from its surface, with loops of braided copper extending from their edges as patch points. It is basically a modular synthesizer, with a few differences:

- The circuit boards are exposed to touch. This is my earliest experiment in open-faced case, and I did not attempt to hide dangerous nodes. They may not be able to shock you, but they could easily break, especially when crossed by anything metallic. So, to keep the instrument alive you must be very careful to never touch the circuit boards with metal. That could cause them to short from the power rails to a transistor base, breaking it. The only place to touch metal is when patching on the loops of copper. Also, only turn it on after it is hung on the wall.
- It has no knobs for tuning, for the practical reason that since it can roll up, too

many knobs would cause an uneven, breaking load on their shafts. There is the aesthetic result, that tuning is a given for each module, and the only way to change it is by modulation. However, there are knobs for volume of the audio modules, so they can be mixed on site.

- Patching is done standing, and can span a breadth of almost six feed wide, so there is quite a bit of horizontal movement involved, thus patching gesture becomes a performance of dance.
- This patching is by alligator clips connecting the loops of copper. I originally built alligator cords with inline components, such as resistors, capacitors, and diodes, for varieties of control voltage mixing. This concept had been touched upon by Buchla, as part of the discussion on where does mixing take place in control voltages. Usually modules have a current limiting resistor on the output, but some old Serges did not, causing blowouts. The idea of limiting components in the cords themselves allows the infinite current on outputs, and also a way to apportion the amount of each control voltage coming into an input. I almost never use the mixing of control voltages in actual performance, instead relying on a multiplicity of inputs to balance a multiplicity of outputs. This concept is especially important in a synthesizer without knobs (body without organs).

The name for the instrument, *Nabra*, is a neologism I made to refer to the general idea of "analog brain." Thus the word can extend to other instruments or playing modalities, but here it refers simply to the instrument. I see this instrument as

a thesis-piece; it is a large work that tries to elaborate an encapsulated concept set. In this case that concept set is a sort of balancing of modules between square and round, slow and fast, with the radical idea of a hanging tapestry and no-knob tunings.

The *Nabra* contains twelve columns with four modules to each. Some columns are broken into two parts. Here is an overall chart of their distribution, with their poetic names:

Slope	*Slope*	*Shot*	*Dust*	*Rand*	*Swoop*	*Pulse*	*Trang**	*Noise**	*Sine**	*Sine**	*Wave**	*Pow*
Slope	*Slope*	*Shot*	*Dust*	*Rand*	*Swoop*	*Pulse*	*Trang**	*Noise**	*Sine**	*Sine**	*Wave**	*Pow*
Port	*Slope*	*Shot*	*Stair*	*Trand*	*Swoop*	*Pulse*	*Trang**	*Noise**	*Sine**	*Sine**	*Wave**	*Pow*
Port	*Slope*	*Shot*	*Stair*	*Trand*	*Swoop*	*Pulse*	*Trang**	*Noise**	*Sine**	*Sine**	*Wave**	*Out*

This layout follows the classic linear narrative of control-process-generate-filter. The leftmost modules,"Slope," control all the others with slow shapes. They proceed to the right through slow processors, such as "Swoop." Stars mark audio generators, taking processed control signals to generate sounds in silent space. The audio chain could end there or proceed through the "Wave" filters in the second to last column. The rightmost column anchors to power supply cables and yields a buffered final mix at "Out." Note there is a seven to five relationship between control-process and generate-filter.

While surveying this instrument for the first time in fourteen years, I realized that the modules have "hot outputs;" They have no current limiting resistors so connecting two could potentially cause a high current situation that could burn silicon. Early synthesizer designs shared this controversial feature that relies on the

user's sense of control and also linear compositional intent to never cross two outputs; mixing requires a dedicated mixing module, not an ad hoc wiring. Of course this goes against common intuition, so most synthesizers nowadays have a ten kilohm resistor on the output and these can be connected together in any amount to produce linear combinations. However, I designed the *Nabra* for patch cords with in-line passive elements, such as resistors, capacitors, or even diodes. I intended for compositional strategy to include the type of cord, and thus the type of mixing in the connection of outputs. So they have hot outputs to offer a pure, ideal source of current for interpretation by the cord.

At ESI, or Electronic Surplus Incorporated, an old store on the west side of Cleveland, I picked up all the components for this instrument out of great and dusty bins. A look inside it will reveal old varnished resistors, military surplus capacitors, and jellybean chips looking quite miscellaneous. The LEDs are especially fine vintage, of mostly green, red, and amber and placed into the instrument at random without respect to any function those colors might indicate. I savor the results of LED salvage as a chance action; the distribution of red, green and amber is a familiar pattern, sort of like an action painting, that complements the splatter-painted canvas. I can actually hear these old LEDs blinking, with a tiny sound like a clicking relay, that I have never heard in newer LEDs.

Stores at the Mall

Spend a decade making analog synthesizers, and never ask why; a computer

can easily generate triangle, square and rounded sine waves, but you know they are not the same. Perhaps, seek out the difference in what makes circuits sound alive, or graph the patterns of flow to generate visuals (circuit diagrams, schematics, or allegorical depictions). The art is always drawn by hand. The gray analog logic creeps into all aspects of the synth business, questioning binary thinking or dogmatism.

The outcome of these years- strange namings and strange sounds- bears fruit in the hands of experimental musicians. Some instruments remain stubbornly idiosyncratic pieces in themselves; others allow core concepts- modulation, timbre, tuning- to produce both sound and structure with wide-range controls. The business docket contains these instruments, their manuals, schematics and philosophical papers, plus promotional materials such as YouTube video documentary, interviews, and bands organized to play the instruments.

Full to bursting, the corpus may undergo a process of differentiation, spawning new growth that uses the materials in different ways. Are there any unexplored technologies, or what organs deserve treatment as a separate body? When a virus, having replicated itself inside a cell, ruptures it, this process is called lysis; think of the cultural capital contained in one site as capable of this process through a process of reproductive fiction.

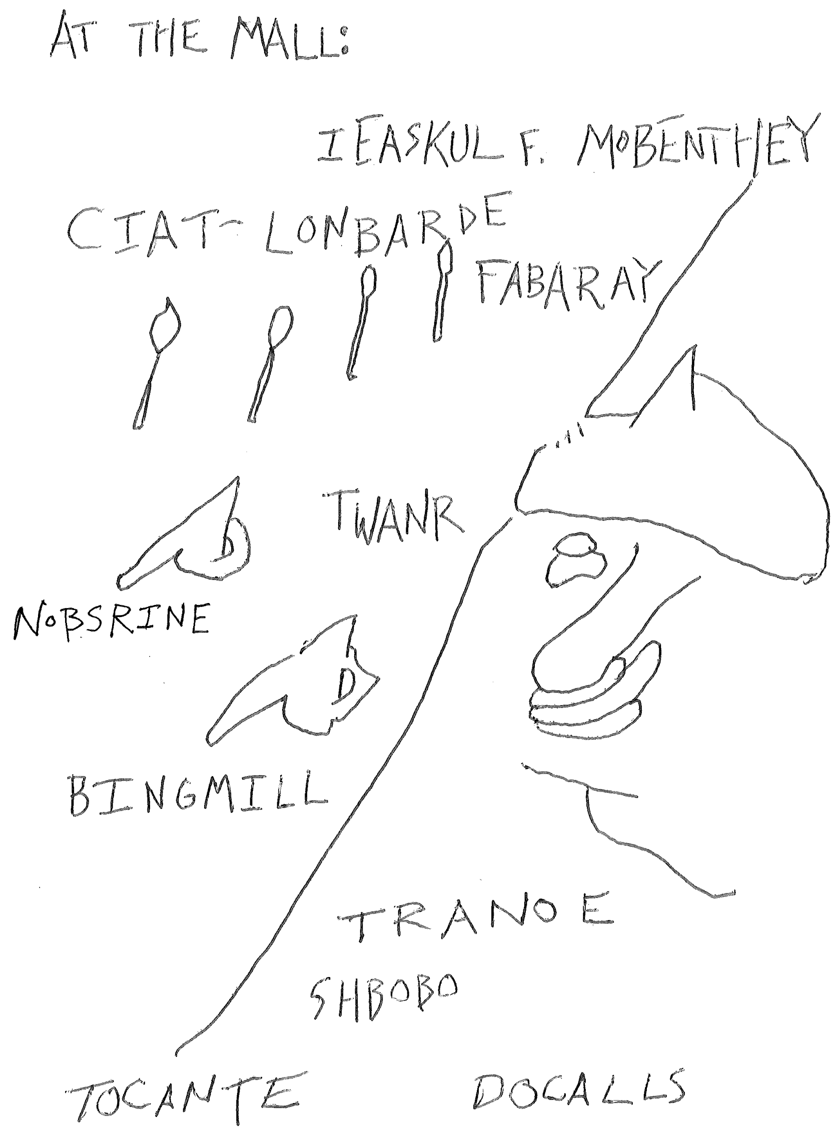

Illustration 4: Stores at the Mall

The origin story of *Ciat-Lonbarde* is a drawing, titled “at the mall,” listing fictional names of stores, suggesting a spectrum of flavors and wares. As I said, my ten-year corpus was a set of circuit diagrams and philosophies relating to analog

synths, encapsulated in this one store at the mall: *Ciat Lonbarde*. A second store, named *Shbobo*, asked the inevitable question, does analog profit from emulation in the digital domain?

The process of emulation offers another way to think of analog forms, and the porting process may continue further to analogizing emulations, offering further inventions along the way. At this point, I realized the importance of the initial "at the mall" drawing, as a generator of different lenses to view certain universal singularities through.[24] This year I began to actively continue mining this drawing, building two new stores:

- *Ieaskul F. Mobenthey*, focusing on modular designs resulting from the afore-mentioned analog/emulation cycle, and finally,
- *Tocante*, devoted to exploring the physical materials of electronics through physical touch.

Synthmall is a fiction, based on an original corpus of analog synthesizers named *Ciat-Lonbarde*, the mall adds possibility for new "stores," to break stylistic monotony

24 While studying for a master's degree in music at Wesleyan, I also managed a synthesizer business, partly to support my family but also as my primary modus of composition. A long time ago I realized that musical instruments are as much a musical release as a CD or record; in these days of streaming, the implosion of the album format, and the rise of DIY and outsider "gonzo" organology (trimpin), the musical instrument has become a creative currency of exchange. I thus submit my activities in synthesis of synthesizers, "synthesynthesis," as the primary thesis herein.

After receiving a bachelors degree in TIMARA (Technology in Music and Related Arts) and also one in East Asian Studies at Oberlin College, I was poised to interact with the circuit fabrication world. A grant from the Daniel Langlois Foundation for Arts and Technology enabled me to develop my first series of touch-sensitive synthesizers: the shinths. I designed bare circuit boards, full of "twittering machines," and curated a tour with musicians skilled in noise experiments: the shinth tour. The shinths had no knobs or other interface, instead designed on circuit-bending ideals, also the "plane of immanence" of deleuze. This thesis consists of a series of recurring themes; I just mentioned one, the idea of a knob-less synthesizer, which will recur in the last chapter, in some of my most recent work at Wesleyan.

and explore the concepts in a prismatic lens. The mall format helps to break out from a single aesthetic, as each "store" expresses maximum individuality from the others.

Alternative Materials for Creativity

In the long dusk of the music recording industry, I saw CDs as gubble.[25] I said to myself, then, that I would not make these plastic discs that clutter, and focus on making musical instruments as my own "release," a product that generates ever-changing musics in response to the diverse moods of its holder.

This began my personal decoupling from the materials most commonly associated with "creative expression," such as paper, paint, and discs, in favor of systems that might be more aptly titled meta-materials for creativity. I do not eliminate traditional materials such as wood, but add data, energy, and concept as material. Thus a basic task of my synthesizer business is to pursue local lumberjacks, who artisanally slice and cure wood to encase my circuit designs. However, I can point to my CNC scripts as another medium, since they dictate plank dimensions and wood choice algorithmically.[26] Working backwards, there is the task of sorting and "post-processing" raw lumber to prepare it for the CNC machine; I select wood based

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25 In Philip K. Dick's "Martian Time Slip," an autistic boy sees newly constructed Martian condominiums as their decayed end product: slums with crumbling walls. He calls this gubble: the future clutter of planned obsolescence. I too, as a college student of electronic music, felt this way towards CDs, which have now mostly gone out of fashion.

26 CNC is an acronym for "computer navigated cutter." It is the final production step in creating a three-dimensional object from a computer design. The process starts with CAD, or "computer aided design," wherein a virtual model of an object is created. Next, in CAM, or "computer aided machining," that model is converted into a series of scripted cutter movements for the CNC machine to interpret. In the case of my work, I skip the CAD design process, and generate the scripted cutter movements directly from a computer program; my wooden cases are thus the result of a generative computer process.

on how it will work as a medium for computerized machining. Traditional "artistic" woodworking celebrates the sublime nature of the material and emotional expression, whereas woodworking is a medium in the digital context.

The shape of wooden cases derives from the circuit board design within. My philosophy is simple, and conducive to creativity: pursue the simplest and most elegant circuits, leaving out any compensation that would clutter the design, and focusing on components that simply work. A design begins with specifying these components. Components can be aesthetically appealing in their form factor, simplicity of their operation, spread of nominal values; I use a parametric search engine to sort these factors along with price.

Compensation in a design can mean anything that tries to idealize a component, such as eliminating paradoxical or non-logical operation, compensating for external radiations such as heat or microwaves, and linearizing response curves. Leaving these out makes the instrument prone to more modes of operation than just the known one, and this contributes to the robust nature of the end experience. The dialectic with recorded, fixed media discs emphasizes diverse experiences with the synthesizer.

To complement the conceptual creativity of the circuit design, its layout is visually creative. There are three sorts of circuit layout: modular, geometric, and free-form. Modular is the most common in a history of circuit design. It localizes functions, and establishes a power feed grid that evenly services all the components. Of course this is the definition of any good circuit layout, so modular could further be refined in definition to include "rectilinear." In contrast, I spent a good deal of time

developing non-rectilinear designs, based on geometries such as polygons. For example, in the *Sidrassi* organ, the circuit board is square for efficiency of production, but it contains a heptagon inscribed within it. This heptagon, of course, is composed of seven slices of circuit pie, the main oscillators. In addition to the power service, a loop around this heptagon, there are outer spirals and inner spirals, that are signal buses so each oscillator can sample any other oscillator. The very center of the board contains a rectilinear module of simple oscillators that are the tuners for each oscillator. And finally, the overlapping boundary regions between heptagon and enclosing square are filled with an almost free-form layout of amplifiers and power support circuitry.

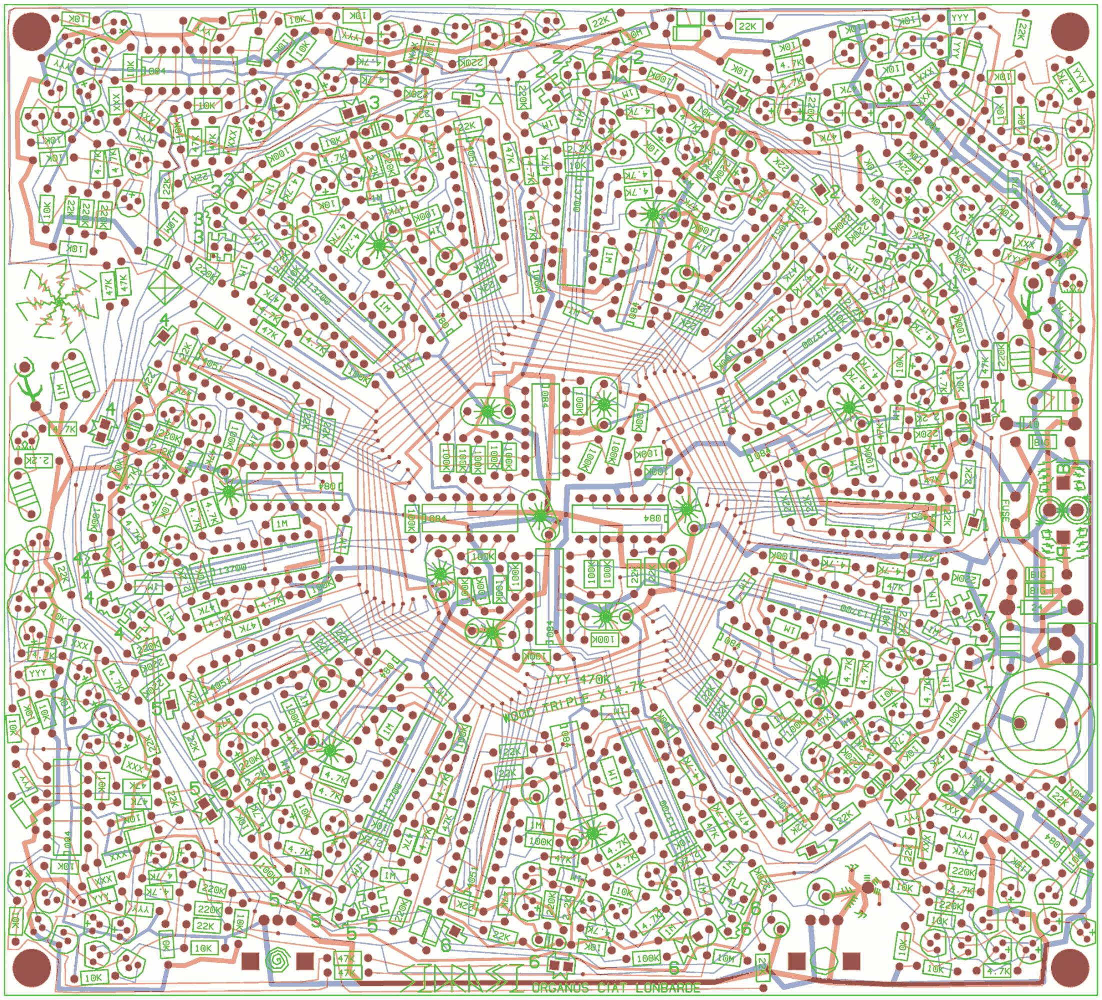


Illustration 5: Sidrassi board layout

All three layout styles exist in one board, and modules compose the geometrical form, which introduces odd angles. My experience in placing components has honed a minimalist aesthetic that allows for odd angles; the simplest way to layout components is to have shortest traces, and the components point to each other. When there are enough components feeding one node, this naturally introduces a geometrical arrangement with odd angles, so that they can all point to the imaginary center of a polygon. And free-form layout naturally arises out of geometrical layout,

because the union of different polygons creates a mesh. This mesh must fold and flex in places to fit into a square board, a necessity for most efficient PCB manufacturing.

Alternative techniques of PCB manufacturing interface this non-traditional creativity of circuit design with traditional materials such as paper. Paper circuitry is not my own idea, but I have used it extensively, to prototype designs, to distribute circuit projects for free as portable document files, and to sculpt.[27] The design requires a mirrored image of the circuit, centered around a fold-line. The printed and folded paper receives a heavier piece glued between, then it dries in a press. A small quintet of basic tools informs the still life of a circuit artist's workbench: pliers, nippers, strippers, iron, and *needawl*, or sewing needle on wooden handle. The *needawl* pierces holes in the paper circuit board. Thus prepared, components feed through the holes, and the mirror image provides lines to form and solder their leads by. The physical act of soldering helps you think: melting material and connecting diverse materials, as metaphor for creative process around it.

The traditional use of paper in the circuit trade is to print handbooks upon. The apex of this art, in many electrical engineers' opinions, would be Tektronix mid-twentieth century manuals for oscilloscopes. Comb bound tomes with leathery green covers held fine schematics, often folding out in quarti, meticulously detailed and annotated with change histories. Brick-lain charts of calibration procedures would offset diagrams of circular tubes, sigilar transistors, and their interconnections through wire and passive components. The language of schematics compels in its

27 I first spotted the idea of paper circuits on the website of an St. Louis artists' collective, known as commonsound. They used the format to share their noisy and chaotic circuit ideas.

aesthetic proximity to magical graphics. However, where Tektronix engineers felt the need to organize by right angle, a creative schematist may see conceptual potential in other geometries, and perhaps as in layout, by free-form methods.

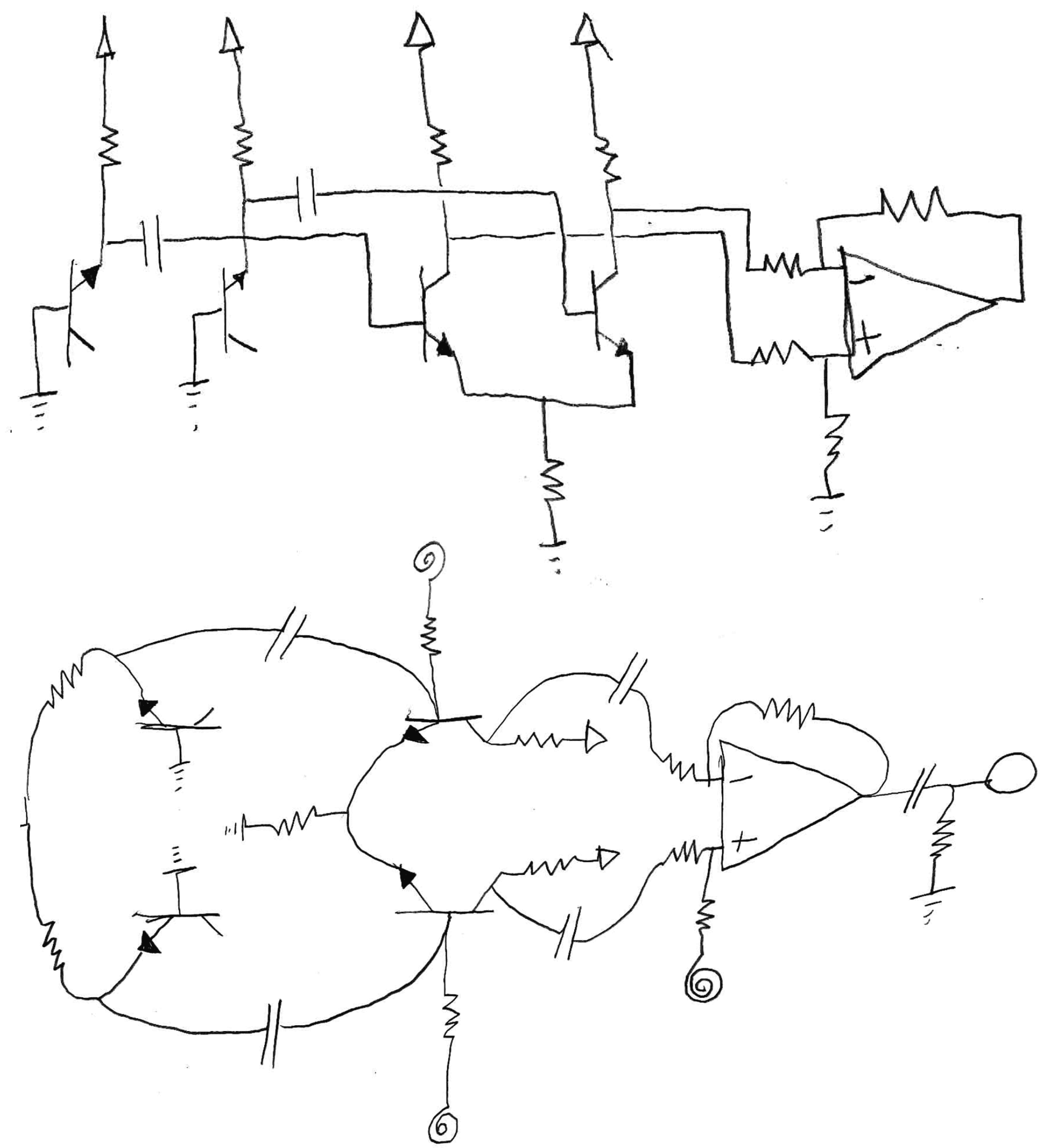


Illustration 6: Rectilinear schematic and organo-form schematic

I would choose my "Plumbutter Schematics Papers" as a radical example of handbook, inspired by the fine art lineage of Tektronix engineers. First, I chose to use the "Jazz" font for all annotations, to create a tension with sheet music. Second, all schematics are hand-drawn, without straight edges for the most part. Since they represent geometrical circuits- triangles, squares, pentagons, and hexagons- they naturally become geometrical. And the simplest two-transistor formation, a differential pair, naturally leads the schematist to think about interconnections in a flowing way. The Tektronix engineers found differential pairs difficult to represent, with many overlapping lines necessary to keep a strict modular, rectilinear layout. However, if you rotate and tuck them, no overlaps are necessary, and their operation becomes clearer. Thirdly, I explored the use of symbols in this project, going beyond simple components such as resistors, trying to really dig up the basement of circuit-thought, that includes ideas about sexuality, metaphors about our relationship to nature, and the hypnotic nature of silicon design.

There is a text in this work, but it is literally a throw-away. The schematics are designed to each fit on a square piece of paper, but since typical office printing equipment works with dimensions of the golden ratio, such as the tabloid size, there is a spare strip of paper on each sheet. This was liberating for me to produce fully stream of consciousness texts, about the circuits and their extended metaphors, as a sort of ad hoc performance. The piece ends with a photo-montage of Pamela and Tommy Lee Anderson, overlaid with silicon wafer photo-lithography. The intention is to highlight the possibility of a sexualized viewpoint in electronics and to spur

radical reactions such as a feminist, or androgynous reading of those same electronics.

At SEAMUS 2014, I had an interesting and unintentional collaboration with Asha Tamirisa et al. via paper.[28] I had traced out several historical pictures from Curtis Roads' "Computer Music Tutorial," and collated them into a coloring book as part of my work designing and programming an embedded computer music device. The conference organizers distributed these Computer Music Coloring papers as a piece of fun along with the other convention materials. However, no one realized they solely depicted men interacting with computers and virtual instruments. Tamirisa thus worked on a remix of the project, by adding feminine features to each page, photocopying it, and re-distributing it. I appreciated this as a radical remix that pointed out my own blindness to the gender inequality in the images I was tracing.

The engineering presentation can be melted and transmuted into a performance with text and synthesizer.[29] I had been waiting a long time for these days in which I am called upon often to present synthesizer concepts in a classroom. My artistic media here are such: the white-board, power-point, students' questions, chalk, and of course whatever synthesizers I brought to the situation.

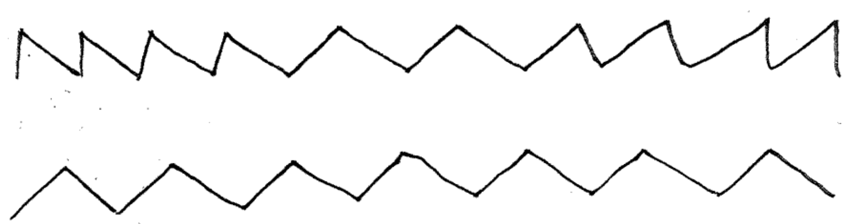
For example, I will herein reproduce the lecture notes for a seminar delivered at UCSB, in April of 2013, concerning triangle waves in analog, and digital emulations

28 The 2014 annual conference of the Society for Electro-Acoustic Music in the United States (SEAMUS) occurred on the campus of Wesleyan.

29 As a boy, my first experience with recorded lecture was listening to my uncle tape-record his notes from fishing at the trout stream. It captivated me for its creativity, to fill up a tape cassette with words, long winded and improvised opinions, and the potential to achieve aesthetic sublime in this recording process. It is recording not for mass production, but as a process in itself.

of them too. The title, "Friendship Bracelets: Deconstructing Triangle Waves," refers to the woven patterns of colored floss as analogy to the work of designing modulation patterns and laying circuits out. To compose the handout for this talk, I sat down to draw some important concepts by hand. I ended up with about twelve sketches of operations on triangle waves, modulating their bounds, their bounce (or slope) and combinations of these operations, also analogies to gestural inputs, resonances, and ending with a true emulation of the analog circuitry in digital.

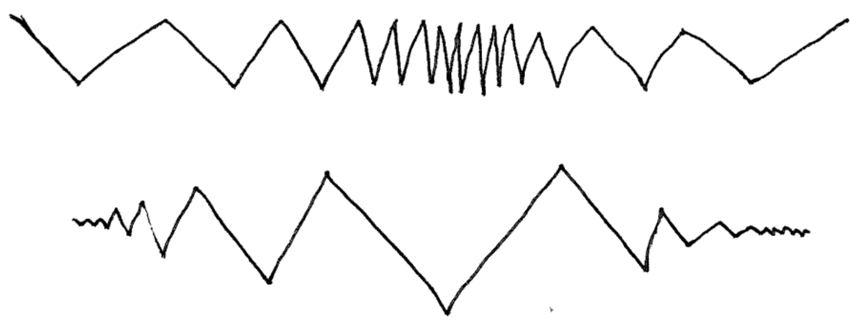
> I would first like to demonstrate an analog synthesizer, the *Sidrax* Organ. Seven flexible wooden bars sense finger pressure, to control seven essential triangle oscillators. It is an amplitude modulation; the instrument is silent when un-touched, and electronic tone loudens with pressure. There are forty-two nodes that when patched by wire or touch, connect voltage representation of gesture and the triangle waves to frequency modulation and glitch inputs. The synthesizer builder learns to make a triangle oscillator very early on, however, it is durable through a wide range of modifications and enhancements. Furthermore, it can be used as sub-component for more sophisticated assemblages. It can work as a clean triangle or a sawtooth, or anything in between:



> The triangle wave is a mechanical system with one capacitor charging and discharging in alternate strokes, controlled by a hysteresis mechanism that sets its bounds. The speed at which it bounces is the usual method of modulation, and this bounce can be further split into two branches- the speed going up and that going down. This is the source of the saw wave and various other articulations between it and the essential triangle wave,

which has equal speeds up and down.

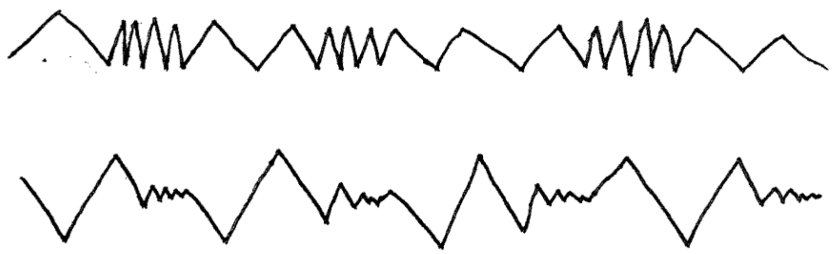
The first point I would like to make is that there are actually two ways of modulating a triangle wave- controlling its bounce as already mentioned, and also controlling its bounds. Actually bounds modulation is practiced quite often, but not distinguished from the other way; hobbyists with the old and brutal "555" chip, when modulating, are actually controlling the top breakpoint,"threshold" of a saw-triangle amalgam. This method is shunned by the more sophisticated synthesizer builders, because it only modulates the bounds,which is an instant in time rather than the continuous modulation of bounce. Bounds modulation is also the route to sync-lock circuits; when the modulator is faster than the carrier, it generates an integer-locked undertone series. This is the magic key to what we will talk about later in the digital emulation of these circuits. But for now, we have opened triangle wave oscillators to two kinds of modulation, bounds and bounce:



A hi-fidelity enthusiast's reaction to the triangle wave is anxiety about infinite energy present in its sharp peaks. This energy is theorized by Fourier analysis of the "perfect" wave, concluding that a harmonic series extending to infinity is the source of the transients. These frequencies, and thus energies, will break speaker cones of the hi-fidelity set. Of course, in reality they are rolled off, but it is an interesting reaction due to the Fourier-dependence of acoustic theory.

A triangle rotated becomes square steps on a staircase; the triangle and square wave go hand in hand, for the square signal is involved in the mechanism of the hysteresis loop, which decides instantaneously to reflect the wave in opposite direction, or sign change.

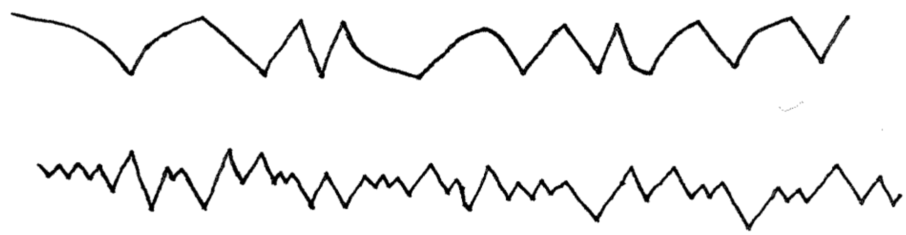
When a boy sees a triangle wave, he will most likely see shark teeth; a geologist, freshly formed tectonic mountains without rounding erosion. I like to see the tail ridges of a basilisk or iguana. Two sources of variation: bounce, or slope and speed; bounds as the height or depth:



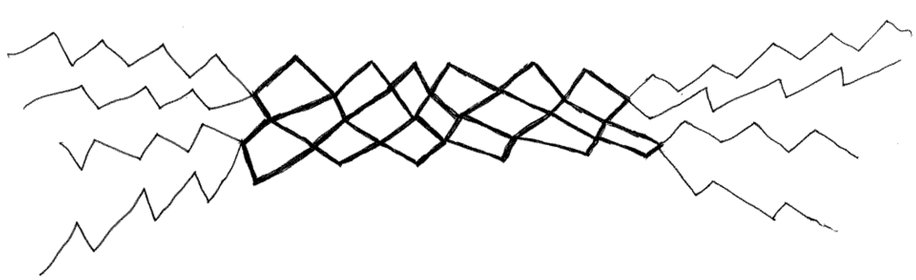
Listen to mylar chips-bags crackling nearby as someone eats a sandwich. As a misophonist, I am repulsed by and attracted to these crackling and crinkling sounds made from impulses of mylar folds flipping from concave to convex. They are an explosion across the spectrum made from sharp changes; mylar is the only plastic that generates ultrasound, and one can easily distinguish it clearly from all the other synthesized sounds in our environment. Listen to it, especially with high pressure in one's ears, and note the difficulty of reproducing these crinkles by Fourier methods; it is hard to mp3 compress a chips-bag. I am spurred by ASMR studies to bring these sounds about for the benefit of listeners who hate sounds, so that they may love them again. Two ways to do this:

1. physically construct sculptural mechanisms such as coke bubbles in aluminum or solenoids that squish candy wrappers. Note that misophonists often need a conscious target for their sound-rage, and if the same sounds are generated by a machine, the anger is diffused.

2. electronically synthesize the chips-bag. here is where assemblage of triangles comes to the fore. Bounds and bounce modulation disclose the chaos and ensuing sound-rage of the electronic chips-bag:



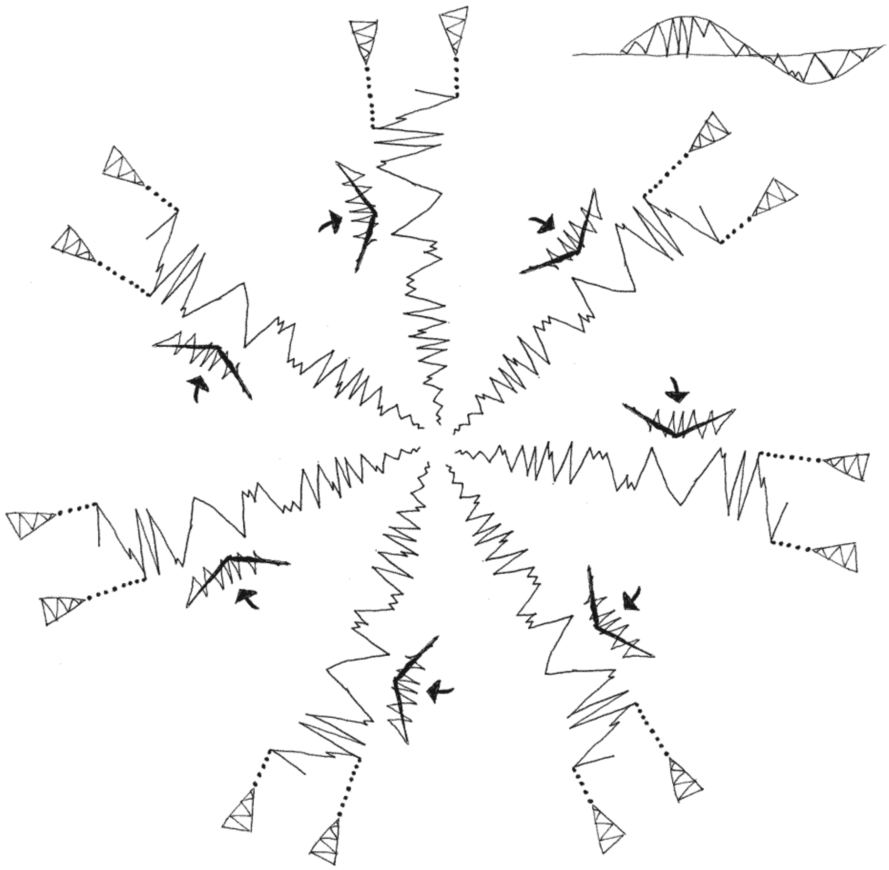
Now I'd like to describe a few circuits that combine triangle waves to break out the inherent possibilities of sharp peaks and modulation to make chaos, or the afore-mentioned "chips-bag". *Fourses* was originally a kit to make "novel musical sounds," available from *Ciat-Lonbarde*. It was inspired by the thinking detailed above, about modulating both bounce and bounds, to see what happens when oscillators bounce off of each other. Four horses is the metaphor of the naming, but it may be easier to think of them as bouncy balls in a greased tube of their diameter plus a little breathing room so they can move smoothly but not pass each other. Incidentally, this is the same sort of thought experiment used in particle studies to highlight how particles of the same sort are indistinguishable from each other so they may be thought of as bouncing or passing through each other. However, these particles are distinguishable, for they have separate bounce controls for each one; traditional frequency modulation of slope makes them unique operators in the experiment. When they bounce, then, they create triangular waves of chaos in the system, to be sampled and enjoyed by all via electro-acoustic diffusion. The *Fourses* mentality is bouncing off of each other's contingent bounds:



I am bringing *Fourses* back in the near future, and I would like to demonstrate how these circuits are initially prototyped on paper. On paper circuit, that is. I have constructed the four oscillators, and their analog

switches connecting bounds to each other, with four knobs in the middle to explore the various settings of bounce that make the assemblage more or less reactive. This instrument is also nodal, in that it has many touch points, for circuit-bending the apparatus and creating further modalities.

