Electronic Friends: David Tudor and Live Electronic Music

by

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**Introduction**

"In my electronics, I work with an instrumental principle. You're completely right in saying that. They become my friends. They have personalities, that only I see, because of my use of them. It's an act of discovery. I try to find out what's there and not to make it do what I want but to, you know, release what's there."\(^1\) - David Tudor

David Tudor is best known today as the post-war avant-garde’s premier pianist, performing definitive versions of the works of John Cage and Karlheinz Stockhausen, among others, but in the mid-1960s he abandoned his piano work and began constructing idiosyncratic electronic sound-generating systems out of repurposed commercial equipment and circuits of his own design. Rejecting the Moog synthesizers of the day as dull and predictable, Tudor always created music on his own terms, finding and releasing the voices hiding in circuits, becoming a Composer Inside Electronics, to use the name of Tudor’s working group of circuit-building musicians. Thanks to the work of Ron Kuivila, a Tudor collaborator, artist, and my advisor for this project, the full collection of David Tudor electronics has been archived in Wesleyan’s Electronic Music Studio as part of Wesleyan’s World Music Instrument Collection. Having the electronics in front of me to tinker with and explore, I decided to do a study of Tudor’s live electronic works, using his original equipment wherever possible while incorporating the influences of my work with circuit-bending, handmade analog circuitry, found sound, the noise subculture, and live electronic music performance practices.

My work with electronic music began with my discovery of circuit bending in

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high school. Simply by putting my fingers on the exposed circuitry of a cheap children’s keyboard, I unleashed a secret universe of internal electronic sounds that was never intended to be heard. Circuit bending, the creative short-circuiting of inexpensive toys and consumer electronics to produce glitches, and new sounds, pioneered by sound and visual artist Reed Ghazala in the 1960s, requires little technical knowledge and is more akin to learning to play a traditional instrument – “the laying of the hands”\(^2\) upon an exposed circuit board is the primary way bends are discovered and played\(^3\). I began to teach myself basic soldering and electronics to be able to better take advantage of these sounds, building control surfaces for interfacing with these “bends”. Eventually, I began searching for other hidden sounds – and found them in the electromagnetic, high-power world. I began to walk around the Wesleyan campus with a Walkman on play with no tape in it – the activated magnetic tape head allowed me to hear electromagnetic interference in the audio range from underground wires, laser printers, and computers, and I began to glimpse into a parallel world - an expanse of undiscovered sound waiting for curious explorers to develop the ears to listen in.

My work in discovering hidden sound continued with “Piece for Human Filters”, a composition for Ron Kuivila’s Composing Experimental Music class. I used the human anal cavity and mouth as resonant filter processors for a recorded reading of Whitman’s “I Sing The Body Electric”, played out over the surface of my body through a moving speaker. The performance caused a stir when a speaker I was using started smoking and squealing from being overloaded by an amplifier, an

\(^3\) Audio Example 1
incident I recalled with pleasure when I read about Tudor’s experience setting an
speaker on fire in Buffalo, New York during a performance of his composition,
“Toneburst”.  

My work has always been about exploring systems for unheard possibilities,
trying to “release what’s there” as a beautiful sound from its confines inside an
electronic circuit so that other people can experience the joy in sound that I do.
Tudor’s work can be seen as proceeding from the circuits themselves as a
compositional process - working through possibilities, accepting chaotic results, and
letting the electronics do the talking. As Nic Collins, a circuit hacker and instrument
builder describes it, “the circuit is the piece.”

My thesis work has taken David
Tudor’s electronics as a starting point to reveal a new sonic universe with endless
possibility for exploration.

**Tudor and “Toneburst”**

The realm of electronics, entered into in the spirit of discovery, can give the musician a new world. Electronic components and circuitry, observed as individuals and unique rather than as servo-mechanisms, more and more reveal their personalities, directly related to the particular musician involved with them. The deeper this process of observation, the more the components seem to require and suggest their own musical ideas, arriving at that point of discovery, always incredible, where music is revealed from "inside", rather than from "outside".⁵ – John D.S. Adams

My study of the David Tudor electronics encompassed the materials he used for his two signature live-electronic pieces, “Untitled” and “Toneburst”, as well as a number of commercial guitar pedals that were used in his setups for later pieces during the 1980s⁶. In these pieces, Tudor used feedback networks, built up from a variety of handbuilt electronics designed by Tudor, Gordon Mumma, and others, as well as some commercial effects processors (i.e. guitar “stompbox”-style effects pedals).

Tudor released the internal sounds from components such as phase shifters, equalizers, and gain stages, using the principle of feedback oscillation.

By feeding the output of several processors back into themselves, sound synthesis is achieved.

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through feedback oscillation will often occur. Feedback oscillation is the most direct way to listen in on the internal workings of processors that were never meant to produce their own sounds. The resulting sounds can be completely different from the way a component processes sound in its normal fashion.

The most common outcome in creating a feedback loop like this is a creating a static tone. Tudor’s constant concern in generating sound was that the feedback systems he patched together didn’t “take off”, in the way a guitar feeding back from an amplifier does. 7 In “Untitled”, Tudor used phase shift (moving a wave’s phase from 0 to 360 degrees out of phase with itself) and ring modulation (performing addition and subtraction to two waves against each other) to break up two feedback loops to create more dynamic, chaotic sounds. Still, Tudor was forced to use prerecorded samples of his feedback system as source material to process, because the system had become too complex, and achieving an interesting result during performance with live sound was difficult.

