



The Digi-Ohm Add-On Module

A low-cost add-on module that gives the Digital Measuring System display module a resistance-measuring capability

By C.R. Ball Jr.

Measuring resistance is a basic requirement in electronics. This ability lets you troubleshoot any unpowered circuit to determine if resistances meet specifications, quickly sort through a pile of unknown resistors to determine their values, match resistor pairs, etc. The Digi-Ohm module to be described provides this needed function for readers who built the "Digital Measuring System" digital display module featured in the August 1986 *Modern Electronics*.

Digi-Ohm is a locally or remotely programmable plug-on ohmmeter support module designed specifically to work with the previously presented DMS module. Connectors on the Digi-Ohm module mate directly with those on the DMS module to permit connection without wire runs. You can locally program a DIP switch for

a desired dedicated range or use a socket, header, cable and rotary switch to add flexibility and versatility in mounting the project and selecting ranges. Digi-Ohm can also be made into a portable ac/dc-operated instrument by using the power-supply module featured in the August 1986 DMS article.

Digi-Ohm is capable of displaying five full-scale resistance ranges from 99.9 ohms to 999K ohms. Calibrated accuracy is better than 1.0 percent ± 1 count. If a 10- or 12-volt source is used with the project to supply the current source around which the ohmmeter module is built and a precision current meter is used for calibration, greater accuracy can be achieved. You can build the Digi-Ohm module for less than \$35.

About the Circuit

Digi-Ohm provides a selectable con-

stant current from a fixed-voltage source. When passing through an unknown value of resistance (R_x), this known current produces a voltage that is proportional to the resistance. Consequently, the DMS equipped with Digi-Ohm does not display resistance but, rather, a voltage that represents the resistance. The value of the display, though, is read directly in ohms.

A basic constant-current source is shown in Fig. 1(A). In the past, constant-current sources have been complex and expensive devices in applications where a wide range of current was required. Fortunately, the LM134/234/334 series of three-terminal current sources, as illustrated by Fig. 1(B), reduces both the complexity and cost of building a constant-current device.

A drawback of the LM series of current sources is that their current is temperature-dependent (a feature

that makes these devices good temperature sensors). To overcome variations with changing temperatures, thermally attached germanium diode $CR1$ and compensating resistor R_T are inserted in the circuit, as shown in Fig. 1(C). The diode has a temperature coefficient that is opposite that of the LM current sources, which nulls out effects due to temperature variations.

Since the LM series of current sources are adjustable over a 10,000:1 range, these devices make ideal inexpensive current sources for the Digi-Ohm. Though all three devices in the LM series provide the same function, for best accuracy and stability, the LM134 is preferred.

The LM134-3's initial accuracy is 3 percent, while that of the LM134-6

is 6 percent. Trimmer potentiometers included for all ranges in the Digi-Ohm permit easy fine tuning during calibration so that initial accuracy is not a critical factor.

Ranges in this project are selected with either two on-board DIP switches or from a remote rotary switch on its own separate panel. One DIP switch is used to select R_{SET} to determine the current range, the other to select the value of the temperature-compensating resistor.

As shown in the basic schematic diagram in Fig. 2, voltage regulator $U2$ provides regulated +5 volts for current source $U1$. A +12- or +15-volt regulator could be used instead of the 7805 specified (with minor circuit-board modifications) to provide better linearity on the high-

est ranges. However, the tradeoff is likely to be temperature drift in the $U1$ LM device on the lowest range as a result of increased dissipation.

Digi-Ohm is connected to the $V+$ and $V-$ inputs of the DMS module as shown in Fig. 2. Since input impedance of the DMS module is greater than 80 megohms, if no resistor is connected between TP1-1 and TP1-4, the DMS module will display "EEE," indicating an overrange (infinite-resistance) condition.

Once a resistor is connected across TP1-1 and TP1-4, the current from the programmed constant-current source flows through it, producing a voltage across the unknown resistor that is proportional to the value of the resistor. This voltage is then displayed by the DMS module. Back-

