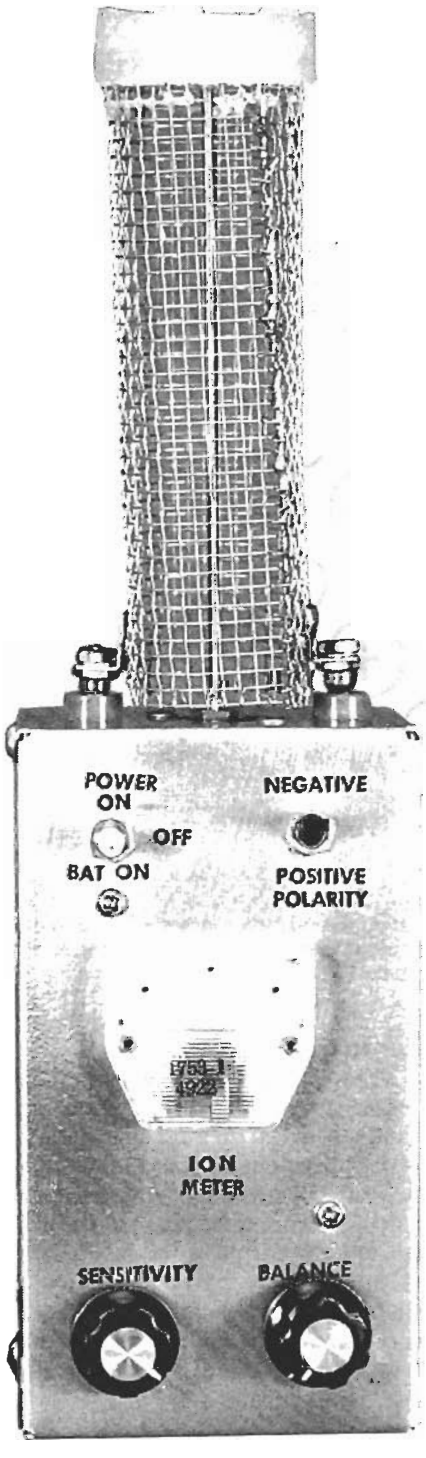
ION METER

Build this ion meter and keep track of the level of ions in your home.

By PETER A. LOVELOCK

A COUPLE OF DECADES AGO, RESEARCH scientists were examining how the population ratio of positive to negative ions in our atmosphere affect human behavior. Many theories were generated—among them, that positive ions cause irritability and erratic behavior, and that negative ions promote well-being. That theory still persists, as can be seen from the numerous products that are marketed to flood your home or office with negative ions.

Because of the interest, the electronics magazines of the time published articles on the properties of ions, how to produce them, and even how to build chambers to measure them. The device in one of the first articles, back in 1969, used a short detector-rod antenna in a cylindrical wire-mesh detector screen. The screen was polarized to plus or minus 60 volts DC, causing ions of the opposite polarity to that of the screen be attracted to it, pass through, and be collected by the detector rod. A special tube was used to amplify the minute voltage induced in the detector rod, which had a 100,000-megohm input impedance. The device used a 1.5-volt battery for the tube filament, a 9-volt battery for the circuit, and a 67-volt battery for the screen.



Circuit description

The schematic of an updated version is shown in Fig. 1. The tube was replaced with a dual-gate RCA 40673 or 40841 MOSFET with both gates tied together as the detector input. The input impedance isn't as high as was the case with the tube, but there's more than enough sensitivity without needing a 100,000-megohm grid resistor; and the gate impedance bleeds off ions without an external resistor. R1 prevents static-voltage buildup on the detector screen in dry weather and instability in M1.

The MOSFET drain feeds a balanced DC bridge using two 2N2222's coupled to M1, a zero-center, ±150-μA meter. Since the MOSFET forms one leg of a bridge, any change in drain current caused by ions at the detector will unbalance it, deflecting M1. Since the device can indicate only relative negative or positive ion levels, the ion meter is balanced for zero, and reads increasing or decreasing levels for the selected polarity; don't interpret M1 as indicating a negative left-hand and positive right-hand scale. Besides filtering the ion type, the detector screen also shields the detector rod from static charge. If the shield is removed, body movements within a couple of feet of the detector rod can make M1 fluctuate, due to static charge that may be present on your clothes.

