The flashtube mounts in the flashlight's reflector. You can enlarge the standard lamp hole in the reflector with a rat-tail file, working carefully to avoid damaging the reflector or scratching its reflective coating. The flashtube's fit should be reasonably close without binding. Place the reflector assembly face down on a flat surface and insert the flashtube in the enlarged hole, positioning it with its point against the glass lens and vertical to the plane of the lens. Run a bead of epoxy or Dow Corning Silastic® cement between flashtube and reflector and allow the cement to set overnight. Be sure to maintain the flashtube vertical to the lens as the cement sets (Fig. 4).

Once the cement has set, you can complete final assembly. Locate the negative (woven) electrode lead of the flashtube and connect it to the hole marked *FT1*(−) in the component-placement guide in Fig. 2. Then connect the positive electrode lead (it exits the end of the flashtube opposite the negative electrode lead) to the *FT1*(+) point on the board. The only connection left to be made is the spark-plug test lead. Locate this lead and connect and solder it to the high-voltage terminal on the flashtube. (Note: The high-voltage terminal is the metal band affixed to the outside of the flashtube.) Pack the connection with Silastic cement to insulate it and set the assembly aside to harden.

When the cement has set, slide the circuit board assembly into the flashlight case and anchor it in place with

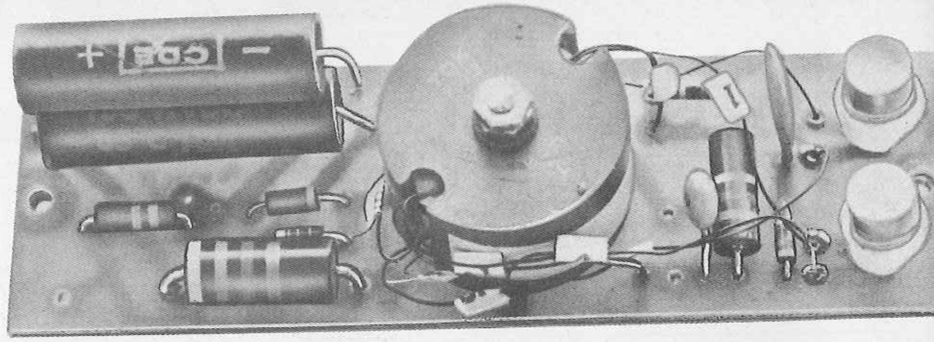


*Fig. 3. Wired pc board assembly shows T1 mounted with hardware fiber washer. C4 is on top of C3.*

two 4-40 × ½-in. machine screws. Screw on the reflector assembly but under no circumstances permit the reflector itself to rotate. If you allow the reflector to rotate, the flashtube will be damaged or a short circuit will develop.

**How to Use.** Before making any timing adjustment on your car, set the dwell time of the ignition points according to the recommendation of the manufacturer of your car. This can be accomplished by using a dwell meter on most General Motors cars and adjusting the points with an Allen wrench while the engine is running. On other car makes, the dwell angle must be set by adjusting the point gap opening. Bear in mind that the dwell angle must always be properly set *before* the timing is adjusted as changes in the dwell angle will change ignition timing.

Locate the number one cylinder of your car's engine. (On 4- and 6-cylinder engines, it will be the one nearest the front of the engine. The number-one cylinder on a V8 engine is also nearest the front, but it could be either on the left or the right.) With the engine shut off, remove the ignition lead to the number-one cylinder and connect the timing light's plug lead to the plug. Replace the ignition wire.

Before starting the engine, it is advisable to clean the flywheel and paint a thin white line over the timing mark so that it is readily visible. Then refer to the decal, located in the front of the engine compartment of late model cars, to determine the calibration of the timing scale and proper ignition timing specifications.

Remove the rubber hose connected to the vacuum diaphragm of the distributor and plug the hose opening with a pencil. This disables the automatic vacuum advance built into the distributor. Timing of an engine is always adjusted with the vacuum advance disabled. If you neglect to do this, you will set the timing incorrectly and the engine will not operate properly.

Connect the remaining two timing light cables to the car's battery, observing the proper polarity. Start the engine. The light should now be flashing at a rate of 4 to 5 times per second. Aim the timing light at the flywheel to locate the timing mark. The mark should appear to be stationary. If timing is not correct, loosen the bolt that clamps the distributor assembly to the engine and rotate the distributor in the direction that yields the proper indication. Tighten the bolt and recheck the timing to make sure it has not changed.

