Bird, Monk, Train: Three Approaches to a Solar Sounder Workshop

Abstract

A solar (panel-powered) sounder contains circuits to drive a speaker. Rather than treat them as a synthesizer, the author emulates specific acoustic sounds in analog electronics, and listens to their behavior in different solar energy conditions. Simple transistor circuits facilitate a group workshop to build a solar sounder flock and install them in the sun. The premise belies an awareness of outdoor sounds, and a yearning for electronics that can explore them.

Introduction

The sun energizes a solar panel on a box, with an analog synthesizer in it, to sound out a speaker. Without batteries, the box reacts to gestures of shadow on its face, and full darkness silences it. It sounds different on hazy days, cloudy days, sunny days. Outfitted in a thick-wall cardboard box, the acoustic object plays itself. I call it a solar sounder.

In a recent order to my solar panel dealer[1], I purchased a couple of larger panels to prototype solar sounders. I found that nine volts and six watts power a “speaking voice” speaker and a bit of circuitry to synthesize the sound. An electrolytic capacitor stiffens the current for the amplifier, but the box still reacts to changing light. Besides their solar panels, the boxes have no other playing interface such as knobs or switches; the art is not in the action of playing them, but placing them in the sun and listening. I think of these not as musical instruments, but installation tools.

Instead of offering a universal palette of sounds, the circuits focus on specific acoustic sounds. In this work, the analysis of three “voices,” begins the task of emulation. Consider the sound-making apparatus of each–a throat for the monk and the bird, and a horn for the train. Imagine its interface, how to control it, and how it makes sound, to conceive a model for its timbre. Then consider the triggering brain, and what triggers it to sound–territorial concerns, meditation, emergency or other contingencies. In the emulating medium (circuits or code), work backward from the brain, ending with the physical sound becoming electronic.

These three acoustic studies and their circuit emulations ask compositional questions: “how closely to imitate?” “how far 'off' can the imitation stray so as to evoke only a poetic allusion to the original?” These questions inspire synthesizers in this piece, to excite a “hackerspace,” enthusiastic for the many and varied implementation possibilities. Here, we hack not an object of technology, but an existing sound.[2]

Solar power is a compositional constraint for these boxes; without batteries or a “stiff” voltage source, the circuit components can bend the sounds.[3] The result reveals idiosyncrasies between designs and

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1 Sunny Chuang is a solar panel merchant out of Hong Kong. The panels in question are labeled GH125X195, as they measure 125 by 195 millimeters. They encapsulate eighteen polycrystalline wafers in series, for a total of nine volts at three watts.

2 Hackerspac3: a (mind)place to take ideas apart and put them back together as something new. Workshop: a group of participants (mine)crafting together.

3 The idea of a “circuit bend” comes from the circuit bending movement, where hackers open up a commercial (sound-making) device such as a toy, and reconnect it in ways unintended by the original manufacturer, to make new and

even between “exact replicas.” The shadows of trembling leaves makes the sound rise and fall in the wind, and wilt when a cloud passes over.

[01solarsounder.jpg: A solar sounder–solar panel, speaker, and circuit–responds to sun and shade with sound and silence. This circuit, built on paper, will tuck inside the acoustic box; the solar panel will adhere to its surface.]

In a solar sounder workshop, participants build and customize the following bird, monk, and train circuits. The resulting ensemble reveals the unique properties of each piece; leveraging their differences, they paint a spectral smear around the emulated voice. A performance gesture arises from their response to sun and shade with sound and silence. The workshop organizer must curate a special space, with well-lit tables for solder-working and sunny reverberant spaces for the energy work.

Workshop participants can customize the sound of each box by changing capacitors, which set frequency and timing characteristics. In this way, the emulation alludes to the breadth of variation in virtual voices. For example, an electronic bird calls mournfully slow, beyond the physical capabilities of its living counterpart. Customizing the circuits by their capacitors contrasts with voltage control of synthesizer parameters; the physical choice and placement of components restricts each box to a certain range and mode of recitation.

Gyuto Monks

The Gyuto monastery is a sect of Tibetan Buddhism. It is well known for two reasons: enduring religious purges of Chinese Communism by moving down from the mountains into northern India, and; the unique sound signature of the monks' undertone chant. Undertone chanting involves the glottal folds of the esophagus, usually silent in most traditions. The monks activate these glottal folds at a subharmonic of their chanting voice, emitting a supernaturally low basso voice. It is also called “throat singing” because the magic happens in their throat.

