Don Lancaster's

Hardware Hacker

April, 1993

Video game repair videos
Piezoelectric fundamentals
Understanding Curie Points
Simple home EDM machining
Stunning new ic opportunities

Every once in a while, a new hacker opportunity comes by that is absolutely stunning. An entire book crammed full of them is an even rarer event.

So, drop what you are doing right now and *run* out and grab yourself a copy of the new and free *Integrated Circuit Systems* data book.

These folks have just come out with an unbelievably mind blowing assortment of exciting new high-end hacker integrated circuits. Figure one gives you a quick summary of some of their more interesting products. Included are VGA to NTSC genlocks, 25 voice, CD quality synthesizers, 5 channel digitally controlled mixers, and SMPTE to MIDI time code chips.

Compared to these wonderments, their new fast battery charging chips and the unique new caller id devices seem hardly worth mentioning!

Whoops. A major boo-boo. Back in the resistance story, I shoulda said that 17.58 watts is a heating *rate* of one BTU *per minute*. Well over half of the "correction" letters I got on this were in themselves wrong.

Another good source for Nichrome substitutes is *Hoskins*. Their brand name is *Chromel*, and they are very big in alloys for higher temperature heater elements.

Piezoelectricity

Piezo stuff seems really superb for hacking. But a lot of you helpline callers seem badly misinformed over what you can and cannot do piezo-wise. Let's take a closer look…

As figure two shows us, certain dielectric (or insulating) materials exhibit a *piezoelectric* effect. If you bend a piezo material, a charge can appear on its surface. Reversibly, if you apply an electrical charge to a piezo material, it should bend. Or at least try to bend, creating a force against whatever is restraining it. Thus, you can use a piezo material to convert mechanical forces or motions into electrical signals. Or vice versa.

The oldest classic piezo material is quartz. Which can be sliced up and plated for use in frequency standard crystals, filters, accellerometers, time delay lines, or force transducers.

A quartz crystal is just a rock. A highly mechanically resonant rock which has a few wires added to it. Depending on the application, the crystal should electrically appear as a very low impedance series resonant circuit. Or as a very high impedance *parallel* resonant circuit. Positive feedback externally applied around the quartz crystal might cause it to oscillate at its resonant frequency or at a chosen overtone. The frequency can end up very exact because of the temperature stability and very high Q of the mechanical system involved.

GSP500 –

A VGA to NTSC video genlocking processor. Allows VGA and super VGA text and graphic images to be displayed on standard NTSC televisions or recorded on a VCR. Also genlocks and synchronizes external camcorder or VCR inputs.

ICS1399 –

A music synthesizer for high performance professional keyboard instruments. Includes 25 voices and on-board real time digital filters and digital-to-analog conversion. Synthesis is by way of table lookup, so virtually any real or imagined instrument can be emulated.

ICS2101 –

A digitally controlled audio mixer that accepts five stereo input pairs and provides one stereo output pair. Log attenuation at half a decibel per step over a sixty decibel range. Optional panning mono mode. Intended for audio cards in multi-media personal computers.

ICS2008 –

A SMPTE Time Code receiver and generator. Offers both the older LTC longitudinal time code and the newer CITC vertical interval codes. These codes are often used in video editing and to synchronize multimedia events. Supports NTSC, PAL and film rates.

ICS2010 –

A MIDI compatible SMPTE time code processor. Allows you to use standard video time codes to control and sequence any MIDI music environment. Supports MIDI quarter frame messages. Selective video overlay is available as an option.

ICS1700 –

A "Quicksaver" controller for Nickel-Cadmium batteries. Does a full charge in twenty minutes. Uses a temperature sensing and rate of charge termination to determine a fast yet safe charging rate. Ideal for notebook computers and portable video applications.

ICS1660 –

A telephone caller id chip that includes ring detection and calling party number extraction. When provided by the phone company, the caller id signals appear between the first and second rings and are extracted by FSK modem techniques. Includes power down features.