“Toneburst”, a later piece, used only one feedback loop as source generation material, to simplify the task of controlling the system from “taking off” and generating static tones. Tudor was thus able to realize his idea of performing entirely live, without prerecorded material. The signal from one loop was then processed through several different sets of processors, giving Tudor several different finished signals to choose between and “use” in a performance by sending out through a speaker. 8 Tudor’s attention to speaker placement is well documented, and he would often use four or more channels of sound in performance. Using a switching matrix

8 Audio example 2
to choose any of several signals and send them to different speakers, Tudor could create
tremendous variety and layering of different sounds in a shifting texture that could move through a room. By equalizing the signals to different critical bands of the audio spectrum, Tudor could place many sounds of different amplitudes at audible levels in a space.\textsuperscript{9}

\textsuperscript{9} Personal conversation with Ron Kuivila, Wesleyan University, October 2008
Instrument Building, Hacking, and “Universal Ports”

It's important to consider Tudor not only in terms of his innovations in composition, layering, and structure, but as an instrument builder. Tudor worked with many commercial components, such as guitar effects pedals as gain stages and equalizers, but he also built his own processors. By building processors instead of tone generators, Tudor and his collaborator, Gordon Mumma, a composer in his own right, were allowing for many potential uses of their components and many potentially different behaviors in unpredictable feedback systems.

Phase Shift/Switch Equalizer
Tudor constructed an unpowered resistor-capacitor (RC) matrix with a switch for each RC circuit and a potentiometer to mix processed level with clean level. An RC circuit, the simplest in electronics design, acts as a low-pass filter, blocking signals below a certain wavelength determined by the values of the components. RC circuits also act as phase-shifters, so Tudor could use this component as both a phase-shifter (with each switch specifying a different phase shift) to “break up” a static or locked audio signal, and as a filter. Passive components also open up possibilities for running a signal in both directions:

[Tudor] recognized that the standard arrangement of "inputs" and "outputs" on some of the components could be used more as universal "ports". He found that if he connected certain circuits together backwards (using the output as an input and vise-versa), unpredictably exciting results would often occur.10

-Gordon Mumma

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Mumma’s splitter is essentially the opposite of an active mixer – it takes one audio signal and splits it into four outputs with independently controllable levels of gain. This allows a single signal to be sent back into a system in many different ways, creating more potential new sounds.
The Gordon Mumma ring modulator is a standard ring of diodes that sums and takes the difference of two inputs, with a difference – the source inputs to be ring modulated can be changed. An input can be compared to itself, both inputs compared to each other, or both inputs compared to themselves and each other. Ring modulating two signals that were close in frequency would result in a high-frequency sum, and, significantly, a low-frequency difference tone that could act as a pulse trigger in a feedback loop.
Noise, Feedback, and Subculture

Feedback loops have been adopted by many in the “noise” musical subculture, most famously Japanese artist Merzbow.\(^\text{11}\) Since Throbbing Gristle, the performance art/noise music collective in the 60s and 70s, noise artists have adopted the do-it-yourself ethos of punk, which can be seen in independent music distribution networks, record releases, and, significantly for this paper, instrument building. Instrument building in the noise community is driven by a lack of funds for expensive synthesizers as much as a search for new sounds. As a participant and observer in the noise scene, I’ve become interested in the potential for broader experimentation in noise suggested by Tudor’s work with feedback loops and handmade electronics. Although “noise” as a genre has existed for at least thirty years, it has only recently emerged from deepest underground status, thanks to the networking of thousands of geographically distant noise artists and fans through online message boards and discussion groups.

Noise is posited by participants as against genre, a space where all is permitted:

To quote a well-known and respected noise artist: ‘The best part of doing something this creative or experimental or noisy is actually doing it. Part of the process is experimentation.’ This cannot be closer to the truth about what the essence of noise music is. Noise projects like Hijokaidan were founded on the premise of "anything goes" and any musical rules need to go out the window. Noise music is based on freedom of musical expression without any formal convention. (Though one may say that the idea of such liberated music is a defining aspect of what noise music is).\(^\text{12}\)


Despite this self-conception, noise, as a genre, shares generic standards of sound with other youth subcultures. In his work on the extreme metal scene, also primarily an online subculture, William Berman notes the use of signifiers to denote a recording that adheres to generic conceptions, such as “brutal” and “kvlt”. For example, sounds such as drum blast beats and “low-pitched, growling sounds” act as reference points to judge the degree to which a recording is “brutal”, and therefore, “in opposition to the ‘danger’ of the mainstream.”

Similarly, noise recordings that hold the sonic landmarks of the genre are praised as “harsh”, “droney”, or “atmospheric”. “Harsh”, in particular, connotes noise authenticity, and is linked to high-frequency filtered bursts of white noise and screamed vocals. Generic standards and praise for these ideals encourage noise recordings that share these attributes, rather than experimentation.

Interestingly, these signifiers can be applied across genre to any recording that shares sonic similarities with noise. In a post on a noise message board, Aaron Dilloway, former member of Wolf Eyes, a well-known noise band, places works of the American avant-garde in the context of subculture by commending their “harshness”:

ROBERT ASHLEY -the WOLFMAN from fucking 1964 !!!!! check this one...GETS HARSH AS FUCK! ... MAX NEUHAUS - John Cage's Fontana Mix Feed Fuckin 1958 !!!!!!!! intense feedback drone!!

