Don Lancaster's

Tech Musings

April, 1996

PIC left and right shifting
Hot chassis shock hazards
Low amp fuse substitutions
New power supply resources
Servicing switchmode supplies

As you can tell, I now have a new name for this feature. Sadly, the popular press, the legal establishment, and a few law enforcement agencies have long ago totally subverted the once proud term "hacker".

A proud term that once meant "a limit-pushing quest seeking technical excellence" now seems to be widely misperceived as "some juvenile and socially irresponsible criminal act".

The new column name also better reflects my expanding coverage of science fundamentals, emerging tech opportunities, software, and seldom explored research techniques.

As always, I will make my usual assumption that if I am personally interested in something, the chances are that many of you will also be. If this can involve elegant simplicity or end user empowerment, then so much the better.

Switch Mode Power

Switching mode power supplies are now used pretty near everywhere. Especially in personal computers and peripherals. Instead of doing a direct power conversion at 60 Hertz, raw dc is first created. Which in turn powers a high frequency oscillator of some sort. Isolation, power conversion and regulation typically get done at a 20 kiloHertz or higher frequency.

Switchmode advantages do include a rather high efficiency, light weight, low heat, small size, tight regulation, reduced heatsinking, and low costs. Transformers in particular can end up ridiculously smaller and lighter. As do most filter capacitors.

Even though *severe* safety hazards and oddball circuits may be involved, these supplies can end up fairly easy to understand and service.

Let's take a closer look at some of the fundamentals…

The Hot Chassis: Then and Now

Your power utility provides you with a 220 volt center-tapped home service. One that has its center tap *grounded*. Two individual 110 volt *arms* are split out to supply various circuits in your home. Thus, one end of each 110 volt line is "hot" and one is "grounded". If you come in contact with the hot line, you will receive a mild to severe shock. Should you get *between* hot and ground, the shock could be fatal.

Anything that plugs into the power line needs some way of dealing with possible shock hazards. Both to the end user and to anyone doing service. A power transformer is one costly yet totally effective solution.

At one time, low cost AM radios avoided the use of a transformer by going to their *hot chassis* system of figure one. One side of the ac power line was physically connected to the chassis of the radio. Plugs in those days were *not* polarized, so you had a 50-50 chance of a hot chassis.

If hot side connected, *Touch the chassis and you are toast!*

The reasoning was that the brittle plastic case and easily broken knobs would sort of protect an average user. Well, so long as they didn't put their fingers in the back. And service techs were supposed to know better.

Besides, none of the fatalities ever complained.

I am utterly amazed that scads of people weren't electrocuted by these obvious hazards. Service people (at least the ones that survived) quickly learned to respect a hot chassis.

If you were brave, you touched the chassis through a neon test light. If the lamp dimly lit, you then reversed the plug. If you were smart, you used an *isolation transformer* instead.

Premium hi-fi's and television sets made use of weighty and expensive power transformers. As circuits went solid state and the total power needs dropped, at least some of these went to today's lower power wall-mount transformers. The only hazard here is *inside* your small throwaway unit.

But transformers were still needed if higher powers or lots of different supply voltages were required. These remained big and expensive. Until someone got the brilliant idea to use high frequency transformers instead of 60 Hertz ones.

All other things being equal, a 20 kHz transformer only needs 1/333rd the weight and volume of a 60 Hertz one. Even better yet, you saved *two* ways on filter caps. First because of the increase in frequency. And even more so since you were now dealing with easily-filtered square waves.

