CHAPTER 30

The Future is Now

In this, the second edition of *Handmade Electronic Music*, I have attempted to correct errors and oversights; to satisfy the desire, among readers of the first edition, for further projects; and to respond to how the world has changed since 2006. When I began developing the materials for this book back in 2002, most younger artists working with technology were focused on computers and the multitude of programs available at the time. The contrarian remainder was under the thrall of Circuit Bending. Accordingly, I took basic Bending as the center of my workshops and text, and expanded it backwards and forwards, so to speak. I started with alternate ways of *listening*: making and using contact mikes, coils, tape heads, electret elements, and other alternative microphones, and playing radio circuit boards with naked flesh as a way to sensitize our hands to circuitry. Then, when it seemed that my students, like children at Christmas, would burst if they couldn't open up their toys RIGHT NOW, we moved on to hacking clocks, shorting circuits, and indulging in the other heady, pseudo-random practices that fell under the rubric of Circuit Bending. When boredom set in or students tired of subsidizing toy stores and Goodwill shops, we moved on to our first oscillator. From there our silicon future unfolded like a gnomen, and as the years passed I was pressed to keep adding to the collection of circuits—as reflected in the expanded content of this text.

Subseqûent to the publication of the first edition in 2006 I came into contact with a vast sea of benders and hackers. Every few weeks I received a request for assistance on a recalcitrant project, or someone would send me a link to a YouTube clip or a Web site demonstrating some cool thing whose connection to my book they felt compelled to point out. My correspondents all share a "whatever it takes" attitude toward technology. This new wave of hackers is obsessed with neither technology nor methodology, but moves with grace from hardware to software, from soldering to sawing, from audio to video, from stage to gallery, from adaptive re-use to spontaneous creation, from happenstance to intent, from idiocy to genius. If there is any identifying trait, it is the desire to disrupt technology's seemingly perfect inviolability.

As I said years and pages ago, in the Introduction to the first edition of this book, the sticker claiming "no user serviceable parts inside"—whether affixed to a toy, a TV, a piece of software, a computer, a motor, or even a single integrated circuit—should be taken as a challenge. And for that challenge we must all—hacker and non-hacker alike—be grateful: today's "breakers" become tomorrow's "makers" (to use my son's terminology). Behind any goofy YouTube video might lurk the next Steve Jobs, Pierre

Omidyar, or Sergey Brin, as likely as the next John Cage, Jasper Johns, or Nam June Paik. Like that of snails or finches, technology's evolution seems to follow the pattern of "punctured equilibrium," and our hackers are holding the pointed sticks. And while we wait for the NEXT BIG THING we can enjoy the delicious din of all the now little things.

The DVD includes a gallery of 87 very now things, each squeezed into a 60-second package. Taken together they provide a reasonable overview of what is happening at the moment of this writing. The diversity of activity taking place makes it hard to categorize in a meaningful way, but seven threads seem to weave through the disk: Beyond Bending—the state of Circuit Bending today; Feedback—the guitarist's friend grows up; Off The Grid—abandoning batteries; I'm With The Band—making music together; Sound and Vision—an art school style; Mechanics—getting very physical; Swashbucklers—some virtuosic iconoclasts.

BEYOND BENDING

Circuit Bending has changed since Reed Ghazala coined the term. One factor has been toy technology's shift toward greater integration of functions onto a single chip. At the end of the last century, control of a toy's various functions (making sound, blinking lights, reading switches, defining the clock speed, etc.) was typically distributed amongst several different integrated circuits and associated components, and benders delighted in messing around with the myriad connections between those components. Now integration has reached the point that everything is controlled by a single malevolent-looking black blob. There are no exposed connections to rearrange. And with more and more on-chip clocks, which are not dependent on external resistors, not even the most basic changing-the-clock-speed-bend is possible. Today's bender is condemned to wander the aisles of thrift shops, garage sales, and eBay, continually confronted with the same stock of cast-off toys—while the new models, with their seductively novel sounds, evade corruption.

The frustration this causes is often compounded by ennui. Bending celebrates the first rule of hacking (ignorance is bliss). It shuns theory (Ghazala's Web site is aptly named "anti-theory.com"), and encourages instead the sharing of empirical observations: "insert a jumper between these points and this will happen, don't worry about why; or try anything else and let me know if it works." In contrast to the laborious analytical work that had previously accompanied most electronic engineering, even in hobbyist and musical circles, this philosophy is tremendously liberating for the first-time hacker. But after the thrill of "how" wears off, some of us ask "why?" Accordingly, many younger artists gain access to circuitry through classic bending activities, but then move on to diversify their electronic portfolio: interconnecting toys, combining handmade circuitry with bent toys, hacking other found technology (effect pedals, video circuits, mechanical devices), writing software, etc.

Rather than bending toys, for example, Neal Spowage (UK) built his "Wands," a responsive performance instrument, from metal detectors and security wands (see Figure 30.1). Kaspar König's (Netherlands) "Musguitear" uses hacked mosquito killers. Chris Powers (USA) has modified guitar effect pedals, bringing touch-sensitive contact points from the circuit board out to a set of electrodes he plays with his bare toes

Figure 30.1 "Electro Magnetic Wands," Neal Spowage.

(see Figure 15.14 in Chapter 15). Charles McGhee Hassrick (USA) takes a defiantly ecological approach, and creates audio-visual installation projects using only the discarded trash of the museums, galleries, and other venues where he exhibits.

Many artists extend their bends with computers or scratch-built circuitry. For his "After Math" Chester Udell (USA) hacked a TI "Speak and Math"—one of the most popular bending toys—so that it could be controlled by flight simulator controllers through a computer and MIDI (see Figure 30.2). Ian Baxter (UK) fabricated external body contacts to control a child's voice-changer toy for a performance instrument he calls "The Masher." Japanese artist Haco modified an electronic organ kit to be controlled by a combination of pencil lines on paper (as explained in the section on alternate resistors in Chapter 15—see Figure 15.10) and electrodes for body contact.

Several musicians have "bent" electric guitars and other acoustic instruments by embedding circuitry. Jeffrey Byron (USA) installed bent toys in his electric guitar. Zach Lewis (USA) replaced the neck pickup in his Fender Toronado with photoresistor-controlled oscillators, played with shadows cast by the pick-wielding hand (see Figure 30.3). Peter Blasser's (USA) "Radiothizer" resembles a koto, but contains Theremin-esque circuits that transform the sounds of the plucked strings in response to movement of the arms in the spatial field of the instrument. Ben Neill (USA) added switches and pots to his trumpet in order to control a computer music system via MIDI (see Art & Music 11, "The Luthiers" in Chapter 28, and Figure 28.3).

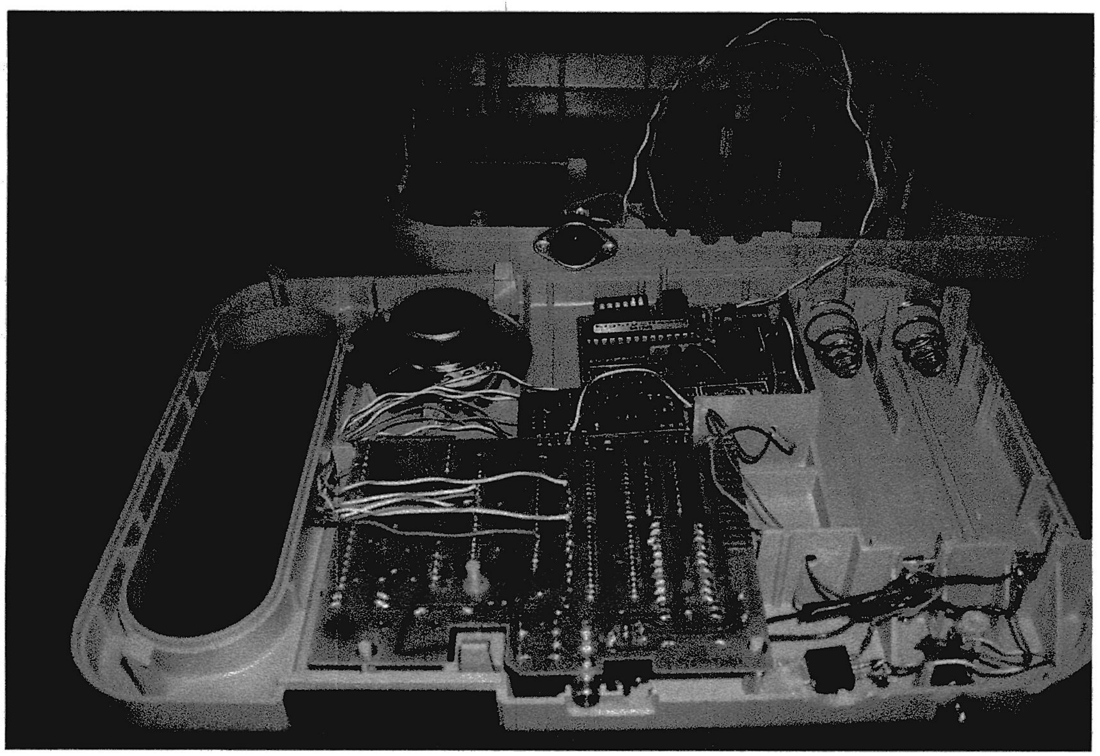

Figure 30.2 "After Math" hacked TI "Speak and Math" showing added MIDI interface board (between speaker and battery terminals), Chester Udell.

