

A few additional comments on the correlation from back in *Hardware Hacker* #54. Our third autocorrelation mask example obviously should have been an 0010 rather than the typo shown. I have corrected this in our *Hardware Hacker IV* reprints.

I should have stated "Radar range depends upon your transmitted pulse energy, rather than is proportional to. Doubling the transmitted radar pulse energy typically can only extend your effective range by nineteen percent.

Good classic texts on radar include Merrill Skolnick's *Radar Handbook*, and the hoary old "Rad Lab One" that refuses to die. Otherwise known as *Radar Systems Engineering* by Louis Ridenour. Another very outdated but popular intro is Robert Page's *Origin of Radar* from Doubleday.

While much of the information on chirp radar techniques is classified or otherwise hard to locate, the *Theory and Design of Chirp Radars* in the *Bell System Technical Journal* for July of 1960 is a good intro. I've also got a summary in my January 1965 *Electronics World* chirp story. More current info can be found through the *Dialog Information Service*.

Numerous readers have questioned that unusual synchronous rectifier example circuit. Yes, this is correct as shown. And, yes, there is one big hidden gotcha. When a MOS power transistor gets used for a synchronous rectifier, you will run it in its *third* quadrant. Not the first quadrant like you might initially expect. This gets done to keep the substrate diode from shorting out the works.

More on quadrants below.

Additional details on synchronous rectifiers do appear in that *MosPower Applications Handbook* by *Siliconix* and in those *Motion, Motion Control, PCIM*, or *PowerTechniques* mags.

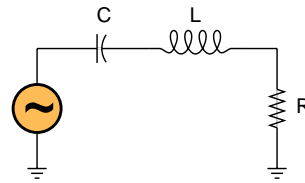
### Fundamentals of resonance

Resonance is certainly one of the most interesting and most important of electronic concepts. But there sure seems to be lots of helpline confusion

over what resonance can and cannot do. Yes, you can produce incredible energy buildups in certain resonant circuits. Destructive and even lethal ones. Yes, you can extract this energy

if you want. No, none of the stored resonant energy is "free". Just as in a piggy bank, you can not take more quarters out than were put in.

At least I do not know how to do



The **RESONANCE FREQUENCY** occurs whenever both the inductive and capacitive reactances are equal...

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

The **AMPLITUDE RESPONSE** defines the ratio of the input to the output voltage, expressed in decibels...

$$\frac{e_{out}}{e_{in}} = -20 \text{ Log}_{10} \sqrt{1 + Q^2 \left[ \frac{f^2 - f_o^2}{f} \right]^2}$$

The **Q** or **QUALITY FACTOR** is defined in several different ways, each of which leads to a different application...

(A) As the reactance to resistance ratio...

$$Q = \frac{2\pi f_o L}{R}$$

(B) As the half power bandwidth...

$$Q = \frac{f_o}{f_h - f_l}$$

(C) As the inverse of the damping...

$$Q = \frac{1}{d}$$

(D) As the resonant voltage rise...

$$Q = \frac{(\text{resonant voltage across L or C})}{(\text{resonant voltage across R})}$$

(E) As the ringing rundown time...

A resonant circuit decays to 1/ε amplitude (or 37% = -8.7 decibels) in Q/π cycles.

(F) As the stored energy ratio...

$$Q = \frac{2\pi(\text{energy stored per cycle})}{(\text{energy dissipated per cycle})}$$

Fig. 1 – A RLC SERIES RESONANT CIRCUIT forms the basis for various electronic tuning, filtering, voltage step up, and energy storage circuits. But there is no way I know that it can produce any "free" energy.

