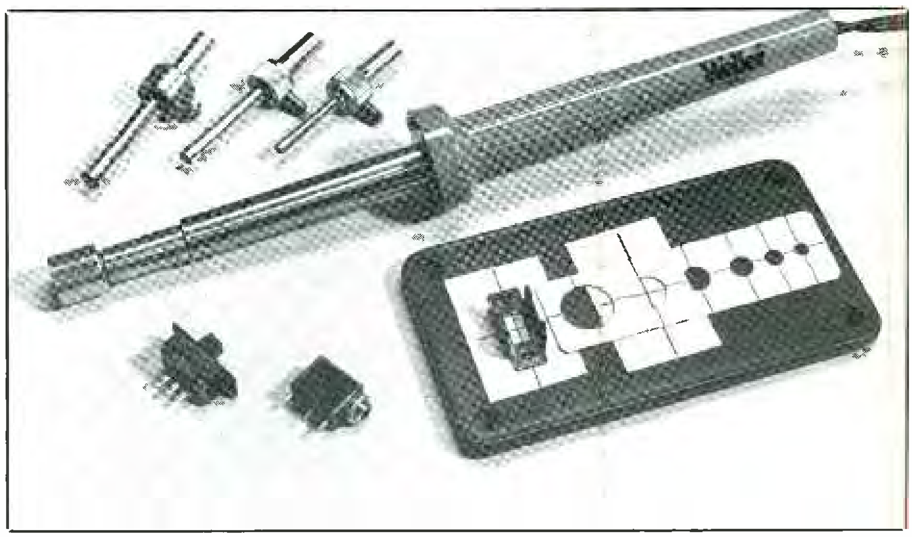
How To Thermally Machine Project Boxes

Give a professional-looking finish to the plastic enclosures in which electronic projects are popularly housed

By Adolph A. Mangieri



Machining the popular polyvinyl plastic project enclosures that have largely replaced costlier phenolic project boxes can be an exercise in frustration. Though shatterproof, these boxes are made from a soft plastic that has a relatively low melting point. As a result, the bit of a hand drill can tear or melt its way through the plastic and "walk" excessively from the exact point you want to drill a hole. Grabbing action often turns larger size holes into ragged and oval shapes. Also, making the square and rectangular holes required for mounting some components is done by tediously drilling many small holes and filing the slippery plastic. You can simplify machining of polyvinyl project boxes with a few thermal punching tools that you make yourself. In this article, we will describe how to make these tools from readily available materials.

The materials you need are brass tubing from TV rabbit-ears antennas for thermal punches and ¼-inch aluminum or brass shafts, couplers and hubs. You can easily make and adapt these tools to a small soldering iron, which provides the heat source. Hole sizes vary from under ⅛ to ½ inch in diameter for use on thermoplastics up to 3/16 inch thick. Rounding out the assortment of cutters, you can make chisel knives and square and rectangular cutting tips. You will discover that, combined with conventional machining methods, thermal machining can simplify installation of components in thermoplastic project boxes.

Plastics & Machining

Common plastics fall into two general categories. Most of the plastics you will encounter are members of a wide variety of thermoplastic resins, such as ABS, polyvinyl, acrylic and styrene. Thermoplastic resins are injection-molded under heat and pressure to form the enclosures used for consumer electronic products, various small electrical appliances and houseware items, to name a few.

Thermoplastics may include fillers such as waxes to add flexibility and fibers to impart strength or better machinability. When heated, this type of plastic gradually softens at first and eventually melts and finally burns, with increasing temperature emitting acrid and toxic fumes. Thermoplastics machine reasonably well, provided you have a drill press and operate it very slow using an assortment of brad- or spur-point bits.