Fig. 1 – EXCITING NEW HACKER CHIPS from the latest Integrated Circuit Systems data book. These will take years to sort out.

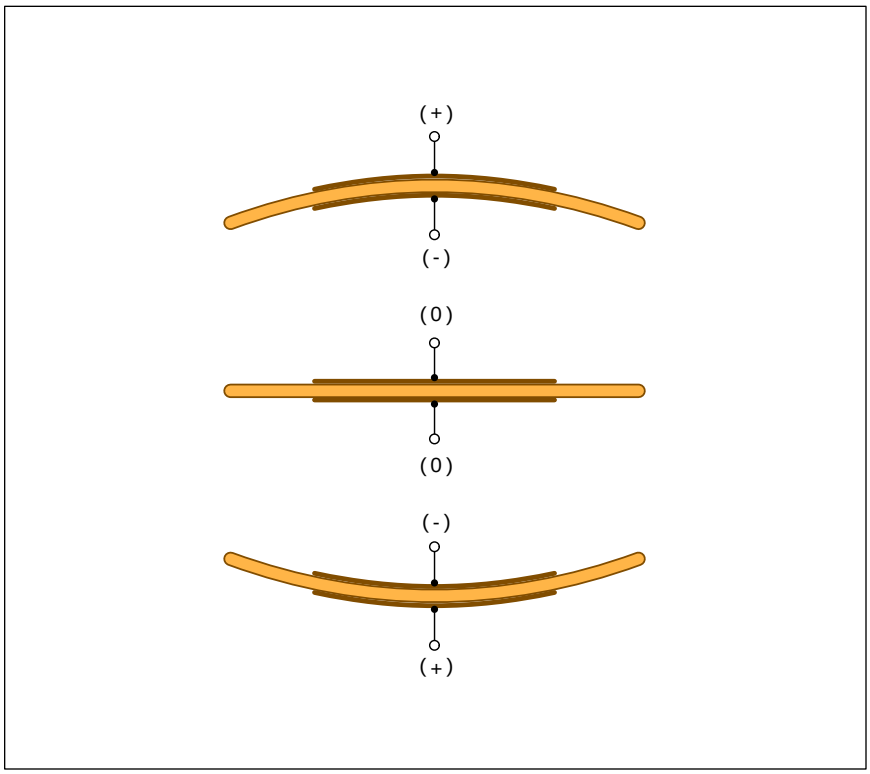

Fig. 2 – THE PIEZOELECTRIC EFFECT in certain dielectric materials converts an input voltage to a mechanical motion or vice versa. Important uses include filters, beepers, sonar, ultrasonics, micropositioners, gyros, microphones, miniature fans, strain gauges, and furnace ignitors.

We'll get further into crystals some other time. My favorite source for the lower frequency crystals is *Statek*, while *Crystek* is one of many places to go for small quantities of custom higher frequencies.

If at all possible, there are only *two* crystal frequencies which a hacker should select. These are the 32.768 kilohertz used in digital clocks, or the 3.579545 Megahertz used as the NTSC (Never the Same Color) subcarrier pilot. These two "magic" frequencies are ridiculously cheaper and easier to get than any other choice. Even if you have to divide or multiply to get what you really want, you'll usually end up far ahead by starting with these.

Another traditional piezo material was *Rochelle Salt*, otherwise known as potassium sodium tartrate. This material got used in "crystal" phono cartridges and "crystal" microphones. But Rochelle Salt was not really that stable or sensitive. You also had to chop up whole crystals, rather than forming it in the precise shape you really were after. Rochelle Salt has largely been replaced by better and cheaper-to-process materials.

But you can buy Rochelle Salt at your drugstore (it is also a laxative) and can easily grow your own piezo materials. See *Crystals and Crystal Growing* in the Doubleday Science Series for more info.

