A Smart Weather Monitor

(Part IV)

Construction details for A/D Memory Expansion and Keyboard modules, sensor/cable fabrication and chassis work

By Tom Fox

Last month, we explained how the A/D Memory Expansion modules work in concert with the CPU and Display modules covered in Parts I and II. In this latest installment, our focus is on wiring of the A/D and Keyboard printed-circuit boards, chassis work, and putting together the sensor/cable arrangements required for taking temperature, light and humidity readings with WISARD. In the final installment, which will be presented next month, we will discuss placement of the sensors to obtain the most accurate and reliable readings, getting WISARD up and running and some hardware and software modifications you can make to expand upon WISARD's basic configuration.

Construction

Use of printed-circuit boards for these two modules is highly recommended because the A/D Memory Expansion module circuitry is quite complex and the Keyboard module will be subjected to mechanical stresses under normal keying pressure. Of course, if you prefer, you can assemble the circuitry on perforated board that has holes on 0.1-inch centers and suitable Wire Wrap or/and soldering hardware instead of pc boards if you wish, but be extra careful with wire runs, especially on the A/D board. Also, whichever board medium you choose, use sockets for all DIP ICs.

From this point on, we will assume printed-circuit construction. If you are using perforated board, make whatever adjustments are needed in the construction details for them.

Fabricate the double-sided A/D Memory Expansion board using the actual-size etching-and-drilling guides in Fig. 12. If you prefer not to home fabricate this fairly complex board, a ready-to-wire board with plated-through holes is available commercially from the source given in the Note at the end of the A/D Module Parts List.

Place the blank pc board on your work surface in the orientation shown in Fig. 13. Begin populating it by installing and soldering into place the DIP IC sockets. If your board does not have plated-through holes, substitute Molex Soldercon socket strips instead to give you soldering access on both sides of the board. In this case, solder *all* connections—not just the socket pins—to the pads on *both* sides of the board. Do *not* install the ICs in the sockets until after initial voltage checks have been performed and you are satisfied that your wiring is correct.

Next, install and solder the three male headers (*P406*, *P407* and *P408*) into place in the indicated locations. Make certain you mount these on the *solder* (bottom) side of the board before soldering them into place. These connectors must plug into mating sockets already installed on the CPU module, where they provide electrical connections and mechanical support for the assembly.

Power supply connector *P1001AD* can be of any convenient type. In fact, if you wish to save a few dollars on the cost of the project, you can eliminate the connector altogether and replace it with a wire cable that directly interconnects the A/D and CPU modules. (The A/D module requires connection to the Enable line of the MCU; so, at least one wire must be connected to the CPU module.)

In the author's prototype, a connector similar to Digi-Key's Part No. WM4406 was used. If this particular connector is used on the CPU and A/D modules, a short six-conductor cable (or six separate wires) with a suitable plug—such as the Digi-Key Part No. WM2106—at each end can be used to bridge the two.

No particular connectors are specified in the Parts List for the temperature sensor cables. The cables can be connected directly from *TS1* and *TS2*. Ten-pin male headers *P408A* and *P406A* are optional. Their purpose is to make further expansion of WISARD a bit easier to accomplish. If you use them, mount these connectors on the *component* side of the circuit-board assembly.

Now mount and solder into place the small components, beginning with the resistors and diodes and working your way up through the capacitors. Make sure that the diodes and electrolytic capacitors are properly oriented before soldering their leads into place.

When the A/D Memory Expansion module is completed, visually inspect both sides of the assembly. Solder any connections you missed, and reflow the solder on any suspicious connections. Check for solder bridges, particularly between the closely spaced IC pads. Use desoldering braid or a vacuum-type desoldering tool to remove any you find.

Set aside the A/D Memory Expansion module and proceed to Keyboard module assembly. Because of the relative simplicity of this module, a printed-circuit board is not needed, though one is recommended just the same. You can fabricate this board using the actual-size etching-and-drilling guide shown in Fig. 14.

When the board is ready, place it on your work surface oriented as shown in Fig. 15. Begin assembly by installing and soldering into place the 20 keyswitches in the indicated locations on the *solder* side of the board. The conductor pattern accepts momentary-contact pushbutton switches made by Panasonic and sold by Digi-Key as Part No. P9952. (If you wish to keep down the cost of building this project, use only the 13 switches that have functions assigned to them, as detailed in Fig. 11. Also, if you have no plans to modifying the project, eliminate *IC303*, *R301* through *R308*, *P301* and *C306*.) Then install and solder into place the sockets for the ICs, but do *not* plug the ICs into the sockets yet.

Install and solder into place the resistors and capacitors. Make sure electrolytic capacitors *C304* and *C305* are properly oriented before soldering their leads into place.

It is highly recommended that you remove pin 19 from *P301* and install a polarization key in socket pin 19 of the cable from the CPU board.