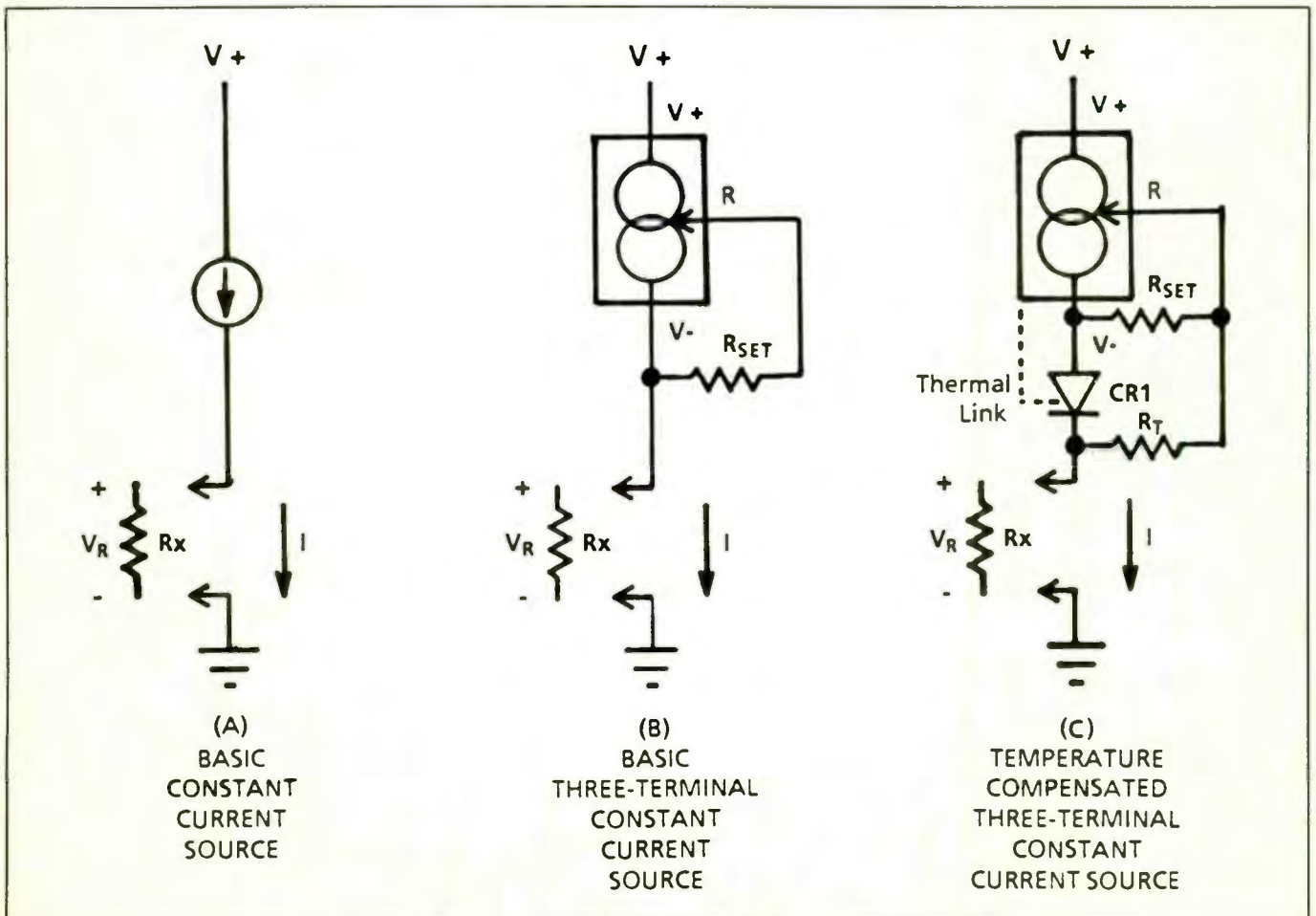
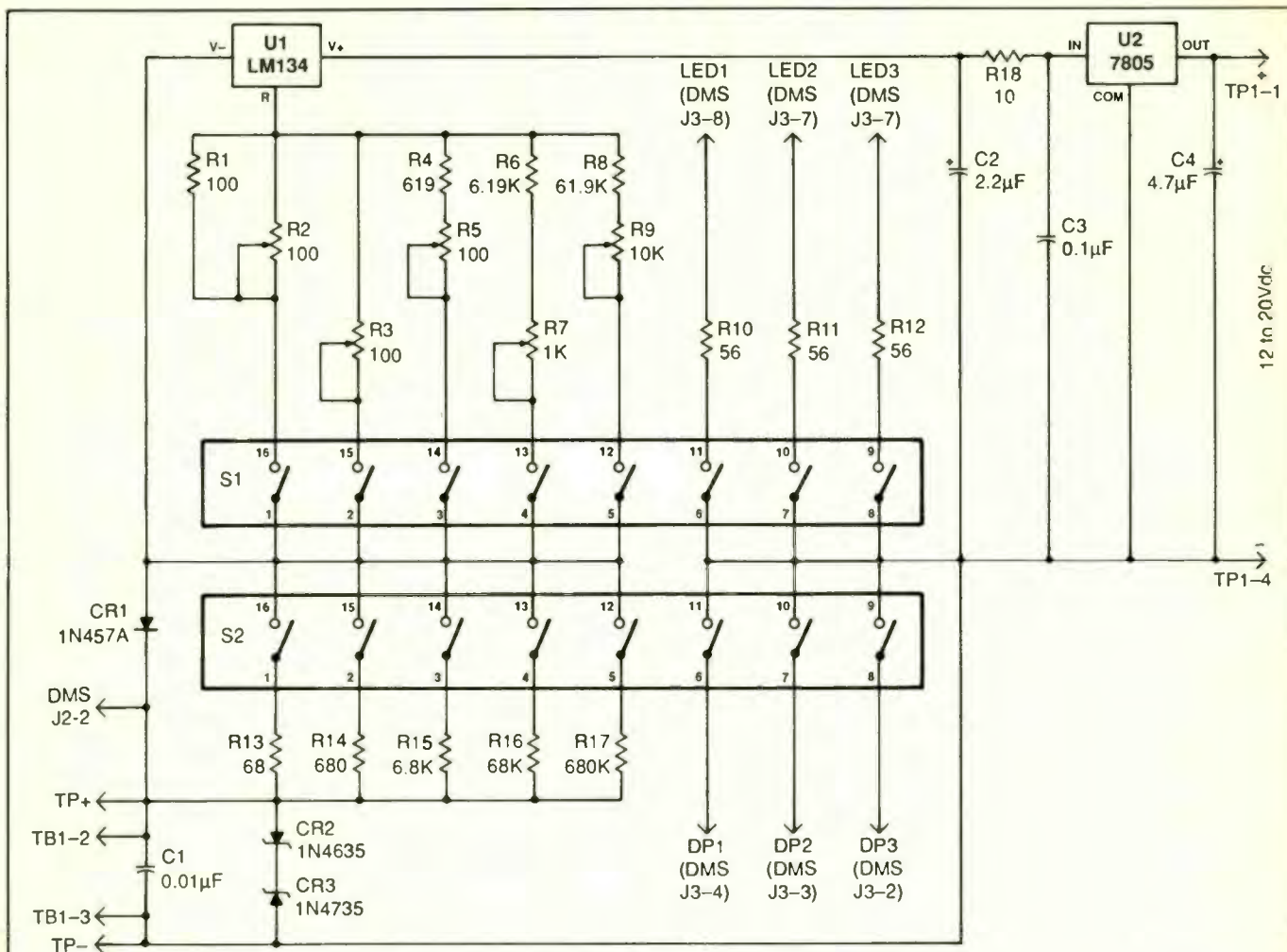


