UV Exposure Light

A professional-quality ultraviolet source for making photosensitized printed-circuit artwork and boards

By Ladislav Hala & Peter Hala

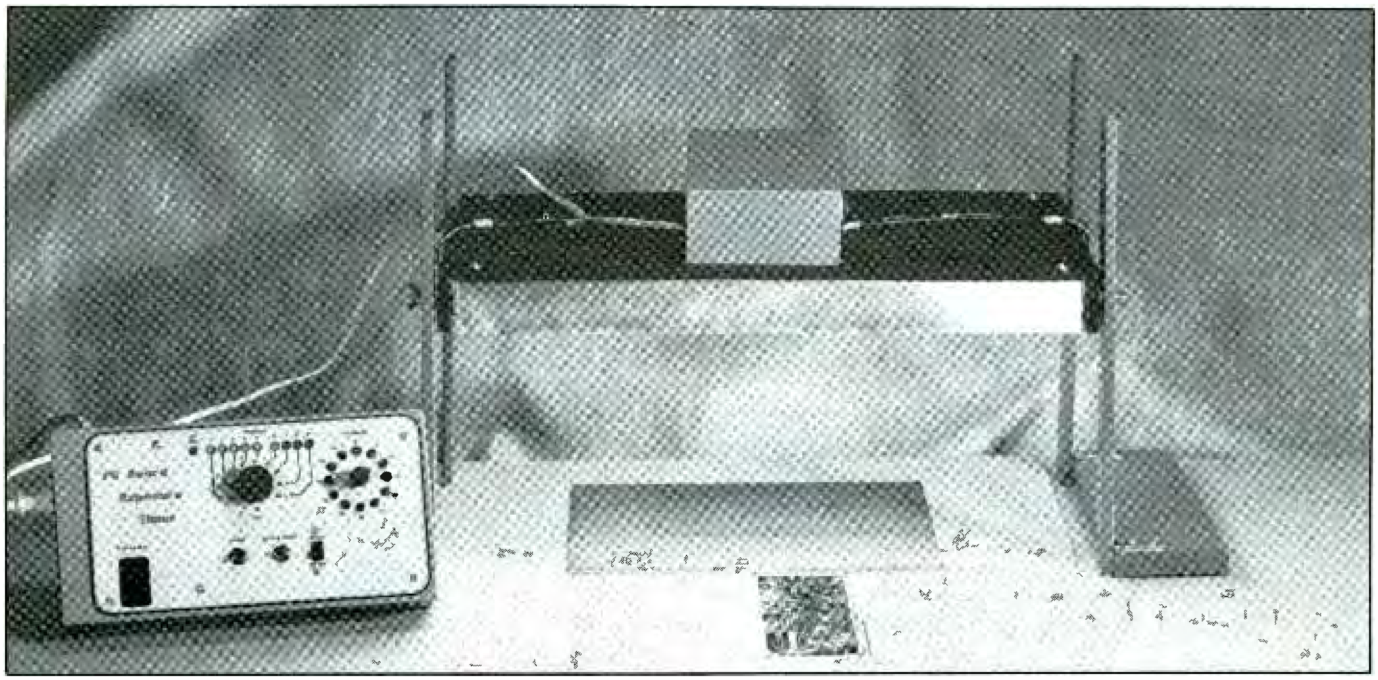
You can use any one of a number of different techniques to prepare printed-circuit blanks for your projects. Freehand drawing of the conductor pattern with a resist pen is workable for very simple circuits. For more complex one-of-a-kind circuits, careful work with the special rub-on patterns made for this process can be successful. For boards on which appear multiple IC patterns and especially for more complex boards on which are to be mounted surface-mount devices (SMDs), the so-called photographic process is the only practical way to go.

Advanced hobbyists and experimenters usually master the photographic process early on, using readily available chemicals and materials. Professional-quality ultraviolet light sources used to activate them are usually quite large and very expensive. In this article, we will detail how to build a suitable UV light source that can be used for preparing pc artwork and blanks measuring as large as 8 by 16 inches at moderate cost. This adjustable UV Exposure Light can be operated manually or, when used with the Programmable Appliance Timer described last month, fully automatically.

Technical Considerations

Anyone who has used the photographic technique to make pc boards is well aware of the instructions that warn against exposing the materials to ordinary light. Though this is a precaution that should certainly be heeded, one might be misled into thinking that using ordinary light from, say, a table lamp would be suitable for making a workable exposure. This might be possible, but it certainly is not practical, considering that it would take hours to make such an exposure and many multiples of hours of making test exposures to determine how long an exposure to use in the first place.

Using a sunlamp, as some instruction sheets recommend, speeds the exposure process up to the 10-to-20-minute range. With this source, you must still first determine correct exposure time by a time-consuming trial-and-error method. Unfortu-



nately, if exposure time is lengthy, the heat generated by the sunlamp can damage the photosensitive coating or material before the determined exposure time is up. Additionally, because of the high level of UV radiation, you must cover all exposed flesh and wear goggles to protect you from "sunburn."