Stop the engine. Remove the timing light and replace the hose to the distributor's vacuum-advance diaphragm. The timing of the engine is now correctly set. It need not be checked again until the points are replaced. ◈

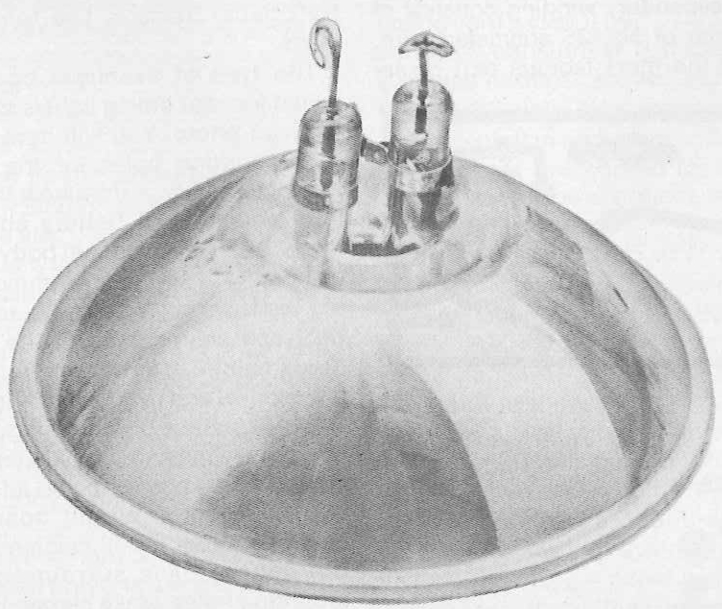
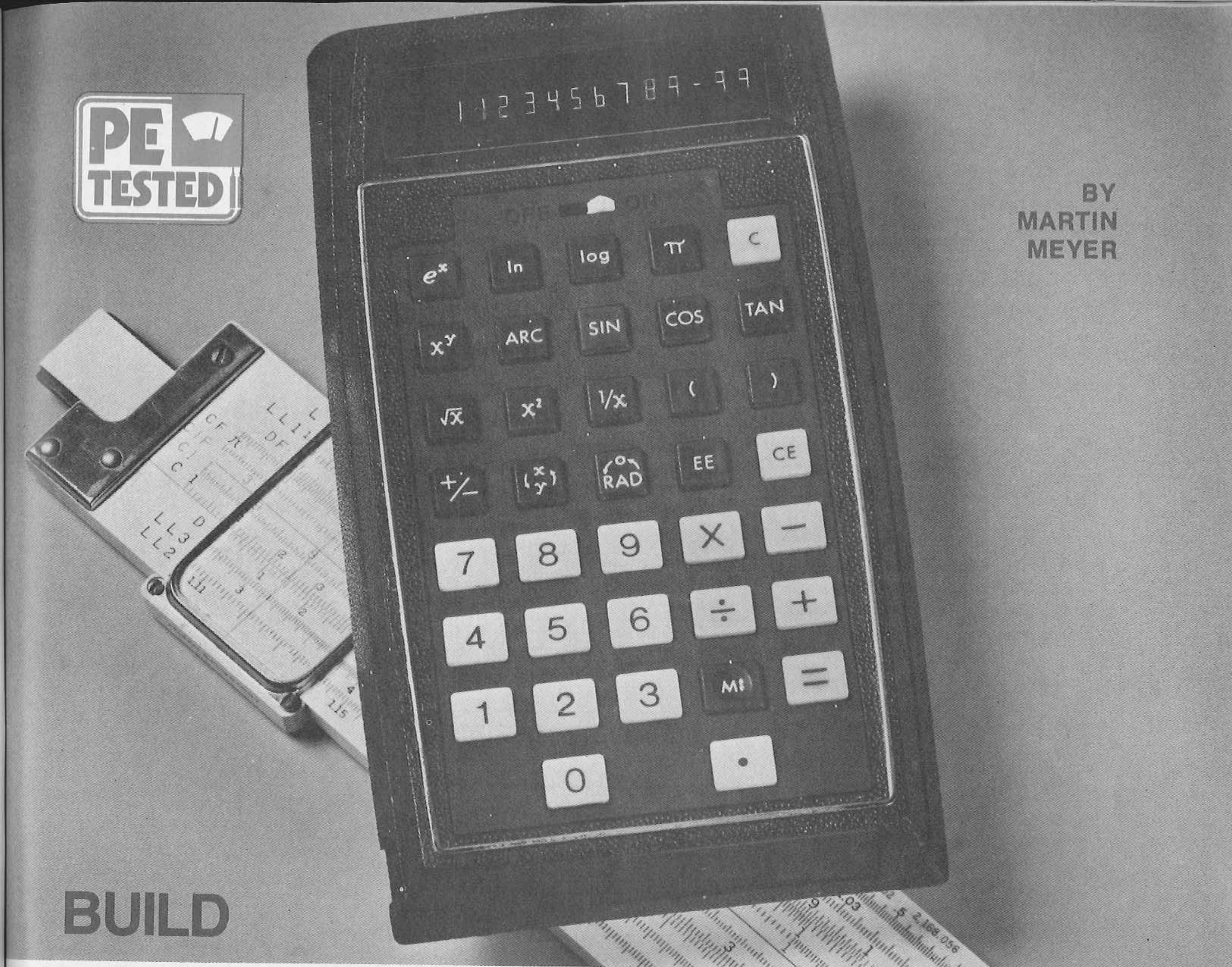


