Contribution from Bianca Miller: Circuit Benders

http://www.anti-theory.com/bentsound/
some samples of bent sounds

http://www.oddmusic.com/illogic/illogic1.html
theory of circuit bending...and other good stuff including circuit bending manuals somewhere for speak and spell remods...

ARIUS BLAZE is one of their granddaddies....
www.audible-ism.com

http://www.anti-theory.com/soundart/emi/

`Arius Blaze` and Qubais Reed Ghazala are two of the main circbend dudes....

i think this is the excerpt/abstract of it: VOLUME 10 #4, JUNE 1995
"Circuit Bending & Living Instruments: The Trigon Incantor": Qubais Reed Ghazala. After a brief preliminary discussion of the beauty of chance and the rhythm of trains on tracks, Reed Ghazala goes on the describe his Trigon Incantor (see his article on the Incantor in EMI September 1992). The Trigon Incantor is an aleatoric electronic instrument made by deliberately applying random pressure using 2" steel balls to the surface of the electronic children's toy Touch and Tell. He also describes his manipulation of a piano which he refers to as the harmonic mute system, which creates harmonic overtones not unlike Cage's prepared pianos [additional keywords: indeterminacy; Speak & Spell; human voice synthesizers]

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CIRCUIT BENDING
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Circuit-bending is an electronic art which implements creative audio short-circuiting. This renegade path of electrons represents a catalytic force capable of exploding new experimental musical forms forward at a velocity previously unknown. Anyone at all can do it; no prior knowledge of electronics is needed. The technique is, without a doubt, the easiest electronic audio design process in existence.

Video Octavox

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.

Countless audio gadgets are experimental musical instruments waiting to happen. Circuit-bending's anti-theory approach to electronic design makes accessible to all audio explorers an endless frontier of original sound-forms to discover, and fantastic instruments to create.

Within these adapted devices, along with the unusual voices of circuit-bending, are often found aleatoric music generators; that is, chance-music composers that stream unpredictable audio events: elements shifting and re-combining in fascinating ways.

Vox Insecta

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.

[circuit-bending]

YOU can circuit-bend. The following discussion will start new benders on the right path. Also see the Anti-Theory Workshop section, the various instrument galleries and the PSF interview with Reed for additional insights into the process.

If you learn to solder and can drill a small hole to mount a switch in, you can circuit-bend. Everything else is a process of non-technical, routine experimentation in which various short-circuits are created in an attempt to alter the target device's audio behavior.

Audio toys not only are easy to circuit-bend, but also are capable of sonic eccentricities beyond belief. The newly-implemented line-output's voice, sharpened with EQ and expanded with reverb (standards in the electronic studio), when fed into an amp or recording console easily stands on its own.

Also important, audio toys are low-voltage devices. Reed suggests not trying the process with any circuit operating on more than 6 volts. Trying to circuit-bend any device operating on the "house-current" of your wall outlet is OUT OF THE QUESTION!!! This holds true even in the instance of AC adapters. Circuit-bending is for BATTERY-POWERED CIRCUITS ONLY.

[introduction]

[closing words]

There is the rare chance in this try-at-your-own-risk art, that a component might overheat and burn out. Or even pop. In Reed's 30+ years of bending circuits such a pop has only happened once. An external power supply of too high a voltage was accidentally applied to the circuit. Half a transistor was tossed across the room. Even though in Reed's experience such a thing has never occurred while bending a device operating on its own correct internal batteries, eye protection should be worn.

More likely, the downside of this odd art is the possibility of destroying the target device through overheating an internal micro-component within an integrated circuit. This rarely occurs, but it does happen. However, circuit-benders find this occurence out-weighed not only by the unique instruments capable of being created, but also by the opportunity to buy audio toys, even complex sampling keyboards and human voice generators, for a few dollars each at second-hand shops. These outlets will supply the bender's workshop with a differing and endless supply of experimental musical instruments to discover.