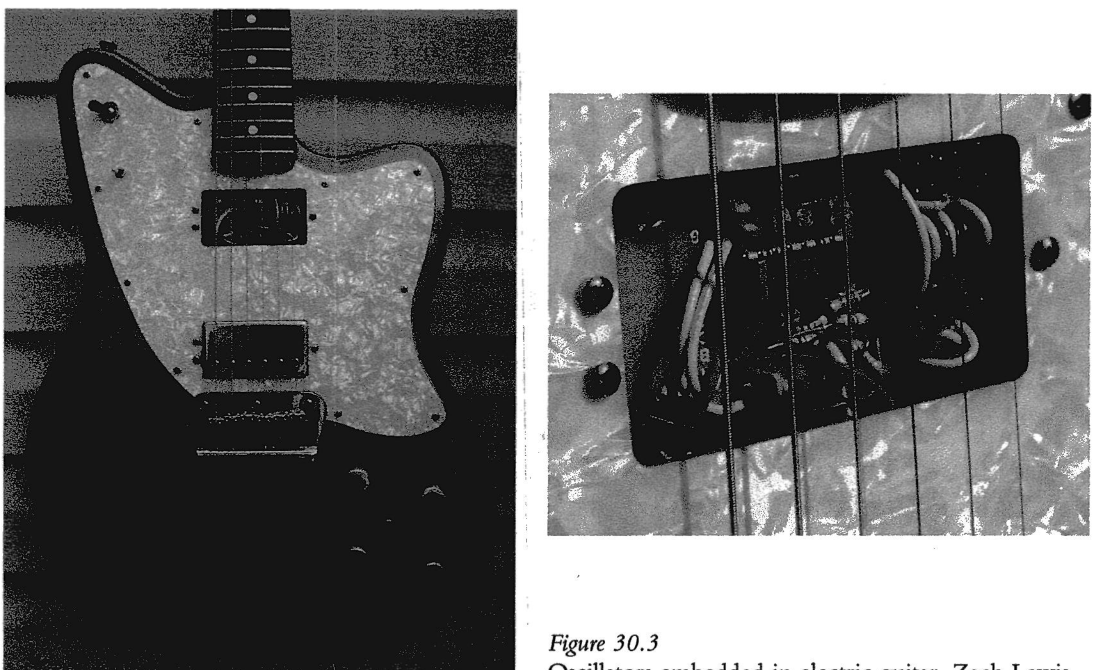

Figure 30.3
Oscillators embedded in electric guitar, Zach Lewis.

FEEDBACK

Interest in live performance and interactivity has led many to experiment with one of the most basic electronic sound resources, feedback. For her "Speaker Synth" Lesley Flanigan (USA) places contact mikes inside the cones of five open speakers and controls their feedback (see Figure 30.4). Minoru Sato (Japan) embeds microphones and small speakers at the opposite ends of glass tubes and adjusts the gain to create a feedback organ. For their performance work, "Crude Awakening," Chris Black and Christine White (New Zealand) use an array of speakers and contact mikes to resonate common objects (metal pans, grills, coils of wire, etc), which are physically twisted to affect their feedback pitch (see Figure 8.14 in Art & Music 5 "Drivers" in Chapter 8). Frederick Brummer (Canada) filters feedback through drum heads. Gert-Jan Prins (Netherlands) continues to do amazing things with radio-frequency feedback between homemade transmitters and receivers (see Figure 3.4 in Art & Music 1, "Mortal Coils," in Chapter 3).

Matrix feedback amongst multiple circuits, as pioneered by David Tudor (discussed in Chapter 26), came back into popularity in the 1990s through the work of Toshimaru Nakamura (Japan) and other advocates of "no-input mixing," in which mixers and arrays of circuits are transformed into oscillators by patching cables from outputs to inputs. Vic Rawlings (USA) configures naked circuits and numerous small speakers in complex feedback loops, which he manipulates by rubbing wire brushes across the circuit boards (see Figure 15.19 in Chapter 15).

OFF THE GRID

Well before gasoline topped $4/gallon hackers began experimenting with alternate sources of energy. Both Daniel Schorno (CH/NL) (see Figure 30.5) and Fred Lonberg-Holm (USA) harness solar power for performance instruments and installation projects. Phil Archer's (UK) "Music Boxes" (see Figure 30.6) and Ithai Benjamin's and Alejandro

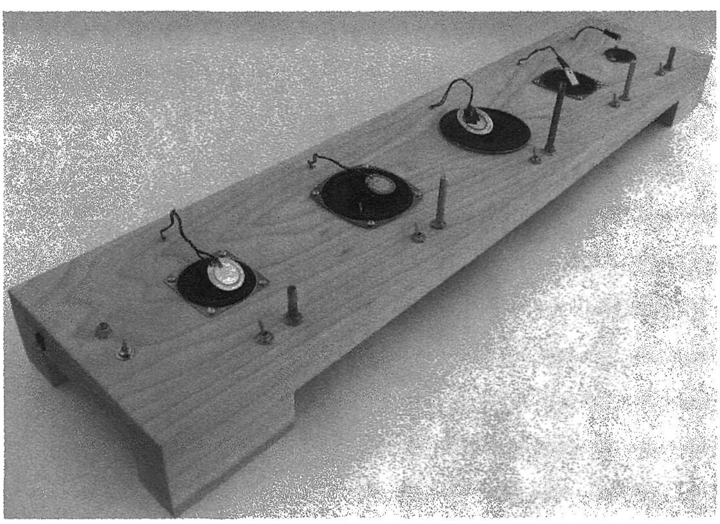

Figure 30.4
"Speaker Synth,"
Lesley Flanigan.

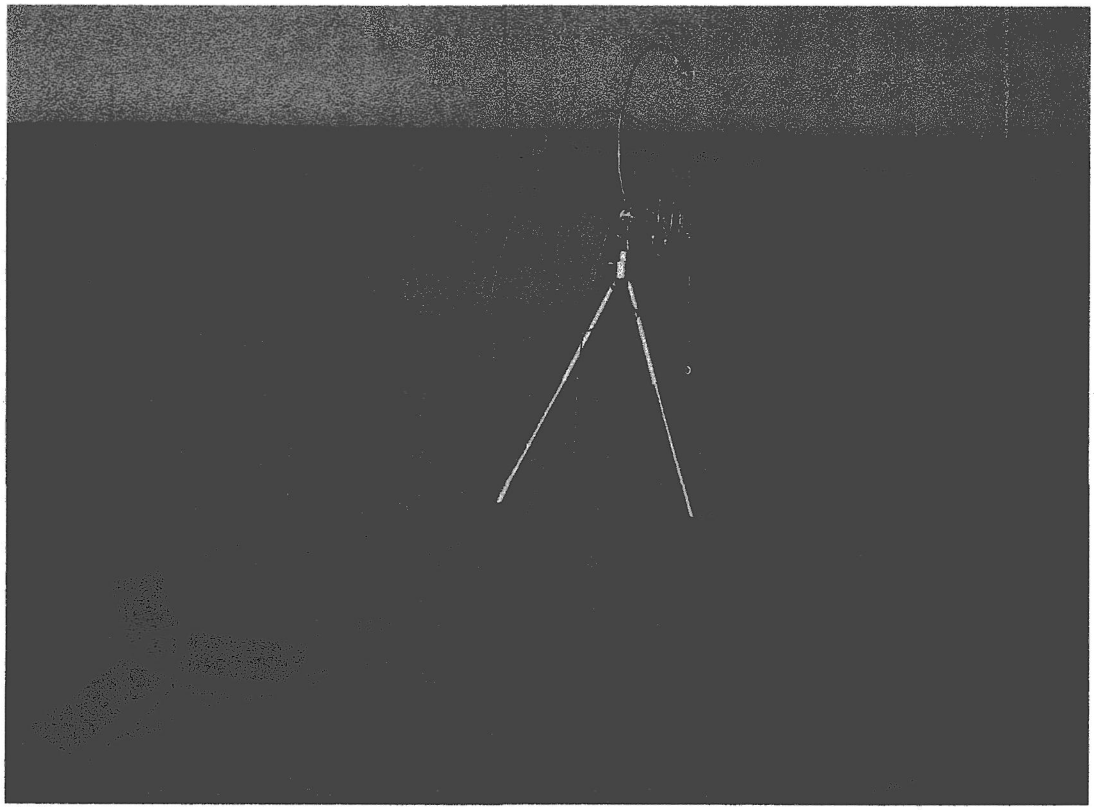

Figure 30.5 "Desert Scorpio," Daniel Schorno—installation, on solar chargeable battery, Erg Chebbi Desert, Morocco, 2007.