14 ibid., p. 64.
15 Audio examples 3, 4
Noise seems to significantly differ from other musical subcultures, and be similar to online subcultures such as extreme metal, in placing sound at the forefront of its self-definition. Since live concerts are infrequent or never occur in many cities where subcultural participants live, recorded material (unadorned, often decontextualized sound from nearly-anonymous artists) traded online is the genre and subculture. In this way, Robert Ashley is a noise artist\(^{17}\), by virtue of making genre-compatible sounds (proto-noise, to noise fans), in a way that the Kinks, proto-punks though they were, will never be considered a punk band.

Another consequence of the dearth of live concerts is the acceptance of (often highly processed) recorded material as an artist’s most authentic output, as evidenced in this message board post:

> For the most part, I have to agree … about "live" releases. I'm aware that there are a few artists who are articulate and skilled in "no overdub, stream of consciousness" recordings, but even those don't interest me as much as pieced-together compositions and sonic mosaics.\(^{18}\)

Obviously, this situates noise, for the most part, outside the realm of live electronic music. Putting sound at the forefront of generic definition has resulted in a fairly well-defined class of noise instruments: distortion guitar pedals, contact mics, white noise generators, and oscillators. King Capitol Punishment’s Glamour Box, a four-oscillator tone generator, provides an example of an instrument whose sounds are the embodiments of the generic ideal:

> The glamour box facilitates a wide range of maddening sounds ranging from sick static to modulating volcanic eruptions which are shoveled into all-out

\(^{17}\) Audio Example 5
sub-thunder explosions, and grated high frequencies. The glamour box has an external audio input that smashes incoming signal inside of the two sweepable oscillators creating a vortex of intense distorted schizophrenic undulations.  

Noise also has an experimental strain, however, of artists influenced by circuit bending, rather than sonic-signified goals. The work of two Baltimore-based artists, Nautical Almanac, and Ciat-Lonbarde, exemplify this trend.

The work of Nautical Almanac as sound artists, creators of the record label Heresee (pronounced “heresy”), and electronic sculptors is idiosyncratic and unparalleled in noise. A fascination with repurposing obsolete technology, in the manner of post-apocalyptic scavengers of consumer devices, pervades their work. Performances and recordings are improvised: member Carly Ptak says, "We spend

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20 Audio example 6
our performances trying to find our sounds. Circuit bending serves as a jumping-off point for other primitive explorations in analog sound technology: Nautical Almanac release their own lathe-cut records “with caveman scientist styled edges”.

Plexiglass double lathe-cut record with two centers.

The circuit-bender-as-performer and artist takes on the persona of an explorer through somewhat unknown sonic territory, rather than an enforcer of generic standards and sounds. The work of Peter Blasser (Ciat-Lonbarde synthesizers), an instrument builder who caters to the noise community, incorporates the influence of

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22 Audio example 7
24 Audio example 8
circuit bending into his circuit design. Blasser builds complex, interacting banks of oscillator and modulator circuits, then essentially bends them himself by finding sensitive points in his own circuits and moving them to the playable surface of the instrument as patch points that can be touched or alligator clipped together to produce new sounds.

Like Tudor’s work, Blasser’s circuitry has many potential uses that can be discovered by the user, including those that were never intended by the maker. Blasser’s Sidrassi Organ consists of seven tone bars, which produce tones when touched, as well as 42 contact points, which are pulled from the circuit. The contact points can also act as "universal ports", in the manner of Tudor - any can be used as a signal in or out to allow the circuit to interact with other circuits.\textsuperscript{25,26}

![Sidrassi Organ](image)

Online reviewers of the instrument confirm its multi-functionality:

I have a few noisemakers, and all of them have an interface that consists of switches and knobs...they're all just variations on a theme. The sounds produced are informed / limited by the way in which you activate the controls.

\textsuperscript{26} Audio Example 9
Not bad, just the way it is. I was frankly skeptical of the playability of the bars, and all the talk about how this interacts with the electrical field of the body. But, it's all true. You can tap the bars like a percussion instruments, you can slide your fingers across them, and at certain settings, I'm convinced even waving your hand next to them will produce sound.²⁷

Although there is an obvious way to play the unit (touching the bars), users are encouraged to discover other layers of functionality, because the interface is open to different kinds of input. The box also comes with no instructions, which I can only assume to be a philosophical decision on the part of Blasser to allow users to discover their own idiosyncratic ways of interacting with the device. Functionality is not "random" in the sense of a circuit bent toy glitching in unpredictable ways, but there is an element of not being in control and finding unexpected inputs to the device.

There is a mysticism to do-it-yourself electronics that one finds in Tudor’s work, as well as circuit-bending. Circuit bending in particular relies on an idea that the complexity of electrical interactions on a circuit board is a chaotic force best left a mystery.