Perfect targets for circuit-bending are audio games and toys that already produce interesting, good-sounding voices. Synthesized human and animal voices, as well as imaginary and musical sounds reside within many of these gadgets. As mentioned, musical keyboards, even sampling keyboards, turn up at these second-hand stores now and then.Keyboards often produce chance (aleatoric) music when circuit-bent. Reedcalls these circuit-bent instruments Aleatrons. (Casio SK-1 article here, Aleatron gallery here). These games/toys/keyboards can often be bought for a few dollars each.

Carrying a supply of batteries, 4 "AA"s, "C"s, and "D"s, will allow you to try the devices at the stores before buying.

[tools]

>Low-wattage (30 watts or less) soldering "pencil" (small soldering iron) with a very narrow tip, perhaps filed down for fine work. These are cheap and can be found at the usual electronics outlets. Better yet, a soldering station including a cleaning sponge and resting cradle for the pencil. These pencils usually have an assortment of tips available, including the smaller diameter (around 1/16th") that circuit-bending may require. These stations are well worth the additional expense in the long run.

>Thin rosin-core solder.

>Small drill with which to create holes for mounting switches and other components. A hobby drill, such as the Dremel™, is handy for this job. A 1/8" bit is used to drill the pilot holes; a ball-shaped "burr" bit of the correct diameter is then used to bring the hole up to the correct size for the component being mounted. Optional: a tapered hand bore. This is a hand tool used to ream-out holes to the correct size; a nice addition to the circuit-bender's bench. This tool will increase the 1/8" pilot holes to the exact size for

unusual components or those too large for a Dremel™ burr bit, as in a 3/4" diameter pilot lamp housing.

>Set of small, all-metal, non-insulated "jeweler's" screwdrivers; slotted and Phillips.

>Set of miniature crescent wrenches (Craftsman, Sears stores; for fastening all panel-mounted controls).

>Small wire clippers.

>Small wire stripper capable of stripping wire as thin as 30 to 25 gauge.

>Test leads (insulated wire terminated at each end with an alligator clip).

>Optional: resistance substitution wheel. This device, containing assorted resistors of increasing values selected by the turning of a dial, is clipped by means of its two leads into a live circuit so that the selected resistor's effect on the circuit can be heard. This will help determine the correct resistance or resistance range needed at a circuit point so that a resistor or potentiometer of the needed value can be soldered into place.

In fact, a custom circuit-bending console tool can be built in the form of an elaborate substitution box. This would be, essentially, a housing containing selectable (via multi-position rotary switches) components to run the circuit-bending paths through -- various resistors, capacitors, potentiometers, sensors, LEDs, etc.). Like the resistance substitution wheel, this would be another two-lead device clipped between two circuit-bending points and adjusted to observe audio changes within the operating circuit. No, it's not as confusing as it may sound. Read on...

[parts]

>Miniature toggle switches.

>Miniature push-button switches.

>Assorted resistors.

>Assorted potentiometers (variable resistors, as in the familiar volume control) in values from 50 ohm to 10 meg.

>Assorted photo cells (light-sensitive variable resistors).

>Assorted capacitors.

>Assorted body-contacts (any metal knobs, etc., that can be wired to the circuit and bolted to the instrument's case).

>Assorted panel-mount audio output jacks (1/4" "guitar jacks", RCA "phono jacks", 1/8" miniature jacks, etc.).

>Assorted LEDs.

>Several colors of insulated 30 or 25 gauge "wire wrap" solid-core wire.

>Assorted other small-to-medium-gauge wire... solid core, stranded, bare, insulated.

NOTE: While nearly all the above tools and parts are available at the well-known electronics outlets at premium prices, they are also available through numerous mail order electronic surplus outfits as well as walk-through surplus warehouses. Not only are surplus prices so much better, but often the quality of items is higher than the flimsy parts offered by the majors in the malls. In addition, surplus retailers acquire very strange parts to work with, odd designs to be found nowhere else.

[exploring the art]

[parts]
[exploring the art]
[how it works]
[direct wiring]
[potentiometers]
[capacitors]
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[solar cells]
[leds]
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[closing words]

Before your first circuit-bending project, if you've never used the above equipment before, buy and build a beginner's electronic kit. An LED flasher, a digital clock, an integrated circuit noise maker... anything that will familiarize you with soldering, wire clipping and stripping, etc.... the basics of electronic circuit-building.