Fig. 1. Constant-current resistance-measuring circuits.



PARTS LIST

Semiconductors

- CR1—1N457A diode
- CR2, CR3—1N4735 zener diode
- LED1, LED2—Red T-1 1/4 light-emitting diode
- U1—LM134, LM234 or LM334 current source (see text)
- U2—7805 fixed +5-volt regulator (optional; see text)

Capacitors

- C1—0.01-µF, 100 volt ceramic disc
- C2—2.2-µF, 16-volt tantalum
- C3—0.1-µF, 25-volt ceramic
- C4—220-µF, 25-volt electrolytic

Resistors

- Metal-Film** (1/4-watt, 1% tolerance)
 - R1—100 ohms
 - R4—619 ohms
 - R6—6,190 ohms
 - R8—61,900 ohms
- Carbon** (1/4-watt, 5% tolerance)

- R10, R11, R12—56 ohms

- R13—68 ohms
- R14—680 ohms
- R15—6,800 ohms
- R16—68,000 ohms
- R17—680,000 ohms
- R18—10 ohms

Cermet Trimmer Potentiometers

- R2, R3, R5—100 ohms
- R7—1,000 ohms
- R9—10,000 ohms

Miscellaneous

- S1, S2—8-position DIP switch (see text)
 - S3—4-pole, 5-position nonshorting rotary switch (optional; see text)
- Printed-circuit boards for Digi-Ohm and LED modules; DIP sockets for S1 and S2; AP Part No. 929834-04 36- or 40-pin male header strip; OK Part No. K180 4-pin terminal board; red and black banana or pin jacks or 5-way

binding posts (see text); clear Lexan or Plexiglass for front panel(s), 1/2" thick; 16-pin header plugs optional; see text; pointer-type control knob for S3 (optional) suitable enclosure; ribbon cable; 6-32 machine hardware; solder; etc.

Note: The following items are available from BALLco, Inc., 148 S. Clayton St., Suite 131, Lawrenceville, GA 30245: Etched, drilled, plated and silk-screened Digi-Ohm pc board No. 860-810, \$10.95 PPD; complete No. DMS-OHM kit of parts, including LM334, all headers, terminal boards, DIP switches and pc board but not including S3, cabinet, etc., \$34.95 plus \$2.50 P&H; LED pc board kit No. 651-032, including two pc boards, four LEDs and ribbon cable, \$7.95 PPD; front-panel kit No. 651-001, including Lexan sheet, inlay and machine hardware, \$8.85 PPD. Georgia residents, please add state sales tax.

Fig. 2. Schematic diagram of Digi-Ohm module.

Table 1. Ranges and Currents for Digi-Ohm Module

RANGE	DISPLAY	CURRENT
1. 100Ω F.S.	0 - 99.9 Ohms	10 mA
2. 1KΩ F. S.	0 - 999 Ohms	1 mA
3. 10KΩ F. S.	0 - 9.99K Ohms	100 μA
4. 100KΩ F. S.	0 - 99.9K Ohms	10 μA
5. 1MΩ F. S.	0 - 999K Ohms	1 μA

board. Including them in your project, however, will give you an opportunity to substitute the optional rotary-switch later if you desire. If you are building Digi-Ohm with the remote switching arrangement from the start, you must include the sockets to provide a means by which to interconnect it to the module.

Once the sockets are in place, install and solder into place the fixed resistors, capacitors and zener diodes but *not* CR1, as indicated. Take care to observe polarity for the polarized capacitors and diodes. For the fixed precision resistors, you *must* use metal-film types to ensure good temperature stability. Color-coded precision resistors have five color bands and are easy to confuse with some military-style carbon resistors that also have five bands. So exercise care when reading resistor value codes.

Install the trimmer potentiometers as shown. The pc pattern on the

to-back zener diodes CR2 and CR3 in Fig. 2 provide static and overvoltage protection for the A/D converter in the DMS module.

Full-scale indications that are possible with the Digi-Ohm/DMS combination are listed in Table 1, along with the display range and test current for each.

Shown in Fig. 3 is the schematic diagram of the optional remote range-select switch that can be used with Digi-Ohm.

tions are identified using the technique described in "Dress Up Your Projects" in the September 1985 issue of *Modern Electronics*.

When you are ready to wire your boards, refer to Fig. 4(B). Wire first the main board, starting with the sockets for S1 and S2, assuming you have decided to use sockets for the DIP switches. Sockets are optional for the DIP switches, which can be soldered directly into place on the pc

Construction

Assembly of Digi-Ohm is essentially straightforward. However, as with the other modules in this series, printed-circuit wiring is a must, this time because the pc copper conductor pattern is required for temperature tracking between the temperature-compensating diode and current source. Hence, if you attempt to build this resistance module on perforated board, you may discover that the project does not operate as it should.