Thermosetting plastics, such as the phenolics, make up the second category of plastics. Thermosetting plastic is formed by chemical reaction between phenol and formaldehyde. it does not soften when heated but does eventually char at sufficiently high temperatures. Thermosetting plas-

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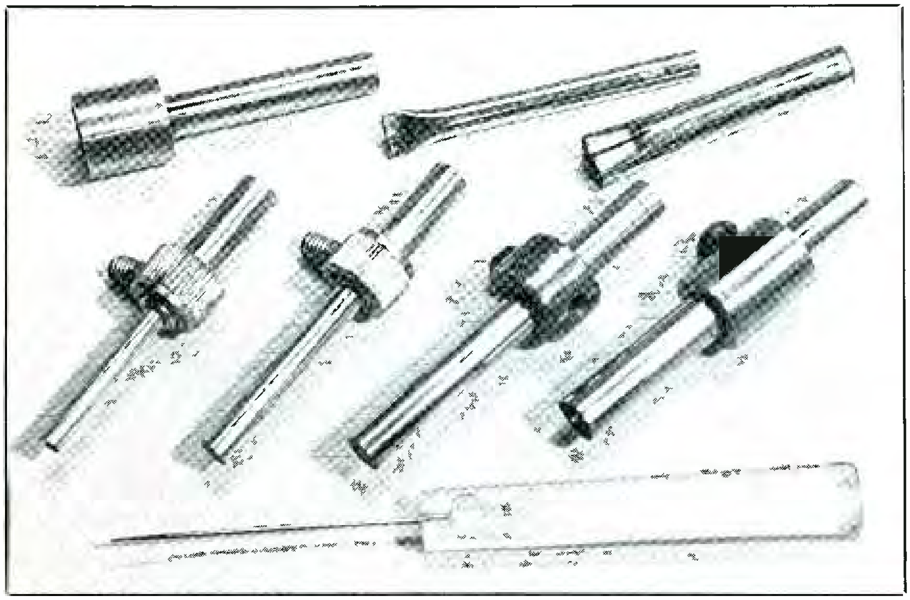

Fig. 1. Small hole cutters include thermal punches made from TV rabbit-ears antenna sections and round, rectangular and knife shapes. Clean-out tool is shown at bottom.

tics are used where high strength, dimensional stability and resistance to high temperature are required. With excellent electrical properties, the plastic is widely used for switch board panels, relay frames, motor switch parts, and the plastic parts of cooking utensils, toasters and steam irons. Non-reinforced types are very brittle. Products reinforced with fiberglass cloth or fibers are nearly unbreakable. Plastics including glass and silica fillers quickly dull drill bits. The relatively hard plastic is easily drilled but may tend to chip when the drill breaks through, and large holes are usually a bit difficult to machine.

Recommended for thermal punching is a 40- to 50-watt soldering iron that accepts ¼-inch-diameter slide-in tips. A typical example of such an iron is the Weller Model SP40 40 watt unit shown in the lead photo. You can easily make any needed adapters and tools using ¼-inch brass or aluminum shafts, shaft collars, spacers and hubs salvaged from TV tuners, radios and the like. Multi-deck wafer switches yield assorted spacers, and metal inserts of knobs yield ¼-inch collars. The metal hubs of wheels and gears of tuning mechanisms yield collars and ¼-inch shaft couplers.

Shaft couplers, shaft extenders and collars are usually available from companies that cater to amateur radio needs. The thin-wall hard brass tubing of TV rabbit-ears antennas provides durable high-strength cutting tips. A single "ear" of such an antenna usually consists of four sections of tubing measuring about 9/32, 15/64, 3/16 and 1/8 inch in diameter, all of which can be put to good use as thermal hole punches.

Shown in Fig. 1 are four thermal punches of assorted sizes installed on adapters that have a ¼-inch-diameter upper portion. The adapters fit into and are retained by a ¼-inch brass shaft extender, shown at top left in Fig. 1. The shaft extender replaces the the original soldering tip and butts firmly against the barrel of the iron. It transfers axial punching force to the barrel of the iron—not to the inner end of the heating element. You may need to cut the shaft of the extender so that it does not bottom out against the inner end of the heating element.