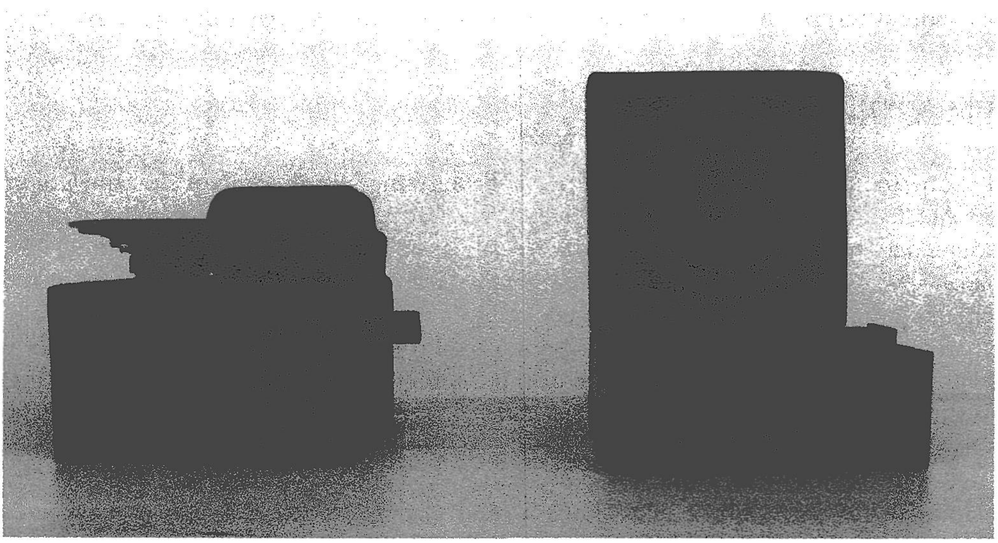

Figure 30.6 "Music Boxes," with hand-cranked dynamo power, Phil Archer.

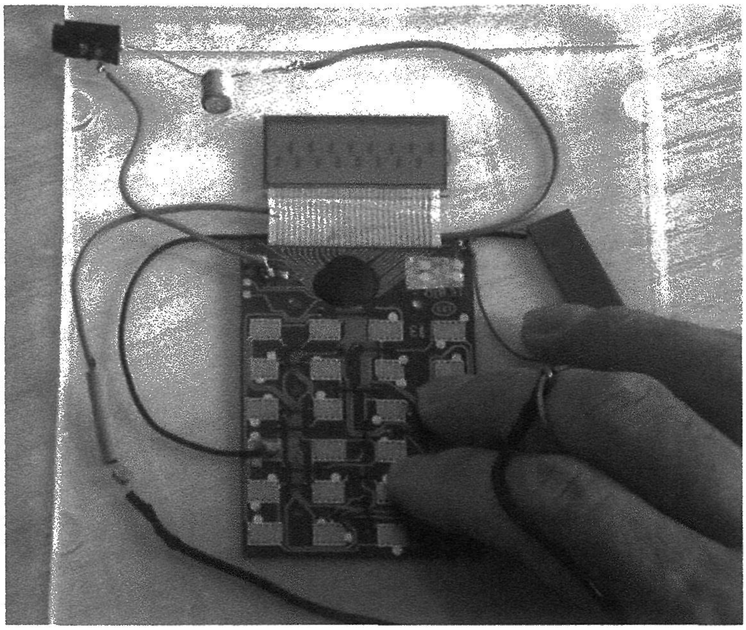

Figure 30.7
Solar power calculator touch synthesizer, Emir Bijukic.

Abreu's "Synthinetic" (see Chapter 29, Figure 29.12) incorporate hand-cranked generators as power sources whose instability becomes a defining characteristic of the circuit's performance. Emir Bijukic (Italy) listens to various points on the circuit board of a solar-powered calculator as he varies the light level and brushes his fingers across the exposed traces (see Figure 30.7). Lorin Edwin Parker's steam-driven synthesizer was described in Chapter 4 (see Figure 4.2). And in a tour de force of engineering, M. R. Duffey (USA) is designing "Solar Thermal Automata" based on plans and descriptions dating back to classical Greece and Rome, which utilize heat engines to generate organ-like sound directly from solar heat, without the need for any electronic circuitry.

I'M WITH THE BAND

Among the many benders and hackers that have formed bands are NotTheSameColor, an Austrian duo (Billy Roisz and Dieter Kovacic) that combines live manipulation of sound and video (see Art & Music 10 "Visual Music" in Chapter 24, and Figure 24.1). Japan's (e)-bombers are a bending big-band: six guys with bent toys and homemade circuitry, each wearing his own PVC-encased speaker system. Oscillatorial Binnage (Toby Clarkson, Chris Weaver, and Dan Wilson), Owl Project (Simon Blackmore and Antony Hall) and P. Sing Cho (Knut Aufermann, Moshi Honen, Sarah Washington, Chris Weaver, and Dan Wilson) are all electronic ensembles active in the UK today. (The Owl Project also developed the "m-Log"; a USB controller interface embedded in a hollowed out log, which can be purchased through their web site.) Grace and Delete (James Dunn and Chris Cundy) mix hacked electronics (including bent keyboards and, appropriately enough, a tinnitus analyzer) with bass clarinet. Stewart Collinson and Duncan Chapman (UK) recently formed the Bent Radio Orchestra, which—building on the grand tradition of the Scratch Orchestra and Portsmouth Sinfonia—invites the public to bring, open, and lay hands upon radios (as demonstrated in Chapter 11) for mass performances. The RGB~Toysband, formed after a workshop I gave in Brussels in 2005, takes electronic music into the streets, train stations, and other public spaces; its members have published a manifesto of sorts encouraging others to create satellites of the original group (similar Hacking bands have sprung up out of workshops in Cuneo and Padova, Italy, and Zurich, Switzerland.)

Finally, several new ensembles make a point of building circuits in front of their audience, rather than bringing completed instruments to the stage. The Swiss Mechatronic Art Society gives regular performances that feature live soldering—once, with all members of the group linked to a central master clock powered by dripping water. (This group also conducts workshops and publishes circuit designs online.) The members of New York-based Loud Objects (Tristan Perich, Kunal Gupta, Katie Shima) program microcontroller chips to produce and process sound, then solder them together on top of an overhead projector in front of the audience, who can watch the connections proliferate on a big screen (see Figure 30.8). My own workshops always end with a public event in which the audience wanders amongst the busy hackers as they assemble and test their last contact mikes, bent toys, and noisy circuits—a sort of factory-floor concert. In my recent piece "Salvage—Guiyu Blues," seven players use test probes to make a dozen connections between a simple circuit of my design and contact points on a dead circuit board (from a computer, cell phone, fax machine, mixer, etc.), reanimating

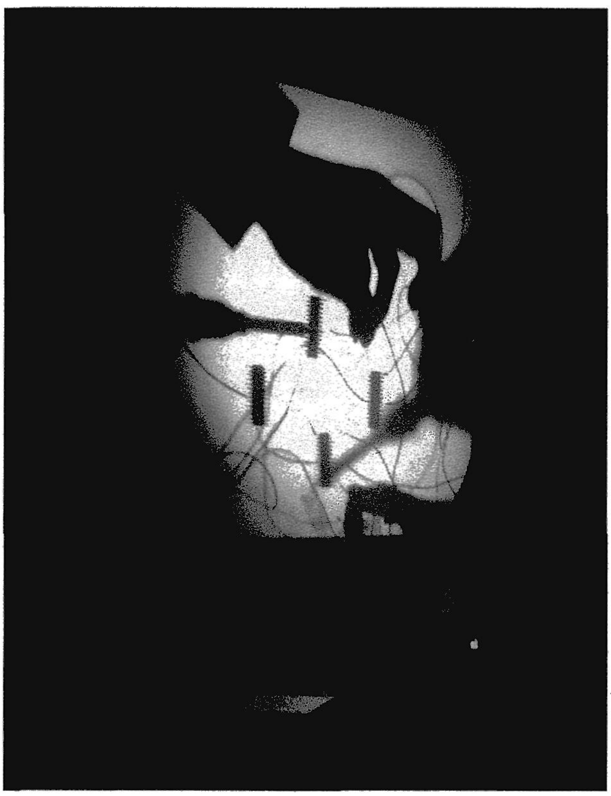

Figure 30.8
Live soldering performance by Loud Objects, showing overhead projection of work surface.