You can fabricate your own printed-circuit board for the project using the actual-size etching-and-drilling guide shown in Fig. 4(A). Alternatively, you can purchase a ready-to-wire, silk-screened board from the source given in the Note at the end of the Parts List. If you make your own boards, you can apply to the component sides self-adhering clear plastic sheets on which the component loca-

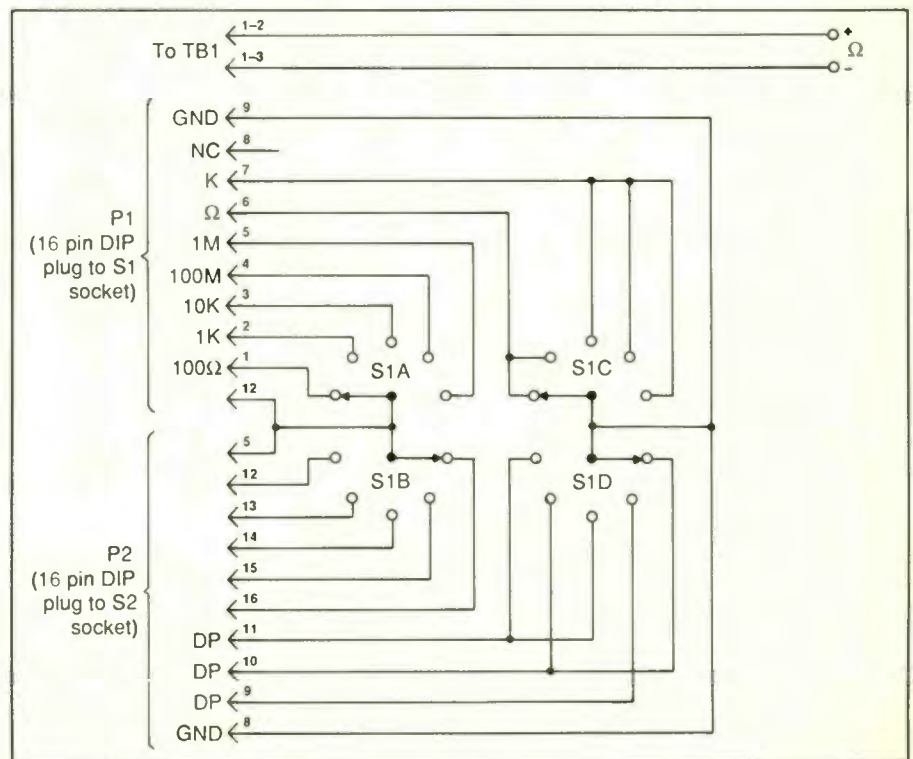


Fig. 3. Schematic/wiring diagram for optional range-selection switching arrangement.

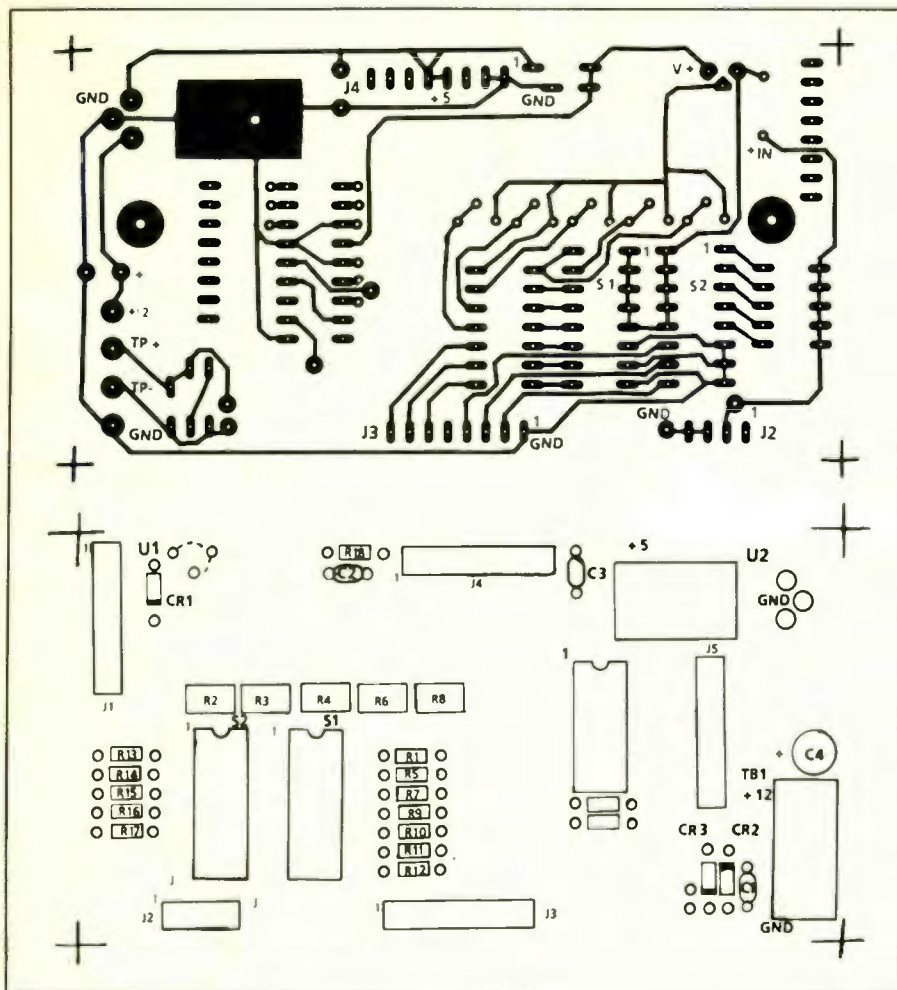


Fig. 4. Actual-size etching-and-drilling guide (A) and wiring diagram (B) for Digi-Ohm pc board.

board has been designed to accommodate either vertical- or horizontal-mount trimmers. Use only cermet or wire-wound trimmers, again to ensure temperature stability.