One group of improved materials involve the technical ceramics such as barium titanate or the "PZT" lead zirconate titanate. These ceramics can be molded into pretty near any shape before firing. The resonant structures similar to quartz crystals get used as filters, especially for radio and tv intermediate frequency amplification stages. *Murata-Erie* is one leading supplier here.

Fancier piezo resonant structures can go by the name of *surface wave devices*. By carefully controlling the metal patterns on a piezo surface, you could launch and recover acoustical energy. The patterns can give you precise higher order filtering, time delays, or an equalization response. One big advantage of SAW devices are that they are pre-tuned and need no adjustments. The important uses include cable tv, television if filters, cellular phones, and microwave apps. Ads for these show up in *Microwaves New Product Digest*.

Larger flat piezo *benders* resonate at audio frequencies and can form beepers or squawkers. You'll find a wide selection at *Radio Shack*, while a leading volume supplier is *Projects Unlimited*. Note that a bender does *not* oscillate by itself. It has to get used for feedback in a transistor or a logic inverter circuit. Some benders have taps provided to make their feedback easier. A pair of oscillators can get used to produce a series of beeps, instead of a continuous tone.

Physically smaller benders form ultrasonic microphones. These were once applied for ultrasonic Doppler burglar alarms before all those new pyroelectric "people detectors" blew them out of the water. And for remote controls before infrared diodes did them in. Ultrasonic sensors are still used for the electronic measuring devices used by contractors and rug installers. And to annoy dogs and mosquitoes. But, near as I can tell, though, all these really do is make the mosquitoes hungry.

Piezo devices in sheet or strip form could get used for hi-fi tweeters and higher quality, low cost electret-style "condenser" microphones. Unlike the traditional electrostatic mikes, no bias voltage supply is needed.

Larger size and higher power piezo transducers can be used for ultrasonic machining, cleaning, and for those underwater sonar aps. One source of ultrasonic cleaning transducers is *Branson*, while *EDO Acoustics* offers custom higher power piezo devices. Surplus sonar devices are sometimes provided by *Fair Radio Sales*. One leading sonar piezo manufacturer is *International Transducer*.

A sudden mechanical force applied to a stack of piezo elements creates a sparking barbeque lighter or a gas furnace striker. You can check your local hardware store for these.

A shorter and far more controlled stack makes a *piezo micropositioner*, a device which can precisely adjust things those micron sized distances required for microscopy, integrated circuit manufacturing, or for DNA

research. Surprisingly high forces are now available. One micropositioner source is *NEC*. Others do advertise in that *Laser Focus World* and *Lasers and Optronics* trade journals.

Piezo fans have gotten built by resonating a pair of mylar blades. These can be an interesting way of handling low power spot cooling, but are unlikely to put the smallest dent in the muffin fan market. The main supplier is *Piezo Electric Products*. While interesting piezo steppers and motors have been offered, these seem to be commercial failures.

Other emerging piezo uses include accellerometers, rate gyros, and for apps involving pressure transducers.

An exciting new variant of piezo material has now been developed by *Atochem/Pennwalt*. Ordinary *Kynar* plastic films are heated above their *Curie Point* and have a strong electric field applied. When cooled, this new electric field will get locked in, thus creating a piezo device known as an *electret*.

You will now find zillions of new applications for this thin, light, and ultra low cost Kynar piezo material. Including infrared people detectors (the films can be both piezoelectric and pyroelectric), for driveway traffic detectors, bounceless pushbuttons, impact sensors, for electronic drums, shock detectors, handicapped aides, and bunches of others.

Those Atochem folks do have free sample piezo transducers available for you, along with instructions on how to assemble microphones, flame detectors, touch switches, and lots of other hacker stuff with them. Using nothing but business cards and foam coffee cups. They also offer a series of piezo development kits.

Tech info on piezo stuff tends to get spread a little thin. I know of no piezo industry trade journal, and the older *Piezoceramic Manufacturer's Association* appears to be long gone. There is a small *Ultrasonic Industry Manufacturer's Association*.

