3 Live electronic music

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It is perhaps a general human habit to view the technological and the organic as opposites. It is certainly the case that the phrase 'live electronic music' strikes many a music fan as oxymoronic. Isn't the purpose of electronics to do things for us so we don't have to do them 'live' ourselves? To record, perfect and play back performances so we can listen while cycling stationarily? To facilitate the creation of inhumanly intricate compositions that spew themselves out of speakers at the touch of a button, instead of all that messy sliding about on strings? While there is no question that composers of tape music and computer music (and a fair number of pop music producers as well) have employed electronics to exactly these ends, electronic technology has another, and possibly more profound power: enabling new and volatile connections. Don't think Edison, think Alexander Graham Bell. Since the 1930s (well before the advent of tape) composers have been using this property of electronics to produce not just new sounds but fundamentally new approaches to organising the sonic world.

Pre-history

Electronic music has its pre-history in the age of steam. In 1897 Thaddeus Cahill patented the Telharmonium, a machine that weighed in at over two hundred tons and resembled a power station more than a musical instrument. It generated sine tones with dynamos, played from an organ-like keyboard. Cahill understood that electricity could provide not only sound but a means of distribution as well: the Telharmonium's sounds were carried over the telephone lines that were beginning to be laid in major cities, intended for playback through speaker systems in restaurants, hotel lobbies and homes of the rich. Cahill envisaged a subscription-based music service, not unlike that of the Muzak corporation thirty-seven years later, but unlike pre-recorded Muzak, the Telharmonium was an instrument that had to be played to be heard.[1]

Better known today is the eponymous electronic instrument of the Russian inventor Leon Theremin, created in 1920. Theremin rejected traditional instrumental interfaces such as keyboards, frets or fingerholes, and introduced the first 'free air' gestural controller. The Theremin was played

by moving one's hands in the proximity of two antennas (one controlled pitch, the other affected volume), effectively incorporating the player's body mass into the circuitry. Popularised by a number of charismatic performers (most notably Clara Rockmore), the instrument became the physical embodiment of futuristic sound: in film soundtracks it evoked psychosis and flying saucers, and in pop songs it shifted from ghoulish to groovy (it is the signature instrument in the Beach Boy's 'Good Vibrations'). Though marketed as an instrument that could be played by anyone, it proved to be extremely difficult to play *well* – a fact that limited its popular use.[2]

The Theremin established the paradox of, as well as the paradigm for, the 'Electronic Instrument': it looked and sounded modern, but somehow lacked the legitimacy and substance of more conventional instruments. Other early electronic instruments such as the Ondes Martenot (1928) and the Trautonium (1928) were similarly incorporated into a few works of chamber and orchestral music by some composers of note, and played evocative roles in film soundtracks, but it wasn't until Laurence Hammond's development of the electric organ that bears his name in 1935 that an electronic instrument was generally accepted by the musical public, and it did so by making inroads into broadly popular, rather than elitist, genres – it might be electronic, but it was a workhorse equally adept at playing Hindemith, hymns, polkas and jazz.

These early electronic instruments were just that: they made new sounds but did nothing to change the nature of musical composition or performance. 'Tape Music', which didn't arise until some fifty years after the Telharmonium, did represent a fundamental rupture with older modes of composition, but its roots lay in the film tradition of pre-scripted editing and montage, rather than in live performance. [3] Tape Music embodied a kind of high Modernist desire for extending composerly control and independence. But, beginning in the late 1930s quirky composers began using electronic tools to exploit serendipity on the stage as well.

John Cage

The most radical musical use of electronic technology did not rely on specialised instruments such as the Theremin, but on the rapidly expanding realm of consumer flotsam that characterised mid-twentieth-century America. John Cage established himself early in his career as an innovator not only of musical forms but of instrumental resources as well. In 1939, after several years of writing for ensembles of homemade percussion instruments, he began working with live electronic sound in *Imaginary Landscape No. 1* (1939), scored for piano, a large Chinese cymbal and two turntables

equipped with records of test tones. Cage asked the performers to manipulate the pitch and rhythm of the tones by changing turntable speed, spinning the platter by hand, and dropping and lifting the needle. Though vehemently uninterested in pop music, Cage can be credited with inventing the Disc Jockey as a stage performer.