These new high frequency circuits are known as *switching mode power*

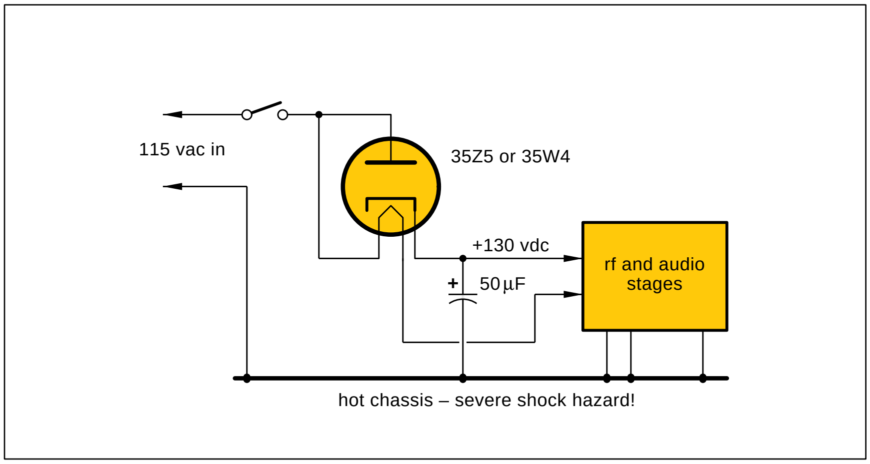

Fig. 1 – THE HISTORIC "HOT CHASSIS" PROBLEM. Tube type "AC-DC" am radios had one side of the ac power line connected directly to their metal chassis. Depending on how the line cord was plugged in, you had a 50-50 chance of receiving a bad shock when you touched the chassis.

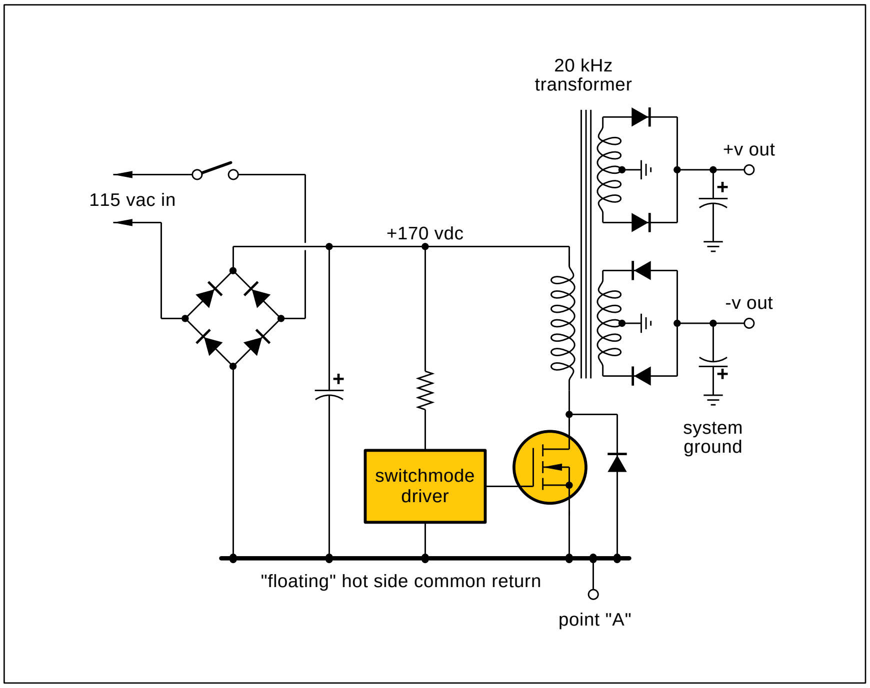

Fig. 2 – A TYPICAL SWITCHING POWER SUPPLY. Note that there is an EXTREME shock hazard to the left of the transformer. Be sure to note that connecting a scope ground lead to point "A" will instantly blow one or more power diodes! An isolation transformer MUST get used for ALL service.

supplies. As figure two shows us, the end user is fully safety isolated and has nothing to worry about.

Not so the service person.

For there is now a *hot side* and a *cold side* to any switch mode supply. There are high to *very* high voltages involved on your hot side. A person servicing tube radios gets a shock every now and then as a reminder. It was not nearly as unheard of as in most modern repairs.

There is an extreme shock danger on the hot side of any switching mode power supply!

Moreover, there is usually a diode bridge on the input. So, the negative side of your filter capacitor is *always* one diode drop removed from the hot side of the ac power line!

If you connect a scope ground to the "ground" side (point "A") of your filter capacitor, you will *immediately blow out at least one of the diodes in the bridge!* No matter if any fuse is present. The diode will usually blow first because you just put the full line voltage *directly* across it. Also, in the process, you are likely to vaporize your scope probe lead, burn yourself, and receive a severe shock.

So, the old "hot chassis" problem is now back in spades. And it's much *worse* than before. Because reversing your line cord (A) is not possible and (B) will not work anyhow.