Some piezo material appears in the *IEEE Transactions on Sonics and Ultrasonics*. Also check the *Journal of the Acoustical Society of America*. And, of course, you can thoroughly and cheaply research *any* technical topic through the *Dialog Information Service*.

The Problems

As I see it, there are two serious hacker misconceptions over piezo devices that seem to be causing a lot of helpline grief. These are the facts that *most piezo devices must be kept cool*, and that *most piezo devices are ac only and will not in any manner respond to continuous, steady state, or dc inputs*.

Any piezo device has its critical temperature called the *Curie Point*. Above the Curie Point temperature, *all piezo effects are lost*. And stay lost unless you go through a fancy and critical "recharging" process.

For most of the high volume, low cost materials, the Curie Point lies somewhat above the temperature of boiling water. You absolutely must keep both your ambient temperature and any internal heat buildup above ambient way under the Curie Point temperature at all times. For instance, using live steam near typical piezo devices is one big no-no. At least for the current crop of materials.

You must be extremely careful when you solder a piezo device to make certain you avoid reaching the Curie Point. Those ancient "crystal" phono cartridges seemed especially susceptable to soldering damage.

Yes, there are higher Curie Point piezo materials. But most of these are expensive and out of the mainstream. *Piezo Kinetics* is one innovator here.

In general, though, any time that you try to "push the envelope" of any device capabilities, something has to give. The chances are very good that raising your Curie Point will lead you to much higher materials cost, lower conversion efficiencies, and some matching/coupling problems. All of which will translate to more internal heat and poorer economics.

A piezo device is nothing but a capacitor that swaps charge back and forth. Figure three gives us a closer look at what really happens here. Say you apply a positive voltage. The device will bend when the voltage is

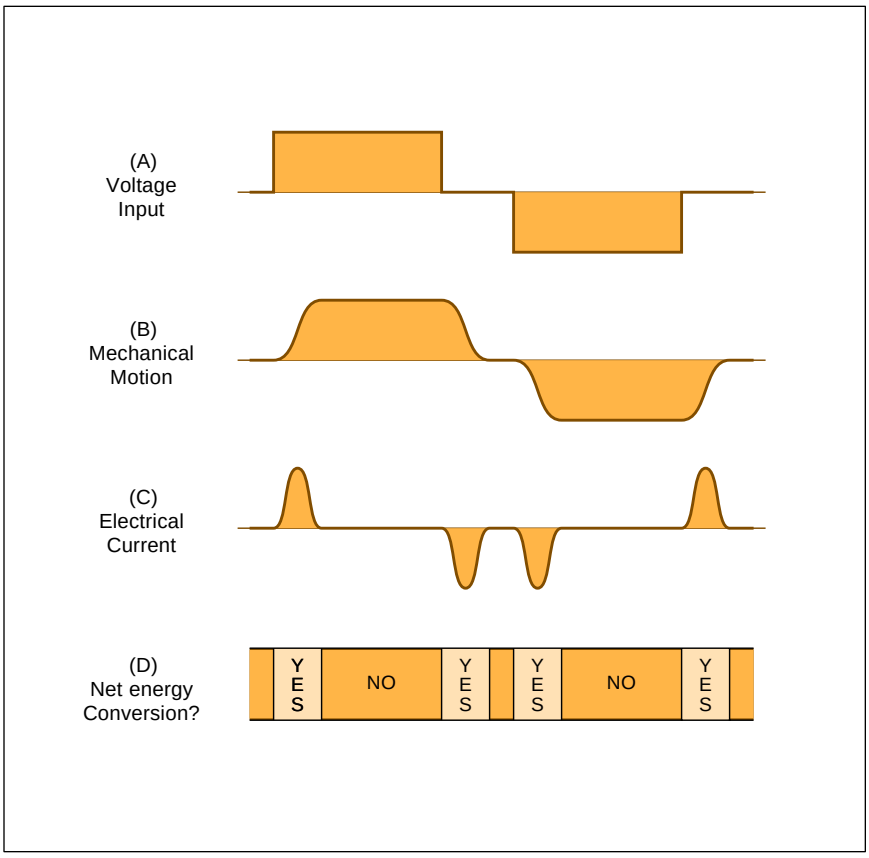

Fig. 3 – JUST LIKE ANY OTHER CAPACITOR, a piezo device obeys an "ac only" response. The only time you will get any energy transfer between electrical and mechanical inputs is when one or both are changing.