Next, cut the header strip into four strips of eight and one strip of four pins. From the *component* side of the main board, push the longer-pin end of the eight-pin headers through the board's holes at locations J1, J3, J4 and J5. Seat the headers so that their plastic separators sit solidly against the surface of the board. Do the same with the four-pin strip in the J2 location.

Plug the header pins into the mating header sockets on the DMS module to assure proper header align-

ment. Solder each pin to its associated copper pad on the Digi-Ohm board. Take care to avoid creating solder bridges between the pads on the bottom of the board.

After soldering all pins to the Digi-Ohm board, unplug the DMS module and set it aside. Then install and solder into place the four-contact terminal block at TB-1 on the Digi-Ohm board. Make sure that the holes in the terminal block face the edge of the board, as shown in Fig. 5(A).

Turn over the board and mount CR1 in place, again making sure that it is properly oriented before soldering its leads to the copper pads. This diode must mount on the *foil* side of the board and must be in intimate

contact with the copper pattern to ensure proper temperature tracking with U1. Hold the diode tight against the copper pattern as you solder each lead into place and until the liquid solder sets.

Install U1 on the foil side of the board as follows. First position it so that its leads are as shown in Fig. 5(B). Then before soldering it into place, bend its leads so that the flat side of the device's case is against the foil pattern near CR1. Hold the diode tight against the board while soldering its leads to the copper pads and until the liquid solder has set. Later, after calibration has been performed, you will epoxy both CR1 and U1 to the board to ensure maximum temperature stability.

The circuit board has provisions for an on-board +5-volt regulator at U2. If you do not need this regulator, install a jumper wire in the two outside regulator holes to connect TB1 to header J4.

Loosely twist together two 3¼-inch lengths of No. 24 hookup wire and strip ¼ inch of insulation from both ends of both wires. Plug one wire into the hole labeled J nearest the edge of the board to the left of CR3 and solder into place. Plug the other end of this wire into the hole labeled J at pin 4 of J2 and solder into place. If both wires have the same color insulation, use an ohmmeter or continuity tester to identify the other end of this wire. Then plug the ends of the other wire in the twisted pair into the remaining holes labeled J and solder into place.

As you approach final assembly, decide how you are going to use the Digi-Ohm—as a single, fixed-range device; as a DIP-switch selectable multiple-range device; or as a remotely selected multiple-range device. How you plan on using this project determines how to proceed with final assembly.

If you have decided to use Digi-Ohm as a single, fixed-range device, simply solder a jumper wire in the