The enclosure in which you house WISARD can be any type that is

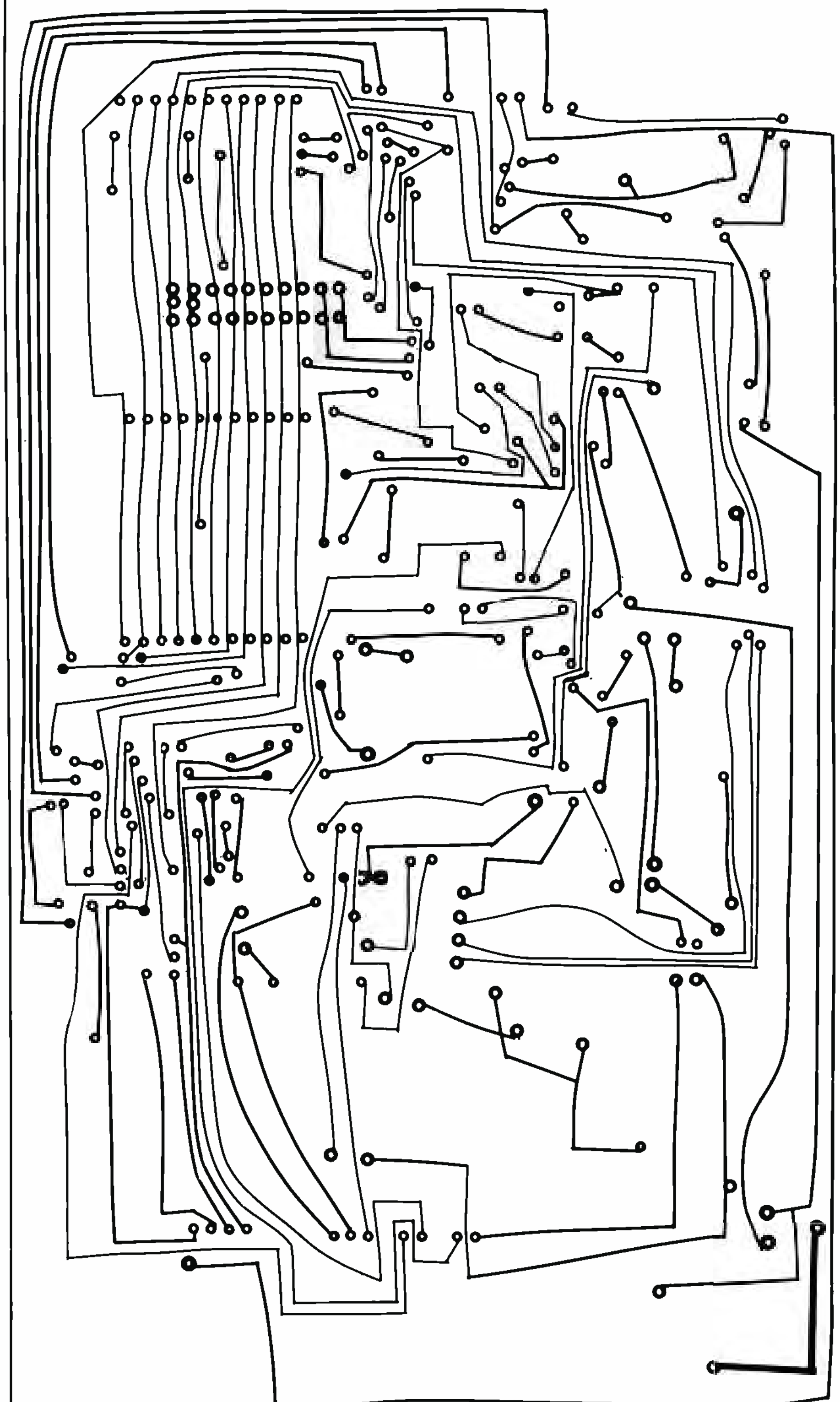

Fig. 12. Actual-size etching-and-drilling guide for A/D Memory Expansion module printed-circuit board.