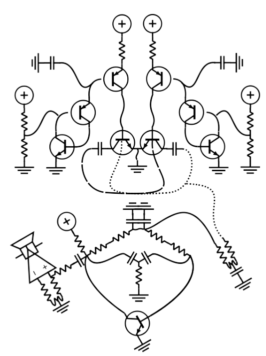
A simple circuit to realize this is a bass pulser. A square wave with an extreme duty cycle becomes a bass pulser, also known as a rectangle wave. The pulse wave is richer than a square wave, so it can excite the overtone synthesizer–a resonant filter to synthesize the Gyuto overtone singing. Overtone

exciting sounds. Extending this concept, a circuit can bend itself in the following way: the components exert strain on the power supply and if it should yield not ideally stiff current, then components will talk to each other through the power supply; they make new connections as if hacked or bent.

singers, including the Gyuto monks, shape their mouths to create a whistling harmonic–usually the fifth–dwelling in and deriving energy from the throaty undertone.

[02gyuto_notation.svg: Curve tracings of an assortment of tibetan chant manuscripts (Gyuto school). A monk synthesizer should strive for such modulations (parallel, symbolic, or convoluted). Listening to monks on Youtube, one hears slow glissandi, rhythmic chanting, and the mysterious undertone and overtone effects.]

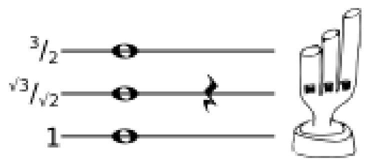
The monks, as they chant, join these two elements–the basso throat and whistling mouth–with a third: the text that specifies symbolic meaning, movement of the tones, and other throat modulations. In a simple transistor emulation, slow ramp generators modulate the bass pulser through various low notes, tracing curves and sub-curves. A look at Tibetan chant notations inspires the synthesist because they have no bar-lines, focusing instead on the unmediated squiggle. A resonant undulation, perhaps undulated again in speed, may generate a more sophisticated interpretation of the notated curves. A simple transistor hack, however, facilitates the quick workshop, to emulate the monks, their chanted text and otherworldly whistles in ensemble.



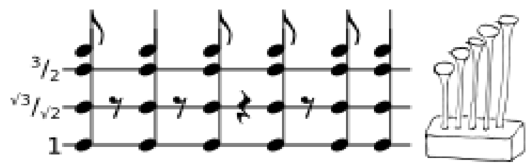
[03gyuto_circuit.svg: Schematic of the monk synthesizer. In the simplified flow chart, text feeds throat feeds the mouth. The realization is with transistors, capacitors and resistors.]

Night Trains

I hear a train's call echoing in the river valley. From how it sounds, I imagine the train horn to be a cluster of three to five “hornlets.” Their range stays mostly within a musical fifth, as the millwright metalworkers who created these horns realized this ratio by practical plumbing of different length pipes. Perhaps these plumbers sought the loudest possible outcome of a steam or gas pressure horn, or the most aesthetically tooled, vandal proof fixture for a powerhouse vehicle. I relish the absence of conservatory training in the subtle tuning variations of the trains' multiple hornlets–a concentrated burst of industrial frequencies. I can hear the alternative tuning of industry as (not particularly westernly musical) tempered neutral thirds and other finer gradations.[4] Taking the musical fifth range, and the presence of neutral thirds, I have devised a simple clef to notate the hornlet relationships. The perfect fifth, a ratio of three to two, lines the top, and in the middle, its square root (the most tempered possible neutral third) relates to the tonic at the bottom. The clef is printed wide to express tuning nuances between the lines.