Ghazala calls his program to teach circuit-bending “anti-theory”, both against the neat physics of textbook electronics, and suggesting an irrational force governing electricity, allowing circuit bending to exist. The very appeal of circuit bending is the fact that the circuit is not known or understood, and cannot be understood in the misused fashion in which benders repurpose it, hence the possibility for unexpected sounds to come to light – random gibberish, new tones, or secret internal functions.²⁸


²⁸ Audio Example 10
Ghazala emphasizes the alien-ness of circuit-bent sounds, and sees the connection between human-as-electrical-being and instrument as a synthesis through touch:

The circuit-bent instrument, often a re-wired audio toy or game, is an alien instrument: alien in electronic design, alien in voice, alien in musician interface. Through this procedure, all around our planet, a new musical vocabulary is being discovered. A new instrumentarium is being born...Body-contacts are also found through circuit-bending. These allow electricity to flow through the player's body, flesh and blood now becoming an active part of the electronic sound circuit. This interface extends players and instruments into each other, creating, in essence, new life forms. An emerging tribe of bio-electronic Audio Sapiens.\(^{29}\)

Hacking toys is one thing, but how can one design using this approach, when everything on a board must be understood in order to function? Blasser’s approach of allowing the user to bend his instruments is one way; another is working beyond the expected operational capacities of a component, which is often what Tudor did in creating feedback loops – using familiar components in unexpected ways.

Blasser claims to build without intention as a way towards new discoveries in chaotic electronic sounds:

To make a shinth [one of Blasser’s instruments], you must eliminate all intentions or hierarchy or goals. In electronic design this is difficult because practicality has overwhelmed the field- there are no wandering paths in it anymore, just straight ones to a well defined goal. This "goal-oriented" design has penetrated the whole field of electronics, so that hierarchical thinking marks every stage of the process; the design process has a hierarchy (plan, test, build), as well as the object designed (input, process, output) … Designing a shircuit, you get lost; as you experiment with the materials, they suggest their own systems, and you forget why you're doing it in the first place. It's like staring at an object until it becomes a non-object …The shinth is made up of a web of shircuits: non-circuits make up a non-synthesizer. I made a board of them, and then connected them until I didn't know what was going on...\(^{30}\)


Tudor’s claim that the electronics become his friends seems to reflect the approach of the modern electronic artists I have discussed – although for Nautical Almanac, Ghazala and Blasser, these secret voices seem more genuinely spiritual – an electronic/shamanic divination from the mysterious world of electrons! Despite its limitations, I believe circuit bending opens up possibilities for exploration in the noise scene otherwise obscured by genre-derived sound goals.
This piece constituted the major result of my study with the Tudor electronics. It began as an attempt to build a system, using only the Tudor electronics, that behaved similarly to Tudor’s Toneburst patch, creating pulsing tones with unpredictable behavior. I also limited myself to EQ, gain, and phase shift pedals, to remain true to Tudor. My initial configurations of simple pedal feedback loops were frustratingly boring – most locked quickly on a single tone.31

My breakthrough in creating more complex sounds was parallel feedback loops. I created two similar feedback loops, and sent each output to each input. When these loops interacted with each other, they would behave in unpredictable ways,
sometimes modulating each other’s signals, creating new sounds unfamiliar to either of the original loops, or just noise.  

Interestingly, parallel feedback loops interacting are also the functional basis for Chua’s Oscillator, an easily constructed but chaotic electronic system whose behavior cannot be predicted.  

Early in my work, I decided to come up with a novel way of re-patching any system I built on the fly, as a way both to quickly test potential combinations of feedback loops, and a performance strategy. Without a concept of piece and 

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32 Audio example 14, 15, 16, 17
composition, I decided that any music I wrote for my system would proceed from the circuit I constructed.

In his systems, Tudor worked with re-patchable systems in performance with a switch matrix to make and break connections between signal processors and create new sounds during performances. Tudor’s music proceeded from this switching and re-patching, allowing him to dramatically change sounds and structure a piece in terms of “events”, rather than masses of sound.

My previous work with feedback loops had always involved static patches of electronics. A weakness of working with a static patch is that sound events punctuated by silence are nearly impossible – the patch doesn’t change, so the only changes that can be made are parameters of the system, usually controlled through knobs. Every sound created in a static patch much be “traveled” to by adjusting settings in a system. A rapidly re-patchable system would help move the sound mass of my feedback system from an evolving sound-mass drone to a landscape of individual sound events.

I decided to build a touch patch-bay that could be used for this purpose, intrigued by the gestural possibilities of touch in transforming electronic music. The STEIM Cracklebox, a touch interface for a simple oscillator circuit, provided the main inspiration. All sound on a Cracklebox is produced through finger combinations on its six touch pads. The Cracklebox further situates itself in the physical music world with the omission of an audio output jack – sound can only come out of the onboard speaker, so it is necessarily based in physical space.$^{34}$

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$^{34}$ Audio example 18
The creator of the Cracklebox, Michael Waisvisz, observed that his touch interface had immediately located the instrument’s sounds in the realm of the acoustic, since they were controlled by human fingers:

We noticed that listeners to radio programs that broadcasted our early experimental electronic touch concerts did not believe the sounds were generated electronically. To them it sounded like wood and metal. They seemed to be able to distinguish the motoric 'shaping' and did not associate these with electronic music. Electronic music was at that time (in to some degree still is) shaped by mathematical functions… Composers acted like managers of formulae and processes.  

The touch patch bay design was also informed by a touch panner designed by Don Buchla, synthesizer maker to Morton Subotnick and other electronic music pioneers of the 1960s and 70s. Buchla’s panner uses an idiosyncratic touch matrix with five contact points. Touching anywhere on a sensor generates five control voltages, used as amplitude envelope generators for five output channels. I hadn’t considered touch panning before as a performance strategy, but gestural control of signals made sense...