Although a sunlamp is frequently recommended by manufacturers and suppliers of photosensitive chemicals and materials, these lamps can be very awkward to use. Other possible UV emitters, such as a carbon arc or 1,000-watt photoflood light, are impractical because of the excessive current they draw and heat they generate or the extended period of time required to produce a successful exposure.

For purposes of pc photo-fabrication, the band of wavelengths of interest lies between 320 and 400 nanometers (nm), which is commonly referred to as the near-ultraviolet spectrum and is popularly known as "black light." UV sources that radiate in this range include F15T8BL and F15T8BLB fluorescent tubes. Both provide satisfactory UV energy to properly expose photosensitive pc materials in a relatively short time with no detrimental physical effects to the materials themselves from heat and other undesirable side effects.

Both tubes measure 18 inches long and are 1 inch in diameter. These are the same dimensions of the FL-15D "daylight" (white-light) fluorescent tubes used in home utility lighting fixtures. Hence, the hardware from such fixtures can be used directly in building this project.

Though the F15T8BL and F15-T8BLB tubes both produce about the same results in pc photofabrication, the F15T8BL is the better choice because it is more readily available from specialized lighting retailers and department stores and can usually be ordered through hardware and home-center outlets. Depending on availability and whether or not the retailer must order it from a wholesaler, the F15T8BL tube will cost between $10 and $20 each.

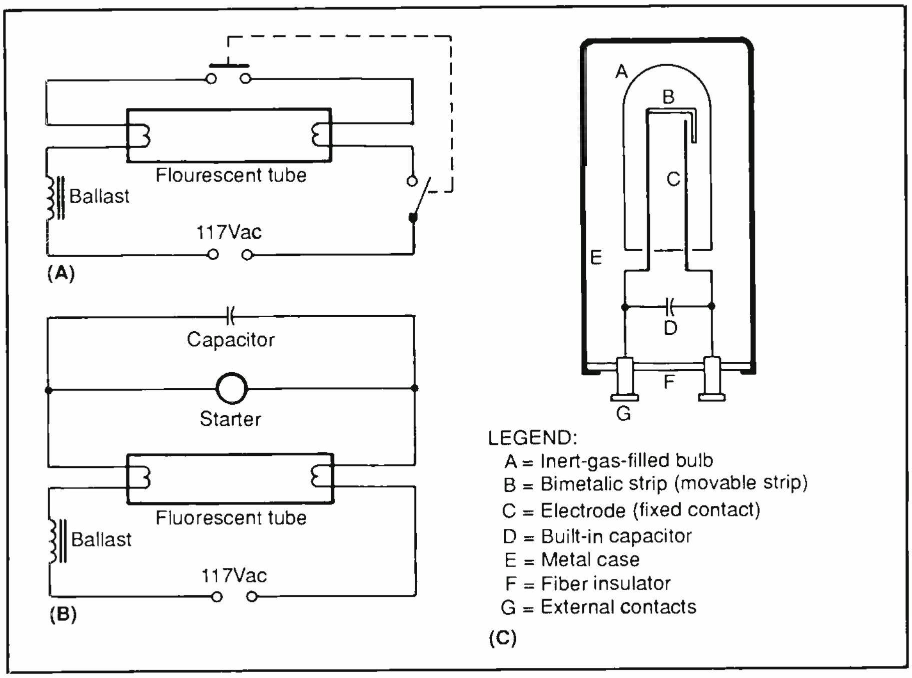


Fig. 1. Manual-start (A) and automatic-start (B) circuits for preheat-cathode fluorescent tubes and internal details (C) of glow-switch starter.

If you do not plan on fabricating very large pc boards, you might be tempted to build a smaller version of this project, using a shorter UV tube. This is one instance where smaller can be a disadvantage, however. Shorter tubes emit less-intense UV radiation, which will add to exposure times. Furthermore, the shorter UV tubes actually cost *more* than the F15T8BL does.

Theory of Operation

Being a preheat-cathode type of tube, the F15T8BL's electrodes must be preheated before high voltage is applied. Tubes designed for such operation have two connector pins at each end that are used to apply the heating current to the electrodes inside the tube. Preheating takes a few seconds and can be accomplished manually with the circuit arrangement shown in Fig. 1(A). Alternatively, preheating can be done automatically with the circuit arrangement shown in Fig. 1(B).

The manual switch in Fig. 1(A) is a pushbutton arrangement made up of one pair of line contacts and one pair of momentary-action contacts. The line contacts place the tube's electrodes in series across the output of a ballast when the button is pressed and held in that position for 2 to 3 seconds. During this period of time, the momentary-action contacts allow current to flow through and heat both elements. When the button is released, the line switch remains closed, but the contacts of the momentary-action switch spring open, disabling the current flow through the filaments.