Nodal synthesis is not the topic of this discussion, but it is fruitful in triangle waves, because their synthesizer is a mechanism that you can "go into" to massage its inner, soft workings. The charge capacitor and hysteresis loop are circuit bending points that correspond to the formal modulations of bounce and bounds respectively. Another instrument that uses nodes as well as the formal modulations is the *Sidrax* organ. In this organ, which I demonstrated earlier, I wanted to take the modalities of *Fourses*, generalize them, and offer gestural control via the wooden bars. The seven oscillators are arranged in a circle, for continuous bounce modulation from one to the other, controlled by an aptly named "chaos knob". In addition, each oscillator has two nodes, called "glitch" inputs, which rewire their bounds to refer to other oscillators, as in the *Fourses*. The difference is, that *Sidrax* has a "ground state" where each triangle operates within fixed, normalized bounces, yielding a perfect, singular frequency wave. I've found it important to have such a base state to start performance, and take it from there. The conceptual schematic of *Sidrax*:



Sidrazzi Gamelan

The *Sidrax* inherits its interface from earlier instruments, known as *Sidrazzi*. They are wooden instruments, with seven bars that flex. They have a “base state” of silence, that responds to touch to produce pure tones. To tune the pitches, there is a master pitch knob, but also a button for each. This button, when depressed, scrolls through a wide range of pitches, to hold the tuning when released. I call it an analog scroll, because it scrolls through possibilities with a simple analog circuit. The circuit has a chaos control that smoothly transitions the oscillators from un-modulated to complete circular modulation. Finally, it offers a total of forty-two nodes for circuit-

bending; intuitively patching them with wire or touching them brings about further modulations to the internal circuitry.

The chaos control deserves a little more explanation. It is known from dual oscillator systems that if oscillator A modulates oscillator B and vice versa is true as well, the resulting sound can become quite noisy, from the indeterminate and independent phase states. We shall term this circular modulation, and extend it to the *Sidrazzi*'s system of seven oscillators. Inserting a VCA at each point of modulation, all can be controlled from un-modulated clean tones, up to a very pure sort of flavored noise. This is the master chaos control, and it complements the master pitch control, likewise affecting all oscillators. These two knobs generate a wide variety of pitched and not so pitched sounds. Using the nodes of the instrument is not necessary except for the pursuit of pursuing hyper-chaos; as a solo instrument this is quite interesting but not so much when the amount of players is increased.[30]

A base state of silence suits improvised music situations, such as with acoustic instruments. although my favorite mode of playing was alone in the organ-testing loft, late at night or any other suitably esoteric time, playing faraway and strange types of hyper-chaos by circuit bending, the basic method is popular in groupings of musicians. A social setting focuses on basic interactions with the instrument. That was my interest in a 2014 workshop and concert activity called, “Sidrazzi Gamelan.”

> “A sidrazzi is an electronic organ that emits a spectrum of pitched and chaotic sounds. The gamelan is an ensemble of gongs and a music of multiple-layered aesthetics. Through compositions and improvisations,

30 Hyper-chaos, a term coined by Quentin Meillasoux, means not just chaotic or noisy sounds or actions, but the possibility to instantaneously rupture into simple or traditional modes.

graduate music student Peter Blasser’s ensemble will weave the two together.”

So goes the copy for a Wesleyan concert in early Fall of 2015. Since John Berndt, a Baltimore organizer conceived the idea for a “Sidrazzi Gamelan,” it has been realized thrice in different settings. The first concert, in the Creative Alliance, Baltimore, reflects Berndt's unique viewpoint on pataphysics and directed improvisation, and added quite a bit of live theater. Here is the program note for the event:

> "Sidrassi Gamelan" is a new project directed by John Berndt that is a homage to the disparate sensibilities of Martin Denny [known as the father of exotica], Peter Blasser, and Peter Zahorecz.
>
> Based around Peter Blasser's original "Sidrassi Organus" instrument, the ensemble performs composed music that is to Balinese and Indonesia music (where I recently visited) as Walt Disney was to Freudian Psychology. In other words, it is "exoticism beyond exoticism," attempting to get to the other side of the projective mirror of imagining other cultures by projectively creating a culture that doesn't exist (rather theoretically like the Afro-Germanicism of Multiphonic Choir, albeit very different in practice).The ensemble involves electronics, gongs, special lights, costumes, and electronically processed voices [...] The music is composed by John Berndt.

A wide array of gongs and choir complemented the original Sidrassi Gamelan. One of John Berndt's musicological inventions is *relabi*, form the Latin word for slipping. It refers to an always varying rhythmic pattern, activating glitches and re-flowings in dancing; it is a rhythmic analogy of circuit bending. In realizing these beat patterns, different techniques of random or chaotic generators are explored and contrasted against each other; something like sample and hold controlled metronomes may actually be too random and create an un-danceable situation, while subtler

modulations of the beat are more suitable. Thus Berndt came to use a circular modulation of low frequency oscillators to generate *relabi*, like the chaos control of the Sidrassi. This emphasis on slipping beat was part of the Sidrazzi Gamelan from the beginning, and it may be equated with the free-meter flowing introduction of a traditional gamelan piece. (Berndt, 2009)

My involvement with the first Sidrassi Gamelan was minimal, however Berndt did ask me to coin names for a list of structured improvisation concepts. Following is the result of that linguistic collaboration:

- Cranslong: sudden, syncronized random changes of tempo
- Accrescence: rhythmic patterns speed up to crescendo
- Wabawaba: rhythms fall apart into a pulsating bed.
- Succo-Inculcubi: ornate melodies that continuously elaborate
- Griodus: strange trickster figure who interrupts music
- Huap: backwards singing
- Barberibus: endless upward elevator

That Spring, in 2011, I was visiting professor of TIMARA (Technology in Music and Related Arts) at Oberlin College, in Ohio. One of my duties was teaching the Performance Technology class. Because my workshop (and wife and child) remained in Baltimore while I taught in Ohio, I would have to build instruments in batches, and thus had enough Sidrazzis available for my class, so it became clear that we too would have a gamelan in Oberlin. The terms developed for the Baltimore

gamelan were useful, but it seemed we needed another element to aid the ensemble in its conducted improvisation.

Youtube provides pedagogical material for Performance Technology class, with its vast store of interface documentation. The classic channel is that of STEIM, the Dutch institution whose masthead reads

> "Touch is crucial in communicating with the new electronic performance art technologies. Too much the computer has been used, and designed, as an exclusive extension of the formalistic capabilities of humans. At STEIM the intelligence of the body, for example: the knowledge of the fingers or lips is considered musically as important as 'brain-knowledge'."

To learn this knowledge, we used Youtube to have "STEIM-time" in class, focusing primarily on the spiritual leader of that organization, Michel Waiswicz. At the time of the birth of MIDI, his team designed an interface to capitalize on that protocol, a set of "hands," organo-form prosthesis that embraced his hands and encrusted them in various touch and distance sensors. The students were struck by his sincerity at using the instrument, remarking that perhaps this interface highlights a social relationship more than its technology; that is the human nature of STEIM's goals.

It is my sort of creativity to latch onto positive reactions, such as the students who at the depths of music-technology despair, actually responded well to STEIM. Spurred by this, I created a non-electronic simulacrum of Waiswicz's hands, and introduced it to the students as a conducting tool for the Sidrazzi Gamelan. I asked them to explore their instruments, contributing ideas for sound systems that

“responded” well to conducted cues. The conducting here is more gestural than that with a baton- the assemblage of micro-gestures paired with sensitivity of *Sirazzi*s makes a more intimate, twitchy relationship possible. Because of the presence of the hands, as precedented by the Youtube videos of Waiswicz performing it on a bare stage with synthesizers hidden, it was decided that I the conductor would solely inhabit the stage, and *Sidrazzi*s would operate from the audience. Also, the students let me know that they had no interest in being on stage performing with technology- a typical post-aughts stance. The site for this student concert was Warner Concert Hall, a traditional conservatory space, with quadraphonic sound. As creative facilitator, I feel the responsibility of site-resourcefulness, meaning that if there is quadraphonic sound, use it. It helped that the gamelan were in the audience so they could connect directly to the sound board in the center of the space, and react to hearing their own sound so clearly. Since the organs respond to press and release in a stereo way, we thus spatialized them paradigmatically so that all speaker relationships were represented:

- Left front, Right front (front stereo)
- Left back, Right back (back stereo)
- Left front, Left back (front to back stereo)
- Right front, Right back (other side front to back stereo)
- Left front, Right back (diagonal)
- Right front, Left back (other way diagonally)

The concert was not video recorded, and I feel this added to its success as experimental music. I still have a tension with video documentation, and I ended up playing with this for the next gamelan, in Wesleyan. There, in 2014, several students formed a DIY club, focusing on soldering, 3d prototyping, screen printing, and woodworking. They asked me to lead a project. I had recovered several obsoleted *Sidrazzi* circuit boards, and fine wooden cases to go with them, just for this sort of task. I always have extra stock of older instruments for the purpose of sharing with young people; it is a great business move to keep on refreshing the user stock, and also interacting with them brings up new questions and ideas.

We planned to have a workshop in a small maker space tucked in the back of the experimental music studios. I procured some fine mulberry wood from Massachusetts- this wood is very flexible and prime for bars- and sliced it into some blanks for the students to finish. They also had to sand and finish the case, installing buttons and other components. The *Sidrazzi* circuit board is my first design for surface mount manufacturing- a robot had already placed and soldered all the transistors and resistors so thankfully we did not have to toil on that task. However, because it was my first design, I was unsure about what capacitors to use, so I left them open for stuffing with through-hole components. This was a small but noble task for the students, who could modify the values, distributing the oscillators' ranges, and also the analog tuning scrolls could be sped or slowed. The tuning scrolls used to be much faster resulting in more arbitrary pitches, but also having a distinctive, scrambling sound that could be applied to any bar as an effect. In most of my early

instruments, I specified a variable range for crucial capacitors, allowing for personalization of the instrument.

We made and tuned. The ensemble, by nature of the analog scroll button, is always in arbitrary tuning, contrasting with the traditional gamelan in fixed tunings. However the gamelan does have the idea of "pleng," meaning slightly detuned, a concept that is important in analog synthesizers. Pitch drift is miserable to some musicians, and important to those who make interesting sounds, because the detuning creates beats. Needless to say, we used tuning as an abstract idea in the ensemble, never tuning to fixed pitches. For example, in the first piece we practiced, Eine Kleine Gamelan Music, by Daniel Goode, we needed to have three consecutive tones, so we made tuning part of the concert; each student consecutively scrolled pitches to find these three pitches, according to her own taste.

Most of the soldering was done in Spring of 2014, so the first students could spend Summer with their instrument. Over the break, I asked them to think of a simple sound idea that would work in ensemble. In the Fall, we added a few new members in the workshop, totaling eight. Daniel Fishkin also built a "*Sidrazzi* Bed" around this time, using two circuit boards, for a total of fourteen piezo surfaces; I say surfaces here because he did not build bars per se, but made long piezo cords that could affix to the slats of a bed, or the cushion of a chair. His central console was a fine wood coffee table, with a perspex plate to house the circuit boards and jacks for the piezo cords. In this piece, he also brought forth the forty-two circuit-bending nodes of each *Sidrazzi*, as brass screws, that could be patched by simply putting a

metal cup down on them, or house keys, or traditionally with wire or crocodile clips. None of the other students brought forth their circuit-bending nodes; they remained a hidden feature for the concert because of the extra work to install them, but also the density and unpredictability that circuit-bending adds to the sound.

Wesleyan's World Music Hall was the site for the concert, and we spent about two practice sessions there, on Tuesday nights. The hall is an interesting treatment of the traditional gamelan ensemble. Normally sitting on a flat floor in an open pavilion in the royal court, the sound of the gamelan could broadcast acoustically through all the functionary buildings, and enjoy the mild breeze, escaping the tropical sun and rain. However, Connecticut is a different climate, with cold winters and much snow. The Center for the Arts features many underground spaces, such as the kitchen and lounge in WMH, and a vast network of tunnels in the concert hall complex, in part to escape the drastic climate that pervades the school year. With current developments in weather patterns, the tunnels are frequently flooded and humidity has become a problem in the WMH, especially threatening to the wood and skin foreign instruments. Perhaps the open pavilion will be more appropriate in the future. But as it is, the WMH is a brutalist-humanist manifesto, with a unique, tiered arrangement for the gamelan:

> "The tripartite performance area represents another cultural adaptation, as it displays the gamelan for performance and makes every instrument and player easily visible from the audience. This increase in visibility heightens the overall spectacle and intrigue of the ensemble, keeping the audience's attention. The space's emphasis on the gamelan's visuality hearkens back to the fascinating yet problematic history of this particular set of instruments." (Chilton, 2014)

The tiered gamelan is balanced by a tiered, carpeted seating arrangement, separated by an open parquet floor for dancing. The four PA speakers are not quite quadraphonic; they are more like four speakers pointed at the audience, but not surrounding it. Yet they are separate sound sources above the square space of the dance floor. I used the in house mixer, at the foot of the carpeted audience seating, and placed the synthesists here in the front of the audience. The dance floor was still open, and we decided to move some comfortable seating up, to make up for the invasion of the audience space. Also, the soft chairs were outfitted with Fishkin's piezo cords, and muted during the performance to be activated and sonify their movements after the concert. The following program note describes each piece:

> Eine Kleine Gamelan Music, by Daniel Goode
>
> Gamelan Son of Lion is “a new music repertory ensemble based in downtown New York City specializing in contemporary pieces written for the instruments of the Javanese gamelan.” Daniel Goode was one of the founding composers, and this piece is a good example of minimal modern composition; the score is a short segment of rhythmic measures, with type-written notes on possible variations and performance: “Construct 3-note melodies of a step followed by a skip or a skip followed by a step in any scale, mode, key, in any tuning, either upward or downward (but not both in the same melody)...” We have adapted the piece for the Sidrazzi organ, plus the gongs of Wesleyan's gamelan Kyai Pradah and Mentul, which mean generous and bouncy.
>
> Is Always Left, by Daniel Fishkin
>
> Fishkin's piece is a short social element where only one channel of each organ is connected, and players are instructed to lie down and apply pressure to the bars statically, such that the jerking of muscle twitches can be heard as objets-sonores. Fishkin's piece sonifies fatigue, creaking of bones, and twitching of muscles.
>
> The Hands of Michel Waiswicz, realized by Rachel Day, Daniel Fishkin,

Cecilia Lopez, Angus Macdonald, Luke Macdonald, Dan Muro, Sean Sonderegger, Ron Shalom, and Ben Zucker

Inspired by a video of Michel Waiswicz and the mystery of his instrument, "The Hands," we collectively defined a set of improvisational states to be conducted using a non-electronic simulacrum of that instrument. We identified a collection of different dynamic characters, such as: silence but with possibility for micro-gestures, slow changing parameters, parallel movement, beach sounds, and marching; the conductor has scripted gestures for each. This piece explores electronic interface by using a social contract as sensors and interpreter. It also pays homage to the media image of Michel, who shines in his improvisations with a sincerity that transcends his electronics.

About the Sidrazzi Gamelan

The Sidrazzi Organ is an electronic musical instrument that senses touch by flexing seven wooden bars. Inside, there are seven oscillators, stereo amplifiers for each, and pitch controls as well as a chaos knob, that causes the sweet triangle waves to gradually become a sort of noise by inter-modulation. The Sidrazzi Gamelan is composed of two groups of four plus one griot, who solely plays the Tetrazzi, an organ designed as complement to Sidrazzi. Sidrazzi generate sweet triangle waves with the option for chaos, whilst Tetrazzi generates anything between saw to triangle waves; it has more timbre available and acts as punctuation. The Tetrazzi griot sits in the middle, and the two groups flank him. They sit in the terraced, carpeted area usually reserved for audience in the hall, facing a mixer. The reason is practical; this way they can all monitor the sound directly from PA system, and also they are close enough to the mixer to make wiring a simple affair. The bars of the organ, when pressed, emit tone out one channel, and when released switch to the other channel, and so the sounds will constantly move from speaker to speaker.

Analog Assemblage

The popular conception of synthesizers wholly refers to analog electronics in the 60s, which were quickly subsumed by digital techniques. However, analog electronics have experienced a recent comeback. Whereas earlier synthesizers attempted to generate universal tones, newer designs describe idiosyncratic

assemblages of metaphors. Naming and narrative inscribe the new fictions in circuits of silicon and copper. I conceived the Plumbutter synthesizer around a psycho-geographical model, and a drum machine composed of basic building blocks in novel configurations. Its story grew to include a personality on Facebook, a model of Lyme disease etiology, and a computer game design. This is the instrument's "artist's statement."

An assemblage is an "individual singularity" comprised of interconnections of constituent parts, and its historical context or contingency. It is both decomposable, or subject to analysis, but also irreducible, or allowing for the possibility of synthesis. The term "synthesis," like "analog," has a double meaning; in the harmonic context it means "to put together sounds," and in the philosophical context, "to assemble disparate concepts." It can be said that a synthesis of synthesis results when analog sound circuits are treated as an assemblage. The term "individual singularity" implies that each assemblage is unique due to its connections, parameters, and historicity; however it can manifest "universal singularities" such as feedback, bifurcation, and accumulation in its diagram. A dialectic can be seen here; an assemblage is ultimately dependent on its materiality, however its diagram can be shared, as a metaphor, with other processes. (Delanda, 2011)

Manuel de Landa derived assemblage theory from the writings of Gilles Deleuze. On first encounter with Deleuze and Guatarri's "Thousand Plateaus", I thought, these writings that smash the idea of hierarchy and structuralism, how nice they would be if applied to synthesizers? For example, Deleuze contrasts the notion

of arborescence, or hierarchical structure, with that of the rhizome, or a root-like, horizontal spreading nature. Structuralist analog synthesizers rely on a strongly typed system of inputs and outputs, and it is this linearity that makes them arborescent. What if nodes could be made that are both input and output, or neither? Would this lead to a sort of rhizomality wherein connections could be made horizontally and thus any node could manifest a facet of the entire assemblage? This led me to name a concept, *sandrodes*, to hold the meaning of "androgynous nodes." In naming a concept much is done towards taming it.

Not only did the writings of Deleuze inspire the naming of *sandrodes*, but the milieu of the early 21st century was heavy on noise music and especially the circuit bending to coax strange new sounds out of old toys and synths alike. These treatments of electronics emphasize intuitive probing and experimentation with the innards of circuits. I was searching for a way to make a musical instrument circuit-bendable by design, so it needed to have nodes that could be crossed with each other in infinite combinations. An earlier instrument, the *Shinth* was just a circuit board to be touched, but if metal got near it, it was dangerous; some nodes are "harder" than others and can break the instrument if connected directly. This was the pragmatic reason to curate *sandrodes* and bring them solely to the surface of the instrument.

I prototyped this strategy in a manifesto-instrument, known as the *Din Datin Dudero*. Here there were several analog circuit components, linked by various modulation schemes. Two large knobs act less as continuous controls and more as gesture mappers linking contingently to the inner assemblage. The whole surfboard

responds to wiring on its brass *sandrodes*, and touching it can cause internal re-wirings.

Illustration 7: Din Datin Dudero

I theorized two types of *sandrode*: inter and intra. Intra *sandrodes* are essential to the operation of a particular analog module. Eliminate the intra *sandrode*, or reactive self-linkage, and the module stops functioning. This *sandrode* may also link with timebase passives such as capacitors. An inter *sandrode*, however, is simply a voltage or current connection from one module to another, as a connection from output to input. It is a pre-wired analog synthesizer patch; if it did not exist, the

separate modules would still continue to function. The art of *sandrode* strategy is two-fold: extracting and revealing the intra *sandrodes*, and weaving the modules to each other to create inter *sandrodes*. The weaving should have meaningful purpose, but also a base state; the instrument should sound relatively neutral at rest, so touching or wiring sandrodes brings it into a higher level of activity. This is how *sandrodes* induce intuitive play.

It can be said, in an assemblage theory of *sandrodes*, that they reduce territoriality; any one *sandrode* can connect to another, resulting in a novel change of state in the whole. When inter *sandrodes* connect, it is like folding a lace pattern over itself; the preexisting modulations cross with new ones to further the complexity. When intra *sandrodes* connect it may be a more paradoxical or unpredictable situation. It is possible to have a mixture of the two types, where paradoxical behavior mixes with more linear superpositions.

Rolz-5

In 2007, I sought to extend the concept of *sandrodes* to a new synthesizer, built as paper-circuits, that functions as a “free-jazz drum machine.” The inception was a bus ride to the Baltimore public library, where I meditated on my band's need for a synthetic drummer. Being a three person band with unfixed instrumentation, we often shared the duty of establishing a pulse. That said, I disdained the moment when one person stops improvising and becomes a dogmatic beat machine. So I wanted to use transistors at their best, as a replacement for the human beat machine. This beat

machine, due to other idiosyncrasies of analog, would desire to become an improviser, reversing the polarity of the human-machine musical equation.

In the TK section of the Baltimore public library, I picked up a book by Delton T. Horn, titled "Oscillators Simplified with 61 Projects." In the book Horn describes various oscillators, including the astable multivibrator, a compound of what I would term two identical transistor "neurons." I use this term to suggest the three essential properties of both the neuron and this transistor configuration: discharge, threshold, and amplification. The transistor neuron uses a capacitor and resistor to set a discharge time, a transistor that has a built-in threshold at its base, and an inverted and amplified signal at its collector. A biological neuron also has a threshold, below which it does not fire, a discharge time based on chemical factors, and amplification of signals. Transistor neurons connect to each other in a loop of two to make the simplest square wave oscillator, known since the days of tubes as the multi-vibrator. Horn described this first, then experimented with a novel configuration consisting of three neurons in a loop.

When I prototyped this oscillator, I found it did not produce a regular beat at all. Instead, it tried to resolve its paradoxical conditions by spiraling into a ultrasonic instability. I learned of its paradox nature by extending the multi-vibrator concept from two neurons, through three, into loops of n- neurons. In investigating longer chains, I found a strong connection between parity and signal type; multi-vibrators with even amounts of neurons produced a steady and predictable beat, while those with odd amounts produced ultrasonic chaos. To understand this behavior I theorized

the paradox state, as can be simply diagrammed below.

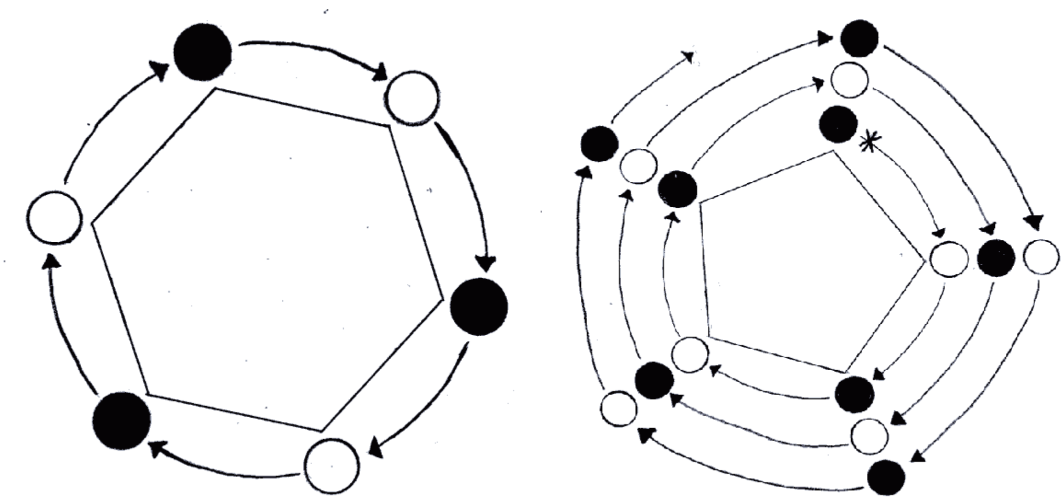


Illustration 8: Even and odd pulse rolls

The diagram shows the two parities of multi-vibrator, using a lozenge to indicate the instantaneous state of each neuron in the loop. As transistors are inverting amplifiers, the lozenge changes polarity from one neuron to the next, shown with alternations of black and white. As can be seen in the even loop, the instantaneous state sustains and accentuates itself, and this is how a normal multi-vibrator works; by an even amount of inverting amplification, states are held for a definite period of time. However, with an odd amount, the alternating states do not add up to unity on any revolution, so instead they produce a spiral of paradox.

As far as complex sounds went, the paradox spiral could not compete with other sources, such as the recursive torque inter-modulations of Sidrax, but I did have an intuition that it might help with the drum machine that desired to improvise. I

theorized that an assemblage of even rolls and odd rolls could generate a combination of steady beats mixed with limps and bursts of noise, as a free jazz drummer. To investigate, I drafted up a series of paper circuits, known as the rolls, with three, four, five, or six neurons each. These paper circuits were particularly immanent, as a sort of magical symbol and practical instantiation in one diagram; the function of the circuit is immediately visible in the layout.

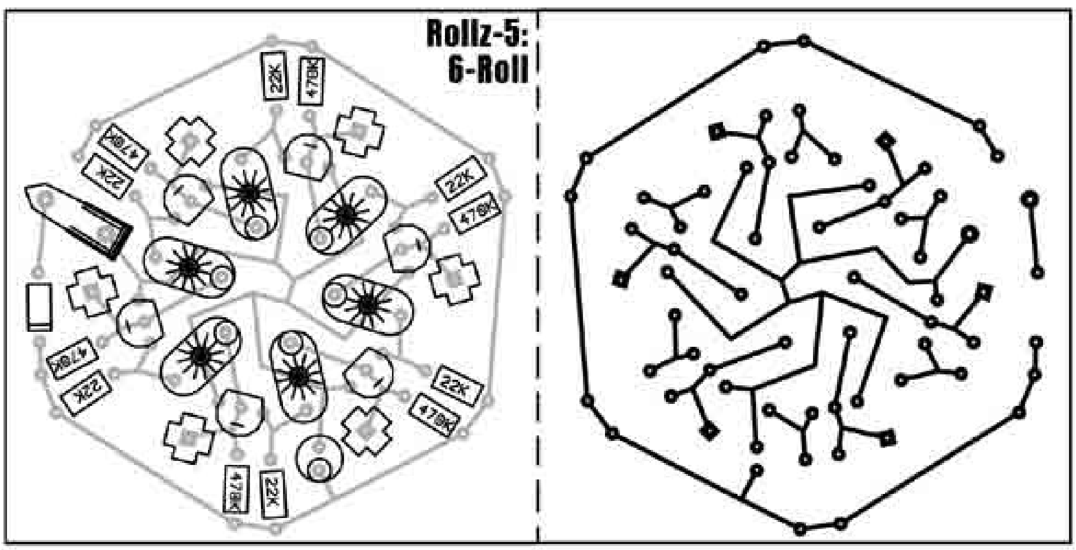


Illustration 9: Paper circuit for a roll

Now that I had working models of the various rolls, I could connect them together in various configurations. First I would define a connection point, ideally androgynous in nature so that any one could connect to any other without hierarchy of inputs and outputs. The node at the base of each transistor, connected to the previous neuron through capacitor, is both an input and an output, so I identified it as the necessary *sandrode* and marked it with a cross symbol on the paper circuit. This node connects to the surface of the instrument as a brass rod. The advantage of an exposed

connection such as brass rod is that, as with *sandrode*, they can be wired together as well as touched, as a web of connections with unique in-line resistances.

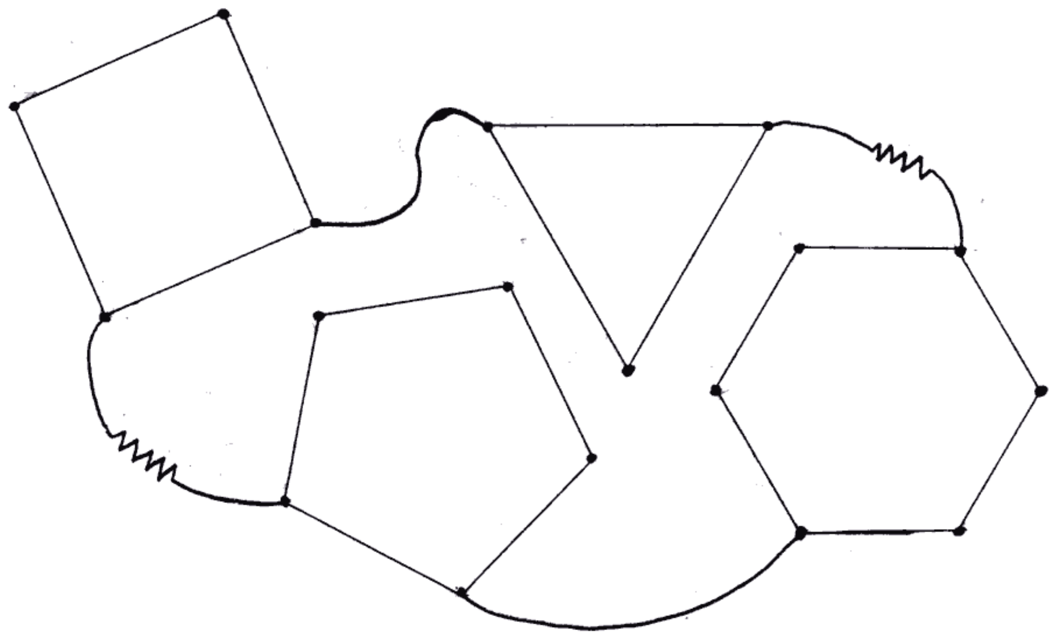


Illustration 10: Assemblage of rolls geometries

These geometries of neurons, loops and spirals, are the foundation for the earliest village of Plumbutter, known as “Rollz-5.” They are like members of a tribe that intermarries. When an odd and even tribe connects, the resulting assemblage has a mixture of the attributes of each: a little bit of paradox and a little bit of stability.

What does the paradox sound like? Because the odd roll is constantly trying to resolve its state to no avail, it generates a chaotic ultrasonic noise wave form; it required an ultrasound translator. Up until then it was all a forest of *sandrodes*, but the first translator had a separate input and output, marking it not androgynous. Thus began the translator layer, taking *sandrode* activity and manifest some facet of its

rhythm, resonance, or micro-sonic texture. In the ultrasound filter, a heterodyne, or frequency multiplication, translates ultrasound down in spectrum to audible frequencies.[31] This is also how bat detectors work.

The final two translators, known as *Gong* and *Avdog*, compliment each other. To describe their operation, consider their constituents: the mechanical oscillator and the harmonic resonator, respectively known as VCO and VCF in analog synthesis.[32] I see them as sun and moon, or male and female, if we shall be permitted to take a re-constructive view of such an oppressive binary. The oscillator is like the sun because it only generates waveforms, whereas the resonator is like the moon in that it takes waves and reflects them; the resonator has an input, whereas the oscillator does not. Also, the oscillator works in a mechanical, sharp edged manner, whereas circular, tidal forces drive the resonator. The oscillator uses an if-then logic to pump up and down; the resonator uses differential equations to pendulate any added energy.

At this point I would introduce an alternative notation for the components introduced so far. It is based on the tri-centric philosophy of Anthony Braxton, which uses three primal shapes as shorthand for musical concepts: triangle, circle, and square.

> One aspect of the musical system he's been constructing since the 1960s is the terminology he uses to describe and explain it. Thus, to use the examples in the following, "house of the rectangle" refers most generally to the fixed aspects of nature--product rather than process, position rather than trajectory; "house of the circle" is the polar opposite of that, spontaneous improvisation, that which streams; and "house of the

31 If we think of the translator layer as a governmental-industrial corporation, ultrasound filters are "pulsemining" the noise of the rolls.

32 VCO stands for Voltage Controlled Oscillator. VCF, Voltage Controlled Filter

triangle" is synthesis, of those first two houses and in general. (Heffley, 2001)

Since the afore-mentioned rolls generate square pulses, that shape shall denote them, and a broken square shall denote the paradoxical rolls. Because the simplest oscillator generates a triangle wave, then that shape shall represent it. And because a resonator generates sine and cosine waves, the basis of a circle, there we have our final representation. By taking a binarism such as the oscillator and the resonator, and immediately bringing it into a trinarism, I hope to open it up to Braxton's concept of "logics," that is, a plurality of overlapping viewpoints rather than a monolithic "logic" of oppositions. To relate *Gong* and *Avdog*, I will point out that each contains a triangle oscillator, and a circle, or resonator. They each work in two regimes of frequency, that I define as theta for sub audio or rhythm, and omega for audio or pitch. Rollz-5 is essentially a drum machine, so a large amount of it operates at theta frequencies; the rolls are slow and the translators take this slow input. But the audio frequencies are needed to mark the sound in a space of silence: it is like the horn on a buoy that is powered by slow wave motion.

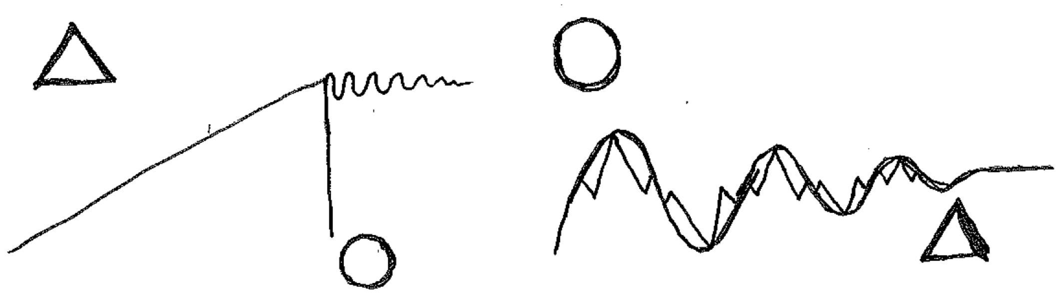


Illustration 11: The Gongue and Avdog ideas

So, in *Gong* and *Avdog*, one component operates at theta and the other operates

at omega. *Gong* takes a rhythm and divides it in time, periodically ringing its resonator, like a gong sound. *Avdog* takes a rhythm and resonates it, and applying this undulation to a triangle wave, thus revealing the proportion of its resonant frequency in the rhythm. In *gong*, the triangle is in theta range, so it provides the relatively long time periods, whereas the circle, a resonator, rings a sound triggered by the triangle. It operates like a gamelan gong player, waiting for long intervals and then striking a resonator.

The materials of Plumbutter are, as follows:

- the square, pulse networks for rhythmic pulse, known as rolls.
- a broken square, representing paradox
- the triangle, a form mechanism for oscillation
- the circle, a flow integrator for resonance

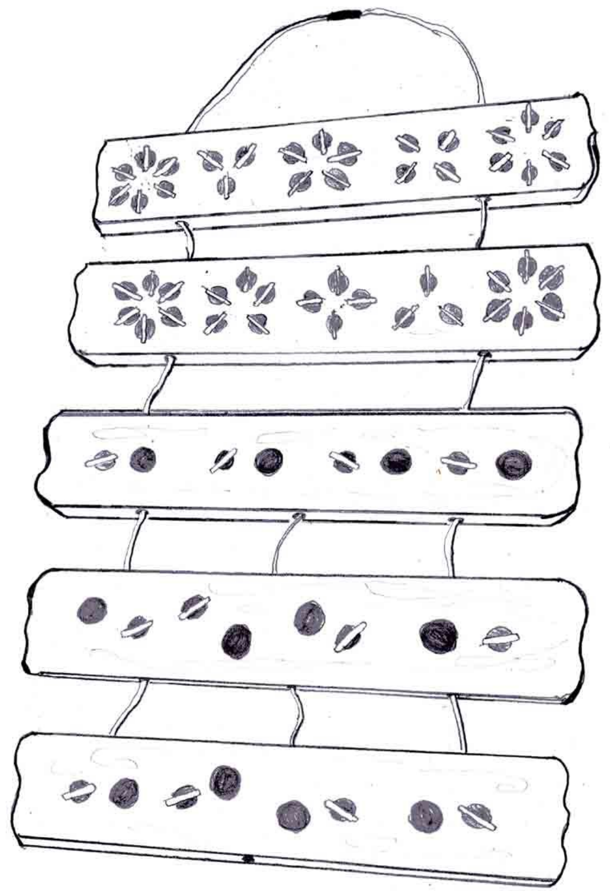


Illustration 12: Rollz-5

In the Rollz-5, then, these elements are organized into five panels. The geometries of pulse-rolls inhabit the top two panels, and the translators are in the bottom three, specifically gong, ultrasound, and avdog in downward order. Each panel has several instances, preset to arbitrary pitch and resonance determined internally by capacitors and resistors. The fixed nature of rhythms and pitches is to prevent an overpopulation of knobs on the instrument, making crucial compositional decisions more about what connections to make rather than how to tweak settings. It

also highlights a recurring theme of letting the materials of electronics speak for themselves, via their industrial valuation, precision, and other idiosyncrasies. In particular, the top two panels of rolls have many arbitrary decisions to be made, as each panel contains twenty-four "hairy" capacitors. I use this term "hairy" in paper circuits to denote a capacitor that can be any value and in that value it affects some aspect of the frequency or time. In this Rolz-5, each neuron of every roll has a different capacitance, from about one micro-farad up to ten; the web of inter-connections is of prime importance in the shape of its rhythm. There is no marking system on the outer face of the instrument, so connections must be probed intuitively or by muscle memory; it is an experimental musical instrument. Likewise, each of the translators has a fixed pitch, such as the tone of the *Gong* or the pitch of the *Avdog* oscillator. But each one does have one knob, for controlling a generic parameter abstracted as density. On the Rollz-5, I wanted to give each module a control of its volume, but with more integration with and reflection on the inner functions of the circuit. In ultrasound, this parameter is simply the cutoff of the switched-capacitor filter; at low settings, the sound is muted and sounds lo-fi, and becomes sharper and more pronounced at higher settings. In *Gong*, density translates as the average waiting period between gong strikes, or the discharge time of theta triangle; a less frequent gong is sparser. And finally, the *Avdog* density knob controls its undulation resonance, also known as "q" or damping. At a high resonance, Avdog responds to a sympathetic rhythm with much energy conservation, thus building up a strong undulation. However, at a low resonance, energy is damped quickly and the

undulation cannot build up. Thus Avdog can become sparse or dense depending on this knob. These are all re-structurings of the typical volume knob, as a controller of a module's unique sense of density.

