HARDWARE HACKER

Driving inductive loads, more on phone caller ID, Bakerizing and laminating, alternators as stepper motors, and programmable logic resources.

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Let us first pick up on several updates to some of our earlier *Hardware Hacker* topics. One good source for those BA1404 FM stereo broadcasting kits is *DC Electronics*. They also stock the super new *Signetics* NE602 mixer/converter chips and the TEC-200 film for direct toner printed circuits. Another NE602 source is *Active Electronics*.

Telephone caller ID is certainly one hot topic these days. And yet another source of call identifier magic boxes is *Hello Direct*. Prices start at $60. You must, of course, have the ID service available before you can use these magic boxes. States that have at least some local availability of caller ID should now include AL, CA, FL, GA, IL, IN, MD, ME, MI, NC, NE, NJ, NV, OH, OK, SC, TN, VA, VT, WV, and Washington DC. Other areas are still in the planning stages. Most services are still for local calls only.

One handy and rather non-obvious benefit of this new service: When you come back from lunch, you have a complete and time-stamped list of everyone who tried to call you when you were out. Most useful.

I thought we might round up a big collection of odds and ends for this month's column...

Driving inductive loads

If you blindly connect a transistor or another solid-state device to an inductor such as a relay or a motor coil, you will almost certainly blow out your circuit the very first time you power it up. Special protection techniques are *always* needed when you try to control an inductor's current with any solid-state device. These inductive-circuit protection techniques are cheap and simple, but you do have to understand what is coming down to use them properly.

Take a coil of wire and connect it to a voltmeter. Now shove a magnet through the center of your coil. As you insert the magnet, you generate a positive induction voltage. Remove the magnet, and you'll generate a negative induction voltage. Any time your magnetic field *changes*, you generate an induced voltage. And the faster the change, the more voltage you create.

Since any current through a coil can generate a magnetic field, any change in your coil current should produce a change in the magnetic field, which in turn induces a voltage spike. The greater or the more sudden the change in the current, the greater the induced voltage. The basic math here says that:

$$e = L\Delta i/\Delta t$$

or, in plain English, your induced voltage across any coil is proportional to the size of the inductor and the *rate of change of current through the coil.*

Say you decide to control a relay. You turn your relay on by sending a current through your coil. And then you attempt to turn your relay off by suddenly disconnecting your coil current. What happens?

Your magnetic field will suddenly collapse, generating a horrendous voltage spike. You tried to make Δt zero, and, since you're now trying to divide by zero, you get a theoretically *infinite* voltage spike. Thus, *suddenly ceasing the current in any inductance is guaranteed to create a humongous voltage spike.*

Sometimes you might choose to purposely do that. For instance, the current through the coil in any car ignition is suddenly broken to step up the 12-volt battery into many tens of thousands of volts of ignition-spark voltage. And a related technique gets used for television high-voltage.

But, should you suddenly cease a current through any coil in any solid-state circuit, the voltage spike you'll get is almost certain to blow up the transistor of whatever happens to be controlling your coil.

The rule here is simple: *Never let the current through an inductive load suddenly drop to zero in any solid-state circuit!*

Figure 1 shows you how to add a plain old power diode to your relay coil to provide spike protection. Note that the diode appears "backward" so that it does *not* normally conduct any supply current.

If you suddenly try to turn off the inductor current, a small induced voltage will immediately be created that, in turn, forward biases and turns on the protection diode. *The current you had before can then continue on through your protection diode and back into the relay coil.* The current will now drop down to zero fairly quickly, dissipating itself in the forward drop of the diode and in the internal resistance of your relay coil. At no time is any voltage spike generated that exceeds the 0.6 volts or so of your diode's forward drop.

This simple diode despiker works quite well. But there are some minor side effects that can sometimes cause problems. Note that your relay will *stay* pulled in for a brief time delay after you thought you turned if off. That happens because there is still diode-provided current going through your coil. In a larger relay, the time delay could extend a few tenths of a second, and could cause you timing problems.

The physical dropout of your relay can also end up slower and sloppier. Which could cause contact arcing in higher-current uses.

Your protection diode should also turn on fairly fast. If you use a slow diode, or if there is not enough stray

NEED HELP?