PIEZO RESOURCES

Atochem/Pennwalt
3 Parkway
Philadelphia, PA 19102
(215) 587-7000

AVX Corporation
PO Box 867
Myrtle Beach, SC 29577
(803) 448-9411

Branson Ultrasonics
41 Eagle Road
Danbury, CT 06813
(203) 769-0400

Bruel & Kajer
185 Forest Street
Marlborough, MA 01752
(508) 481-7000

Channel Industries
839 Ward Drive
Santa Barbara, Ca 93111
(805) 967-0171

Channel Products
7100 Wilson Mills Road
Chesterland, OH 44026
(216) 423-0113

Crystek
2371 Crystal Drive
Fort Myers, FL 33906
(813) 936-2109

EDO Acoustics
2645 South 300 West
Salt Lake City, UT 84115
(801) 486-2115

Fair Radio Sales
PO Box 1105
Lima, OH 45802
(419) 227-6573

Int'l Transducer Corp
869 Ward Drive
Santa Barbara, CA 93111
(805) 683-2575

K-tech Corp
901 Pennsylvania Ave, NE
Albuquerque, NM 87110
(505) 268-3379

MG Electronics
32 Ranick Road
Hauppauge, NY 11788
(516) 582-3400

Motorola Ceramic Products
4800 Alameda blvd, NE
Albuquerque, NM 87113
(505) 822-8801

Murata-Erie
2200 Lake Park Drive
Smyrna, GA 30080
(404) 436-1300

NEC
PO Box 7241
Mountain View, CA 94039
(800) 632-3531

Piezo Electric Products
212 Durham Avenue
Metuchen, NJ 08840
(908) 548-2800

Piezo Kinetics
PO Box 756
Bellefonte, PA 16823
(814) 355-1593

Projects Unlimited
3680 Wyse Road
Dayton, OH 45414
(513) 890-1918

Shogyo
287 Northern Blvd
Great Neck, NY 11021
(516) 466-0911

Statek
512 N Main Street
Orange, CA 92668
(714) 639-7810

Ultrasonic Industry Association
PO Box 5126
Old Bridge, NJ 08857
(201) 679-9666

Valpey-Fisher Corp
75 South Street
Hopkinton, MA 01748
(508) 435-6831

applied and unbend afterward. There will be no current before the voltage is applied. There will be a *positive* current *only while your bending is taking place*. The energy goes into the physical motion work load and raising the internal charge state of the piezo device. After your bending is finished, you'll still need to apply a voltage to *keep* the device bent, but there will be *zero* current, either into or out of the device.

When you remove the voltage, the device returns to its flat state. This time there should be a net *negative* current *out* of the device as the higher internal energy state gets released. Some of this negative energy may get spent overcoming any air resistance, producing internal heating, or doing other mechanical work.

At any rate, our key point here is *there is only a net energy flow into or out of a piezo device whenever the applied voltage or your mechanical force is changing*. The steady state response is *zero*.

Just like any other capacitor.

Now let's look at it backward. Put a "perfect" voltmeter on your piezo device and push on the device. What happens? As soon as you press, there is a net surface charge which your voltmeter measures. As long as you are pushing, the voltmeter will *still* read the voltage resuting from this charge. But, *if there is any external or internal resistive load at all, the charge will rapidly drain off.*

Use a "real" voltmeter instead, and you will get a positive pulse when you first apply your pressure, and a negative pulse when you release it. Why? Because the resistance load inside the voltmeter drains off the previous charge.