To play the Rollz-5, connect a mono phone plug to the jack on the bottom of the instrument. Next, connect one nine volt battery to its battery snap on top. Gravity should hold the battery on, since the instrument hangs from a peg on the wall. The *Gong* and *Avdog* modules will produce a variety of sounds on startup, as they stabilize. This is a good way to check their function, by listening to their startup sounds. Proceed with patching the instrument, according to the following typical routine:

1. Connect an even roll to the ultrasound filter, and check its rhythm.
2. Take an odd roll and connect it to an empty node on the aforementioned even roll.
3. Listen to the effect, and repeat connections between even and odd rolls, building a web.
4. Next, consider orchestration by *gong* and *avdog*, and modulate their density.

You will notice that connecting rolls to translators will affect their rhythm somewhat; this corresponds to the notion in physics that the observer will always affect the experiment by the process of observation. Since the rolls can be very sensitive, especially when even and odd are mixed, the various impedances at translator inputs can affect the assemblage. If you don't like it, step back one connection, or compensate by adding other new rolls to the web. The goal is to avoid

hysteria such as fast repetitive spasms, and achieve a limping, ever-changing, somewhat stately rhythm, with free interjections of ultrasound chaos. It should be an entertaining rhythm, with a sense of court intrigue, and the diurnal tidal motions of commerce, sea-trade, and farming taken into consideration. This is the poetry of the "village" form of Rollz-5, a collection of paper-circuit rolls and translators, installed in various cases and boxes.

Roolz Republic

Since much of my work is driven by custom orders, a new turn happened in 2010 when one customer wanted a Rollz-5 plus two Deerhorns altogether in a case. I began by designing and ordering a single circuit board containing all the Rollz-5 circuits. With a newly standardized Deerhorn circuit board, I could fill this customer's order. The name of this new instrument is Roolz-Gewei, a pseudo-Dutch compound of Rollz and that languages word for deerhorn, "gewei." Since all the circuits of the "village" form had been unified into one circuit board, I cast this formation as a "republic." The republic also reigns in surrounding wild-lands, as represented by the Deerhorn modules.

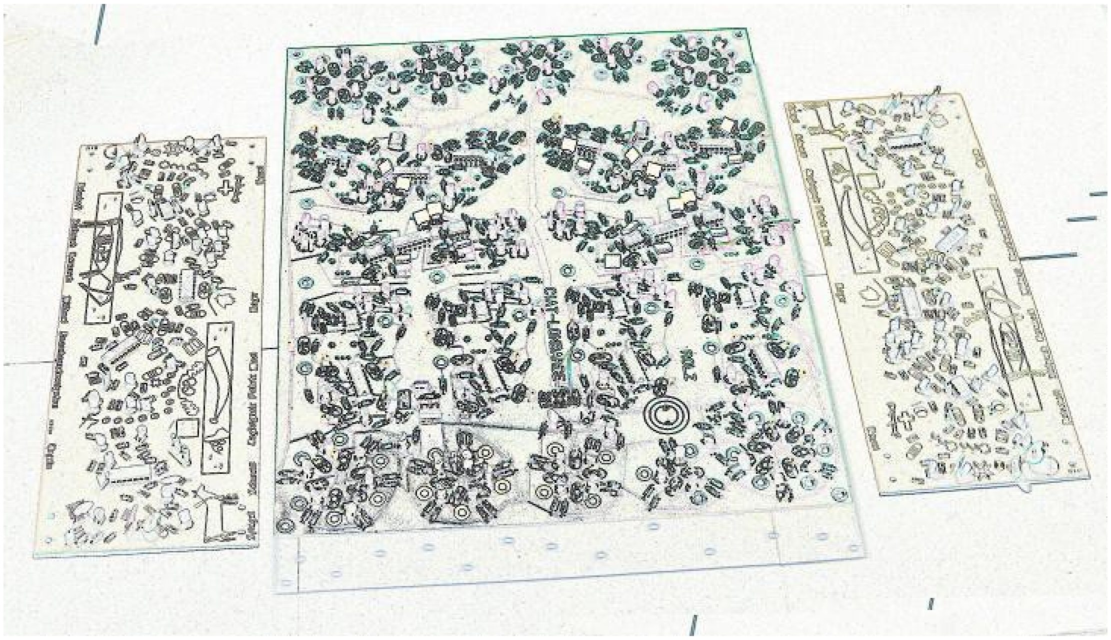


Illustration 13: Roolz-Gewei

Because of their massive scale, I could only build about five of these instruments until I decided to redesign it again. Five other circuit boards went into the hands of friends and students who wanted their own Rollz-5 conveniently laid out in board form. Two remained until a time, at Wesleyan, when fellow master's candidate Daniel Fishkin and I decided to form a “soldering band.” A soldering band does not concern itself primarily with writing songs, but rather soldering circuits together for a sound installation. The band's name is Deertick, and its purpose is uniquely Connecticut driven– to use synthesizers as an analog for the epidemiology of Lyme's disease for the purpose of awareness among the student body. Our first installation occurred in Zelnick Pavillion, on February 4, 2014, lasting for a few days. It included:

- Two Roolz boards, assembled by Daniel and myself
- Two hanging Deerhorn tapestries, each consisting of four modules

- A diorama of the natural environment for deer and their ticks
- An informative pamphlet about the synthesizer as metaphor for Lyme disease (Lyme is a place in Connecticut where the tick borne illness first occurred with noticeable frequency).

The daily maintenance of this installation included patching the Roolz boards that sat on a stone counter in the pavilion. They remained uncased, revealing their raw components and layout. The nodes were mounted as brass bolts directly to the circuit boards, for patching with alligator clips. Like with the Rollz goals, we attempted to make the most stately but unpredictable rhythmic pattern. The Roolz circuit board does have an optional resistive element to control the base frequencies of each module; in the installation we used cadmium photocells, so that at night the sounds became inaudibly low in frequency, and rose during the day. Since the pavilion has dimmers, the modules could be tuned by light levels.

Whereas a nine volt battery powers the Rollz-5, the Roolz Republic takes a twelve volt DC power source, via a 2.1mm jack. Make sure when energizing it with this connection, that the metal of the jack does not touch any of the circuitry. This circuit board's case is a pizza box, so it is exposed during the installation and needs extra care to not short it. During the installation at Zelnick, it rested on a granite stone counter, with any metallic objects removed. Like the Rollz-5, it has clusters of pulse-rolls on its outer extremities, and translators on the interior, so its playing technique is the same. The pamphlet for “Deer/tick Zelnick” included the following text:

As I said in the introduction, an assemblage arises from its own materials,

but can share its own diagram with other unrelated processes by metaphor. What does this mean? The materials of Plumbutter are various forms and flows in time, such as the triangle oscillator, the resonator, the pulse brains. Can these circuits act as metaphors for processes in other fields? How about the environment? Already Plumbutter concerns itself with psycho-geography of the urban to rural gradient. In Connecticut, where I was born and now am residing temporarily, I became extremely concerned with the epidemiology of Lyme's disease, since it was discovered here but has spread widely over Eastern U.S. and the world. Its vector, the almost invisible deer tick, Ixodes scapularis, has profited from global climate change as well as suburban incursions and overlapping with rural segments. "Deer/tick, a synthesis and awareness installation," used the Plumbutter diagram to explore the life cycle of Lyme disease, through deer migration patterns, deer tick brain signals, and the unique morphology of the bacteria Borrelia burgdorferi.

During the installation, two completely reconstructed "Roolz Gewei" and four deerhorn circuit boards provided a tapestry of organic synthesized sound that reacted to proximity through radio fields and light sensors to modulate the wiring and response of the pulse brain circuitry. A first analogy made here is to understand how the deer tick decides to jump, from underbrush, onto its host by various sensory inputs and a simple configuration of neurons tailored for this host trigger reaction. The certainty of internal rhythms provided by square rolls is mixed with more edgy signals from the paradox generators. We are trying to hear the sound of the tick brain as it sits in wait, marking time and the seasons in a simple quest for blood, its nourishment.

Then the deer walks quietly through the woods, exciting the tick. Or so it was for many years until Europeans cleared the forest, leaving many liminal zones. In fact, deer prefer habitat between the farm field and the forest, where grass is high, and food is plentiful as well as shelter. The deer tick also prefers this high grass between field and forest, as it provides a great springy vantage point from which to attach to host. Thus we can explore how suburban incursions create more habitat for deer and ticks by extending the frontier line in an ever fractal zig zag; every yard has a boundary with the woods, and it is these boundaries that the deer and ticks follow. This is manifested in the sonic relationship of drum and drama in the Plumbutter. Drum is the machinery that forms building materials for buildings, utilities and roads; drama is the breath of the forest and the organic swell of foliage over the seasons. The two come together and it is their boundary that inhabits the deer and tick.

Lyme disease can be seen as profiting from global climate change; warm winter thaws and the abundance of moisture benefit ticks. The drama of environmental change can be modeled by taking ordinary resonators and modulating them with increasing amounts of chaos; heat creates unpredictability. The goal in any synthesizer performance, methinks, is to short circuit any kind of predictability while still providing an undulating bed within which to dwell. The art of "Deer/tick: synthesis and awareness installation," is to create sonic environments reminiscent of our new global weather patterns. Dealing with this new environment of constant change, wet hot summers, snow lightning, can be informed by the techniques of chaos magic. Essentially, be aware. Even if it is the dead of winter, ticks can prowl due to a temporary thaw. If you planned to skirt the woods, go with your senses if they should say danger.

Finally, there is the microbe itself, Borrelia burgdorferi, a spirochete. It is a long and slender bacterium, with two cell walls, and a shape like a corkscrew. It moves by wriggling through the bloodstream or the tick gut, by the unique action of flagellae inside its two skins, which act as muscles for it to swim. It is usually covered in slime to prevent detection. In Lynn Margulis' theory, these bacteria which wriggled became the genetic basis for neurons in higher life forms, by a process Endosymbiosis, or appropriation of one cell into another. The Borrelia bacteria can also roll up into a cyst and wait, hibernating, in the host; Lyme's disease is thus very hard to treat because at times it is hiding. This morphology of spiral and the roll is also present in the pulse brain of the Plumbutter, with its odd spirals of paradox and even rolls of rhythm. Thus it is an extended sonic metaphor for a highly sophisticated bacteria that fools its pursuers by sliming them, wriggling past them, or lying like a rock amongst them.

Plumbutter

At this point I had already revised the Roolz-Gewei into its final form, known as Plumbutter, so the circuit boards we presented were obsolete technology. Of course, that is desirable in analog, with more limitations yielding more idiosyncrasy and thus composing uniqueness. However, in the accompanying pamphlet I referred to the installation as "Plumbutter." Plumbutter is derived from my own name, Peter Blasser, and the chemical symbol for lead, Pb. Taking "plumbum" and making it a

musical instrument, I thought of a sackbut, that old trombone, and made that part of the name. Names are important in the development of this instrument; Roolz-Gewei inhabits Facebook, with its circuit board as its face, and a unique posting language based on its ideally stuttered and chaotic rhythm.

As I said, there came a time when the republic of Roolz-Gewei needed to be revised into a final form containing all innovations thus far. In addition, all the arbitrary pitch settings would need to be converted into a laboratory system of control. The laboratory analog synthesizer replaces any tunings by resistance with full voltage control. Two knobs are associated with this voltage control: a base pitch and the attenuverter. The base pitch works without any external control input to set whatever desired frequency for the module. The attenuverter modifies control input voltages to both attenuate them and optionally invert them, hence the name. It is an important part of any laboratory synthesizer to tune how much modules affect each other. So for example, whereas Gong previously had a set frequency, now it has two knobs and a control input for this frequency, to set it within a wide range and modulate it. All the modules received this treatment, including the ultrasound converters and the rolls themselves; instead of static rhythms they now had a frequency knob and control inputs. This is the capstone of the development of Rolz-5 from a paper village, through a republic, and now it had become an empire. It was not so esoteric or backwoods anymore, because everything was tunable; it originally was called a “Laboratory Roolz-Gewei” but that was too long, so I devised “Plumbutter” instead.

Designing Mobenthey

The modular system facilitates an ever-expanding collection of modules as object of desire. However, as designer, I feel that new analog designs require a manifesto for its existence vis a vis computer music. The name "Ieaskul F. Mobenthey" began a poetic narrative for this manifesto, originally as a line of synthesizers for children. Although the customers are adults, perhaps I could maintain a playful psychology?

"Ieaskul" parses as an elaborate first person pronoun, an extended collection of vowels inside a skull that speaks this synthesized personality's manifesto. "Ieaskul is interested." "Ieaskul sees." and "Ieaskul does not care." It allows an autobiographical discourse but transposed into this alter-ego and more elaborate version of "I."[33]

His surname "Mobenthey," besides adding to the regal sophistication of his appellation, nods to the thick assemblage of participants in the Eurorack framework: "MOB in THEY." He joins the pack by working within the system, and this is the starting point of his manifesto.

The pain of hearing a synthesizer festival at full blast begets resentment of the industry, a desire for silence. A central tenet of *Mobenthey*'s manifesto is to bring about the downfall of all this Eurorack noise, by striving toward paradoxical electronic situations; undefined behavior brings about this paradox wave. Although analog synthesizers are obsolete, their potential for such behavior drives *Mobenthey*.

For the paradox wave, *Mobenthey* deploys the bounds/bounce oscillator, which

33 Compare the modulation of first person pronoun with Apple's appropriation of it into their aught-years product line, starting with the iPod and iMac.

I first encountered in digital emulations of analog. Imagine a ball bouncing between two walls- its simple movement back and forth generates what analog synthesis knows as a triangle wave. Where it hits a boundary, it changes state and goes in the opposite direction. This change of state, up or down, is the binary opposition that yields its square wave complement. Typically, an analog synthesizer will only modulate the speed of the ball, using fixed walls. Moving the walls, however, allows another modulation possibility, complementary in nature to changing the speed; a smaller speed makes the ball slower, but a smaller space forces the ball to bounce faster. When the ball must bounce between two walls of zero width, a paradox results; the analog synthesizer loses its analogical power, instead revealing the limits of its silicon. This undefined behavior is why typical synthesizers do not allow bounds modulation, but *Mobenthey* pursues it in the following designs.

Fourses

I began the *Mobenthey* project by re-prototyping one of my oldest circuits- *Fourses.* At this point, I had not decided to work in Eurorack, but simply to bring about a new line of instruments working with the paradox wave. As I said before, the name “Ieaskul F. Mobenthey” sounds like a synthesizer store for children, and I was hoping to multi-purpose the *Fourses* design for both a toy synthesizer and a Eurorack module.

Ciat-Lonbarde released *Fourses* in 2004 as a kit, including a wooden case, circuit board, electronic components, a speaker, and more than a hundred brass nodes.

The brass nodes form the interface; touching them with the hand or patching them with wire allows different internal configurations. I designed the original *Fourses* to be circuit-bent, by bringing the interior, “soft-like” parts of each oscillator out.[34] The two most important nodes in a triangle oscillator are “capacitor tank,” and the “hysteresis node,” corresponding directly to bounce and bounds. They are a slope accumulator, using a capacitor to make angled segments; and a bounds tester, comparing against a fixed (or not so fixed) measure. It is with unfixed bounds that *Fourses* works, stacking four simple triangle oscillators so that they bounce off of each other; the behavior of each is contingent on the direction and position of the two surrounding it. The result is a group of four waveforms that sometimes sound periodic but often act aperiodic and chaotic, with a detailed gradient in between.

A knob and voltage input control the speed of each oscillator, and this is how to tune within the gradient of noise and tone. Tuning them all to similar rates introduces more sonic uncertainty because the regime is a contingent multiplicity; by increasing an oscillator's speed, it becomes dominant and forces a periodic tone.

To prototype the *Fourses*, I designed three paper circuits.[35] In each I tested a different modulation scheme for the speed of the oscillators, and I named them based on these schemes: *Fourses Tarp*, *Fourses Arpserge*, and *Fourses Tarpterge*. “Tarp” stands for two Arp-style exponential converters, one each for the upward-going slope

34 The circuit-bending movement uses innards of circuits, exposed to musical touch.

35 To rapidly prototype, I developed a paper circuit technique. The printed design, laminated on a heavy card, is pierced with a needle, and components are threaded and soldered. In teaching workshops, I choose this model to inspire crafty students and create experimental designs– elegant and artful with low overhead. A series of educational paper circuit designs is available for free download on my website.

and the downward-going slope.[36] *Fourses* benefits from different slopes in the waveforms, because the bouncing action depends on the direction of each player. With *Fourses* “Arpserge,” a Serge-style exponential converter is added on top of a single Arp-style, adding an additional control input.[37] “Tarpterge” implies two of each styles, and it is the most complex. At the end of this complicated evaluation, I realized the simplest strategy is best, and went with *Fourses Tarp*, the original schematic.

The paper circuits explored touchable features of the original. However, the modular *Fourses* modular does not include such extended these features, because they are redundant on top of the central concept; the *Fourses* idea itself models inter-related oscillators that “touch” each other. To put the touching idea inside a touching case is artful, but *Fourses* also distills into a small form factor with complete voltage control and range switches, to interface and scramble all sorts of other modules with its manifold outputs.

Swoop

Swoop's original purpose was to generate single triangle events to control parameters on a sonic circuit known as *Dogvoice*. Multiple *Swoop*s trigger each other in loops, webs, or other montages, and the multiple overlapping events result in unpredictable cellular behavior in the final sound. There were swoops and anti-

36 An exponential converter takes a control voltage from external or simply a potentiometer and converts it, with an exponential slope, into a current for use in oscillators. The Arp exponential converter uses two transistors of opposite polarity to eliminate temperature drift. It is useful for two-rail synthesizers.

37 The Serge exponential converter uses two transistors of same polarity, in a differential pair, converting a bias voltage into a pseudo-exponential current.

swoops, meaning some went up and some went down. Physically the circuits were separate. I realized that this circuit parallels the Dual Universal Slope Generator (DUSG) of the Serge synthesizer, as a single event generator capable of multiple events in concert with others.[38]

About six years later, I reused the *Swoop* in a digital emulation, to enable a primitive granular synthesis.[39] *Swoop*, as an opcode, received triggers to generate triangular envelopes. Here I encountered the problem of signed and unsigned, because the digital system worked in those two modalities. The original *Swoop* is signed, in that it only moves above zero; *Anti*-*Swoop* went below. However, a signed *Swoop* goes both above and below zero; it makes a Z shape about the axis. This is a primitive emulation of the bipolar flex gesture of a piezo disc: press and release are an upward swoop immediately followed by a downward swoop.

Swoop also acts as a bounds/bounce oscillator, and this is where it diverges from classic circuits such as the DUSG. With no inputs, *Swoop* actually runs in paradox mode rather than holding; it is trying to cycle infinitely fast between two infinitely close points at zero. In addition to trigger inputs, it has two bounds modulation inputs, causing the oscillator to expand outwards. It thus becomes a wave-shaping filter and voltage processor, different from the DUSG in its continuity of oscillatory state no matter the bounds.

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38 The DUSG takes a triggering signal, causing it to slope up at a certain rate and then return to zero at another rate. It then can re-trigger itself or hold. It is like an envelope generator. It also takes an analog voltage input, which it processes according to the separate upwards and downwards slew rates.

39 Granular synthesis, as distilled here, uses a plurality of oscillators and a matched amount of triggered envelopes to disperse little sounds that may add up to a sophisticated timbre.

Denum

In all bounds/bounce modules, oscillation has a place in space, through positive feedback, as well as place in time, with negative feedback. It is the relationship of the two, in *Swoop* and *Denum*, that determines frequency. *Swoop* generates controlling and enveloping events; *Denum* works with smoother continuous waveforms, offering a completely complementary modulation scheme.

Denum maps its modulations symmetrically in both bounds and bounce. Exponential bounce control is the source of tempered musical intervals such as one volt per octave. Exponential bounds control is opposite, going upside down from an infinitely high frequency to a low place. As a number game, the two controls become numerator and denominator of a ratio that determines the frequency. That is the source of the name “Denum,” a combination of the two parts of a ratio. But there are further implications of the two modulation schemes. The bounce controls slope speed, and thus can modulate it continuously. Bounds, however, only affects the oscillation at its limits; it is a discontinuous and momentary effect. The former is classic frequency modulation with in-harmonic sidebands. The latter can cause alternative behavior, such as locking to an undertone of the controlling signal, and a mixture of that with the classic modulation. Bounds modulation also effects the amplitude of the oscillation; smaller bounds makes a quieter sound. This is not unfortunate in its use, because higher frequencies have more energy, it is natural to want to attenuate them, as with a low-pass filter.

Sprott

With the many kinds of triangle oscillators represented by *Fourses*, *Swoop*, and *Denum*, I felt a need to build a filter to complement them. With all the filters available for Eurorack, the task was unnecessary except for a particular skill set I have, designing chaotic resonators. *Sprott* models a chaotic jerk system with standardized voltage control of all parameters. It takes its name from J.C. Sprott, who has published numerous papers, articles and books on chaos and chaotic circuits, from a rigorous physical view-point. (Sprott, 2000) A jerk system is essentially a resonator circuit and its feedback loops, with an added stage representing jerk and a non-linearity. That it is how it becomes chaos, but the chaotic attractor can shrink down to distill it into a resonant filter that is its sub-circuit. Of course this is a musical module; although the voltage control feature has limited importance in physics experiments, it is crucial to aesthetic purposes.

This jerk system three integrators and one “signum” non-linearity, according to a simple differential equation:

$$0 = ax''' + bx'' + cx' + dSGN(x) - ex$$

In re-structuring the circuit to fit voltage control guidelines, the use of transconductance amplifiers offers an experimental input to change the subtle dynamics of this system: by modulating their linearizing diodes, paradoxically adding to available non-linearities available. The module is experimental, but always can boil down to a simple resonant filter. This is its potency, in going out and coming back to

a basic regime. Since any differential jerk equation is highly dependent on "initial parameters," *Sprott* has a dedicated VCA on the input.

Dunst

On completing the first run of *Mobenthey* modules, I initiated prototyping of a fifth module, called *Dunst*. It is part of a new thrust on this platform and also in *Tocante* to bring forth various assets of zener noise that I have explored in my oldest instruments, such as *Nabra*. That synthesizer contained a Dust module, which simply generates trigger pulses at random intervals below the haptic rate. *Nabra* also contained a Noise module, which acted as an audio generator with VCA inputs. It also took control voltages as a modulation for crackle; its sound could change from smooth white noise to something more like a dusty record.

Dust and Noise operate in two compellingly different manners. Dust "computes" its randomness by sampling a stochastic waveform to mark an arbitrary voltage, then decays to zero to repeat again. Noting that this is an arbitrary bounds modulation, the bounce of the module is free for control by input voltage, thus varying the speed or concentration of dust particles. This circuit is a variation bounds-bounce regime established in the previous modules.

Unlike Dust, Noise uses a zener diode or other suitably noisy silicon source, amplifying the natural noise of indecisive electrons. It modulates crackle by a comparison of that noise and an arbitrary input voltage; near zero, it is pure noise, but crossings of a farther bias voltage become more event-like, approaching the sound of

Dust.

Since both circuits achieve different flavors of the same basic goal, I decided to combine them into a single module. The name is simply an amalgam- Dust with Noise makes *Dunst*. The next step is checking a name on Google. Finding, of course, Kirsten Dunst as the primary placeholder, I also see the German definition of the word is a sort of haze or fog; a good omen. Digging deeper, I find the extended German meaning, in Jagersprache[40], is a shotgun with very fine particle size, for hunting small birds. In fact, that is exactly what the *Dunst* module does, generate bursts of small shots in a random distribution, to trigger the death of birds.

So that is the current state of *Mobenthey*, having completed a run, I add a new and dusty module, tied into the previous modules by the bounds-bounce concept. The new module breaks from the previous modules by focusing on stochastic dust instead of modulated waveforms. It demonstrates the paradox wave, Ieaskul's goal, not by infinite regression but by the indeterminate nature of silicon components themselves- noise.

Dunst fulfills the form-flow synthesizer manifesto, as it supplies essential pulses, for both listening and to trigger embodied events. Minimalist techno has allowed us to delight in dust as a sound in itself.

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40 Jagersprache is the language of the deer hunter. In the forest, all living things can understand a hunter's intent; even the trees have ears. It is best to conceal one's intent as much as possible by using secret words for violent acts committed here. As a secret cypher in the face of natural forces, Jagersprache captivates me with its magical namings.

Deleuzian Synthesizer

I can sum up the linear narrative of synthesizers in four words: “control, process, generate, and filter.” It progresses from slow to fast, like the layering of the human cortex– haptic processing through pitch recognition to analysis of timbre. Control modules are slow, shaping a musical composition. The control outputs feed the inputs of process modules, convolving the music. These in turn modulate the audio generators, which generate raw sounds. Finally, a filter adds resonances higher in the spectrum. Outputs connect to inputs in a causal chain.

With mass production, synthesizers brought this narrative to a wider audience. I would argue that the linear scheme of the devices parallels the broadcast model of their marketing; Moog realized early that star patrons increase sales potential and visibility in the media. In the analog days, recordings mediated that patronage, chaining synthesizer builders, rockers, and recording studios to a public constructed around the physical objects of recordings– hi-fi stereos and vinyl. (Pinch & Trocco, 2002)

A digital instrument, besides stable tuning, also provides a coded, stratified system of modules with scripts to connect them, a realization of early analog synthesists dream. The scripted narrative of sound and modulations in the hardware produces a reliable sound product, again mirroring the broadcast marketing strategy and optimizing the record industry's product, the pop hit.

Piracy, enabled by the mp3 compression format, has transformed the economic situation that a broadcast model is apparently obsolete. (Sterne, 2012) Piracy

encourages new forms tailored for sharing and free distribution. (Larkin, 2008) For example, synthesizer users leverage Youtube's free music short format to share sounds and show their gear.

The unpacking video features sound provided only by the cardboard boxes, mylar bags crinkling, and Styrofoam sliding airily and snug. Unpacking is a new development realized by users; a manufacturer packs but only the user can unpack. They cross the line between fan video and sound study, capitalizing on our strange obsession with packaging.[41]

Of course the predominant synthesizer demonstration features the instruments in their energized state, unpacked and lit. Here is where users matter, by sharing patches and configurations with other users; these are not pop hits but excerpts from improvisations, chosen to demonstrate often the most radical behavior. Synthesizers have changed to meet the visual needs of the user video; the oldest type of analog synthesizers, those with many colorful wires on their face, have returned. The visual imagery of wires is a mess that attracts our gaze.[42] This messier format allows experimentation with non-causal relationships of feedback.

The Deleuzian synthesizer arises from these experimental analog practices.[43] As

41 I think sonic cues are the important clue to understanding this obsession; take away the imagery and imagine the sound of unpacking a deer, hearing different timbres of skin and membrane, bones clicking and cracking, and organs sliding out of the tasty meat. Unpacking is a primal urge following a successful hunt, rewarded by eviscerated synthesizers in this century.

42 To continue the hunting metaphor, a mess of wires is like a deer's entrails that signify a coming feast.

43 That Deleuze's vocabulary is overplayed in the humanities is everywhere obvious. Throughout the aughts, the tendency has been to apply his poetic lexicon to whatever study at hand, producing a confusing and elitist document of the first-rate. I read Deleuze at the beginning of this period, and saw clear implications for the direction I saw synthesizers heading, so I formulated a critical practice around these concepts. That Deleuze's work can apply to anything from psychoanalysis to architecture is a testament to its usefulness, and I think that despite its vest-pocket, hipster vogue,

a post-structuralist, Deleuze established a dialectical if not critical relationship with structuralism, which insists on the functional meaning of words. The linear narrative of synthesizers is a goal-oriented process, relying on functional placeholders– control, process, generator, filter– to efficiently yield musical sounds. A post-structuralist viewpoint would ostensibly reject compartmentalizations, and Deleuze spends most of his effort describing how.

A Deleuzian synthesizer must first reject the linear narrative in order to become a body without organs (BwO). Antonin Artaud first dropped this term in his last radio play, shortly after leaving a mental asylum. The play, *To Have Done With the Judgement of god*, uses non-verbal elements mixed with poetic text. The passage in question equates organs with automatic reactions, and becoming free from these reactions is accomplished by eliminating organs. Deleuze explains further that the BwO may actually have organs, but resists becoming an organism. A vibration travels along its length, causing the organs to change function over time. (Deleuze, 2004) Quoting Burroughs, who dreams of a mouth that becomes an anus, (Burroughs, 1959, p. 150) Deleuze seeks to blur the distinction between inputs and outputs. Thus the BwO is a useful tool to question the hetero-normative nature of analog synthesizers. With so many inputs and outputs, connecting “jacks” with “plugs,” there are important queer and feminist readings of the impulse to have modular, or in electronics parlance, “mating connections.” (Rodgers, 2011)

However much the linear narrative relies on inputs and outputs, they are not

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it will remain a timeless body of work. The time for apologies is over.

natural to an analog synthesizer. Analog circuitry is an assemblage of nodes that do in fact resemble Burrough's mouth-anus, in that each node is a combination of input and output, changing over time and with connections to other nodes. A radio transmitter can easily become a receiver; there are no functional changes, just a difference in relative amplitude.

The interior nodes of an oscillator can interact with external connections, because they combine input and output; the act of listening to them affects them. Proper electronic design dictates that an oscillator circuit buffer its output, to eliminate this interaction. To realize the BwO, we define these androgynous nodes as *sandrodes*. They capitalize on the inherently polyvalent nature of analog nodes to offer a unique interface point on the face of the instrument. *Sandrodes* respond to touch and any interconnections made with wire.

The multiplicity of circuit nodes brought forth as *sandrodes* also fulfills the Deleuzian concept of the rhizome. Like a root it spreads underground, making connections in an intuitive manner. It forms a dialectic with the arborescent structure, a central trunk that supports dependent branches. A tree seems capable of multiple overlapping rhythms– branches that sway and tap each other in the wind– but it still has the trunk, a plexus of power, a “boss.” Arborescent-rhizome is a contrast between vertical hierarchy, the chaining of subservient modules starting with control and ending in filter, with horizontal multiplicity, where modules share influence as a vibration that crosses their breadth.

The *sandrodes* scattered as brass nodes on a wooden surface is a plane of

immanence. Immanent simply means, according to the latin, “dwelling within.”[44] An immanent synthesizer as well has no start- or end-points. It neither represents an idealized chain of command nor expects circuit elements to act that way. Circuits are woven loops of flow, with multiple layers of feedback and bleeding influences all over the place. In certain ranges, these parasitics take over and cause the circuit to become something completely different from what it was intended to be. The circuit desires to be heard for what it is, and *sandrodes* attempt to come closer by revealing exactly what dwells within it. These objects have agency in a network including humans; they are not just objects of study, but interact according to their own desires. That circuits come close to modeling primitive neuronal behavior is no coincidence in their agency; they are not the bricks or mugs of practical objectivism, but more like the non-humans that Bruno Latour wants include in a network with humans. (Latour, 2005)

A transistor neuron has three basic components: an inverting amplifier, a charge pump, and a firing threshold. Combined with other transistor neurons in a loop, they create patterns of firing in regular oscillations. Since they are *sandrodes*, each neuron can be patched to any other at any point in a loop. In a previous chapter, I demonstrated how an even-numbered loop makes a stable pattern, and an odd-

44 In the context of synthesizers, it critiques the idea of the coded interface, with equally latinate structural placeholders, as an imperial ideal. The Latin language, as absorbed into English, provides a set of structural tools for thought patterns, as it did the Romans who codified their empire with it. It is strongly transient, using subject and object to chain relationships of subservience, and its words have come to support this structure. Deleuze uses “immanence,” however latinate, to dissolve the representational imperative in language, and instead write texts that “are” their own meaning. This is why you can read *Mille Plateaux* from any page, because there is no argument that depends on a chronological structure, but that pieces of immanent text, taken over time, induce his points.

numbered loop, due to a rhythmic paradox, oscillates in an unknowable pattern. The wiring together of these different loops smudges the paradox patterns with the stable ones, to create *relabi*, a slipped or limping rhythm (Berndt, 2009). These circuits act autonomously from structured human performative actions; to make a rhythm of concern is an experiment, with failures along the way. There is thus a give and take relationship between human and circuit. Michel Callon described a relationship of interests in a network of humans and non-humans; the scallops of St. Brieuc Bay want to survive, for a different reason than do the fisherman who harvest them, and the researchers who study techniques of restocking them (Callon, 1986). This synthesizer does not work with objects of fact– imperial control terms– but objects of concern; some circuit neurons are hysterical and spasmodic, but some desire to a rhythm not undesirable to the human operator.

Deleuze, musing on Francis Bacon, constructs a dialectic between analog, a language of relations, and digital, a coded narrative of symbols. Modulations are the primary connection of analog, likened to para-linguistic screams and breaths. Meaning is the currency of digital. Deleuze as critic of structure, often creates this sort of dialectic– analog-digital, arborescent-rhizomal, words-howls– but he also works in monadic spaces, often attempting to de-constuct or undermine any strong binarisms. With analog and digital, he uses the diagram, or assemblage, as a tool to show what they may have in common. A diagram could describe the two types of feedback in a triangle oscillator– inverting and non-inverting– that make it stable and continuous throughout time. This diagram is portable between analog and digital

(Deleuze, 2004). A linear narrative of circuit function is a portable diagram as well; control-process-generate-filter works equally well throughout the analog-digital dialectic. But does the Deleuzian synthesizer have a diagram that can cross over to digital?

Physicality is important in an analog synthesizer; you could even say that it is embodied, especially in the discussion of its agency. Digital code is difficult to give form, because it dwells in memory. However a look at the e-waste dumping grounds in Guiyu and Nigeria shows that there is indeed much physicality behind digital computers. And synthesizer builders have always specialized in building a physical product to interact with the human performer, no matter if it is analog or digital. So what about the question of how to make a digital Deleuzian synthesizer? I would start with the *sandrode* as essential element of the plane of immanence, and try to make a collection of digital nodes that are both, or neither, input and output. There is a history of taking digital devices and bending them to mash data for musical purposes. Circuit-benders indeed intuitively seek out points inside consumer devices that cross with other points to bring about paradoxical or absurd behavior. Can digital be purposely designed to be circuit-bent? I would propose taking the premise of smart phones and other digital technologies and adapting them to act more like the Deleuzian analog. The touch screens on smart phones work by capacitive sensing, simultaneously transmitting a signal and detecting that signal and thus sensing fingers by the slew distortion they induce. These touch points can easily become *sandrodes*; the process of sensing involves androgyny. Furthermore, the signals used in

capacitive sensing are always hidden, but can be heard with wiretapping equipment as an array of static pitches. The touch screen is thought of as an input, but it is also an output, making a wide range of radio emissions as part of its sensing procedure. Why treat these pitches as irrelevant, to be hidden, when they could be musical material? They are not intended for users ears, but a system of listening to them would celebrate their immanence. On a touch screen these nodes sense through a piece of glass, but I am proposing making them into brass *sandrodes* on the surface of an instrument, for both touch and circuit-bending with wire. The digital code needs to handle all contingencies– various traditional soft gestures as well as transient interconnections between nodes.

This musical instrument, the digital Deleuzian synthesizer, is sounding more and more like an abstraction of social networks on the internet. As an actor that has profoundly affected the broadcast model of musical delivery, the internet has also shaped synthesizer developments. The Youtube short demonstration video desires not an instrument of presets, but an instrument with its own agency.

Blockage

I started building synthesizers tuned to touch, chaos and contingency when I realized that a career as recording artist would soon become obsolete. I turned to synthesizers as an artistic expression, and naturally questioned the pragmatic linear narrative so helpful to pop musicians but so limiting to experimentation. When introduced to Deleuze I adopted his concepts to my practice. At the time, noise was

experiencing a comeback, probably reflecting the political situation of America in the early aughts. My synthesizers fit in well, since they produced chaotic sounds. At the time, social media had not realized its current potential, but the noise scene, with its many bazaars, gatherings of protest, and situational concert venues, inspired my work. With noise came the underground, and also DIY culture, that I catered to with instrument kits and other methods of open-source delivery such as paper circuits. I developed a lot of cultural capital in those years, from radical circuit design aesthetics to the formulation of the Deleuzian synthesizer, but my profits were enjoyably small.