The ion meter can be powered from either a 9-volt battery, B1, or a 12-volt DC plug-in supply. Whichever supply is in use operates IC1, a 555 which generates a square wave that's fed to a 6-stage ladder multiplier composed of D1–D12 and C1–C14. Each stage acts as a voltage doubler, so the multiplier increases the applied voltage by 2 × 6, or 12. The +5-volt internal supply is boosted to plus or minus 60 volts at the detector screen, whereas using B1 the multiplier generates plus or minus 108 volts DC. The available current is a few microamps, and the output impedance is about 100 megohms, or R1. Also, R1 prevents loading the multiplier, dropping the detector-screen voltage and cutting sensitivity. The voltage polarizes the detector screen, as long as there's no load.

Measuring the multiplier's output voltage is difficult, since most multimeters, despite their high input impedances, will load the output of the ion meter. Typically, a multimeter with 10-megohm input impedance exhibits a false reading of 25–45 volts DC, when using the plug-in supply. The good thing about the very high impedance at the detector is that shorting the plus or minus 60 or 108 volts DC from screen to case won't generate much current, so a short won't damage the circuit. However,

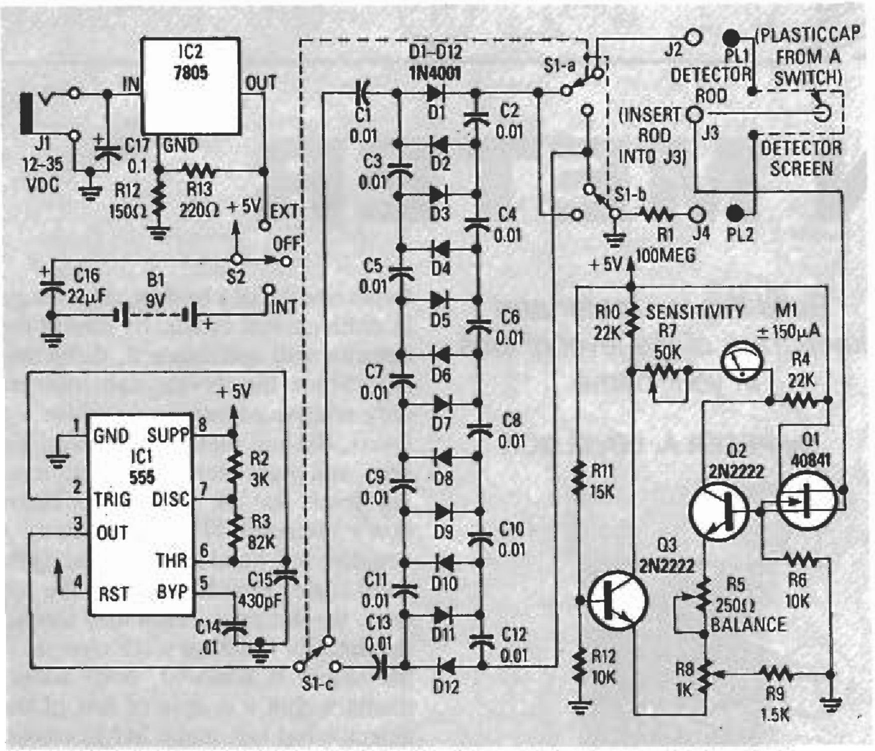


FIG. 1—SCHEMATIC OF THE ION METER; R5 controls the sensitivity of differential amplifier Q2-Q3, and R5 and R8 control the balance. Q1 is a very high input impedance dual-gate MOSFET, and IC1 is a 20-kHz astable feeding a ×12 voltage multiplier composed of D1–D12 and C1–C14.