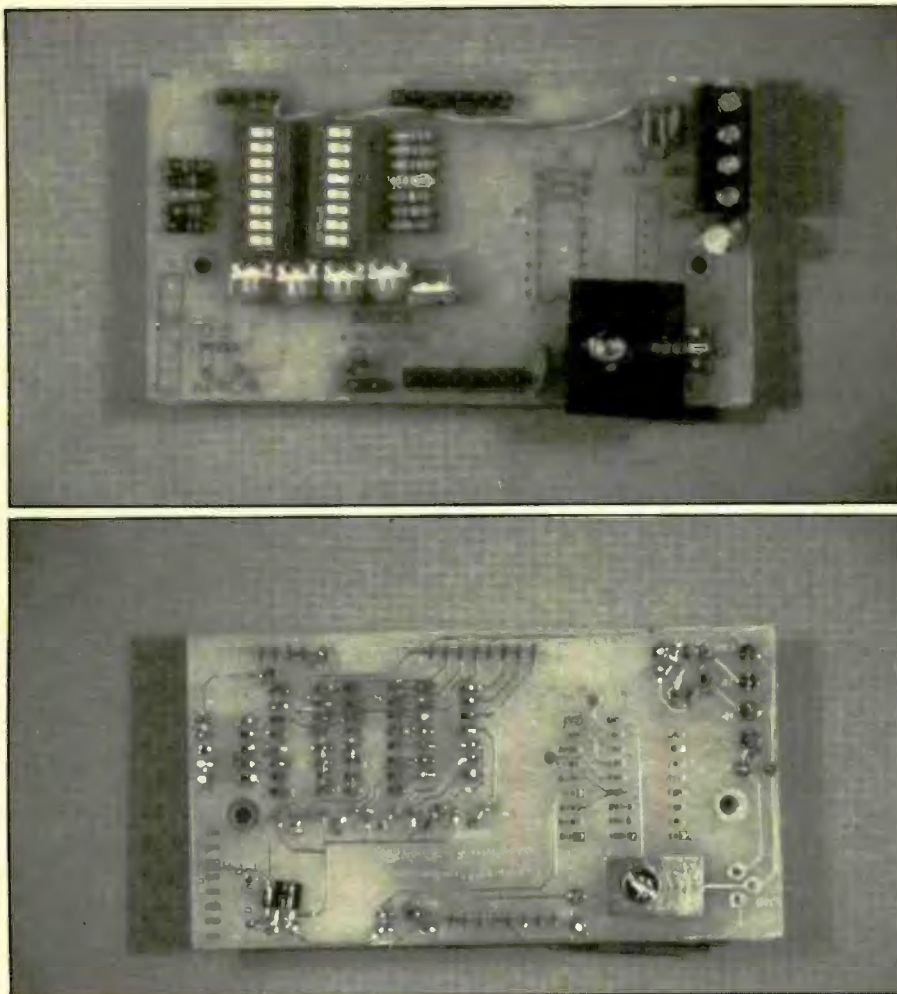


Fig. 5. Top view of wired Digi-ohm module (A) and bottom view (B) showing mounting details for CR1 and U1.

appropriate positions that correspond to the desired range where S1 and S2 would normally complete the circuit. To determine where to install this jumper for any given range, refer to Table 2.

Using the DIP-switch-selection option, simply plug into IC sockets a pair of eight-position DIP switches.

For remote selection, you must wire a four-pole, five-position non-shortening rotary switch to ribbon cable and plugs according to Fig. 3. Label the plugs S1 and S2 to avoid confusion when plugging them into the IC sockets on the circuit-board assembly.

Once the Digi-Ohm board has been fully wired, clean away all sol-

der flux with a spray solvent. Bear in mind that solder flux is conductive, especially in high humidity, and can be the cause of parallel-resistance circuits that can result in measuring errors.

LED boards for the DMS are used to indicate range, function or other information not given in the numeric display and to provide enough space for mounting the front panel. Only one LED board is required for the Digi-Ohm module, to indicate range in ohms or kilohms). The other is used merely as a spacer. If you wish, you can eliminate this second board by replacing it with a 1/8-inch-thick washer.

Prepare two LED boards, using

the actual-size etching-and-drilling guide shown in Fig. 6(A). When this is done, mount two light-emitting diodes on the LED board as shown in Fig. 6(B). Note that the leads of the LEDs plug into the holes from the foil side of the board(s). Plug the leads of the LEDs into the appropriate holes in the board. Bend the leads so that the bottoms of the plastic cases of the LEDs sit flush against the top of the board(s), with the leads wrapping around the edges of the board(s).

Separate the conductors at both ends of a 3-inch-long, three-conductor ribbon cable by about 1/2 inch. Strip 1/4 inch of insulation from both ends of all three conductors. Tightly twist together the fine wires in each case and sparingly tin with solder. Then plug the conductors at one end of the cable into the holes labeled LED1, LED2 and COM on the LED board.

Connect and solder the wire from LED1 to pin 8 of J3, the wire from LED2 to pin 7 of J3 and the wire from COM to pin 4 of J4. Leave the LED board dangling by the short cable until you finish calibrating Digi-Ohm.

Test & Calibration

To test and calibrate Digi-Ohm, you need a tested and calibrated DMS module. The DMS module should not have resistors installed in locations R_x and R_y . It should have a jumper wire installed in the R_z location and a 0.1-microfarad capacitor in the C_z location.

If you are using a +5-volt regulator for U2, before connecting Digi-Ohm to the DMS module, connect a 12- to 20-volt dc power supply to TB1-1 + and GND terminals and then check for 5 volts between pins 4 (+) and 1 (-) of J4. If you do not get a reading of 5 volts between these two points, recheck your wiring and replace U2 if necessary.

If you are not using a regulator, or have finished the above check, plug

Table 2. DIP Switch Positions to Use for Different Ranges

SW1					
Range / Position	99.9 ohms	999 ohms	9.99K ohms	99.9K ohms	999K ohms
1	ON	OFF	OFF	OFF	OFF
2	OFF	ON	OFF	OFF	OFF
3	OFF	OFF	ON	OFF	OFF
4	OFF	OFF	OFF	ON	OFF
5	OFF	OFF	OFF	OFF	ON
6	ON	ON	OFF	OFF	OFF
7	OFF	OFF	ON	ON	ON
8	OFF	OFF	OFF	OFF	OFF

SW2					
Range / Position	99.9 ohms	999 ohms	9.99K ohms	99.9K ohms	999K ohms
1	ON	OFF	OFF	OFF	OFF
2	OFF	ON	OFF	OFF	OFF
3	OFF	OFF	ON	OFF	OFF
4	OFF	OFF	OFF	ON	OFF
5	OFF	OFF	OFF	OFF	ON
6	OFF	OFF	ON	OFF	OFF
7	ON	OFF	OFF	ON	OFF
8	OFF	ON	OFF	OFF	ON

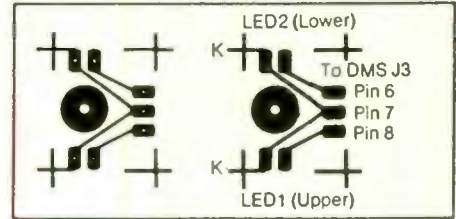


Fig. 6. Actual-size etching-and-drilling guide (A) and wiring diagram (B) for LED boards.

meter used should have a rated accuracy of 0.1 percent.

If you are using the DIP-switch method of range selection, refer to Table 2 and position *S1* and *S2* for the lowest range (99.9 ohms full-scale). If you are using the remote switch panel, connect the cables at *S1* and *S2* and set the selector switch to the 100-ohm range. When using the fixed-range arrangement, substitute the appropriate values (see Tables 1 and 2) for the specific fixed range you have selected.