Cage scored his piece for a common household appliance, though a Theremin might have produced a similar sound. It was a statement of circumstances (Cage could not afford a Theremin) but also of principle:

> Most inventors of electrical instruments have attempted to imitate eighteenth- and nineteenth-century instruments, just as early automobile designers copied the carriage. The Novachord and the Solovox are examples of this desire to imitate the past rather than construct the future. When Theremin provided an instrument with genuinely new possibilities, Thereministes did their utmost to make the instrument sound like some old instrument, giving it a sickeningly sweet vibrato, and performing upon it, with difficulty, masterpieces from the past . . . Thereministes act as censors, giving the public those sounds they think the public will like.
>
> (from the 'Credo' of 1937, reproduced in Cage (1966), pp. 3–4)

Cage's ambition, by contrast, was to give audiences the world and allow them to pick and choose.

A decade later Cage turned his attention to another commonplace appliance with *Imaginary Landscape No. 4* (1951) for twelve radios. In keeping with his growing interest in indeterminacy, the score meticulously notates movements of the tuning and volume controls, but does not pretend to govern the actual sound material received and heard in any given performance. The result elegantly demonstrates the difference between *chance*, as Cage would have it – setting up a fixed compositional structure that forces one to listen to unpredictable sound – and *improvisation*, where the performer is free to choose sounds on the basis of personal preference. Cage never stopped writing for more conventional instruments (he once explained to me, 'If I don't write for these virtuosos they'll have to play music by even worse composers'[4]), but he explored electronic resources extensively in the 1950s and 60s. The very instability of the electronics of the time, and the unpredictable output of his re-purposed appliances, made technology a critical partner in his experiments in indeterminacy.

Cage turned again to the record player in *Cartridge Music* (1960), but this time stripped the pickup out of the tone arm and asked performers to DJ *without* records. The stylus is replaced with anything small enough to fit in its socket – a spring, a twig, a guitar string, a broom straw, a pipe cleaner, etc. When amplified, these unassuming objects produce sounds of astonishing complexity and richness: tiny objects emit low marimba-like tones, and

simple springs evoke the reverberation of a church. In keeping with the novelty of the instruments employed in the piece, Cage forwent a fixed score in favor of a 'kit' of transparent overlays – a wiggly dotted line, amoeba-like blobs, dots, circles and a clock face – with which the performers assemble their individual parts. The graphics specify the distribution of actions over the course of a performance – when and how to play or change an object, adjust the volume or tone control, etc. The piece can be of any duration, for any number of players, using any kind of objects to produce sound through the cartridges. Given that playing a phonograph cartridge requires no traditional musical skill, interpreting the score presupposes no musical literacy, thus matching a radically new instrument to a correspondingly innovative approach to scoring.

With the significant role of chance in arranging the overlays in *Cartridge Music*, performers sometimes find themselves carrying out absurd instructions: futilely twiddling something in a cartridge when the volume is completely off, or raising the level so high that shrieking feedback obliterates everything else. But as Cage blithely advises in the score, 'all events, ordinarily thought to be undesirable, such as feed-back, humming, howling, etc., are to be accepted' (Cage 1960). Cage's acceptance of electronic accident was a sign of things to come. Feedback became the ur-sound of chance: it erupted whenever composers hooked up sound systems without the benefit of technicians; it opened The Beatles' 'I Feel Fine' with a 'pwwwwaaaaooooiiiiinnnnnnnngggggggg' in 1964, and then went on to become a defining element in rock music from Hendrix to Lordi. In the tightly proscribed world of pop it became the bad-boy way to insert the irresponsible and unpredictable. Cheap, loud and only somewhat controllable, it possessed a seemingly wilful independence that, in the 1960s, echoed the spirit of the times. But it wasn't just noise, it had *content* – feedback traced in sound the movement of a microphone or speaker, and it revealed the resonant frequencies of rooms, musical instruments, mouths, culverts and barrels. For many composers influenced by Cage, such as those in the Sonic Arts Union, feedback also suggested a *method*, a way of organising or controlling sounds, and served as the first step onto the electronic stage.

Sonic Arts Union

In the mid-1960s, even as European tape music and serialism were flourishing, at least in academic circles, Cage – arguably the most inventive composer of the twentieth century – was still performing for tiny audiences in lofts, chapels and armories. Cage may have had little institutional support, but his pragmatic approach to technology, combined with his desire to

re-infuse music with risk, was profoundly influential on younger American composers. In 1966 Robert Ashley, David Behrman, Alvin Lucier and Gordon Mumma formed the Sonic Arts Union for the performance of their own compositions, most of which used live electronics in a distinctly post-Cagean mode.