In lieu of a shaft extender, you can make one by installing a 1½-inch length of brass shaft on a ¼-inch shaft coupler. Drill a small spot on the shaft to firmly seat the setscrew. Lacking a shaft coupler, make one from a ¾-inch-long by ½-inch-diameter brass hub with a ¼-inch hole. You may have to install one or two 6-32 setscrews in a shaft hub salvaged from a pulley or gear. Figure 1 also shows a chisel knife tip at top-center, a rectangular tip at top-right and a clean-out tool at bottom.

When making the adapters shown in Fig. 1, avoid high precision tight fits because metal oxidation and thermal expansion may create problems with "freezing" or binding. Be aware, though, that a very loose fit impairs heat transfer. Dimensions specified are nominal and should be altered as needed to match the sizes of brass tubing you are using. Use only brass or aluminum for the adapters, but feel free to modify the adapters to suit your own particular needs.

Adapters for 1/8- and 3/16-inch tips shown at left in Fig. 1 are two-sided collets. For the 1/8-inch tip adapter, use a 1-inch-long by ¼-inch-diameter seamless spacer with 1/8-inch through hole. Grip the spacer vertically in a vise. Then use a fine-toothed hacksaw to cut a ½-inch-long slot lengthwise to form a two-sided 1/8-inch collet. Slip a ¼-inch shaft collar over the slit portion, with setscrew positioned 90 degrees from the slot. Use the same size spacer to make a 3/16-inch collet for the 3/16-inch tip. Using a 3/16-inch drill bit, enlarge the 1/8-inch hole in the spacer to a depth of ½-inch. Slot the drilled portion to form a two-sided 3/16-inch collet. Then install a ¼-inch shaft collar on the collet.

Adapters for the larger 15/64- and 9/32-inch tips shown at the right in Fig. 1 utilize ¼-inch solid shafts. Make the

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adapter for the 15/64-inch tip from a 1 3/8-inch length of shaft. Chuck 9/16 inch of the shaft into a 1/4-inch drill. Slip a washer with 1/4-inch hole on the protruding end of the shaft to protect the drill chuck. At low to medium drill speed and using a flat file, reduce shaft diameter until the 15/64-inch tubing slides onto the shaft. Check frequently as you file, using the tubing as a gage. When the diameter is about right, use a finer file and finish up with No. 240 sandpaper.

Install a 1/4-inch shaft collar to grip the tubing to this adapter. For the 9/32-inch tip, cut off a 1 1/2 inch length of 1/4-inch shaft, which slides freely into the 9/32-inch tubing. Slightly enlarge the hole of a 1/4-inch shaft collar to slide fit on the 9/32-inch tubing.

Use a small tubing cutter to cut rabbit ears tubing to length. Cut off a 2-inch length of 1/8-inch tubing, and square off both ends and remove burrs. With a small tapered reamer, turn the working end of the tip to a knife edge. Then use a high-speed hand grinder, such as a Mototool, and a thin and abrasive cutoff wheel to cut a 5/16-inch-long axial slot on one side of the tip to form a clean-out slot. Wear a face guard when working with the grinder!

Push the tip fully into the 1/8-inch collet with clean-out slot lined up with the setscrew of the collet collar. The setscrew tells you where to find the clean-out slot. Cut off and prepare a 1 1/2-inch length of 3/16-inch tubing and install in the 3/16-inch collet.

Cut off and similarly prepare a 1 1/2-inch length of 15/64-inch tubing. Then make a 1/2-inch-long axial slot at the upper end of the tip 180-degrees removed from the clean-out slot. Install the tip on the adapter with setscrew aligned with the clean-out slot. Prepare a 1 1/2-inch length of 9/32-inch tubing and install on its adapter.