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for a complex system involving four channels of sound.\textsuperscript{36}

Buchla touch panner

Tudor’s pieces always incorporated multiple channels of sound, to great effect. Tudor used devices like the Lowell Cross “strirrer” – a passive signal distributor for mixing four signals (or splitting one four ways)– or simple 4-channel photocell mixers he built.

I built the touch sensor as a way to simultaneously test, compose for, and eventually shape my patch of the Tudor electronics – prototyping was minimal, and my feedback loops spread out from the touch sensor at the center. This idea of composing from three directions – aesthetic intention, sonic goals, and circuits – would inform the shape of the piece I wrote for the Tudor electronics and my touch controller. In the repurposing spirit of circuit-bending, I built my touch controller into a recycled graphic equalizer, and reused the frequency faders as fine-tune resistance controls for the touch sensors. The touch box had ten finger sensors, which would let current pass through my body when multiple sensors were touched, and vary in resistance based on pressure and sweatiness of the fingers. The etched corners of the sensor were grounded to reduce hum in the system.
Analog touch patch bay for 10 line-level audio signals.
I began by constructing three feedback loops, connected through the touch box that were capable of tone generation, using phase-shift, equalization, and gain guitar pedals from the David Tudor collection. This took up six of the ten slots on my touch interface. Each feedback loop’s output went to its own speaker, and I added a fourth speaker that was an equalized sum of whatever signals were playing, pulled from a Signal Merge Matrix I constructed, which was simply a grid of audio jacks wired together.

This construction allowed not only re-patching of all the loops, but distribution of each feedback loop, processed by half of another loop, to any speaker.
This mode of operation, I discovered later, was nearly identical to Tudor’s “Toneburst” system, where a single tone-generating loop is processed by different effects going to different channels, resulting in a diversity of sounds.

This also meant patching and panning were inextricably linked together, a built-in function of the system I exploited to give each sound a “location identity” with a speaker placed in space. Because each speaker had its own processing that a signal had to pass through, it would have its own sonic identity, allowing the audience to associate different filtering with different speakers and locations in the room, adding a sonic and spatial link to each gesture performed on the touch controller.

To add to the complexity (and chaos) of the system I added additional components that could be patched in individually, via a touch pad, to change any loop – the Tudor phase-shifter/low-pass filter, the Mumma ring modulator, and the Lowell Cross “stirrer”, which combined processed versions of each feedback loop with a pre-recorded version of the system.\textsuperscript{37} The recording was a guaranteed way to inject interesting material into the system if it was either “locked up” or wasn’t doing anything of interest, in the manner of Tudor in “Untitled”.

\footnotetext{37 Audio example 19}
Complete feedback system, "Futuree Toneburst Universe"
“Futuree Toneburst Universe” patch diagram (see page 6 for key)
I built two touch identical touch boxes, conceiving of the second one as a control interface for a patch for Supercollider, a computer music programming language. I used an Arduino microcontroller as an analog/digital converter for Supercollider to interact with the touch sensor.

I was interested in the space between analog sound and digital sound, and making both analog and digital systems sound like a middle space between the two. Rod O’Connor ’08 worked with me to code a Supercollider patch to produce these sounds. My original conception to realize these sounds was to essentially code the analog feedback system I was constructing into Supercollider, using digital feedback functions. This proved impossibly complicated, and ultimately unnecessary – much in the way that a touch interface moved the Cracklebox from the sonic world of analog synthesizers to the physical world of acoustic instruments for listeners, my digital touch interface moved Rod’s Supercollider patch from the digital world to the “middle space” between analog and digital – the articulations used on this system simply could not be associated with preconceived ideas of “digital” sound to the listener. During our rehearsals, Rod and I, performing on our respective touch controllers, sometimes had to ask each other whose sounds were whose – an extraordinary testament to the “middle space” we have moved both our systems towards.

A glitch on the Arduino microcontroller also meant that no control voltage was independent – there was a significant amount of “bleed” onto adjacent control voltages. The patch was simple – six control voltages from the touch interface were used to control attributes of sound in Supercollider, such as pitch, timbre, and
waveform, so this “bleed” meant that all the parameters were connected and moved with other when the interface was touched, an unintended but welcome parallel to the unstable world of analog electronic signal bleed\textsuperscript{38}. Another unintended consequence

\textsuperscript{38} See Appendix A for Supercollider code.
of this construction was the extreme sensitivity of the touch pads – mere proximity
could pass voltage, so the unit could be played like a theremin. Conversely, an
indelicate touch could crash the Supercollider patch, in the same way that the analog
system could “crash” through a bad patch. The result was that performing using the
touch sensor required a physical finesse and skill in articulation not usually associated
with computer music.
Realization

At a certain point very early in my work, the Tudor system I constructed became too complicated for me to operate myself. I decided to write for three performers – a toucher, who would patch using the touch sensor, a mixer, who would control signal levels, and a technician, who would manipulate the Tudor electronics. My original conception was a collaborative piece, based on a Nic Collins piece, “Ands”, for two performers collaboratively producing sound. Collins built two parallel circuits that were designed to sound when performers performed the same action at the same time:

The form of the piece results from relationships that develop among the players in performance. The primary score is the circuit itself.  