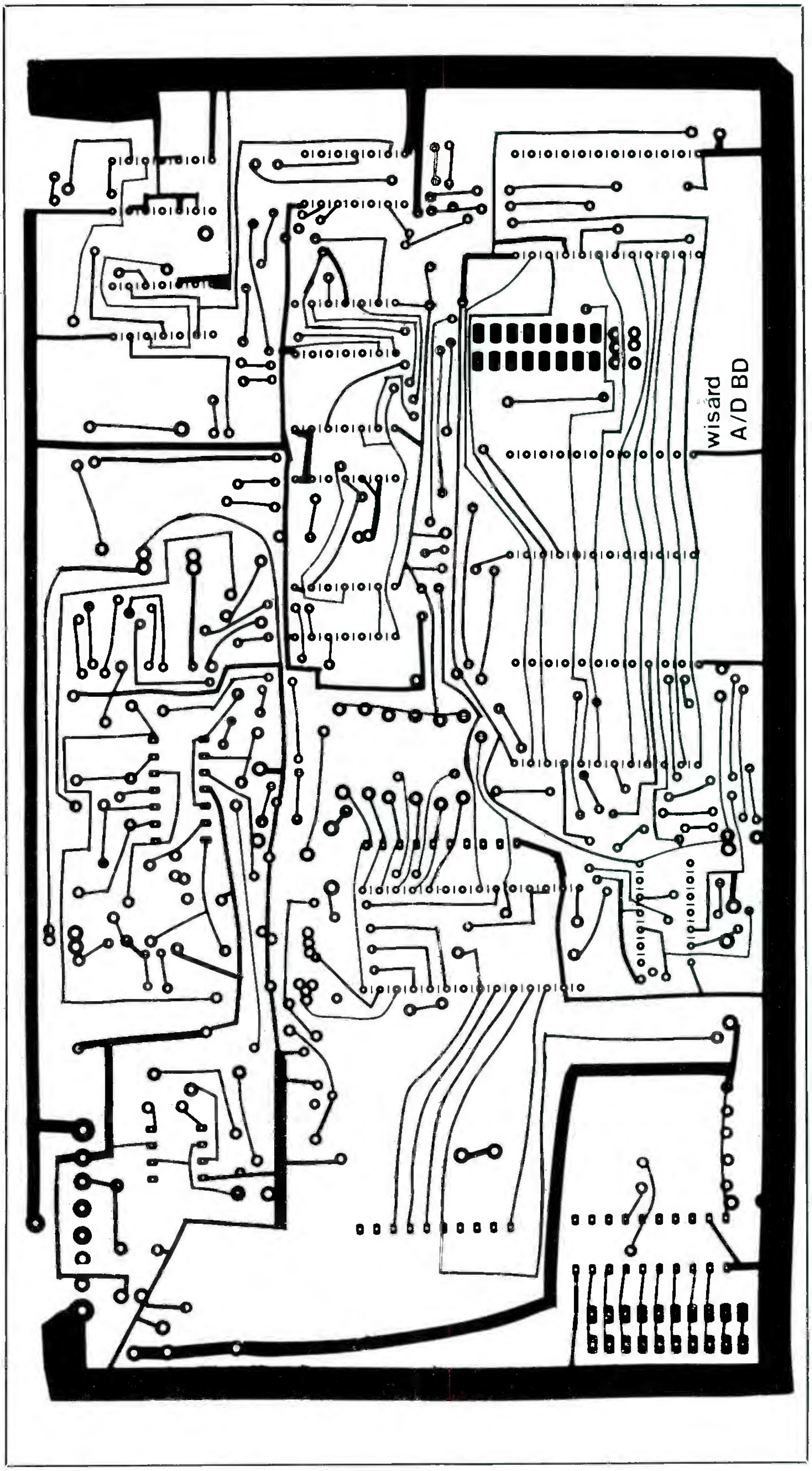

Fig. 12 (Continued).

large enough to accommodate all the assemblies that make up the project. For the prototype, shown in the lead photo, the author used a Digi-Key Part No. L131-ND aluminum console. This enclosure is very roomy and well-made, but it is rather expensive at about $35.

If you want to cut costs, your choice of an enclosure is an excellent place to start. For example, you can fabricate a suitable enclosure. Alternatively, you can look around for a used console. Whatever cabinet you decide upon, it should ideally be made from a conducting material to minimize rfi.

When machining the enclosure, drill mounting holes for the circuit-board assemblies and commercial power-supply module (see Part II for details on ratings). Then drill an entry hole for the ac line cord and separate entry holes for each of the cables for the five sensors described so far. Also cut the rectangular slot for the display window and the square slot for the keyswitch cluster on the bottom of the keyboard module.

The slots are easiest cut using a nibbling tool, after first drilling pilot holes. Alternatively, you can drill small holes in each of the four corners of the slot areas and use a thin abrasive wheel chucked in a rotary tool (such as a Moto-Tool), but be sure to wear safety goggles if you go this route. If you do not have a nibbling tool or Moto-Tool, drill a series of small interconnected holes around the entire perimeter of the cutouts to remove unwanted material and then follow up with a file to square up and smooth the edges.

Whichever method you choose, deburr all sharp cut and drilled slot and hole edges and line the entry holes for the ac line cord and sensor cables with small rubber grommets.

When the enclosure is ready, paint it, if desired. When the paint has completely dried, use a dry-transfer lettering kit to label the panel just below the keypad, as shown in the lead photo and Fig. 11. Protect the lettering with two or more light coats of clear acrylic spray. Allow each coat to dry before spraying on the next.

Glue a red plastic filter over the display slot from the inside of the enclosure. When the glue sets, mount the display module to the panel, using ½-inch spacers with a lockwasher at each end and 4-40 × ¾-inch machine screws and nuts. Then mount the keyboard module in place with 4-40 × ½-inch machine screws and nuts. To make sure that the keyboard module is electrically insulated from the metal panel, place two or three washers or a machine nut between the panel and circuit-board assembly at each of the four screw locations.

Route the ac line cord for the power supply through its grommet-lined hole and tie a strain-relieving knot in it 6 inches from the unconnected end inside the enclosure. Tightly twist together the fine wires in each conductor and sparingly tin them with solder. Connect and solder the conductors to the selected power supply module. Then mount the power supply in its selected location with suitable machine hardware.

Mount the CPU module to the floor of the enclosure with ½-inch spacers, 4-40 × ¾-inch machine screws and nuts and lockwashers. With no ac power applied to and no back-up batteries installed in the project, plug the A/D module into the CPU module by carefully inserting *P406, P407* and *P408* on the A/D module into *S406, S407* and *S408*, respectively, on the CPU module. Note that the ICs should still *not* be installed in their sockets at this time.

Connect the keyboard module to the CPU module in the same manner you used to connect the display module in Part II. However, make certain you use connector P15K-CPU on the CPU module this time to make the connection. Also, be certain you connect the power and ENABLE lines to P10001AD in proper polarity.