Behrman's 1966 composition, *Wave Train*, exemplifies the legacy of *Cartridge Music*'s repurposing of commonplace technology, amplification of small sounds, and incorporation of feedback. Loose guitar pickups are placed on the strings of a grand piano and connected to guitar amps under the soundboard, which are turned up to the point of feedback. The result is a loud mix of guitar-like feedback, amplified piano, and percussive rattling as the pickups bounce on the strings. The pitch material can be nudged (if not actually controlled) by moving the pickups to different strings, and the audience is drawn into this cock-eyed cause-and-effect as they watch arms messing about inside the piano and hear the unpredictable results. Behrman also built his own electronic circuits, favouring arrays of multiple copies of relatively simple circuits that combined to form surprisingly complex textures. By 1974 he had constructed an extraordinary homemade synthesiser with dozens of oscillators, a rudimentary sequencer and pitch-detecting circuits. Stepping through a series of lush chords in response to pitches played on a cello, *Cello With Melody Driven Electronics* (1975) was a harbinger of the interactive computer music of the next decade. For the cellist and audience alike it was utterly unexpected to hear electronic sounds react so directly to acoustic ones in an era when a fixed tape was the default method for adding electronics to a solo instrumental composition.

Even before David Behrman, Gordon Mumma was one of the first American composers to build his own musical circuits, designing sophisticated analogue computers that produced and processed sound in reaction to input from acoustic sources and electronic controls. In *Hornpipe* (1967) a player 'rings' the performance space with a French horn, seeking out the strong resonant frequencies of the room (much like finding the best notes to sing in the shower), while filters in Mumma's homemade 'Cybersonic Console' zero in on these pitches, and gradually increase in gain and resonance until they start to oscillate, spilling feedback-like shrieks through the sound system. Unlike more traditional electronic instruments such as Theremins or oscillators, Mumma's circuits produced no sound of their own – without the French horn and the architecture to complete the network, the Console was mute.

Ashley's work with the Sonic Arts Union was a mix of theatre, spoken word and electronics. The performer in *The Wolfman* (1964) controls very loud feedback by shaping his mouth in front of a microphone to form a series of acoustic resonators that force the feedback to shift to different

pitches. In the 1972 piece *In Sara, Mencken, Christ and Beethoven There Were Men And Women*, Ashley recites an epic poem by John Barton Wolgamot which purports to list the names of all the important people in the history of the world. Via a complex patch on a Moog synthesiser (programmed by composer Paul De Marinis) that responds to the inflection of Ashley's voice, the composer attempts to translate into electronic sound the very formal, somewhat fugue-like structure of the poem.

For Lucier electronics were a tool for articulating acoustic phenomena, and sometimes social ones as well. In *Vespers* (1969) blindfolded performers carry 'Sondols': flashlight-sized devices, designed as navigational aids for the blind, which emit sharp clicks in emulation of the sonar mechanism of bats. By listening to the returning echoes as they 'sweep' the performance space with the Sondols, the performers attempt to gauge the size of the room and detect and avoid obstacles as they echolocate their way across the space. The audience hears the acoustic traces of this (literally) pedestrian task, a sort of stippled sonic portrait of the architecture. Once upon a time a composer's responsibility had ended with the manuscript paper, and the player's with the bell or belly of the instrument; anything that happened after sound left the instrument was down to the architecture, and beyond the control of composer or musician. But in *Vespers* Lucier usurps the architect by attempting to compose the very movement of soundwaves in space. In his best-known work, *I am sitting in a room* (1969) Lucier records his voice, then plays it back through speakers, and re-records it in the same room through the microphone; he plays back this second recording, and again records it through the microphone; he plays back and re-records this third recording, as before; over and over he repeats the process, twenty or more times. With each generation the words become less intelligible as the acoustic properties of the room emphasise certain pitches at the expense of others until all sense of language is lost in a string of undulating tones. Where *Vespers* renders in sound an image of the concert space itself, *I am sitting in a room*, like a seventeenth-century Dutch portrait of a contented citizen surrounded by his prized possessions, brings into public space an acoustic picture not merely of a different room, but of man in his private world.

Living with tape

Lucier's piece demonstrated for the audience how tape could be used to parse a gradual process and reveal the detail in its stages, rather than simply presenting the final product. In the 1960s tape – the essential tool of studio-based music from Stockhausen to the Standells – was reinvented as a performance instrument. Tape delay systems were used by a number

of composers to create realtime counterpoint from live performance. Two reel-to-reel tape decks would be set side by side on a table; a reel of tape would be placed on the leftmost machine and threaded past the heads to a take-up reel on the second machine; the first deck would be set to record and the second to play back; as the tape moved from one deck to the other, sounds recorded on the first would be heard from the second at a delay corresponding to the distance between the machines and the tape speed (a fifteen-inch separation between decks running at seven and a half inches per second yields a delay of two seconds; a fifteen-foot gap would produce a delay of twenty-four seconds).