Something changed around 2008, a year marked by the election of Obama aided in no small part by social media, and also the downturn of the economy. Despite the times, I kept on soldering and found business to be growing. It is common to have a slow growth pattern in the early parts of a business, followed by a final payoff; this is why it's important to stick with it, especially in creative fields. But I would also attribute the rise of social media as an important factor for increased business. I had rejected Facebook, noting how shameless marketing was levied upon that social medium by its users; in fact, I never advertised my business, relying on word-of-mouth physically and in the nascent forums of the time. I proudly write raw HTML on my website, for an aesthetic of DIY and indeed sloppiness was celebrated early, becoming a clean bare-bones later.

A bare-bones website employs little multimedia presentation, such as Flash animations, embedded video, or even sound clips, but relies on text and pictures, as coded in unscripted HTML. An extreme example can be found in beigerecords.com, a

Lynx-compatible website. The Lynx web-browser operates inside a text terminal, so it has no graphical capabilities, just text. It eliminates not only dynamic multimedia but pictures as well; web content is put through the final test- how well it stands as pure text. This is a perennial attitude, from the "continental obsession with text qua text" (Latour, 2005) to the art of tweeting.

The bare-bones website forms a dialectic with social multimedia networks. For example, take the website for Scott Jaeger's analog synthesis modules, at theharvestman.org. Not limited to text, the site employs a few monochromatic yellow images, with subtle data distortion to visually imply its stated design specifications: "no ideals, no consequences." Besides jpeg the only other format is pdf, as a clear and concise users manual for each model. No sound samples speak out to tantalize patrons, and no embedded movies show flashing lights or nests of wire.

Deeper down in the site there is a link to theharvestman's Facebook page, concerning short business status updates, such as modules ready to ship, and pictures of various fully-integrated systems. In this role Facebook serves as an accessible portal to the more esoteric, bare-bones site. Or rather, the website is a totem, or distilled emblem that a clan forms around. But most customers learn about theharvestman modules via Youtube, a platform not directly referenced or linked by the official site. The "first test" video is a popular category for users to display their new modules in short improvisations, poking around the various functions, and recording the visual effect of LEDs on the interface. The camera is focused on the interface, with only the hands of the user visible. An alternative to this close audition

is the presentation format– a synthesizer builder interviewed at a social gathering, such as a synthesizer fair. These videos form a continuous stream of users and viewpoints on the modules, separate from the official website.

There are actually two levels of remove from multimedia on theharvestman.org. The first is elimination of official sound clips embedded in the site. This would seem to be a practical need in a synthesizer website, especially if it has an opaque interface of knobs, and sophisticated functionality, as most analog synthesizers do. However, Peter Edwards of casperelectronics.com, explained that he prefers to leave the sound recording to the users; instead of an official stance on how the instrument is to be played, users document a variety of performance situations. The second remove from multimedia is to not even provide links to social platforms, such as Youtube, where user videos can be seen. The official website disconnected from social multimedia represents a hermetic totem of minimal intrusion, giving users free reign to do their natural best, interacting with other users through sound and video.

As in most social spheres, the internet forum is the predominant site of interaction for users. Muffwiggler is one of the larger forums for technical questions, answers, sharing photos and setup ideas, and general banter. In theory, Facebook is for the social discussions and performance announcements or reviews, and Muffwiggler is for practical issues and advice from expert users. However, the relationship is complex and sometimes the two switch roles. Multimedia linkage is frequent among users of both, using offsite platforms such as Soundcloud and Youtube to share sounds and videos respectively.

The user-produced, user-consumed short video is a negation of the broadcast model of synthesizer marketing; in fact it is an anti-marketing non-strategy. As synthesizer builder, to withdraw from marketing with media such as video and sound is a dialectical reversion of the older Moog model of star patrons and mass marketing of recordings. From theharvestman.org: “There is no 'featured artists' list because I don't divide my client list into a hierarchy of notability.” As a social manifestation of the Deleuzian synthesizer, the users are *sandrodes*, representing the inner workings of their modular units, as both inputs and outputs; they are the rhizomal narrative of sound production. The community is patched together, like their synthesizers, on a horizontal social plane.

In considering the unique position of analog synthesizers as obsolete due to digital technology, it is helpful to compare their network to that of other physical objects. Consider food posts on a social medium. On Facebook, this topic would include the recorded image of repast, a description of its qualities, its likes, and comments. Comments are important because they provide a mechanism to temporally extend the topic as a thread, sometimes discursive, creating an ad hoc social network around it. I would propose one similarity between the comments of synth posts and food posts: the visceral nature of reactions. An analog synthesizer performance, like a meal, is more likely to be perceived as an ephemeral action, to be met with expressions of ecstasy or disgust, but not with technical revisions or semantic critique. Like a meal is warm, so too is the analog improvisation.

To compare analog synthesizers with computer music, take the free computer

music program Supercollider, a non-graphical, exclusively text-based language for audio coding. In its early days, it was quite powerful to compose algorithmic computer music, but I have watched it develop progressive layers of meta-language to deal with changes in musical mood, improvisation, and the notion of the segue. These developments were aided by the development of an on-line community of experts, working in forums. The computer music language mobilizes social networks to improve itself through techne.

The history of techne starts with the Ancient Greek meaning of craft, or bringing something new to the natural world. Proceeding through the Foucault and the technologies of the self, techne is self-improvement that may involve practical work or introspection, incidentally a good rationale for the tedious craft of handmade synthesizers. In the context of software and virtual worlds, techne is a patch, or crafted improvement to the world by users. In this respect it is what animates the practice of world-making– individual uses of technology to construct a local and subjective reality. Tom Boellstorf shows how in a virtual world, techne is accelerated and compounded as “recursive techne,” or worlds within worlds (Boellstorf, 2008).

A computer music language is a virtual sound-world. It is replete with terms and techniques for creating a world, such as:

- spatialization, positioning sounds in specific stereo locations, or diffusing them as ambient
- reverberation, causing various spectral elements to move in time as they decay in space

- granular synthesis, a way to spawn sub-identities with smeared characteristics– a texture
- flocking behaviors, to give grains more agency and build a meta-organism
- traditional synthesis techniques for modeling voice, extending to animals and robots

These terms are easily mobilized as opcodes, the functional module of computer music languages. Since Supercollider is text-based, micro-worlds are easily mobilized on twitter, as an sctweet. In the following example, user rukano describes the sound of a windy location, as perceived through a virtual microphone:

```
play{LeakDC.ar(CompanderD.ar(LPF.ar(Normalizer.ar(Compan
derD.ar(BrownNoise.ar!
2,0.1,0.1,4)),LFDNoise3.kr(8,90,150)),0.1,1,0.5))}
// wind mic
```

I chose this sctweet because it is a particularly poetic sound that strongly evokes a location, such as a night walk on the shores of Lake Erie. It is also a reflexive world because of the virtual microphone; by simulating that implement of recording, the transducer between real and virtual media, this sctweet evokes multiply layered worlds. It even sacrifices precious character count for a short comment, marked by double slashes. "// wind mic" describes this world for those who read the code; such comments are important meta-texts, marking the social aspect of coding and initiating a conversation with the potential for responses as code with allusive commentary.

All sctweets share the potential for recursive techne; as coded entries on Twitter

they encourage responses in the same code, as a remix. Since Supercollider is released under the GNU general license, derived works also retain that license, so a tweet has the potential for reuse in another tweet. Usually this forms a thread of allusions, a poetic microcosm of the larger progressive coding apparatus of the computer music forum. Whereas tweets stay in the realm of depiction, forum work may attempt active patches on the virtual mechanisms of the platform, eventually becoming hardcoded into it.

The comparison with computer music highlights the physical analog synthesizers' *blockage* to recursive techne, or conceptual compounding and world-making. Deleuze defines a natural *blockage* as an individual singularity that defies comprehension by conceptual or symbolic terms, and the logic of code. (Deleuze, 1994) The analog synthesizer, with its nest of inter-connections, infinitely resolved knobs, and dependence on environmental factors is a physical instantiation with unique idiosyncrasies. It dwells deceptively on the threshold of narrative, without ever crossing fully into pure virtual code. The *blockage*, as a Facebook post, demands visceral comments, such as Deleuze's “howls,” rather than recursively coded responses. In the real world, physical objects bind us to reality and restrict our movements. In the context of social media, a physical object, as a *blockage*, becomes a line-of-flight and a discursive moment.

The Deleuzian synthesizer deploys *blockage* in its radical extremity. Without knobs to tune it, or a legend to mark a narrative, and fully dependent on the contingency of inter-connections, it creates a situation with an individual singularity,

perfect for the intuitive and improvisational nature of the “first test” Youtube video. Working from the *blockage* strategy, I recently built a series of instruments without knobs, for playing by touch. The *Tocante* instruments rely solely on the materials of electronic components to tune the oscillators, thus eliminating the need to intentionally control tuning by both instrument builder and performer. The instruments, built in three primary “shapes,” triangle, square, and circle, are played by touching these runes on their outer edge. However, they can also be circuit-bent by fingers drifting into the heart of the circuit board, where their *sandrodes* lie.

Manuel De Landa interprets Deleuze's materialism as a dialectic between the universal singularity and the individual singularity (De Landa, 2011). In the *Tocante* instruments, the universal singularity includes the schematic for the circuit, the idea of using industrial values for a musical tuning, and the geometric shapes that represent different instruments. The individual singularity is the instrument itself as a physical object, idiosyncrasies of its transistors across the range of frequencies, the accuracy and precision of its tuning elements, their response to temperature, its susceptibility to circuit bending, and its relationship with a human as circuit-bender. The universal singularity is a diagram that ports well to computer code, but the individual singularity is the cause of *blockage*. It is the *blockage* that is on display in “first test” videos of this instrument.

The analog synthesizer can help bolster strong lyrics in a pop hit. But what about the synth as an object of ambiguity? Is there a resonance to the object as an evacuation of the political? The sounds and physicality of an analog synthesizer, in

its stubbornness to coded meanings and possibility for ambiguity, does this have a political resonance? I propose a field of study in the *blockage* as ambiguous signifier, and its relationship to state censorship.

The history of synthesizers shows them as capable of serving a broadcast model of marketing, by adopting their structure to a linear narrative. In the story of synthesizers, the dark ages were brought about by the end of mass distribution of recordings due to piracy, and also the transformation of studio practices away from physical objects to computer music languages. However, an equal and opposite reaction to the effects of the internet is in the horizontal user network centered around archaic analog synthesizers as resuscitated cultural icon. Intuition and improvisation are important in this network, as users create videos as a form of communication, not as a monolithic broadcast. Analog synthesizers have changed over time to meet this need, taking a little more agency as an actor in the improvisation. Their polyvalence is idealized in the Deleuzian synthesizer, with androgynous nodes: *sandrodes*. The synth user on Youtube proudly features its dependance on environment, connections, and touch, that would be so undesirable in a broadcast-geared synthesizer. In social media, this highly embodied object is a *blockage* to code; as an individual singularity it is more like a non-human actor that howls than a meme that infects.[45]

45 The secret of *blockage* shall remain an academic pursuit. As I write this thesis, I realize that the theories enclosed herein are a sort of magic. I deploy the magic of *blockage* in my work composing synthesizers for my business, the *Synthmall*. The art of blogging incantations and the discipline of academic theory shall never mix for they would sully each other. They are mutually “bad for business.”

Tocante

Tocante is a store at the mall, but I had not known that it also means “regarding, or about” in Spanish. Serendipitously, I can argue that this instrument ensemble is “about electronics itself,” by way of its idea of tuning. There are no knobs to tune the instruments, unlike the *Mobenthey* modules; and the touchitivity and aliveness of the sounds contrast with cold formal synthesis. The derivation of *Tocante*, in Spanish, is from “tocar,” meaning “to touch,” which also happens to be a goal of the ensemble.

In the Summer of 2014, I spent much mental energy designing the *Mobenthey* modules. To meet the demands of modular customers, they have wide-range tuning knobs, many modulation inputs, and generally act as versatile as possible. During the requisite period of waiting for the board assemblies, I redoubled my creative energy to work out a diametric counterpoint to the modular aesthetic, under the name *Tocante*.

The creative impetus came from a simple need to explain the visual impact of copper and circuit board in the face-plates of the *Mobenthey* modules. The precedent of aluminum as material for modular face-plate had been set through many synthesizer makers, including Buchla, Serge, and Doepfer. Of course, throughout the history, and especially in the zanier west-coast tradition, other materials can substitute, especially if there is a need such as a touch operated face-plate, that needs an insulating substrate such as fiberglass. However, I chose to use the fiberglass circuit board for *Mobenthey* face-plates simply for its aesthetic dimension, anticipating the reaction from conservative sources as part of the modules' appeal.

The simple design consists of a two millimeter fiberglass substrate, a layer of copper, and then silkscreen, as on a normal circuit board, thus echoing the working materials from the inside. As a plus, fiberglass is a good diffuser for LED light sources shown at it from the inside.

The spare, copper on fiberglass look of *Mobenthey* reminded me of a much older instrument I had made around 2000, called Blowing Bear. Blowing Bear was a nice piece of driftwood with a hand-drawn, etched circuit board installed. The circuit was simply an array of astable multivibrators, using the 555 chip as silicon controller. The generated square waves, at various tuned frequencies, appear as large, touchable "bean" pads, skirted by but not connected to a thin trace that feeds a buffered output signal. Thus the instrument is activated by touch on the pads, invariably connecting them through skin to the output trace. The name "Blowing Bear" hints that the moisture of a close breath also activates the instrument in a gentle dynamic.

Illustration 14: Blowing Bear

Having completed the serious work of 2014, with the submission of the *Mobenthey* dockets to their manufacturer, I turned to explore the image invoked by their copper face-plates, in this old Blowing Bear. That I had lost the physical

instrument did not matter, it is a simple idea of an array of oscillators played by touch. However, I remembered that the original instrument had trim potentiometers inside it, to allow each pitch an arbitrary tuning. Over the years, I've developed a distaste for such tunable systems. They initially served my micro-tuning needs quite well, as they have many composers over the history of electronic music. But the idea of fixing an analog synthesizer to an arbitrary pitch by ear seemed unfaithful to their potential as fluid and gray generators. I celebrated the inevitable detuning of such instruments, as a relief to the philosophical rigor of the various precise tunings I had attempted. But if I were to build another, I would throw the whole arbitrary tuning apparatus away, and focus on tuning by intrinsic properties of the electronic materials.

The designer of electronic instruments must specify a list of components, unless found or salvaged items compose the circuit as an improvisation. Active silicon components have multi-dimensional metrics such as voltage and current, operational flows, and indeed aesthetic rubrics to consider in the specification process. In contrast, passive components such as resistors and capacitors offer relatively simple comparisons such as value and precision.

There is one profound aesthetic dimension to the simple metric of value in passive components- the use of preferred numbers. The designer of musical instruments specifies vibrational lengths based on the number two, in Western culture regulated by the partial exponent of twelve; these are its preferred numbers. However, passive electronic components prefer the number ten, regulated by partial exponents

of six or twelve. Both systems are geometric sequences; the power of heard doublings causes a musical preference for two in the base, whereas our ten finger thinking-space decades the electronic base. The electronic system is an international standard (IEC 60063), trying to make resistor values compromise between logics of doubling and decimal notations. It could be argued that the musical system of base two, is universal.

$$10^{\frac{n}{6}} \approx 2^{\frac{n}{12}}$$

One rarely hears the dissonance between the two due to *potentiometers*; a synthesizer operator will tune it to match the dominant vibrational space, usually a western equal temperament (WET). The electronic oscillator forms the basis of electronic musical instruments. Usually, it goes that digital instruments tune these oscillators into a rigorous simulacrum of musical intervals, and analog instruments leave them open to tuning by knob. Furthermore, a desirable analog circuit will exponentially convert the voltage yielded at knob; following the laws of exponents, this knob can then produce equal intervals of any base. This “infinite tunings” nature of analog is its attraction in the contemporary electronic scene.

I've always felt a strong force pulling away from knobs, and the feeling of infinite control they impart. Synthesizers without knobs use other gestures, like touch, to actuate sound.

But what about the tuning given by the electronic components themselves, does it have aesthetic merit? Listening to the artifacts of the electronic age is like listening

to a maze, for there is no base pitch or octave, as they are always compounding by tens. Also, exotic intervals such as the neutral second are heard. Although the preferred numbers are based on the irrational exponent, their practical values are whole integers: 10,15, 22, 33, 47, and 68. This set is an arbitrary generator of just intoned scales, and listening to computer emulations and compositions is an easy way to access it. It also makes an interesting prospect in synthesizers, to leave out any voltage control, and rely on simple, precision capacitors to set pitch. This is letting the materials of analog circuits speak for themselves, disposing of the complex apparatus of voltage control and tuning pots.

Analysis of Preferred Number Tunings

What follows is a highly numerical analysis of the pitch set of the Tocante instruments. I will use some bar graphs to visualize intervals, and just intonation ratios to classify the relationships. Just intonation may at first glance appear very technical, like a science, but like all musicology, it is based firmly in aesthetics. I am interested as always in the intersection of science and art, so these following bar graphs and ratios are meant to be pleasing and entrancing, like numerologies and astrological tables.

I attempted to use traditional musical notation to express the subtleties of these tunings, and failed. Then I tried to use an alternative tuning, such as seventeen tone equal temperament, and found it to express some of the neutral intervals more effectively, but it still did not jive with the mercurial nature of a base ten system, and

also the fundamentally just-intoned nature of hand-picked numbers. Also, since I have a hobby of playing the seventeen tone guitar, there is an aesthetic dissonance between the scale chosen for its musical value and a scale chosen for its electronic convenience. Finally, I ended up doing the analysis in a spreadsheet program, that I find most effective.

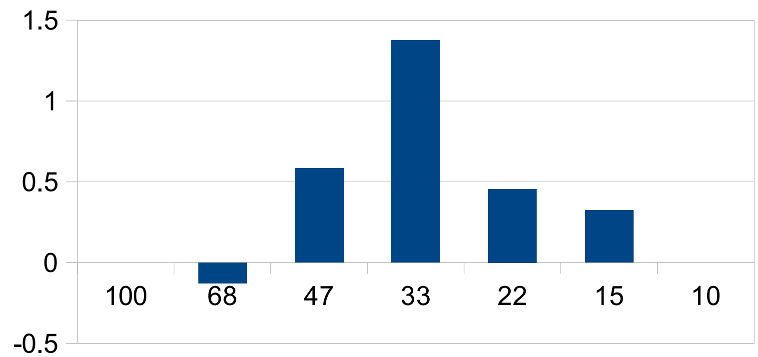

Illustration 15: E6 Preferred numbers' divergence from logarithmic generator

First I analyzed the E6 preferred numbers. "E6" refers to the fact that there are six values within the decade, as expressed in the exponent above. Actually, they diverge from the exponent, to make whole integer numbers. The engineers who chose them evidently used a simple, but arbitrary procedure, first calculating the base-ten exponent, rounding to an integer, but then arbitrarily "fixing" some numbers. I found in my spreadsheet analysis that 47 should be 46, and 33 should be 32. Apparently, the International Electronics Commission liked 47 and 33 so much that they bent their values to fit. I can appreciate that, for 47 is a relatively big prime for musical purposes, while 33 maintains the eleven factor that 22 also has. 33 and 22 form a

musical fifth, but also relate to the dominant 10 in neutral intervals. Computer programming offers a term, “magic number,” for complex values that do not fit in rational or formulaic coding. Whether it was a typo or an intentional numerical semaphore, the two nudged magic numbers are part of an “aesthetic of E6,” that I intend to reveal as a musical synthesizer.

From these initial considerations of the numerical origins of electronic component values, I entered a period of pragmatic experimentation, building about twelve prototypes using various oscillator circuits. The most important exploration in these prototypes was the distribution and range of capacitor values, and the subjective responses evoked by the different scales. I could modify the capacitor values by installing them in parallel or serial, resulting in respectively doubled or halved frequencies. This technique yielded new scale formations because preferred numbers are not based on two, but on ten, so octaves of any value do not duplicate another, but often line up very close. For any oscillator circuit, the formula for frequency equals the reciprocal of the product of resistance, capacitance and some constant such as pi or natural log of three. As a result, the final frequency calculations put the preferred numbers and their octave modifiers in the denominator of an equation, with the numerator as some constant. Thus pitch relationships involve not harmonics, but sub-harmonics. A capacitor value of 100nF yields a lower frequency than 10nF. All circuiteers know this intuitively, that a fatter capacitor makes a fatter bass, but the denominator relationship is now explicit for the sake of music theory.

$$f = \frac{1}{kRC}, \frac{l}{[10,12,15,18,22,27,33,39,47,56,68,82] \times [2,1,\frac{1}{2}]}$$

As is often the case, the very first scaling I derived ended up as the most musically durable. Realizing that the raw E6 preferred number series generated a mutant circle of fifths, I filled in these wide intervals with sub- and super-octaves from different parts of the scale. This is due to the simple electronic law about two capacitors of the same value, that arranged in series generate an exactly half capacitance, and in parallel exactly double. If the electronics numbers were base-two, this law would be useless, but since they are base-ten, it contributes new scale degrees where there were none. For an example, take a central capacitor, 33. Then pick two values at two steps in each direction: 15 and 68. Now double the 15 and halve the 68, and the three numbers, 30, 33, and 34 form a pitch cluster. Applying this process to a range of, say seven base values produces a ladder of clusters.

I found this scale most pleasant, because the intervals are arranged in fifths, but also feature neutral seconds and other odd microtonal intervals. I did try a few other systems, first involving the E12 series, that contains twice the amount of values in a decade: 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, and 82. First, to explore this series without doubles and halves, I built a prototype with only single values, yielding a continuous series of various flavors of the third: major, minor, and neutral. In fact, one of the interval relationships, 27/22, is that prescribed in ancient Persian music as the Wosta of Zalzal, a neutral third. (Farhat, 1990) Although the simple single series

contained such radical intervals, it nevertheless felt hollow, especially when attempting a melody, for it could only proceed in variations of the third. Next I tried to apply the doubles and halves process to this finer series, and it generated so many new intervals, that some of them almost overlapped. These prototypes also proved unsuitable because of the confusing array of microtonal variations, but they remain an interesting and necessary experiment. I tried one more idea with the E12 series, to break it into two parts, the original E6 series of 10, 15, 22, 33, 47 and 68, and an alterna-E6 of 12, 18, 27, 39, 56, and 82. Thus I produced two prototypes of doubled and halved cluster series, that interlocked with each other; they are like the natural and accidental keys on a piano. I noticed that these instruments worked well in combination, producing a rich variety of interval combinations distributed among different physical players. Although the general system of clusters in fifths was common, I could feel the subtle differences in mood caused by the magic number nudges across these two instruments.

One further experiment was to build a bass version. To do this I used capacitors of a decade multiple as before, producing an instrument that went from the original lowest notes, down to a sub-bass, into a haptic range of rhythmically countable clicks. It was also in the system of clustered doubles and halves as before, and this worked well in the bass range. It is a possible further development to produce this instrument, but I decided from all the prototyping, that I would concentrate on the treble instruments, in the cluster tuning that I had worked out.

The *Tocante* process negotiates an intuitive method of poking components with a

strict reliance on the materials for tuning. To figure resistor values, I made rough guesses, and then poked around for closer matches, between the different oscillators so that the line is in tune across each instrument.

Another negotiation at play is in terms of precision and temperature coefficients. In Eevblog episode #215, Dave Jones measured hundreds of modern resistors into a spreadsheet, and found a gaussian distribution. His conclusion is that resistors are even more precise than their markings, which mark the farthest tolerated outliers. *Tocante* uses fixed 1% resistors, which would offer little detuning to the final musical scale, but the capacitors may vary more widely. At first I balked at a 5% tolerance, but hypothesized that modern, automated production techniques make for a gaussian spread in capacitors as well as resistors. I specify MLCC (multi-layer ceramic capacitors), which are made solely by machine, and thus should have a higher precision than their tolerance markings.

The tuning game is such that each instrument sounds a little bit different. I've noticed that emotional affect of these variations in precision are wide, but when the instruments are in chorus, they become a pleasant cloud of close notes.

Schematics

Creativity is inspired by a mix of resourcefulness and archeology; there were material reasons for *Tocante* as well as historical influences. The need to visually explain the copper and fiberglass visual of *Mobenthey* caused me to purchase a pack of copper board blanks online, to etch into new circuits for touch. I made all my early

circuit boards by hand, actually drawing the traces with a sharpie and etching them in ferric chloride acid. The Blowing Bear is a good example of a purely hand-made electronic instrument. For *Tocante*, I developed a new technique using the CNC machine, but I still indulged in hand working the prototypes to realize this product. Another simple material concern for the design was my overstock of PNP transistors that I wanted to use; this cemented my decision to use discrete circuits. I remembered my history using transistors; understanding them is slow, and many beginners use them in intuitive ways to produce unorthodox sounds. The strict formalism of op-amps is not built into transistors; their three pins inter-relate and act differently depending on current density and voltage direction. I wanted to recover the beginner's knowledge of transistors, using them freely and intuitively, tempered with masterful design goals such as low-power design. An overstock of high-quality nickel metal-hydride battery packs incited a re-evaluation of the power design for this instrument, targeting it as portable, solar-powered, and with its own speaker amplifier: a solar sounder.

I will return to the internals of low-power design, because my first step was to identify the game-plan for the externals- the oscillators. First, I considered the decision between monolithic chips such as op-amps and transistor circuits. I used a 555 timer in the original Blowing Bear, and I remember all sorts of unwanted behavior, such as overheating chips, a slight shock from touching the instrument, and a lot of spurious noise. I always enjoyed using transistors for their primitive circuit formations, but there was another new reason lurking in this project- to build an

unbreakable open-face circuit. If I was to build circuit boards for touch, I should plan for the contingency of metallic shorts by limiting current on all exposed nodes. The simplest current limiter is a resistor, always required by a transistor circuit. I edited transistor oscillators until any connection to positive included a resistor. This resistor would connect to the transistor on the circuit board, but its other end would remain inside the case, forming a massive nest of leads with the other resistors soldered together. By hiding this positive power node inside the case, all the other nodes floated either at ground or offset by a current source, so I ensured that any short circuits would not melt transistors.

I quickly identified three primal arrangements of transistors that produce vibrations: phase shift, astable, and thyristor. All are quite old, known even in the tube days. Applying tri-centric logics to the situation, I had found three primal shapes in the materials- square, circle and triangle. Anthony Braxton developed the tri-centric philosophy to balance three "houses" of composition: the rectangle that refers to fixed aspects, circle for a complementary flow of improvisation, and the triangle that synthesizes the previous two.[46] The three primal oscillator circuits speak for themselves as tri-centric. The astable multivibrator produces a square wave. The phase shift oscillator generates sines and cosines, the Cartesian decomposition of a circle. Its feedback loop, when damped, filters an input and resonates along; such resonance models the flowing improvisation as in the house of the circle. Finally, the thyristor relaxation oscillator produces triangular waves. By taking a binarism such as

46 Anthony Braxton: The Third Millennial Interview with Mike Heffley

the oscillator and the resonator, and introducing a third, I hope to open up Braxton's concept of "logics," that is, a plurality of overlapping viewpoints rather than a singular "logic" of oppositions.

Naming, as always, is important from the start. Having found a compelling tri-centric schema, I next started an intellectual docket on the textual message. Through various revisions, and checking Google searches of each synthesized name, I ended up with three five-letter words to masthead these products: *Phashi*, *Bistab*, and *Thyris*. Each obviously derive from the original functional names; I strongly prefer to not synthesize any radically new names these days, but take cues from historical precedents. *Bistab* was a misnomer that I chose to keep; I often confuse the meaning of bistable with that of astable, the former is a stable memory circuit, the latter is the oscillator I would use. But the astable does have two sides, and I had no luck coming up with a mellifluous abbreviation for it, so I kept the original Bistab name.

The first task of prototyping circuits is solving their resistor values for the particular application. Low power consumption is a first priority, achieved by choosing higher resistances. Since capacitance dictates tuning, resistance need only a small pool of values, that I chose by preference and convenience from the E3 series: 22k, 100k, 470k, and 1m. Two spaces separate the initial values for ratios of approximately five and twenty to one, followed by a consecutive value, for a double of those ratios. Analog design “programs” the circuit by such ratios, so resistor specification inherently hinges on relationships. Serendipitously, these four values can tune the circuits to unison or an octave of each other.

Prototyping also established the need to buffer the output; unbuffered pitches felt squishy. Here, "squishy" means that on touching the output of an oscillator, its pitch bends slightly due to body capacitance. It is essential to have a base state for each performance point on any instrument, where a stable and simple tone is available. With a base state established, the instrument may then offer squishy bending opportunities. In the transistor oscillator, interior nodes that function both as input and output are androgynous, and I call them *sandrodes*. Due to the through-hole components in the prototypes, these *sandrodes* presented themselves on the board face next to their official buffered outputs. Thus the finger that activates a stable base state can creep further within to bend and squish the inner *sandrodes* for aperiodic or chaotic sounds. Each oscillator responds differently to this bending touch.

Each schematic contains three *sandrodes*, symbolized by an empty circle, one output node marked by asterisk, and a combination of one, two, or three capacitors. Really, each bold capacitor symbol denotes one of the following: two of the same in series, a single, or two in parallel, as in the following diagram.

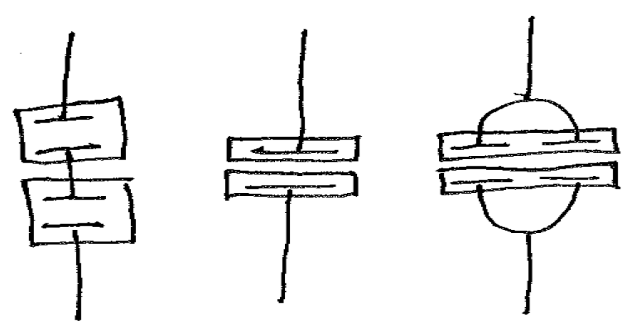

Illustration 16: series, single, and parallel capacitors

As noted above in the analysis of preferred number tunings, these three

arrangements repeat in banks, with the series capacitors on the lower pitch, and parallel towards the higher pitches. The single capacitor in the middle is graded so as to produce a consecutive sequence of pitches across the length of the instrument.

Thyris

The first circuit I worked with was Thyris. It is a relaxation oscillator with hysteresis achieved by complimentary feedback pair, also known as programmable uni-junction (PUT).[47] The PUT uses one PNP transistor and one NPN with their bases and emitters inter-connected to simulate a four-layer device, that is a PNPN silicon device also known as thyristor. The two inner regions use avalanche breakdown to induce hysterical, or state-memory, switching between conducting and cutoff. Since hysteresis is a necessary requisite of the mechanical (not the phase shift) oscillator, the PUT simply needs a ground connection, current source to charge a capacitor, and a reference voltage for the switching point.

47 http://www.4qdtec.com/putpr.html. Very stable: Accessed anytime between 2003 and 2014!

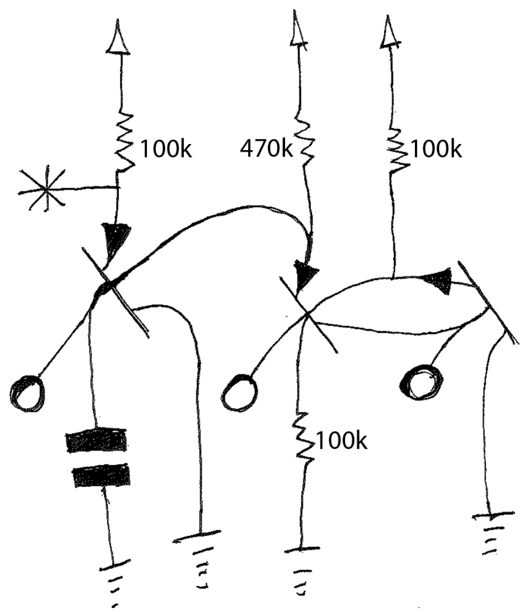

Illustration 17: single Thyris schematic

In the schematic, the leftmost transistor is output buffer, a PNP emitter follower, with grounded collector and 100k emitter resistor to positive. Its base is shared with the top of the PUT pair, a PNP and finally an NPN. The capacitor and 470k resistor are the charge and bucket, and the 100k resistor divider sets a midpoint voltage for the hysteresis. The three circuit bending nodes access these features, and touching them is a rich combination of pitch bends and different kinds of inter-modulation. In fact they can be analyzed as bounds and bounce- the charge and bucket can be touched to modulate bounce, and resistor divider controls bounds.

A fastidious circuiteer will notice an apparent error but I assure you from years spent with this circuit, it is not so. The NPN transistor's emitter faces upwards to the PNP, and not down to ground. In fact, its collector is grounded. I have found that with BC546 and BC556 transistors, the circuit only works in this configuration. I could

theorize that the monolithic four-layer device has some sort of silicon interaction that can only be simulated by an unorthodox transistor flip; although both are N-doped, the surface area of emitter and collector is different and this matters here.

The circuit, as a relaxation oscillator, will charge via the 470k resistor, according to a time constant set by capacitor, until it reaches near the hysteresis voltage, when it will quickly discharge again down to near ground. Thus it produces a sawtooth wave. The thyristor is an early electronic development, essential for power handling and switching, but the idea of a multi-layer complimentary feedback oscillator has been known since tube days, as the Phantastron. (Parker, 2013) It uses a tricky connection between suppressor and screen of a standard pentode, to create a hysteresis loop, or state-memory switch. Vocal cords, reed organs, and the heart are all variations of the relaxation oscillator, defined by Balthasur van der Pol in 1926. (Jenkins, 2013) At the time, much was known about the physical nature of harmonic oscillators and their resonance, but the relaxation oscillator has no resonant frequency. Van der Pol was attempting to relate the two, but the latter is more a result of industrial culture; Maxwell studied it in the context of control systems using governors. The hysteresis node is the governor of the electronic system- when pressure exceeds a certain point it discharges it completely.

Bistab

Bistab, the astable multivibrator, shares a lack of resonant frequency with the relaxation oscillator, and it could almost be defined in terms of hysteresis and discharge cycles. However, the truth is that it is a multivibrator, consisting of two

stages of inverting amplification. Thus instead of one capacitor it has two. It forms a loop, from collector through capacitor to base, and again. There are two separate discharge cycles synchronized to each other in this loop, set by the relationship between 470k resistors and the main capacitors.

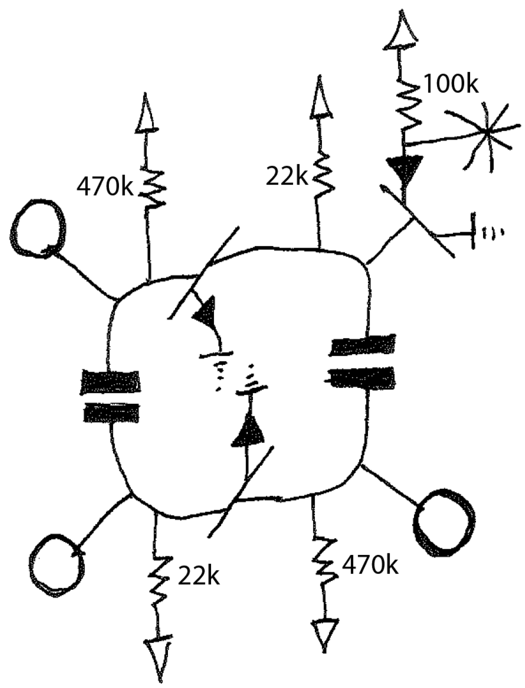

Illustration 18: single Bistab schematic

Originally I did not buffer the output node, because I assumed the common emitter amplifier would be firm enough to maintain a steady pitch when confronted with a finger impedance. Well, it retained pitch but an interesting thing happened- the instrument had become monophonic with each oscillator sync-locking, or slaving to the highest pitch touched. The collector output was also coupled to the base input of the next stage, so touching it could easily re-trigger it with other signals present. It was a strong mode of performance, but I realized it was already there in using the

inner *sandrodes*, so buffering the output allowed a polyphonic sound like the other circuits, and this sync-lock behavior is accessed as its unique circuit-bending characteristic.

Phashi

At this point I realized I was to make a triptych, and the specification of *Phashi*, the phase shift oscillator, came about quickly. It did have some finer points to work out though, such as the workings of the output buffer. Initially I tried it without buffer, and pitch was squishy. Then I tried it with output buffer, but with feedback proceeding from its buffer, trying to have a sense of complete closure in the loop. I found again that pitch was squishy, and judged that output buffers should be output buffers- not connected to anything inside but only the outer world. *Phashi* uses three capacitors, as defined by the classic equation; each shifts the phase about sixty degrees, then the NPN transistor inverts and amplifies, completing a full circle.