Species Device

Reading a beginner's electronics book is highly recommended. "Getting Started in Electronics" by Forrest Mims Jr. (available at Radio Shack) is a good place to start. There also exists a small "Engineer's Notebook" series by the same author. These handbooks get into more advanced subjects as well, but also cover the basics of circuit construction in one or two early volumes.

Beginner's guides will explain nice-to-know terms and cover how switches, potentiometers, resistors, capacitors, LEDs and other components operate. Circuit-bending will eventually teach all this, but it's much better to enter with

a general understanding of these basics that must fall outside the scope of this present writing.

[how it works]

First, clip the smallest two metal jeweler's screwdrivers in the alligator clips at the ends of the test lead. This gives you a wire with a probe at each end, and is your most important circuit-bending tool. (Obviously, a custom test lead with a permanent probe at each end can be made for this job, as well as the elaborate console described at the end of the tools section).

Probes

Remove the back from the game or toy to expose the circuitry.

Turn the device on and activate the sounds (press keys/buttons, or tape/wedge in place to sustain sound production).

With the device MAKING A NOISE, press the tip of one of the test lead's screwdrivers to a printed circuit trace, component lead or integrated circuit pin. Keep this screwdriver tip in place for the next step.

The Act of Bending

Now, with the other screwdriver at the opposite end of the test lead, begin touching various parts of the circuitry while listening for interesting changes in sound.

Electricity will follow the new course you've provided with the lead. This may have no effect on the sound at all. On the other hand, the audio effect may be outrageous.

Each time an interesting sound is created, note with a marker directly on the circuit board the pair of points that were connected to each other to create the sound.

Once the traveling end of the test lead has explored the circuit's corners and all interesting connections have been noted, place the stationary screwdriver tip on a new circuit point.

Again, the traveling end of the test lead explores the rest of the circuit; interesting sound-changing connections are marked.

This process is repeated until the entire circuit has been searched in such a manner.

Given a bit of luck, the circuit will now be marked with a number of potential connections discovered with the test lead.

At this point, a number of choices face the explorer in implementing the creative short-circuits discovered:

[direct wiring]

Wires can be soldered directly between the points marked as pairs on the circuit board. In the middle of these wires would be soldered toggle switches so that these new sound-activating connections can be turned on and off at will. Use the simple mini toggle switch, the common "SPDT" (Single Pole, Double Throw). One wire will go to the switch's middle terminal, the other will go to the terminal OPPOSITE the direction of the switch's toggle handle when in the ON position. These toggle switches can usually be mounted on the device's housing, creating the new control panel. If you are

using "SPST"s (Single Pole, Single Throw), there will be only two contacts to solder to; either of the two wires of your pair can go to either terminal.

Note: It is assumed that the soldering skills of the bender (you) are such that quick and precise connections can be made. This is important and not hard to learn. Quick, because some components can be damaged by the heat of excess soldering, especially since the bender may at times find it necessary to solder directly to integrated circuit (IC) pins leading to micro-miniature delicate electronics inside the IC. Precise, because, as in the example of IC pins, clearances can be minimal. The danger here is accidentally creating a "solder bridge" between IC pins (or other tightly-spaced metals... printed circuit traces, component leads, etc.) that were not meant to be soldered. There are several devices available to remove solder mistakes from a circuit. These work either by heating the solder and drawing it away from the circuit by means of vacuum, or by drawing the heated solder, through osmosis, into a metal braid. Both techniques are a hassle. Practice soldering until you feel comfortable with "quick and precise"; avoid the solder mistakes and their correction tools.

The wiring procedure begins with counting how many pairs of connections you'll need switches for. Next, decide how the switches will be mounted on the device's case (remember to check for internal clearances so that the backs of the new switches don't hit the device's internal parts when the unit is reassembled). Holes are drilled, the switches are mounted, the pairs of circuit-bending connections are then soldered through their respective switches and the device is reassembled.