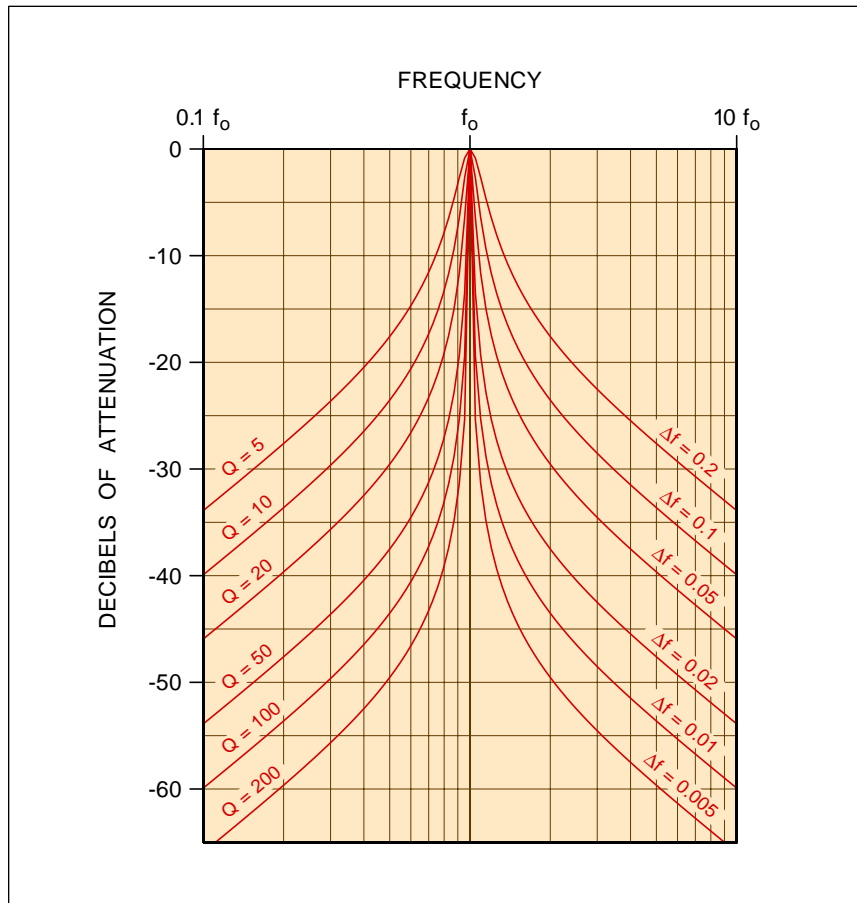


Fig. 2 – EXTENDED RESONANCE RESPONSE CURVES for a series RLC circuit. Note the "flattening out" for frequencies well away from resonance.

this, and 100% of all earlier attempts at "free" resonant energy have failed miserably. Most of these were not even wrong. Let's take a fresh look at resonance fundamentals...

Figure one shows you the simple series combination of one resistor, an inductor, and a capacitor. This is a *series resonant circuit*. Assume for now that the resistance is your load, the inductor and capacitor are very high quality, and the signal source is a very low impedance.

At extremely low frequencies, the inductor will look like a short circuit and the capacitor will appear as a very high capacitive reactance. Very little signal will reach the load.

Similarly, at very high frequencies, the capacitor will look like a short circuit, and the inductor will appear as a rather high inductive reactance. And once again, very little signal will reach the output load resistor.

At one certain frequency, though,

both of the inductive and capacitive reactances will be equal in strength and opposite in sign, and will cancel out to zero, transferring *all* of your input signal to the output load. This "magic" frequency is defined as the *resonance frequency*.

As figure one does show us, the resonance frequency is determined by the *product* of your L and C values. Resonant circuits are often *frequency selective*. They allow you to *tune* to a chosen frequency. This is how you select any particular am or fm radio station while you tune out all of the others. Resonant circuits can also store surprisingly large quantities of energy. One very important energy storage use for resonant circuits is in the deflection circuitry of television sets and computer monitors. Sneaky resonant switching tricks are used to sweep the beam back and forth while recycling the available energy.

The "Q" of a series resonant circuit

can get defined in several stunningly unique ways. Q (standing for *quality*) could get defined as the ratio of the resonant inductive reactance to the load resistance. Or as the *bandwidth* between your -3 decibel *half power points*. Or as a function of the *ringing decay time*. Or as the amount of the resonant voltage *increase* you'll get across your inductor or capacitor. Or as determining the ratio of the stored to the dissipated energy per cycle.