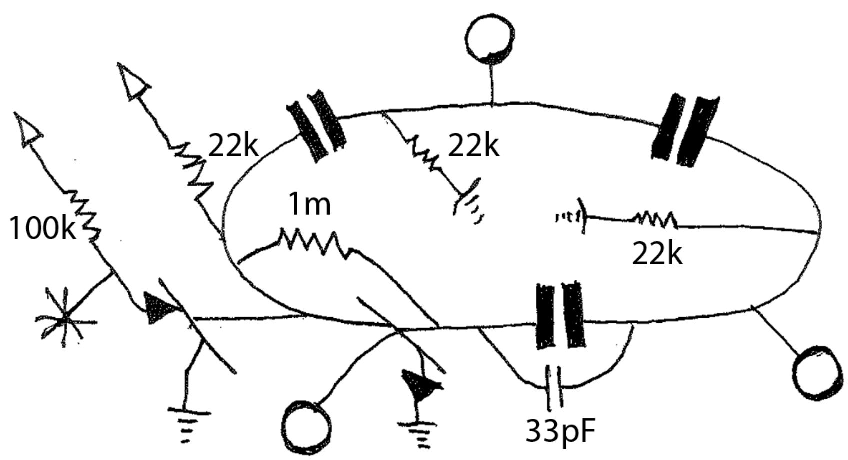

Illustration 19: single Phashi schematic

The pitch is fixed by 22k resistors and the capacitors, in a calculable relationship, but I found that the 1m negative feedback resistor also affected pitch. I tweaked it by ear to bring it in key with the other circuits. In fact, this feedback resistor was the source of an alternative playing modality. In the other circuits, touch activates sound, but I did produce an experimental *phashi* as the reverse- active unless touched. Touch would bypass the feedback resistor, giving more feedback, and damping the circuit. Thus it was initially an instrument that you would have to hold tight to make quiet, an inversion of the typical. In prototyping, I found the sound of damping was a spectacular counterpoint to the other oscillators, that did variations of "hard" circuit bending. However, it hurt my fingers to keep them tightly clenched, and I decided to move the playing operation back to the standard, touch to activate. The damping feature remains in the three inner *sandrodes*, that when touched, easily cause the resonance to fall out of focus, thus bending the pitch a little while muting it.

Power

These three circuits, *Thyris*, *Bistab* and *Phashi*, are an exercise in the utility of *sandrodes*. Each has a unique response to touch, summarized as pitch-bending and crackling for *Thyris*, sync-locking and subharmonic generation for *Bistab*, and resonance manipulation and damping for *Phashi*. The prototyping process was marked by exploring some compounded ideas, but eventually pulling back and letting the *sandrodes* themselves do the work, and ensuring that each had an output buffer for a stable baseline performance pitch.

The power circuitry also was an exercise in minimalism, although I did try a

few variations. It consists of essentially three modules: a boosting solar charger, a touch sensitive power timer, and a speaker amplifier. This practical circuitry deals with higher currents and thus it is completely encased inside the box, not to be touched. It only connects with the touchable board by supplying it power and ground, and one wire that is the touch-trace. When a pad is touched on top, the finger connects the output buffer of an oscillator to this touch-trace.

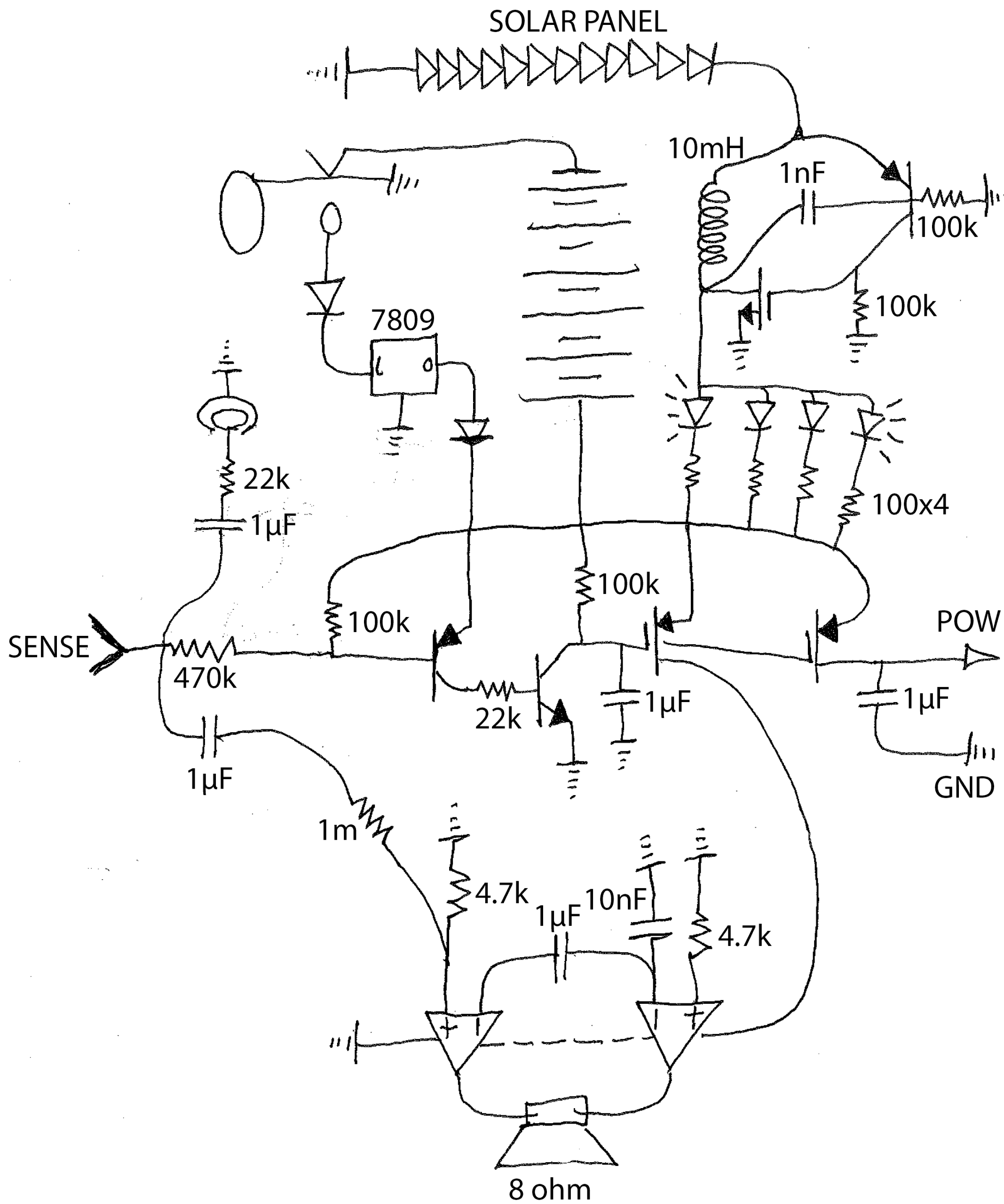

Illustration 20: Tocante power works

The sense input works two ways- it connects directly to the speaker amplifier input, and it also triggers the power timer, turning the instrument on. The power timer detects a path to ground caused by touch, and immediately disconnects power when

this path is lost. The sense input connects through a 470k resistor to the base of a PNP transistor, that is always powered directly by the battery. However, it does not draw any current if it is off, so it won't discharge the battery over any time. When it turns on, it is amplified by another stage, an NPN transistor, and both are unbiased, in full saturation. The NPN's collector discharges a capacitor at the gate of the MOSFET switches, thus energizing the amplifier and oscillators. The gate capacitor can charge up again via 1m resistor during non-touch, turning all circuits off.

The solar charger also uses an N-channel MOSFET to pull current suddenly through a ten millihenry inductor, when sun shines on the panel. When the inductor is fully fluxed, its field begins to collapse, sending a positive spike to the base of the PNP feedback transistor, turning the MOSFET hard off. The inductor then compensates by swinging as positive as possible to discharge its stored energy, through a diode and into the battery. The battery is actually two battery packs in series, for six cells total, with a nominal potential around 7.2 volts. I used a boost converter instead of a nine volt panel, because the former would take up a lot of space, and potentially provide too much current; a solar panel should match its receiving batteries, because you don't want to ever provide too much charge at once. The boost converter is self-starting, and it works in half-light, so it can really extract energy in a lot of light situations.

In an eco-musical setting, batteries' role in electronic instruments is in relating day to night; because the primary method of charging is with solar panel. There is a deep and ancient meaning saving charge and its associated musics until night-time;

imagine sitting around a fire surrounded by darkness, making sounds on the loud drum and shrill flute to keep the ghosts away. Electronic music is like magic; it has best effect in the dark, when the dominance of visuals recedes into shadows, and understanding by peering becomes wondering at hearing. As instrument designer I pay closest attention to this type of primordial logics, and thus spent a great deal of labor designing the battery charger/ amplifier inner circuit board.

The Tocante Makerspace

A workshop is a space for making things, where wooden forms balance the symbolic and philosophical considerations of electronic design. I had spent many years as a handwork purist, when for reasons of design growth and fabrication convenience I adopted computer navigated cutting (CNC). This machine subtracts material from wood by routing a cutter along a scripted path. I write the bulk of my scripts in Ruby, leveraging object orientation to stamp out physical objects, sometimes in arrays.[48] I decided to forgo any computer aided design (CAD) software as it abstracts away important physical aspects of the working material; wood grain informs the woodworker's cutting strokes and it has diverse personalities across its species. For this reason I chose to script the cutter according to what I knew from handwork, scribing various patterns in it out of resepect for the material. For example, I derived a specific, up-and-down cutting pattern to release the piece from its blank,

48 Yukihiro “Matz” Matsumoto developed Ruby in the mid-1990s, as a general purpose scripting language for embedded use in large applications and also as a stand-alone interpreter. It supports multiple programming paradigms, including functional, object-oriented, and imperative, including more post-modern features, such as duck-typing, that allow quick development and recycling of code. I learned about it from working with Google's Sketchup CAD application, that employs an embedded form.

to prevent forceful ejection that scars it; this pattern leaves a herringbone pattern on side faces, echoing the common triangle wave oscillator within.

Over the years, I have sought out a few sincere country gentlemen who provide my lumber. I esteem these men- Ed, Jeremy, Dave- as artisans of the tree and the saw. They surprise me with their passion and deep knowledge of the many hardwood species of the American East Coast. For example, here are the species I have procured from each:

- Jeremy (rural Maryland): sassafras, walnut, sycamore, poplar, cherry, mulberry, juniper
- Ed (Pennsylvania mountains): walnut, catalpa, apple, mulberry, sassafras, locust
- Dave (rural Massachusetts): mulberry, sycamore, catalpa, sassafras, hackberry

These woodmen deal not in impersonal lumber, but in a web of farmers whose land yields fallen trees of diverse species, that they transform into a unique local material. I mediate the transition from this place of sap and the smell of sawdust to a final synthesis with electronics that so desire an organic case. Metal is too heavy and indeed dangerous to electronics that it surrounds; plastic is hazardous to its worker, who huffs the fumes and suffers from damaged creativity; truly warm wood protects the electronics as contrapuntal and inspiring to analog arrangements of crystals, copper and ceramic.

In this mediation, a scripted CNC machine represents the cyborg prosthesis to

the arboreal ecology of man and wood.[49] Thus I adopt a continuum of words for this workshop, such as medialab, makerspace, fablab, that imply the relationship of code to material, in this case both organic and not.

The sound world of a makerspace includes the quiet sounds of plastic and metal components tumbling on desks, a boon to close listeners, to carving crackle and sanding hiss on wood. The pedestrian sounds of synthesizer calibration unintentionally inform the song of mockingbirds outside, although it may be a source of anxiety to the maker who hears a malfunction. With the CNC machine, the makerspace sounds fully cyborg, as pulsed rectangle signals course through stepper motors, releasing acoustic energy through the work piece.

I find it no coincidence that the electronic music genre Dubstep employs a harsh rectangle wave for its synthesizer line, with rising and falling portamento and wobbling modulations. Control algorithms for stepper motors will invariably ramp the speed on startup and stop, to prevent punching the workpiece and tool with instant acceleration.[50] This startup ramp sounds like the rising and falling portamento of Dubstep, the robotic incantations of the acoustic cyborg. A CNC program may often cut circular holes, and the phased relationship of X and Y steppers tracing sines and cosines sounds like the haptic wobbles of the Dubstep synthesizer. The only thing missing from a CNC is a harsh two step drum pattern, but we can add this by playing

49 Donna Haraway, in *A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century*, develops an ontology for the cyborg as fusion of animal and machine, with radical implications for humanities, feminism, sociology of science, and primatology; the cyborg relationship can even include animals.

50 Mach3 CNC software users manual.

it on a dust-proof stereo. Dubstep is anthem of the cyborg makerspace.

The *Tocante* instruments measure approximately eleven by three by one inches. Initially this form factor derived from pricing; a typical business move is decide a price point and proceed scaling the product. The broader philosophy of "stores at the mall" is to generate bantam synthesizer ventures, for the sake of renewed aesthetic vitality and the benefits of eclectic and diverse product lines. The business plan of this new store, *Tocante*, flirted with the idea of accepting payment in Bitcoin, a virtual monetary system, worth about $365 at the time.[51] The disadvantages of Bitcoin include a shady legal reputation and price volatility, so it was not employed. However, the $365 form factor remained, since it fits well in the hands, and encloses a convenient amount of compact circuitry. This anecdote shows how even currency and pricing informs the creative process by scaling the product.

Coding a case begins with laying out the circuit. The aforementioned form factor would fit about twenty one oscillators, in seven groups of three. I arranged touch pads around the circuit board's edge, with the supporting oscillator circuits in its heart. That way, the instrument is held in two hands with digits coursing up and down the length of its two symmetrical keyboards. The circuit faces out, and the speaker faces back at the performer's chest.

51 Satoshi Nakamoto invented Bitcoin in 2008. It is a peer-to-peer cryptocurrency with block chains maintained by mining activities.

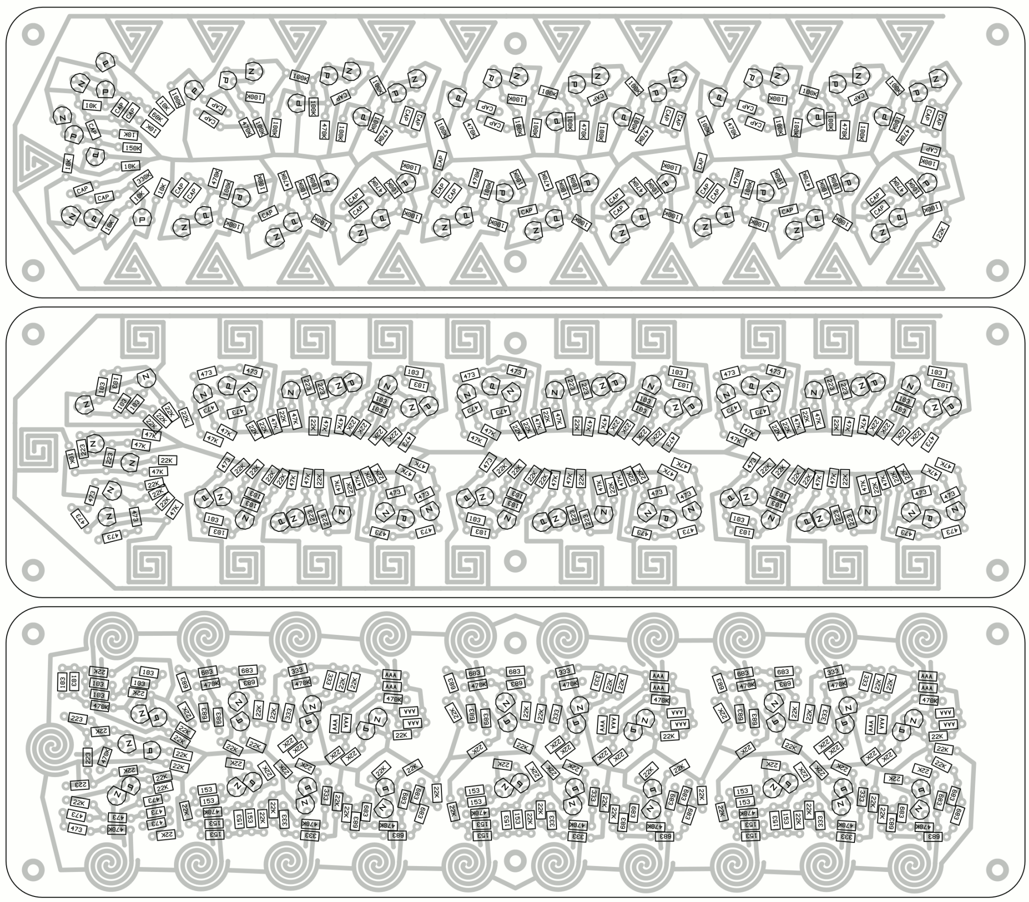

Illustration 21: Tocante design for CNC prototyping

To design the touch pads on each of the three instruments, I wrote a short script to draw geometric spirals of n radial breakpoints, and called the function with arguments of three, four, and fifty, for triangle, square, and circle respectively. Each spiral contains two lines: one for the output signal of the oscillator, and another for the sense node of the amplifier circuit. The two are thus enmeshed and ready for touch to connect their close coursing. I laid these pads out in a group of three and proceeded to lay out the planned transistors, resistors, and the capacitors that varied in number over each triad. With the clusters laid out, I spawned them as seven sub-

designs to complete the layout. I had originally intended Tocante instruments to be completely free-form in layout, but time quashed this lofty goal. However, the far left cluster, where the pitch set rounds the corner, required some massaging of components in a free-form way.

The *Tocante* prototypes, since they employed single sided circuit boards, required a secondary circuit board, tucked within the case, to handle the power circuitry and conceal it from danger. As detailed in the schematic above, this board holds batteries, solar charger circuitry, an audio amplifier, and the touch sensing

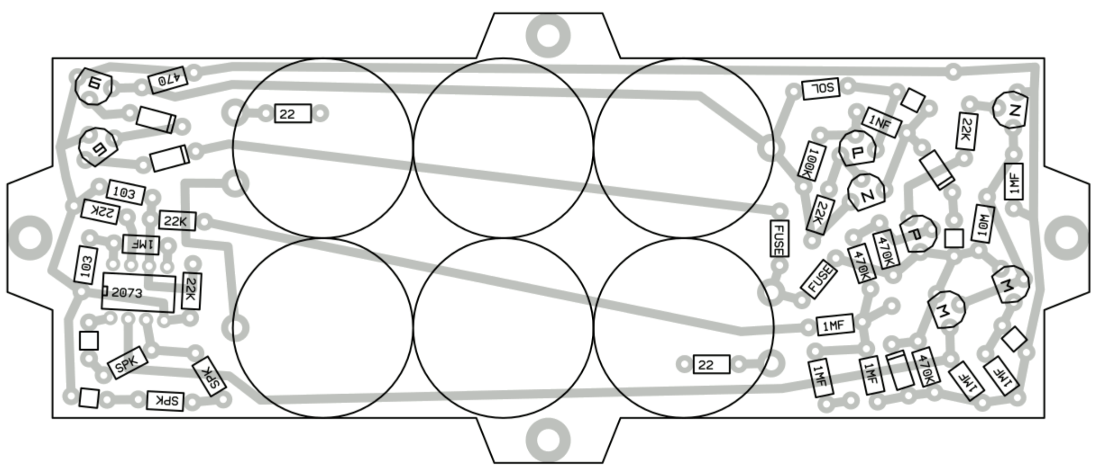

Illustration 22: prototype power board

power switch.

To prototype, I needed to learn a new skill: CNC circuit board fabrication. Unlike etching with acid, this technique uses a high speed cutter bit to isolate circuit traces by routing around them. The CNC machine simply takes gcode, a base level scripting language consisting of simple coordinations. As with routing wooden cases, I needed a higher level script to convert my design to this low level language. This time, the script would run within my circuit design program, Osmond. This

application has an embedded Lua interpreter for manipulating parts and other components of a circuit design. Lua is similar to Ruby, as dynamically typed languages with memory management and multiple programming paradigms, but it is quite more lightweight than the other.[52]

I had experience with Lua as an embedded script for video game development, so it was simple to use. The trigonometry, however was tricky, to trace around circular pads with traces radiating at any angle. I eventually succeeded with a bare-bones solution. In any circuit routing, there are three steps with three different bits: drill, trace, and excise. Drilling is boring a small hole completely through the board, for the purpose of threading through-hole components. Tracing is the most intensive stage, when a triangular bit lightly cuts the thin layer of copper to isolate the traces. And finally a 2mm chip cutter bit passes around the entire edge of the piece, to release it from the work blank.

In cutting traces, the bit can easily cut too much or little, so to compensate, traces and pads should be as wide as possible, giving the whole piece a bold look. The time and work programming and loading the CNC mill yielded about twelve unique prototypes that feel completely hand made, with the patina of copper. But I decided to quit this task as the dusty fiberglass and long hours taxed my body and soul. To continue the project, I decided to redesign the circuits for surface mount components and machine assembly.

For the first time in my circuit career, I switched working units from inches to

52 Roberto Ierusalimschy, Luiz Henrique de Figueiredo, and Waldemar Celes designed Lua in Brazil, 1993.

millimeters, for practical reasons as well as aesthetic. The native units of most assembly houses are in millimeters, however this usually causes no problems for inch work, for the machines and data are very precise. However, I do believe the whole number system one uses affects the soul of the layout work. Inches relate to feet as one does to twelve. Twelve multiplies three and a couple of twos, so trisection and bisection are its intrinsic abilities. In contrast, the metric system is decimal, so it handles three irrationally, skipping instead to the higher prime of five, as the fingers on most people's hands. In addition to these numerical implications, the scale of each system is different. For the pads of Tocante instruments, I found an inch to be too large spacing, but two centimeters just about right. I have big hands so I can always rely on my own judgment if something feels too big. So the final dimensions of *Tocante* Gold, the production line, are in centimeters, 8 by 28, that happens to line up very closely with the imperial prototype dimensions.

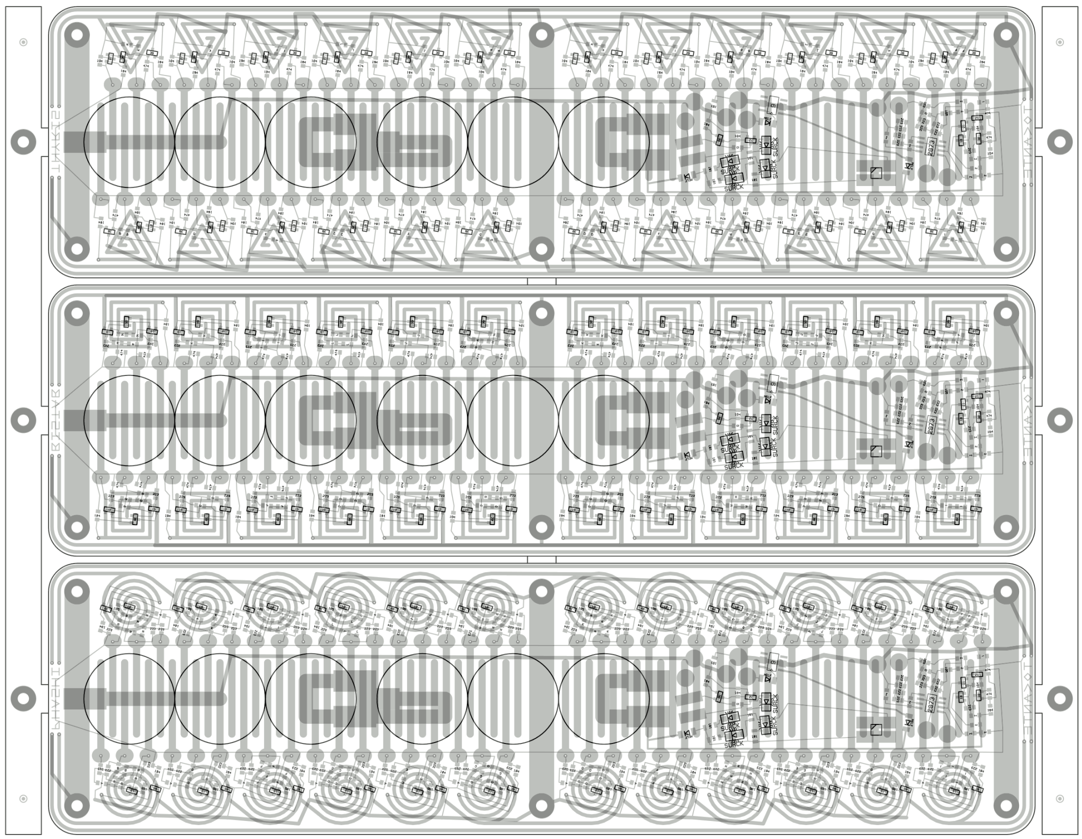

Illustration 23: Tocante production instruments

I communicated with the assembly house about possible finishes, trying to preserve the original bare copper of the prototype line. These circuit boards are now double sided, unlike the prototypes. On inside, I could lay out all the power and amplifier circuitry, without one single via, or penetrating connection to the other side. Thus the fiberglass isolates inside circuitry from outside nodes that are decorative and optimized for touch. Each oscillator circuit dwells approximately beneath its pad, and its output node and several *sandrodes* penetrate the board for distribution above. All pads require some kind of plating to proceed through solder pasting and assembly. The usual platings are electrolytic tin or gold, although lead was predominant before

RoHS.[53] A plastic coating masks this plating from the copper traces, but the touch-traces need be bare, so I would need a peelable soldermask to achieve the bare copper look of the prototypes. At this point, my aesthetic goals diverged from practicality, and I decided to finally part with one of the original goals of *Tocante*: to visually explain the bare copper "grandmother-driven" aesthetic of *Mobenthey*. I decided to instead use one of the two common finishes on hand at the assembly house- tin or gold. Gold plating is actually quite competitive in pricing, because it is only a very thin electrolytic deposit. The noble metal is bio-compatible, tarnishes not, and erodes slowly. Thus, the Tocante production line is gold as opposed to the copper prototypes.

Zenert

Tocante is an elemental reaction to *Mobenthey*, a line of highly configurable modules. Tocante intends to escape from the endless tweaking of Mobenthey's Eurorack, but both are linked in time and intention. So, when it came time to design a new module for *Mobenthey*, at the end of its first run, it also came to *Tocante* to diversify into a fourth instrument. Since the basic thrust of *Mobenthey*'s new module, *Dunst*, is noise, that too became the new *Tocante* idea.

Zenert is a simple name, deriving from the source of its noise, a zener diode, and the spectral flavoring applied by a simple resonant circuit, the twin-t. Its operation diverges from the previous *Tocante* pieces, where finger-touch simply connected oscillator outputs to an amplifier. In *Zenert*, finger-touch injects the zener

53 Restriction on Hazardous Substances: Lead, Mercury, Hexavalent Chromium, Cadmium, Polybrominated Biphenyls, Polybrominated Biphenyl Ethers, in addition to the obviously vile Polychlorinated Biphenyls.

noise into the inputs of the flavoring circuits. So instead of a number of discrete symbols at its rim, *Zenert* has a band of copper tracing, scripted to mimic the waveform of noise. The inner nodes, for circuit bending on *Thyris*, *Bistab* and *Phashi*, are now the injection points for each resonance.

The resonators on *Zenert* share the same tuning-by-capacitor scheme, establishing continuity with the previous ones. Thus *Tocante* shares a two-faced nature with its nemesis, *Ieaskul F. Mobenthey*; looking backward to previous designs for the general framework and manifesto, but looking forward to new ways to break out of the mold.

Zenert required some design work beyond the resonant operators that repeat around its rim with a gradient of capacitor values; the noise generator required a specific process, including amplification, putrefaction, and a high voltage source. Over many designs for noise, I have found that zener diodes are inferior in their noise amplitude, and instead opt for reverse biased transistors, which become a sort of highly noisy zener. Unfortunately, their zener voltage is around eight volts, so the 7.2 volt battery power of *Tocante* was deficient. Glumly, I investigated digital non-linear shift register noise generators, and low voltage zeners, but yearned to use the same assemblage I had perfected for the *Mobenthey* generators, which have enough voltage at twelve volts positive.

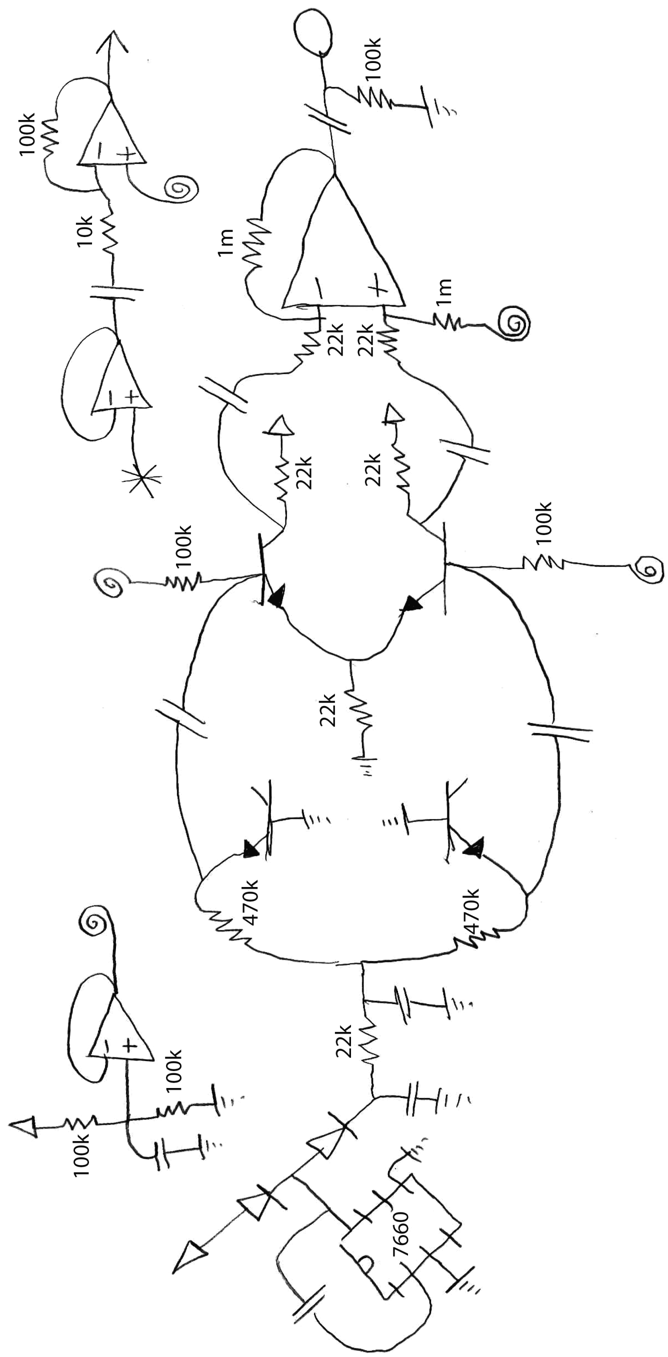

Illustration 24: Zenert noise generator

To solve the problem, I specified a switched capacitor voltage multiplier chip, the LM7660. This chip uses a high frequency, around 10 kilohertz, square wave, to

rapidly pump charge into and out of a capacitor, then rectifying it through diodes, and magically generating around fourteen volts out of seven! It can power tens of milliamperes, but the reverse biased transistor zeners only require less than a single milliampere. You might think that since the noise generator employs high amplification, the switching frequency, 10 kilohertz, would show through, but it does not, for the amplification is completely differential throughout. Also, noise is a great cover for high frequencies. The noise was so white, that when I touch its trace, my body emits radio frequency noise, soiling the circuit, so I filtered it down to pink noise for the purposes of the flavoring filters to follow.

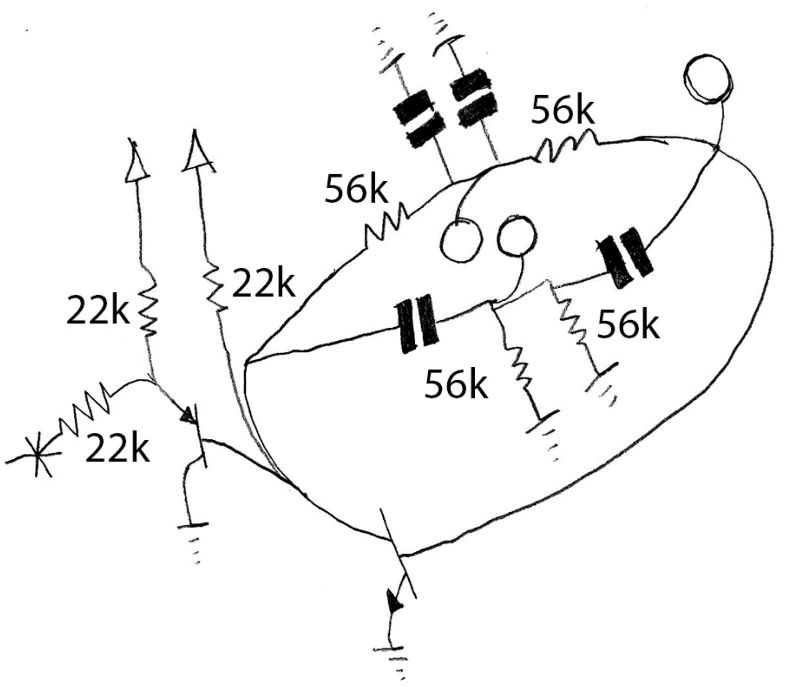

Illustration 25: Zenert twin-t process

The filters are simple twin-t resonators, with tuning established, again, by capacitors. They have three possible inputs: at the base of the transistor, giving the

most unflavored noise; at the junction of the parallel capacitors, for the most resonant lowpass effect; and at the junction of the series capacitors, giving a sort of highpass.

The final design challenge highlights *Zenert*'s difference from the previous three designs. With them, the buffered oscillator signals traverse a touch-finger, directly into the amplifier. With more touch, the signals actually attenuate because they average with each other. Thus, touch can lead to amplitude control, not only for louder notes, but also through the compression of averaging, to quieter signals. With *Zenert*, I wanted to use the finger-touch as a conductor of noise into the filter, whose output feeds internally into an amplifier. Thus there is less agency over compression, with the theoretical potential for clipping and distortion. However, a simple resistor could be the cure, changing the raw noise signal from an output, to an impeded flow, that through touch to filters, attenuates as well as the other designs did.[54] This is the thought experiment that I leave up to the circuit materials to prove.

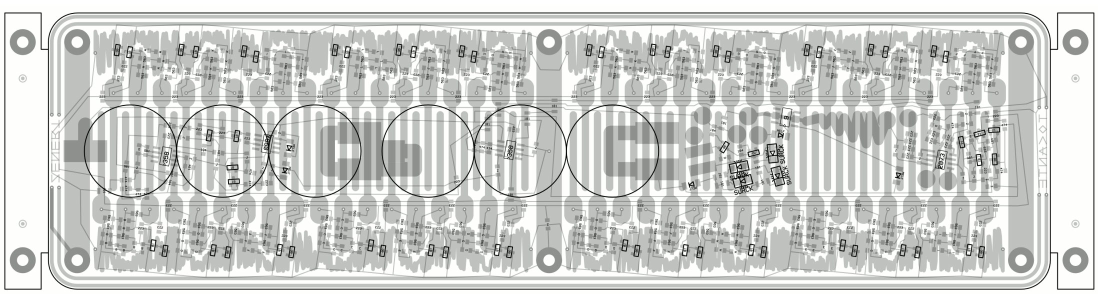

Illustration 26: The Zenert board design

It protrudes into uncharted territory, to mine new resonators by noise-injection. With it, I mimic the hollow cave on a windy night, or echea- little pots inserted into the theater walls for their resonance (Valière et al., 2013). I test this design by making

54 I am grateful to Professor Ron Kuivila for helping me usher this design to completion, by realizing the resistor that impedes noise, damping proportional to its touch and consumption by resonators.

it. I resist the easy path of before, using hard outputs through the finger, because this new one employs a special noise source beneath its batteries, and it is a vector to future developments. Noise injects into resonators of the twin-t sort, but a compound of this principle is the Karplus-Strong algorithm as resonator- strings! I sketch this idea in the back of my head, using twenty-four micro-controllers, each with ADC and DAC and a small buffer of string space, tuned again to the preferred series. This is the thought experiment that I will leave up to the circuit materials to prove.

At the Lead Mine

When building electronic instruments, they dictate so much- tuning, timbre- but also the aesthetic of building an ensemble of instruments makes it difficult to include traditional instruments such as violins; the maker has spent much creative energy on making a new sculptural form and often does not want other forms to crowd it. Yet, often it is profitable for the music and scintillating to the audience when one adds a violin to ground it or guide a tour of the weird sounds. So those opportunities to connect with skilled musicians should be pursued to not make the music to introverted.

But still you have an orchestra of essentially your own composition, even if you use a trombone or a piano to highlight its difference from orthodoxy. Do you want to layer another, written, composition on top of the one that's already there? Do you have energy to produce such a composition and will it do the instruments justice in exploring their possibilities? Can notation be used for invented instruments? I am not

advocating all-out improvisation as an hegemonic replacement for strict composition, but perhaps a shift of mind beginning with the realization that the job of composition has been completed, and now it is time for observations, research, or simply presentation.

This is why I turn to site-specific composition for development of an event. After all, your invention of instruments is tied to a place through the walks and talks you've had there. I learned about the history of Middletown, Connecticut, at Kidcity children's museum, a creative and well-crafted collection of themed activity rooms. In the “fish room,” while my son was absorbed in cataloging and loading colorful rubber fishies onto conveyor belts, I perused reproductions of old maps and historiographical materials pasted on the walls, no doubt for entertainment of dads, as it was.

On one old map I could see the original college row, nothing more than a stone chapel, large hall, and a bell tower. Looking down to Brainerd street where we resided here, I see untamed wilderness and a creek draining into a small pond. On another wall, I read about the use of the river during colonial times; the river bend at middletown was a natural spot to stop and transfer cargo, and the sweet waters were a cleansing salve for the marine bore-worms that plagued sailboats of the day. Before Andrew Jackson closed off trade to England, surplus Connnecticut agricultural products could be sold at the docks, and also the mineral exploit were profitable.