Due to opening of the momentary-action switch while it is under load, a transient potential is developed in the circuit. This inductive "kick" aids in igniting (turning on) the tube.

The disadvantages of the manual starting switch arrangement are that you can start only one tube at a time and that starting may require you to make several attempts if the button is

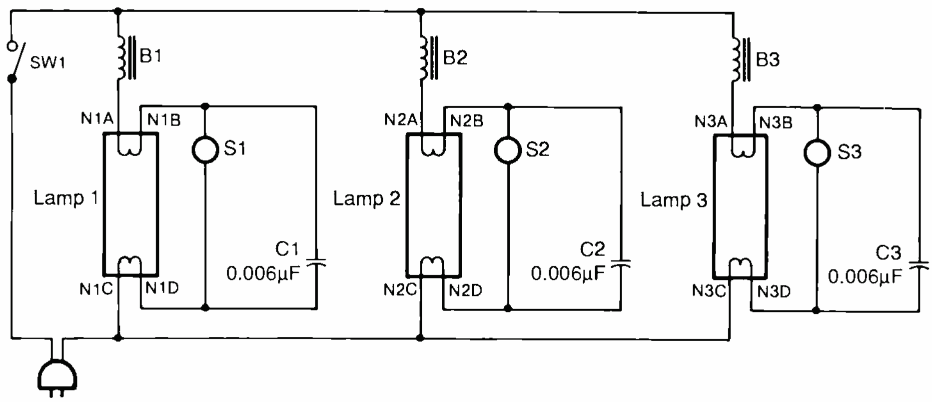


Fig. 2. Complete schematic diagram of project's circuitry.

PARTS LIST

B1,B2,B3—Type KS600A 15-watt ballast (see text)
C1,C2,C3—0.006-µF Mylar capacitor (part of S1, S2 and S3—see text)
N1,N2,N3—F15T8BL UV fluorescent tube (see text)
S1,S2,S3—FS-15 15-watt glow-switch starter
SW1—Spst slide or toggle switch
Misc.—Printed-circuit board or perforated board and suitable soldering hardware; ac line cord with plug; medium bi-pin fluorescent-tube sockets (6 each—see text); 18-gauge or heavier hookup wire; solder; etc.

not held pressed long enough. On the other hand, if the button is held pressed for too long a time, the lamp's filaments may overheat. The result is shortened tube life due to excessive loss of electron-emitting material from the filaments.

Several types of automatic starters for preheat-type fluorescent tubes have been developed over the years. The first was a magnetic vibrator type that repeatedly opened and closed a set of contacts. Each closing allowed the cathode to heat more and more until electron flow was sufficient to start the ignition arc. This starter made possible quick ignition, but it consumed up to 2 watts of power continuously thereafter while the fluorescent tube was in operation. Also, the tiny moving parts inside the starter were a constant cause of maintenance problems.

A later development was the thermal starter, which used a bimetallic contact strip to pass current through the tube's filaments. When sufficient heat built up, the contacts sprang open and the tube ignited. Normal operating current for the lamp through the heater coil held the bimetallic-strip switch open, which resulted in an unnecessary constant load of 1 to 2 watts.

The glow-switch starter, whose internal details are illustrated in Fig. 1(C), was a still later development. This starter consists of a small glass bulb that is filled with some inert gas like argon, helium or neon, the particular gas being used depending on the voltage characteristic desired.

On starting, when the line switch is closed in a glow-switch starter circuit, practically no voltage drop is developed across the ballast, and the voltage at the starter is sufficient to produce a glow discharge between the contact of the bimetallic strip and fixed electrode. The heat from the glow discharge distorts the bimetallic strip to allow heating to begin as the movable contact touches the fixed contact. In turn, this short-circuits the glow discharge, the bimetallic strip cools and, in a short time, the contacts open to apply open-circuit voltage in series with an inductive spike voltage. If the tube fails to ignite, the open-circuit voltage again develops a glow discharge in the bulb and the entire sequence of events repeats.

Under normal operation, not enough of a voltage drop appears across the tube to permit further glow discharges of the starter's gas-filled bulb. Hence, its contacts remain open. A small capacitor, whose value is on the order of 0.006 microfarad, is usually placed across the starter to reduce radio-frequency interference (rfi) and to set up oscillations that in effect make the inductive kick from the ballast last longer.

Advantages of the glow-switch starter include no continuous power consumption once the fluorescent tube ignites, automatic restarting until the tube does ignite, simple mechanical construction and low cost. These all add up to make the glow-switch starter the most popularly used starter for preheat tubes.

Another essential part of the fluorescent tube's starting circuit is the ballast, which is simply a coil of wire wound around a laminated iron core. Placed in series with the tube, the ballast limits current flow to the level for which the tube is designed.