[potentiometers]

[circuit bending]
[introduction]

Instead of switches, potentiometers (variable resistors) can be soldered in the middle of the pairs of connections. In many cases this will allow the adjusting of the new effect with the turn of a dial. Potentiometers, like non-adjustable common resistors, come in a variety of values measured in ohms of resistance. Experiment with different values to learn their effects. Potentiometers usually have three soldering points, or lugs. Solder your two wires so that one connects to the middle lug and the other to one of the outside lugs. Which outside lug you choose depends on what you want the effect to sound like as the potentiometer's dial is turned in a pre-determined direction. Example: The volume control on your stereo is a potentiometer. If you were to reverse its outside lug wiring the volume would go DOWN when you turned it up (clockwise).

Switches can be used along with potentiometers between the pair of circuit-bending connections as well. In this way, effects can be pre-set with the potentiometer's knob and turned on and off with the switch. A wire would be

soldered to one of the points in a circuit-bending pair, through the toggle switch, then through the potentiometer and back into the circuit-board to the other point of the pair. This switched component wiring may be used with any components, including the following...

[capacitors]

Capacitors, again available in a wide range of values, can be wired between the pairs of points. These may change the tone of the effect produced or pulse the sound in differing ways.

NOTE: Some larger electrolytic capacitors can hold a substantial charge and can transfer it to you in the form of a very real shock.These are cylindrical, two-lead (usually) devices, the ones of concern most often being larger than a cigarette filter. These capacitors appear in the circuitry of strobe lights, power supplies and other higher-voltage dependent applications. They practically

NEVER appear in the circuits here under discussion. However, all beginner's guides to electronic circuit design cover this subject. If you're not familiar with how the electrolytic capacitor looks, get a guidebook, (again, like the one by Forrest Mims Jr. at Radio Shack), and learn these basics. Such capacitors are easy to recognize and discharge, in the very rare event that you should ever find one in the way.

[photo resistors]

These are light-sensitive buttons (at times called "cadmium sulfide cells") with two wire leads. They convert light into electrical resistance, so to speak. They have the same effect upon a circuit as a potentiometer. However, instead of turning a dial to vary the resistance and thereby the sound, hand shadows are allowed to fall upon the photo resistors. These sensors can be used in many wonderful ways, including environmentally directed instrument designs since ambient light and shadow -- tree leaves, water reflections, clouds passing, etc. -- may be employed as player.

[solar cells]

These are light-sensitive wafers that convert light into electrical energy. They can be used to inject their varying small voltage (or resistance in some situations) into the circuit between the paired bending points. Of course, wired in series these wafers can be used to supply the operating power to an instrument, connected "end to end", just like, but instead of, batteries.

[leds]

[potentiometers]
[capacitors]
[photo resistors]
[solar cells]
[leds]
[humidity sensors]
[body-contacts]
[reset switch]
[line outputs]
[other techniques]
[cautions]
[closing words]

LEDs- (Light Emitting Diodes) are usually, for the sake of circuit-bending, low-voltage light sources. Like all diodes, their core function is to act as a one-way valve for electrons, but their nice glow and long life nearly eclipses this concern in much electronic design. You may find points on the circuit you're bending between which LEDs will glow or pulse. These can serve as function indicators or pilot lights. An LED wired to the speaker leads may work as an envelope light also, flashing with the intensity of the sound waves.

LEDs are "polarized" components; if they don't glow when connected between promising points on a circuit, try reversing the leads. If they still don't glow, there is not enough power available to activate them. An over-driven LED will burn out. Might even pop. Be aware of the LED that, when tested in a circuit, momentarily lights brightly but then dims to an off-color glow. Or lights too brightly while shifting color. Or simply lights too brightly. These are all signs of too much power being applied. Burn-out will eventually result. LEDs may also affect the sound of the circuit depending upon where they are connected.

[humidity sensors]

These are sensors that convert airborne moisture into electrical resistance (as found in Weather Service "radiosondes", balloon-suspended devices that measure atmospheric conditions and radio this information back to the ground tracking stations). This can give a breath control function to an instrument, raising a pitch, perhaps, as the sensor is blown upon.