In works such as *I of IV* (1966) Pauline Oliveros built up thick abstract textures from simple oscillator tones that panned back and forth, reverberated, and accumulated in layers as they fed back from the playback deck to the record deck (Oliveros 1984, pp. 36–46). The delay feedback retained and extended every adjustment made to the oscillators, and having to put up with the consequences of her actions for several minutes put Oliveros in a contemplative state – her tape delay pieces are characterised by small changes over long periods of time. Terry Riley used a similar two-deck delay to provide accompaniment to improvisation on soprano saxophone and electric organ in pieces such as *Poppy Nogood and the Phantom Band* (1969) and *Rainbow in Curved Air* (1970). Riley's work was highly melodic in comparison to Oliveros, and he used the delay accumulation to build up canonical counterpoint that favoured modal playing. For both composers the delay system served initially as a novel performance instrument, but had greater long-term significance as a *listening* tool: the sustained textures, drones and modal, just-intoned harmonies led both Riley and Oliveros into deeper investigation of non-Western music and culture. In the 1970s Riley began many years of serious study of North Indian singing, which greatly influenced his own compositional style. By the 1990s Oliveros had fused her electronic work, her background as an accordionist, and her interest in meditation into her 'Deep Listening' music project, which relies on both computer programs and unusually reverberant acoustic spaces (such as underground reservoirs, caves, etc.) to replicate and extend the effects of her original delay system.

In 1965 Steve Reich began experimenting with a simple and elegant idea: when two identical tape loops of speech were played on two decks running at slightly different speeds, unusual sound patterns would emerge from the interaction of the loops as they slipped out of phase, moving from perfect synchronisation, through flanging-style filtering effects, to distinct rhythmic counterpoint. He created two studio compositions based on this effect (*It's Gonna Rain*, 1965, and *Come Out*, 1966), after which he looked for ways to achieve similar effects with conventional instruments (as a composer his

primary interest lay in live performance, not tape composition). In *Violin Phase* (1967), Reich retained the tape loop, but added an instrumental part. In preparation, the violinist records a ten-note, twelve-beat figure that is cut into a tape loop. As this loop plays back, the violinist doubles the part, initially in perfect sync, then – after increasing his speed by a tiny amount – gradually slipping out of phase with the loop until, after five minutes, the violin is four beats ahead of the recording. A second loop, four bars out of phase with the first (and in sync with the violin) is faded up, and the violinist spends a few minutes mimicking the 'chalk talk' – the inner voices that appear as a result of the interaction between the two loops, which Reich likened to optical illusions such as those in the work of M. C. Escher. The violinist repeats the slippage process against the second, and later a third, loop. With *Piano Phase* (1967), for two pianos, Reich abandoned tape entirely and moved on to techniques whereby players could produce 'phase music' without recourse to electronics. As with Oliveros and Riley, experimenting with tape had revealed musical vistas that extended beyond the technology. Today Reich is one of the most visible American composers of large-scale multimedia operas, but artefacts of the tape loops can still be heard in his current works.

Gavin Bryars took a droll approach to phase music in his 1971 composition, *1, 2, 1-2-3-4*: each musician in a small ensemble was given a cassette player, a pair of headphones, and a cassette of the same piece of music. After starting tape playback on cue, the musicians mimic their respective parts on the tape as best they can. Given the inconsistencies in speed between the various machines and the impossibility of all the tapes starting in perfect synchronisation, the musicians gradually drift apart, producing phase patterns similar to those in Reich's work, but with a few critical differences: the source music is often in an 'easy listening' style, and the instruments are somewhat out of tune with one another because of the vagaries in the cassette playback speed, puncturing the potential for pomposity implicit in any avant-garde enterprise, and embracing the idea that *chance* can produce both Zen and slapstick.

