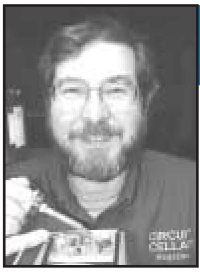

by Ed Nisley

Analog Tips and Tricks

Are you looking for ways to improve your analog and RF circuitry? Take a few tips from Ed to get started. In this column he shows you how easy it is to take your PCB wiring skills to the next level. Who knows, your digital projects just may improve too.

Circuit Cellar has always attracted readers who enjoy building gizmos, both at work and for their own use. My December 2004 column, "Building Boxes," prompted enough comments and suggestions regarding additional techniques that I decided a follow-up was in order.

Although these tricks are designed to improve your analog and RF circuitry, even your digital projects will benefit, because digital is just analog with the gain cranked way up. You're sure to find at least one technique that will make your next project work better.

BUILDING BOARDS

I wire most of my projects on PCBs built in my basement shop, using a process that produces both circuit documentation and reasonably high-quality hardware without too much effort. I've come up with some tricks that should help you get good results too.

I use CadSoft's EAGLE schematic capture and board layout software, which runs on Windows, Linux, and Mac OS X (www.cadsoftusa.com). The free version can handle most of the circuits in this column, and the Standard version is reasonably priced. EAGLE is perfectly stable on my SuSE Linux 9.2 desktop system.

The board layout program can produce output files in nearly any format, including the Gerber files used in board production shops. I save the output for each layer as a Postscript file, and then import the files into the GNU Image Manipulation Program (GIMP) image-editing program at 600 dpi.

The top image in Photo 1 shows the copper plane pattern for the charge-pump LED power supply I described in my April 2005 column. I panelize them with the GIMP to produce a single image with multiple patterns in a rectangular grid. Because all this happens digitally, there's no loss of resolution and no smudges. I then print the image through an HP LaserJet 1200 on a sheet of toner-transfer film from either Pulsar (www.pulsar.gs) or Techniks (www.techniks.com). It turns out that toner contains a thermoplastic that both adheres to bare copper and resists the etching chemical solution.

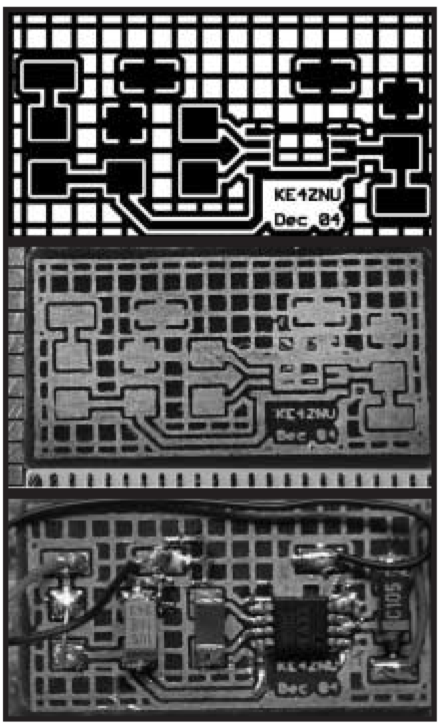

Photo 1—*The top image is the top copper layer from an EAGLE board design. The bare board shows several flaws, but the one on the bottom came out fine. The ruler scales are 0.050″ vertically and 1 mm horizontally. The board has extremely small features!*

Because most of my boards are extremely small, they don't fill a complete sheet of the toner-transfer film even after I panelize them. I print a sheet of paper, tape a square of film that's approximately 1″ larger than the patterns atop them, and then run the paper through the printer again. The adhesive on cheaper tapes tends to melt at laser printer temperatures, so use good tape and monitor your results. Put a single strip on the leading edge of the toner-transfer film to allow the paper and film to shift slightly as they pass through the fuser rollers.

Although I've tried applying the film to the circuit board using a clothes iron, I eventually bought a modified laminator that provides uniform pressure and regulated heat across the width of the film. The results aren't always perfect, as evidenced by the bare board in Photo 1. However, the finest lines on that board measure 10 mils, with approximately 10-mil spacing between IC leads, and the 3-mil strokes in the letters fall well below the recommended 6-mil width: these dimensions are aggressive for the toner-transfer technique. Most of my larger boards came out perfect. You'll have no trouble with through-hole components and 50-mil traces.

I have produced double-sided boards using toner-transfer films, but registering the two patterns presents a challenge. I accurately align the films face-to-face on a light table, tape them together along one edge, align the blank board between the films, feed the taped edge into the laminator, and hold everything together until the input rollers grab the board. This is good to 10 mils and requires pads and vias that are somewhat larger than normal .