For calibration with precision resistors, connect a 50-ohm test resistor between TP+ and TP- and adjust the setting of *R2* until the DMS displays "050." For calibration with a current meter, set the milliammeter to a range that will measure 10 mA. Adjust the setting of *R2* for a reading of 10.00 mA on the milliammeter. Repeat the procedure for each range, using the proper middle-of-the-range resistor (first method) or adjusting for the current indicated in Table 1. The appropriate decimal point and panel LED (Ω or $K\Omega$) should light as each range is selected.

If you encounter any difficulties, check to see if the proper value of trimmer potentiometer has been installed for each range. If no current is present, check *U1*, *CR1* and the range-selection arrangement. Make any necessary repairs and then repeat the calibration procedure.

After calibrating all ranges, apply a small amount of fingernail enamel to the trimmer screws to prevent

the Digi-Ohm module onto the rear of the DMS as shown in Fig. 7.

Connect test leads to *TB1* at TP+ and TP-. Connect an appropriate power source to TP+ and GND and turn on the power supply. At this point, your DMS module should be displaying "EEE," indicating an overrange (infinite-resistance) condition. Shorting TP+ to TP- should cause the displayed reading to drop to "000," indicating a 0-ohm (short-circuit) condition.

If you encounter any problems at

this stage, *U1*, *CR1* or the headers are the probable cause.

There are two ways to calibrate the Digi-Ohm module. The first is to use several precision resistors of different values, one per range. The second, more accurate, method is to use a precision current meter.

If you use precision resistors for calibration, select resistors of known value in the middle of each range to be calibrated. If possible, the resistors should be 0.1-percent tolerance. For the second method, the current

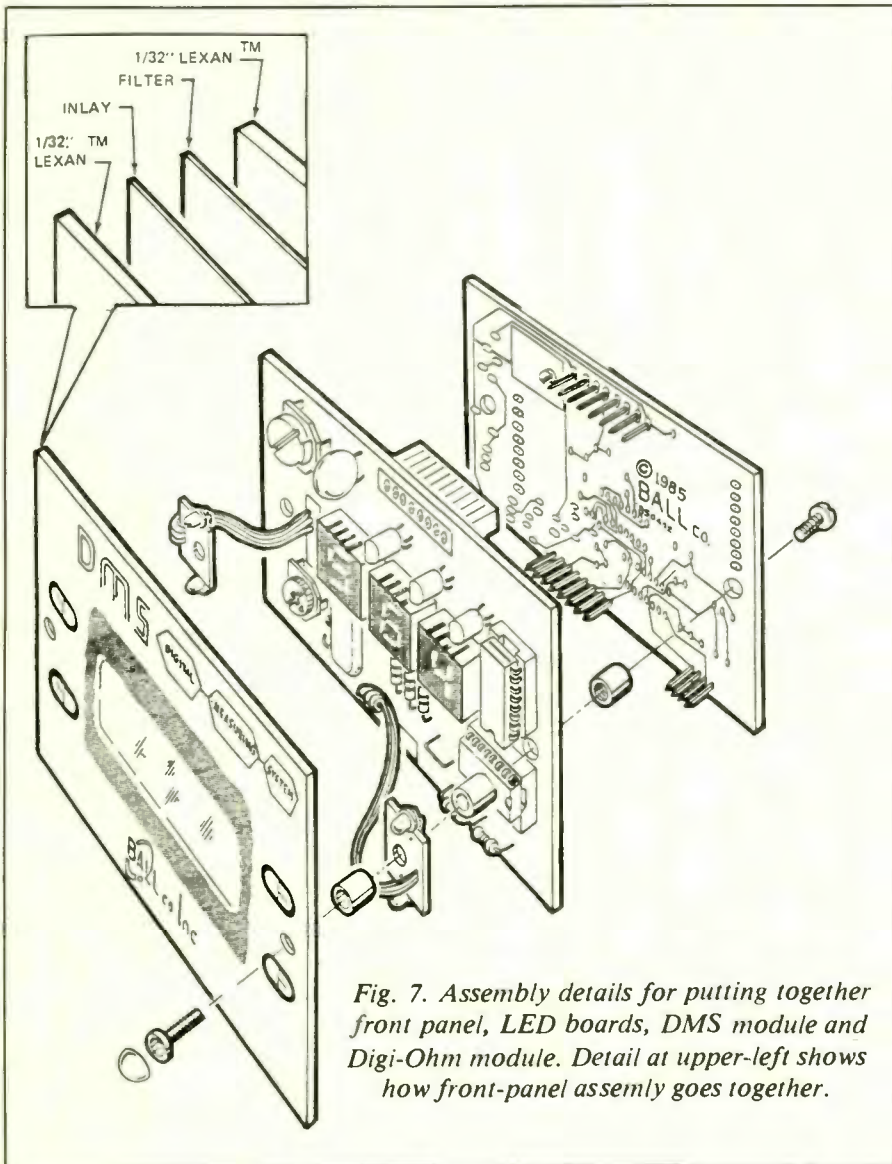


Fig. 7. Assembly details for putting together front panel, LED boards, DMS module and Digi-Ohm module. Detail at upper-left shows how front-panel assembly goes together.