All of these figure one definitions of Q are identical, but they will lead you to profoundly different uses and applications for resonant circuits.

You change the resonant frequency by shifting your *LC product*. You can change the Q by shifting the *LC ratio*.

Figure two shows exactly how the response of series resonant circuits will change with frequency and Q. The higher the Q, the *narrower* the final bandwidth between your half power (or 0.707 voltage amplitude) points. Note that each of these curves starts out by rising at +6 decibels per octave, swings up through a sharp resonance peak, and then eventually ends up falling at a -6 decibels per octave rate. No matter how steep your near-resonance dropoff, you reach a point where either the inductor's or the capacitor's reactance is too small to make much difference.

If you need more attenuation well away from resonance, you usually are best off adding extra series resonant *poles*, or otherwise cascading.

You can quickly sketch most any resonant curve. You should get zero attenuation at the center frequency, and -3 decibels of attenuation at the half power bandwidth points set by  $1/Q$ . You then locate your resonant frequency point "Q" (converted to decibels) down and sketch a pair of 6 decibel per octave lines on downward from there. Then smoothly connect all of the dots and the lines.

In high Q series resonant circuits, the usual reactive voltage across the inductor or capacitor will be many times that of the input. For instance, a one volt input at resonance and a Q of 100 will produce a nasty 100 volts across the capacitor or the inductor. Some switching mode power supplies make use of this resonant rise for a transformer-free voltage increase.

The resonant voltage step up can

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cr -.8 1.7 (-60) cr
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Fig. 3 – GURU GONZO POSTSCRIPT CODE used to create camera-ready semilog artwork for figure two. Send code to Acrobat Distiller.

easily become destructive if the input signal gets too big.

Just as a pendulum swaps kinetic for potential energy as it oscillates, the inductor stored  $Li^2/2$  energy is at a maximum on current peaks, and the capacitor stored  $Cv^2/2$  energy is at a maximum on voltage peaks. While the energy appears to swap back and forth between inductor and capacitor, *your total stored energy over any one cycle remains constant.*

One definition of Q is  $2\pi$  times the energy stored per cycle divided by the energy dissipated per cycle. Thus, if you do have a Q of 100, a one amp input and a one ohm load, at series resonance you will dissipate one watt per cycle while you store around 15.9 watts per cycle.

Just where did the 15.9 watts come from? The same place the stash in the piggy bank came from. It got built up earlier, a quarter at a time. During the *transient* times when you first apply a signal, input energy slowly will get saved, building up the inductor's and

capacitor's internal energy storage.

Very large amounts of energy can be stored in resonant circuits. In the case of a large color tv or computer monitor, as much as 5 kilowatts of resonant power are involved in the horizontal sweep circuitry. In a very efficient circuit which continuously recycles resonant deflection currents. More on this in the *Hardware Hacker III* reprints.

If you deliver an impulse to a high Q resonant circuit, it will *ring* for a *rundown* time as shown in figure one. The higher your Q, the longer your ringing time. One obvious use is for electronic chimes and gongs.

More on rundown times appears in my *Active Filter Cookbook*.

Although I have shown a single resistor in our resonant circuit, you really have a load resistor, a source impedance resistor, and the resistive losses in the inductor. All of these have to be accounted for in the real world. For a series resonant circuit to operate, you *must* drive it from a very

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low impedance source.

You can also create the *dual* of this RLC circuit by placing everything in parallel, creating a *parallel resonant circuit*. Any parallel resonant circuit reaches a very *high* impedance at its resonance and operates only when it is driven from a very *high* impedance current source. Instead of voltages multiplying by Q, the reactive current multiplies by Q instead.

More on resonance fundamentals appears in most electrical engineering texts. Such as Skilling's *Electrical Engineering Circuits*. And lots more on working with and using resonant circuits appears in my [Active Filter Cookbook](#).