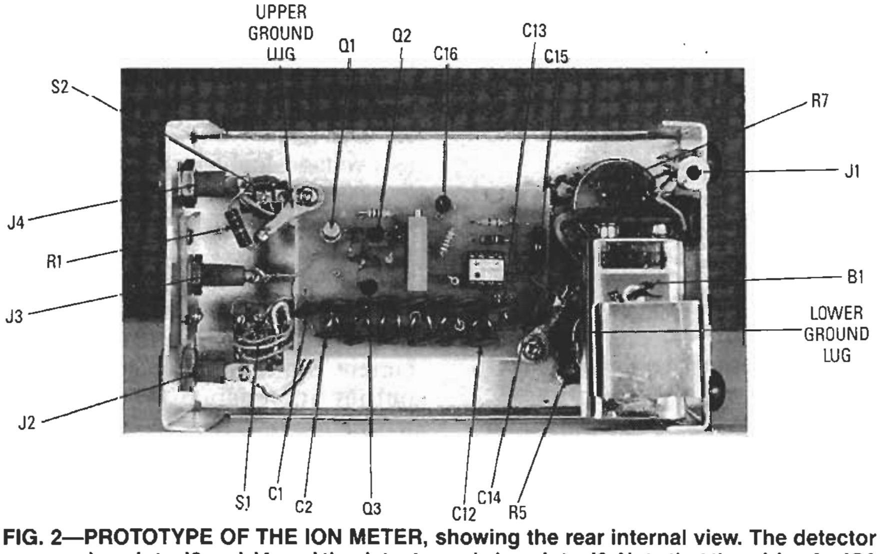


FIG. 2—PROTOTYPE OF THE ION METER, showing the rear internal view. The detector screen plugs into J2 and J4, and the detector rod plugs into J3. Note that the wiring for IC2 is fairly tight, and also that the jumper running under C12 is supposed to be run on the foil side of the PC board.

be very careful, regardless of the low current, when dealing with voltages of that magnitude. Switch S2 reverses the multiplier input-output connections, letting the detector screen voltage be either positive or negative, regardless of whether IC2 or B1 is used as the supply. The ion meter draws 4 mA at 9-volts DC, so a standard 70 mAh, 9-volt battery should be enough to give you 16 hours of continuous use.

Construction

The interior view of ion-meter prototype is shown in Fig. 2. You can build the circuit on a 2 × 3-inch piece of perforated circuit board, or you can etch a PC board using the pattern provided in PC Service. Before you use the foil pattern provided in PC Service, you may have to modify it slightly. Figure 3 points out two jumpers that must be added, and one that must be cut. The PC-board source in

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise indicated.

R1—100 megohms (see text)
R2—3300 ohms
R3—82,000 ohms
R4, R10—22,000 ohms
R5—250-ohm, 2-watt, cabinet-mounted potentiometer
R6, R12—10,000 ohms
R7—50,000-ohm, 2-watt, cabinet-mounted potentiometer
R8—1000-ohm, 15-turn, PC-board-mounted, trimmer potentiometer
R9, R14—150 ohms
R11—15,000 ohms
R13—220 ohms

Capacitors

C1–C14—0.01 μF, 35 volts, disc ceramic
C15—470 pF, 50 volts, disc ceramic
C16—22 μF, 16 volts, tantalum
C17—0.1 μF, 16 volts, tantalum

Semiconductors

D1–D12—1N4001 silicon diode
Q1—RCA 40673 or 40841 dual-gate, P-channel MOSFET
Q2—2N2222 NPN transistor
IC1—555 timer
IC2—7805 5-volt DC regulator

Other components

S1—miniature 3PDT switch
S2—miniature SP3T switch
M1—±150-μA meter with centered needle
PL1, PL2—threaded banana plugs and nuts
J1—miniature monophonic jack
J2, J4—banana jacks without ground lugs
J3—miniature pin jack

Miscellaneous: Chassis box, 5-¼ × 3 × 2-⅛-inches, PC board standoff kit, TO-220-type transistor case insulated mounting kit for IC2, 120 VAC-to-12 VDC plug-in power supply, 4 × 5-inch piece of ⅛-inch grid metal screening, 8-pin DIP socket, two 3-pin transistor sockets, one 4-pin transistor socket, 9-volt battery clip, plastic cover from subminiature switch for detector rod, solder, wire, hardware, etc.

NOTE: The RCA 40763 dual-gate MOSFET is available for $2.00 plus $3.00 shipping and handling from Circuit Specialists, P.O. Box 3047, Scottsdale, AZ 85271-3047, (800) 528-1417 or (602) 966-0764; shipping time is normally about 10 days. The PC board is available from R.R. Assoc., 31066 Glendon, Los Angeles, CA 90034, for $4.50. That includes shipping and handling; California residents add sales tax.