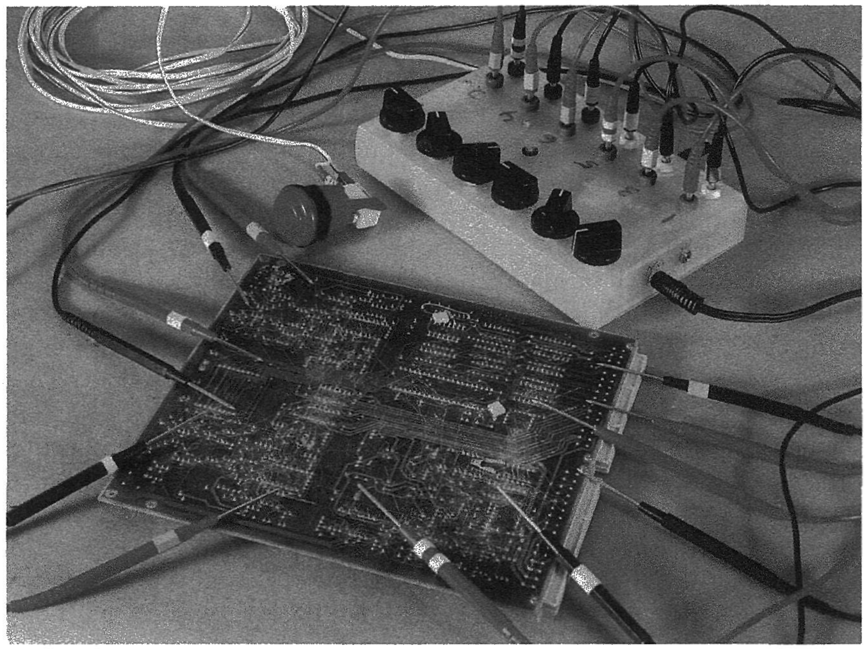

Figure 30.9 "Salvage—Guiyu Blues," Nicolas Collins—control circuitry, probes, and dead French Telecom circuit waiting to be re-animated.

the dead circuit and transforming it into a complex oscillator (see Figure 30.9). At the NIME Festival in Brooklyn in June 2007 I battled my young British *dopplegänger*, Nick Collins, for the Nic(k) Collins Cup (commissioned from British Potter Nic Collins) in a concert that pitted live SuperCollider programming (by Nick) against live circuit building (by Nic).

SOUND AND VISION

To state the obvious: sound is more than music. This has always been true, but the traditional distinction between "found" sound (produced in the world but living its life outside human intent) and "constructed" music (the imposition of human genius upon selected, designed sounds) is increasingly moot. Not only is music often "found," sound is often "designed." This is true in the rarified realms of art, the globalized realms of commerce, and the erudite realms of science.

Perhaps I'm attuned by virtue of having taught in an art school for the better part of a decade, but my ear tells me museums, galleries, and artists' studios just keep getting noisier: it's not that there is so much more "sound art" now than ten years ago, but rather that so much more art has sound. There are myriad reasons for this, from the high-falutin' and theoretical to the incidental and pragmatic. For many artists the digital camcorder has become the new sketchbook, and it is so difficult to defeat the camera's built-in microphone that most video footage has sound by default. And, just as a camera often redirects the artist's eye, so the constant presence of a soundtrack, whether intentional or not, draws attention to sound. My students shoot video with the lens cap on for the sole purpose of gathering sound, and they play back audio from camera tapes, without bothering to hook up a video monitor. When it comes time to edit, video and sound are cut and pasted using the same keystrokes and mouse clicks, with neither media privileged over the other.

As a result, music (or "sound art," if you prefer) is emerging from art schools, utilizing many of the same materials and tools found in music schools, but often with a very different set of skills, aesthetic concerns, and historical baggage. Some of this work takes the form of "pure sound"—CD tracks or MP3 files—but frequently it is characterized by a heightened sensitivity to visual implications of the technology of its production. That technology can be pretty diverse, since artists today tend to be "multi-instrumentalists": the majority of my students don't identify with a specific medium—they flit with ease between paper, film, videotape, wood, metal, computers, canvas, and circuits.

As materials go, electronic toys with their lurid plastic casings, and homemade circuits packaged in cigar boxes and Pringles tubes, are more varied and seductive to the eye than laptops and software. Moreover, for those who want to work with sound but lack traditional musical training, the learning curve is easier than that of most "normal" musical instruments.

Brett Balogh, Adrian Bredescu, Kyle Evans, Alex Inglizian, James Murray, Chris Powers, and Aaron Zarzutzki—all former students of The School of the Art Institute of Chicago—are typical of this new generation of electronic artists. Balogh works extensively with radio technology, adapted as a creative medium, rather than a source of news or existing music. Bradescu and Evans have built rich extensions of the circuits featured in this book. Inglizian is very active on the Chicago bending scene, conducting workshops as well as performing regularly, bending toys and building his own circuits (see Figure 30.10). Murray draws on his background as a DJ to design homemade circuits, developing instruments for cutting and mixing (see Figure 26.8 in Chapter 26), as well as multiple touch-radio synthesizers (such as those in Figure 11.5 in Chapter 11). A typical Chris Powers' hack to a guitar effect box is shown in Figure 15.18 in

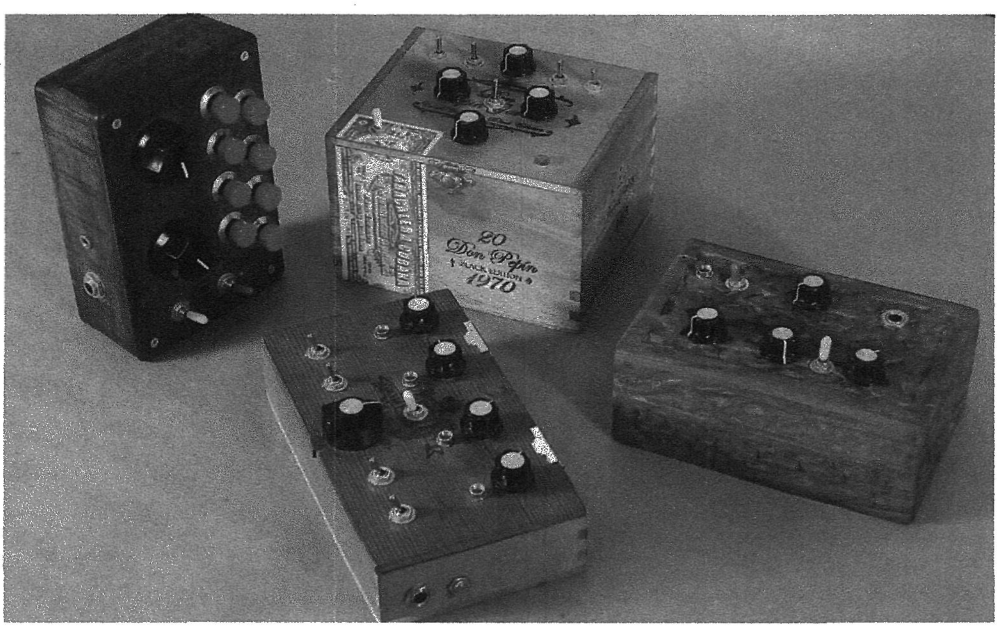

Figure 30.10 Various homemade circuits by Alex Inglizian.

Chapter 15. Zarzutzki built a wonderful instrument from crystal oscillators intended for computer clocks: the crystals oscillate at frequencies in the megahertz range, well above human hearing; but the difference tones that result from non-linear diode mixing (like we used in Chapter 18, Figure 18.19) yields unstable tone clusters that we can hear (see Figure 30.11).

This trend is not limited to trained artists, of course. A visit to YouTube makes it very clear that video cameras (especially those built into cell phones) have supplanted not only the sketchbook, but the Brownie, Instamatic, Polaroid and Super-8 as well—the documentary tools of previous generations of amateurs. And the content on the YouTube site demonstrates the international popularity of bending and hacking as musical forms.

Some of the most interesting work to come out of the new audio-visual sensibility involves circuitry that either generates simultaneous audio and video signals, or allows the two to interact. Americans Jon Satrom (see Art & Music 10 "Visual Music" in Chapter 24 and Figure AM10.6) and J. D. Kramer (see Figure 30.12) have independently hacked children's video paintboxes to generate fractured digital video and glitch-laden sound. The English trio of Phil Archer, Luke Abbott, and Dan Thomas, as well as the American Jordan Bartee, use hacked Sega game consoles for live video and sound. Phillip Stearns' (USA) "Pixel Maelstrom" is a video synthesizer constructed by radically hacking an old TI99/4a microcomputer; Stearns has also created a series of pieces using an array of analog electronics to process sound and video through feedback loops.