Here is where I read that Middletown had the largest and richest lead mine in the state of Connecticut, ironically in a kid's museum; lead is toxic to developing minds and is a constant worry to parents especially in the old houses of the college

town, where it was heavy in paints and ceramic glazes. I was moved to research and visit the site of the lead mine, where Indians had once noticed heavy and dark stones poking through the ground, which they no doubt carried with them for various purposes. In colonial times, the mine was dug deep to fully extract all the lead, which was then used in the revolutionary war for cannonballs.

Lead is a formidable pollutant of 20th century electronics, and a poison to children. Late night I was forced to use it in soldering a *Tocante* prototype, and mused on the dust and lead that covers all the old David Tudor touch circuits in the Wesleyan collection. The lead mine has a double/poetic meaning, going deep in the ground, the resonances there, and secrets too.

My recital "At the Leadmine" is an attempt to emulate a lead mine in the heart of Wesleyan's Center for the Arts, in its underground concert hall "J." I wanted to portray the work of playing, practicing, and composing as a process of mining; to perform this art of chipping away rock and carting it away, I asked not for rehearsals, so it was a raw and mineral effort for those performers. They were many, including those who had helped me in the Sidrazzi Gamelan, plus the whole cast of graduate students in music, and some undergraduates who had helped experiment with the *Tocante* prototypes.

I initially wanted to bring the audience to the tunnels behind the hall, but it was impractical for safety purposes and because machine noises fill those tunnels, not like the quiet wetness of a cave. So I decided to abstract the mine on stage and let the audience sit in cool comfortable chairs, to befriend them. For the rock matrix, I

littered the small stage with the various white box pedestals available in the tunnels behind the hall. On these strewn cubes, I asked the performers to place their instruments, traditional or synthesized. The circuit boards of copper and glass, a brass saxophone, violin and viola, and wooden synthesizers are the rare earth of this tableau, to be picked up in musical chunks by mine performers.

The tableau completed, my work was finished. I had long before sintered the minerals into musical instruments, and conceived and workshopped social situations for them. I even had an escape plan for the after-recital drinks at Eli Canon's, a bar. This brilliant plan worked this way: I would perform the recital in reverse time, so the recital actually started in a "virtual Eli Canon's" where the audience is now waiting for a table, "for a period of time equal to the length of the recital which preceded it." I thus took up my role with the wireless mike, as navigator of the recital in reverse.

The recital thus ended (began) with two "pure" examples of the constructed dialectic between acoustic and electronic. They were improvised imitations, in both directions. For electronic imitates acoustic, Sean Sonderegger improvised on the baritone saxophone, inciting the Sidrazzi Gamelan players to imitate the gestures. It was a bombastic ending (beginning), that I realized reflected my lewd and acid feelings for the synthesizer fair. For acoustic imitates electronics, a trio of *Tocante* instrumentalists provided short held chords which a duo of strings (violin and viola) imitated. This ensemble relieved the tension of the other, feeling more like miners at the campfire after a long day underground.

The next (preceding) piece was a demonstration of my digital synthesizer, the

Shnth, as controlling a game called Mikey Walker. The game demonstrates how the Shnth, which uses squish gestures not unlike the Sidrazzi, can cause Mikey to navigate by walking, and to punch too. The performance was simply beating the game, and talking about it all along. The game provides an experimental soundscape by its enemies, called chubes. Chubes are really synthesizers, these box-like entities that inhabit townes. They pollute the townes, since they use electricity that causes smog. The less chubes, the less the towne exists; when the final chube dies by Mikey's punch, the towne disappears back into dark, natural space. As Mikey punches them, they rock back and forth, and if punched at resonance they fall over. Meanwhile, they synthesize sounds in response to these punches. Since these sounds are quite abstract, I asked Hal Blej to noodle loosely on the theme of steel-pan Super-Mario, as accompaniment.

The next (preceding) piece ostensibly was a demonstration of the *Ieaskul F. Mobenthey* modules, but it was so much more on top of that. One factor covered by its prerecorded tape part was my own condition of misophonia, or sensitivity to certain eating sounds. The other track in the tape part was excerpts of Deleuze's "Francis Bacon: Logic of Sensation," which most concisely sums up the Deleuzian influences in this thesis. In fact, the two most important chapters "Hysteria," "The Diagram," and "Analogy" provided their own excerpts as a previous library loanee had underlined the most salient phrases. I asked professor Ron Kuivila to read, and my colleague Daniel Fishkin to eat loudly and rustle chips bags, sipping water with aspiration. For this reason, the backing track could be called "ASMR Deleuze" and

you may find it on Youtube under this heading.

For the live part of this piece, I asked Jason Brogan to enter the room with a box on his head and improvise on the modular synthesizer.

The first and final piece of the recital was a simple poem, about synthesis, which I wrote many years ago, including abstract notes for synthesizer. The synthesizer notes, such as “positif,” “stair forms,” “rand melo,” “noise,” “swell,” are open to interpretation, for which purpose I loosely strung together some presets for the Shnth. I started by performing the poem without accompaniment but realized part of the way through that the synthesizer notes are important to incite a coloring and creative background to the text, which is as follows:

I know you hold the blackened pole
Don't tell me how you hid
the wine and the horses.
Why keep on talking about the price of ice
in a frozen land?
The change of state has no message,
for the leader changes his outfit
and his beard,
but no one talks about a magician-
we know it's only a speckled robe.
When do you want to fetch the monster?
Why do you say someone else
tied it to the radio tower?
Who lured it to the top of the hill?
Who heard the secret on the radio?
Who drew the seven squares beneath
the waterfalls?
Who blackened the pole?

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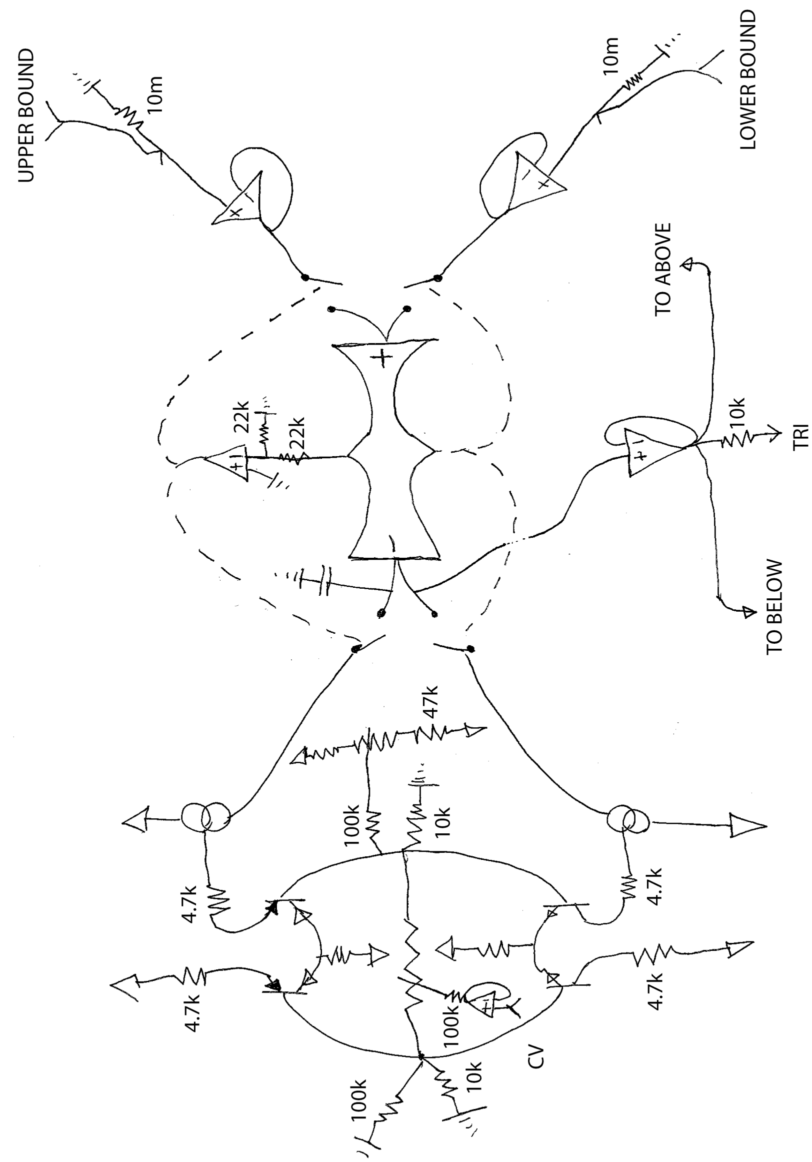
Appendix I: Mobenthey Schematics

Fourses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LOWER BOUND
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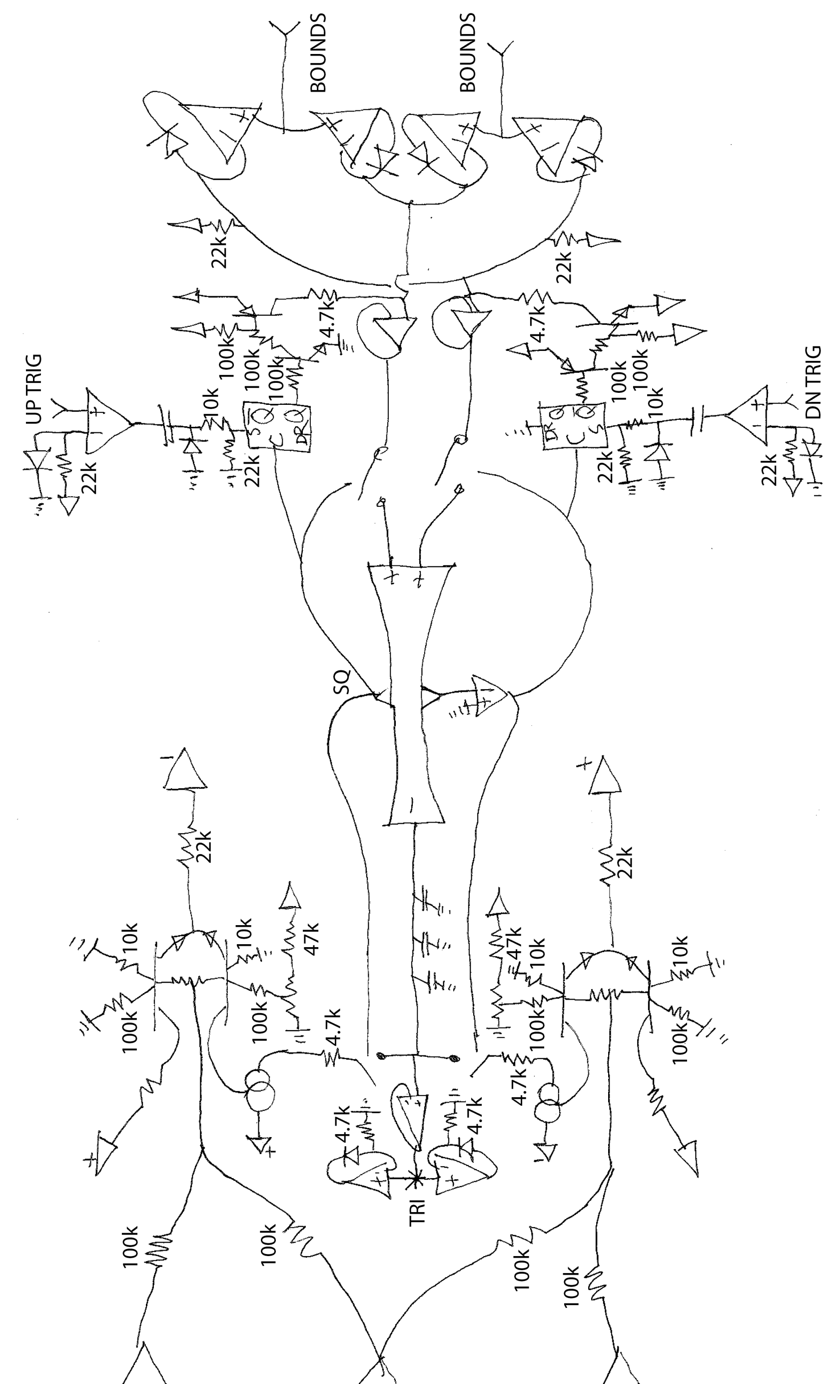
CV

Swoop



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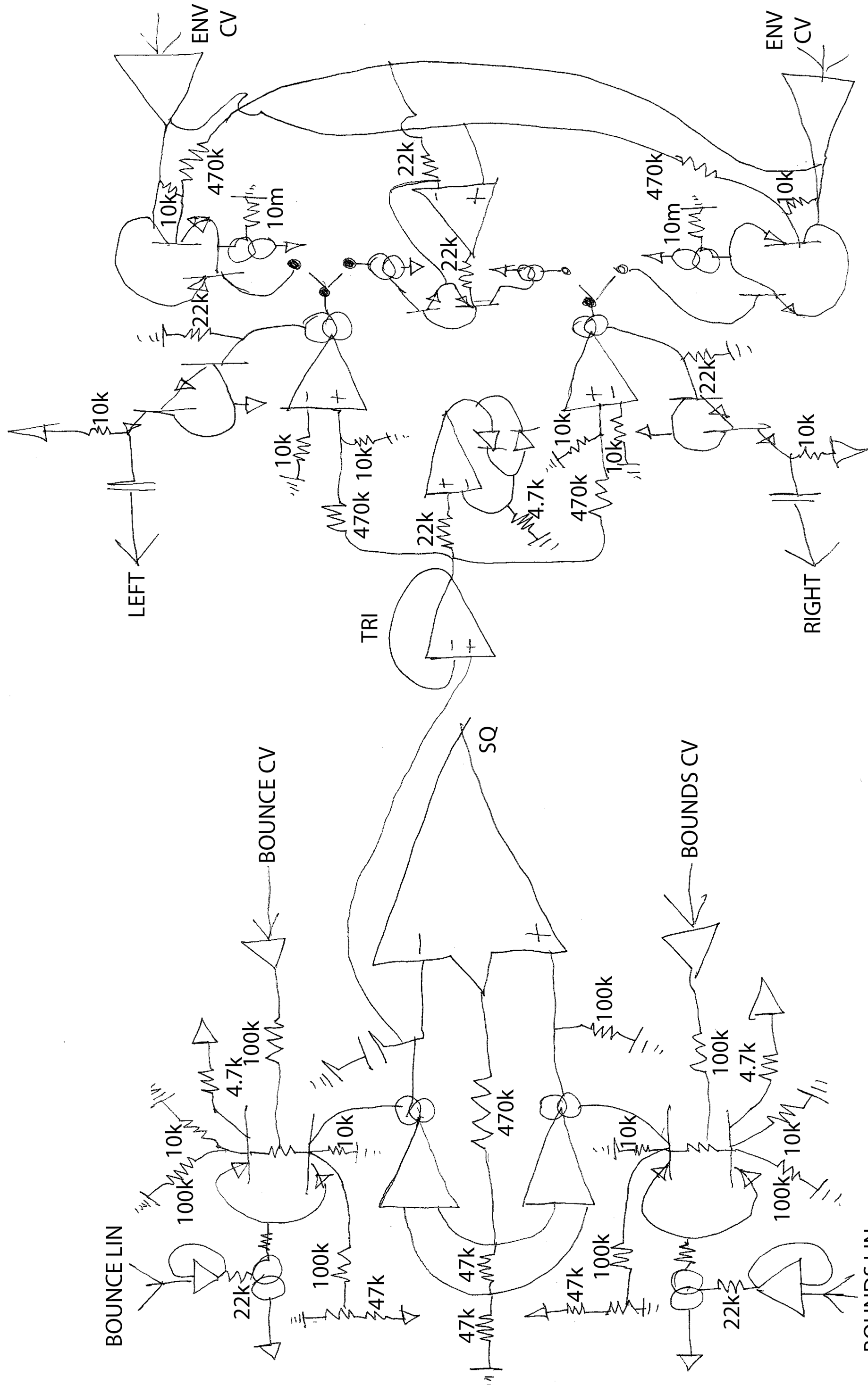
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BOUNCE CV
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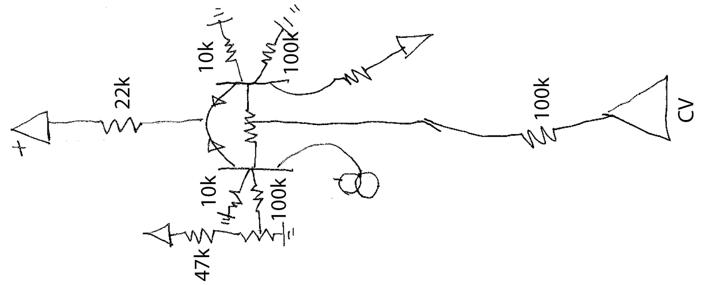
BOUNCE LIN
BOUNDS LIN

Sprott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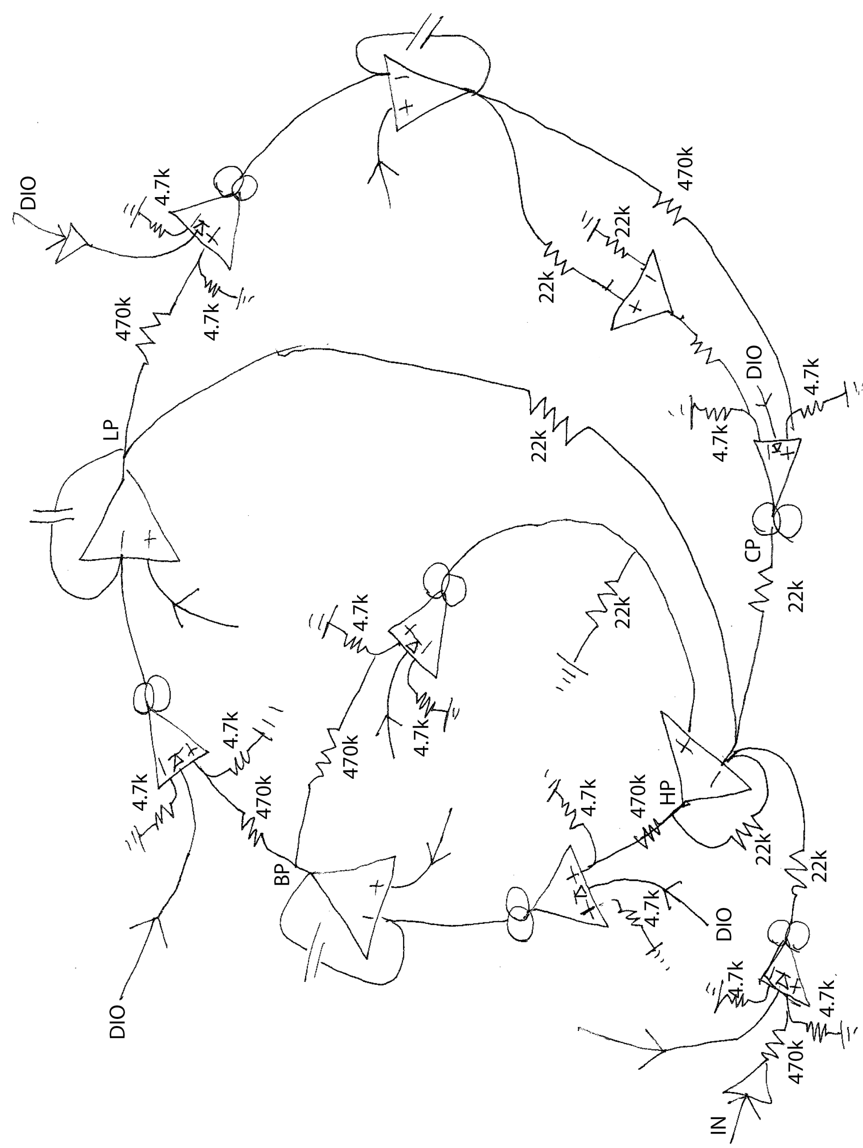
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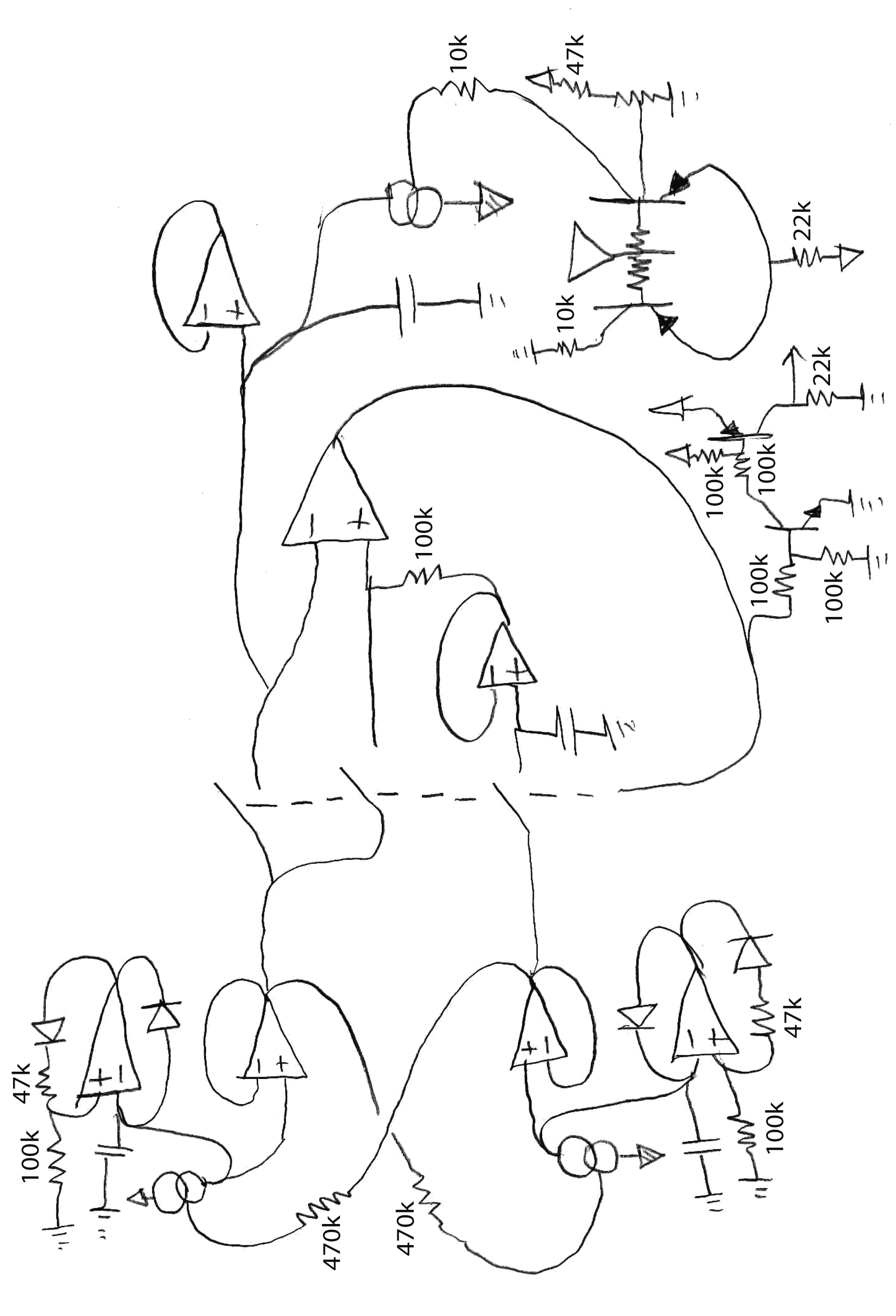
IN

Dunst

Dust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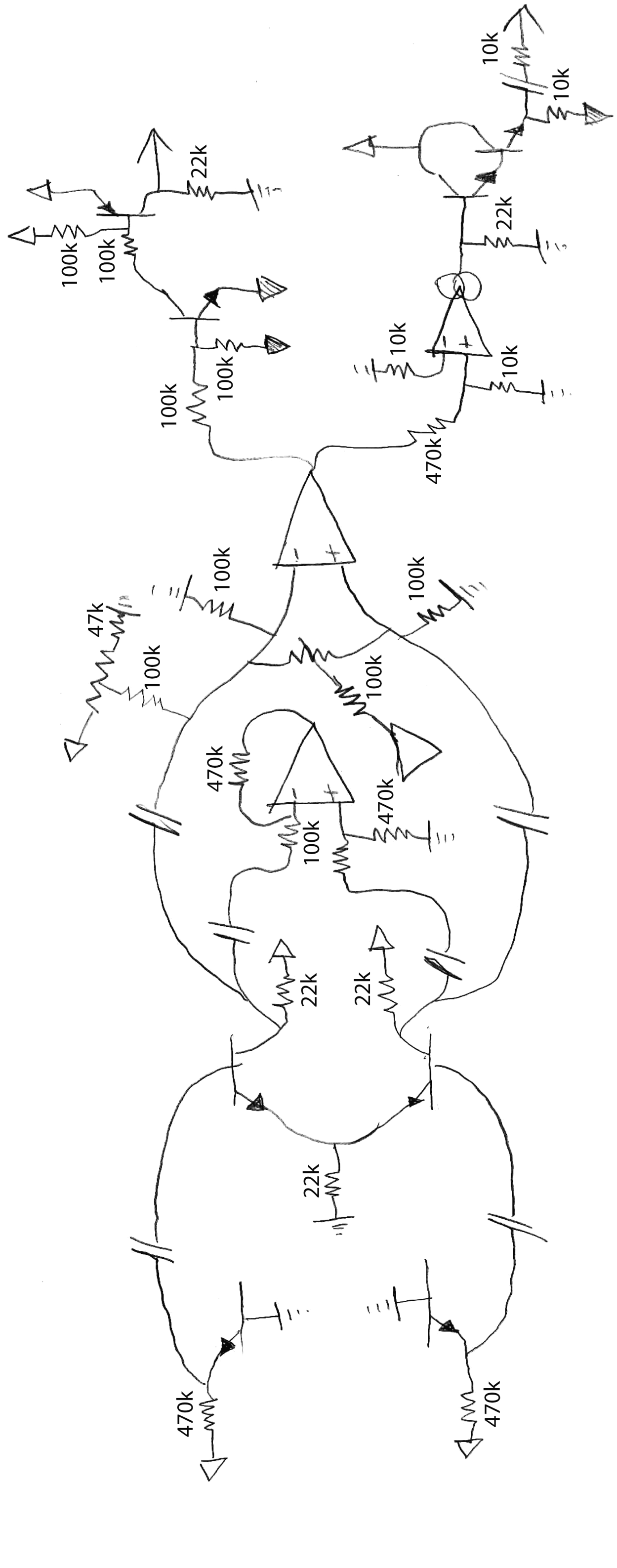
Noise



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Appendix II: Historical Instruments

I was born in the submarine base at Groton, Connecticut. 34 years later, my second son Hakuto was born in Connecticut's Middlesex Hospital while I attended graduate school in Wesleyan University, under the tutelage of Ron Kuivila. To satisfy the requirements for master's degree in composition, I concertized in several recitals, assisted in undergraduate classes, and composed a thesis. The thesis was to cover the philosophy of synthesizer design including new developments during this period.

However, great personal changes also marked this time. With two children approaching schooling age, my wife and I realized I could not return to Baltimore, where I still own a workshop that has served me well for ten years or so. The creative environment there nourished radical musicians, improvisers, and still does foster deep performance art and synthesizer building- it was a great fit for a growing artist, especially with cheap and abundant property space. The school situation is tricky, and my older son Kirito has sealed the matter by indicating that he cares not for Baltimore. His parents may have good friends, business partners, and artistic collaborators there, but we must move on as a family.

Over the years, I transformed my Baltimore workshop on Bentalou street, on the inside with a expansion of creative spaces, and on the outside with planters and gardening. I am proud of the living things I brought there- a pawpaw tree out back that yields many custard apples each Autumn, sumacs out front, and in the alley, three osage orange trees that I grew from little seeds. Every Winter, we stockpiled firewood in the basement, for the sole heating system- a wood stove. As part of an artists enclave in the west-side of Baltimore, the mandatory entrance fee was going “off-grid” by cutting out the gas company. It seems almost foolish that I scrapped all the old radiators in my house, but wood heat served me well, especially since I could stoke and tinder it with dry scraps from the wood-shop, bolstering its flame.

Besides logs, the basement also held old musical instruments from my earlier experimental periods. They are a diverse group of prototypes, whimsies, and thesis-pieces. Their forms include tapestries, heavy wooden casks of tubes, futurist baroque furnitures from Pier I, and furry things. I have performed with them sporadically over the years, and tried to maintain them, but a chance to unburden myself of the collection presents itself. For liability reasons, I must sell the workshop on Bentalou, and remove the instruments to a safer place. The safer place shall be Wesleyan's world instrument collection, newly expanded by professor Kuivila to include prototypes and odd things from the age of electronics. I am honored to become a member of a collection including David Tudor's complete works as well as those of David Behrman.

To assist anyone who may wish to play these instruments, I now insert this manual into my thesis, with remembered origin stories and design intuitions, that may bolster it with their history. I will emphasize any pragmatic decisions made in the history of the instrument after its completion, such as repairs and re-workings of the

interface, to induce a feeling that such idiosyncratic pieces are a living thing that can change. I hope that their history becomes a collaboration with the reader of this manual, aiding curative efforts, restorations and repairs with a sense of mutability. Remove your white gloves so you may feel the lead here; I used that element in all of these early pieces, as American electronics adopted safer solders quite late and I followed suit for my early career.

The following chart indexes the instruments chronologically with a name and a picture. To learn more about any one, page forward to the chapter on that instrument.

Illustration 27: Admiral's Coat (2000)

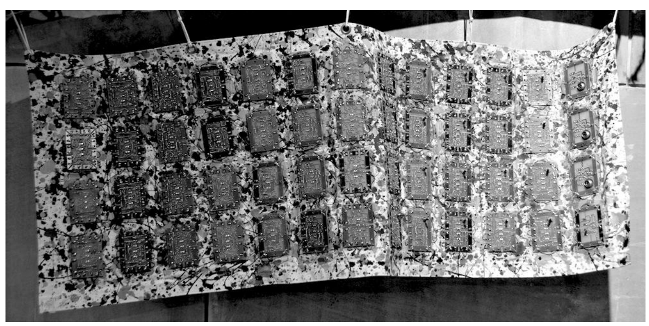


Illustration 28: Nabra (2001)

Illustration 29: Wavy Gravy Pear Shaped Lute (2006)

Illustration 30: Tube Trimin I (2006)

Illustration 31: Tube Trimin II (2006)

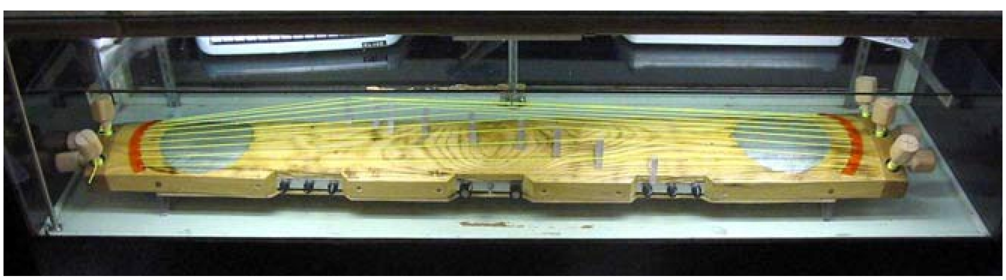


Illustration 32: Radiozither (2007)

Illustration 33: Deerhorn Baltimore (2007)

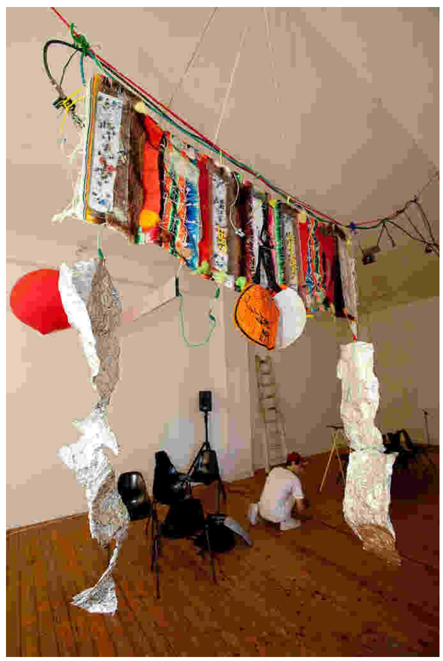


Illustration 34: Deerhorn Berlin (2009)

Illustration 35: Deerhorn Gewei (2011)

Illustration 36: Plumbutter (2012)

Illustration 37: Cocoquantus (2013)

Admiral's Coat

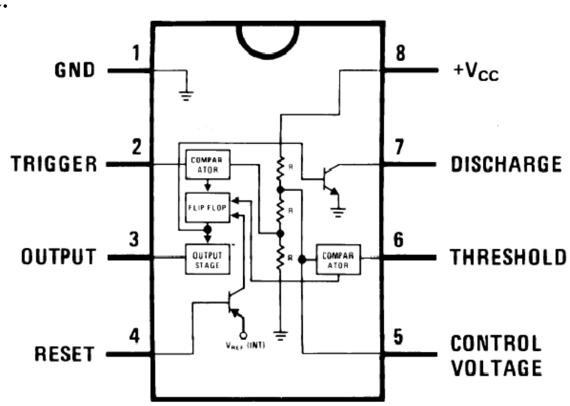
In late 2014, I concertized using two older instruments, and in the process of their excavation, I cleaned, repaired and documented them. Early in my career making synthesizers, I was much more interested in the spectacle of the instrument. These instruments manifest a physical performativity, embedding circuits in a textile garment and also a tapestry. I developed the tapestry form of synthesizer out of a distaste for hunching over tables of gear, to perform standing and transform the ritual of patching into a sort of dance. Likewise, the coat synthesizer induces a standing performance, but not a dance; as envelopment of the body, the coat necessitates closed movements epitomized by the notion of tweaking. There is not open space between patcher and synthesizer as with a tapestry. To introduce these performance modalities, I will start with a low level description of the instruments and conclude with a narrative of the long-term relationship I've had with them.

I built the Admiral's Coat in Oberlin, OH, around the year 1999. My father had just passed away and I conceived this piece partially as an homage to him; he was a rear admiral in the Coast Guard. I procured the garment substrate, a sort of military green coat, at an Ohio thrift store, and constructed twelve wooden bezels for its modules, fitting in two parallel columns on the front. Each module has four knobs arranged in a square, except for the master module, with only two knobs.

The circuit concept is change-ringing using simple resonant filters and the two main applications of the 555 timer chip: as astable and as monostable. The Admiral's Coat and Nabra are my only extant pieces using the popular 555. This chip, used by hobbyists all over to generate square waves and time brackets, has become enshrined in electronic folk music and art over its long career. Its eight pins map onto a set of sub-modules that encapsulate analog mechanics- comparator, latch, and charge pump.

However, there has always been a bit of backlash against it, and I too developed a distaste for it. The ostensible reason to distrust the chip is the way it handles energy. It firmly spikes the power supply during its duty cycle, and it is not soft to DC current either; I remember a chip that, hot from current, exploded into my eye. The true reason for disfavor is that many hobbyists use the chip for noise and power music, and that rolling one's own is the more professional choice when an oscillator is needed. I follow this route because it allows me to examine the sub-modules of a circuit in detail.

Why roll your own? Besides pride there are still a few good reasons. The goals of analog design are not to specify any particular chip or assemblage of transistors, but to realize certain modular singularities, such as the astable, bistable or monostable, current mirrors, exponential converters (not yet implemented at this stage in my career), positive and negative feedback. The only difference in discretizing is access to sub-flows such as the current based signal transfer system, and also the possibility of blurring the boundaries between modules. The chips I am discussing at this point all work to abstract an assemblage of singularities into a black box, that takes voltage, or symbolic, inputs, and likewise outputs idealized and buffered, symbolic outputs. A control voltage input and a square wave output is how the 555 works as astable. It does this by input comparators that determine the boundaries of a charge/discharge waveform, and a flip flop that remembers the binary state. Those are its sub modules. But if you work with it for hours, you will find that it is not so ideal. For example, no synth designer except for intuitive or outsiders will use its control input, because of how it responds very uniquely in modulating its frequency as an astable. Consider the internal schematic of the 555. Both the trigger and threshold inputs reference a resistor ladder that the control input modulates. Trigger compares its input against a lower bound and when found to be below, sets the flipflop. Threshold, likewise, compares against a higher bound and when above, resets the flipflop. These bounds are set at one and two thirds of the power supply referenced to ground, but they can be shrank towards ground by control input. So the 555 control input is not modulating the instantaneous slope of its charge circuit, but the bounds around which it switches. I call this bounds modulation, but it has a familiar sound, of the sync-lock circuit.



The Admiral's Coat employs two classic cookbook recipes for this chip- the astable and monostable circuits. An astable is simply a square wave oscillator, and it served as the main rhythmic clock of the machine. However, the 555 in this master module has broken over the years, and I blame the chip and its current consumption. Anyway, the coat hung unused for years, until I recently excavated it for a performance with some Wesleyan graduate student colleagues. Needing a working clock module, but lacking a 555 chip, I removed the old one and replaced it with a simple button wand for hand clicking of the clock. I am interested in the consequences of repairing old pieces, and the contingencies of that work, that sometimes revisions occur as in the Admiral's Coat. Now there is no mechanical sounding master clock, but an organic gestural possibility in hand made beats.