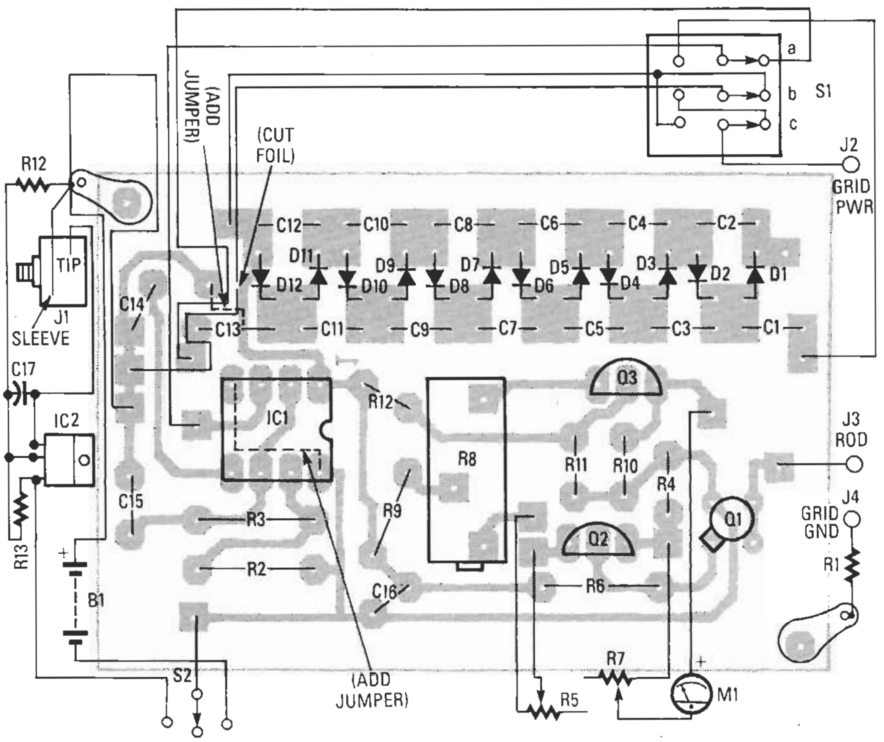


FIG. 3—PARTS-PLACEMENT DIAGRAM of the ion meter. Note the terminals used for J1, and the modifications to the PC board (all they involve is cutting a foil and adding two jumpers).

the Parts List will make every effort to make those changes for you in advance, but be aware of them anyway.

R1 may be hard to find; an alternative is ten ¼- or ⅛-watt, 10-megohm resistors in series. Potentiometer R8 is a 10–15-turn, PC-board-mounted version, while R5 and R7 are the case-mounted variety, and permit easy adjustment of M1. The parts-placement diagram is shown in Fig. 3. Mount the voltage multiplier first, being careful with C1–C13 and D1–D12. A mistake there can reduce detector-screen voltage, or result in no polarizing voltage at all. The resistance from the cathode of D1 to the anode of D12 should be about 300 ohms.

Install IC1 using an 8-pin DIP socket, then R2, R3, and C15. Next R4, R6, R8–R12, R15, and C16 are installed; R4, R10 and R15 are to be vertically mounted. Then, connect M1, R5, R8, S1, S2, and the detector. Leave plenty of extra lead length; you can trim off the surplus when the PC board is installed in the case. Install