Composing inside electronics

The beauty of the tape recorder, as demonstrated in Bryars' piece, is that it can be found and played by anyone. But as Mumma and Behrman had shown, there was something to be gained from getting inside actual circuitry. Just how much could be gained became evident in the career of David Tudor. Tudor started out as a virtuoso pianist of the avant-garde, premiering compositions so technically demanding they were deemed 'impossible' to play,

such as Pierre Boulez's *Deuxième Sonate pour Piano*. By the early 1950s Tudor was serving as pianist for the Merce Cunningham Dance Company (whose approach to movement closely paralleled the work of its musical director, John Cage), and assisting in the realisation of Cage's own electronic pieces. Over the next ten years Tudor gradually abandoned the piano and emerged as the first virtuoso of electronic performance – he treated a phonograph cartridge or electronic circuit with the same seriousness of intent and dextrous musicality as he had the piano. Tudor underwent a two-part metamorphosis: from pianist to electronic performer, and then, in the mid-1960s, from performer to composer in his own right. Expanding on Cage's exploration of 'found' technology, Tudor embarked on the arduous process of acquiring enough knowledge of circuit design to construct his own new instruments. He believed that new, object-specific, intrinsically *electronic*, musical material and forms would emerge as each instrument took shape: 'I try to find out what's there – not to make it do what I want, but to release what's there. The object should teach you what it wants to hear' (Schonfeld 1972). This clearly stated ethos of music *implicit* in technology served as a paradigm for much American electronic music of the 1970s.

Beginning in 1968, Tudor composed a series of pieces under the title *Rainforest*, which culminated in *Rainforest IV*, a work developed at a workshop in Chocurua, NH, in 1973. The principle underlying *Rainforest* is that of sounds played through transducers fastened to solid objects, which filter, resonate and otherwise transform the sounds; the processed sounds are directly radiated by the transduced objects, which serve as 'sculptural speakers'; contact mikes on the objects pick up the vibrating surfaces of the objects, and these micro-sounds are mixed and heard through ordinary loudspeakers around the space. *Rainforest* exists in a twilight zone between a concert and an installation: the players sit at tables mixing sounds sent out to a maze of twittering objects, through which the audience is free to wander. With an open-form score that encouraged experimentation in the design of both sound generators and resonated objects, the piece was a creative catalyst for a number of young composers, who subsequently formed a loose collective ensemble called 'Composers Inside Electronics'. Over the next twenty-eight years this group served as a laboratory for artist-designed circuitry and electronic performance, presenting dozens of installations of *Rainforest IV* worldwide, as well as performances of works by individual members of the ensemble.[5]

Tudor, along with other 'first generation' composer-engineers, had had to confront the baffling world of transistors in order to build their instruments, but by the early 1970s Integrated Circuits (ICs) had transformed the landscape of electronic design. ICs grouped transistors and other components into affordable, Lego-like functional modules that contained ninety

per cent of a functional circuit – a circuit, moreover, designed by someone who really knew what he was doing. The remaining ten per cent could be filled in by non-engineers swapping notes and browsing hobbyist magazines. A musical community formed around this exchange of information. In addition to the 'Composers Inside Electronics', it included students of David Behrman and Robert Ashley at Mills College in Oakland, CA; of Alvin Lucier at Wesleyan University in Middletown, CT; of Serge Tcherepnin at California Institute of the Arts in Valencia, CA; and others scattered throughout the USA and, more thinly, Europe.[6]

Some participants were naïfs or muddlers who designed beautiful, oddball circuits out of ignorance and good luck. Ralph Jones encapsulated this spirit in *Star Networks* (1978), which asks performers to build circuits on stage according to a configuration that forces almost any selection of components into unpredictable but charming oscillation, neatly bypassing any need for a theoretical understanding of electronics on the player's part. In defiance of the conventional wisdom of using oscilloscopes and other test equipment as a visual aid to the design process, in *Star Networks* the instruments are designed by ear alone, and the audience follows every step of the process by ear as well. Other composers proved sublimely talented, if idiosyncratic, designers: Paul De Marinis included bits of vegetables as electrical components so his circuits would undergo a natural ageing process (*CKT*, 1974); incorporated sensors that responded to a person's electronic field (*Pygmy Gamelan*, 1973); and built 'algorithmic' music composing circuits that anticipated later trends in computer music (*Great Masters of Melody*, 1975), one of which was intended to be played by a bird (*Parrot Pleaser*, 1974).