There are many other components that can be wired into the path of the pairs of circuit-bending points, but the above will launch hundreds of possibilities as well as pave the way towards the understanding of wider concepts.

To quickly try different components between the discovered pairs of points, a modified test-lead system can be used. This consists of the two screwdrivers as before, two alligator clip test-leads instead of one, and the component to be tested (potentiometer, photo cell, LED, etc.). Clip a screwdriver at one end of each test lead. Between the empty ends of each test lead now clip the component to be tested. The screwdrivers again serve as probes with which to search the circuit, now sending the signal through the component clipped in the middle between the two leads.

Beyond direct electronic component wiring await other expansions...

[body contacts]

These are simply metal contacts -- drawer knobs, threaded brass light fixture balls, whatever -- that are wired to the pair of circuit-bending points. Each of the two circuit points goes to its own body-contact. Nothing is wired between them at all... no switches, potentiometers, sensors... nothing. These contacts, when mounted on the instrument's case, are meant to be bridged by the player's body. This placing of human flesh amidst the circuitry, now conducting electricity as surely as any other component on the board, turns the body into a potentiometer of sorts. A variable human resistor (but then, mustn't we all be already?).

Body-contact circuitry points are discovered in the exact same way as the circuit-bending pairs... with a test lead system. However, instead of the alligator clip test lead grasping a small jeweler's screwdriver at each end, you do. You simply hold a screwdriver in each hand. The search process is the same as before. The circuit makes its usual sounds while you listen to the changes that might occur due to the electricity now flowing into one screwdriver, through you, and out the other screwdriver back into the circuit. If good points are discovered, they are wired, as mentioned before, each to a metallic body-contact mounted on the instrument's case. These can then be touched by the player, creating the same body-circuit as discovered with a screwdriver in each hand.

Rarely is this electricity ever felt by the player. In a certain 9 volt amplifier, Reed's first circuit-bent instrument, the body-contact system did deliver small shocks. But nothing like the static shocks of wintertime carpet-strolling, or worse, the dangerous shocks that befall most musicians now and again from improperly grounded stage equipment.

The important note here, however, mentioned before and worth repeating endlessly, is to try these circuit-bending techniques ONLY ON BATTERY-POWERED AUDIO DEVICES OPERATING ON AN ONBOARD BATTERY POWER SUPPLY OF 6 VOLTS OR LESS. Trying to circuit-bend anything plugged into the "house-current" of your AC wall outlet, directly or through an AC adapter (power supply, power converter, "wall wart", etc.) is OUT OF THE QUESTION!!! NEVER TRY TO CIRCUIT-BEND ANYTHING PLUGGED INTO A WALL OUTLET.

[reset switch]

[potentiometers]
[capacitors]
[photo resistors]
[solar cells]
[leds]
[humidity sensors]
[body-contacts]
[reset switch]
[line outputs]
[other techniques]
[cautions]
[closing words]

Circuit-bending, in its anti-theory universe, creates electronic realities that at times are too bizarre for its own electronics to handle. The circuit crashes. Turning it off and back on might reset it, but it might not. Interrupting power from the battery supply may be the only way to reset the circuit. The batteries can be removed, of course, and put back in.

But more conveniently (and safer, since some crashes represent the possibility of circuit damage and resetting should be done quickly), wiring a push-button switch in the middle of one of the two wires connecting the battery compartment to the circuit board will give you instant access to power interruption.

Push-button switches come in two types: "normally open" (this MAKES the connection when pressed), and "normally closed" (this BREAKS the connection when pressed. You want the "normally closed" version to break the connection between the batteries and circuit. Mount this switch on the instrument's case where it's out of the way and not likely to be hit by accident.