Thus, piezo devices are inherently ac devices that only respond when the force, motion, or electrical signal is *changing*. There is no "dc", "constant voltage", or any "steady state" energy conversion response.

Many popular piezo devices have a natural time constant of one second or so. They can be used at sub-audio frequencies. But their dc steady state response is zero. Piezo devices are thus largely unsuited for such things as weigh scales, nav accellerometers, position transducers, or pressure to voltage converters. Unless you get really sneaky and use fancy chopper, carrier, or integrator stunts.

Piezo Power Generation?

Several helpline callers have asked whether piezo devices are suitable for commercial power generation. The possibilities look very grim here. By far the highest power piezo electricity generator I know about is the lighter for the carbide light on my caving helmet. Which is just a modified gas furnace igniter. And while the small wattage piezo fan motors do exist, they don't exactly have the entire air conditioning industry quaking in their collective boots.

Yes, there are higher power piezo transducers. Hundreds of watts for ultrasonic cleaners and machining. And perhaps thousands of watts for sonar. But I know of none of these ever *producing* electricity.

In fact, I would be very surprised if

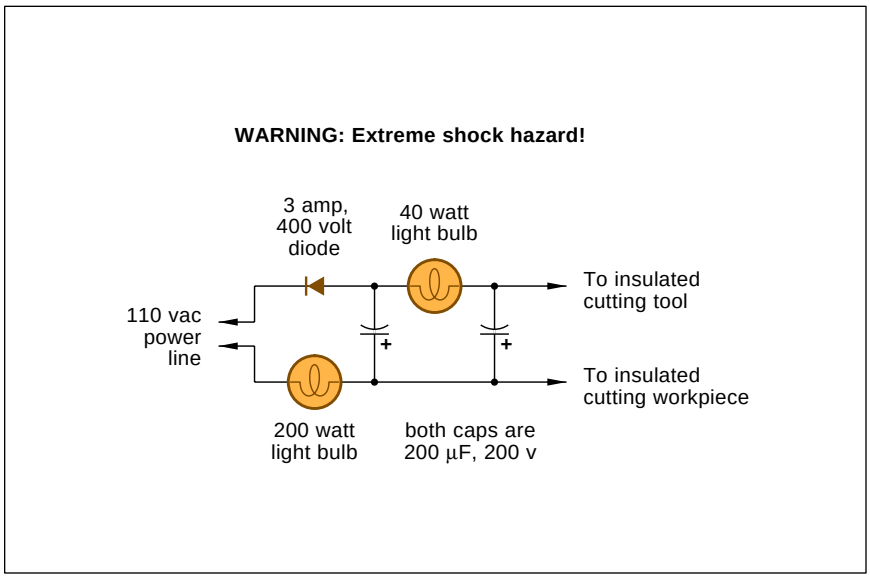

Fig. 4 – AN ULTRA-SIMPLE EDM LASHUP. The lamps act as dynamic regulators, with the smaller one setting your sparking rate Be certain to keep the tool and workpiece insulated from ground at all times. A dielectric fluid must be used. Kerosine is possible but not recommended.

there *ever* was *any* piezo device to date which generated more recovered electrical power than was used in its construction.

Many new piezo aps seem stuck under a two watt limit. Recent fans, positioners, and stepper motors above this size have been non-competitive with traditional solutions.

Commercial power recovery would require new devices hundreds or even thousands of times larger than the two watt limit. Once again, whenever you push the envelope, something has to got to give.

For piezo power generation, the mechanical work input would have to be oscillatory and usually has to be resonantly coupled. *Ya gotta shake the transducer, not simply push on it*! Piezo devices also must be kept cool. If they get anywhere near their *Curie Point*, all piezo effects stop.

Worse yet, the best efficiencies of the high power units are often fifty percent or less. Leading to very bad economics and internal heating.