### PostScript to the rescue

At one time, drawing camera-ready charts and graphs such as figure two was a real hassle. First you had to find some semi-log paper and then trace it to the correct resolution. Then you had to calculate all of the needed points. Finally, you had to ink them with splines or French curves, messy pens, and similar drafting tools. Final size and detail changes were a real bear. Especially if you had to stretch or shrink it in one direction only.

Even then, the editor might decide it's not good enough and has to redo the entire figure from scratch.

These days, instead, you simply

use that incredibly superb PostScript language to draw the whole job for you. Instantly and hassle free.

PostScript is one totally *general purpose* and super friendly computer language that is absolutely ideal for many hardware hacking tasks. One of PostScript's utterly minor and almost insignificant capabilities is to dirty up otherwise clean sheets of paper.

In any way you like. Totally device independently. So the same old word processor text file you use for your rough proof copy can also now be phototypeset. Interchangeably, on *any* brand of personal computer.

Figure three shows you the ultra simple PostScript code required to create all the fancy semilog decibel resonance plots of figure two. You just shove this through your favorite word processor and then send it to a PostScript printer using a two-way comm setup. Ethernet, AppleTalk, Serial, or Shared SCSII comm will all work just fine.

But *never* use a parallel port with PostScript! To do so blindfolds you and ties both of your feet together. Many PostScript programs will not run at all over a parallel port.

UPDATE: Sending the code to Acrobat Distiller or GhostScript is now much faster and much more convenient. Full details are found in [DISTLANG.HTML](#)

All you need to write PostScript code is your favorite editor or word processor.

I have just posted a PostScript for Hardware Hackers tutorial as #511 NUTS9.PS to my *GENIE* PSRT.

Among the many hundreds of other PostScript-as-language files, the full Smith Chart drawing routines as file #367 SMITHCHT.PS and my printed circuits as #401 PRINCRCT.GPS. The PostScript startup secrets tutorial now appears as #335 SECRTEMP.GPS and PostScript speedup secrets tutorial as #460 SPEEDUP.PS. Unique PostScript code to let you instantly draw all the camera-ready figures in this column appears as HACK59.GPS.

Finally, if you do not now have a PostScript printer, I've posted the GHOSTSCRIPT files to PSRT. These let you run PostScript with just about *any* printer. They also give you full viewable display PostScript on any monitor. The current PSRT banner will show you the latest GhostScript version numbers to use.

While figure two can easily be done in "raw" PostScript, I've made my coding even faster and simpler by opening a convenient and powerful layout/illustration dictionary I use. This file is #517 GONZO15.PTL and gets persistently downloaded at the start of your work session. One single "guru" command opens up this set of power tools for you.

You can also write or call me for a free new PostScript secret resources mailer.

UPDATE: Many of the mentioned files are slowly being transferred to [www.tinaja.com](http://www.tinaja.com) as time and banner sponsors permit.

### High side drivers

There's a new game in town called *high side drivers* that are becoming super important. A high side driver is a solid state relay placed between the positive dc supply line and any loads that you wish to control.

Automotive people like high side drivers because only a single wire is needed for each load with the chassis forming the ground return. Laptop and palmtop computer folks like high side drivers because the inputs and outputs of the controlling circuits are not hurt by any floating grounds.