The ink in ordinary Sharpie fine-point permanent markers is surprisingly resistant to copper etchant, so I use it to touch up small flaws. I preserve broad areas of copper around the edges of the panelized images with package-sealing tape.

Ferric chloride warmed to approximately 160°F on a hotplate etches 1-oz. (1.4 mil) copper in about 15 min. I hand-agitate the boards in a shallow glass tray, wearing my shop apron, latex gloves, and splash goggles.

I plate a 50-microinch layer of silver atop the copper, which both improves solderability and makes board photographs look better. A 4-oz. bottle of silver plating powder from Cool-Amp (www.cool-amp.com) could become a family heirloom passing from generation to generation.

Until recently, I had been drilling holes using carbide bits in a Dremel tool drill press, but now I'm using a Sherline CNC milling machine. I wrote an EAGLE user language program (ULP) that converts the hole information in a board layout to a G-code file for the milling machine. The ULP sorts the holes by drill diameter and then visits each hole in nearest-neighbor order. This crude solution to the traveling salesman problem works well enough for my small boards.

Laser printers are digital devices, but the paper and film media carrying the circuit patterns remain analog. I don't have hard numbers, but I have found that the CNC mill puts holes where they should be, which may not quite match up with where the copper patterns actually are after they go through the toner-transfer process.

The problem arises because the sheets travel through the printer with slight speed variations, they expand and contract at temperature extremes, and they squish under laminator pressure. Boards less than a few inches in each dimension, which constitute most of my projects, have fewer troubles. Run several test pieces before you commit to fine-line, large-area, double-sided boards!

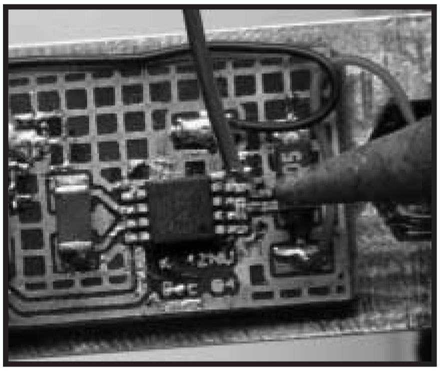

Photo 2—*Hand-soldering SMD parts is possible if you learn some new techniques. First of all, the board must be horizontal so the parts don't slide off!*

SOLDERING PARTS

Circuit board assembly lines use solder paste and heated ovens to mass-solder surface-mount parts over the entire board at once. The process requires considerable calibration to achieve solid joints while not overheating the semiconductors, so it isn't amenable to the production of one-off prototypes.

Photo 2 shows the relative sizes of 30-mil solder and a fine-point soldering iron compared to the board in Photo 1. I wear a magnifying headband and place the board flat on my bench, using needle-pointed forceps to maneuver the parts.

After I apply liquid flux to the board pads, I use a piece of Soderwick (that's right, no "l") as a sponge to put a thin layer of solder on them. Then I tack diagonally opposite leads of each IC to the board and solder the remaining leads, all without adding more solder. This doesn't produce a classic solder fillet, but I avoid having to join all the leads in a solder blob.

I tack one side of larger SMD components (such as the capacitors shown in Photo 2) to the tinned board, solder the other lead, and then put a fillet on the first lead.

Analog and high-speed digital circuits benefit from a low-impedance ground plane. The grid in Photos 1 and 2 is a compromise between an ideal solid-copper plane and something solderable.

Many of my SMD boards have numerous small vias between the top-surface ground areas and the unetched bottom plane, with C- or Z-shaped pieces of hookup wire substituting for plated-through vias. I solder brass shim stock along the edges for a low-impedance connection between the layers.

I've been using 4%/96% silver-tin solder rather than the familiar 60%/40% tin-lead alloy for my electronic projects. The silver alloy melts at 440°F, about 70° higher than tin-lead alloy, and a temperature-controlled iron is pretty much required for good joints.

A tip for stabilizing your soldering iron: drape the cord around your arm so your forearm supports the weight of the cord. I reach through the cord loop, flip the cord over my arm, and then pick up the iron as usual. Try it. The iron will float in your hand.

Glue a pair of mouse pads face-to-face to get a convenient work surface that won't slide around as you install the components. The black background also helps reduce glare.

BUILDING BOXES

I use JB Weld epoxy for both bond-

Photo 3—*This section of PS/2 keyboard cable shows the insulated conductor molded outside the shielding foil. A keyboard wouldn't notice, but a microphone might misbehave.*

ing small parts and filling unwanted holes on boxes. Jon Titus recommends Bondo's Glazing & Spot Putty to eliminate minute cracks, bubbles, and pits like the ones remaining after I bond a plate in a hole (www.bondo-online.com). It's available in hardware and auto body supply stores.