Shown in Fig. 17 is an interior view

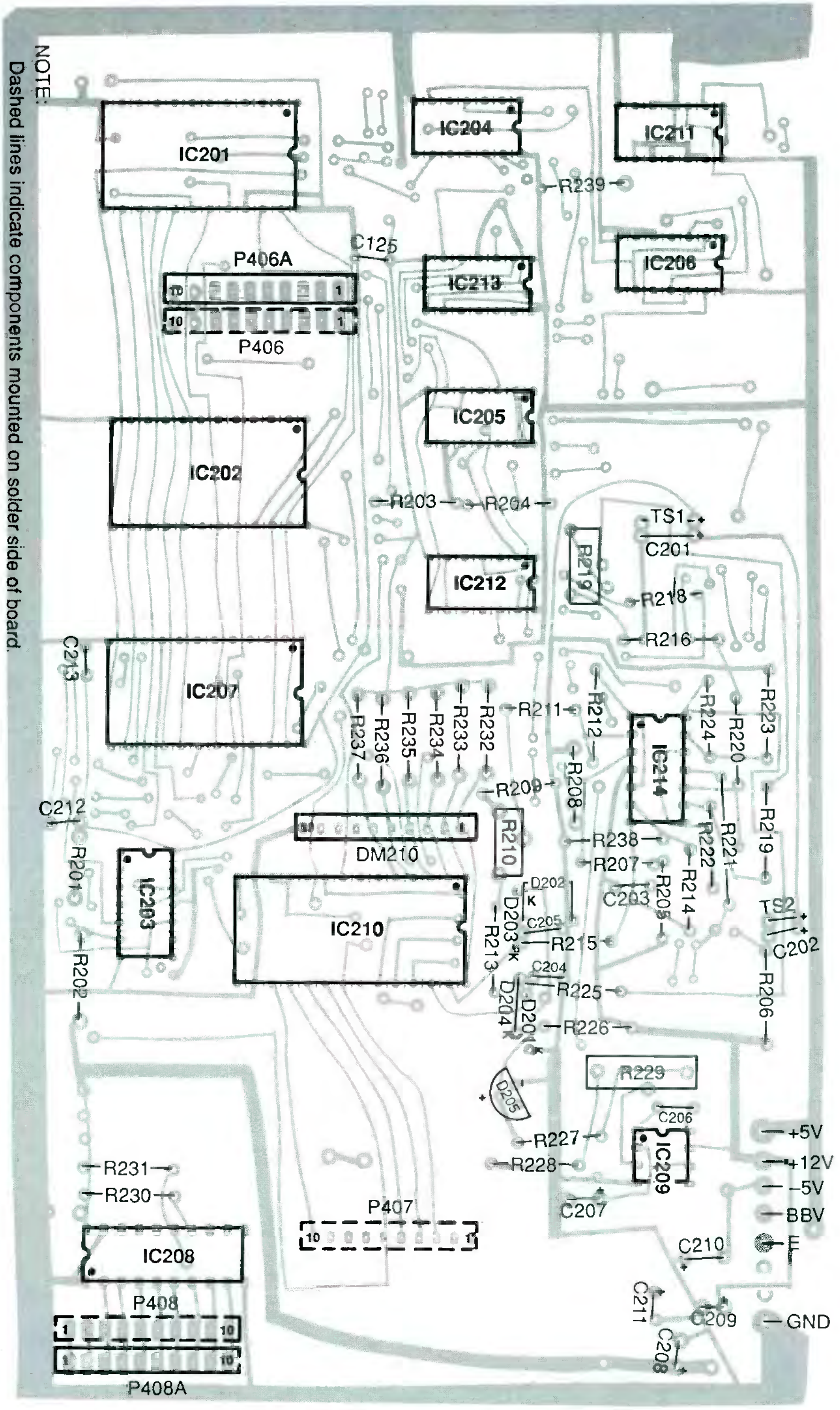

Fig. 13. Wiring guide for A/D module.

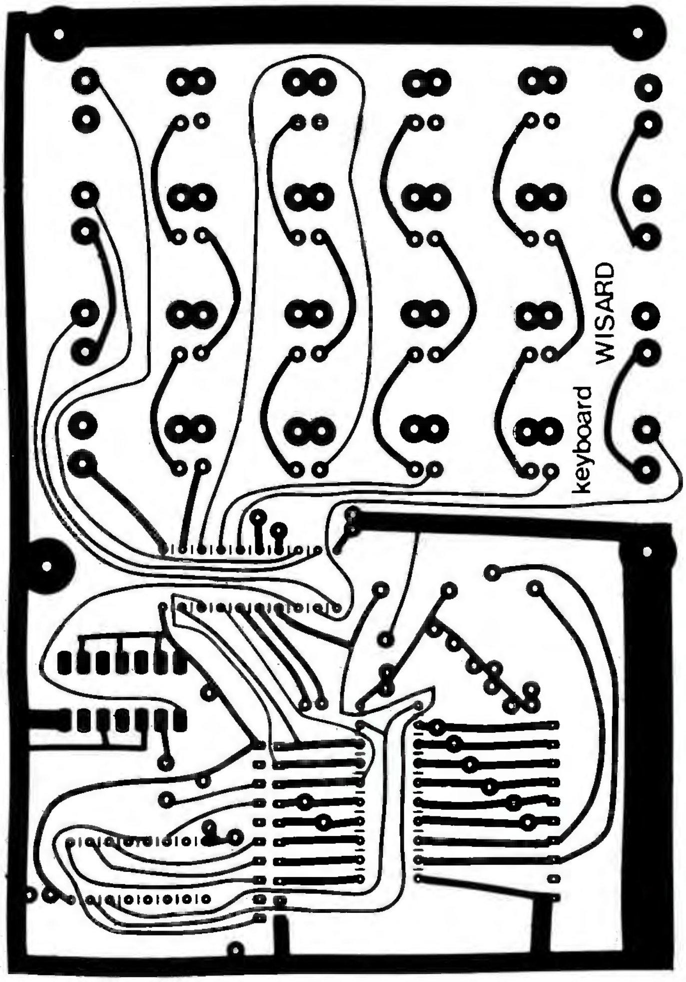

Fig. 14. *Actual-size etching-and-drilling guide for Keyboard module printed-circuit board.*