Many high side drivers are smart enough to protect themselves against

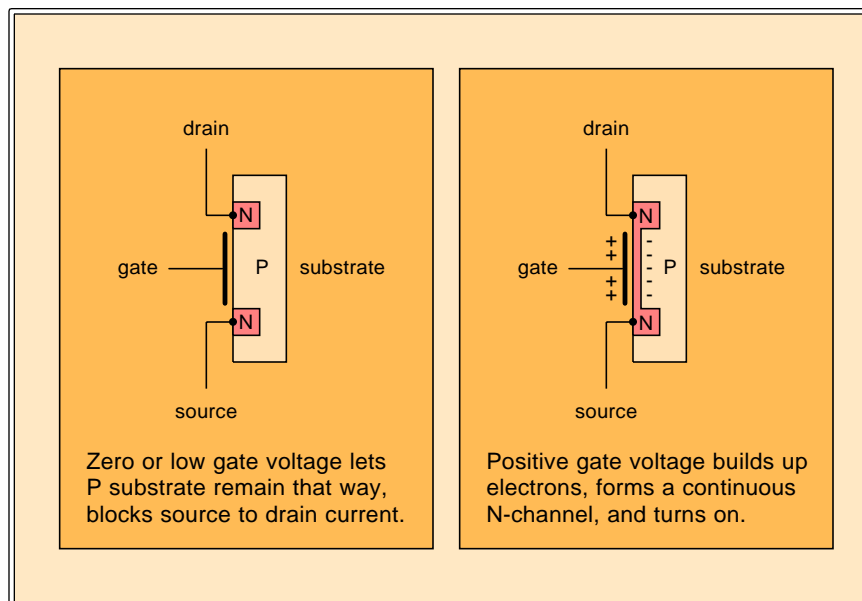


Fig. 4 – THE N-CHANNEL POWER MOSFET is now the most popular and most economical power switch in use today. Increasing the gate voltage above its threshold value turns the device on.



shorts, overloads, and other faults. What gets tricky fast about high side drivers is that the preferred choice in any electronic switch today is the N-channel power MOSFET. To turn on an N-channel MOSFET that's been connected to your positive supply voltage, you'll need a gate control signal well *above* that of the supply.

Before we see just how we can get a control signal that is well above that of the most positive supply line, let's briefly review just what an N-channel MOSFET is and how it works. Figure four shows details.

You start with a block of P-doped silicon. Add a non-rectifying or an *ohmic* terminal to it, known as the *substrate*. Now you implant two N-channel wells in the substrate. Ohmic contact these and call them the *source* on the bottom and the *drain* on top. Now, build a capacitor by adding a superthin dielectric and a conductor between source and drain. Call this lead the *gate*.

If the gate is at a zero or negative potential with respect to the source, there will be a zero drain to source current, since the MOSFET looks like a pair of back-to-back diodes. There will also *never* be any steady state gate current, since all your gate ever does is charge up or discharge a small capacitor.

Let the gate get somewhat positive with respect to the drain. Electrons have to pile up on the substrate side of the gate capacitor, so that area will become *less* of a P-type material. Let the gate voltage exceed a *threshold* value, and the extra electrons on the substrate side will actually change the substrate into a continuous N *channel* between source and drain. You now have three N regions tied together into a solid block. These look like a plain old resistor and allow current between source and drain.

Below the threshold voltage, you'll have an open circuit between source and drain. Above threshold, you have a small resistor between source and drain. A grounded gate turns you *off*. A gate above the threshold voltage turns you *on*. The typical threshold is around +4 volts or so, but to really turn the device solidly on, a gate to source voltage of +10 is preferred.

Unlike the NPN power transistors, there are no saturation effects or P-N

junctions in your main current path. There is also zero steady state gate current needed. A turned on MOSFET acts as a plain old low value resistor.

Your "on" resistance of a single N-channel MOSFET isn't really that great. For instance, in the CMOS 4066 quad analog switch, the on resistance is a high 16 ohms or so. To beat this, power MOSFETS are really hundreds, or even thousands of tiny MOSFET transistors all internally connected in parallel.

There are lots of sources of power MOSFET chips. *Motorola*, *Siliconix*, *Texas Instruments* and *International Rectifier* are typical. Because of their quite low cost and high gain, these have become the main power switch of choice for many electronic uses. Although there are also P-channel MOSFETs, they do cost more and are less efficient. And because of certain fundamental device physics, they are likely to remain so.

Since a turned on power MOSFET is really nothing but a resistor, *it does not matter which direction the main current goes*. If you do the obvious and make the drain go positive with respect to the source, you are said to be in *quadrant I*. On the other hand, if you make the drain negative with

respect to the source, you end up in *quadrant III*. High side drivers work in quadrant I. But most synchronous rectifiers which use MOSFETS will normally run in quadrant III to avoid substrate diode conduction.

