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 Another very outdated but popular intro is Robert Page’s Origin of Radar from Doubleday.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

![RLC Resonant Circuit Diagram]

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

\[ f_0 = \frac{1}{2\pi\sqrt{LC}} \]

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

\[ \frac{e_{\text{out}}}{e_{\text{in}}} = -20 \log_{10} \left( 1 + Q^2 \frac{f_0^2 - f_0^2}{f_0^2 - f_0^2} \right) \]

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...

\[ Q = \frac{2\pi f_0 L}{R} \]

(B) As the half power bandwidth...

\[ Q = \frac{f_0}{f_h - f_l} \]

(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/e amplitude (or 37% = -8.7 decibels) in Q/\pi cycles.

(F) As the stored energy ratio...

\[ Q = \frac{2\pi (\text{energy stored per cycle})}{(\text{energy dissipated per cycle})} \]
now that the resistance is your load, reach the output load resistor. And once again, very little signal will as a rather high inductive reactance. In a circuit, and the inductor will appear the capacitor will look like a short little signal will reach the load. Very high capacitive reactance. Very inductor will look like a short circuit a very low impedance. High quality, and the signal source is the inductor and capacitor are very series resonant circuit. Assume for at resonance fundamentals¼ even wrong. Let’s take a fresh look recycling the available energy. At extremely low frequencies, the resonant voltage increase for a very low impedance. 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 attention 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 your inductor or capacitor. Some switching mode power supplies make use of this resonant rise for a transformer-free voltage increase. The resonant voltage step up 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.

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Saved, building up the inductor's and piggy bank came from. It got built up from? The same place the stash in the per cycle while you store around 15.9 resonance you will dissipate one watt input and a one ohm load, at series if you do have a Q of 100, a one amp ringing time. One obvious use is for potential energy as it oscillates, signal gets too big.

Fig. 3 – GURU GONZO POSTSCRIPT CODE used to create camera-ready semilog artwork for figure two. Send code to Acrobat Distiller.

Just as a pendulum swaps kinetic for potential energy as it oscillates, the inductor stored $L^2/2$ 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

% Requires download of GONZ015.PTL utility from www.tinaja.com. (C:\windows\desktop\gonzo\gonzo.ps) run /% rename to suit
guru save /snap1 exch def 200 300 10 setgrid % 30 30 showgrid
line1 1 setlinecap 10 0 m t 0 28 r lineto stroke
1 1.10 (log 10 mu 0 moveto 0.28 rlineto stroke) for 10 100 (log 10 mu 0 moveto 0.28 rlineto stroke) for 0 2.28 (0 exch moveto 0.28 rlineto stroke) for /v{2.5 div 26 add} def /hsf{log 10 mu 10 add} def /incperdec 50 def /startal 0.1 def
/wholecurve{Q exch def newpath /val startat def val dup fnc mt incperdec 2 mul 1 add {val fnc val hsf exch vsl lineto /val val 1 incperdec div exp mu def} repeat 0.06 setlinestroke def
[5 10 20 50 100 200] (wholecurve) forall grestore
c/stretch 0.01 def /fstretch 0.03 def /yinc 1 def
/font1 /Helvetica 0.85 gzent text
/font2 /Helvetica-Bold 0.85 gzent text
/font3 /Helvetica 0.7 gzent text
/font4 /Symbol 0.75 gzent text
/font5 /Helvetica [0.7 0.0 0.7 0 -2] gzent text
/font6 /Helvetica [0.85 -0.85 0 0 0 0] gzent text
/f{gsave vsl lineto /val val 1 inperdec div exp mu def} repeat 0.06 setlinestroke def

1 1 10 {log 10 mu 10 moveto 0 28 rlineto stroke} for 10 10 100 {log 10 mu 10 moveto 0 28 rlineto stroke} for
cursor 0.01 def /fstretch 0.03 def /yinc 1 def
/font1 /Helvetica 0.85 gzent text
/font2 /Helvetica-Bold 0.85 gzent text
/font3 /Helvetica 0.7 gzent text
/font4 /Symbol 0.75 gzent text
/font5 /Helvetica [0.7 0.0 0.7 0 -2] gzent text
/font6 /Helvetica [0.85 -0.85 0 0 0] gzent text
/f{gsave vsl lineto /val val 1 inperdec div exp mu def} repeat 0.06 setlinestroke def

/line1 1 setlinecap 10 0 mt 26 u 0 0 mt 26 pu 20 pr 26 pd 20 pl gsave line1 stroke grestore gsave
guru save /snap1 exch def 200 300 10 setgrid % 30 30 showgrid
v2 /2  energy is at p times the $\frac{1}{2} L I^2$ resonant power are involved in the Hardware Hacker III reprints.
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 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
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.
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 gears, dirty or defective temperature sensors, feed creasing and jamming, or general grunge accumulation.

Don Thompson of TechGraphics 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.

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.


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 TradeNews. But it does not strongly emphasize electronics.

Replica kale is newly offered by Garden Way Products.

Free samples of their new AlInGaP 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 Speleomics.

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 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.

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