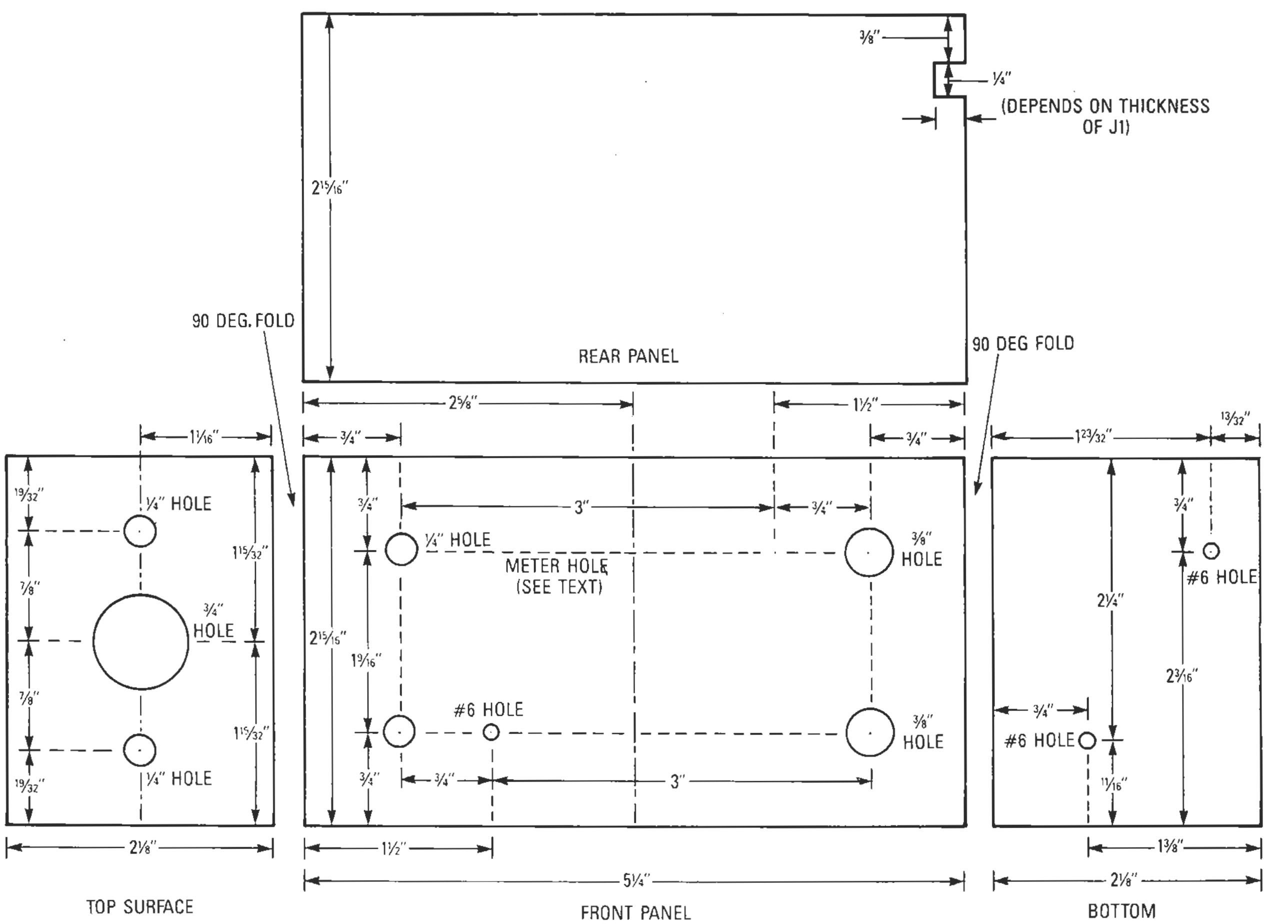


FIG. 4—ION METER CASE LAYOUT, consisting of top surface, front panel, bottom surface, and rear panel. Make sure that everything has been carefully measured before any drilling or cutting.