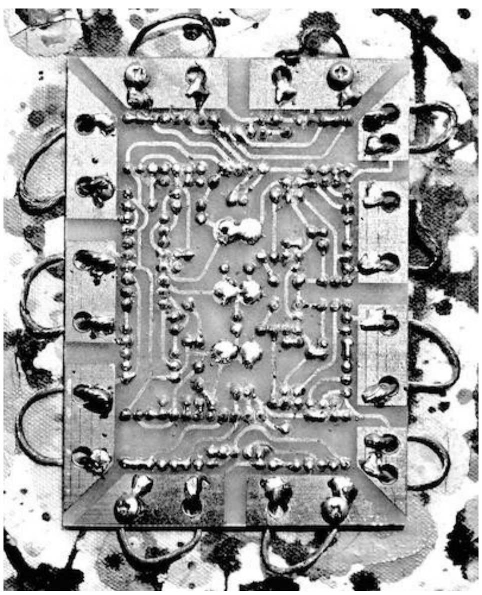
So much for the astable multivibrator. The monostables are still intact in the coat, as the eleven sub-modules use them for super-division of the master beat. Super-division, as a rhythmic concept, means to take a beat pattern and periodically trigger, as in the gamelan's gong cycle. The concept is a compliment to the idea of sub-division, taking a beat and creating more frequent integer divisions. A characteristic of simple electronic circuits is that super-division is much easier to achieve, as the 555 evinces; the undertone series, heard often in 555 folk music, is but a tonal version of the rhythmic idea of super-division. The Admiral's coat uses a monostable 555 circuit, or one-shot, to take the master clock and filter out beats within a certain window, then sending an impulse into a resonant, twin-T filter. Thus periodic super-divisions are associated with damped sine-wave percussion events. I hacked a twin-T network to tune its frequency and Q, within a small range, so each module has these two controls, in addition to a mix volume knob and super-division control knob, i.e. wait period. Since they can only tune to within a small range without extra active circuitry, I arranged them on the coat from lower to higher frequency ranges.

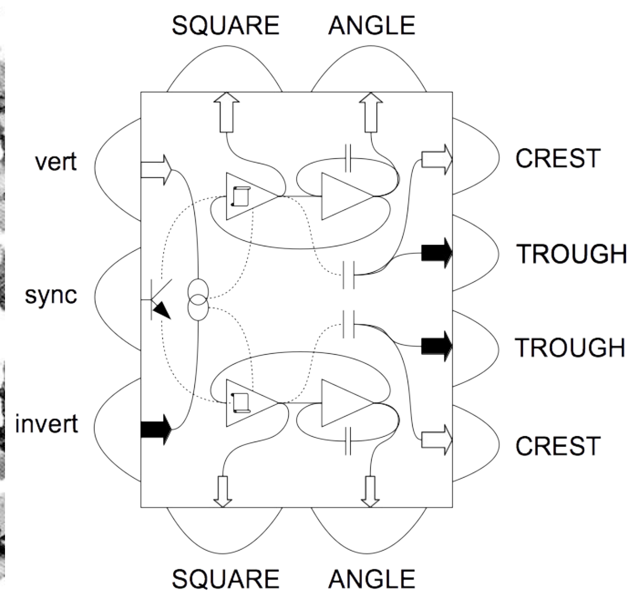
The Admiral's Coat was my first experiment in creating an un-boxed synthesizer. It has a certain stage presence, implicating a bomb suspect with its twelve red panels and miniature white knobs that look something like a bat-bomb. However, there is no real technical or performative reason to have a change-ringing drum machine in a coat, so its spectacle value rests solely on the disjunction of hard circuits inside soft garment, and its rhythmic sounds emanating from a standing performer with minimal gestures. In fact, the only gestures to be made on it are tweaking the module knobs, and the new gesture of clicking the master clock button. In fact, that serendipitous repair saved the instrument, since it was simply a drum machine beforehand, and now it puts gestural control into the hand of the wearer and thus the standing performance has a minimal task associated with it. But immediately after building it, I realized that the garment synthesizer was not for me, part of a series of realizations about the spectacle and hype of synthesizers. Really, with synthesis, one deals with abstract energy flows, and hopes to inject a stage presence or identity by sundry prostheses. The reflexive gesture of tweaking knobs on one's coat, I feel, was not successful, because there was no space between the performer and instrument.

Nabra

I have a reflexive oral history about this instrument; no connections are labeled and I traverse it with my personal knowledge. In the following module descriptions, I found that schematics cannot fully capture something that is intentionally unintelligible, so I allowed the diagrams to poetically diverge from implementation quod libet. In general, inputs are to the left, and lead into arrowheads that point to outputs. Almost every module has a pair of "vert" and "invert" inputs, that affect the main parameter in opposite directions; this is crucial for an instrument without knobs to have multiple modes of affect. I have reused some symbols, such as the transistor, and made up some symbols. Treat them as compositional sketches rather than official circuit diagrams. While documenting, I realized the inherent unintelligibility I built into this instrument. Capitalization means the function is an output, and lowercase means it is an input.

Slope

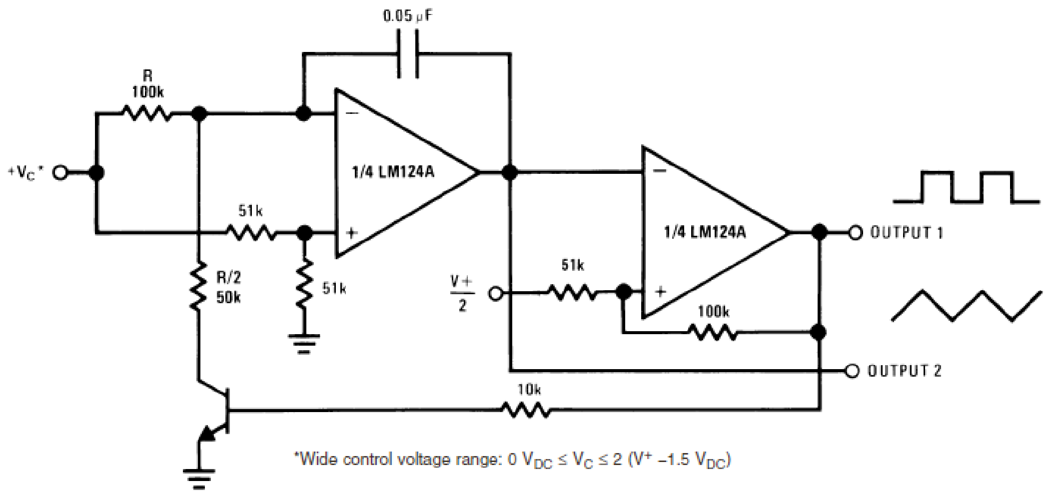




Slope is a dual triangle and square wave generator at low frequencies. It has two complimentary inputs, vert and invert, that control the speed of both oscillators. The sync input takes a pulse and causes both oscillators to lock to that pulse, but they freewheel without a pulse. The outputs are simply a square and triangle for each oscillator, plus two pulses that mark the crest and trough of the waveform. Thus the two equal halves of the rhythm can be sent to separate processors. This sets up for the importance of pulses in the synthesizer- as time markers that trigger other processes and envelopes.

It is derived from a well known "voltage controlled oscillator" application note from the LM324 data sheet:

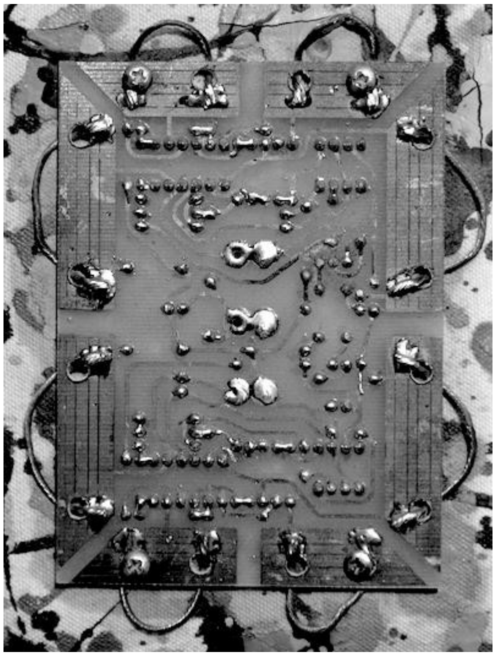
Voltage Controlled Oscillator Circuit

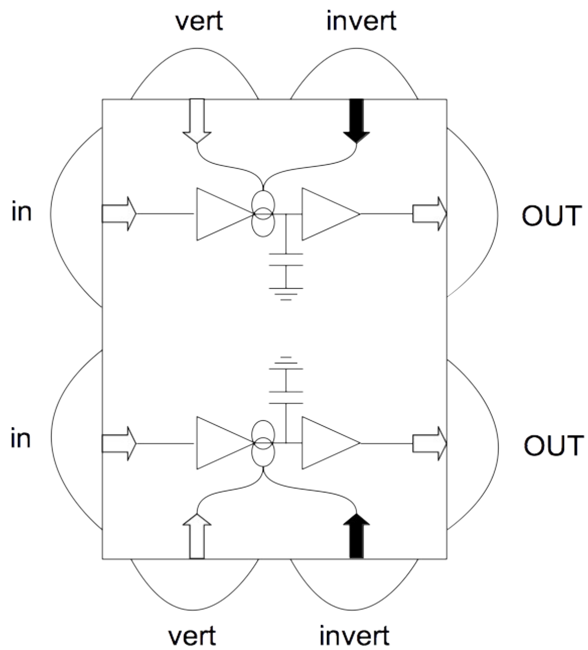


*Wide control voltage range: 0 $V_{DC} \leq V_C \leq 2$ (V^+ −1.5 V_{DC})

This oscillator is well known in the synthesizer world, but infrequently questioned as to its linearity or how exactly it works. An integrator and comparator are the two op-amp sections as used, but it also includes feedback through a transistor, and the control voltage feeds into a split between the inverting and verting input of the integrator. The triangle wave is always set in bounds by the hysteresis of the comparator, but be careful in thinking this is an ideal oscillator. For one, as in all of the Nabra, there is no exponential conversion on modulation, but that is a legitimate mode of operating, with a linear relationship between control and frequency. Modulation input ostensibly affects the slope of the triangle wave, as a truly ideal VCO would, by controlling the current of charge and discharge. However, because of the one transistor and the resistor splitter on the input of the integrator, this VCO is not ideal, especially when modulated by higher frequency inputs. It tends to sync-lock like the 555, but an uneven mixture between the ideal bounce modulation and bounds modulation. Thus this circuit is an animal to itself, a source of idiosyncrasy, as I learned during years of using the Nabra Slope modules. I have learned to make more ideal VCOs, but sometimes chose to use this circuit because of its simplicity and also for its unique way of treating modulations. Two of these fit into each Slope module, and they are tuned by a fixed capacitor, for a range between minute-long periods to sub-second periods. Each dual module has a pulse input that acts on a transistor in parallel with the existing one as a sort of sync-lock reset input, to lock the oscillators to another. Each module has the double modulation inputs, verso and inverso, that reflect the core philosophy of patching without knobs. The inputs affect both sub-oscillators equally, but their outputs are separate: a triangle waveform, square wave, and two pulses that mark the upward and downward transitions, for triggering other modules.

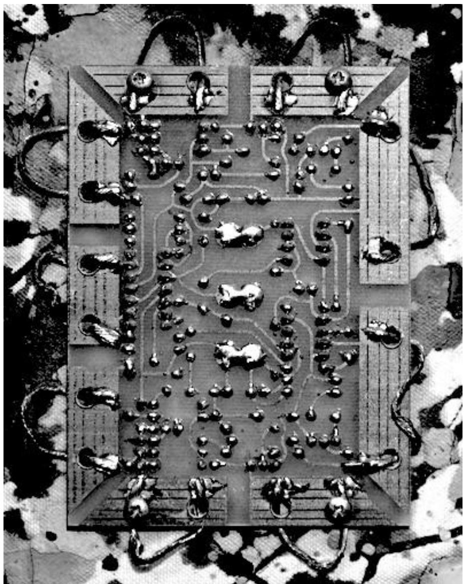
Port

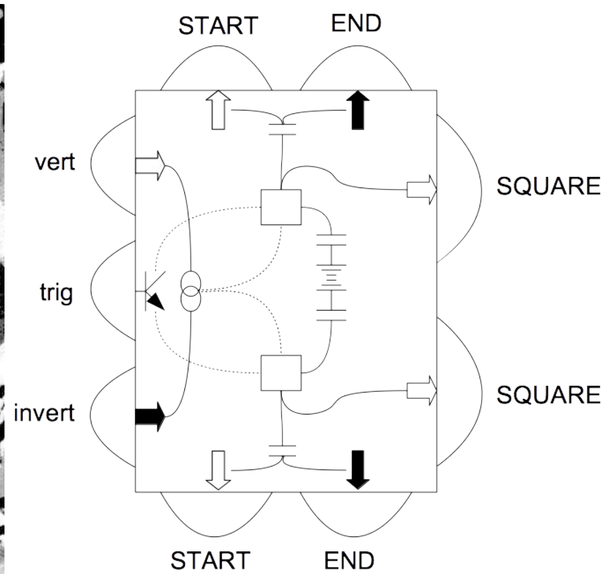




Port is short for "portamento." This one is a simple dual processor, with two inputs and two outputs. It limits the velocity of changes, thus smoothing any hard edges. Its effect would be most dramatic with a square wave as input, transforming it into a triangular shape. The vert and invert controls would change how much change is smoothed. I use this module infrequently.

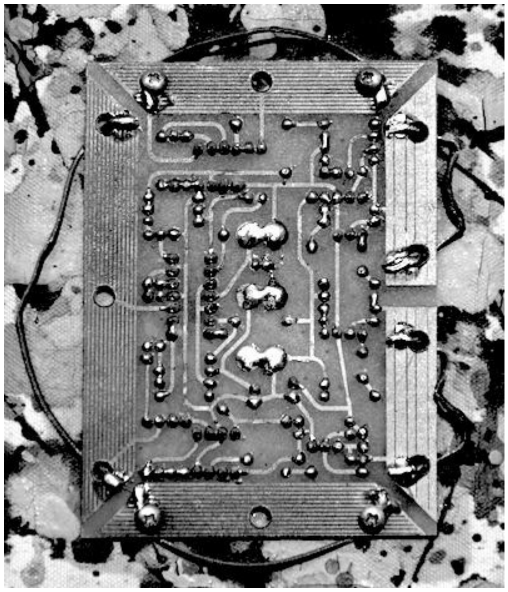
Shot

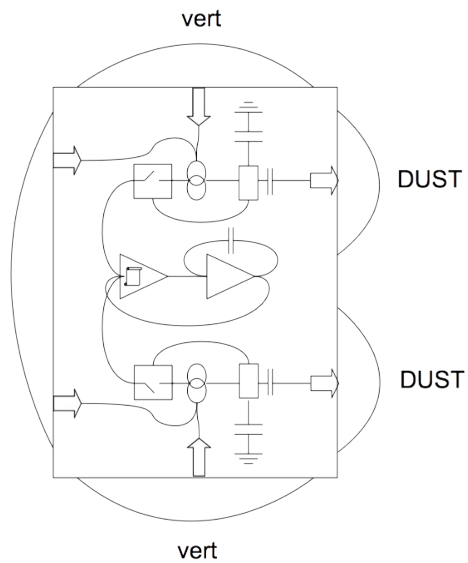




Shot is an example of a triggered module. Its name refers to its function as a "one-shot." It shamefully uses the 555 monostable circuit, in a dual configuration. The trigger input causes each to go high for a period of time, and then reset to a low state. The time periods are set by capacitor, but with vert and invert modulation inputs. There is a square signal output for each of the two shots, and also two pulses marking the beginning and the end of each shot. Of course the pulse for marking the beginning is redundant; there are a few modules that have such redundancy built in, for experimental purposes.

Dust



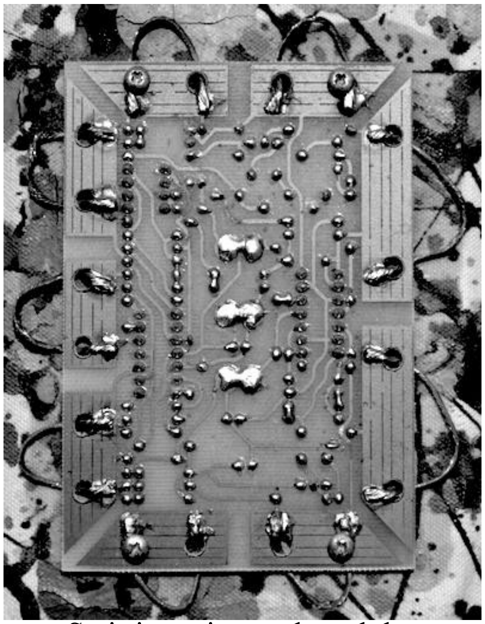


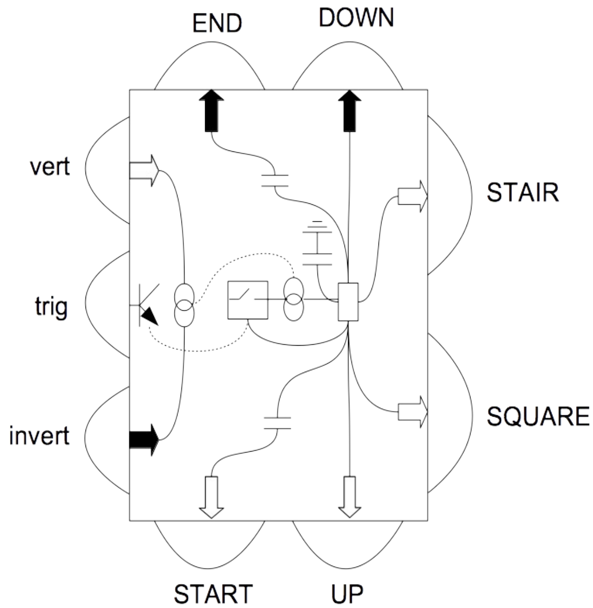
The computer music programming language Supercollider, by James McCartney, included a useful opcode, called “Dust,” for generating pulses of uneven timing, but with an input for their average density over time. This opcode is important for spawning sound events with short envelopes, with a result that can approach granular synthesis. I wanted to make an analog module of this opcode, and called it Dust as well.

I started with an internal oscillator of arbitrary high frequency; a typical move in random control and processing modules. This oscillator seems random when sampled at a low frequency. So I sampled it, into two separate capacitor tanks, and then allowed them to decay at a fixed, low rate. The result is that different voltages, when sampled, take longer or shorter times to decay to zero, whence they are resampled. So pulses of erratic spacing are generated.

The vert inputs control the speed of decay to generate different densities of dust. In each module, the default decay is different so there are different densities represented by default. The “both” input modulates both equally.

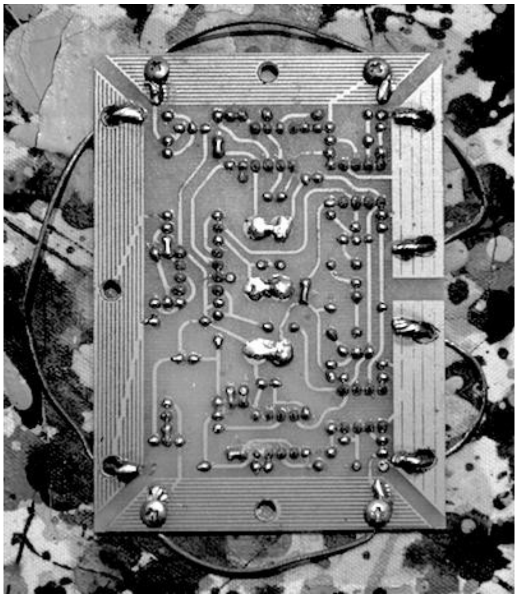
Stair

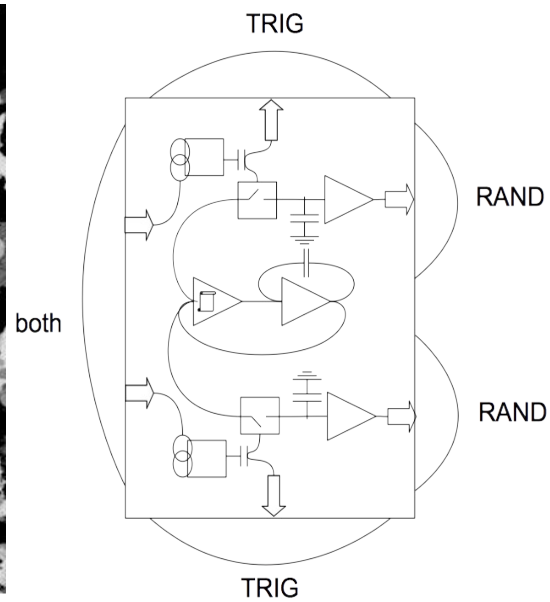




Stair is a triggered module, a variable step-height staircase generator. I rarely use it in favor of the random melodies, but theoretically it has application within this assemblage. It has a trigger input that causes the output to step up an arbitrary amount until reaching a high point at which it is reset. The step amount is controlled by separate vert and invert inputs. In addition to the staircase output, there is an "UP" square form, that shows when the stair is rising, coincident with a pulse on "START." Likewise, there is a "DOWN" square form, when the stair has stopped rising, coincident with an "END" pulse, when it resets back to a low state.

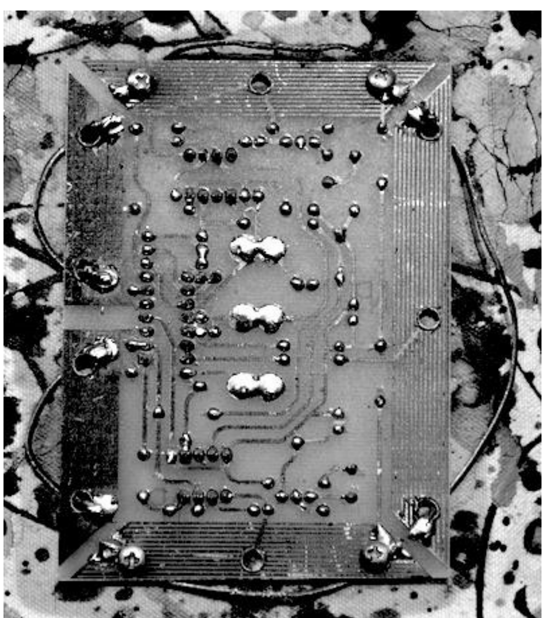
Rand

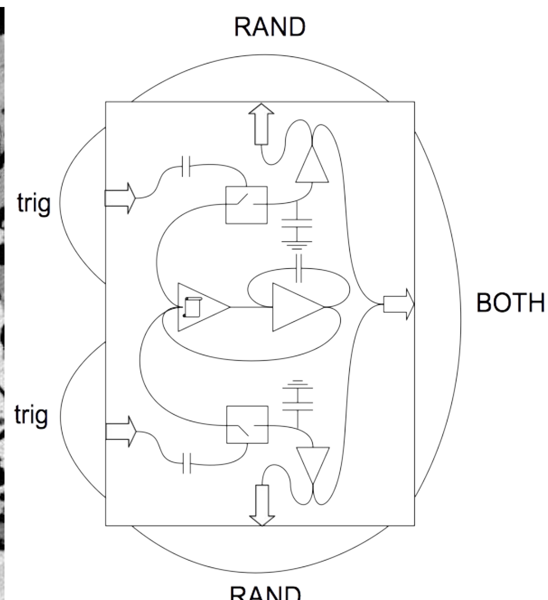




As I said, I prefer the random melodies, and they are of two types: Rand runs freely and Trand needs a triggering signal. Both types are of the sample and hold sort, with internal oscillator of arbitrary frequency. Rand also incorporates simple square wave oscillators, with modulation input for its timing, that causes samples of the internal oscillator. A “RAND” can be fed back into its “both” input to produce random voltages at random timings. The “TRIG” output would thus sound something like DUST.

Trand

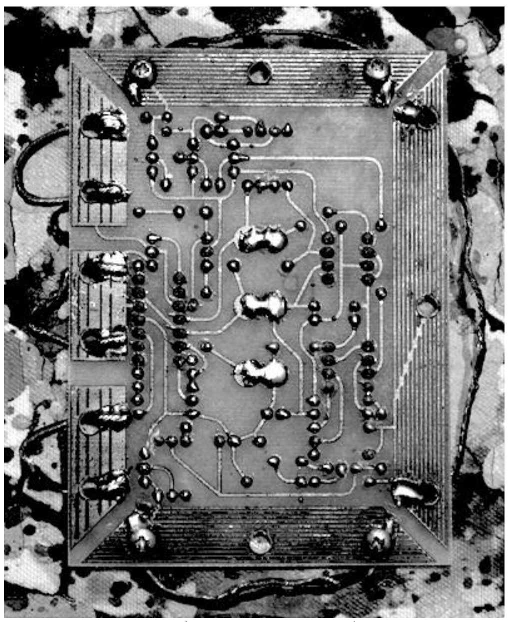


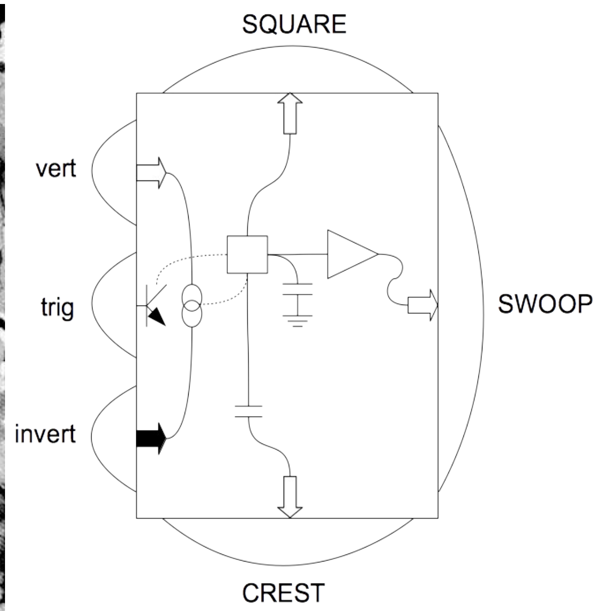


Trand, not incorporating a timing oscillator, is the more essential random

melody, inspired by the simple ones heard from Serge modulars of the past. Listening to a random melody, or "infinite rambler," as controlling the frequency of a triangle oscillator, is a simple pleasure, as it activates melodic tropes in the listener, but instantly demolishes them or overlays them. In all these modules, the easiest way is employed, using a sample and hold circuit to excerpt very brief moments of a high frequency triangle wave at periodic moments, so the perceived effect is of an ever-changing stepped melody that never repeats itself. Trand takes separate triggers, and outputs separate "RAND," and also it sums them together at "BOTH."

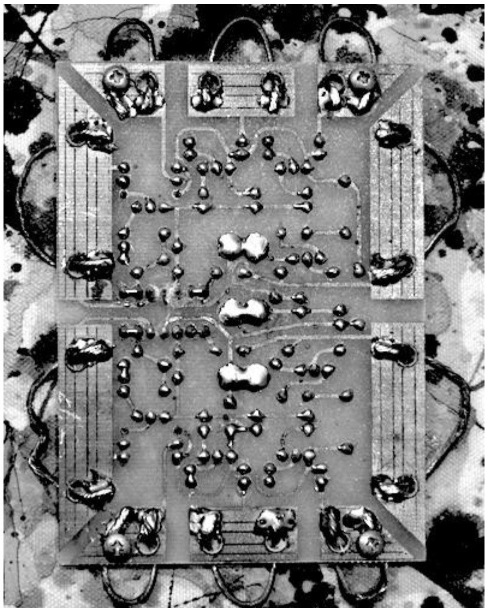
Swoop

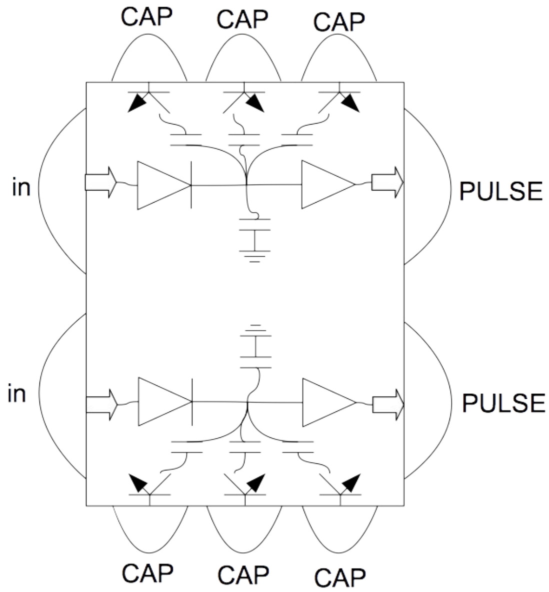




Swoop deconstructs the stereotypical ADSR, or attack/decay/sustain/release envelope. Swoop is a more original module, but only because it is a gross simplification of the more sophisticated four part envelope. Actually, Swoop is more related to the Serge universal slope generator, in that when triggered, it goes up, and then goes down, and then waits to be triggered again. It is a great way to mark off a periodic event in time, with limited envelope. Each of the four swoops has a different time length, set by capacitor, but of course it can be modulated by vert and invert inputs. It outputs a triangular shape for each swoop event, a square wave for the period of activity, and "CREST" pulses marking the peak moment. Thus Swoops can be chained in a row of sound events.

Pulse

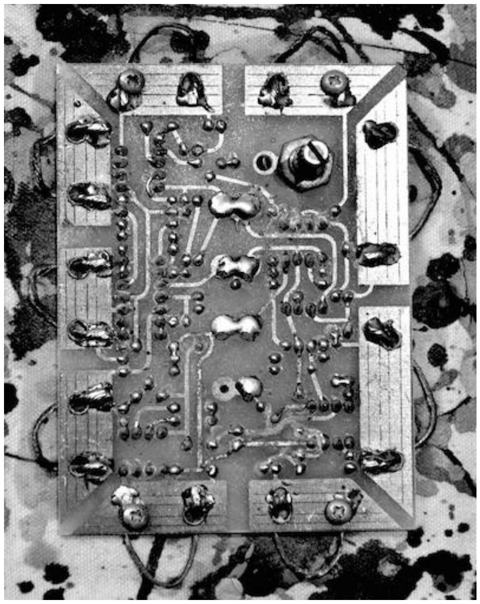


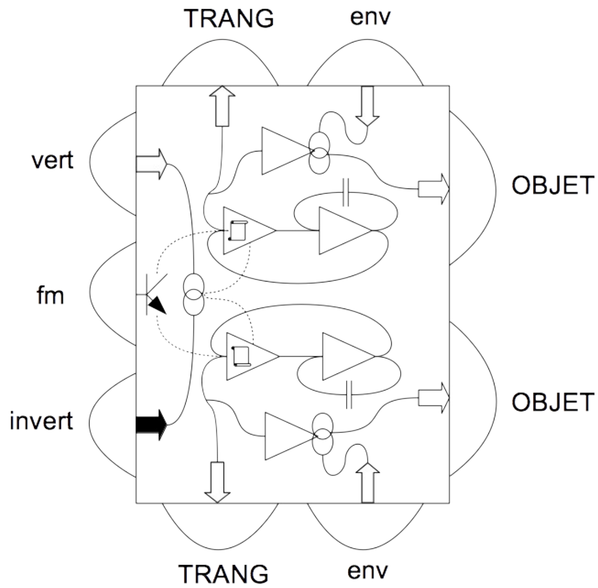


Pulse is a simple version of a variable slew, that allows a quick positive attack, but stretches the decay by a variable amount controlled by input voltage. It allows for percussive envelopes of variable duration. In this synthesizer I was still learning the basics of current control, so I often made hacks like the "CAP" controls herein. Basically, an "rc" decay curve, with its exponential slope, was preferable to the current-controlled, linear decay, that sounded less punchy when controlling an envelope. So, I decided to gate different capacitors into the decay, giving a crude control of different decay times. This sort of circuit hacking produces the most wonderful side-effects. For example, charges are held on the gated capacitors when they are off, and when turned on again, they cause short glitching murmurs in the output. So the module for all its hacked nature actually has a little bit extra personality.

Having toured the toolkit of control modules, we have arrived at audio generating modules. Each of the following will have a potentiometer mounted on the circuit, for mixing and fading them in and out. The default output, that goes through the potentiometer, is called "OBJET," short for objet-sonore, an idea of sound in space coined by Pierre Schaeffer. Each "OBJET" is composed of a raw waveform with infinite duration, that requires an envelope; all modules by default are silent, requiring an activating signal on their VCAs.

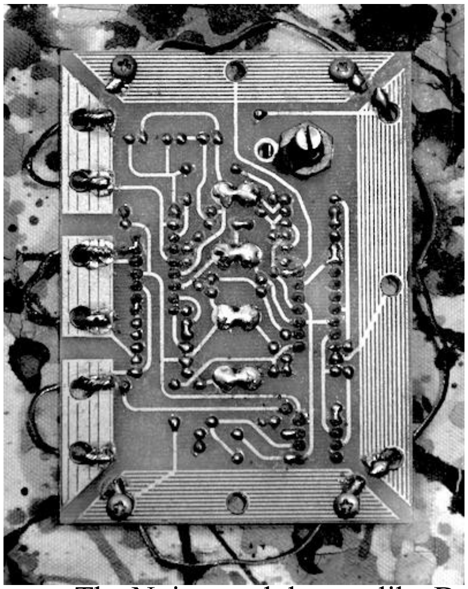
Trang

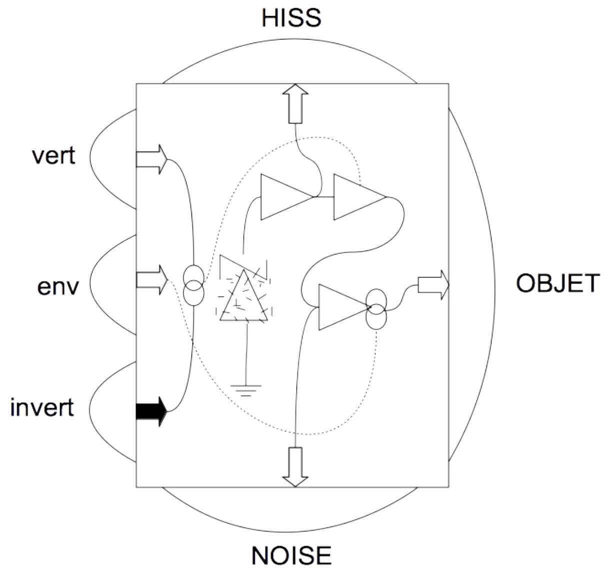




The first column of audio modules is called “Trang”. It uses an old chip, the 566, which is tailored especially for synthesizer applications. It is simply a voltage controlled triangle generator. Like the 555, it is a black-box that conceals a few sub-modules, and it was expensive in its day. However, I got mine for cheap from Electronics Surplus Incorporated, a Cleveland warehouse that facilitated much of my early synthesizer experiments. On Trang, I wanted to make dual modules, that were tuned to a basic fifths relationship, for easy implementation of power chords. Thus there is an internal trim pot for each, that has gotten horribly off pitch over the years, but this only adds to its charm, as it now makes powerfully dissonant chords. Here is one of the few places where I broke from the simplicity of tuning by capacitor values to implement an arbitrary perfect pitch relationship, only to have it drift later. In addition to the usual voltage control inputs, the “env” input causes each sound to speak as an OBJET out of silence.

Noise

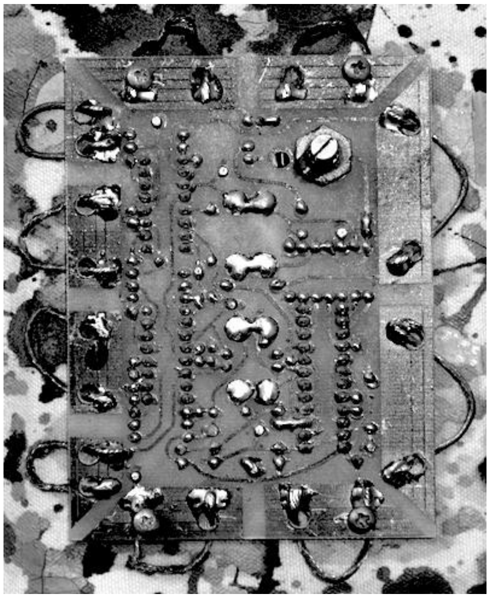


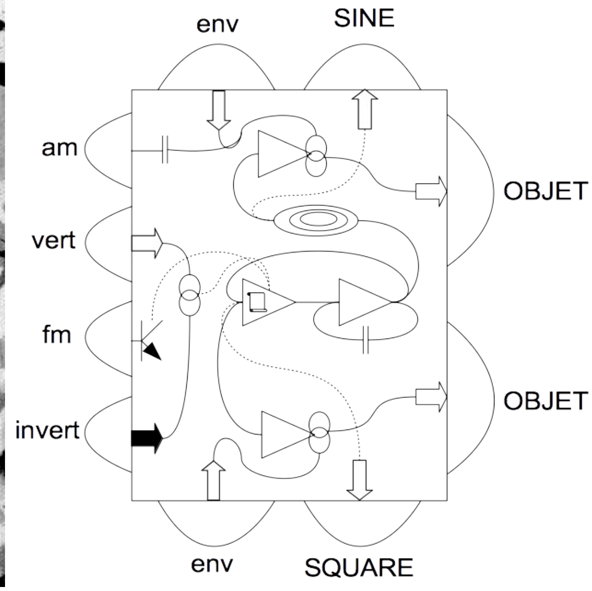


The Noise modules are like Dust modules, but with a higher density, that ranges between ten per second up until it sounds somewhat like white noise. This range is controlled by vert and invert inputs, giving a powerful timbre control to the module, that works in tandem with its own VCA. To make it work, I used noisy zener diodes, with a threshold voltage around 6.6 volts for optimal noise amplitude. I amplified this signal in high gain opamp sections, and finally fed into a comparator against a set voltage offset from zero. Noise uses a dusty zener diode. In fact all the components of this synthesizer are dusty, and leaden as well. I acquired them all at a ESI, a massive warehouse of old treasures, inventoried by a chain-smoker so everything had a thin layer of lead and tobacco on it. Directly across the street, a road led sharply down to the great, now bankrupt steel pits of Cleveland's west side.