To use a N-channel MOSFET as a high side driver, you just connect the drain to the positive supply, and your source to the load being controlled. To turn the switch off, you leave the gate at or below the positive supply voltage. To turn the switch on, you connect the gate to a value well *above* that of your positive supply, typically by +10 volts or so.

Where on earth do you get an extra supply that is well above your main supply voltage? Quite little average current is needed since you are only charging or discharging a small gate capacitor. A number of new low cost integrated circuits are now available which use *charge pumps* and similar circuit tricks to let you reliably apply N-channel MOSFETS for high side power switches. Typical examples do include that *International Rectifier* IR2125, the *Maxim* MAX620, and the *Linear Technology* LTC1155.

The LTC1155 is a very interesting chip. This gives you a self-protecting pair of micropower dual high side

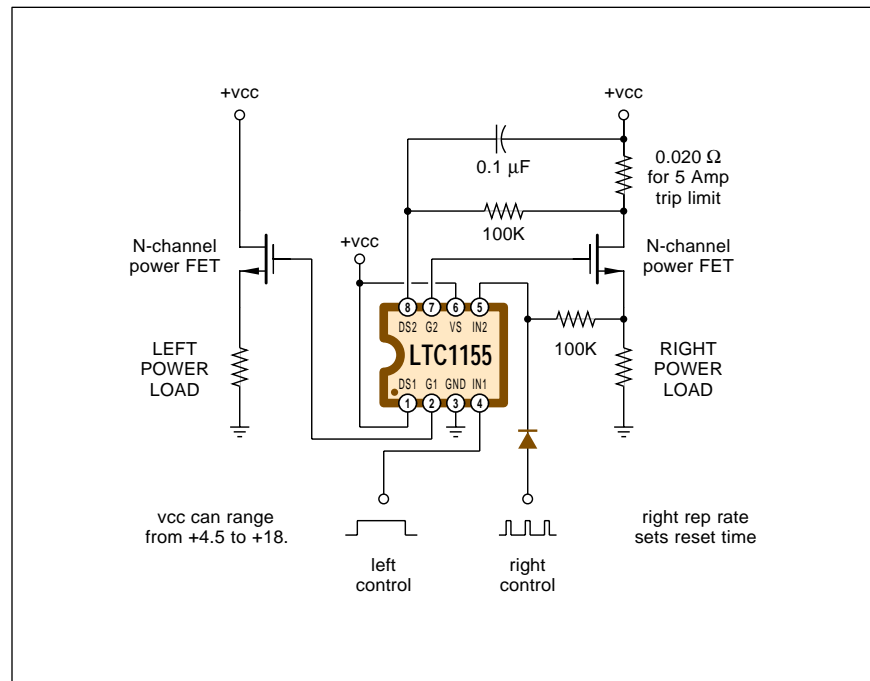


Fig. 5 – A DUAL HIGH SIDE DRIVER. The left side is shown as a simple power relay, while the right side includes "slow blow" current sensing and an auto breaker reset. The boosted gate voltages are internally generated.

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drivers in a single eight pin mini-DIP. A dual high side circuit breaker is shown you in figure five.

Here is how either half of this circuit works: A built-in charge pump continuously generates a reference voltage above the positive supply.

Leaving IN1 low leaves your load unpowered. Raising IN1 to a TTL logic one (+2 volts or higher) turns on your load. The load gets turned on by supplying the boosted gate voltage to the power MOSFET. With a five volt supply, your boosted voltage is around +12 total, or around +7 above the supply. Higher boost voltages are generated for higher value supplies.

The load power normally stays on until IN1 drops to a logical zero under 0.8 volts. There's also a protection input known as DS1. If DS1 ever gets more than one tenth of a volt below the supply, it automatically shuts things down. You can add a load sensing resistor of one tenth of a volt per amp to shut down on any overcurrent as shown.