I decided to use one of Cage’s parameter-based “Variations” pieces as the source material to perform collaboratively. “Variations II”, the piece I focused on, is written for any instrument. The performer/interpreter uses transparent plastic sheets with dots and lines to determine numeric values specifying pitch, timbre, amplitude, length, and complexity, of as many sound events as the performer would like. As James Pritchett notes in his essay on Tudor’s performance of “Variations II”, Cage imagined a virtual synthesizer, with knobs specifying each parameter, as the instrument to be played. The numeric values, in Cage’s conception, would correspond to actual values in terms of Hertz or decibels on whatever instrument was played. However, given the complexity of the system I had constructed, performing

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in this manner was impossible – and actually counterproductive to allowing my unpredictable system agency and a voice of its own, my original intention.

As James Pritchett notes in his article on Tudor’s realization of “Variations II” for amplified piano, Tudor faced the same difficulty, and broke with Cage’s conception of the piece by rewriting a score for himself that specified tendencies, rather than values, for parameters. Thus, a frequency could be low, mid, or high, and actions could be “simple” or “complex”. In doing this, Tudor was allowing for the possibilities of unexpected results in the complex feedback system of a multiple-miked piano, and moving his own realization towards actions to be taken, rather than concrete sound goals. These actions were conceived to bring out the unpredictability of a chaotic system, rather than acting within a strict Cagean world of specified sound. I realized that forcing my own chaotic system to perform strictly parameterized sounds was actually limiting its range, rather than expanding it, as Tudor also discovered:

Unless there is a formal structure the performance is like performing the possibilities which are in front of you. And so what's in front of you becomes the composition. And then going on from that, you choose among the possibilities what you want to appear, and then it's the task to make those things appear. So if they don't appear at one time, they might... then you try another time. The initial choice is, how much variety you wish there to be. So you try to make it happen or you try to arrange for it to happen. That's what I do.\(^4\)

To explore all of my system’s possibilities and allow for unexpected sound events, I abandoned collaboration in favor of separate action-based scores for each performer. Like Collins’ piece, I consider the circuit to be the “true” score of the

piece, and written scores performance aids. I wrote visual scores for touch sensors and mixer, which gave specific physical/gestural directions to performers. There scores required no interpretation on the part of the performer – they were direct specifications of physical interactions to take with the touch sensors.

Drawing on my experience circuit-bending, and treating the touch sensor as a circuit board one could “bend”, I came up with a list of physical actions one could perform in the realm of touch: tapping, sliding, varying pressure, proximity, and moving in predetermined patterns. A set of simultaneous actions was notated, along with a start and stop time within a thirty-second bracket. Thus, silence was notated between each event, although the scores for the digital system and the Tudor system were time and gesture-independent of each other, so complete silence was rare.

The mixer score was written with the Tudor idea of creating a shifting soundscape of many small and large sounds, with some existing under the surface (but always present) until they were brought to perceptible audio level and revealed. I gave myself the task of live calibration of the Tudor electronics to ensure a diversity of sounds and to prevent the system from locking on a specific frequency.
Gestural score for digital touch interface in *Futuree Toneburst Universe*
Mixer score for four channels of sound, *Futuree Toneburst Universe*
I have been working with reel-to-reel tape delay and feedback systems for the past four years. With this piece, I constructed the most basic tape feedback system – one record head, one playback head and one microphone. Audio from the microphone is recorded on the first reel-to-reel player, and is then played back at a delay of several seconds on the second player. The length of the delay is determined by the distance between the reel-to-reel players.

For this piece, I used the lesson of the Tudor electronics – parallel feedback systems interacting produce more interesting results – and thus constructed two parallel tape delay systems. The idea was to create an electronic music based purely on motion – movements of microphones and movements of tape. Feedback between the microphones and speakers builds up, and can then be articulated and shaped.
through these movements. Any sound produced in one system is replicated in the second system after a short delay, then returns to both systems, acoustically equalized based on room resonance in the manner of Alvin Lucier's piece "I am Sitting In A Room". Sounds intrinsic to the tape machines -- hum, bleedover from motors running, and tape hiss - are all amplified and manipulated in the absence of source material other than feedback. Manipulating the tape by bending, tapping, and touching can produce tonal material that will then be delayed and filtered, bouncing back and forth between speakers on subsequent playbacks.

A score dictated movements for a performer with two microphones, and another scored dictated my tape manipulations. The piece succeeded as completely transparent, physically intelligible electronic music – and revealed the richness of simple parallel systems interacting in a subtle, multi-layered sound event mass. The incredible richness of live tape delay/feedback music, as opposed to musique concrete or John Cage's tape splicing pieces such as “Williams Mix” has been extensively explored in the early music of Pauline Oliveros. Her pieces "Big Mother Is Watching You", as well as "I of IV", from 1965, utilize banks of oscillators and live feedback systems to create complex textures. I challenged myself to make the most interesting and complex sounds with the simplest setup, as a counterpart to my enormously complicated Tudor system. The piece used many of the same articulatory strategies of my other piece – dynamics changes, “breaking up” a signal (in this case, by wiggling the tape), and a motion-based scoring strategy that allowed for unpredictable sound results.