Figure 2 shows 3/8- and 1/2-inch round "cookie cutters" and two square cutters made from 1/2-inch lengths of deep-drawn thin-wall

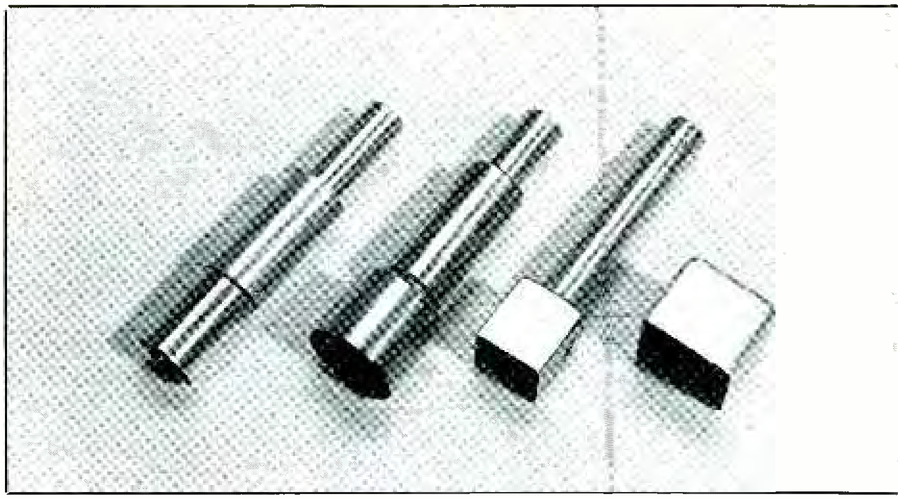

Fig. 2. Cookie cutters include large round and square hole makers made from shells of battery cases and miniature r-f transformer shields.

brass or stainless steel cups. For round cutters, use the bottom portion of stainless-steel cases from AAA and AA alkaline or nickel-cadmium cells. Use caution when cutting these cells because the contents are caustic. Thoroughly clean the cutters and square up the open ends.

Bevel-sharpen round cutters inside to a knife edge using a cone-shaped mounted stone by hand. Drill a central hole in the bottom of the cutters to pass a 6-32 machine screw. For the Weller Model SP40 iron, cut a 1 1/4-inch-long by 1/4-inch-diameter shaft. For other irons, slide the shaft stock fully inside the iron; then withdraw it 1/8-inch and mark and cut it to length. Square up one end and drill and tap axially for a 6-32 machine screw. Secure the cutter to the shaft with a 6-32 × 1/4-inch screw and lockwasher.

In use, the cookie cutters replace the soldering iron tip, with cutter butted against the barrel of the iron to take up punching forces. These cutters can also be retained by the shaft extender to permit ready interchangability of all cutters. In this case, and especially for the larger cookie cutters, install slide-on spacer bushings, as shown on the round cutters in Fig. 2. The bushings increase heat flow and impart rigidity.

You can use the brass or aluminum outer fine tuning shaft of rotary-type TV tuner switches to make the spacers. Make the spacers long enough to butt firmly between the top surface of the cutter and the front edge of the shaft extender. Carefully square up both ends of the spacer to assure good thermal contact.

Use the brass shield of a subminature r-f transformer to make the 3/8-inch square cutter. Use the shield of a miniature r-f transformer to make a 1/2-inch square cutter shown unmounted at the right in Fig. 2. Bevel the inside edge of the tips to a knife edge with a small fine flat file. Clean-out slots are optional on these cutters because you can easily pry out the waste slug with a clean-out tool made from the plastic handle of a toothbrush and a medium-size sewing needle. Drill a small hole in the end of the handle and secure the the needle in place epoxy cement.