In the spirit of Yasunao Tone's "Molecular Music" (see Art & Music 10 "Visual Music" in Chapter 24 and Figure 24.6), Jeffrey Byron and Jay Trautman (USA), Joe

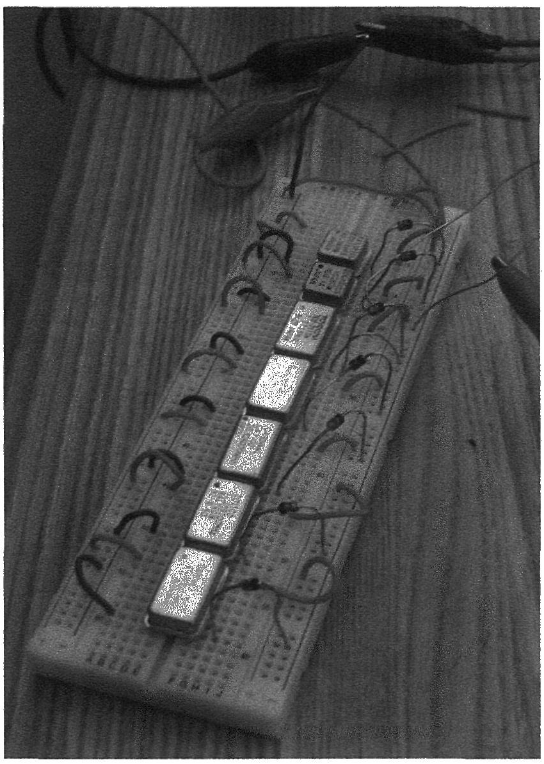

Figure 30.11
Multi-crystal beat-frequency oscillator, Aaron Zarzutzki.

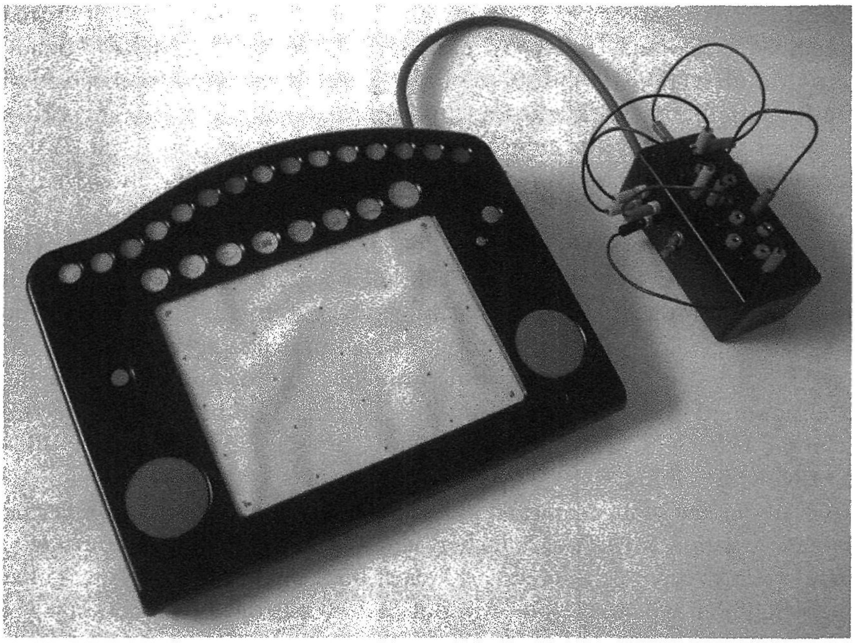

Figure 30.12 "Permutator" video synthesizer, J. D. Kramer.

Grimm (USA), and Infusion (USA) have built oscillators and signal processors that respond to film and light projection or sensors taped to a video screen. Michał Dudek (Germany/Poland) has connected oscillators and a bent keyboard to LCD TVs to disrupt the video sync and thereby modulate the broadcast images. As described in the box in Chapter 24, several artists—including BMBCon (NL) and myself (USA)—have built simple video projectors using LCD screens from small TVs and handheld games.

At the more sophisticated end of the technological spectrum, the New York-based duo LoVid (Tali Hinkis and Kyle Lapidus) have designed the "Syncarmonica," a system of circuit modules, set into a table top, that can be patched together like an old-fashioned analog synthesizer to generate sound and video (see Figure 24.7 in Art & Music 10 "Visual Music" in Chapter 24). LoVid has also embedded video and sound circuitry into soft sculpture, such as their "Ghoti" ("fish," in the variant orthography suggested by William Ollier in 1855 as a comment on the irregularity of English spelling, but often attributed to George Bernard Shaw). Ilias Anagnostopoulis has built an analog video synthesizer that harkens back to the Sandin Image Processor and Paik-Abe video synthesizer of the 1960–70s.

MECHANICS

Alvin Lucier once said that circuitry didn't interest him because it was "flat," while sound in space was three-dimensional. Ron Kuivila and I, his students at the time, bristled, but 33 years later I'm inclined to accept his analysis as a simple, non-judgmental fact. Several contemporary artists have reacted to the flat nature of circuits and computers by incorporating mechanical devices in their hacks. In Leah Crews Castleman's installation "Compose, Construct, Control," visitors press organ pedals with their feet to activate a beautifully crafted array of motors, cams, levers, and cables that animates an automated percussion ensemble, composed largely of trash (see Figure 30.13). Martin Riches' elegant "Motor Mouth" (1998–99) is an acoustic speech synthesizer, a mechanical version of the human mouth with moving lips, teeth, tongue, and larynx, with a blower which serves as the lungs; its controlling computer is programmed with a few sentences and can also speak individual vowels, semi-vowels, nasals, labials, and fricatives (see Figure 30.14).

A vaguely erotic physicality drives the work of Catalan musician Ferran Fages, who presses cones of styrofoam against the spinning platter of a cheap record player; the result sounds electronic but is produced purely acoustically, through friction, in a nod to the record player's pre-electronic, gramophone roots. Similarly, Chris DeLaurenti's (USA) "Flap-o-phone" is a manually activated, acoustic turntable: folded cardboard, a needle, and a stick exhume sound from 78 rpm records; this is a variant of the CardTalk record player devised in the 1950s by Christian missionary Joy Ridderhof for playing back Bible recordings in unwired locations.

The historicism implicit in mechanical devices is knowingly exploited by Guillermo Galindo, who describes his "MAIZ" as a "cybertotemic instrument": an assemblage of trash (wine crate, street sweeper parts, credit card, cigar box) and instrument parts (guitar neck and three strings), all whacked by a powerful motor controlled by a computer in

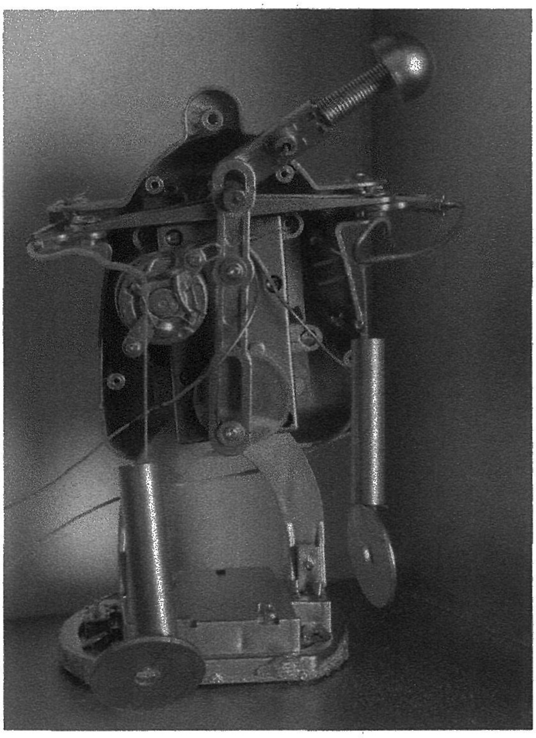

Figure 30.13
Detail from "Compose, Construct, Control," Leah Crews Castleman.

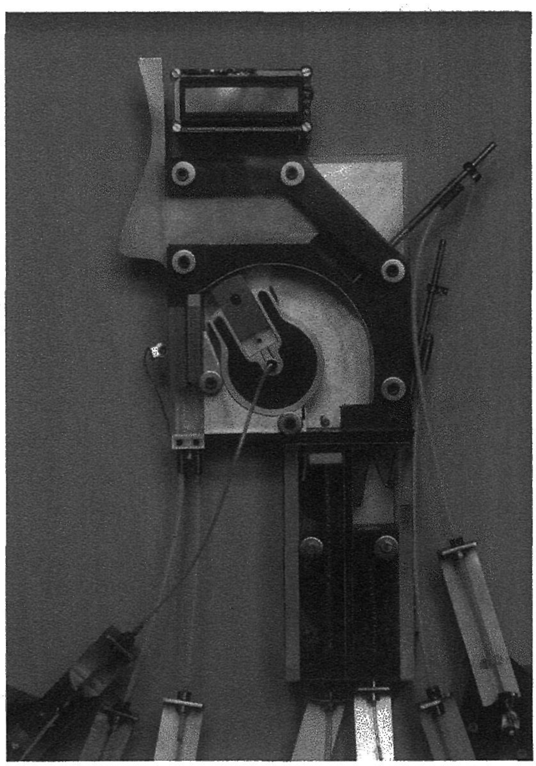

Figure 30.14
"Motor Mouth" (1998-99), Martin Riches.