While the American electronic music scene of the 1970s was characterised by a homespun, but rhapsodic, high-tech ethos that embraced seat-of-the-pants performance, in Europe a well-established state-funded tradition of collaboration between composers and technicians perpetuated the production of meticulously crafted tape music in studios. Live performance with homemade music circuitry erupted in odd pockets nonetheless. Andy Guhl and Norbert Möslang formed the Swiss duo 'Voice Crack' in 1972, and over the next thirty years honed their skills at 'cracking' everyday electronics, which included circuits for extracting sound from blinking lights, radio-controlled cars, radio interference, and obsolete Dictaphones. Dutch composer Michel Waisvisz developed a series of synthesisers played by direct contact between skin and circuit board, culminating in the battery-powered, paperback-size, highly portable 'Cracklebox' in 1975. The tactile quality of these gizmos made them extremely expressive, often dramatic performance instruments, which Waisvisz used primarily in improvisational and theatrical situations.[7]

The rise of the computer

The exact moment when 'circuits' grew into 'computers' is hard to pinpoint: composer-designers like Mumma had been building what were essentially analogue computers for sound since 1960, and the same digital ICs that went into 1970s computers were being used in discrete musical circuits at the same time. Music had been produced on massive mainframe computers (those room-sized things with flashing lights and spinning reels) as early as 1949, but this music was made to be recorded directly onto tape in academic computing centres (Dornbusch 2005; McCartney 1999, pp. 163–4). The machines themselves were not seen on stage until the advent of affordable, portable microcomputers in the late 1970s. Cajoled by the visionary Bay Area artist Jim Horton, a handful of musicians invested in the Kim-1 – a single A4-sized circuit board that looked like nothing so much as an autoharp with a calculator glued on. There was no high-level software available, so every action had to be programmed in machine language, the very low-level instructions that the Central Processor Unit must execute to accomplish anything from adding two numbers to emitting a beep. It could be an arduous, counterintuitive, headache-inducing process, but it offered one great advantage over soldering circuits: it was easier to correct a mistake by re-programming than by re-soldering.

Moreover, even computers as crude as the Kim-1 had memory (one kilobyte of RAM!) and could execute sequential logical operations. These features enabled the creation of instruments that could make ad hoc decisions based on past incidents, a feature of particular interest to composers drawn to the quixotic unpredictability of live performance. Rather than just give more control to the composer, computers extended Tudor-esque electronics: a clever programmer could add attributes of the performer to the hybrid of instrument and score that had come to exemplify circuit-based instruments.[8] Over the next decade Apple, Commodore, Atari, Radio Shack and other companies introduced machines whose increasing sophistication and expanding software base gradually reduced the angst of programming. Homemade circuits by and large faded into anachronism.

Despite the musical potential of computers, however, the ASCII keyboard (even when augmented by the introduction of the Macintosh mouse in 1984) was essentially a typing tool, and a poor performance interface compared to Cage's cartridge or Waisvisz's Cracklebox. In 1983 MIDI (Music Instrument Digital Interface) was introduced as a digital protocol for interconnecting synthesisers, which made it possible to connect a basic organ-like keyboard to a computer, but for some musicians even this was not expressive enough. Considerable energy was spent on the design of novel 'alternative controllers' starting from the late 1980s, most notably at STEIM in Amsterdam.[9] In 1987,

for Australian musician Jon Rose's 'Space Violin', STEIM engineers attached an ultrasonic distance measuring device and a hair-pressure sensor to his bow. Wired up to a tiny computer, the system translates the movement of the bow – whether rolling across the strings or fencing with Paganini's demons (as was Rose's occasional wont) – into electronic accompaniment to Rose's acoustic improvisation. This remora of an instrument frees Rose from ever having to touch a computer keyboard, and instead extracts extra musical expression not only from the ordinary gestures of playing the violin, but from a new vocabulary of movement across the concert stage.

From 1991–4, STEIM, together with freelance designer Bert Bongers, helped Laetitia Sonami build various versions of her 'Lady's Glove', an eveningwear take on a virtual reality controller. In her text-centred performances, Sonami uses the glove to translate hand gestures into computer-generated accompaniment for her storytelling. In my own 'trombone-propelled electronics' (begun in 1988) I coupled the slide of an old trombone to part of a computer mouse, attached a small keypad to the slide, affixed a compact loudspeaker to the mouthpiece, and connected the whole thing to a homemade digital signal processor. The slide acts as an overgrown mouse: by pressing buttons on the keypad as I move the slide I can adjust various sound parameters in a program that samples and transforms sounds 'on the fly'; these sounds play back through the speaker and come out of the bell of the trombone – they can be acoustically filtered by moving the slide or using a mute, or bounced off surfaces in the room by aiming the trombone. I wanted a computer instrument with a self-contained acoustic quality that would blend well with other more traditional instruments, for use in both composed work (such as *Tobabo Fonio*, 1988, based on processing Peruvian brass band music) and improvised settings (such as the forty-two short duets on my 1989 CD, *100 of the World's Most Beautiful Melodies*).