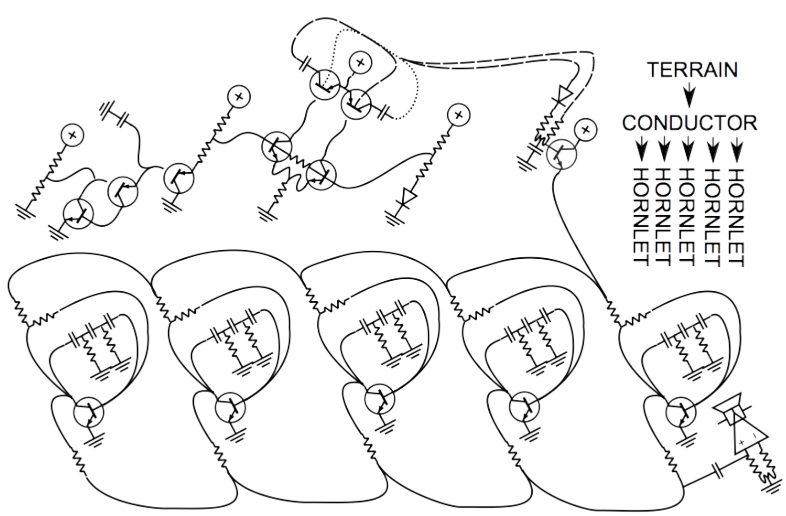


[04threeHORN.svg: Single long toot of a trio train horn, 6:00 PM, on a Sunday. The fixture's imaginary shape.]



[05fiveHORN.svg: Quintet horn heard at 3:00 AM–an irregular, symbolic pulsing. Is this the conductor's call sign?]

A train starts its journey and I hear the conductor signal to his friends at the docks, later at an intersection with the road; the toots follow company regulations or the conductor's whim. The terrain–a slow unfolding of brief intersections and signaling events (pulses)–affects the driver to toot his horn, infrequently in a pulsing manner. To emulate these night-sounds, you need a terrain, a driver who toots, and his horn, a set of three to five static pitches, perhaps overdriven sine waves, normally silent, to be tooted.



4 The neutral third distinguishes Arab and Islamic music from Western twelve tone music. Sitting somewhere between the minor (sad) and major (happy) third, I would like to speculate that it evokes warm and memories to those who grew up in Islam, and a fear to those who fear, including those who believe in only "sad" and "happy." It reflects a deep subtlety of emotion to map a pitch in the unknown, irrational place between the strong poles of major and minor. Ancient Arab theorists searched for a representative integer ratio, and only came up with subtler variations. The numbers in the "Wosta of Zalzal" ratio–27/22–pop up in the most common resistor values of electronics design. Exploring the musical dynamics of resistor ratios, I have found many neutral thirds. I can also hear them in train sounds, because the industry has tacitly found efficiency in this temperament.

[06trains_circuit: The train circuit reuses some of the ideas of the monks. This time, there are five final resonances, as the hornlets for the train conductor to toot. He waits for triggering events in a slowly unfolding terrain; a slow ramp modulates the pulsing trigger for the hornlets.]

Interlude

I first emulated natural sounds in fifth grade. While the most popular and handsome boys competed for murderers or kings in our class production of Macbeth, I attained foley-man status. Focusing on the witches' scene, I worked long and hard to generate crickets and other night-sounds on the classroom synthesizer keyboard, which was by Casio or Yamaha. I realized it could never generate a perfect imitation, so I went with the weirdest. As I timidly faded these sounds in over and around the cauldron, I judged the parental audience's reaction from the side- not a flinch. How could they perceive these strange electronic sounds without wondering about their emanation? The answer is that one expects the supernatural in an imaginary witches' heath.

In the basement of Oberlin College and Conservatory, I pieced together an idea about synthetic bird songs, programmed in CSOUND.[5] At the time, I was working with Gary Lee Nelson, a pioneer of that program, and Tom Lopez, who shared a love of the Ohio landscape and nature. I wanted to bring the synthetic bird songs to a wild setting there, as an experiment. I chose three general categories for the birds–a bat for a little cave near the Elyria waterfalls, a seabird for the rock caves in the wetland pier by the lake, and a rock dove for the alleyway behind La Sotano restaurant.

In coldest winter, with tape recordings of the CSOUND output files and a playback device, I headed to the locations and re-recorded them into a mike. The tape piece was performed in Warner concert hall, with the following titling:

Rock Dove, in alleyway behind La Sotano restaurant – Seabird in rock cave --Bat in cave

The piece was a great success, receiving snickers and jostles-in-pews, but some in the audience were confused. Tom advised me that some of his students' concert reports asked, unaware of the synthesis experiment, “why did he record a bird for an electronic music concert?”

After college, building “performance” synthesizers kept me away from most frivolous thoughts of synthesizing birds, but birds did call in synthesis language. In Baltimore, my workshop on Bentalou street adjoined an alley with parallel, brick walls, and a juniper tree that hosted a perennial mockingbird resident. I felt privileged to develop a springtime relationship with the bird. In addition to imitating car alarms, it sang the circular and wobbly modulations emanating from the electronic organs I put under test.