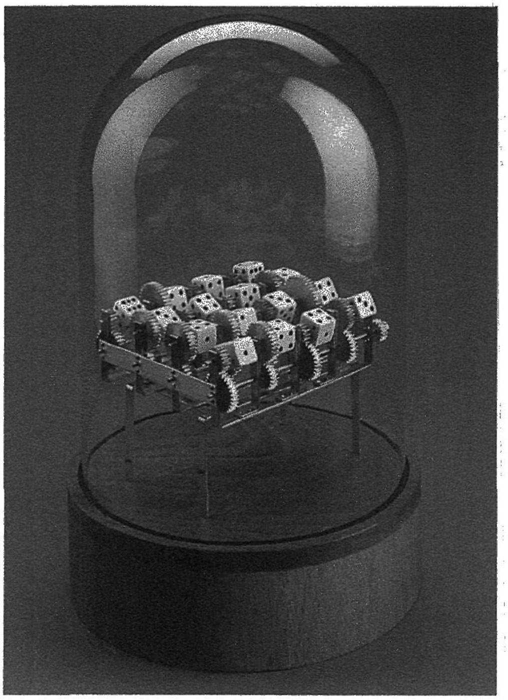

Figure 30.15
"Mandala #2" (2000), mechanized dice thrower, Marc Berghaus.

response to various sensors, the MAIZ merges pre-Colombian imagery, hurdy-gurdy mechanics, and digital interactivity. Marc Berghaus chose gears over computers, and uses Newtonian technology to create "chance machines" for generating haikus, throws of dice, and permutational music on tiny acoustic pianos (see Figure 30.15).

SWASHBUCKLERS

Driven by the desire to hear a world just over the horizon, more and more artists are building circuits from scratch, either to aid and abet the transformation of found technology, or in its stead. Sebastian Tomczak and Christian Haines in Australia, Tuomo Tammenpää in Finland (see Figure 30.16), Alejandra Perez Nuñez in Chile, and Douglas Ferguson and Steve Marsh in the USA have all developed beautiful extensions of the sort of circuitry featured in this book. In addition to his beautiful spring-and-piezo gamelans, as shown in Art & Music 3 "Piezo Music" in Chapter 7 (Figure 7.15), Adachi Tomomi (Japan) has been building and selling quirky Tupperware-encased music circuits since 1994 (see Figure 30.17). Florian Kaufmann (Switzerland) and Osamu Hoshuyama (Japan) are both serious fans of

Figure 30.16
"NAND Can," oscillator group, Tuomo Tammenpää.

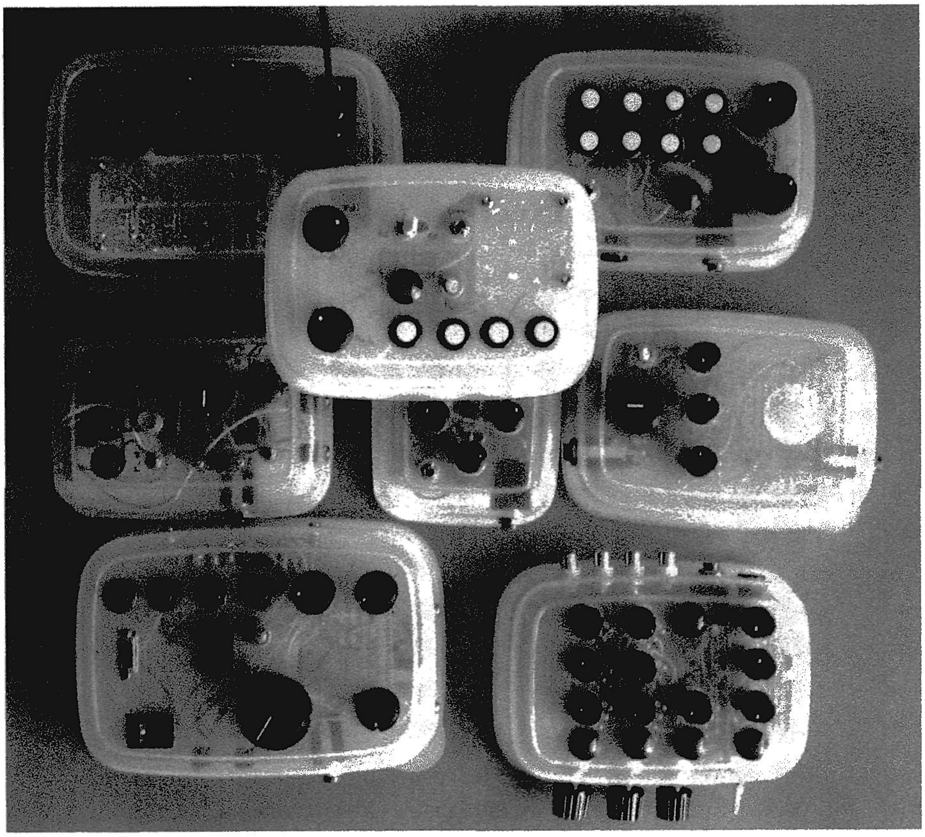

Figure 30.17 Assorted Tupperware-encased instruments, Adachi Tomomi.

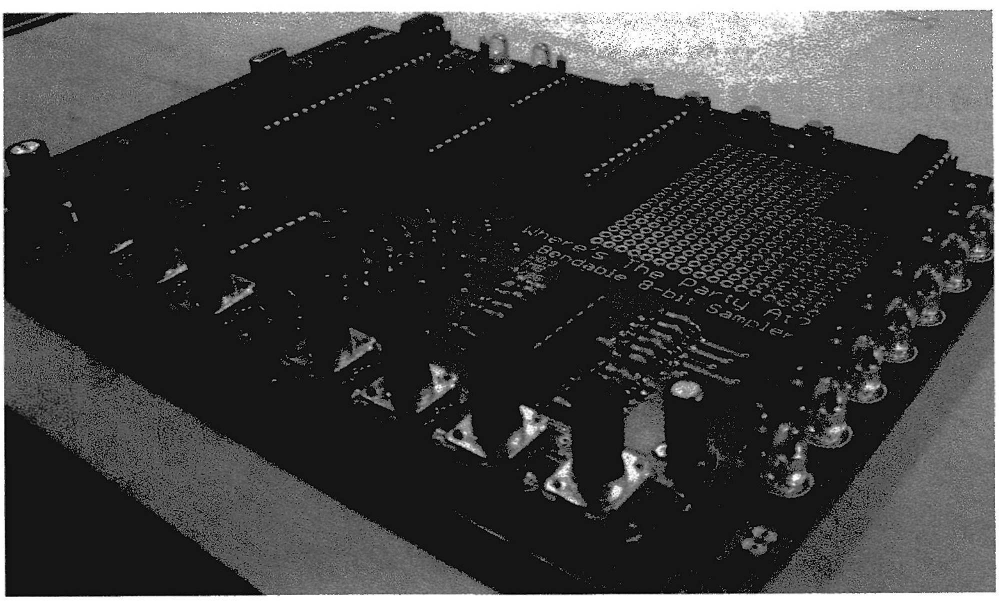

Figure 30.18 "Where's The Party At," hacker-friendly audio sampler kit, Todd Bailey.

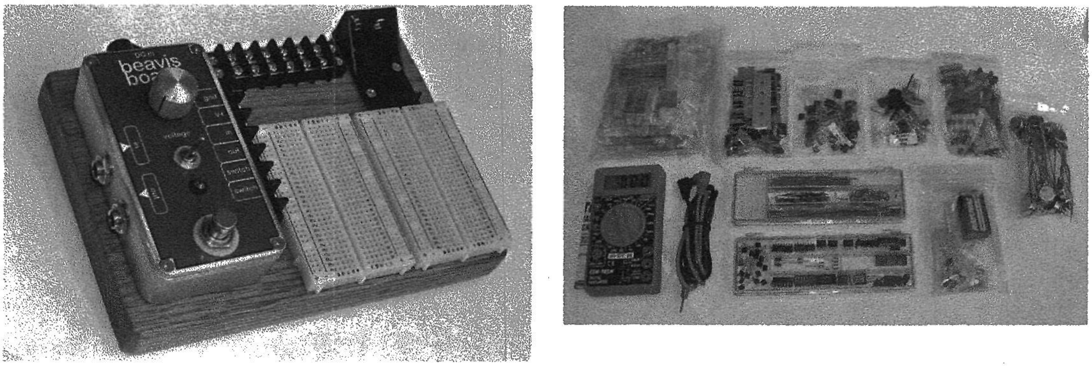

Figure 30.19 "Beavis Board" (left) and parts kit (right), Beavis Audio Research.

CMOS audio, and have set up Web sites with designs that go well beyond those I discuss.