The foregoing explains operation of the project's circuitry, which is shown schematically in Fig. 2. In this circuit, starters *S1*, *S2* and *S3* are standard FS-20 (20-watt) glow types, and 0.006-microfarad Mylar capacitors *C1*, *C2* and *C3* are built into the starters themselves. Ballasts *B1*, *B2* and *B3* are simple transformer-type KS600A units.

Construction

For this project, the ballasts were salvaged from existing fluorescent-light fixtures, as were the bi-pin sockets for the UV tubes. Unless you can find a source that supplies these as

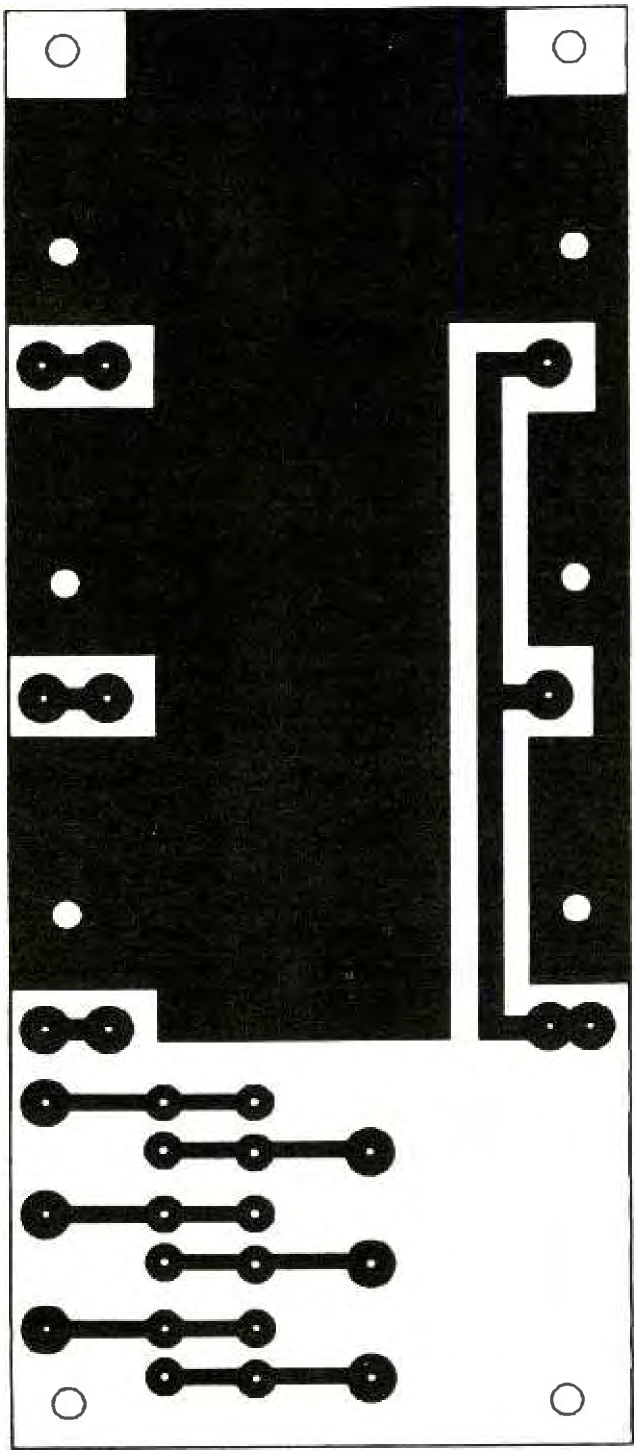
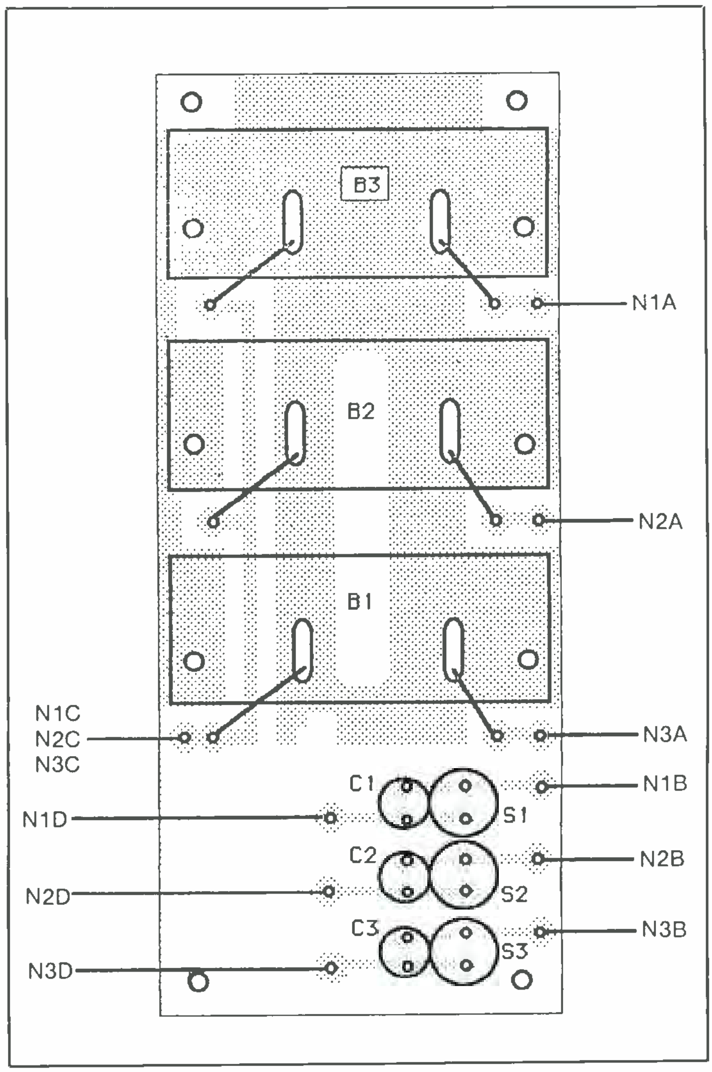