*Any attempt at servicing **any** line operated switch-mode supply **must** make use of an isolation transformer!* In addition, *you **must** be extremely careful where you place your scope ground lead!*

You should first run through a 110 volt safety isolation transformer. 200 watts is often good enough for most modern gear. This could optionally be followed by a variac.

Variacs are particularly handy to troubleshoot problems where the fuse instantly blows. Even without a fuse blowing, doing your troubleshooting around 85 volts may reduce the fault currents. Always place the optional variac *after* the isolation transformer, never before.

If you can't afford a variac, one ploy the old timers used was to put a large light bulb or two in series with their load. Plus a bypass switch.

By one of those utterly astounding coincidences that seem to infest this column, I just happen to have a few isolation transformers and one variac left from my recent surplus sale.

Servicing Your Switching Mode Power Supply

Repairing a modern switch mode power supply can end up tricky. First because their non-standard circuitry may not be all that obvious. Second, because of the really *extreme* safety and isolation problems. And third, because everything is connected to everything else in obscure ways.

Let's look at a repair example. I'll show you a little known sneaky trick that I personally use. One that might make things a lot easier for you.

But: *Do not even attempt a repair unless you have a decent scope, total safety isolation, and accurate service information on hand!*

A full schematic is ideal. At the bare minimum, you should know the pinouts of all output lines and have data sheets for *all* integrated circuits and power semis involved.

I picked up a *Tektronix* 2215A scope at an auction. Plainly marked "power supply bad".

Sure enough, no trace and not even a power-on LED. Thankfully, the fuse was fine and did not blow on power up. Figure three shows a simplified schematic of the switch mode power supply used.

The main linear power transformer outputs on several windings for all of those needed scope supply voltages. That second feedback transformer is a *saturating* one that will set the base drive feedback.

I did have a not-quite-right manual for their older 2215. Whose appended change info section was "sort of" like the circuit in use. A look-and-sniff inspection revealed nothing obvious in the way of burned transformers or discolored parts.

The usual 10X resistance check of the output transistors found that all junctions were still working. Neither open nor shorted. A resistance check on all of the output voltage lines also showed nothing suspicious.

Later on, hindsight revealed that Murphy's Law had indeed struck. In misreading a key point. Owing to a missing (but still marked!) jumper. One used on the 2215 but not on the newer 2215A.

I hooked up the required isolation transformer, followed by a variac and ran it up to 85 volts. The preregulator never got out of its startup mode. It would try, but it quickly shut down from excess current. It would wait a few seconds, and then try again.

A scope viewing at that common emitter resistor "B" on the converter showed current ramping up above the one amp limit and then shutting off. A look at points "C" and "D" revealed that the transistors were not able to pull their windings down very far at all. But they did at least seem to try. And there were some encouraging 20 kHz "fumes" present.

This said that the main transformer was shorted, excessively loaded, or improperly driven. And Tek's factory list replacement transformer pricing nearly equals the wholesale value of the entire scope.

So, here's the sneaky trick I used to isolate the real culprit: Very few integrated circuits or diodes do much of anything below 0.3 to 0.6 volts. I next injected an 0.4 volt peak-to-peak *triangle wave* to points C and D.

With the power cord disconnected and all grounds removed.

With any 42 volt, one amp supply, you'd expect that the 20 kHz no-load input impedance at this point to be well above 42 Ohms. Instead, it was way down in the milliohms. *Telling us the short was real*. Gotcha!

But a check on the high voltage output winding did reveal a smallish triangle wave. And, on switching to a square wave, transformer-type droop and ringing appeared. So there was at least some hope.

Tek does provide some jumpers to simplify servicing. Cutting these did not help at all.

But we *already* knew that from the previous resistance tests! Duh.

The next logical step would have been to remove the transformer from the circuit board and thoroughly test it. A slow and painful process. So, just for luck, I first ran an Ohmmeter around the diodes. Sure enough, there was a dead short across the diodes on the 30 volt supply.

The usual candidate for a shorted part is the filter capacitor. A shorted diode in any properly designed and inherently current limited supply is *extremely* unlikely.