Rick Mainhart builds boxes with a fillet of solder joining the copper foil on the inside edges. I used Gorilla Glue and Loctite Epoxy Putty for my headset box because of the tight clearances around the connectors, plus a certain aversion to cooking my fingertips. Hard silver solder would work better than soft lead solder in this application.

Rick solders a layer of copper foil, burnished and fluxed, to strengthen and smooth outside edges. He gets rolls of copper foil tape from craft stores that normally sell it to stained glass artists. The stores around here don't carry it, but a quick Internet search turned up many suppliers. Some foil tapes have adhesive backings, which you definitely don't want.

I have used brass shim stock that's available from machine tool suppliers in thicknesses starting at 1 mil. Brass isn't as conductive as copper, but that's not critical in this application because of the large surface area. I've bought shim stock from suppliers including Enco (www.use-enco.com) and Victor Machinery Exchange (www.victornet.com).

Home repair stores like Lowe's and The Home Depot carry 20- to 30-mil copper roof flashing. That's far too thick for circuit board boxes, but it can be useful for high-current or low-impedance conductors. You saw a piece of it as a ground strap inside the attenuators I described in "Robot Mechanics" (*Circuit Cellar*, 167, June 2004). Some flashing has asphalt-saturated paper backing that's intended to galvanically isolate the copper from aluminum or steel structural elements, which makes it useless for our purposes.

Micro-Mark carries precision brass angle stock in miniature sizes that work well for interior corners where you need high strength: solder a right-angle bracket to the copper foil inside the joint. This requires careful fluxing and far more heat than a standard pencil iron can produce (www.micromark.com).

An abrasive cut-off wheel in a Dremel tool slices thin angle brackets that are too delicate for a hacksaw. An ordinary scissors works well for brass shim stock up to approximately 10 mil in thickness.

POWER ON!

The ubiquitous wall wart power supply has become the scourge of modern life. Every device requires a slightly different combination of voltage, current, and charger intelligence. Worse, no two warts can share adjoining outlets. If you don't already know about power strip Liberators, go to www.cyberguys.com and search for "Liberator."

Matthew Karas suggests using PC cases to hold larger projects. They have plenty of internal room, good structural qualities, great EMI shielding, and a "free" power supply. However, remember that most PC-class switching supplies have a minimum load requirement for at least one output. If your circuitry doesn't draw that much current, you must add ballast resistors that will get hot; heatsink them to the case.

Nearly everyone selects standard battery holders for smaller projects. Most of these holders use nickel-plated, spring-steel wire to contact the cells, which works well for low currents, but devices with high-current motors or solenoids will see a voltage drop at the holder's output terminals. Even if you run separate supply wires to the battery holder, pulses from high-current devices can feed back into your logic or analog circuitry.

Ken Boone recommends adding unfluxed Soderwick (again, without the "l") to the holder's contacts, folding it over the ends of the springs so that the copper braid contacts the cells and carries most of the current in parallel with the springs. This wouldn't work in production, but for prototypes and one-off projects, it could make the difference between success and failure. Ken should know. He routinely places at or near the top in the Trinity College Fire-Fighting Home Robot contest.

ODDS & ENDS

My enthusiasm for soldering connectors burned out long ago, so I now adapt standard cables whenever possible. Even if you have a standard cable designed for something completely different, it's probably better than anything you could build yourself.

For example, the microphone preamp I described four years ago connects to my bike helmet through a PS/2-style keyboard cable ("Mic Check: A Communication System for Cyclists," *Circuit Cellar*, 133, August 2001). These work extremely well for about a year's worth of riding, then the wiring fails at the helmet despite my best efforts at stress relief. Keyboard cables simply aren't designed with continual flexing in mind, but I haven't found a more durable cable that's both lightweight and inexpensive.

The last time I cut a new cable, I found the situation in Photo 3. The foil shield should have enclosed all six conductors and the drain wire to help reduce EMI. The orange wire somehow made its way out of the foil and was molded into the outer insulation along the entire length of the cable. (Color photos are available on the *Circuit Cellar* FTP site.)

The lesson? Use a destructive test to verify some of the specs! This cable would pass any low-speed electrical test and might even pass an EMI test, but it isn't what you'd want for a critical application.

CONTACT RELEASE

This is the golden age of RF and analog hardware hacking, with more easy-to-use stuff available than ever before. Fire up those irons, keep building, and tell me how it works out!

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PROJECT FILES

To download color photos and the EAGLE ULP to drill board holes, go to ftp.circuitcellar.com/pub/Circuit_Cellar/2005/181.