Fig. 3. Actual-size etching-and-drilling guide for control circuit's printed- circuit board.

Fig. 4. Wiring guide for pc board.



separate components, you may have to go the route we followed, which should not be too expensive if you shop the discount stores.

You can wire the project's circuitry on a printed-circuit board you fabricate yourself using the actual-size etching-and-drilling guide shown in Fig. 3. Alternatively, you can wire the project on perforated board, using suitable soldering hardware.

From here on, we will assume you are using the pc board, and the following details will apply to this method of construction. If you wire the circuit on perforated board, follow the same general layout given in the wiring diagram in Fig. 4.

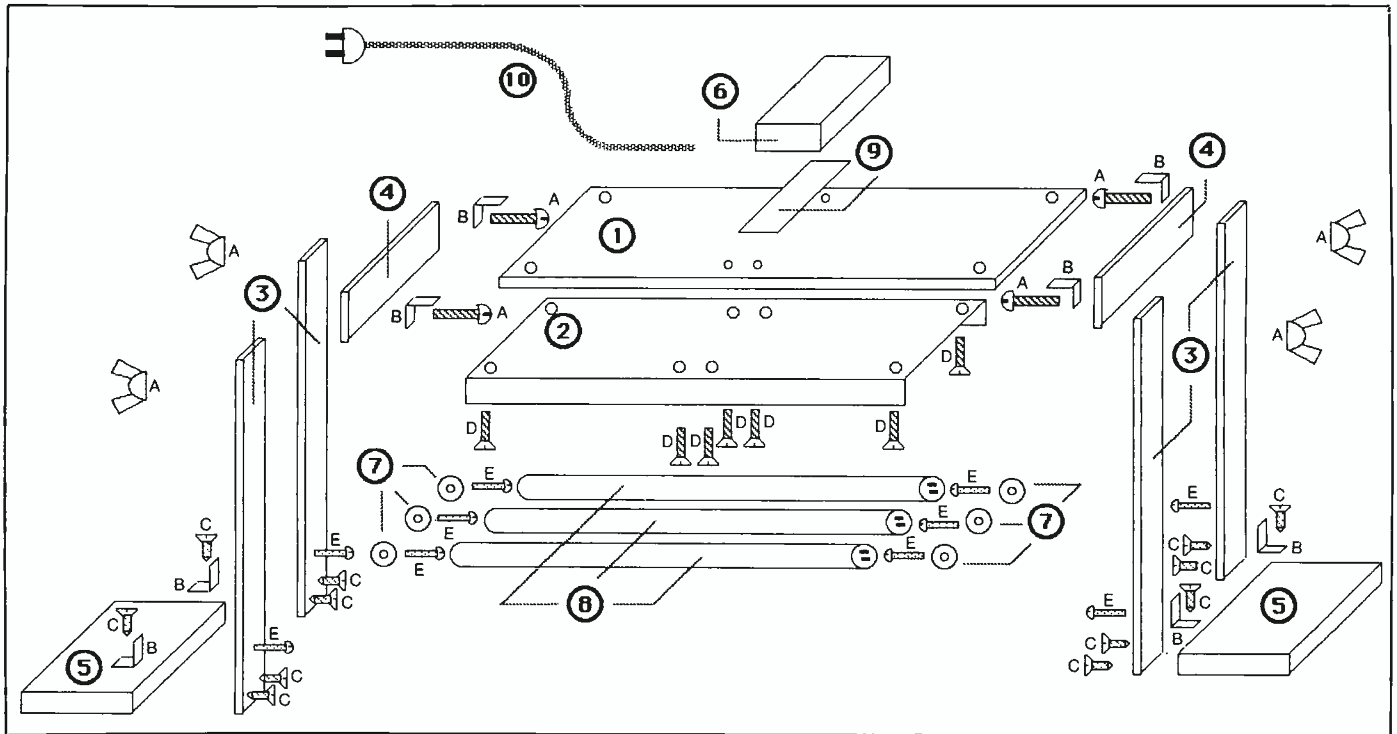


Fig. 5. Assembly drawing of UV Exposure Light stand made from aluminum flashing and lumber.