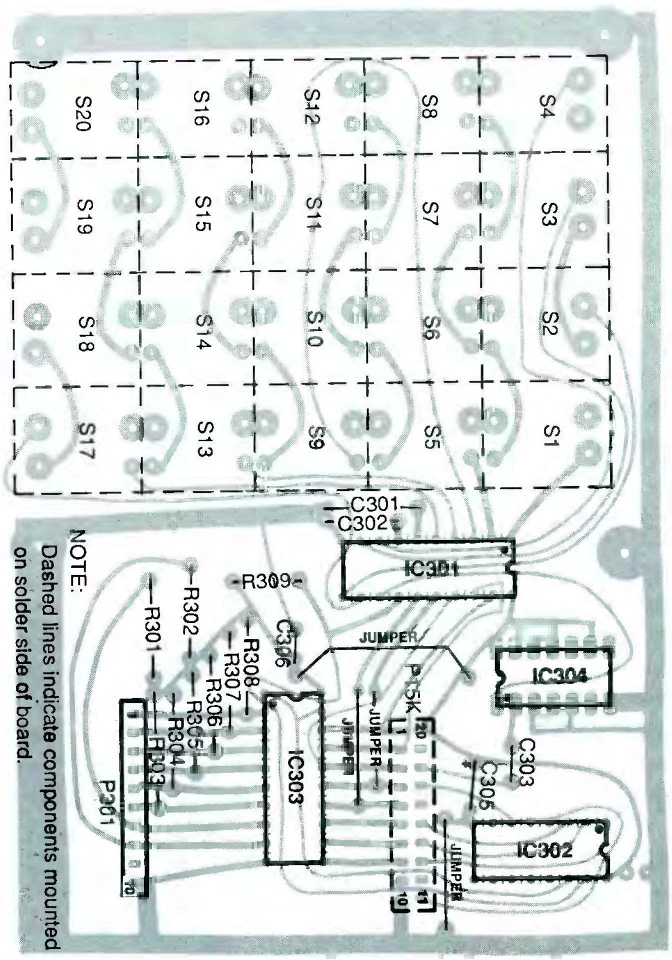

Fig. 15. *Wiring guide for Keyboard module.*

of the author's prototype with the top of the console swung up. As you can see, the commercial power-supply module is shown mounted to the left of the CPU and A/D modules on the floor of the enclosure. The keyboard and display modules are shown mounted in their respective locations on the sloping control panel of the enclosure. The black-tape-wrapped item shown in front of the power-supply module is an optional panel-mounted bayonet fuse holder that can be wired into the primary side of the transformer in the power-supply module.

Preliminary Checkout

With all cables connected, apply power to WISARD. Use a dc voltmeter or a multimeter set to the dc-volts function to perform preliminary voltage checks. Since all measurements are to be made referenced to circuit ground, clip the common lead of the meter to a suitable ground point on the A/D module.

Now, touching the "hot" probe of the meter to pin 24 of the *IC207* socket should yield a meter reading between +4.8 and +5.25 volts. Pin 12 of this socket should be at 0.0 volt. You should obtain a reading between +4.8 and +5.25 volts at pin 20 of the *IC301* socket on the keyboard circuit-board assembly, and pin 10 of this socket should be at 0.0 volt.

Now measure the voltage at all +5-volt power supply pins of all IC sockets, referring back to Fig. 1 and Fig. 2. Your readings should be close to +5 volts, though you might obtain a shade different readings from the rest at the *IC202* and *IC205* sockets. The measurement at pin 4 of the *IC214* socket should be close to +12 volts and at pin 11 should be close to −5 volts. This completes the voltage checks. Whether you obtained the proper readings or not, turn off power to the poject.

If everything appears to be normal up to this point, install *IC209* in its socket, making sure that it is properly oriented and that no pins overhang the socket or fold under between IC and socket. Turn on the power and adjust *R229* for a reading of 5.00 volts at pin 6 of *IC209*.

Turn off power to the project and install the remaining ICs in their respective sockets. Again, make sure each IC is properly oriented, that no pins overhang the sockets and that no pins fold under between ICs and sockets. Then install the fully charged back-up battery. If optional RAM *IC202* is not used by custom firmware, do not install *IC202* or *IC205*. These ICs will only be an unwanted drain on the back-up battery.

Once the project has passed these tests, fabricate the sensor/cable assemblies. There are four such sensor/cable assemblies that are normally located remotely from the project itself. The fifth, *TS1*, samples the temperature inside the project and mounts directly on the A/D circuit-board assembly. When installing *TS1*, be sure to properly orient it before soldering its leads into place.

Cables for the sensors are all simple two-conductor lines and can be either light-duty zip cord or plastic-jacketed two-conductor cable. Use cable that has easily identified conductors, either ribbing of the insulation on one conductor of zip cord or two different colors of insulation on plastic-jacketed cable. Before you cut any of these to length, decide on where you will locate the WISARD console and the individual sensors. Obviously, the shortest distances between sensors and console are preferred to keep down line attenuation.

Begin fabrication by cutting to length the four cables needed. Add about 6 feet to the measured length for the cable to permit moving the console if needed. If you are using zip cord, separate the conductors at both ends of all cables a distance of 1½ inches. If you are using plastic-jacketed cable, remove 1½ inches of outer plastic jacket. Then strip ¼ inch of insulation from both ends of all conductors, tightly twist together the exposed fine wires and sparingly tin them with solder.