Mourning Dove

On moving from Baltimore to Portland, I experienced shifts in natural climate, personal attitudes, and also a profound and illuminating difference in the shape of the mourning dove's nesting-coo song.[6] Throughout my east-coast childhood I could hear a calm, summer afternoon heralded by the bird's “oo wah-hooo-hoo-hoo.” The onomatopoeic notation consists of three essential motifs: “oo,” a held tone;

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5 Csound is a computer music language by Barry Vercoe, initially modeled by Max Matthews. I have a fondness for the “orc/sco dichotomy,” wherein two files feed the program–an orchestra and a score. With this strict separation, one can play the instrument builder one day, and compose the next. A score is simply a list of “notes,” but a birdsong takes different types of notes than a piano song–more about melisma and swoops than tonality or pianoforte.

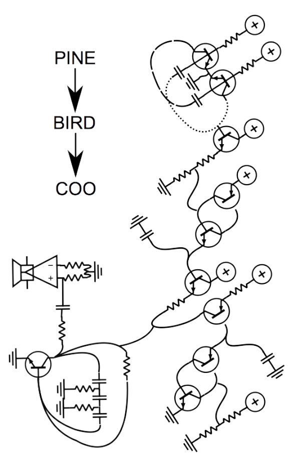
6 The mourning dove, *Zenaida macroura*, related to the rock dove or common pigeon, is a territorial bird of the mild temperate climates. It generates three unique types of sounds- the whistling rush of its wings on a startled flight, a shrieking emergency call, and the calm song of its nesting-coo which is the subject of this study.

“wah,” a swoop up high; and “hoo,” a mournful and pensive falling tone. Newcomers think it an owl by its night-like serenity, but grandmothers can correct that misapprehension. In the west-coast, however, the song changes, and boils down to a simple “oo hooo-hoo-hoo;” the western bird has forgotten about the swooping “wah” of the east.

[07mournFFT.svg: the call of an eastern mourning dove, analyzed with fast fourier transform (FFT) and imported into vector graphics, rescaled to emphasize the melismatic details of the call. The long held tone connects directly to the swoop tone, followed by the long hoo, short hoo, and final long hoo.]

I can imagine that the bi-coastal song variations come from the same bird, but the climate has modulated its brain to suppress the eastern “wah;” that motif lies dormant and unactivated. Does climate modulate brains? A typical stereotype of the two American coasts is that eastern humans have more grit from harsher climate, and western ones can relax, dial it back due to the pleasant weather. A circuit emulation of the mourning dove call-brain should allow for all of its three motifs–the “oo,” “wah,” and “hoo.” The circuit should also suppress “wah” as a compositional motif.

The nesting-coo signals territorial boundaries to males, and a willingness to mate females. Its period is about every minute if the bird is relaxed, but it can speed up in response to the proximity and frequency of neighboring nesting-coos. Because it involves waiting, I chose “pine” as the codename for the call-brain's periodic trigger. The pine tree has always symbolized waiting, but as a popular nesting spot for this species, it now means space-waiting: the dispersion and spacing of pine trees as territorial markers. The “bird” nests in the heart of the circuit; its call-brain must formulate the “oo,” “wah,” and “hoo” as well as their requisite timing in the call.



[mourn_circuit.svg: The mourning dove's “oo,” “wah,” and “hoo” come from a peculiar compound of triangle oscillators, triggered by a slow pulse, and sung by sine-wave resonator.]

Extra credit goes to an emulation that can change coasts by suppressing the “wah,” preferably without internal logics, but according to external (climactic) circumstances. In the solar sounder circuit format, the variable current output of the solar panel provides that variation. The transistor circuits are primitive enough that their reliance on supply current will modulate their sonic characteristics.[7] In the mourning dove circuit, the "wah" arises from changes in the power supply. Full sun suppresses it, but shadows articulate it.

Tricentric Analysis

The tri-centric music of Anthony Braxton has informed me of an exciting way to analyze musical circuits. With his hands, he signals three shapes–square, circle, and triangle–to conduct an orchestra. The square represents fixed forms, such as a composition on paper; the circle represents improvisation, and the triangle synthesizes the other two.[8]

An entry point for the analog synthesist is the three shapes' relationship to the three most common waveforms: square, sine,[9] and triangle. In monk, train, and dove, each of the three shapes shall appear in different sizes according to their time scales–big for slow and smaller for higher frequencies.