Working in the real world

In the 1980s, almost half a century after Cage put the first DJ on the stage, the turntable finally achieved broad cultural recognition as a performance instrument. In the hands of musicians as different as Grandmaster Flash and Christian Marclay, it became the most visible – and occasionally the most overtly virtuosic – electronic instrument of the 1980s and 90s. Building on techniques used by club and radio DJs during the Disco era, and by Jamaican toasting DJs such as Kool Herc, Flash (Joseph Saddler) invented, perfected or popularised several of the turntable techniques that formed the core of 'hip-hop' DJ practice, including scratching and back-cueing for rhythmic emphasis, and cutting between two copies of the same record to extend passages

(he installed a switch in his mixer to facilitate rapid cross-fading).[10] In the early 1980s Marclay established his reputation as the premier 'Downtown' DJ through his work with John Zorn and other improvising musicians. Marclay favoured a more abstract, less rhythmically driven style, as befitted the looser music of the downtown scene, often performing with four or more turntables ('hip-hop' DJs typically worked with two), using stickers to force records to skip in repetitive loops, drilling off-centre spindle holes that wobbled the pitch of the record, and collaging together pie-like slices from several records to create thumping musical sequences. The notion of 'playing' records actively rather than passively finally came into its own. Recently, younger DJs such as France's Erik M have merged the Marclay and Flash traditions by combining extended, experimental technique with a strong pop sensibility; and for sheer virtuosity it's hard to beat 'turntablism' as practised by the Invisible Scratch Pickles, a Bay Area turntable quartet. In 1999 it was widely reported that turntable sales exceeded those of electric guitars,[11] although most turntable playing these days is used to create a seamless, beat-matched sequence of tracks, with the occasional discreet scratched accent on top – less about performance per se than replaying the music of others.

Searching for life after vinyl, and intrigued by the possibility of corrupting the new and supposedly 'perfect' medium of the Compact Disc, Yasunao Tone began 'wounding' CDs in 1984 with the skilful application of Sellotape. When played back, Tone's CDs fulfill a Cagean dream of an indeterminate record: the output is a torrent of glitches and micro-fragments of the original recording, and while |<< and >>| can be used to encourage the laser to move to different parts of the CD, the damaged CDs often display a wilful disrespect for direct control. Several of my own compositions also depend upon misbehaving CDs, but for pieces such as *Broken Light* (1991) and *Still Lives* (1993) I modified the CD players, rather than the CDs themselves. Hacks to the circuitry allow performers to draw out recordings (typically of early baroque music) into a sequence of slightly irregular, glitch-accented skipping loops, against which they play their acoustic instruments. The musicians familiarise themselves with the original recordings and their scores, but can never be sure exactly where the next loop will land, which lends a certain tension to the performances.[12]

Some composers chose to engage the messy physicality of the real, analogue world in ways antithetical to the innate precision and often cubicle-constricted countenance of the computer. In one of the sweatiest pieces of electronic music ever composed, *Speaker Swinging* (1982), Canadian Gordon Monahan's three performers whirl blaring speakers around their heads. The viscerally three-dimensional Doppler-shifting tornado of sound emanating from three glistening spandex-clad youths has no equivalent

Figure 3.1 Live performance of *Speaker Swinging* at the Music Gallery, Toronto, 1987. Time exposure shows several revolutions of the speakers with light bulbs attached. Speaker Swingers are (clockwise from top left) Bruce Mau, John Oswald, Sandor Ajzenstat. Gordon Monahan at the sound controls (photo by Dwight Siegner)

in the digital domain. For *Mini-Fan Music* (1992), German sound artists Jens Brand and Waldo Riedl placed handheld fans next to a dozen string instruments strewn around the performance space; the fan blades strum the strings until the batteries run down (typically three to four hours with cheap batteries), the droning sound field slowly changing as the fans slip along the floor and lose speed. In *Humbucket* (1990) Dan Farkas connects a guitar cord to a chain of two dozen guitar effect pedals (bought at Brooklyn stoop sales), and plays the hum of his thumb on the end of the jack as he stomps on their switches, building up layers of distortion, echo, wah-wah, equalisation and myriad other effects.