Route one end of each cable through its own rubber-grommet-lined hole into the enclosure. Tie a strain-relieving knot in each cable 10 inches from the free end inside the enclosure. Separate the conductors of three cables an additional 2 inches (or remove an additional 2 inches of outer plastic jacket) at the ends inside the enclosure. Plug the conductors of one cable into the MOISTURE SENSOR and any available nearby ground holes and solder into place. Plug the conductors of a second cable into the Q1 EMITTER and any nearby +5-volt holes and solder into place. Similarly, plug the conductors of the third cable into the Q2 EMITTER and any nearby +5-volt holes and solder into place. The free ends of the remaining cable solder into the TS2 holes in the A/D circuit-board assembly.

Refer now to Fig. 17 for fabrication details at the other ends of the Q1, Q2 and TS2 sensor cables. All three of these sensors mount on blocks of lumber that have been drilled as shown to permit mounting of the assemblies in the selected outdoor locations. A screw-type baby juice jar is ideal to protect the sensors from rain, sleet and snow.

After drilling the holes specified sand the lumber smooth and paint all

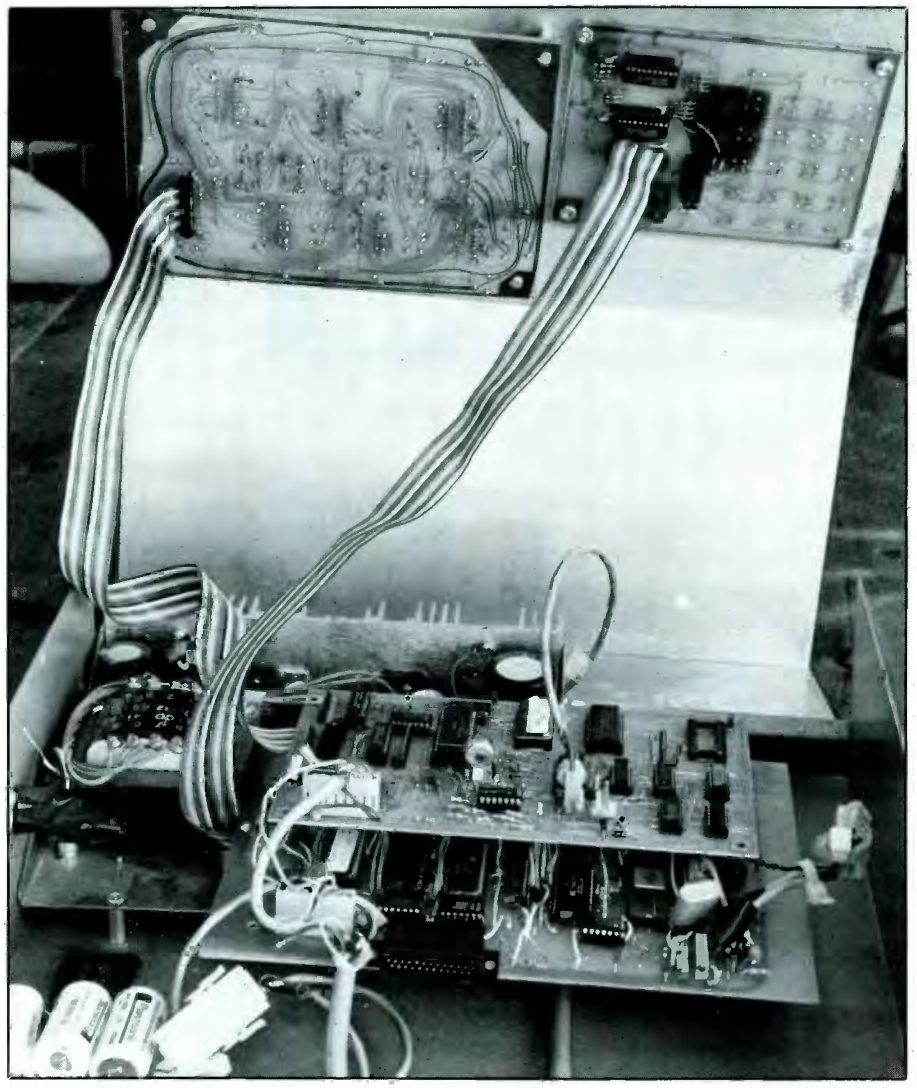

Fig. 16. Interior view of author's prototype built into custom console enclosure.

surfaces with outdoor-rated enamel. Give the lumber two coats of paint, waiting for the first coat to completely dry before painting on the next. When the paint has completely dried, route the free ends of the cables through the drilled holes as illustrated, leaving about 2 inches of free cable visible from the tops of the boards.

Now drill a ¼-inch-diameter hole in the center of the fruit-juice jar lids and ⅛-inch-diameter holes to either side of this one as shown. Set the lids into place on the painted lumber, routing the free ends of the cables through the holes. Secure each lid in place with a small woodscrew.

Trace each cable back to its source and place and label each according to the sensor with which it is to be terminated. Also identify the polarity of each temperature- and light-sensor cable conductors. Then cut to length six 1-inch lengths of small-diameter heat-shrinkable tubing.

Slide a piece of tubing onto each of the conductors of all but the MOISTURE SENSOR cable. Clip the emitter lead of one TIL78 phototransistor to ½ inch in length and form a small hook in the remaining lead stub. Crimp the conductor of the cable that originates at the *C6/R14/R15/R18* junction on the CPU module to this emitter lead and solder the connection. Then repeat the procedure for the collector lead and the conductor that originates at the +5-volt bus. Slide the tubing up over the soldered connections until it is flush with the phototransistor's case and shrink into place.