But a good diode would never let this weak test signal even reach the cap! If your cap was bad, a larger

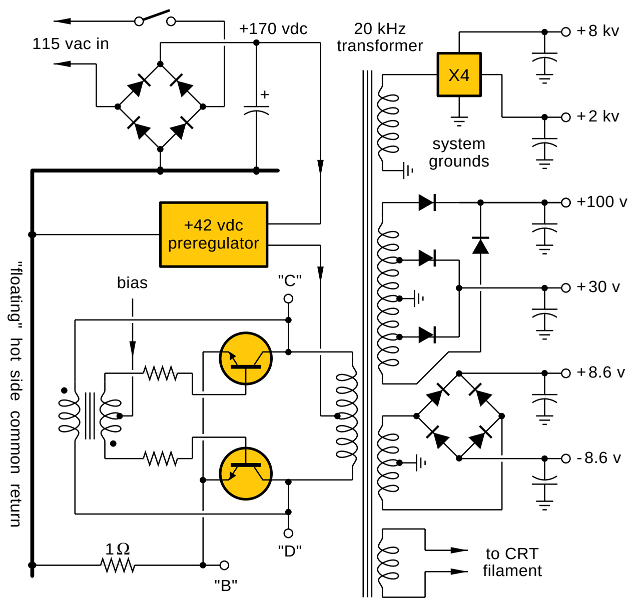

Fig. 3 – A PARTIAL SCHEMATIC for the switching supply on a Tektronix 2215A oscilloscope. To resolve a power problem, first use an isolation transformer and monitor the current waveform at point "B". Then remove the line cord and all grounds. Next, inject a 0.4 volt peak-to-peak 20 kHz triangle wave at points "C" and "D". Noting when and how the triangle wave clips can quickly isolate a defective transformer, diode, circuit load, or filter capacitor.

REGISTER SHIFT RIGHT –

This method first clears the carry...

```
SRIGHT1  BCF S,C   ;clear the carry flag
         RRF F,1   ;rotate all bits right
```

This method repairs possible damage instead...

```
SRIGHT2  RRF F,1   ;rotate all bits right
         BCF F,7   ;force bit 7 to zero
```

REGISTER SHIFT LEFT –

This method first clears the carry...

```
SLEFT1  BCF S,C   ;clear the carry flag
        RLF F,1   ;rotate all bits left
```

This method repairs possible damage instead...

```
SLEFT2  RLF F,1   ;rotate all bits left
        BCF F,0   ;force bit 0 to zero
```

OPTIONS –

Use of RLF F,0 or a RRF F,0 puts shifted result into the accumulator instead.

To shift a value already in the accumulator on low end PIC devices, MOVWF to temporary register storage, then use above methods. Note the accumulator is already register mapped on 17CXX PIC chips.

Note also that the carry flag exits in an unknown state.

Fig. 4 – THE PIC MICROCOMPUTER lacks simple "shift right" and "shift left" instructions. Here is how to provide them in two or three code bytes.

POWER SUPPLY RESOURCES

Analog Devices PO Box 9106 Norwood MA 02062 (617) 329-4700	**International Rectifier** 233 Kansas St El Segundo CA 90245 (310) 322-3331	**National Semiconductor** 2900 Semiconductor Rd Santa Clara CA 95052 (800) 272-9959	**Supertex Inc** 1350 Bordeaux Drive Sunnyvale CA 94089 (408) 744-0100
Coilcraft 1102 Silver Lake Rd Cary IL 60013 (800) 322-COIL	**Linear Technology** 1630 McCarthy Blvd Milpitas CA 95035 (408) 432-1900	**PCIM** 2472 Eastman Ave #33-34 Ventura CA 93003 (805) 658-0933	**Surplus Traders** PO Box 276 Alburg VT 05440 (514) 739-9328
Electronic Compt News 1 Chilton Way Radnor PA 19089 (215) 964-4345	**Magnetics Inc** Box 391 Butler PA 16003 (412) 282-8282	**Phillips Magnetics** 1033 Kings Highway Saugerties NY 12477 (914) 246-2811	**Teccor Electronics** 1801 Hurd Drive Irving, TX 75038 (214) 580-1515
Electronic Products 645 Stewart Ave Garden City NY 11530 (516) 227-1300	**Maxim** 120 San Gabriel Dr Sunnyvale CA 94086 (800) 998-8800	**Power Transmission Design** 1100 Superior Ave Cleveland OH 44114 (216) 696-7648	**Texas Instruments** PO Box 809066 Dallas TX 75380 (800) 336-5236
Ferroxcube 2001 W Blue Heron Blvd Riviera Beach FL 33404 (407) 881-3200	**Motion Magazine** Box 6430 Orange CA 92613 (714) 974-0200	**Sensors** 174 Concord St Peterborough NH 03458 (603) 924-9631	**Toko** 1250 Feehanville Drive Mt Prospect IL 60056 (708) 297-0070
Galco 26010 Pinehurst Dr Madison Heights MI 48071 (800) 521-1615	**Motorola** 5005 E McDowell Rd Phoenix AZ 85008 (800) 521-6274	**SGS** 1000 East Bell Road Phoenix, AZ, 85022 (602) 867-6100	**Unitrode** 580 Pleasant St Watertown MA 02172 (617) 926-0404