Circuit bending

Underlying all this stomping and swinging and strumming remains the circuit – the thing that makes Electronic Music electronic. And while the geniuses in Silicon Valley and China have made circuits ever more beautiful and mysterious, sealed with stickers that sternly warn 'no user serviceable

parts inside', there are those who see these things not as finished products but as raw material. Reed Ghazala started publishing articles on what he dubbed 'Circuit Bending' in the influential (if quasi-underground) journal, *Experimental Musical Instruments* in 1992.[13] Ghazala incited readers to transform inexpensive found electronics, such as toys and cheap keyboards, by connecting wires between various points on the circuit board at random, until one either induced an interesting new noise or the toy blew up. Circuit Bending tries hard to preserve the innocent enthusiasm of accidental discovery, and discourages spoiling the process with theoretical understanding. It emerged as the perfect antidote to the deterministic world of computers, which had come to dominate all aspects of music production, replacing manuscript paper, tape recorders, mixers, effect boxes and instruments. Circuit Bending is also a truly international movement, with active practitioners on every continent, thanks largely to the use of the World Wide Web as a forum for the open sharing of information.[14]

Phil Archer is representative of the emerging generation of benders, who effortlessly combine bent circuits with Tudor-era contact mike technology and even sophisticated computer programming. Archer did a 'classic' bend to his Yamaha PSS-380 keyboard: exposing the circuit-board, placing the inverted instrument on the performer's lap, and making arbitrary connections between components on the board in live performance. As he writes:

> These connections induce tones, bursts of noise and corrupted 'auto-accompaniment' sequences from the device which are unpredictable in their details but generally 'steerable' overall with practice. The precision and control afforded by the standard keyboard interface is eschewed in favour of direct contact with the circuit, and the performer is continually forced to rethink and re-evaluate their relationship with the instrument in light of the sonic results.[15]

The future present

The first years of the new millennium have seen the rise of grassroots movements in electronic music as diverse as Circuit Bending (with its emphasis on wilful damage to found circuitry) and Phonography (the gentle art of recording interesting acoustic environments) – movements that often blur the distinction between pop and avant-garde, and between music and reportage. More and more art – video, sculpture, film, web art – now incorporates sound, which is no longer the exclusive material of music. The 'Dorkbot' movement ('People doing strange things with electricity') has united hackers in the analogue and digital domains of visual and sonic art.

Their monthly meetings in cities around the globe are occasions for musicians, artists and tinkerers to share their work – performances, installations, videos, web sites, or pure research – all presented to a live audience. Multimedia artists Tali Hinkis and Kyle Lapidus (known collectively as LoVid) perform and create interactive installations with bent and homemade video systems, building graphic synthesis circuits into soft sculpture and bar tables. Nintendo and other game systems have become hacking targets of artists such as the Beige collective (Cory Arcangel, Joe Breuckman, Joe Bonn and Paul Davis) – their unauthorised cartridges, requiring active engagement by the player, take performance off the public stage and into the private space of the home. With over a century of electronic history behind them, some younger artists are creating wonderful hybrids of modern and 'ancient' technology. Lorin Edwin Parker recently built a steam-powered synthesiser: he coupled a small steam engine to an electric motor and wired the motor terminals to a speaker; when the motor spins it produces electric sound much the way the Telharmonium did 120 years ago.

And to state the obvious, the World Wide Web has become an invaluable resource for music. Peer-to-peer file exchange has made self-publishing and self-promotion affordable to anyone and, to the chagrin of major labels, greatly increased the public's access to a wide range of recordings. Web sites and e-mail have replaced the inefficient samizdat-style hand-to-hand exchange of information that characterised the first wave of composer-designers, and have facilitated the rapid, global, free dissemination of answers. The Web has also become a venue for the performance of music beyond that of bar-hopping avatars. Sergi Jorda and others have developed software that allows people anywhere in the world to collaborate on group composition and improvisation. In *Global String* (1998) Atau Tanaka and Kaspar Toeplitz stretch several yards of heavy string across a room in each of two cities. Vibration sensors and computers link the strings to each other through the Web. Visitors to either site can pluck the real string in their real space; a computer calculates the pitch and overtones of the enormous virtual string connecting them through cyberspace and plays this sound through speakers in each location.

But the very non-corporeality of the Web has served to highlight the significance of actual physical performance. Rather that disappearing in an onslaught of software, circuits handled by hand continue to insinuate themselves into the fabric of music-making – sometimes it's still nice to reach out, touch a sound, and be surprised. As composer-performer-bender Sarah Washington says, echoing David Tudor from four decades earlier, 'I am an improvising musician . . . the choice of sounds is down to the circuit – whatever it comes up with is fine by me.'[16]

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