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Audio example 20
Score from *Physical Electronic Music*. Yellow and blue lines indicate microphone movement; red and green, tape stretching.
Conclusion

My experience working with the David Tudor electronics changed my approach to electronic music. Tudor’s approach to his electronic feedback systems in terms of spacing, dynamics, and concept was completely unique, and I feel as if I only touched the surface of analyzing his materials, technically and conceptually. I used only a small segment of Tudor’s equipment in preparing this project – my constraints of time and knowledge of electronic circuits prevented me from more in-depth exploration of the systems used in his other pieces, as well as some of the “Toneburst” and “Untitled” materials. Hopefully, other Wesleyan students will be attracted to Tudor’s mystique, and the idea of finding new sounds, as I was – and continue to study the electronics of this composer.
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Sound Example Track Listing

1. Brendan O’Connell, circuit-bent example: “Galaxy Guitar”
2. David Tudor, excerpt from “Toneburst”
3. Incapacitants, “I Hate Derivatives”
4. Wolf Eyes, “Human Animal”
5. Robert Ashley, “The Wolfman”
6. King Capitol Punishment, Glamour Box example
8. Nautical Almanac, lathe-cut CD recording
9. Peter Blasser, Sidrassi Organ example
10. Reed Ghazala, “There is a Secret Garden” excerpt
11. Brendan O’Connell, *Futuree Toneburst Universe* feedback loop 1
12. Brendan O’Connell, *Futuree Toneburst Universe* feedback loop 2
13. Brendan O’Connell, *Futuree Toneburst Universe* feedback loop 3
15. Brendan O’Connell, *Futuree Toneburst Universe* feedback loops 2 and 3 patched together.
16. Brendan O’Connell, *Futuree Toneburst Universe* feedback loops 1, 2, and 3 patched together and ring modulated.
17. Brendan O’Connell, *Futuree Toneburst Universe* feedback loops 1, 2 and 3 patched together.
18. tombola, STEIM Cracklebox example
19. Brendan O’Connell, *Futuree Toneburst Universe* pre-recorded material
20. Pauline Oliveros, “Big Mother is Watching You” excerpt
Appendix A: Supercollider Patch, *Futuree Toneburst Universe*

```
//pattern streams to control envelope lengths
a = Prand((0.5,0.6..7.0),inf).asStream;
b = Prand((1.0,2.0..10.0),inf).asStream;
c = Prand((0.3,0.4..5.0),inf).asStream;
d = Prand((0.25,0.5..4.0),inf).asStream;
e = Prand((1.0,2.0..8.0),inf).asStream;
f = Prand((0.3,0.6..9.9),inf).asStream;

//pattern streams to affect ugens

g = Pn(Pseg([0.1,0.4,0.01,0.35,0.49].mirror,7,'exponential')).asStream;
h = Pn(Pseg([1.1,1.4,1.01,1.35,1.49,1.99].mirror,5,'exponential')).asStream;

SynthDef("sine", |out=0, freq=1000, freq2=100, pan=0,
     delay =300, amp =0.5, fold =100, fold2 = 100,
     trig1=500, trig2=500, trig3=500, trig4=500, trig5=500, trig6=500,
     wet = 0.0, dry = 1.0, shift=1.0, boost = 1.0, threehun=100, pdist=100, tdist=100|
     var osc, osc2, audio, filter, env1, env2, env3, env4, env5, env6, mix, crakl, noise, pitk, tone;

    //envelopes

    env1 = EnvGen.kr(Env.linen(0.2,0.3,0.5), Trig1.kr(Dust2.ar(trig1-500),0.1), levelScale:amp, timeScale:a);
    env2 = EnvGen.kr(Env.linen(0.2,0.3,0.5), Trig1.kr(Dust2.ar(trig2-450),0.1), levelScale:amp, timeScale:b);
    env3 = EnvGen.kr(Env.linen(0.2,0.3,0.5), Trig1.kr(Dust2.ar(trig3-500),0.1), levelScale:amp, timeScale:c);
```


env4 = EnvGen.kr(Env.linen(0.2,0.3,0.5),Trig1.kr(Dust2.ar(trig4-400),0.1),levelScale:amp,timeScale:d);

env5 = EnvGen.kr(Env.linen(0.2,0.4,0.5),Trig1.kr(Dust2.ar(trig5-400),0.1),levelScale:amp,timeScale:e);

env6 = EnvGen.kr(Env.linen(0.2,0.3,0.5),Trig1.kr(Dust2.ar(trig6-500),0.1),levelScale:amp,timeScale:f);

//sound producing ugens
osc = LFTri.ar(freq*0.75,0,1).softclip;
osc2 = Impulse.ar(freq2*0.25,0,1).softclip;
osc = osc *BrownNoise.ar(1);
filter = CombC.ar(osc,0.5,g,0.2);

audio = osc.fold2(fold*0.01)*LFClipNoise.ar(delay*10, 0.25);
audio = HPF.ar(audio,freq*2);
noise = LFClipNoise.ar(freq2,amp)*LFPulse.ar(threehun*f,0,5);
noise = LPF.ar(noise,fold*1.75);
crakl = Crackle.ar(1*h)*LFSaw.ar(freq2*3);
crakl = BPF.ar(crakl,freq*h,1/fold,3.0).wrap2(fold2*0.001);
tone = SinOsc.ar(fold2*0.5,0,1);

//mixdown
mix = Mix.ar([audio*env1,osc2*env2,osc*env3,filter*env4,crakl*env5,noise*env6,tone*env3]);

pitk = PitchShift.ar(mix,0.4,shift,0.5,0.4);
mix = Limiter.ar(Mix.ar([mix*dry*boost,pitk*wet*boost]).distort,0.8,0.01);
audio = Pan2.ar(mix,pan);
Out.ar(out,audio)