Worst of all, most piezo elements are inherently very high impedance devices. Usually in the ten megohm range. For maximum power transfer out of any system, the impedances of your source and load *must* be made equal. This means you'll usually get a high voltage, higher frequency, high impedance output from any piezo device. Tens of kilovolts or higher for larger devices. Efficiently converting this into recoverable power is not a trivial task.

Several of the ap notes drive home how dramatically piezo output power drops when you try to drive too low a resistance load. From watts down to milliwatts even.

It's also not at all obvious to me how you can efficiently and cheaply combine the multiple outputs from several piezo devices.

Finally, unless you are in an "Uh, compared to what?" situation in outer space or on a desert island, the first and foremost question in any power generation scheme is "What are the economics?" If the rate of the energy production cannot more than pay for the time value of the money used in construction, then your conversion scheme is totally useless.

Infinite cost breakeven times are trivially easy to pick up. All that has to happen is that the interest on the time value of the construction money exceed the value to date of all the generated power.

Viable alternatives to piezo power generation are covered in depth in *Electric Power Research Institute* or the *Association of Energy Engineers* tech publications.

NAMES AND NUMBERS

Alpec
55 Oak Court
Danville, CA 94526
(510) 820-1763

Amusement Business
Box 24970
Nashville, TN 37202
(615) 321-4250

Assoc Energy Engineers
4025 Pleasantdale Rd, Ste 420
Alanta, GA 30340
(404) 447-5083

Carnivorous Plant Newsletter
Fullerton Arboretum, CSUF
Fullerton, CA 92634
(714) 773-3579

Dialog
3460 Hillview Avenue
Palo Alto, CA 94304
(415) 858-2700

Electric Power Research Inst
PO Box 10412
Palo Alto, CA 94303
(415) 855-2000

Elsworth Adhesives
1610 North I-35, Ste 208
Carrollton, TX 75006
(214) 446-8000

Randy Fromm
1944 Falmouth Drive
El Cajon, CA 92020
(619) 593-6131

GEnie
401 N Washington Street
Rockville, MD 20850
(800) 638-9636

Hoskins
10776 Hall Road
Hamburg, MI 48139
(313) 231-1900

Integrated Circuit Systems
PO Box 968
Valley Forge, PA 19482
(215) 666-1900

Journal Acoustical Society
335 E 45th Street
New York, NY 10017
(212) 661-9404

MCM Electronics
650 Congress Park Drive
Centerville, OH 45459
(800) 543-4330

Synergetics
Box 809
Thatcher, AZ 85552
(602) 428-4073

Teltone Corp
22121 20th Avenue SE
Bothell, WA 98021
(800) 426-3926

Unitrode
7 Continental Blvd
Merrimack, NH 03054
(603) 424-2410

The bottom line: There are all sorts of incredible hardware hacking apps which use piezoelectricity. Especially with all those new Kynar films. But commercial power generation does not seem to be one of them.

Piezo Resources

I've gathered some of places to go for more piezo info into our resource sidebar. Most of the sources shown but not covered above are suppliers of materials and devices.

For this month's contest, either (A) tell me about a piezo trade journal, or (B) show me any new and hacker friendly piezo ap that does not violate the "no dc response" and "low temp only" rules. There will be all of my *Incredible Secret Money Machine II* book prizes, plus an all expense paid *tinaja quest* (FOB Thatcher, AZ) for two going to the very best of all.

As usual, send your entries directly to me here at *Synergetics* and not to **Electronics Now** editorial.

More on EDM Machining

Warning: What follows can involve severe shock and fire hazards. Do not try this trick at home unless you know exactly what you are getting into!

But this one seems far too cute to ignore. Awesome, even.

I've had a lot of helpline requests for more details on the EDM electric discharge machining we looked at two columns back. It turns out a very cheap, stunningly elegant, and ultra simple scheme for EDM machining first appeared in the March 1968 issue of *Popular Science* and later on got reworked in the January 1991 issue of *Home Shop Machinist*. Their circuit appears in figure four.