Some loads might have large but expected inrush currents. This often happens with incandescent lamps and solenoids. A resistor and capacitor time delay can be added to the current sensing to allow inrush currents but still react to overloads. This simulates the operation of a slow blow fuse. See the LTC1155 data sheet for more details. Many other innovative circuit examples are included.

Be certain that the inrush filter capacitor goes to your positive supply and *not* to ground!

A snap action gets involved on a circuit overload. Once any overload occurs, the input must be brought low and then back high again to repower. This can be done either manually or automatically.

Switching times are fast but not stunning. The turn-on time is around half a millisecond. The usual turn-off time is around 32 microseconds.

Note that any simple *exclusive-OR* gate could get used for external fault detection. If the on command is high and your load is low, you have an output short. If the on command is low and the load is high, you have an output open. If both are low, you have a normal switch turn-off, and if both are high, you'll have a normal switch turn-on condition.

The standby current when off is a mere 8 microamps, making this ideal for battery saving applications.

Lots of additional details on analog switches are in my *CMOS Cookbook*.

You'll be seeing lots more on high side drivers as they are one of the hottest of new electronic applications areas. What unusual or off-the-wall uses for these can you think of?

### More semiconductor houses

This month, we will continue our multi-part resource sidebar listing of semiconductor houses, picking up *Gould* through *NEC*. I have left off some of the more obscure outfits that don't seem too innovative.

*General Electric*, *Intersil*, and *RCA* are now part of *Harris*. A few of their better chips remain available.

Similarly, the *Sprague* folks have now become *Allegro*, *Amperex* has sold out to *Philips*, and the dregs of *Mostek* were long ago absorbed into *SGS*. *General Instruments* has moved across the country and all their good sound effects chips fell off the truck on the way. Most of the low volume power semiconductor houses are now changing their names so fast it is hard to keep up. See *PCIM* and similar trade journals to find just out who is currently calling themselves what in this specialty area.

### Laser repair training bargain

*Canon Inc.* manufactures by far the most popular laser printer engines in use today. *Hewlett-Packard*, *Apple*, *QMS* and several of the other major players all use Canon engines in their laser printers.

Of these printers, by far the most popular mid-range units all will use the Canon SX engine. And by far the largest single repair item on all these machines is cleaning and repair of the SX fusion assemblies. The stuff that typically goes wrong with SX fusion assemblies are the scored or swollen rollers, broken or burned out quartz heater lamps, worn or tooth-missing gears, dirty or defective temperature sensors, feed creasing and jamming, or general grunge accumulation.

*Don Thompson* of *TechniGraphics* has long offered the very finest laser printer repair training. He recently sent me a sample of his new *SX Fuser Assembly Master Kit*, and has agreed

to offer it to *Electronics Now* readers at a very special price \$350.

For the price of one new fusion assembly or one single fusion repair from a typical computer dealer, you get a complete set of *all* the quality hand tools and supplies required to become a fusion rebuilding expert; a two hour lucidly detailed videotape; secret insider info on the "tye wrap" spring retainer method; a personal tech help hotline; and replacement parts for just about everything that can go wrong with these units.

Individual bits and pieces are also economically available as needed to continue your own fusion rebuilding enterprise. Most other sources will sell only complete assemblies.