Repeat the above operation for the other phototransistor, connecting its emitter lead to the Q2 cable conductor that originates at the *C7/R22/R16/R21* junction on the CPU module and the collector lead to the remaining conductor of this cable.

Clip the + lead of the LM335 to ½ inch in length and form a small hook in its stub. Crimp this lead to the TS2 cable conductor that originates at the *R206/R221* junction on the A/D module and solder the connection. Then repeat for the − lead and remaining conductor of the cable. Once again, slide the tubing up over the connection until it is flush with the bottom of the case of the LM335 and shrink into place.

Screw the fruit-juice jars onto the caps to see if they touch the tops of the sensors. If any do, gently but firmly pull on the cables to reduce the amount sticking up through the holes in the lids until no sensor touches the glass jar.

Remove the jars from the lids. Seal the cable entry and exit holes and the screw heads with silicone sealer. Allow the sealer to fully cure for at least 24 hours before screwing the glass jars onto the lids.

Meanwhile, plug the conductors at the free end of the remaining cable into the holes in the home-made moisture sensor (see Part II) from the *copper-trace* side of the board and solder into place. Turn over the board and clip the protruding leads flush with the surface of the board.

Drill a ¼-inch hole in each of the four corners of a 5 × 5 × ¼-inch piece of Lucite or similar plastic. Use two strips of double-sided foam tape to secure the sensor to the plastic plate, centering it all around.

Place over the cable a small U-shaped plastic or metal cable clamp, positioning the clamp about ½ inch away from the sensor. Mark the locations for the two holes for the cable clamp on the plastic plate. Drill the two holes, making them just large enough to accommodate small sheet-metal screws.

Secure the cable to the plastic plate using the cable clamp and ¼-inch-long sheet-metal screws.

Operational Tests

Set *S1* and *S2* to ON and *S3* and *S4* to OFF (these switches are located in the DIP switch assembly on the CPU module). Plug the project into the ac line and turn on power. The display should flash on and off the message "6803UP." If not, power down the project and remove the A/D module.

If when you restore power to the project the "6830UP" message now flashes, there is likely a short circuit in the address or data bus for the A/D module. If the display appears "dead" or "resting," power down the project and remove the cable from the Keyboard module. Now if the test message appears when you restore power, there is a short circuit in the data bus or address line of the keyboard. If the message still fails to appear in the display, refer to Part II for hints on troubleshooting the CPU module.

Once you get the "6830UP" message to appear in the display, turn off the power and set *S2* to OFF. When power is restored, the display should alternately flash "1.00 A" (the preprogrammed start time) and then a temperature reading in Fahrenheit and Celsius. The trailing "i" you see in the display at this point indicates the display is of the inside temperature. A different temperature with a trailing "o" should appear in this display, this for the "outside" temperature reading.

If WISARD fails to perform as described, power down the project and use an ohmmeter or audible continuity tester to check for continuity between the A/D and CPU modules. Also, check all connections, especially those to the *IC210* and *IC207* sockets. As a last resort, try replacing *IC210*, *IC203*, *IC204*, *IC213*, *IC206*, *IC208* and *IC207*.

Set the clock and calendar by first pressing the TIME SET switch, which causes an "S" to periodically appear in the display, indicating that the clock can be set. Hours, minutes, month, days and years are set by pressing the appropriate switch the necessary number of times. Then to start the clock you again press the TIME SET switch at the exact second. (Note: If a time or date switch is pressed *before* pressing the TIME SET or DISPLAY switches, the message "ErrOr" will appear in the display.)

A quick and easy way to calibrate the temperature circuit is to use a digital dc voltmeter or multimeter set to the dc-volts function. Connect the common lead of the meter to circuit ground. Power up the project and adjust *R210* and *R217* for a 2.33-volt reading at each of their center (wiper) lugs. This method of calibration results in a typical error of 1° C(2° F), but it could be as much as 10° F!

For guaranteed accuracy, it is best to use the "ice point" of water for calibration purposes. Half-fill a small plastic bucket with small ice cubes or crushed ice and add water until the bucket is about 75 percent full. Assuming you have waterproofed the sensors, place both temperature sensors in the ice-water mixture. Stir the mixture for a few minutes. Then set *R210* and *R217* for a 32° F (0° C) display for both temperature readings (trailing "i" and trailing "o"). Because of the nature of the sensors and use of precision resistors, only a single-point calibration is required.

Now wet the moisture sensor. The display should now flash "rAIn," after the indoor and outdoor temperatures are displayed. Place SUN sensor *Q1* in sunlight and adjust *R20* so that the display flashes "SunnY." Place this sensor in a room with average lighting. The display should no longer show "SunnY." If it does, readjust *R20* until this message disappears. Then go back to bright sunlight conditions and check to make sure the "SunnY" message returns. If necessary, repeat the adjustments under both conditions until you obtain the correct responses.

To adjust the "daylight" sensing circuit, use a meter to monitor the voltage of pin 7 of *IC8*. Place LIGHT sensor *Q2* in a dimly-lit—but not dark—area. Adjust *R25* until the measured potential on pin 7 of *IC8* just drops to between 0.0 and 0.3 volt. When you place *Q2* in total darkness, the potential on pin 7 should rise to nearly +5 volts.