HISS differs from NOISE in that the former is the lesser amplified, more linear result from the noisy zener, and NOISE is the fully amplified result of comparing against a threshold. As in all audio modules, “env” is a required input to yield sound out the OBJET and through to the main mixer.

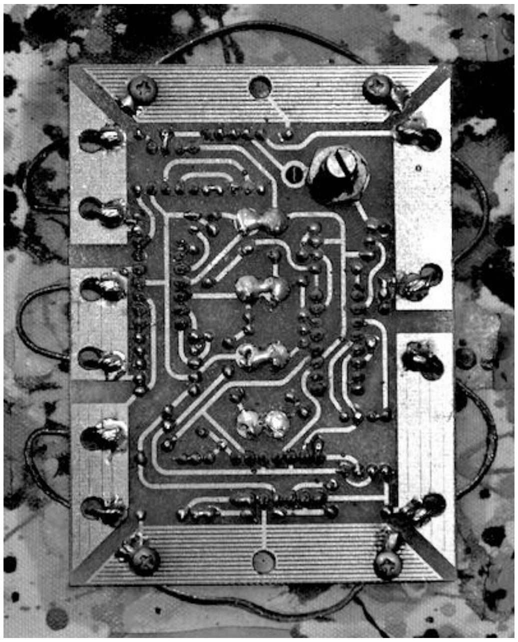
Sine

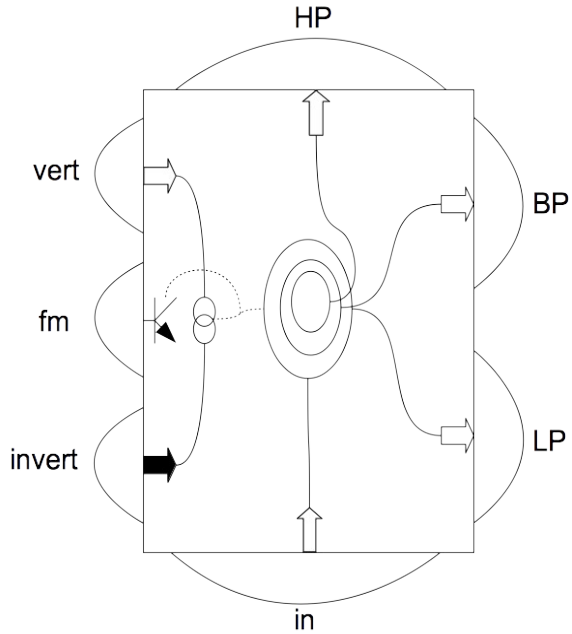




Now we have two columns of Sine modules, employing the XR2206 "monolithic function generator," that I also procured as surplus from ESI, like the 566 chips. It is a deluxe, high quality chip, with wide range capabilities for its oscillator, plus a shaper to make a facsimile of a sine wave from the triangle wave that is its default. Sine-shapers are an attempt to simulate the resonant wave, without the frequency instability of Q and other problems associated with resonators. The chip also has control voltage inputs, so I could easily package it into a module, with an added VCA section. These modules, like all the others, are tuned to default frequencies by capacitor choice, so there is a range from bass to soprano, represented here. It has a "SQUARE" output, but when controlled by an "env" this square does not go out to the main mixer, but stays at its own "OBJET" output; only the sine wave is available as default main output. Besides shaping tone with vert and invert inputs, there is an fm input for frequency modulation, and an am input for amplitude modulation by other audio rates.

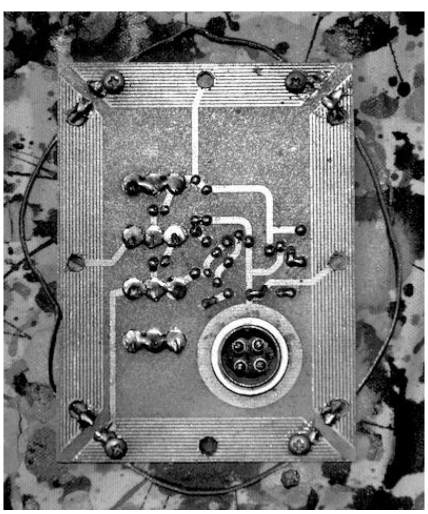
Wave

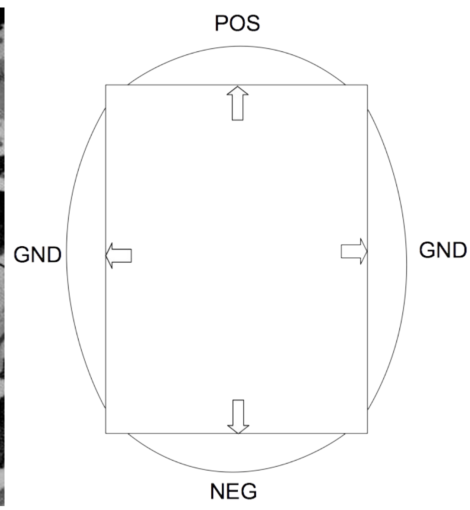




The final column is of the typical voltage controlled state variable filter found in many synthesizers. It is a filter, so it has an input, and it lacks a VCA section, since it is by default silent. It can also be triggered with pulses from the control modules, for short percussive blips. As with all state variable filters, it has low pass (LP), band pass (BP), and high pass (HP) outputs.

Pow

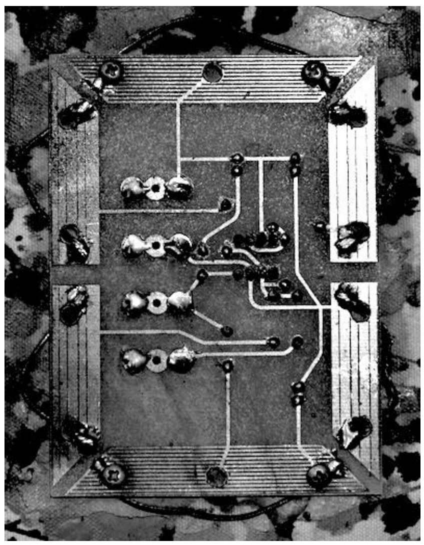


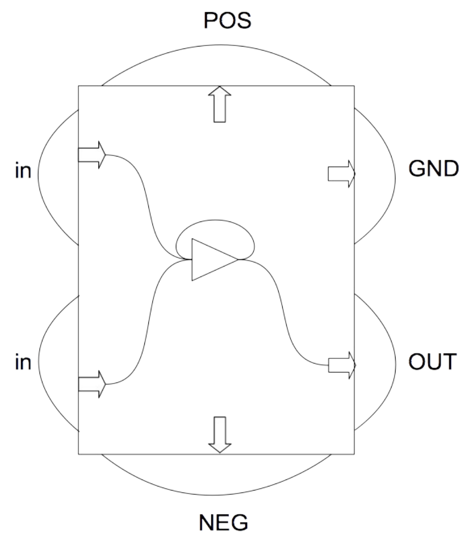


The power modules are for interfacing and regulating potentials for powering the whole tapestry. They provide positive, negative, and ground outputs to create

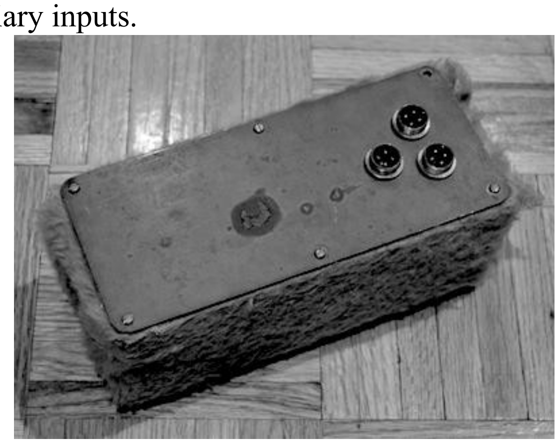
various bias signals with resistor-inline patch cords. To power up, connect at least two four-pin cords from the dog to the power modules. There is a pin insert to align them correctly. The dog is an external transformer in a box, necessary because a heavy transformer would be awkward in a hanging tapestry. Thus besides providing voltage potential, it also provides aesthetic potential, in anchoring the tapestry to an auxiliary object. Working the dog is working the relationship between the hanging object and its practical needs, such as power, and in other tapestries, acoustic amplification.

Out





The "Out" module, in the bottom right corner of the tapestry, is where it sends sound to an external amplifier or recording device. An audio cord with alligator terminations for ground and signal must be used. Connect the ground alligator to "GND" and signal to "OUT." The module, like "Pow" gives out positive and negative references, and has two auxiliary inputs.



Recipes and Conclusion

Here I would sketch some quick patch strategies I have used. To do so, I will use a nested syntax like functional, object-oriented computer code. A particular output of a module shall be marked with dot notation, as in "Slope.ANGLE." Inputs shall be thought of as a function, that that previously mentioned output could be used as a modulation as in "Swoop.vert(Slope.ANGLE)." So rightward motion on the instrument will become leftward motion in the notation, but I feel this encapsulates it most tightly. This is just a quick guide to get you started, and show how I mostly concentrate on the instrument. The following recipes use only one instance of each type of module, so work with the same one to start out with:

1. Sine.env(Slope.ANGLE); Swoop.trig(Slope.CREST); Noise.env(Swoop.SWOOP)
2. Trand.trig(Dust.DUST); Sine.vert(Trand.RAND); Pulse.in(Dust.DUST); Sine.env(Pulse.OUT);
3. Trang.env(Slope.SQUARE); Trang.vert(Rand.RAND); Sine.fm(Trang.OBJET); Sine.env(Slope.ANGLE)

Basically, I like to use slow slopes to mark off sines in space, then modulate those sines with random melodies. I use various triggers on swoop, and this can envelope noise or maybe a trang. Fm modulation is essential.

In conclusion, there are several factors that contribute to the unique sound of this instrument, that I have turned to focus on as strong points over the years of playing it. First and foremost, the base rate of each module is set by capacitor to an arbitrary value, and series of modules will be valued to represent a range of rates. From there, rates can be modulated by dedicated inputs. The input response, however is never exponentially converted, so the linear response is usually attenuated to a certain range, to reject unevenness at the extreme ends. I would eventually choose to apply an exponential response to all inputs on the synths I make, because this gives the widest range without unequal perceived distribution of frequencies. However, it makes a synth interesting to have the primitive, linear response, and the compromise of attenuated modulation ranges to make it sound alright. Finally, the simplicity of Dust, Trand, and Swoop make control forms that reject the typical sequencer/ADSR logics of traditional synthesizers. The Rollable Synthesizer was one of my first manifesto pieces, a tradition I would develop about open-face circuit boards in the Shinths.

Radio Instruments

The trimin, radiozither, and deerhorn all utilize radio fields to generate tones and further processes. I wanted to restructure the only real radio-musical instrument in existence, that is the Theremin. Lev Theremin invented his namesake in 1920, as a result of researching proximity sensors for the Soviets. The precursors of this instrument already existed, in the humble radio receiver, that heterodynes a detected

wave against an internal oscillator. If the frequencies of each are near each other, the heterodyne results in a high energy difference tone at an intermediate frequency. What Lev did, was simply to add another oscillator at the pitch antenna for the detected wave, and make the heterodyned intermediate frequency into the audio product of the instrument. A third oscillator controls volume by a second antenna. This system of two antennae- one for pitch and one for volume, has existed in the most simple, durable, yet musical instrument for almost a century.

The unmistakable tonal clarity of the Theremin, sliding like mercury between fixed notes, has lent a mystic serpent to many musical compositions. Performers and musicians who may not know much about electronic music can easily identify or specify a Theremin for their sonic needs. I did not wish to subvert or change the simple utility of this instrument, but I was driven by unheard possibilities and the mystery of invisible complexities to make changes. In fact, I will use the word “Theremin” as the name of a simple component inside a radio instrument, that creates an audio tone from two radio oscillators. These projects began with no particular sound in mind, just an eagerness to experiment with antennae and inductors.

Historically, the use of inductors predates any other component; as a coil of wire, its form and function are almost magical. However, a synthesizer builder will not use inductors in a typical, modular instrument, because capacitors and transconductance circuits such as the gyrator and integrator replace them, in a smaller space. So experimenting in radio circuits is a way to work with the inductor as a material in a new context. Likewise, the antenna and its invisible shapes of transmission and reception fields is specific to radio circuits. Note then, that these are not only circuit diagrams and ways of inter-modulating them, but experiments in how to construct them in a space transected by the generated radio fields.

I think I was attracted to radio technology because of the androgynous nature of any component, as both receiver and transmitter. Thus an array of oscillators or other radio elements can act as a field of *sandrodes* connected in space. And what follows is that playing it is an intuitive effort of experimentation with various connections and tunings, and adjustment or compensation depending on the outcome.

Trimin

For my first project in the radio realm, I searched for surrealism in the linguistic of the Theremin's name. In it, I found the number three, and twisted its meaning to conceive of a triangular circuit. At the time, I had already designed a few geometrical circuits, that perpetuate inter-modulations around their closed loop of oscillators. I intended to take the idea of perpetual inter-modulation and apply it here, to the case of oscillators in the radio realm. It is relatively simple to frequency modulate a radio field, using a varactor diode configuration.

I initially realized the Trimin in a series of paper circuits, available on my website as part of a larger series of DIY instruments. The layout simply reflects the function, like the rolls in the Rolz-5; There are three oscillators in the triangle, tipped by connections to antennae. Each connects to a potentiometer for the antenna tuning that is necessary in any radio circuit; the capacitance situation will vary widely as an instrument is moved or weather changes, so a performer must always compensate. But besides compensating, the control also tunes the resulting tones. Each oscillator also contains a simple heterodyne and varactor diode. With the heterodyne, it creates an audio product out of its own radio field and the previous oscillator counter-clockwise. It then feeds this audio product to modulate the frequency of the next oscillator by its varactor. Thus it is a closed loop of modulations. With the three tuning controls, a wide variety of tones and indeed chaos realms are produced.

The Trimin has no audio output jack, because it has three tones, and furthermore, it is already “outputting” them into the radio field around the energized instrument. To hear them, I borrowed a simple technique known to many circuit benders and electronics performers- an AM radio in proximity can provide a spatially dynamic rendering of the tones, mixed by their position. At the time, I could find vintage AM transistor radios in the trash of Baltimore evictions. The AM band contains only nostalgic oldies stations and political underdog ranters, and so these radios are seen as obsolete. But they have an immense advantage for sonic diagnostic; in their simplicity they do not limit spurious transmissions with an automatic gain control, thus giving robust readouts of a complex radio space and its byproducts.

Finding vintage transistor radios, with their colorful space-age cases of plastic

and aluminum, was an innocent enough pursuit. But it was simply a gateway to more dubious salvage operations, such as when my friend Dan Conrad, on his retirement from a career of teaching high school physics, invited me into the back room. The school was to dispose of a large stock of tube oscilloscopes, and I took all of them. Furthermore, I did not reuse them as they were, in a perfectly fine working state, but I actually took them apart completely, thinking I would build some new sort of electronic instrument out of the parts.

Many of the parts from this operation went unused, but I did manage to build Tube Trimins I and II. Each employs a six inch cathode ray tube (CRT) and its associated power supply, a heavy power transformer, plus a few triodes, tetrodes, and pentodes, to manifest the trimin with tubes. A laboratory oscilloscope, such as the source for these parts, uses no fly-back transformer to generate the high accelerating voltage; the heavy transformer itself generates the several thousand volts to energize the CRT. So the power circuitry is quite simple, just some diodes and capacitors to rectify, plus a choke to clean the supply. These smaller CRTs use electrostatic deflection to move the beam, so they don't need an electromagnetic assembly around their yoke, but provide four high impedance inputs at their base for each of the X+, X-, Y+, and Y- deflection plates. That the axes are so simply modulated provides another simplification for the sake of creativity. There are actually three axes, with Z equivalent to brightness of the beam, so the Tube Trimin inherently visualizes on all dimensions of the CRT- X, Y, and Z.

Tube Trimin I sits facing forward, and has three huge antennae that can easily couple the radio fields to each other. For this reason it produces a quite chaotic signal when tuned. Tube Trimin II sits on the ground facing up, and the three radio oscillators can be seen through perspex windows on its sides. The radio oscillators are some sort of Hartley, a common variety using a custom wound coil. If a pentode is the driving tube, modulations can be introduced by its screen or suppressor grids. If two oscillators are fed into the control and screen grids of a tetrode, this makes a great heterodyning amplifier. But tetrodes can be harder to find, so simply buffering the oscillations and feeding them both into the control grid of a triode will create enough heterodyne; the non-linearity is, as in a transistor heterodyne, in the ohmic difference between push and pull on the output.

The Tube Trimins are a simple technology, and should be simple to enjoy. First, plug them in, and watch them heat up and glow. Second, focus the beam and give it the proper intensity, while positioning it with the X and Y controls. These are four knobs- focus, intensity, X position, and Y position. The next step is to tune the oscillators. On Tube Trimin I, there is only one ganged variable capacitor for all three oscillators, and tuning is done by it and also the positioning of the antennae. On Tube Trimin II, each oscillator has its own variable capacitor. There is no correct tuning, but it is an exploration. You might want to bring an AM radio into range, and tune it to start hearing the resultant tones. Also note, that in a quiet room, you can hear the tones inside the tube without external amplification. Try contact miking the tube itself, as all its internal wires and metallic structures make a sort of reverberation

chamber.

In the end it took a lot of work to salvage these tubes, and also a lot of work to responsibly dispose of them; the extras were all back-doored to a surplus operation in Hudson, NY, at no profit whatsoever. Indeed, I must have suffered because of these tubes and my temporary obsession with them, with their heavy metal coatings transferring dullness like a virus to mine own brain. The one thing I take from these tubes is a teaching unit on esoteric technologies, alchemy, and RoHS (Restrictions on Hazardous Substances) that I delivered at Oberlin College in 2011. The tube is like a hermetic vial of metals and other substances that are transmuted by rectification, vibration, calcination, reverberation, sublimation, and newer processes such as the heterodyne, into golden technologies for musical sound or iron piercing war machines. Electronic music profits from the alchemical metaphor, as well as the modern understanding that these materials are dangerous and should be limited from our environment. The vintage days of tube technologies were like a leaden bridge from the archetypal thoughts of pre-technology to our current age of micro-silicon technologies.

Radiozither

The Radiozither began as an urge to embody the radio-musical circuit in a sounding body. I had always appreciated *guqin* zither music; traditionally this zither is played by males alone and in the woods, as part of a meditation and focusing process. Because it is not intended for an audience, the zither is not loud; I felt it would be a compelling contrast to mix silent radio fields with a quiet zither, for the loud effect of electro-acoustic performance.

As I looked around Baltimore for wood for the zither, I noticed that the exact traditional species grows wild there, especially near train tracks. Pawlonia seeds arrived in America as their china wares received protection from a packing of their light and airy seed pods. The seeds would blow off the shipping trains and establish themselves by the tracks. The wood is a noble one, gracing the emperor's palace in Japan, and decorating its five hundred yen coin. It is completely neglected and universally despised in its Baltimore habitat, yet it springs forth and grows aggressively from the poorest of soils, even pushing through broken concrete. That is how it shares the name “ghetto palm” with another Asian species, the Ailanthus tree. Both grow from extensive underground rhizomes, and can form thickets that defy any human attempts to eliminate.

This is the backdrop for my work with these woods- a sort of salvage operation of golden sound-wood from the broken surroundings of west Baltimore. It turns out that Pawlonia is diametrically opposite from Ailanthus in terms of sound quality; the former is clear and airy transmitting the minutest sound, but the latter is hard and dulls sounds as well as tools. Ironically, they are difficult for the novice to distinguish from bark alone, and I became very good at identifying the two, from my trials in hewing a zither out of the wrong wood. It was a natural prompt for my wife and I, when our son was born, to name him after the Pawlonia tree.

After a Pawlonia tree is felled and rough-cut into planks, the wood must dry and age for several years according to Japanese koto makers. The tree's limbs arc as it grows, and that form transfers naturally into the arc of a koto. A *guqin*, however, is straight, and so it must come from the central trunk. All zithers, from the *guqin*, to the *guzheng*, *kamageum*, *koto*, and *ichigenkin* can use Pawlonia as their central material. It is like the soundboard of a guitar, light and hollow, and transmitting the crystalline sounds of its strings.

After it has spent much time drying and learning its new shape, the Pawlonia can be hollowed, smoothed, and fitted with bridges and tensioning devices for strings. At this point I make my intervention. I designed a dual heterodyne circuit to go inside the hollow form, so at each end of the zither, an aluminum antenna wraps around the outside. For each antenna there are three controls: M, T, and V. T stands for tuning, used to bring the antenna into range and vary its base pitch. V stands for volume, controlling how much the audio product feeds into the final circuit. And M stands for modulation; there are two separate Theremins at each end of the zither, and they can modulate each other in a sort of loop as described for the Trimin, and controlled by the M knob.

The final circuit is another sort of heterodyne mixer, but for acoustic and electronic audio forms. The first task is to sense and amplify the soundboard, using piezo elements. I have experimented with many different distributions of these contact mikes, in arrays and at singular points under the instrument's bridge. While I still could experiment more to be conclusive, it seems that as long as the instrument is sonorous, the location and amount of mikes does not matter, for audio rates. However, as a flex sensor, it's best to locate directly beneath the bridge.

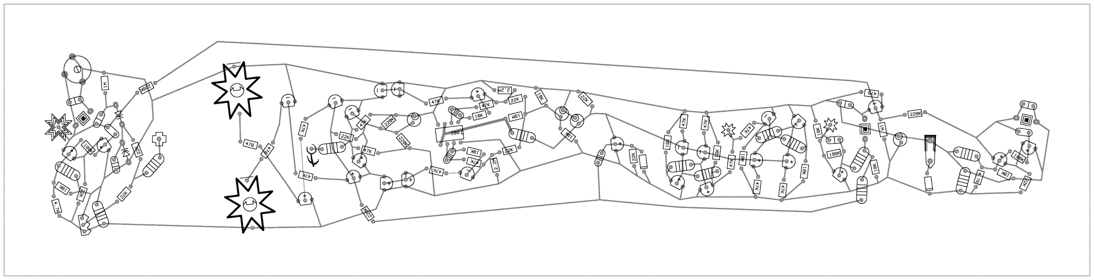
After transduction and amplification of the soundboard vibrations, the Radiozither then multiplies them by the output of each Theremin. This is the main role of the final circuit, as amplitude or ring modulator of acoustic and electronic. The resulting output has the characteristic ring modulation sound, but with the coupling of plucking gestures to radio-musical ones as both are coincident to the instrument. In its middle face, it has three controls for the final tonal characteristics: a master volume knob, an envelope follower switch, and a grunge knob. The envelope follower is a further enhancement of the amplitude modulator to make it ultra-quiet during silences. It follows acoustic energy and applies a resultant envelope to the electronic sound, so that no modulation is heard when un-played. The grunge knob does the opposite; it allows for the ring modulation to become exaggerated during quieter passages, for the purpose of the so-named grunge effect, and also to explore feedback resources. The Radiozither is very interesting as a feedback device, because the amplitude modulation of the radio elements creates a sculptable granular swirl around any potential for piercing monotony.

In grunge mode, the zitherist harnesses massive electro-acoustic energies with his long plank by waving hands above it. Perhaps this is the final modality of the gentleman scholar, to have a zither and not touch it?

Deerhorn

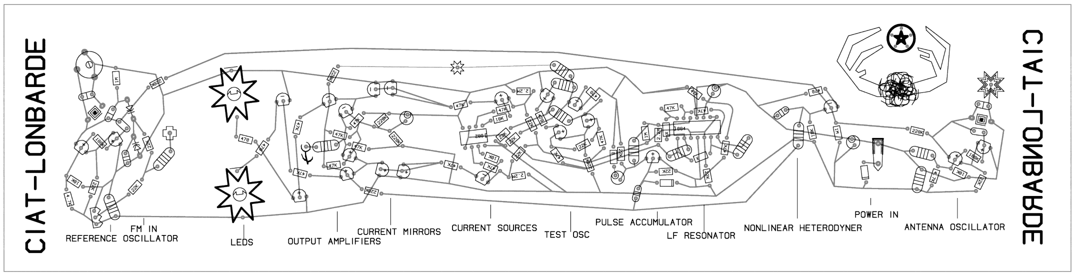
The Deerhorn Project investigates invisible fields that surround architectural objects in the space. It is inspired by the question, "what is a museum of the invisible like?" The Deerhorn antenna is a metaphor for other kinds of invisible fields- political, psycho-geographical, subterranean, esoteric, and aesthetic.
The Deerhorn Installation shall utilize any number of Deerhorn circuits, to sonify movement in space. These circuits consist of two radio oscillators, a Phase Locked Loop circuit, and a two channel audio synthesizer. Each circuit generates two tones representing visitors' complementary approach to and withdrawal from the antenna. These antennae shall be crafted from easily resourced material such as aluminum cans. The body of each circuit shall be encased in fabric, carved wood, or other site-specific materials, or left suspended in the air. The circuits are low-power, operable from Solar Panels, and able to cross-modulate to create more "animalistic" sounds. During a Deerhorn workshop, participants will assemble their own Deerhorn circuits, fit them into cases, and help in the final assemblage/installation at a suitable site. Afterwards, participants may keep their handiwork. Some may want to build multiple copies, to yield a "sub-organ" of their own, and this is encouraged.
The design of the Deerhorn circuit has evolved much since it was first created to answer Clara Rockmore's original complaint with the Theremin: "Can there be more than one pitch?". Lev Theremin responded that one would need more than two arms, but the Deerhorn makes this possible by extracting gestural information from the radio fields and using it to control both pitch and envelope. In fact the first Deerhorns used the same heterodyne as the Theremin, adding additional control circuitry. Several revisions were built as paper circuits until the design became formalized, eschewing the simple heterodyne and instead using a PLL-type detector for enhanced stability. Currently, in workshops, the Deerhorn circuit is assembled on a fiberglass circuit board, avoiding the precarious step of building delicate paper circuits.
The naming of this project Deerhorn implies the idea of "wild". In fact it can create very wild, untamed sounds as an analog synthesizer, and we will further develop "the wild sound" by inter-modulating Deerhorn circuits within the organ. Finally the pure synthetic tones may become somewhat like a giant organic flock of deer within the space, responding to the humans that visit it.

Deerhorn Baltimore



I designed the first Deerhorn circuit in Baltimore, 2007. It was a simple affair; a large expanse of paper separated two radio frequency oscillators, and in that space, a simple one-transistor heterodyne circuit produced an audible waveform from the difference tones. This waveform fed into a primitive frequency to voltage converter; a positive zero crossing triggers a brief pulse through a transistor, and these pulses pull a capacitor higher when they are more frequent. This voltage is the main distillate of the process, for it reflects hand position. Its side-product is the heterodyned waveform, exactly like that of a Theremin. In fact, the first Deerhorn were simply the Theremin idea with just more circuit on top. The control voltage went on to two interpretive functions: a decoupling capacitor leads it into a bipolar voltage to current source, feeding into two transconductance amplifiers, to envelope the Theremin audio by movement gestures; the voltage also controlled two low frequency multivibrators, intended as modulators for other Deerhorn. So there are two uses of the control voltage, transformed into an envelope of the Theremin, and transformed into a low frequency square wave mixture. The enveloped Theremin controls the LEDs and feeds the audio output bus.

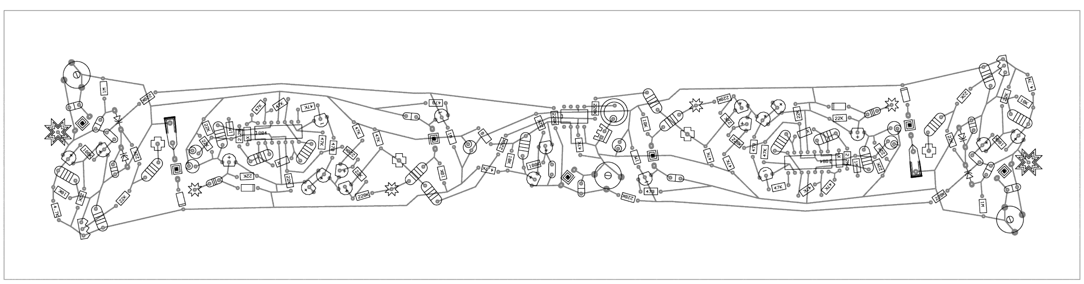
This Deerhorn, mounted on a canvas tapestry, has a few controls. There is the connection for an antenna on the top. Hidden inside, near that connection, there is a trimmer capacitor to bring the antenna into range. On the outside, also near that connection, is a trimmer potentiometer for fine tuning of the antenna circuit. Go to it first, and trim it so that the two LED "eyes" teeter evenly lit between the pair. Now, for each Deerhorn module, there are three brass eyelets crimped onto the tapestry. These are actually electrically active, a novel connector system for modulations. The one to the left is an input; it feeds directly into the varactor diode of one radio oscillator– frequency modulation directly on the radio field. The two to the right are both outputs; from top down they are the Theremin tone, and the two square waves summed. Connecting these to another input will quickly bring this Deerhorn satisfactorily into animal utterances.



Deerhorn Providence

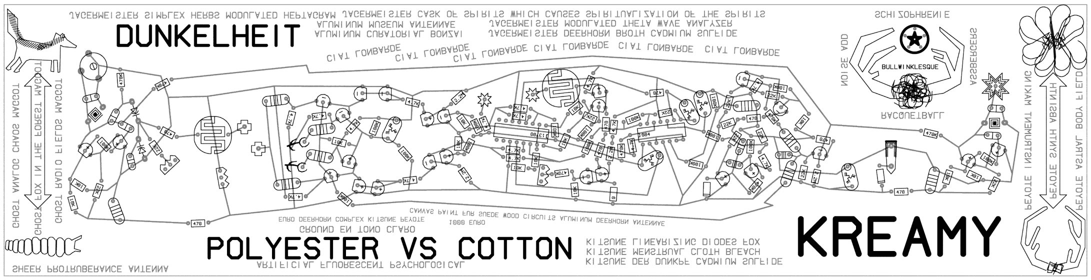
The next Deerhorn I designed took the original design, annotated it, removed the square wave oscillators, and added a low frequency resonator instead. I wanted a circuit to respond to different speeds of gesture; a low frequency state variable filter has a resonant peak, that the performer can learn to activate with a certain undulation of gesture. It's like a spectrum analyzer of movement. I developed this new Deerhorn for a 2009 installation at Stairwell Gallery, in Providence. In a small workshop, I lead a few solderers in making these paper circuits, and then we installed them behind velvet curtains in the gallery. I re-purposed the tube amplifiers from old radios to diffuse the Deerhorn sounds. After the installation, participants kept their circuits and the amplifiers as well. This started a trend of workshopping the Deerhorn circuits.

Deerhorn Moon



Deerhorn Providence worked very well to detect different types of movement, and on returning to Baltimore, I immediately worked up a new Deerhorn with three radio oscillators, one in the middle as a reference to heterodyne the two outer ones. So there would be two Deerhorn Providences crammed into the space of one, with two separate low frequency resonators to detect two different gesture speeds in close proximity. I call this Deerhorn Moon because it was never made on this planet.

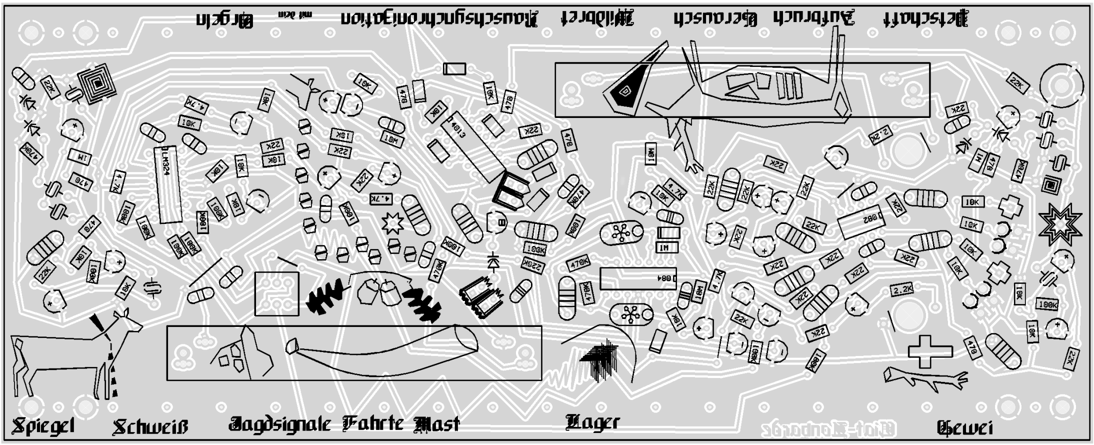
Deerhorn Berlin



In Summer of 2009, a summer camp in Berlin for hackers, SOMMERKAMPWORKSTATION, hired me to conduct a circuit workshop. The event, curated by Derek Holzer, was informative; I met some great artists such as the code philosopher and geo-hacker Martin Howse, my friend Jessica Rylan was printing her analog chaotic resonances, and Tor Honore Boe built acoustic laptops. I brought a Deerhorn paper circuit, for about ten participants to build. Deerhorn Berlin continued the idea of a low frequency gesture resonator to the next logical step, a voltage controlled undulation. With some extra silicon, now a knob could select what spectrum of gestures to resonate, from slow to fast. It also included cadmium photocells on its inputs, to attenuate various control voltages presented there.

To demonstrate the circuit to participants, I brought a finished tapestry of four. The Deerhorn Berlin tapestry is run off of a nine volt battery or twelve volt transformer. It hangs on a wall like the other tapestries. Unlike the first Deerhorn Baltimore, the antennae do not point upward, but hang down. Grasp a piece of metal like a bean casserole pan with the hanging alligator clips, and use the inset trimmer capacitors to bring it into range. You should hear when it crosses into range because the resonators will receive a lot of energy and undulate quite a bit when in range. Stop there, and they will die down and now it should sense any movement. The control voltages are hard wired, so it only needs a little bit of light on the photocells to begin intermodulations.

Deerhorn Gewei



This is the final iteration in the Deerhorn design cycle. I designed this circuit board in 2010 as a Gewei, or Deerhorn, to accompany the Roolz. It incorporates symbols and the language, Jagersprache, of the deer hunter to maximize is analogical potential. The hunter uses this language to conceal the violent meanings of his utterances in the woods, so that the deer may not hint upon his secret intentions, heard by the forest itself. In this final revision, I discarded the Theremin heterodyne and took up a more elaborate, but justifiably elegant translator for the invisible and unheard radio fields. On this design I constructed a radio frequency phase locked loop, using a flip-flop, some diodes, and an resistor-capacitor filter network. This detects the phase difference between two radio oscillators at each end of the board, and generates a correction voltage to bring one in sync with the other one. So if a hand movement disturbs either, a change in voltage quickly brings the other in line. This resulting voltage can control oscillators, now fully modular and a direct result of a heterodyne. The problem with a heterodyne wave is that low frequencies are difficult to tune to, because at a certain proximity the radio oscillators lock to each other, eliminating any beat tones. By separating the audio synthesizer from that of the radio field, any audio range can be dialed by that modules own pitch knob; in addition to the antenna tuning knob, now there is a oscillator pitch knob.

The Deerhorn Gewei wall piece seems to have little zithers mounted on it; these are soundboards of Pawlonia, with multi-layer piezo-electric speakers within. They make a quiet tone, but they work at high frequencies. The tuning process is similar to all other Deerhorns- bring the antennae into range by making the two indicator lights teeter against each other. Then range the pitches as desired, and add any modulations with banana cords on the sides of each module. Each has an orange output for control voltage, white outputs for audio, and a blue input for frequency modulation.

The Deerhorn Symbol

- Ancient Chinese guqin (scholar’s zither) makers rub deerhorn powder into the instrument to harden the wood and reinforce its virility.

- Deerhorn is hung in gentlemen's lodges as a trophy.
- Thus it is associated with Jagermeister, an herbal drink for deerhunters, and through German Herbalism, to Goethe.
- Mexican shamans looking for plant medicine, call it "hunting deer"

The deerhorn visually represents a cycle between the flesh of the brain and the "air" or "ethereal connection" at the tips of the horn. Model a deerhorn in modern material, Aluminum, and it becomes an antenna for radio waveforms. This is where the electronic arts come in, by designing a unique sort of radiosonic heterodyne to resonate the antenna. There are invisible fields around instruments and this is where we link the electronics with the psychical/spiritual. To sound out movements and gestures within space, fill the architecture with deerhorn. At this point, the deerhorn is physically hidden, to simulate the esoteric idea of "the museum of the invisible". Thus the body of the instrument becomes metaphysical. The heterodynes are designed to respond gracefully to unknowing, pedestrian movements within the room. For travel, there is a portable tapestry, a rollable synthesizer analog brain (nabra). Its circuits are made out of paper, so it is lightweight. On arrival at the venue, the tapestry is unfurled and hung on the wall, ready to sonify gestures. Touring with such an instrument is "art as art handling", symbolized on its case by a carrying handle made out of deerhorn.