Todd Bailey (USA) incorporated numerous contact points and an open area for extra components in his audio sampler kit, "Where's The Party At," to encourage customization by the user (see Figure 30.18). Beavis Audio Research has produced a guitar effect kit for those who fear solder: preamps, distortion circuits, filters, tremolos, etc. can be plugged together on a breadboard that connects to jacks and pots on a sturdy metal base (see Figure 30.19)—"learning to solder sucks," states the Beavis website.

Hans w. koch (Germany) has created a series of pieces based on the physical idiosyncracies of specific computers: in "Bandoneon Book" he opens and closes the lid of an Apple Powerbook, with accordion-like gestures, to affect feedback between the computer's built-in mikes and speakers; the feedback is further processed by software running on the computer, controlled from its keyboard. He bows the case of another laptop in "Electroviola"; the sounds of rosin on plastic are picked up by the internal mikes and, once again, transformed by koch's code. And in the melancholy tradition of Mahler's "Kindertotenlieder," in "Core-sound" we listen to the death rattle of an old PC as koch drips water onto its motherboard.

Phil Archer's (UK) early work with classic keyboard bending, percussion activated by a dot matrix printer, and a CD player-driven Hawaiian guitar were described in the "Bending" sidebar in Chapter 15 (Figures 15.11 and 15.12). Gutting another pair of CD players, Archer connected the sled of each one to the circuit board of the other, causing the lasers to chase each other's tails and play back a torrent of glitches. His series of hand-generator powered music boxes are described earlier in this chapter. Like hans koch, Archer has experimented with the heretic interaction of moisture and electricity, dripping water onto a Yamaha keyboard in his blithely-titled installation, "What's the Worst That Could Happen?" He has also incorporated growing plants in his circuits as components that react to human touch and presence in a distinctly spooky fashion, reminiscent of Tom Zahuranec's experiments in the 1970s. Archer's compatriot Dan Wilson has also used a discarded dot matrix printer as the core for an instrument: he amplifies the printer's internal springs, motors, and coils, as well as some added strings, in his "Printar" (see Figure 30.20). Wilson has built instruments out of floor sweepers, used the principles of the Victorian Oscillator (Chapter 5) to pluck strings and springs, employed worms to play Cracklebox-style electrode-controlled circuits, resonated objects

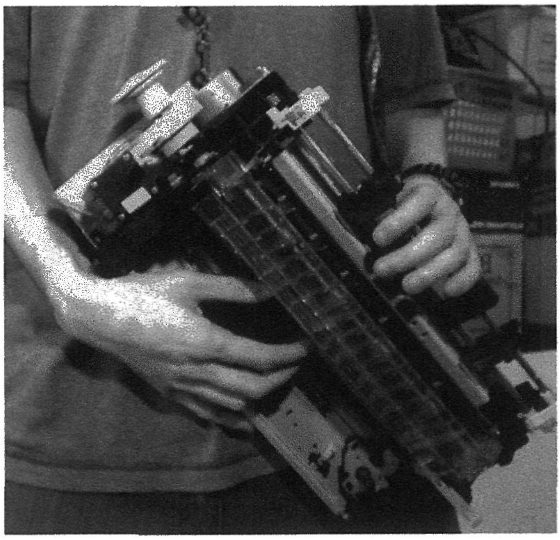

Figure 30.20
"Printar," Dan Wilson.

Figure 30.21
Thumb piano with electromagnetic drivers, Dan Wilson.

large (lampposts) and small (mbiras) with electromagnetic feedback (see Figure 30.21), and, very briefly, persuaded a pair of hedgehogs to play a zither in his back garden.

Alex Baker (UK) has created a number of pieces that explore the interaction of sound and mechanical forces. His "Wind Powered Record Player" (see Figure 30.22) is an acoustic gramophone whose platter is turned by the wind. In "Catch" a ping-pong ball is tossed into the air by a speaker cone pulsed with sound. Transducers attached to the heads of his "Autonomous Drum Kit" transform the skins into reversible microphone/speakers: first they are used to record sticks striking the drums; then they are reversed to play back the recorded sound through the heads, evoking a ghostly, phantom drummer.

Douglas Repetto (USA) was instrumental in setting up Dorkbot ("for people doing strange things with electricity to get together to talk about their work") in New York in 2000; subsequently, satellite groups have sprung up all around the world. For years

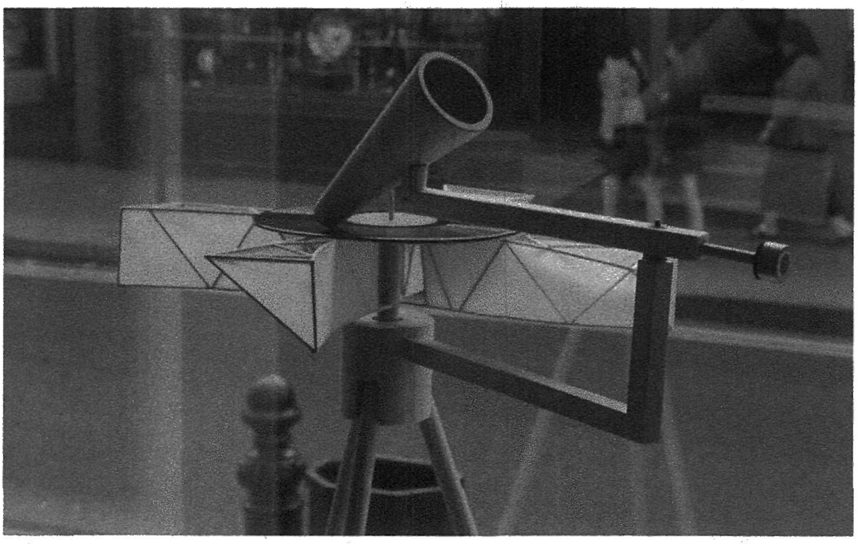

Figure 30.22
"Wind Powered Record Player," Alex Baker.

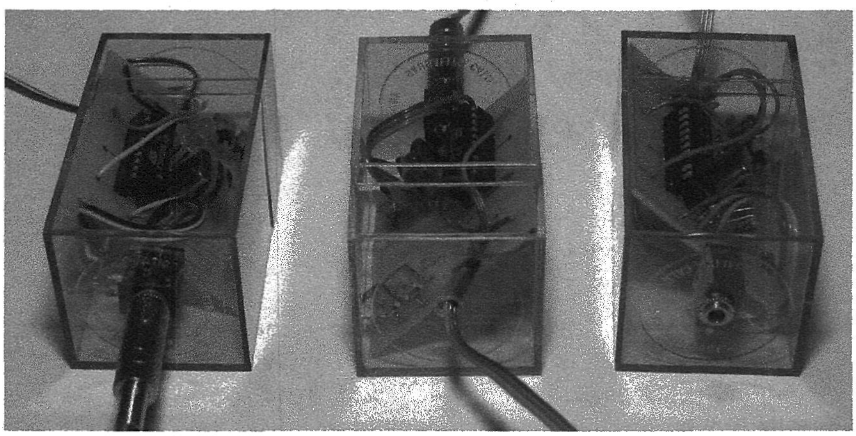

Figure 30.23
Three of 42 circuits from "Crash and Bloom," Douglas Irving Repetto.

he has been at the radical fringe of hacking culture as an educator (he is director of research at Columbia University's Computer Music Center), organizer, inventor, and prolific artist. In "Crash and Bloom" 42 identical small circuits emulate the cycle of growth and collapse of certain biological systems (see Figure 30.23). For "Fuseboxes" Repetto built miniature noisemaking circuits into 20 tiny tin boxes from fuses. "Slowscan Soundwave" attempts to make sound waves visible by translating air pressure patterns in a room into the movement of suspended plastic sheets.

Like Repetto, Phillip Stearns (USA) evokes the biological world in his impossibly complex "AANN" (Analog Artificial Neural Network). Stearns soldered up 50 identical neuron-simulation circuits, interconnected them, and ended up with a "squid baby" that responds to sound and light by "lighting up like a Christmas Tree" and "shrieking like so many dying seagulls" (see Figure 30.24). For his "Burlap" series Stearns wove circuitry into fabric for exhibition on a gallery wall (see Figure 30.25). Stearns' video work, using both digital and analog technology, was described earlier in this chapter.

Electronic components, as small as they are these days, are not quantum—a change of scale and the mysteries of what had previously been the lowest level of operation

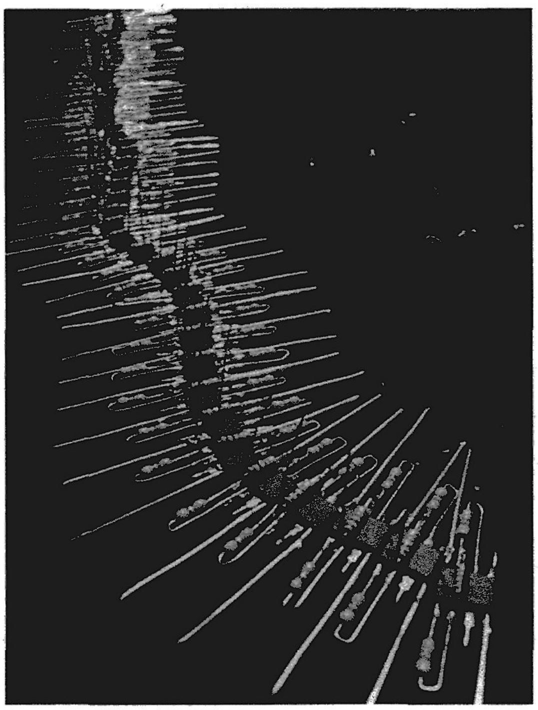

Figure 30.24
Series of neuron subassemblies from "AANN," Phillip Stearns.