*Fig. 4. Flashtube mounts in enlarged hole in light reflector.*



PE TESTED



BUILD

BY MARTIN MEYER

# An Under-$90 Scientific Calculator

***Ten digits of mantissa with 2-digit exponent and a full range of scientific operations, including double-nested parentheses.***

THE inexpensive four-function calculator is an eminently practical tool for everyday home and primary-school use; however, high-school students, engineering and science majors in college, and practicing engineers and scientists require more sophisticated equipment. Fortunately, there is a new breed of calculators that is rapidly gaining popularity in professional and advanced-student circles. Going by such names as "scientific" and "slide-rule" calculators, they expand by several magnitudes the number of functions and the information-handling capacities of "ordinary" calculators for limited uses.

Scientific calculators may be capable of obtaining *n*th roots and *n*th powers; trigonometric functions (sine, cosine, tangent, etc.); natural and common logarithms; degrees-to-radians conversions; and many other functions. As a general rule, these calculators also feature at least one level of store/retrieve memory, a 10-digit mantissa with two-digit exponent, and separate displays to indicate negative quantities (in both mantissa and exponent) and overflow and disallowed functions.

Most scientific calculators with the capabilities described above sell for $150 or more at this writing. But the POPULAR ELECTRONICS full-function, 200-decade scientific calculator costs only $89.95 in kit form. It is 3⅜" wide, 6" long, and 1½" thick.

**What It Does.** What can you, as an electronics experimenter, do with such a calculator? The answer is, just about anything you want to do in problem solving. For example, suppose you wanted to know the equivalent resistance of a network of three resistors (560 ohms, 390 ohms, and 670 ohms) in parallel. By hand, this problem might take you 10 minutes or more. With the calculator, less than 30 seconds is needed to get the answer (171.1638788.).