In the monk circuit emulation, a the triangle wave ramps the monk's throat. The text spells the chant, and a small circle represents the whistling mouth tone–the triangle wave modulates the square wave which feeds the resonant filter.

For the train, the terrain is a big triangle, like a mountain–a sloping gradient of danger and triggering events. The conductor and his square-wave toot-toots! Finally, the hornlets are the sine-wave resonances, in a group of five.

The dove circuit swaps the roles of triangle and square, so the slow pine tree takes fixed form; it waits and briefly toggles "on" long enough for the bird to make its mournful call. The modulated triangle wave shapes the call as well as an independent triangle, to help with the subtle voice-crack and moan of this bird's call, again realized on the circle of a sine-wave.

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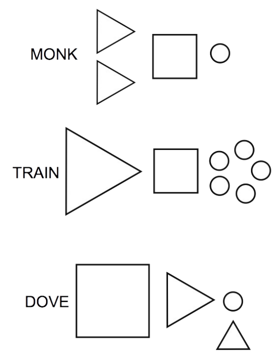
7 What is a primitive circuit? In this context, the lack of a regulator makes it simpler and more vulnerable to limited supply currents. A regulator is often placed on a circuit's main supply to force it to a certain voltage. Without one, the circuit becomes more primitive and wilder. Another point to look for is the presence of transistors versus their more stable counterpart, the op-amp. Transistors, if uncompensated by tricky uses of complimentary pairs, react to changes in temperature and exhibit a wide variation in multi-dimensional characteristics that make each emplacement prone to idiosyncrasy. A final point about the solar sounders as primitive circuit is that their speaker amplifiers share the same solar panel as the synthesizer circuitry. Speaker amplifiers use decades more current then the actual generating circuitry, and as such they spike and "hog" the power line with all sorts of feedback. When this feedback enters the synthesizer by its power line, it can yield parasitic oscillations–extra and unplanned sound squirts–as well as dampening functionalities by sapping the power from a shady solar panel. An elegant trick to prevent these symptoms is to separate the power supplies with two solar panels, and that helps define the single panel option as "primitive."

8 "Anthony Braxton: The Third Millennial Interview with Mike Heffley," http://www.autodidactproject.org/my/braxton2q.html

9 The sine wave trigonometrically inscribes a circle in euclidean space, with its cosine friend.



[09tricentric.svg: A tri-centric graph of the three circuits: monk, trains, and dove.]

Having executed a triptych of circuit compositions, exalting in escapes from binarism, one asks how to escape the trinary? By making another circuit or two, of course! Miles Davis trumpet style is *microsound*,[10] and as such deserves electronic emulation, for the interesting paths and alleys it opens to the composer. All the little squeaks and noisy flutters, which he never hid, like a bird call, disclose nested tiers of modulation. Like the mourning dove's "wah," they have subtly suppressed calligraphy of song.

For a fifth emulation topic, I look to the beach, and try to undulate on the soul of the "sneaker" wave–the noticeably stronger wave that crests about every ten waves. The decade, or power of ten, is strong in electronic design because decimal notation overwhelms all others. So formulating the tenth wave could be as simple as choosing capacitors for cascaded decades of oscillators.

Cezanne used the word “tourbillon” to describe his spinning brush strokes and their perception in the eye. He found the idea in the old physical texts of Lucretius, who conceived of the atom as *vortex*–a whirlpool. Leveraging this term, Cezanne's paintings generate solid objects, such as an apple, in the mind's eye, out of the little whirling “tourbillons.”

I think the Gyuto monks really evoke this sense of the material world made out of little whirling things, that bridge the gap between matter and sound. I will strive to emulate this. I need a lunchtime courtyard in a mediterranean country, optional goat on spit, and of course the workshop and participants to solder. The sun shines harsh–we call it “mid-day sun–” on the stone columns and the clean air resonates the whistles emitted. Like island radio stations, the rare sounds of these things–doves, monks, and trains–pierce the silence of the mid-day sun.[11]