## NAMES AND NUMBERS

### ASD/AMD Trade News

2525 Ocean Park Blvd  
Santa Monica, CA 90405  
(800) 421-4511

### Asian Sources/Wordright

1020 Church Street  
Evanston, IL 60201  
(708) 475-1900

### Bell System Tech Journal

101 John F. Kennedy Parkway  
Short Hills, NJ 07078  
(201) 564-4454

### Cherry Semiconductor

2000 S County Trail  
East Greenwich, RI 02818  
(401) 885-3600

### Dallas Semiconductor

4401 S Beltwood Pkwy  
Dallas, TX 75244  
(214) 450-0448

### Dialog

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

### EG&G Reticon

345 Potrero Avenue  
Sunnyvale, CA 94086  
(408) 245-2060

### Garden Way Products

102nd Street & 9th Avenue  
Troy, NY 12180  
(800) 732-6354

### GENie

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

### Hewlett-Packard

PO Box 10301  
Palo Alto, CA 94303  
(800) 752-0900

### Industrial Market Place

7842 N Lincoln Avenue  
Skokie, IL 60077  
(800) 323-1818

### International Rectifier

233 Kansas Street  
El Segundo, CA 90245  
(310) 322-3331

### Linear Technology

1630 McCarthy Blvd  
Milpitas, CA 95035  
(408) 432-1900

### Maxim

120 San Gabriel Drive  
Sunnyvale, CA 94086  
(408) 737-7600

### Motorola

5005 E McDowell Road  
Phoenix, AZ 85008  
(800) 521-6274

### Siliconix

PO Box 54951  
Santa Clara, CA 95056  
(408) 988-8000

### Speleonics

Box 5283  
Bloomington, IN 47407  
(812) 339-7305

### Texas Instruments

PO Box 809066  
Dallas, TX 75380  
(800) 336-5236

### Don Thompson

23072 Lake Center Dr #100  
El Toro, CA 92630  
(714) 855-3838

### Trade Winners

PO Box 2868  
Vancouver, WA 98668  
(206) 694-1765

### Far East sources

I continually get helpline calls for hardware hackers who seek Far East contacts for computers and electronic assemblies and custom work. We have already seen that *Trade Winners* is one possible resource. This is sort of a Hong Kong *Computer Shopper*, only wholesale.

But I may have found the mother lode. There's now a Hong Kong trade journal publisher by the name of *Asian Sources* who publish seven magazines, one each for computers, electronics, electronic components, timepieces, fashion accessories, home products, and "hardwares". The latter is apparently their term for machinery

and industrial supplies. Yes, they are all printed in English.

These cost \$70 each per year via surface mail. But they do offer free samples on a one-sample-per-request basis. Per their bingo cards.

### New tech lit

From *Dallas Semiconductor*, a fat new 1993 Product Data Book. Full of exciting, innovative, and very useful hacker chips. Mostly timers, clocks, non-volatile memory, smart sockets, telephone and security stuff.

Through *Cherry Semiconductor*, a new data book on automotive, sensor, motor controlling, and power supply circuits. And from *Reticon*, a *Solid State Camera Products* data book.

The *Industrial Marketplace* is a great tabloid shopper with lots of outstanding surplus offerings and full auction listings. Mostly mechanical and machine shop stuff, but definitely some electronics. I get the impression that this is *the* wholesaler's surplus insider's mag.

Another interesting and readable surplus shopper mag is the *ASD/AMD*

### 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](mailto:don@tinaja.com)  
Web page: [www.tinaja.com](http://www.tinaja.com)

*TradeNews*. But it does not strongly emphasize electronics.

Replica kale is newly offered by *Garden Way Products*.

Free samples of their new AllnGaP lamps are available through *Hewlett Packard*. These are incredibly bright LED's visible in direct sunlight. And intended for eventual use as auto tail lights and turn signals. These are the first LED products with efficiencies about the same as an incandescent lamp. A detailed discussion of this new technology appears in the current issue of *Speleonics*.

I've recently posted a thorough and complete list of inventor's resources to PSRT as #520 INVENORG.PS. Also see #477 NOPATENT.PS. We'll have some more info on inventions and inventing in a future column. Many other of my PostScript programming examples are also uniquely available in this PSRT library. Your average downloading costs are around twenty one cents.

UPDATE: These files are slowly being added to [www.tinaja.com](http://www.tinaja.com) as time and banner sponsors permit.

Sorry for the inexcusable delays, but I've at long last gotten my new *Incredible Secret Money Machine II* backlog worked off. I am currently shipping autographed copies of this newly revised guide to forming your own small scale tech, craft, or artistic venture.

As usual, we've shown most of the mentioned resources in our *Names & Numbers* or *IC Resources* sidebars. Be certain to check here first before calling our tech helpline.

Let's hear from you. There's some great opportunities here. ♦