Approaching a more difficult prob-

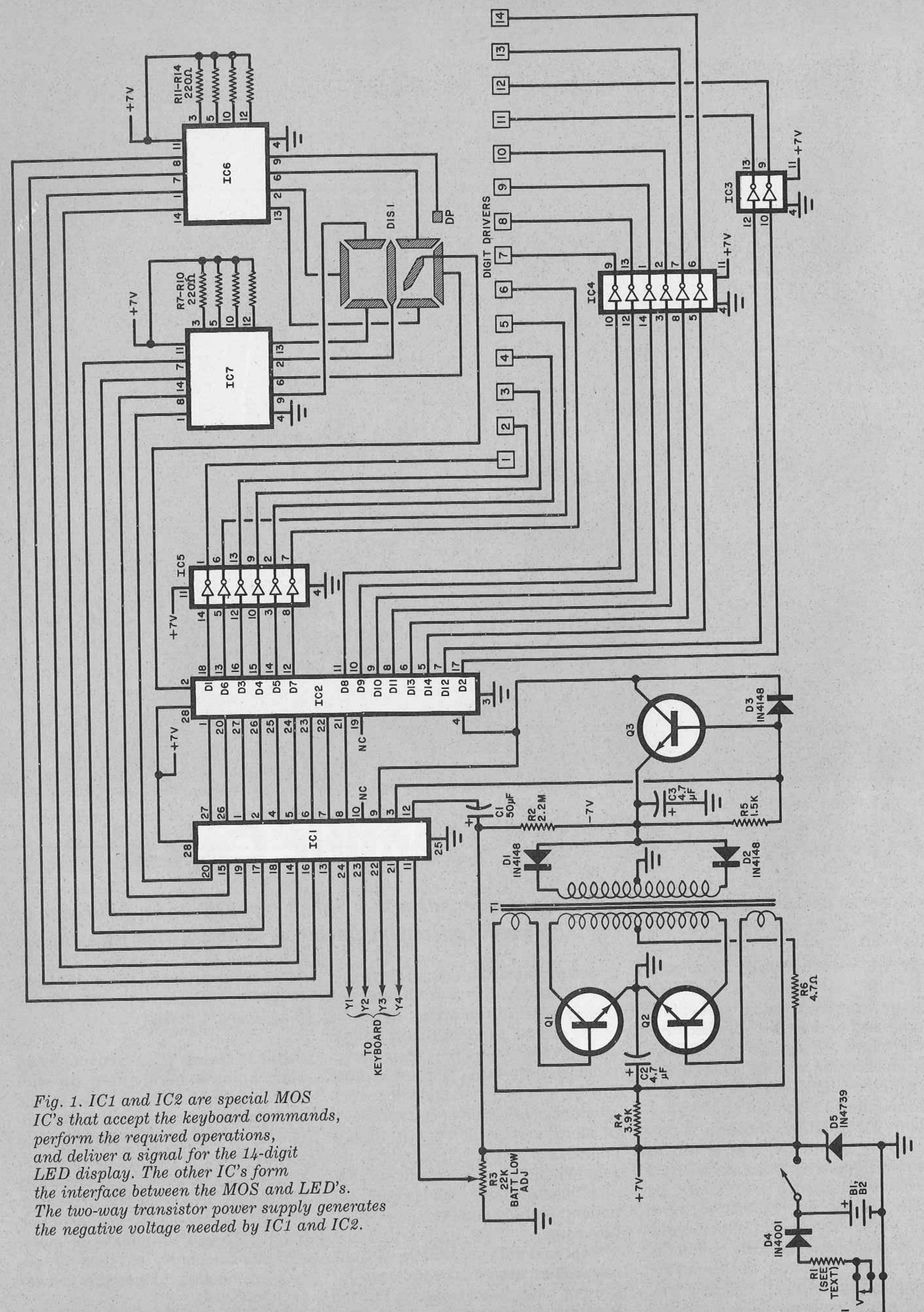



*Fig. 1. IC1 and IC2 are special MOS IC's that accept the keyboard commands, perform the required operations, and deliver a signal for the 14-digit LED display. The other IC's form the interface between the MOS and LED's. The two-way transistor power supply generates the negative voltage needed by IC1 and IC2.*

## PARTS LIST

B1,B2—3.5-volt rechargeable batteries
C1—50-√F, 6-volt electrolytic capacitor
C2,C3—4.7-√F, 10-volt electrolytic capacitor
D1 to D3—1N4148 diode
D4—1N4001 rectifier diode
D5—1N4739 zener diode
DIS1—14-digit light-emitting diode scientific display
IC1,IC2—MOS scientific calculator integrated circuits (see note)
IC3 to IC5—SN75492 hex inverter integrated circuit (Texas Instruments)
IC6,IC7—SN75491 7-segment driver integrated circuit (Texas Instruments)
J1—Subminiature phone jack
Q1 to Q3—2N5232 transistor
R1—Optional charging resistor (value contingent on charging current desired)
R2—2.2-megohm, ¼-watt resistor
R3—22,000-ohm miniature printed circuit potentiometer
R4—3900-ohm, ¼-watt resistor
R5—1500-ohm, ¼-watt resistor
R6—4.7-ohm, ¼-watt resistor
R7 to R14—220-ohm, ¼-watt resistor
T1—Special converter transformer
Misc.—Calculator case; keyboard assembly; recharger; mounting nuts (2); thin insulating washer; Molex Soldercon® printed circuit connectors; fine solder; etc.
Note: The following are available from Network Research Corp., 27 Eagle St., Spring Valley, NY 10977: complete kit of parts including manual, batteries, and ac adapter/recharger for $89.95 (New York residents add sales tax); #N1003 keyboard assembly for $12.00; #N1002 display assembly for $19.50; #N1001 etched and drilled pc board for $5.50; #N1000 MOS scientific calculator IC's for $60 the set; #N1005 transformer for $3; #N1004 interface IC's (5) for $9.50 the set.