input signal (above 0.6 peak volts) would *clip*, not reveal a total short. Which was my reason for using a triangle wave in the first place.

I ignored this obvious fact, and removed the filter cap anyhow. Sure enough, it tested just fine out of the circuit. At least as a quick and dirty "watch it kick" Ohms test.

Lifting one end of each diode did in fact reveal one of these to be a dead short. Very rare indeed.

Note that these are higher speed power diodes that have special short recovery times. But even direct from *Tektronix*, their exact part cost only fifty-five cents.

Once again, please remember that *any misplaced scope ground lead can instantly ruin a line-operated switch mode supply!* **Always** use an isolation transformer, and *think before you connect or measure!*

Getting *Tektronix* info and parts can sometimes be tricky. Older parts and manuals are no longer available. Certain key newer items can often be outrageously overpriced.

An outstanding alternate Tektronix resource is *Stan Griffiths* and his fine *Oscilloscopes–Restoring a Classic* book. Stan also knows of several low cost sources for long-gone to modern Tek parts. These private sources did *not* wish to be listed in any national magazine, but they sometimes can be made available to you when you call or write Stan.

I've also got a major collection of genuine Tek manuals available at reasonable prices. Write or call for info. More details on *www.tinaja.com* as file SURPCAT1.PDF.

Power Supply Resources

For this month's resource sidebar, I thought we'd review a few places to go for power supply information.

Your finest supplier is probably *Maxim*, who provide lots of ap notes and free samples. Other chip sources include *National*, *Motorola*, *Analog Devices*, *Unitrode Inc*, *International Rectifier*, *Texas Instruments*, and the *Linear Technology* folks.

One useful trade journal is *PCIM*. A good power supply web site can be found at *http://motioncontrol.com*

A complete review for all power electronics appears as NUTS46.PDF in my *www.tinaja.com* site. I've also got a large pile of aerospace quality lab power supplies at very low prices in our freebie surplus flyer. Printed copies on phone request or online interactive as SURPCAT1.PDF.

NEED HELP?

Phone or write all your US Tech Musings questions to:

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Web page: *www.tinaja.com*

Another PIC Trick

I've been doing a lot more with the PIC microprocessor, especially for new magic sinewave development. Uh, it seems that plain old shift-right and shift-left commands are missing from the PIC instruction set. Among many other uses, these are real handy for dividing or multiplying by two.

Several helpline callers have also requested these commands. Figure four shows some easy workarounds. Just use a rotate right or left through the carry, and then repair the possible damage with a second zero-forcing code byte. Even with two clocks and two cycles, this patch still blows the competition away.

Let me know if there's any other PIC programming tricks you want to see. A free *Incredible Secret Money*