}).store;

)

(~con = Conductor.make { |con, pattern = 'Conductor', vals,

pinone, pintwo, pinthree, pinfour, pinfive, pinsix,
rate,wet,dry,shift,boost,pdist,tdist |

var arduino;

vals .sp([0,0,0,0,0,0], 0, 1024);
rate .sp(0.1,0.01, 1, 0, 'exp');

pinone .sp(100, 100, 1000,0.1,'exp');
pintwo .sp(100, 100, 1000,0.2);
pinthree .sp(100, 100, 1000,0.1,'exp');
pinfour .sp(100, 100, 1000,0.1,'exp');

pinfive .sp(100, 100, 1000,0.1,'exp');
pinsix .sp(100, 100, 1000,0.1,'exp');

wet .sp(0.0,0.0,1.0,0.001);
dry .sp(1.0,0.0,1.0,0.001);

shift .sp(0.5,0.5,4.0,0.01,'exp');

boost .sp(3.0,3.0,40.0,0.1,'exp');
pdist .sp(0.0,0.0,2.0,0.01);

tdist .sp(0.0,0.0,0.4,0.01);

con.name_ ("arduino");

pattern.name_ ("synth");
con.action_({
    ~arduino = arduino = ArduinoSMS("/dev/tty.usbserial-A4000PI5", 115200);
}, {
    ~arduino.close
});

con.task_({
    var pins;
    pins = [pinone, pintwo, pinthree, pinfour, pinfive, pinsix];
    ~arduino.action = { |id... msg|
        vals.value = msg.collect { | v | v ? 0};
        pins.do { | v, i |
            v.value = vals.value[i]
        }
    }
};

loop {
    ~arduino.send($r, $a);
    rate.value.wait;
}

pattern.synth_( (instrument: \sine),
    [freq: pinone, freq2: pinfive, fold: pinthree, threehun: pinfour,
     delay: pintwo, fold2: pinsix, trig1: pinone, trig2: pintwo,
trig3: pinthree, trig4: pinfour, trig5: pinfive, trig6: pinsix,

wet: wet, dry: dry, shift: shift, boost: boost});

};

~con.show

)
Program Notes

Futuree Circuits: Live Electronic Music from David Tudor and Beyond
March 1, 2008
CFA Cinema
8pm

Physical Electronic Music

**Dana Matthiessen** - microphones
**Brendan O'Connell** - tape

Feedback generated from two microphones moving in coordinated patterns is manipulated through lengthening and shortening of tape on two parallel tape delay systems, resulting in an electronic music controlled purely through motion.

Futuree Toneburst Universe

**Dana Matthiessen** - handmade analog console
**Roderic O'Connor** - Supercollider with handmade analog console
**Brendan O'Connell** - David Tudor electronics
**Anthony Zannino** - mixer

Three parallel analog feedback loops are mixed through a touch patch-bay. As new configurations are created through physical touch and motion, the systems interact chaotically. A comparable digital system run in the Supercollider musical programming language is controlled by another touch patch-bay with chaotic interactions and signal bleed between control voltages.

Futuree Jock Jams Galaxy

**Dana Matthiessen** - feedback electronics, circuit-bent toys, handmade chaotic tone/noise generator
**Brendan O'Connell** - tape delay/feedback system, handmade chaotic tone/noise generator

A reworking of my noise band, Jock Jams, into a David Tudor galaxy, using notated materials and a new attitude.
I have always been an electronic musician. My first piece was an unwitting realization of Alvin Lucier's "I am sitting in a room" on my family's computer with a cheap microphone and a sound recording program at age 13. Since then, I've been making electronic music with the means available to me - discarded reel-to-reel players, Radio Shack mixers and equalizers, and whatever I could build with my limited technical knowledge. My motivation is equal parts cheapness and a desire to use only the materials available to me - even (or especially) when they are only half-functioning. Discovering circuit bending, the creative rewiring and short-circuiting of toys and consumer electronics to create new sounds, in high school was a revelation for me. By touching a circuit board with my fingers, I could unleash a sonic universe that was unpredictable and much more interesting than any sounds the manufacturer intended.

My interest in circuit bending led me to the work of David Tudor, a fellow tinkerer from another era. Tudor is best known as the performer of avant-garde piano music from composers such as John Cage and Karlheinz Stockhausen during the 1950s and 60s, but later in his life, he moved towards esoteric electronic systems of his own creation in pieces such as Rainforest, Pulsers, and Toneburst. Along with Gordon Mumma, Tudor built his own electronics, which could be patched together in the manner of an analog modular synthesizer. Using three fairly simple analog electronic concepts (amplification, equalization, and phase shift), Tudor constructed complex systems that produced sounds not found on Moog synthesizers of the day, exhibiting chaotic interactions and strange sounds.

Thanks to the work of Ron Kuivila (Adjunct Professor of Music), the full collection of David Tudor electronics is now archived as part of Wesleyan's World Music Collection, allowing me access to all of Tudor's original equipment, as well as his papers and notes. This concert is the result of months of tinkering with, restoring, and playing with the Tudor electronics, as well as building my own modules to explore my ideas. -Brendan O’Connell

Thanks are due to:
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Anthony Zannino, for being here to help,
My family, for encouraging my lifelong interest in highly noncommercial pursuits,
and my girlfriend, Sarah Lippincott, who supported me throughout this project.