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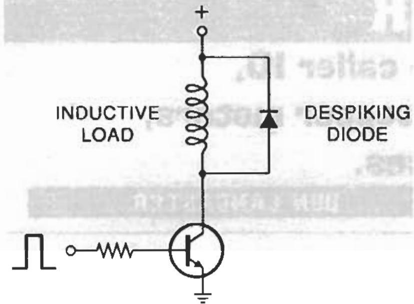

FIG. 1—ANY SEMICONDUCTOR can be instantly destroyed if you use it to suddenly turn off the current in an inductive load. The despiking diode shown here allows the coil current to continue long enough to safely dump the magnetic flux energy without creating a killer transient.

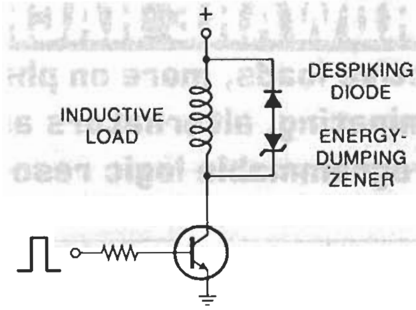

FIG. 2—ADDING A SERIES Zener diode shortens and sharpens the dropout time. This minimizes turn-off delay and contact arcing in power relays. Your control transistor must be able to block the supply voltage PLUS the Zener voltage.

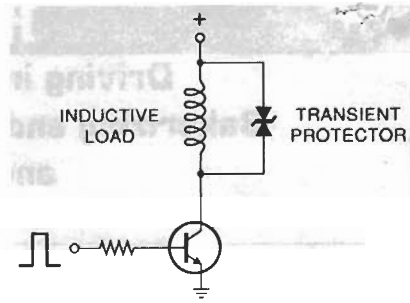

FIG. 3—TRANSIENT SUPPRESSORS are commercially available bi-directional devices that are also known as varistors, MOV's, TRANSILS, or several other trade names. These must be carefully matched to the allowable voltage rise and the magnetic flux energy to be dumped.

circuit capacitance around, a large and possibly destructive spike can build up during the time your diode actually starts conducting.

Figure 2 shows you an improved spike-protection circuit. Here we have added a 24-volt Zener diode in series with the protection diode. This combination will conduct no current in one direction and will conduct in the other direction only when the voltage across it exceeds the Zener breakdown of 24 volts. You can think of this series combo as an "inefficient diode" with a 24-volt forward drop.

Whenever you suddenly disconnect your relay current, a large but acceptable 24-volt high-voltage spike is created, which turns on both diodes in the series pair. The current continues through the diodes, but will fall to zero *much* faster as you now have a 24-volt drop burning up all of your remaining coil energy. Thus, the circuit will still give you protection, but will shorten the excess holding time by a factor of 40 or so. Your contact release will also be that much faster.

What happens is that you've now made a tradeoff. You are allowing a reasonably sized spike in exchange for a big reduction of the release time. Note that your transistor will see a maximum voltage of your supply voltage *plus* the drop of the Zener during break time. For instance, on a 12-volt supply, your transistor would have to block at least 36 volts if it is not to be damaged.

There are special back-to-back Zener-like components intended for spike protection. They go by the names of *varistors*, *MOV's*, or *transient protectors*, and do have various brand names. They work the same way as Fig. 2 in that they do not conduct until spike time. Then they do conduct heavily and internally dissipate the inductor's flux energy. Figure 3 is a typical circuit.

SGS is one of many suppliers of the *TRANSIL* spike protectors. Their BZW04P23 is typical. At 25 volts or under, it draws only 5 microamps. Above 30 volts it starts conducting heavily, and by 41.5 volts it draws at least 10 amperes. Despite the tiny package, these devices can withstand 50 amps for 10 milliseconds. Higher-power units are also available.

You do have to carefully match your protection device to the size of the spike you are willing to allow and the amount of energy that you need to dump from your coil. If at all possible, you should also isolate your coil drivers from more sensitive parts of your circuit. Optoisolators and individual power supplies are great for this. More info on spike protection and computer interfacing appears in my *Micro Cookbook*, volume II.