When the board is ready, drill a final ⅛-inch-diameter hole, centering it in the blank area at the lower-left of the board and mount here a No. 6 solder lug with 4-40 machine hardware. Begin populating the board by mounting ballasts *B1*, *B2* and *B3* to the board with suitable hardware. Trim their leads as necessary and strip ¼ inch of insulation from them. Tightly twist together the fine wires in each lead and sparingly tin with solder. Then plug these wires into the appropriate holes and solder them into place.

Carefully open the cases and remove the starters and capacitors. Trim or desolder the starter and capacitor leads from the socket pins and separate the two from each other. Install and solder the capacitors in the indicated locations on the board. Then do the same for the starters.

Cut to 36-inch lengths eleven 18-gauge or heavier stranded hookup wires, if possible, using five different colors of insulation to keep of what you are doing. Use one color of insulation for all N1 wires, another for all N2 wires, a third for all N3 wires, a fourth for the N1,N2,N3 wire and a final wire that will be crimped but not soldered to the solder lug. Strip ⅜ inch of insulation from one end of all wires. Then tightly twist together the fine conductors and sparingly tin with solder.

Install a solder post in the N1,N2,N3 hole and solder into place. Plug one end of these wires (except for the one that goes into the N1,N2,N3 hole) into the indicated holes and solder these into place. Crimp one end of the remaining wire to the solder post and solder the connection, The other ends of these wires will be connected later.

BILL OF MATERIALS

1—Top panel: 18¾" × 9¾" × ¼" plywood or Masonite
2—Reflector: 16½" × 12¼" aluminum flashing
3—Vertical stand bars: 13¾" × 1¼" × ¼" pine (4 required)
4—Light attachment bars: 9¾" × 1¾" × ¼" pine (2 required)
5—Base pieces: 9¾" × 3½" × ¾" pine (2 required)
6—Control board housing: Top panel—8¼" × 4⅜" × ¼" plywood or Masonite; Side panels—8¼" × 2¼" × ¼" plywood or Masonite (2 required); End panels—4¼" × 2¼" × ¼" plywood or Masonite (2 required)
7—SK-20 fluorescent-tube sockets (6 required—see text & Parts List)
8—F15T8BL ultraviolet fluorescent tubes (3 required—see text)
9—Control circuit-board assembly (see text)
10—Ac line cord with plug
A—⅜" × 1" bolt and matching wing nuts (4 sets required)
B—Small L bracket (8 required)
C—⅛" × 1½" flat-head wood screw (12 required)
D—6-32 × ½" round-head machine screw and nut (4 sets required)
E—6-32 × ½" flat-head machine screw and nut (8 sets required)
Misc.—Wood glue; etc.

For now, temporarily set aside the circuit-board assembly.

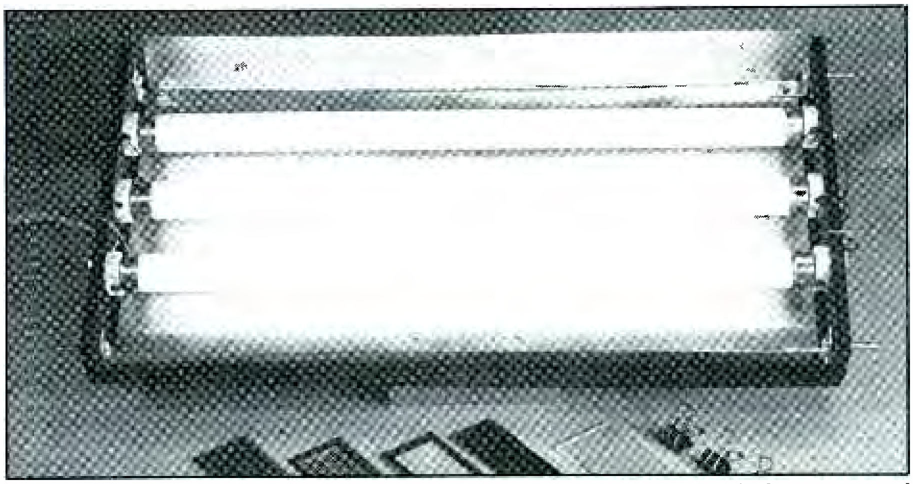
In deciding upon the design of the UV Exposure Lamp, we had to choose between two basic options—an exposure box or stand arrangement. To keep things as simple as possible and not tax the shop skills of the builder, we opted for the stand arrangement, which is simpler to execute and much more flexible to use because it allows you to make adjustments to suit different needs that are not possible with a box-type arrangement.