[line outputs]

[circuit bending]
[introduction]

"Line" outputs, the electronic audio signals usually fed to a mixer or amplifier, can be derived from the wires going to the speaker of the unit you're working on. Simply solder two more wires to the speaker terminals and solder the other ends of these wires to an output socket of some type (1/4" "guitar" jack outlet, "RCA" phono jack, etc.) mounted on the instrument's case. A standard cable can then be used to make the connection between the new instrument and the other equipment. BUT...

Use a test amp first! This can be an inexpensive, low-watt amp, bought 2nd-hand and driving a small non-critical speaker. Such a system can be found for $20 at Goodwill & Salvation Army outlets, yard sales, pawn shops, the classifieds, etc. As long as the unit has a standard line input to plug into ("tape", "tuner" or "accessory" phono jacks, usually), it will serve the purpose.

The idea here is that unknown signal levels will be sent into the amp during various circuit-bending experiments. This might risk the well-being of the amp or speaker if certain precautions are not followed. So, an expendable amp/speaker is best.

Be sure to have the amp turned all the way down when first determining if the speaker-derived line output will work. Connect the extended speaker wires to the amp's line input. This can be done by clipping one end plug from an input cable (like a standard phono cord) and stripping the insulation off to expose the two wires within. Connect these two wires to the wires you soldered onto the speaker terminals. With the other end plugged into the amp's line input and the new instrument making its sounds, slowly turn up the amp.

If the sound from the amp is louder than the usual line-input signal from a standard source (tape deck, guitar, etc.), the new instrument's output level, coming from the speaker wires, may be too high or "hot". To tame this output, a resistor of the correct value can be soldered between one of the instrument's speaker terminals and then to the wire that leads to the amp. Better yet, a miniature potentiometer, called a "trimmer", can be soldered in place of the aforementioned resistor. The trimmer can then be adjusted to set the instrument's output level precisely. Experiment with trimmer values around 1 MEG, but have higher & lower values at hand as well.

Creating line outputs is very important in circuit-bending. The small speakers that most of the circuit-bendable devices come supplied with cannot come near to reproducing the frequencies that the electronics are creating, even before circuit-bending. And after circuit-bending, frequency response can be mind-boggling since clocking speeds are commonly altered. This results in ranges of frequencies that can surpass human hearing at both the high and low ends. A hi-fi reproduction system can illustrate the power of the circuit-bent instrument's voice in wonderful ways. Also, line outputs open the circuit-bent instrument's voices to signal processing: reverb and EQ, namely. These standards of the electronic music studio can expand and sharpen the circuit-bent instrument's voice, as with the voice of any electronic instrument.

[other techniques]

[circuit bending]
[introduction]
[tools]

Along with creating new circuit paths, as discussed, replacing components with others of a different style or value will also bend circuits in wonderful ways.

For example, a standard resistor on a circuit board can often be replaced by a potentiometer or photo cell (both are variable resistors). If this is a resistor that had set the pitch of a voice (very common), that voice now becomes tunable, changing frequency with the turn of a dial or the shifting of light. As would follow, a potentiometer can be replaced with a photo cell as well (i.e., the pitch dial/potentiometer of an oscillator could be replaced with a photo cell providing theremin-like, hands-in-space frequency control).

Motion sensors such as mercury, boxed ball, and "tilt" switches can be wired into small devices for dance or gesture-driven instruments.

Two solutions are at hand in addressing limited space for the mounting of new controls. Circuitry can be completely removed from its original housing and installed in any number of new enclosures. Or, a remote control panel containing the new switches and dials can be constructed and run into the

original housing by means of braided or ribbon cable, a type of self-contained color-coded multi-conductor wire.

In the instance of limited space to solder to, as in short component leads, IC pins, etc., study the circuit to see if the area you wish to solder to is connected to an easy-to-get-to trace on the board. This is often the case. A hard-to-get-to resistor lead within the circuit, for example, might connect with a printed-circuit trace that emerges, with full access, on the other side of the board. Soldering to a trace that connects to the desired component elsewhere is the same as soldering to the component lead itself. This technique can be a real tight-space problem-solver.

[cautions]

Along with protecting yourself and the components you add to the circuit as you bend it, there are precautions to take that will protect the circuit itself. If you're working with a rare or hard to replace circuit, take heed...