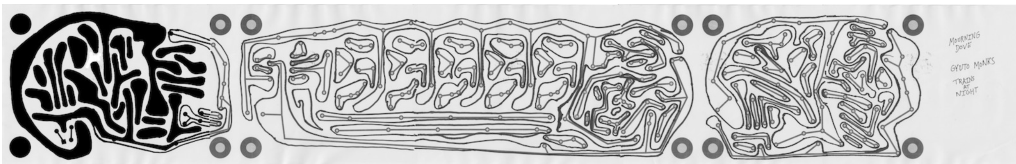
Circuit Assembly

I built the original circuits as paper circuit prototypes, and moved later to fabricating them on fiberglass. To give the circuits a vintage feel, I learned to emulate hand-drawn traces in the digital

10 Microsound, a treatise by Curtis Roads, defines an approach to sound, inspired by the ability of digital editing workstations (DAW) to zoom into sounds and reveal moments smaller than the usual, or acoustic, musical consideration. From this standpoint, consider the trumpet playing of Miles Davis: other sounds of "ghost" duration, hide between every "official" musical note. These sounds may not have musical qualities such as fixed pitch; they may swoop in tone or disclose much noise.

11 We will trove the nicest, phattest capacitors to deepen our tones to the ghostly range, and let them go on and on all through their residence, while we dash about the beach caves.

format used at the printed circuit board (PCB) house. First, I laid out the circuit in PCB software, and printed it out at four-times scale. Using a sharpie, I traced around the sharp lines to make organo-form shapes, scanned and converted them into vector graphics. The result, reimported into PCB software, would be difficult to edit, but seems fitting for the analog circuit ideas.



[10mastro_gonkilius.png: A screen capture during the process of converting hand-drawn traces into digital format.]

The first Solar Sounder Workshop shall occur at Rhizome, DC, with four pieces of each monk, train, and bird boxes. Outfitted in archival specimen cases, they shall each employ a four inch "woofer" speaker, a nine volt three watt (125mm by 195mm) solar panel, and fiberglass prints of the circuit board. In October, rain clouds may seep ominous so we are prepared to test the boxes *in situ* with nine volt batteries. As permanent residents of the Rhizome instrument library, the boxes will eventually chance upon strongly sunny days–and with the help of a good curator, sing out then!

To build a paper version of the circuits, print out the port-dock [link to pdf: http://ciat-lonbarde.net/paper/BMT.pdf], at full-size. It will only fit on legal, or extra long paper. Fold the printout down the middle, and cut a piece of card stock to fit in between the halves. Using a squeegee, spread white glue, affix the paper, and clamp the sandwich under books. When it's dry, poke holes with a *needawl*–a needle with wooden handle.[12]

Insert the components as notated:

- rectangles are resistors, in values 10k, 22k, 100k, 470k, 2.2m, and 10m
- diodes are like resistors but with polarity stripe
- transistors are "+" for bc556, and "-" for bc546 or substitutes
- the chip is an njm2073

For capacitors, use plastic film or ceramic, except for the large electrolytic marked by a circle and polarity marks. Excepting the electrolytic, all capacitors are in jellybean symbols. Try MLCCs[13] for the biggest, poly film for the general audio range, and styrene for the smallest. The following table suggests a value for each, and explains in parentheses what customizations avail the sound. For example, making a "bird brain" capacitor bigger will yield a slower call.

- electrolytic: 1000 uf or to taste (affects the overall "bentness" of the circuit)
- spoke: 0.01 uf
- SPKIN: 0.1 uf
- SPEAK: 1 uf
- CALL: 1800 pf (dove pitch)
- bird: 0.1 uf (bird brain)
- BIRD: 1 uf (bird brain)

12 http://ciat-lonbarde.net/paper/
13 Multi Layer Ceramic Capacitors

- pine: 1 uf (bird call length)
- PINE: 10 uf (bird call wait)
- HORNA-E: 1000pf – 2200pf range, in homogenous groups (train horn sounds)
- condu: 0.1 uf (brisk conductor or one echoing in mountain tunnels)
- TERR: 10 uf (speed of the terrain)
- coner: 4700 pf (length of the toot-toots)
- CONDO: 1 uf (wait between toot-toots)
- MOUTH: 0.01 uf (frequency of the monk's mouth)
- TEXTA, B: 10 uf (change rate of the monk's chant)
- thort, THROT: 4700 pF and 0.1 uf, respectively (the timbre of the monk's throat)

On inserting a component, shape its leads to follow the lines and solder it. Power comes from a nine volt solar panel into the obelisk shape. Its square pad is ground. The speaker connection is to the crown shape near the njm2073 amplifier chip.