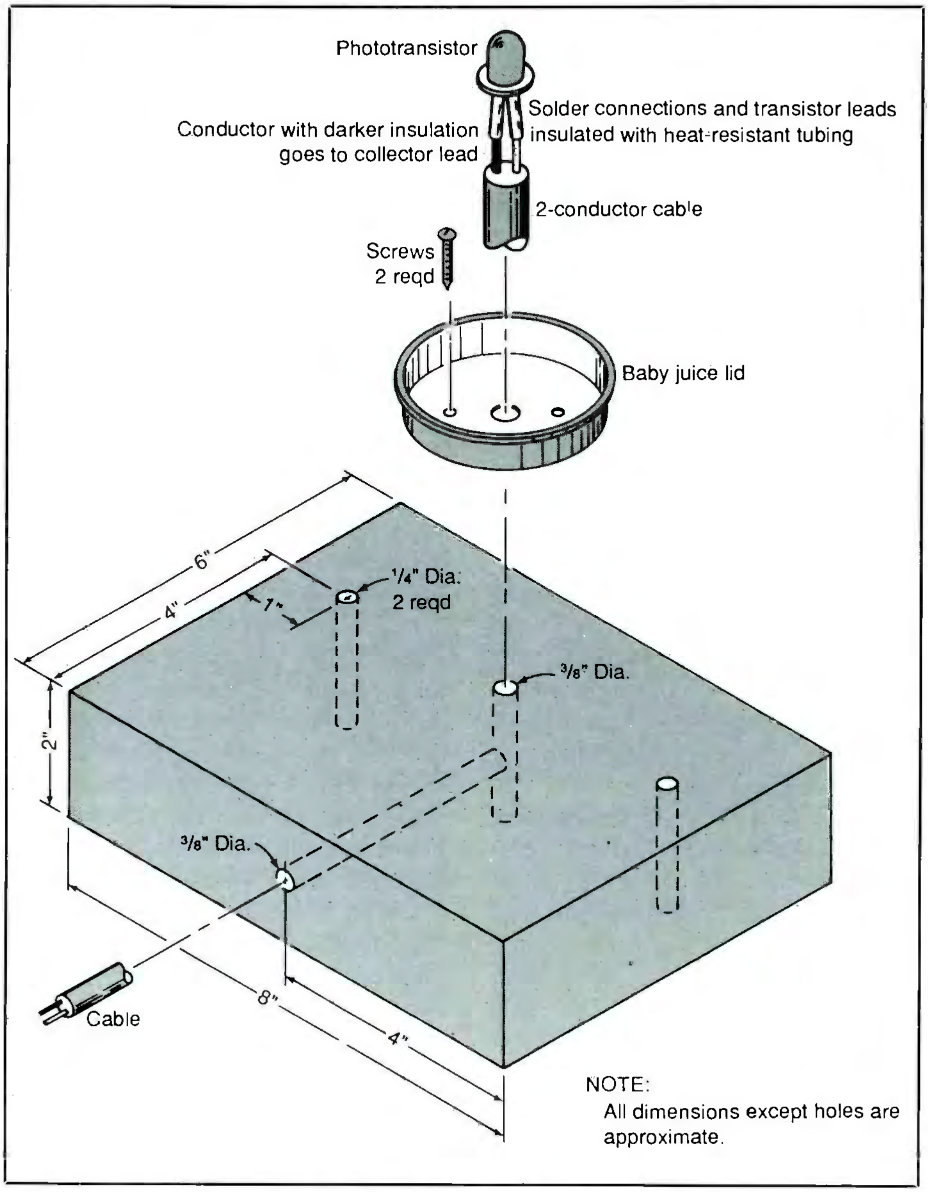

Fig. 17. Details for finishing off input cables with sensors. Infant juice jars with screw-on lids make ideal see-through weather sealers for sensors.

To use the serial interface, you need a printer, terminal or computer that has terminal-emulation software and a serial interface that can be set to 4,800 or 600 baud. The following assumes that a printer is being used. Many printers with a serial interface require only three conductors at their RS-232 connectors. Those that require more can be made to work by appropriate placement of jumpers and other educated "fixes."

WISARD sends data on pin 3, and its Request To Send (RTS) input is on pin 4 of its RS-232 connector. Pin 7 is ground. All pin numbers correspond to standard RS-232 connections. For 4,800-baud operation, set *S4* to ON and for 600-baud, set it to OFF. The baud rates of WISARD and the printer *must* be identical.

Before connecting the printer to WISARD, turn off the power to both units. WISARD "reads" *S4* only on power-up. Connect the printer to the project and turn on the printer and then WISARD. After a few seconds, the printer should print a message that starts: "WISARD (ME1)—FIRMWARE(WISCPUBD) ver 1.XME(F1)." The "power-on" time and date and present outside temperature are also displayed.

Now press the PRINT key. Most, if not all, temperatures on the printout have question-mark entries. This means WISARD had its power off at the times listed. If there are no missing characters, everything is probably working properly. If characters are missing, or the printer appears to be dead, the most likely cause is a handshaking difficulty. If this is the case, disconnect pin 4 from WISARD's RS-232 interface from pin 4 of the printer's interface and try connecting it to pin 5 on the printer.

If the printer still does not respond properly, try connecting WISARD's RTS input to pin 6 or even pin 20 of the printer's interface connector. If the problem still persists, read the manual supplied with the printer. With information from the printer manual and a working knowledge of WISARD, you should be able to achieve compatibility.

Coming Next Month

Next month, we will discuss sensor placement and details on using WISARD, including specifics on controlling alarms, heaters and other heavy-duty electrical equipment. We will also include hints on modifying the firmware to suit specific needs and the equipment needed to modify the firmware. ME