All you have is a half wave dc power supply powering a relaxation oscillator, with your *insulated* tool ending up negative and the *insulated* work being positive. Any old three amp, 400 volt power diode from *Radio Shack* could get used as the rectifier. Fresh and very high quality electrolytics are recommended. 200 volts minimum. Older or very cheap ones could possibly explode in this circuit. A "bomb shelter" type of case is recommended.

The light bulbs have much lower resistances when they are cold than hot. These sneakily act as dynamic regulators to limit the current should your tool get stuck. This is elegant simplicity at its best. The size of the smaller lamp sets your cutting rate.

Both the tool and the workpiece must get fully and totally insulated from ground! If you want to ground your workpiece (a darn good idea), a large isolation transformer *must* be added to your ac input.

While you might employ plain old kerosine as a dielectric cutting fluid, it is highly flammable. Not remotely as nasty as gasoline, but very much a fire hazard just the same. I would instead recommend using the "real" water based dielectric resins we saw back in the EDM survey. You'll have the best luck with a drill press or a mill that has a slow controllable rate vertical power feed.

The most obvious use is to remove broken taps or stuck drills. Be sure to remember that a continuous flow of dielectric fluid between the tool and work must be maintained at all times.

A reminder that *EDM Today* is the leading trade journal here, and your foremost place to check for ads on machines, materials, and supplies.

New Tech Lit

From *Teltone*, their new *Design Solutions* data book all about tone receivers, call progress detector ics, and phone signalling devices. Along with a few good ap notes. From *Unitrode*, the new *Linear Circuits Handbook*. Mostly on drivers, power supply circuits, and battery chargers.

Randy Fromm's Big Blue Book of Really Great Technical Information tells you bunches about commercial video game repair. In a readable and well organized format. Randy also offers videos on video monitors and on game repair and refurbishment.

He has lots of insider tricks that

can quickly and cheaply solve typical repair problems.

I am amazed at how klutzy and primitive many video games still are. Most of these are still foot square circuit boards crammed with jelly bean TTL or CMOS chips. Thus, they fail often but are easy to fix. I guess that the desire to retrofit previous machines has pretty much kept the older technology in place.

Speaking of video games, *MCM Electronics* offers $8 bit drivers that let you remove the tamperproof *Sega* or *Nintendo* game cartridges.

If you are about to come unglued, check out *Elsworth Adhesives*. They do seem to stock just about all major epoxies, hot melts, cyanoacrylates, silicones, and such from nearly all of the major suppliers.

The price of laser pointers is still in free fall. The cheapest this week is the $72 model from *Alpec*. Range is around 55 yards or so.

NEED HELP?

Phone or write all your US Tech Musings questions to:

Don Lancaster
Synergetics
Box 809-EN
Thatcher, AZ, 85552
(520) 428-4073

US email: *don@tinaja.com*
Web page: *www.tinaja.com*

Note that you can't just connect a visible laser to a battery. Careful and tight current regulation is needed to prevent the fragile die from literally blowing itself off its mounting.

Normally, an internal photodiode is used in a feedback loop. I'll try to work up some more details on this in a future column.

Our two unusual magazines for this month are *Amusment Business* and the *Carnivorous Plant Newsletter*.

The former is where you go to rent the Batmobile, buy a steam calliope, see how much your favorite rock star is making on their concerts, or find job ads so you can run away and join the circus. The latter is for veggies that go chomp in the night.

A reminder here that I have got autographed copies of my revised *Incredible Secret Money Machine II* here for you at my own *Synergetics*. This book is a must if you are starting up your own tech venture. Also, our no charge voice tech hepline can be reached via (520) 428-4073. The best calling times are often 8-5 weekdays, Mountain Standard time.

Most of those items I've mentioned do appear in our *Names & Numbers* or *Piezo Resources* sidebars. Be sure to check here first before calling our technical voice helpline.

Let's hear from you. There's lots of exciting new opportunities here. ✦