Fig. 8. Actual-size front-panel inlay artwork to use when Digi-Ohm module is attached to DMS module.

them from being accidentally rotated. Press *UI* and *CRI* together against the circuit board and secure them into place with a fast-set epoxy cement to ensure good thermal tracking between the two.

Final Assembly

Unplug the Digi-Ohm module from the DMS module. Prepare the front panel inlay (shown actual-size in Fig. 8) for the numeric display and LEDs. You can use the Fig. 8 artwork directly, backing it up with a sheet of matte black paper (to prevent the print on the opposite side of the page from "phantoming" through to the front) with appropriate cutouts for the display window area, LEDs and mounting hardware, or a same-size photocopy of it without the black paper backing. Sandwich the inlay and a red filter (red cellophane works well, or you can use piece of Ruby-lith, purchased from an art-supply store) between two thin, preferably 1/32-inch, pieces of Lexan or Plexiglass, as shown in the detail at the upper-left in Fig. 7.

Feed two 6-32 × 1-inch machine screws through the front-panel assembly as shown and slide onto each a 1/4-inch spacer. Follow with a LED circuit-board assembly (or 1/16-inch-thick washer) on each screw end (the right screw *must* have a real LED board) and another 1/4-inch spacer. Slide onto the screw ends the DMS circuit-board assembly and finish up with a threaded 1/4-inch spacer on both screws. Make the spacers only finger tight. The ends of the screws should not protrude through the ends of the threaded spacers.

Plug the Digi-Ohm circuit-board assembly onto the rear of the DMS module and secure it in place with 6-32 × 1/4-inch machine screws, driven into the open ends of the threaded spacers. Unless you have decided to use the remote range-select option, this completes assembly of the DMS with its ohmmeter func-

tion. The front-panel, LED-board, DMS-module and Digi-Ohm-module "sandwich" arrangement is illustrated in Fig. 9.

If you have decided to incorporate the remote range-select option into your project, you must assemble it in much the same way as you did the DMS, Digi-Ohm and front panel. Shown in Fig. 10 is the actual-size inlay to use for the switch panel. You can cut this out and cement it to a sheet of matte black paper or make an actual-size photocopy of it and use it directly without the black paper. Sandwich this between two thin layers of Lexan or Plexiglass, as you did for the instrument front panel. Then mount the rotary switch and input jacks in place.

Make the hex nut on the rotary switch only finger tight to start. Slide the pointer-type control knob onto the switch's shaft and, while holding the switch in place, rotate the knob fully counterclockwise and note if the pointer lines up with the 100Ω index on the panel. If it does not, remove the knob, loosen the hex nut and reposition the switch as needed. Then securely tighten the nut (do not make it so tight that it cracks the plastic of the panel) and replace the knob on the switch shaft. Now as you rotate the knob clockwise, its

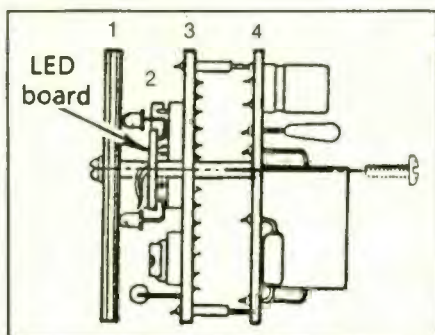


Fig. 9. Finished project consists of "sandwich" of front-panel assembly (1), LED boards (2), DMS module (3) and Digi-Ohm module (4).

pointer should stop at each panel legend index in turn.

Install a red and a black banana or pin jack or five-way binding post in the "+" and "-" INPUT jack holes, respectively, in the panel. The only thing left to do now is plug in the ribbon cables that connect the remote switch panel to the Digi-Ohm module into the appropriate S1 and S2 sockets.

If you wish, you can house the project in any small plastic project box that will accommodate it. If you built the remote switch option, this should be housed inside the same box, perhaps with the two modules' panels stacked one above the other or side by side. **ME**

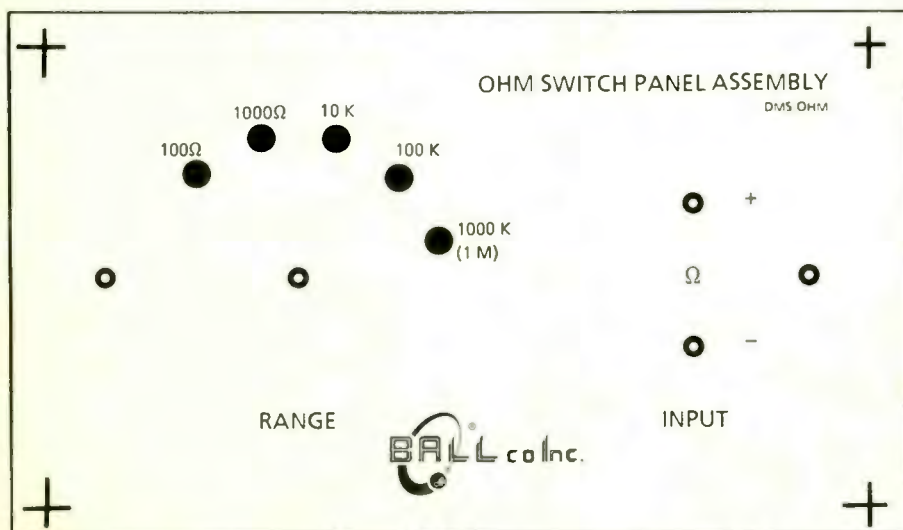


Fig. 10. Actual-size panel inlay artwork for optional remote range switch.