The tip shown at the top-right in Fig. 1 has a rectangular cutting edge for roughing in the slots of slide switches. To make square and rectangular tips, prepare and sharpen the end of the tip but defer slotting of the clean-out slot. Use the square and rectangular tapered tangs of files as a forming mandrel. If needed, true up

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MATERIALS LIST

- ¼ " diameter brass or aluminum shafts
- ¼ " brass shaft extender
- ¼ " brass shaft coupler
- ¼ " shaft collars (4)
- ¼ " diameter spacers (1 " long with ⅛ " hole)
- TV rabbit-ears antenna (four sections)
- AA and AAA alkaline or Ni-Cd cell shells
- Brass or aluminum spacer or hub (¾ " long, ¼ " hole)
- Miniature and subminiature r-f transformer shield cases
- Medium sewing needle
- Plastic handle (see text)
- Light-gauge sheet aluminum
- 40-watt soldering iron with ¼ " tip (Weller Model SP40 or equivalent)
- Solid-state incandescent lamp dimmer
- Ac line cord with plug
- Small enclosure
- Chassis-mount ac receptacle
- 5-ampere 3AG fast-blow fuse and holder

the file tang on the grinding wheel.

Slide the tip firmly onto the tang and pinch, peen and shape it until a rectangle is formed. Because the hard brass tubing is not highly malleable, the rectangle may end up being slightly barrelled. Lastly, cut a clean-out slot in the tip as shown.

The beveled chisel knife cutter shown at top-center in Fig. 1 handily forms large cutouts. As an example in making chisel knives, cut off a 1½ inch length of ¹⁵⁄₆₄-inch tubing. Pinch one end flat for ¼-inch in a vise to obtain a double-thickness flat blade.

One or both vertical edges of the flattened portion will probably split. Select the best side of the flat blade for the knife, and remove the other side, leaving a single thickness blade. Do this by scoring the blade ³⁄₁₆ inch from the end with a fine triangular file and pry off the waste portion. Use a file to true up the blade and bevel it on one side to a knife edge.

Assorted tool guides or templates and a panel machined with these tools is shown in Fig. 3. Use light-gauge aluminum sheet to make templates. Lay out and drill the holes slightly undersize and ream to final size to clear the tip. Scribe cross-hair lines. Make the DB9 connector template shown at top-left in Fig. 3 by drilling a number of small holes and filing the hole to final size. Metal frames of miniature and standard slide switches and other components serve well as tooling templates.

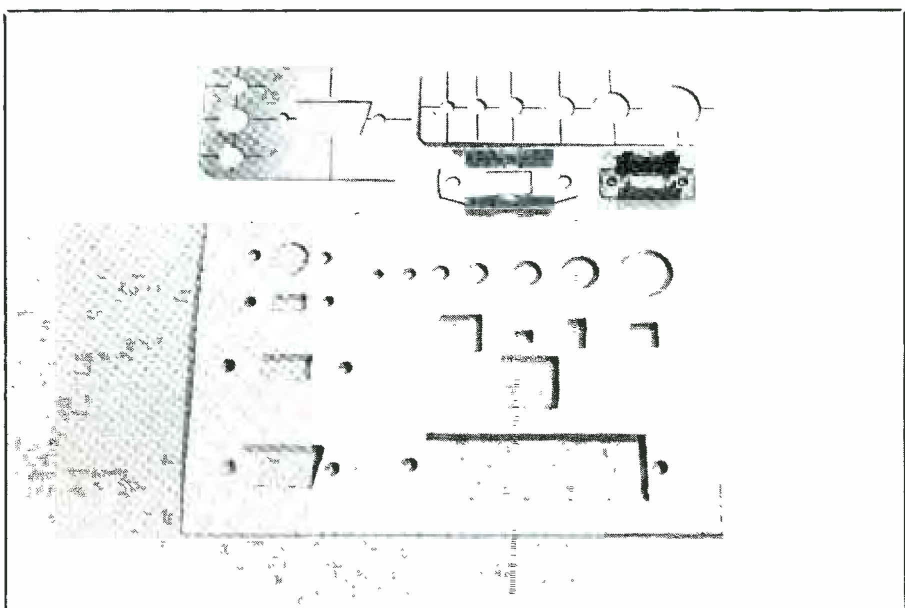

Fig. 3. Hole templates and switch bodies aid machining of panels.