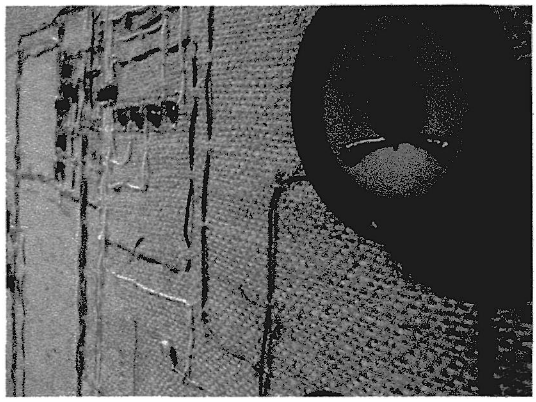

Figure 30.25
Detail from "Burlap-II," Phillip Stearns.

become tangible, touchable, hackable. Some artists experiment at this component level. Patrick McCarthy (USA) makes his own potentiometers with cardboard, safety pins, and pencil lines. Nyle Steiner's (USA) website, "Spark, Bang Buzz," guides viewers through making their own diodes from zinc, using a flame as an amplifier, listening to a drop of salt water, building TV picture tubes and lasers from scratch, and other esoteric projects. Substituting cozily familiar materials for the arcane can have a humanizing effect: Peter Blasser (USA) builds circuits on sheets of paper, rather than fiberglass circuit boards. Grégoire Lauvin has created several gallery installations that use live plants as capacitors in oscillators, causing the pitch world to change as the plants grow (see Figure 30.26); he's also built a beautiful "Potato Organ" whose notes are tuned by impaling vegetables and fruits on nails emerging from the instrument's housing (see Figure 30.27).

THERE IS NO CONCLUSION

But there are anecdotes. Here's one: a few years ago I was conducting a hacking workshop at a very high-tech European music research institute. The group was made up of composers, computer programmers, acousticians, and electronic engineers. Real smart people. One student got very confused as soon as we started breadboarding our first oscillator. I asked if he was by any chance either dyslexic or a conservatory-trained composer (two population groups for whom matrix topology seems unusually vexing).

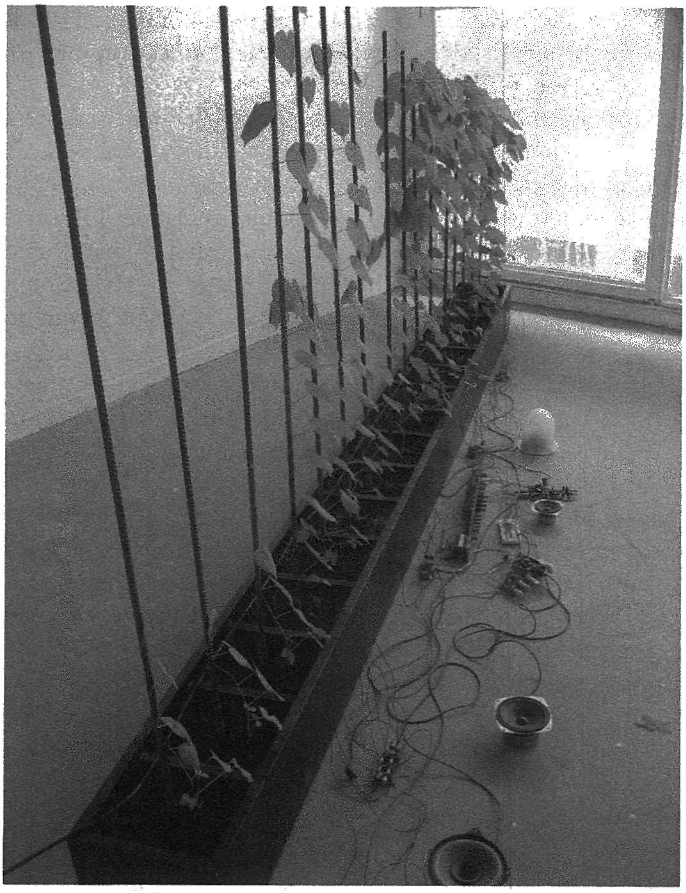

Figure 30.26
"Bio Oscillator,"
Grégoire Lauvin.

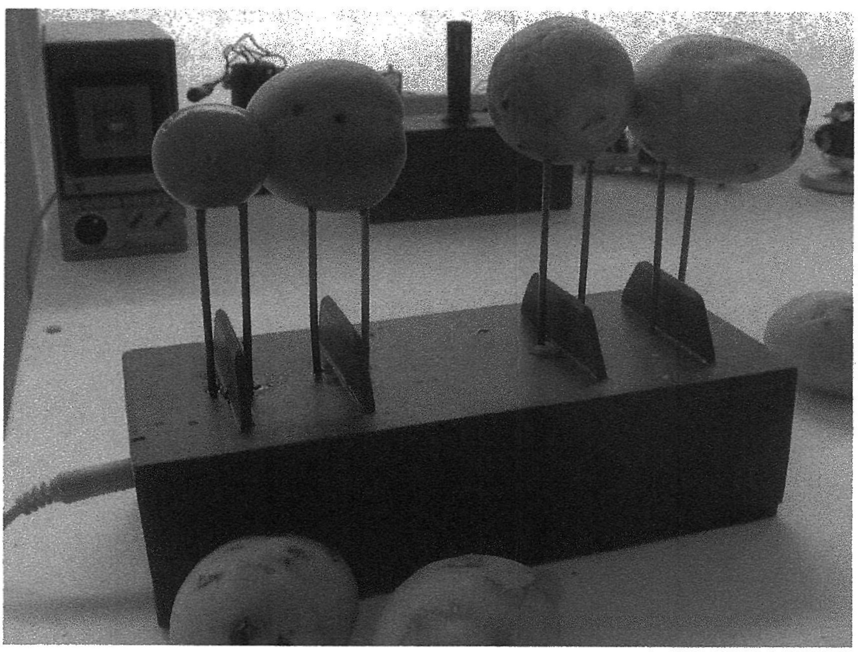

Figure 30.27
"Potatoes Organ,"
Grégoire Lauvin.

"No," he replied cheerfully, "I'm an electronic engineer. I designed a complete Digital Signal Processor for my senior thesis, but I did it all with software on a computer—I never actually touched a chip before today."

My engineer is not alone. Sociologist Richard Sennett observed that after computers became ubiquitous in the 1980s "we tended to forget the importance of physical senses." Or, as Bill Burnett, Executive Director of the Product Design program at Stanford University, put it: "a lot of people got lost in the world of computer simulation." Burnett goes on to add the all-important truth that "you can't simulate everything." That simple and obvious idea—that there is a world before and beyond simulation—has become ever more important as simulation has snaked its way into more and more of our waking hours.

The material world is now making a comeback. *Make* magazine, the de facto journal-of-record for hackers of all stripes, boasts a paid circulation of 100,000 and 2.5 million visits per month to its web site. Bug Labs, a recent New York-based startup, sells Lego-like components that let the user snap together GPS receivers, cameras, LCD displays, motion detectors, and other sub-modules to design and build their own digital products; the company "envisions a future where CE stands for Community Electronics, the term 'mashup' applies equally to hardware as it does to Web services." A West Coast activist who goes by the name of Mr. Jalopy has drafted a "Maker's Bill of Rights," advocating that "meaningful and specific parts lists shall be included," "batteries shall be replaceable," etc. "I want companies to start thinking about shared innovation," says Jalopy, "to realize that they're not selling to customers, but to collaborators." The software giant Adobe invited Gever Tulley, who normally teaches children at his Tinkering School in Montar, CA, to get their designers to put down their mice, pick up their screwdrivers and make *things*. "The physical act of making things helps the whole person," says Tulley.

The first edition of *Handmade Electronic Music* was intended as an invitation to reach out and collaborate with commodities, and as an introduction to those pioneers who had been doing so since the dawn of the silicon age. All puns intended, it seems to have touched a chord, or at least to have bumped one string of an ongoing arpeggio. Today there's more to listen to, more to look at, more to learn, more pages in this book.

There you have it: 30 chapters of circuits, suggestions, and glimpses of the work of some of the most interesting artists ever to confront a clip lead or soldering iron. The rest is up to you. Run inside and play.