lem, suppose you wanted to know the equivalent impedance of a 560-ohm resistor and a 25.5-mH choke at 2500 Hz. The solution, 687.5569736, takes about a minute with the calculator, considerably more time with paper and pencil.

To give you a better idea of how practical the calculator is, you can throw away your logarithm and trigonometry tables. You won't need them again because they are only a few keystrokes away in your calculator—all figured out to an accuracy of nine decimal places. And that goes for π as well. (A more detailed list of the capabilities of this calculator is given in the box.)

The POPULAR ELECTRONICS calculator has built into it two levels of nested parentheses, each of which defines a variable before executing a function command. This permits the problem to be "written" into the calculator exactly as it is written down on paper. When a new parenthetical statement is opened, the previous results and functions are stored in the calculator until that level of parentheses is closed later in the problem. So, a complex problem like

$$x = \sin\left[\frac{1}{1 + \sqrt{(a+b)^2 - (c+d)^2}}\right]^3$$

where a = 4, b = 5, c = 2, and d = 3 can be solved quickly with the aid of the parentheses. The keystroke sequence would be: 1, +, (, (, 4, +, 5, ), $x^2$, −, (, 2, +, 3, ), $x^2$, ), $\sqrt{x}$, =, 1/x, sin, $x^y$, 3, =. When the last keystroke is executed, the display will read the answer, 8.70831579 −09, which means that the mantissa is the number shown raised to the negative ninth power of 10 ($10^{-9}$), which means further that the calculator employed another built-in feature—automatic scientific notation. (The calculator goes automatically to scientific notation whenever the solution is an excessively large or an excessively small number.)

Note that in the above sample problem no memory or external scratchpad was required to find the solution.

**About the Circuit.** The schematic diagram of the complete scientific calculator is shown in Fig. 1. Special MOS integrated circuits *IC1* and *IC2* are the heart of the circuit. They accept keyboard entries, perform all mathematical operations demanded, and deliver a multiplexed output to the driver circuitry for the 14-digit LED display. (The display consists of 10 mantissa digits, two exponent digits, one negative-sign digit for the exponent, and a final digit that combines the disallowed-function, minus-sign, and radian-function notation to the left of the mantissa.)

Buffers *IC3* through *IC5* drive the 14 digit-enable lines, while *IC6* and *IC7* are the segment drivers for the display. Note that all similar segments are driven simultaneously, with the digit selector choosing the correct digit of the moment.

Because the MOS chips require both positive and negative 7 volts dc referenced to common to operate and only a 7-volt battery is used in the calculator, a two-transistor (*Q1/Q2*) dc-to-dc voltage converter is required. In conjunction with *T1*, R4, and *C2*, the Q1/*Q2* circuit forms a push-pull power oscillator. The output of *T1* is rectified by *D1* and *D2*. It is then filtered by *C3* to deliver the −7 volts required. Transistor *Q3* is the power-saver switching regulator, while potentiometer *R3* permits adjustment of the battery's low-voltage cutoff point.

Rectifier diode *D4* converts the ac from the plug-in charger to pulsating dc for charging the two batteries. Zener diode *D5* keeps the voltage from exceeding the approximately 8 volts required for recharging. An optional resistor (*R1*) is used to limit the charging current to a safe level.