You need a means to adjust the voltage applied to the soldering iron used with your home-fabricated tools. I use a bench powerstat (variable-voltage transformer) with calibrated dial. It has two ac receptacles, which permit operation of two hot-punch irons at the same time. You can use a full-range solid-state traic motor speed controller instead. An inexpensive wall-mount solid-state rotary incandescent light dimmer that handles loads up to 600 watts performs just as well.

Wire together the dimmer and iron as shown in Fig. 4. Install the dimmer in a small enclosure and calibrate its dial in 10-volt steps from 60 volts to maximum. To calibrate, connect a 60-watt incandescent lamp and an ac voltmeter (preferably true-rms—*not* peak—type) to the "load" side of the dimmer.

Using the Tools

Like in soldering, the technique used to machine thermoplastics with thermal tools requires some practice at first to master it. For hot punching with little or no melting of the plastic, the rate of heat flow and tip temperature is just sufficient to allow the tip to be forced through the plastic with moderate downward pressure on the tool. The tip softens the plastic and you push the tip through the plastic.

At appreciably higher temperature, the plastic melts rapidly and very little force, if any, is needed as the tip penetrates the plastic. However, high heat often produces acrid toxic fumes and fouling of the tip with sticky plastic. Therefore, the objective is to use the tools at lower temperature to avoid fumes and fouled tips.

Practice on scrap pieces of vinyl siding, ABS plastic taken from TV cabinets and plastic housewares until you perfect your technique. Initially, operate the soldering iron at 117

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volts. Then, after a 3-to-8-minute warm-up period, position the iron vertically and push down on the plastic while moving the top of the iron in a small circle. Place a piece of tablet back or chipboard under the plastic.

At 117 volts, the tip is likely to be too hot, penetration will be rapid and some sticking of plastic to the tip will occur. If so, lift the iron after penetration and quickly remove the waste slug. Wipe the tip with fine steel wool or a heavy cloth to remove the adhering plastic. If the plastic melts inside the the tip, twirl a small drill bit inside the hot tip to remove it.

Perform trials with the powerstat or light dimmer set to 40, 60, 80, and 100 volts in turn. At insufficient input power, heat flow down the thin walls of the tip will fail to soften the plastic. At about 80 to 100 volts, the tip will heat sufficiently to soften the plastic and permit you to push the tip through in 2 to 4 seconds without creating fumes, melting the plastic or fouling of the tip. The holes will have little or no burrs, and the waste slug will be barely deformed, if at all. This is the desired operating condition. Usually, the powerstat is set for 70 to 100 volts after initial warmup at 117 volts. If you are using a solid-state controller with arbitrary dial calibration, take note of the dial indications as you determine the correct setting.

Figure 3 illustrates a plastic panel machined with the thermal punches. At left from top to bottom, the cutouts accept a phono jack, miniature slide switch, standard slide switch and DB9 connector. At lower-right, the large cutout accepts a Centronics parallel printer connector. The series of graduated holes at top-right accept screws and a wide variety of jacks, switches and potentiometers. (Use a reamer to increase hole size as required.) Below are several holes punched with the squared cutters.

To make the hole pattern for slide switches, position the template at the desired location with clear double-sided tape. Use a square or oblong-shaped cutter to remove the waste material in the oblong hole in several penetrations. Punch the mounting holes and remove the template. Touch up the oblong hole with a small file. If necessary, slightly ream the two mounting holes.

When making cutouts for DB-style connectors, proceed in a similar manner. When using the beveled knife for DB-connector cutouts, place the flat surface of the cutter against the edge of the template and make a series of overlapping penetrations. If necessary, use an X-acto or other hobby knife to break out the large waste slug. Finish the edges of the hole with a small file. For large oblong cutouts, lay out the hole pattern in pencil. Place a thin metal strip along the edge of the pattern and use it a a guide as you cut the hole with the chisel knife.