NAMES AND NUMBERS

Comlinear
4800 Wheaton Drive
Fort Collins CO 80525
(970) 226-0500

Stan Griffiths
18955 SW Blanton
Aloha OR 97007
(503) 649-0837

ITS World
859 Willamett Street
Eugene OR 97401
(541)343-1200

Eastman Kodak
343 State
Rochester NY 14650
(716) 724-4385

LZR Electronics
8051 Cessna Avenue
Gaithersburg MD 20879
(301) 921-4600

The Mart
899 Presidential Ste 110
Richardson TX 75081
(800) 864-1155

Mitsubishi
1050 E Arques Ave
Sunnyvale CA 94086
(408) 730-5900

Parallax
3805 Atherton Rd #102
Rocklin CA 95765
(916) 624-8333

Raychem
300 COnstitution Drive
Menlo Park CA 94025
(800) 227-7040

Recharger
4218 W Charleston Blvd
Las Vegas NV 89102
(702) 438-5557

Synergetics
Box 809
Thatcher AZ 85552
(520) 428-4073

Tektronix
PO Box 500
Beaverton OR 97077
(800) 835-9433

Telecom Gear
15400 Knoll Trail Ste 500
Dallas TX 75248
(800) 866-3241

Temic
2201 Laurelwood Road
Santa Clara CA 95056
(408) 970-5700

Tessco
34 Loveton Circle
Sparks MD 21152
(800) 472-7373

Vetra Systems
275J Marcus Blvd
Happauge NY 11787
(516) 434-3185

Machine II book will go to a dozen of the best requests.

A magic sinewave tutorial appears as MAGSINT.PDF on *www.tinaja.com* I'll also be happy to mail you a free copy on request.

Cheap Low Current Fuses

As we've seen a time or two in the past, *Recharger* magazine is *the* best source for all laser printer cartridge reloading info. Uh, it appears that some epsilon minuses at *Xerox* have recently been including sequentially blowable fuses in their laser printer cartridges. Their intent is to make recharging a tad more challenging.

The fuses are apparently rated at 20 milliamperes and 200 volts. The host blows the first fuse after a few hundred copies, the second when it thinks toner is low, and third when it decides your toner is out.

Several *Recharger* authors are now looking for a low cost source for low current fuses. A fast check into any distributor's catalog reveals that low current fuses are insanely expensive and ridiculously hard to find.

Well, in nearly all lower current protection schemes these days, you substitute a cheap and automatically resetting *positor* instead. Such as those made by *Raychem*. A positor's resistance sharply *increases* with the heating caused by an increasing load current. This resistance change will in turn greatly reduce the available power delivered to the rest of your circuit. Reset is automatic, happening shortly after the overload goes away. But a positor clearly will not work where any fuse is to be *intentionally* and permanently blown.

Instead, try using a single strand of #000 steel wool! These have a near zero cost and typically will open in the tens of milliamperes. The strands are usually solderable *if you do not touch them*. And if you use a better grade of liquid solder flux.

This same trick works just fine in a

student lab to protect milliameters and microammeters. Hang a pair of reverse parallel silicon diodes across the meter terminals, and put a single strand of steel wool in series.

New Tech Lit

From *Mitsubishi*, a superb *ASSP Availability Guide*. Covering all sorts of interesting chips. Including their M65830 digital echo, M50194 digital reverb, 66330 fax codec, their 67405 surround sound processor, and 66512 laser beam controller.

From *Comlinear*, a data book on high performance analog amplifier chips. From *Tessco*, a new full line catalog of wireless communications equipment and supplies.

A very useful *IRDA Compatible Data Transmission Design Guide* is now offered by *Temic*. Included are the IrDA infrared comm specs.

Ricoh has ap notes and data sheets available on the new 5A128 low cost speech recognition circuits. A free new *Glossary of Image Sensor Terms* tutorial is offered by *Kodak*.

There's a brand new trade journal on intelligent transportation systems. Called, of all things, *ITS World*. This one features everything from smart highways to GPS to CD ROM maps.

The best two telecomm shoppers are *Telecom Gear* and *The Mart*. One source for phone premise wiring and parts is *LZR Electronics*.

I do get a lot of calls from readers wanting remote PC keyboards, RS232 adaptors and extenders. Dozens of products to handle these tasks are offered by *Vetra Systems*. A PIC is the obvious choice to build your own instead. Start with the *Basic Stamp* from *Parallax*.

A reminder that I've just reprinted my *Active Filter Cookbook* for the *seventeenth* time. Refer to my nearby *Synergetics* ad for full details.

I've also acquired quite a unique collection of classic microprocessor trainers. Everything from genuine KIM-1's to gold plated HP 5036A's to superb little book-shaped *Z80 Micro Professors*. The latter with printers, no less. They all are both usable and highly collectible. ✥