**Construction.** There is no practical way of assembling the calculator without the aid of a printed circuit board. Unfortunately, since the board must have conductors on both sides

### FEATURES OF THE POPULAR ELECTRONICS FULL-FUNCTION SCIENTIFIC CALCULATOR

- Basic arithmetic: add, subtract, multiply, divide
- Any positive or negative number between $1.99 \times 10^{-99}$ and $1.99 \times 10^{99}$ can be entered and displayed
- Entry can be in either floating point or scientific notation, with automatic conversion to scientific notation in very large and very small numerical results
- Algebraic problem entry with two levels of parentheses
- 10-digit mantissa with 2-digit exponent numeric display, plus battery-low, minus-sign, radians, disallowed-function, battery saver display.
- Positive/negative sign selection for mantissa and exponent
- Transcendental functions: sin, cos, tan, $\sin^{-1}$, $\cos^{-1}$, $\tan^{-1}$, common log, natural log, $e^x$, $x^y$
- Convenience functions: $\sqrt{x}$, 1/x, $x^2$
- Separate memory register for storage of constants or intermediate results
- Chain calculations with any sequence of functions desired
- Independent system and entry clear
- Trigonometric functions can be performed in either degrees or radians
- Separate ← key with 9 decimal place accuracy
- Automatic display cutoff to conserve battery power
- Rechargeable batteries
- Battery charger that doubles as ac-operated battery eliminator

and the components must be mounted as close to the board's surface as possible, there is no practical way of making this board at home. While you might be able to make the required double-sided board at home with all points properly registered, there is no known method that can be used at home to plate-through the holes. Hence, you will have to purchase the pc board from the supplier listed in the Parts List.

Shown in Fig. 2 is the component-placement guide for the main board assembly. The view is from the component side of the board. (The two sides of the board are readily identifiable because the bottom side on which no components are mounted bears the legend BOTTOM.)

Start assembly by installing and soldering into place the fixed resistors. Then proceed to installing the three electrolytic capacitors, the diodes, and the transistors, taking care to observe proper polarity and basing. Mount the transistors close to the board's surface. Use a fine-pointed soldering tip, thin-strand solder, and a minimum of heat. Frequently clean the soldering tip with a damp rag to remove excessive buildup of solder. This will minimize the possibility of solder bridges between the closely spaced foil conductors. *Do not touch or remove the MOS IC's (IC1 and IC2) from their carriers until instructed to do so.*

If you inspect *T1*, you will note that there are three pins in one of its corners. These pins serve as the installation "key." Install and solder into place the transformer. Potentiometer *R3* mounts in the upper-right corner of the board. Then install *IC3* through *IC7* in their respective locations, carefully observing the notch code. As you proceed, carefully inspect the board for the presence of solder bridges. If you locate a solder bridge, reflow the solder and remove the excess.

Install the two flat (negative) battery contacts as shown. Solder them at both ends and on both sides to the copper conductors. (Note: There are small holes in the board and the battery contacts are dimpled. When properly installed, the contacts are positioned with their dimples engaging the holes.) Install and solder into place the spring-type battery contacts, making sure that the pin-connector side is vertical to the plane of the board. Mount and solder into place jack *J1*.