With close observation and slight twist of the tool, you can usually feel and determine full penetration of the tip through the plastic. Tip penetration is easily felt by allowing the tip to fall through the plastic by about 1/16-inch. Place a 1/16-inch thick chipboard shim under the workpiece but clear of the hole. Alternatively, use a sheet of dense foam plastic as a backup to readily feel and limit penetration of tip through the plastic.

Holes for miniature and subminiature phone jacks are preferably hot-punched with the aid of the centering template. The hole can be punched slightly undersize and enlarged with a tapered reamer. A piece of wood held in a vise provides backup on the inner walls of a project box.

When making medium to large round holes, the waste slug can be made to remain in the plastic, eliminating the need to remove the waste from the tip. Push the tip through the plastic without axial rotation. The plastic in the clean-out slot retains the waste in the panel. Use a pencil to push out the slug. To lift the waste with the tip, rotate the tool slightly after it penetrates the plastic to cut the material in the clean-out slot.

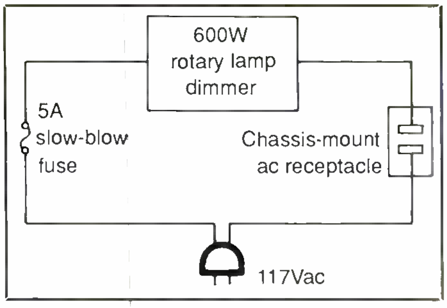

Fig. 4. Wiring details for light dimmer and soldering iron circuit.

When machining the panel of a plastic project box, cover the entire outer surface of the box with masking tape to avoid scratches as you work. Mark hole locations on the tape and punch from the outer surface. At correct tip temperature (not critical), the holes produced are remarkably clean. At higher heat and with thicker panels, a small annular ring may form on the entrance and a small burr on the exit sides of the hole. Remove burrs using the countersink bit or knife.

These thermal punches are intended to be used on plastics up to 3/16 inch thick. Holes were punched in plastics up to 1/4 inch thick, but such a thickness requires more heat and time to penetrate the plastic. Filled plastics, such as ABS TV cabinets, punched satisfactorily. Acrylic and styrene plastics tended to foul tips.

After several hours of use, remove the shaft extender from the iron and clean both to prevent buildup of oxides and seizing. From time to time, remove the shaft collars from the tips, and the tips from the adapters and clean them with fine steel wool.

Variations

The following may prove to be helpful if you experiment with larger- or smaller-wattage soldering irons or cutter tips that are different sizes and

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lengths. For a given power input to the soldering iron, the heat available to soften the plastic is primarily limited by the effective thermal conductivity of the relatively thin walls of the cutters. Halving tip length doubles the heat flow. Stainless-steel cutters are relatively short because this material is a poor conductor of heat.

The tips shown in Fig. 1 can be adapted to a soldering iron that accommodates ⅛-inch screw-in tips. After you identify the threads on the original soldering tip (probably metric), you will need a screw tap that matches the threads of the soldering tip and corresponding machine screws. Drill and tap the upper end of the collets or adapters to accept the machine screw. Install the screw in the collet, driving it in until it binds firmly. Cut of excess screw length. Tips so constructed tend to work loose but otherwise perform well. Limit tip size to smaller diameters.

Thermal shaping and cutting tools are frequently used in plastic arts and crafts projects. You may have need for larger cutters and chisel knives best adapted to higher-wattage soldering irons. Relatively compact, Weller's Models WP80 80-watt iron with ⅜-inch slide-in tip and WP100 100-watt iron with ½-inch slide-in tip are recommended for heavy-duty use in punching larger holes. Cutters made from C- and D-size cells were adapted to the larger iron and performed well.

"The teacher wants us to bring a pencil to school tomorrow . . . what's a pencil?"