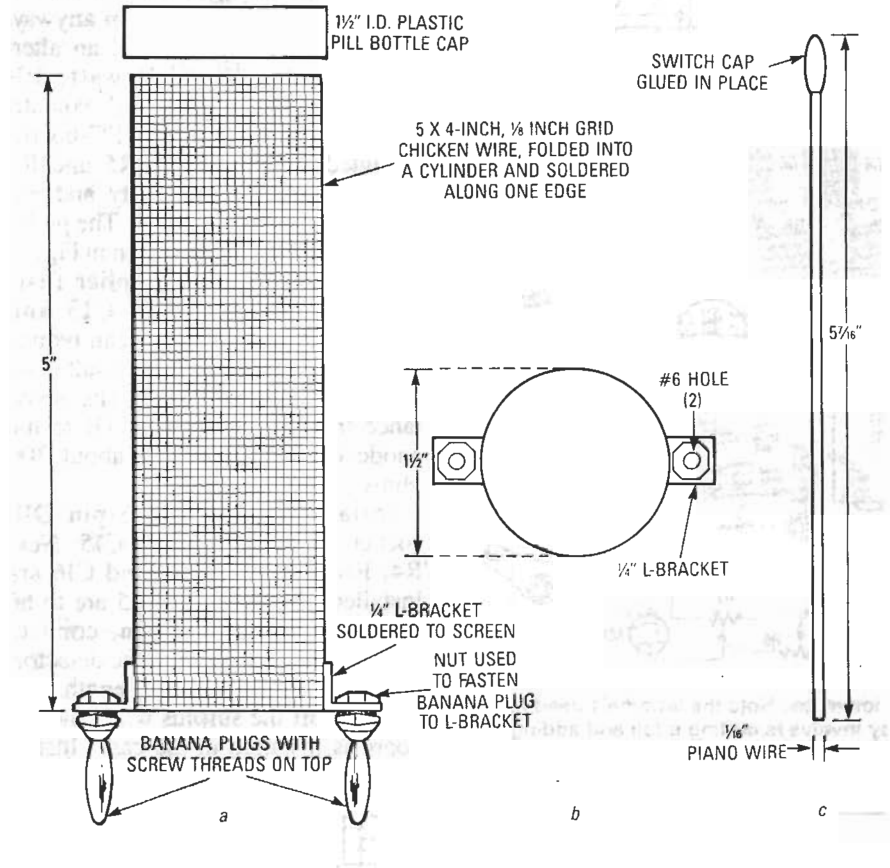


FIG. 5—DETECTOR SCREEN, SHOWING (*a*) the cage with the banana clips, and (*b*) the cap over the top of the cage, made from a 1.25-inch inner-diameter pill bottle cap.

Q1–Q3 with transistor sockets if possible; otherwise, use minimal soldering time and, preferably, a grounded soldering iron for Q1.

The case

All prototype components were mounted in a two-piece, 5-¼ × 3 × 2-⅛-inch box. One half serves as front panel for R5, R7, S1, S2, and M1. The top of that half supports the detector rod and screen as shown in Fig. 2-*a*. Figure 4 is the dimensioned case layout, showing the upper surface, front panel, lower surface, and rear panel. Use a straight-edge and pencil to locate the front-panel holes for S1, S2, R5, and R7, mark with a center punch, and drill. Check the shaft diameter of the parts you plan to use, and adjust the drill sizes accordingly.

The hole for M1 isn't dimensioned since yours may vary from that of the prototype. You'll need a ±150-μA zero-center meter for M1. A surplus FM-radio tuning meter should work nicely. Some meters are "D"-shaped, requiring modification of the hole with a small file, for an easy fit. If yours uses mounting screws, drill additional holes, and mount M1 on the front panel with screws, clips, double-sided adhesive tape, or rubber cement. Apply the latter to both the rear surface of the meter and the front panel, and let it dry. It'll act like contact cement, but you can still pry M1 off.

Drill a #6 hole for the heatsink of IC2 in the bottom surface of the top half of the case, as shown in the lower surface drawing of Fig. 4. For a case other than the one specified in the Parts List, modify the drilling dimensions. You can try a plastic case if you want to, but a metal one might provide better shielding. When all the holes are drilled, don't mount any components until you've applied the lettering using rub-on transfers.

Clean the front panel with steel wool or rubbing alcohol. Cut the lettering with an X-acto knife, hold with tweezers, and position on the front panel; don't mount the knobs, screws, or M1 until you're done. Press the lettering with a fingernail, run a pen over the surface, and lift the backing off with tweezers. Cover with pa-

ing off with tweezers. Cover with pa-
per, and rub firmly with a fingernail for a good bond. Let it dry for a day before applying varnish.

The detector

The detector screen is made from a 4 × 5-inch piece of ⅛-inch metal screening, as shown in Fig. 5. Roll it into a 5-inch long cylinder, hook the ends to form a seam, and solder. Solder small L-brackets with #6 holes to one end, and mount banana plugs PL1 and PL2 with nuts; they plug into J2 and J4. The opposite end of the detector-screen cylinder can be closed with a large plastic pill-bottle cap (1.5-inch inner diameter).

Figure 6 shows the detector-rod in-

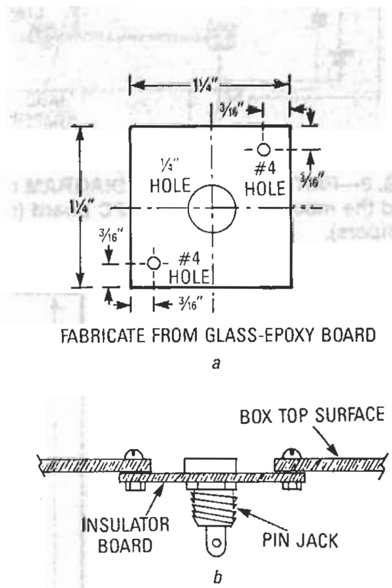


FIG. 6—DETECTOR-ROD INSULATOR BOARD, showing (*a*) physical layout and (*b*) assembly into the case.

sulator board, made from a 1.25- × 1-¼-inch piece of glass phenolic; the detector rod plugs into J3. As shown in Fig. 4-*b*, mark and punch the ¾-inch hole for the detector-rod insulator board. Drill two ¼-inch and two #6 holes as shown. Center the hole for J3 on the ¾-inch hole in the top of the case, and drill two holes in the insulator board through the mounting holes in the top of the case.