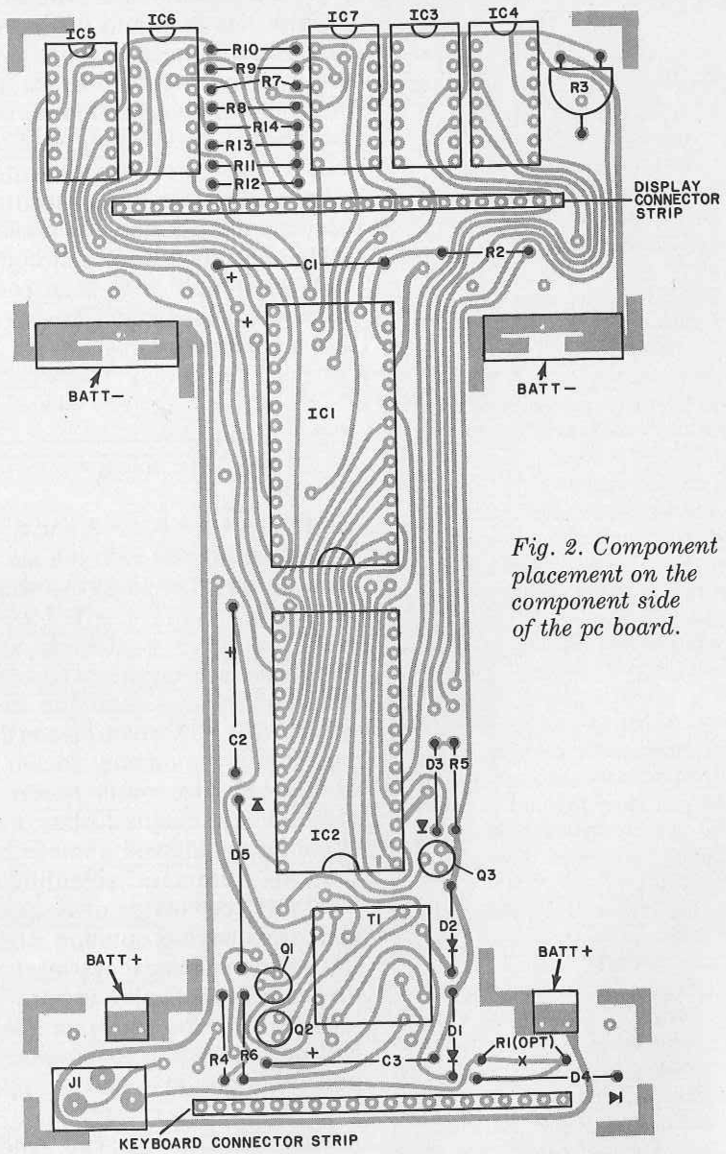



*Fig. 2. Component placement on the component side of the pc board.*

Straighten a strip of 24 Molex Soldercon® connectors but do not remove the connector strip. Force the end pins of the strip through a 2½-in. by ⅛-in. (16- × 3.2-mm) piece of masking tape from the non-adhesive side. Mount the connector strip in the holes just below the five IC's at the top of the board, pressing down to seat the tape firmly against the board's surface. Flip over the board and solder the protruding pins to the copper foil. Be very careful to avoid solder bridges. Flip over the board again and, using long-nose pliers, bend the connector strip back and forth until it parts from the connectors. Be careful to align the connectors properly.

In the same fashion as described above, mount a strip of 20 Soldercon connectors along the lower edge of the board. This time, use a 2-in. (51-mm) length of masking tape. (The upper strip of connectors is for the display interconnect, while the lower is for the keyboard interconnect.)

Straighten four Soldercon strips, each consisting of 14 connectors. Install these in the holes for *IC1* and *IC2*. Then, before breaking away the connector strips, make sure the connectors are straight and that the IC pairs are parallel to each other. Now, before you even consider opening the carrier in which *IC1* and *IC2* are packed, carefully read and become familiar with the procedures for handling MOS devices by reading the instructions given in the box on page 57.

With yourself properly grounded and all conditions for good MOS-device handling met, open the carrier.




With the IC's still in the carrier, determine which is which and the locations of pins 1. Pin 1 is near the small bump on each IC. To be absolutely certain of pin 1 on each IC you can use a small magnifying glass to check the IC leads near where they enter the packages. Only pin 1 in each case has a tiny hole drilled through it.

With the forefinger of the hand you have grounded pressed against the metal plate on top of *IC1* remove the IC from its carrier. Check to make sure its leads are in straight lines. Then carefully install the IC in its appropriate connectors on the board. First engage the pins along one side of the IC in the connectors. Once this is accomplished, work the leads along the other side into their connectors. Apply firm, even pressure to the IC to seat it in its connectors. Do not force the IC into the connectors or subject it to torsional forces or you might misalign or even break off pins. If insertion is difficult, replace the IC in its carrier. Then, insert and remove an old IC in the connectors several times to "form" them. Any DIP IC will do; just make sure to cover all connectors. Now, install the IC from the carrier.

Repeat the above procedure for *IC2*.

The display comes as a completely wired assembly, with its 24 connector pins already mounted in place. Just make sure that the pins are in a straight line. Carefully fit the display-board pins into their respective connectors on the main board. Press the display board into place so that it rests on the five upper IC's with a slight tilt.

The keyboard also comes as a complete assembly, including connector pins. Straighten any out-of-line pins and engage them in the connectors along the lower edge of the main board. Gently seat the keyboard assembly in place until the narrower portions of the upper two plastic posts on the keyboard assembly engage the smaller of the holes above the negative-terminal battery contacts on the main board.