Materials for the stand are simple to locate because all you need are aluminum flashing, which can be obtained from just about any hardware store, and some lumber. These and their dimensions are detailed in the Bill of Materials that accompanies the drawing shown in Fig. 5.

Cut all lumber to the dimensions given in the Bill of Materials. For the top of the stand, identified at part No. 1, use either ¼-inch plywood or Masonite. The remaining lumber pieces should be pine, except for the small box on the top that houses the control circuit-board assembly and can be the same material as the part 1 top panel.

Once you have cut the lumber to the proper dimensions, strike a line down the center of each No. 3 vertical stand bar and drill 5/16-inch-diameter holes ¾ inch apart and starting ½ inch from one end down the center of all four. If you have access to a drill press, clamp together the bars and drill through all four pieces simultaneously. Otherwise, drill the holes individually through each bar. Measure up 3/16 inch from the other end of all four pieces and strike a line across their widths. Then measure 3/16 inch from both ends of each line and strike cross lines at these points. Drill wood screw starting holes at both locations of all four pieces.

Place a No. 5 stand base flat in front of you and stand the end with the two side-by-side holes drilled



Light/reflector assembly showing wiring to tube sockets routed along top and around edges of assembly. Wiring can also be routed through holes drilled in one end member, as described in text.

through it upright against the side of the No. 5 piece. Holding the two pieces together in that orientation, place a small L bracket atop the No. 5 piece and align its upright hole with the line drawn down the center of the No. 3 piece. Strike a short line across the first one at the center of the hole. Remove and set aside the No. 5 piece and L bracket.

Mark the same location on the three remaining No. 3 pieces. Then drill a 5/16-inch-diameter hole through each piece centered on the crossed marks. Next, spread a thin layer of wood glue across the bottom end of one No. 3 piece and align it against the one edge of a No. 5 piece and secure the two together with two ⅛ × ½-inch flat-head wood screws. Then use another wood screw and a ⅛ × ½-inch round-head machine screw and nut to secure the L bracket in place to the No. 5 and No. 3 pieces, respectively. Repeat for the remaining No. 3 and No. 5 pieces. Make sure all four No. 3 pieces are perpendicular to the No. 5 pieces.

Cut the aluminum flashing to size. Then bend the two side edges of the aluminum flashing to form the reflector assembly into a U channel with legs 1½ inch high. Use two straight boards to help you make the bends.

When it is ready, place the flashing flat on your work surface, channel legs pointing upward. Center the control circuit-board assembly box across the channel and use a soft pencil to mark its outline on the flashing. Set aside the box. Now measure 1 inch from each corner along the long sides and strike a cross line at each measured point, extending these lines about 1 inch from the outline.

Replace the box on the flashing within its outline. Without moving either piece, set a small L bracket against the box, aligning it with one of the last-drawn lines, centering the line in the mounting hole and draw the outline of the bracket's holes on both the flashing and box wall. Do the same for the three remaining lines.

Drill 5/16-inch-diameter holes centered in each hole on both the flashing and box. Also drill three ¼-inch-diameter holes for exit of the wiring from the circuit-board assembly, entry of the line cord and for mounting POWER switch *SW1*. Locate these holes near where N1, N2 and N3 on the lower-left of the board will be. Secure the L brackets to the box with 6-32 × ½-inch machine screws and nuts. Feed the screws through the holes from the inside of the box. Then mount the switch in its hole.

Center the flashing all around on

top panel No. 1 and draw the outlines of the four holes in the flashing onto the panel. Remove the flashing and set it aside. Then drill 5/32-inch-diameter holes through the center of all three marked locations. Loosely secure the flashing to the panel with four sets of 1/8 × 1/2-inch flat-head machine bolts fed through the panel and then flashing and matching machine nuts.

Place the assembly on your work surface with the channel legs pointing up and align a No. 4 light attachment bar with one end of the channel so that it is flush with the top and both side edges. Place a small L bracket in one corner of the flashing channel and against the No. 4 piece and draw the outline of the hole in it on the panel. Do the same with another L bracket and the opposite corner.

Check the hole outline locations against the spacing of the holes drilled through the No. 3 pieces in one previously prepared assembly. Do this at more than one level of holes in the latter to make sure that they are trued. If the holes do not line up, adjust the spacing of the outlines on the No. 4 piece so that they do. Then drill 7/16-inch diameter holes through the centers of both new hole outlines. Then do the same for the other No. 4 piece.

Secure the No. 4 pieces to the No. 3 pieces with 3/8 × 1-inch bolts and wing nuts. Choose the top hole pairs in both vertical stand bar assemblies for this. Invert one assembly and align it against the top assembly. Draw the outlines of the holes in the L brackets onto the flashing. Then repeat for the other assembly.