During the exploration process using the test lead to search the circuit for bending points, apply the traveling screwdriver's tip to the various circuit points tested very briefly -- just for a moment. In this moment beware of the following conditions. Don't try the connection again if you observe:

>a spark

>a dimming of electronic displays or lights

>a "pop" from the speaker

>a volume decrease or failure of the sound in progress

>a humming in the speaker

>a component heating up on the board

>batteries heating up

As electricity flows its course through a circuit, the resistance of circuit components often reduces the voltages in the circuit "down stream" of the power supply. These components are, in many cases, meant to operate on these diminished voltages rather than the full voltage of the batteries. Due to this, it's best not to jump the battery voltage into the areas further away in the circuit for fear of overloading them and causing the conditions listed above. Essentially, this means to avoid the area where the battery power enters the circuit board during your initial explorations with the screwdriver-test-lead apparatus.

Another important fact to remember is that while individual new circuit-bending paths may have no adverse effect upon the circuit when they are switched on by themselves, such paths in combination with each other might not be so forgiving. In other words, switch "1" let's say, which activates your first discovered pair of circuit-bending points, adds a nice warble effect to the instrument's voice and works just fine when turned on by itself. Switch "2",

which activates your 2nd circuit-bending connection, adds unpredictable pulsing to the instrument's voice and works just fine when turned on by itself. But you'll notice that when both switches "1" and "2" are turned on at the same time the speaker volume drops or disappears. Or you'll notice another of the above trouble signs.

As mentioned previously, eccentric circuitry can cause a crash. Battery supply interruption may be needed to reset and safeguard the circuit. This is an important consideration; be sure to install a RESET SWITCH as described toward the end of the EXPLORING THE ART section, above, in any instrument prone to crash.

The reality is that the new wiring of circuit-bending is compounded in many convoluted ways as the different controls are combined with each other. This may cause trouble. Be aware of such switching combinations; avoid them or modify the wiring behind them by finding another pair of points to wire one of the switches to. Re-test.

On the other hand, this chaotic snowballing of creative short-circuiting is at the essential and surreal heart of this chance process. There is no way to experience all the switching combinations as the new wiring is being charted on the board. It is not until the instrument is complete that it can be fully explored by the designer, since it is not until then that all discovered connections and new controls are in place at once and can be combined. At that point magic occurs. The instrument is explored, revealing itself in ways never evident during the initial, one-effect-at-a-time, discovery process. This is a wonderful moment.

But to the point: good circuit-bending connections create unusual audio behavior without taxing the circuit, without draining power and without any destructive effect upon the electronics at all. Feeling the integrated circuits, resistors and other components on the circuit board while bending is a very good idea. If a connection is made that causes a component to become unusually hot (some components will warm up a bit normally), avoiding that connection is a good idea!

It's best to also avoid using AC adapters to power circuit-bent instruments. This is because such power converters are known to add noise to circuits as well as damage electronics due to poor voltage regulation and inadequate surge suppression. Use high-quality rechargeable batteries with back-ups.

Along the course of circuit-bending, some circuits will be destroyed. As a general rule, don't try to circuit-bend anything you can't live without. Experience, however, will lead to more successes than failures, and in time a fascinating collection of instruments will come about.

[closing words]

Circuit-bending, for the most part, is self-illustrative. Following these guidelines the art will begin to unfold itself for the experimenter.

Doppler Wind

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While this discussion has remained fairly topical to construction techniques, much of the intrigue of this new art lies in the growing extra-technical anti-theory it illustrates and the new contemplations of music that circuit-bending forces. In addition to the materials to be found across the many branches of this web site, further insights into the wider implications of circuit-bending can be found by the links section.

Incantors, circuit-bent Speak&Spells, Speak&Reads and Speak&Maths, are prime examples of circuit-bending's power to produce alien music engines. The anti-theory electronics at work within these human voice synthesizers result in a stunning instrument capable of producing literally endless abstract sound sequences to listen to and work with. Incantor aleatoric (chance) music streams are simply intriguing.