Slide the entire assembly into the top half of the calculator case until the two small plastic tabs on the bottom end of the keyboard engage the molded slots in the case top. At this time, two threaded plastic posts should appear through the holes immediately above the negative battery contacts on the main board, and *J1* should slightly protrude through its slot in the case.

Holding the board assembly in place in the case, secure the two together with small nuts over the threaded posts. (Note: Because of possible interference between nut and close-by foil conductor near the left post, precede the nut here with a thin insulating washer.)

Place the power switch in the OFF position, and tape it in place until the batteries have been installed. The batteries are marked with + and − signs. The + sides are protected by sleevings that extend beyond the bodies of the batteries. The sleevings are notched in such a manner that the batteries will fit into their respective locations in only one way. Slip the batteries into place. This completes construction.

## SAFE HANDLING OF MOS IC'S

Prior to any construction and before removing MOS IC's from their protective carriers, it's imperative that certain precautions be understood and followed:

All insulated-gate MOS devices can be permanently damaged by excessively high electronic fields. Random electrostatic charges *must* be kept away from MOS devices. Anyone who handles the devices should wear anti-static clothing (preferably cotton) and, if possible, cotton gloves. Do *not* wear synthetic fabrics, particularly nylon; they readily build up static charges.

All working surfaces where MOS devices are handled should be conductive and at ground potential. Before handling, you should also be grounded. And avoid dropping MOS devices because of possible contact with charged surfaces or objects.

All apparatus that is to come into contact with MOS devices must be grounded, including your soldering iron's tip. Never insert or remove a MOS device in a powered circuit. When inserting or removing a MOS device, touch the grounded surface only after you have grounded yourself. If possible, ground the conductor pattern around the area where the device is to be installed with conductive tape or aluminum foil during installation and removal. When a good MOS device is removed from a circuit, immediately install it in a protective carrier.

You can ground the tip of your soldering iron by wrapping around its thick portion a copper strap and fastening the strap to a length of meshed cable. The free end of the cable then goes to a good ground. To ground yourself, use a similar procedure. Wrap a length of meshed cable snugly around your working-hand wrist and connect the free end of the cable to a good ground.

**Checkout and Adjustment.** Plug the recharger into *J1* and let the batteries charge for a few hours. Then disconnect the charger. Remove the tape from the power switch and set it to ON. The right-hand mantissa digit and its decimal point should come on, displaying 0. Leave the power applied and, after about a 30-second delay, the 0 and decimal point will blank out, being replaced by a minus sign in the exponent display. This indicates that the battery-saver feature is working.

Press the clear (C) key to restore 0. to the display. Feed in the numbers 1 through 0; operate the +/− and EE (enter exponent) keys; feed in 88; and press the +/− key. The display should now read −1234567890−88. Press the degrees-to-radians key; a small diagonal bar segment should come on to the extreme left of the display. Operate this key again, and the bar should extinguish. Press the C key.

Press the π key. The display should now read 3.141592654. Depress C. Now, with 0. displayed in each case, press log (common logarithm), 1n (natural logarithm), and 1/x (reciprocal). In each case, before depressing C, the disallowed function indicator, an inverted L, should show at the far left of the display.

To adjust battery-low indicator potentiometer *R3*, it is necessary to first fully charge the batteries. Plug the battery charger into *J1* and the ac outlet. With the power switch set to OFF, charge the batteries for about 8 hours. Then use the calculator for about 4 hours. Then, with the power ON, adjust *R3* with a thin-bladed screwdriver through the hole in the bottom of the main board, until the battery-low indicator (an L at the left of the display) comes on.

Install the back of the calculator case by inserting the two bottom "hooks" into their respective slots at the bottom end of the calculator. The top end simply snaps into place. A narrow slot at the top of the case is provided to permit the case to be reopened as desired with a coin or screwdriver blade. Simply twist.

The calculator can be operated from fully charged batteries for about 4 to 5 hours. When the charge runs down, simply plug in the recharger. Recharging takes 8 to 10 hours. The battery charger can also be used as a convenient battery eliminator. However, *under no circumstances should the recharger be used if there are no batteries in the calculator.* ◈