Set aside the two vertical stand bar assemblies and drill 5/32-inch-diameter holes through the centers of all four hole outlines going through flashing and top panel. Test fit the flat-head machine hardware to make sure that everything goes together properly.

Retrieve the control circuit-board assembly box and drill two 1/4-inch-diameter holes (make these slightly larger if you are using an aluminum utility box to accommodate small rubber grommets) through one long wall, spacing them about 1 inch apart and about halfway between the top and bottom of the panel. One hole is for entry of the ac line cord, the other for entry of the wiring from the six tube sockets.

Remove the No. 4 light attachment bars from the vertical stand bars and strike a line down the center of each. Strike a line across each of these lines centered from end to end. Measure 2 inches along the long lines from these marks and mark the measurements in all four instances. You have now defined where each of the six SK-20 tube sockets will be mounted. Strike a line down the length of each No. 4 piece 3/8 inch from the top edge. Drill the holes for the wiring between the control circuit-board assembly and tube sockets. You need four 1/4-inch-diameter holes in all—separate holes for the N1, N2 and N3 wires and one for the common N1,N2,N3 wire coming from the circuit-board assembly.

Mount the circuit-board assembly in place inside its housing using 1/2-inch spacers and suitable machine hardware. Drill holes for the hardware as needed. If you are using an all-metal utility box, line the wire and ac line cord holes with small rubber grommets. Then route the ac line cord into the box and tie a strain-relieving knot in it about 6 inches from the free end inside the box. Tightly twist together the fine wires in both conductors and sparingly tin with solder. Crimp and solder one conductor to the N1,N2,N3 post. Then crimp the other conductor to the No. 6 solder lug on the board and solder the two-way connection.

Collect the three N1 wires and route them through one hole in the box. Label this hole N1. Then collect the N2 and N3 wires, route the bundles through separate holes and label the holes accordingly. Finally, route the two remaining wires through any of the three holes.

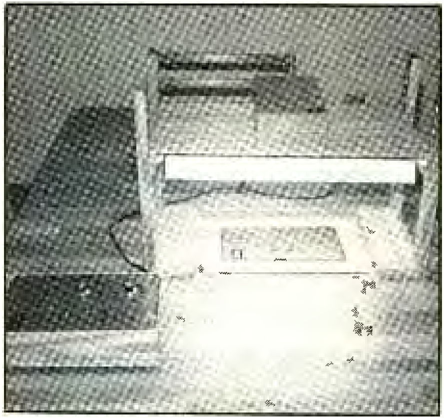
Mount the six bi-pin tube sockets into place on the No. 4 light attachment bars and route the wires through the holes drilled for them in the one bar. Neatly route the free ends of the wires to the appropriate lugs on the socket and trim to neat lengths. Strip 1/4 inch of insulation from the end of each, twist together the fine conductors and tin with solder before connecting and soldering each into place. Daisy-chain wire two 3-inch lengths of prepared wires from N1D to N2D to N3D (see Fig. 2) and connect the free end of the remaining wire coming from the solder lug on the circuit-board assembly to any of these three lugs.

Double check all wiring and soldering. If you suspect any connection, reflow the solder on it to correct what might be a problem later on if left untouched. Make doubly sure that the ac line cord is wired into the circuit properly, and check all wire runs against both Fig. 2 and Fig. 4. When you are certain that everything is properly wired, insert the tubes into the sockets and plug the project's line cord into an ac outlet. Flip the POWER switch to on. If everything is okay, the tubes should light after only a short delay. If not, correct the problem before putting the UV Exposure Light into service.

Using the Project

This project is very simple to use. However, it will take some trial-and-error tests to determine how far away from the photosensitized materials it should be and what exposure times to use for different situations. This procedure can be greatly simplified by using the UV Exposure Light with a programmable timer like the Programmable Appliance Timer presented last month, although there is no reason why you cannot use it in a purely manual mode. ME

• Publication of the "Programmable Appliance Timer" (February 1989) and "UV Exposure Light" (March 1989) couldn't have been at a more fortuitous time for me. I've needed this combination for some time now and thought I would have to design them myself. As you can see in the photo of both projects I built, I made a few modifications in the Exposure Light to create a cleaner appearance. But to get both projects to work, some changes had to be made in the published material.



In the Timer article's Parts List, change C4's rating to 25 volts, change the value of R33 to 820 ohms and include XTAL1 with a frequency of 32.768 kHz. Labeling of IC8 and IC9 in Fig. 1 should be transposed and some gates relabeled to conform to Fig. 6, though Fig. 1 is technically correct. (It would have been helpful if pin numbers had been included in the schematic.) In the Light article, Fig. 2, label the top ends of B1, B2 and B3 with B1A, B2A and B3A, respectively, and use these three designations to replace N1C, N2C and N3C in Fig. 4. The Parts List specifies 15-watt starters for the lamp, while 20-watt units are mentioned in the text. Either can be used, though I would go with the latter.

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