The twelve added features include 2 human body contacts (for real-time pitch bending), 3 voice bending switches (for data stream disruptions resulting in chance music and other unexpected results), 3 looping switches (search, hold, and electric eye for shadow-looping with a wave of the hand), pitch/speed dial (allows for super-slow clocking, disintegrating the voices and tones into intricate showers of deep electronic sounds), reset switch (to restore circuit after crashes), gold-plated RCA output (for feeding effects, mixer and amp), speaker switch (for muting the built-in speaker), blue power LED and ultra-bright red envelope LED (envelope LED is hidden inside casing, positioned to flash on player's hands during volume peaks). Some units will have battery tie-downs instead of a battery door depending on stock at hand. Requires 4 "C" cells.

Speak&Spell version produces the most repeatable sounds, the Speak&Read contains the largest vocabulary and the Speak&Math has the least keypad controls, but also the sharpest voice (though this takes knowing all three to discern, the difference being real but not extreme). All units contain the

original blue fluorescent alpha-numeric display and membrane keypad. All units also take expansion cartridges (hard to find).

Incantors are finished in shaded fluorescent colors and gold veining.

More, excerpted from Reed's EMI article on Incantors:

" ...the SPEAK & SPELL product line eventually included other voice synthesizers... the SPEAK & READ, the SPEAK & MATH, the SUPER SPEAK & SPELL, and a few more not as well known. Circuit-bending the SPEAK & SPELL series brings forth a sonic landscape that in its diversity is nearly indescribable.

"The circuit-bent SPEAK & SPELL, with its headphone output feeding an amplifier or reverb unit, is capable of producing sounds and frequencies that will rival any synthesizer in existence. Its signal-to-noise ratio is better than countless well-accepted electronic instruments, and the unpredictable nature of its endless voices provides the experimental musician with new material every time the apparatus is turned on.

"The concept of such an instrument has always intrigued me. Before computer controlled keyboard synths were common, I spent nearly $1,000 building one in order to be able to write programs based upon pseudo-random variables hoping to produce a machine that would always surprise me with highly variable sound-forms and automatic composition (the PAIA P4700-J). Not that it didn't have its own rewards in other areas (it did some wonderful things!), but within the world of sonic eccentricity it, like most other synths, simply can't touch the modified SPEAK & SPELL.

"1) The operating rate of the circuit can be sped-up or decreased with the addition of potentiometers. This modification can slow the voice down to the point of sweeping electronic growls, fascinating in their frequencies and wave forms."

"2) Several points on all boards can be shorted to each other sending fractured digital streams of information back into areas where such were never ever meant to be. Two categories emerge, one having abstractions mixed with words, and one of pure abstractions with no wordings at all. The abstractions are vocal computer gibberish... chains of vowels, consonants, multi-phonemes, and computer tones. These chains can last for a few seconds or in some cases go on and on as the ROM, RAM, and lattice filter collide within the figure-8 racetrack of circuit-bending. Slowing this digital insanity down with the aforementioned speed control is like having an outlandish sonic microscope to explore sound with. The results are intriguing. Circuit-bending points that incorporate words may also invite ridiculous phrases. One of my modified SPEAK & READs, in a voice that sounds like an intoxicated Jack Benny, occasionally says "Let's smell the scissors s'more."

"3) Perhaps the most interesting composition-viable bending points are those that create a loop function. The digital stream of information (1200 bits per second) is interrupted, the results of this being different each time, giving the instrument the unpredictability and endless effects as mentioned earlier. If the loop function is switched on in the middle of a word, the result is not the simple sustained phoneme you might expect. Instead, a wild course of sonic events ensues, looping endlessly until released by the same switch. Some of the sounds are indescribable, but an example might be: "Ayy" - bell sound - pitch sweeps - "oh" - metal crash - bubble sound. The whole thing then repeats. Loops can be set within abstract voices as well as within wordings, and they can also be slowed down with the potentiometer exposing even more surprising hidden sounds. Circuit-bent SPEAK & SPELLs are audio adventure wonderlands, each foray with its own rewards."