Attach the insulator board to the inside of the top of the case with #4 machine screws. Make the detector rod from a 5-⁵⁄₁₆-inch piece of ¹⁄₁₆-inch piano wire, as shown in Fig. 4-*c*. Glue a rubber cap from a small subminiature switch handle on one end as a grip. That'll let you insert and re-

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move the detector rod with ease; it should fit snugly into J3.

Assembly

Mount S2, R5 and R7 on the front panel. Prewire S1 before mounting it, since access after mounting the PC board is difficult. Leave enough lead length to mount the PC board and S1 without strain. Install two metal PC-board standoffs on the back of the front panel, and connect M1 to the PC board. Mount the PC board on the standoffs, and install S1. Use solder lugs between the mounting screws and the PC board as grounds.

Wire the power leads to S2, making sure that the PC board +5-volt DC lead goes to the center terminal. Switch S2 is an SP3T version, so the up position connects to B1, and the down position to IC2. Solder two wires from the PC board to R5, the balance control; the orientation doesn't matter, since that's just a fine adjustment for R8. Solder the positive battery lead to the bottom terminal of S2, and the negative lead to the upper ground lug. Solder two leads to sensitivity-control R7 so that it's shorted when fully clockwise.

Install shoulder washers in the two ¼-inch detector-screen mounting holes and use #6 screws to attach the detector-screen L-brackets. Also, solder one end of R1 to J4, and the other end to the upper PC-board ground lug. If you can't find any shoulder washers to insulate the detector screen from the case, use ¼-inch plastic grommets in the case mounting holes. Attach the 9-volt-battery clip to the left rear of the bottom surface with a ⅛-inch #4 screw.

Mount IC2 in the case hole shown in Fig. 4-*c*, using a TO-220 insulator kit. Solder R13 between the OUT and GND pins. Solder R12 from the IC2 GND pin to the lower PC-board ground lug. Solder the positive side of C17 to the IN pin of IC2, and the other end to the lower ground lug. Solder a wire to the OUT pin of IC2, and the opposite end to the upper terminal of S2. To avoid attaching J1 to the rear of the box and preventing its removal, cement it to the right rear edge. Connect a wire from the "tip" terminal to the IN pin of IC2, and from the "sleeve" terminal to the lower ground lug (see Fig. 3).

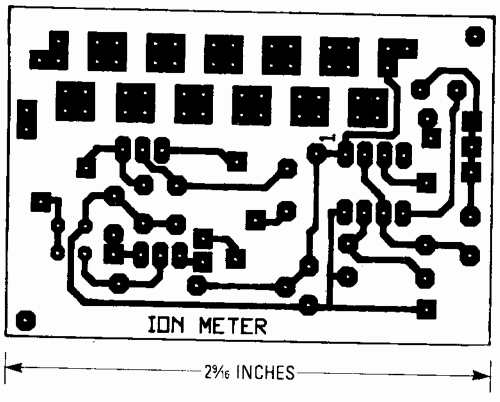
Checkout

Set R7 fully clockwise, R5 to center, S1 to positive, and turn on S2 using either B1 or IC2. With a high-input-impedance multimeter, the voltage from the detector screen to the case should be +35–45 volts DC. Switch S1 to negative, which should give –35–45 volts DC. If no voltage is present, check with an ohmmeter for a short from the detector screen to the case. Check pin 8 of IC1 for 9-volts DC, and pin 3 for 20 kHz. A small AM radio tuned to either end of the broadcast band should pick up harmonics when physically close to IC1.

When you turn the ion meter on, M1 should be nearly centered, and rotating R7 should swing the needle left or right; adjust for full scale either way. Next, adjust R8 until M1 is centered. Repeat until R7 is fully clockwise, and M1 is centered; that represents maximum sensitivity for positive ions. Then, set S1 to negative; M1 should deflect sharply to one side, so reduce sensitivity, rotating R7 counterclockwise until M1 fully deflects. Adjust R8 for center balance with full sensitivity as before; that represents maximum sensitivity for negative ions.

The ratio of negative to positive ions constantly changes. Thus, to balance both positive and negative readings at the center of M1 with full sensitivity is almost impossible. The ion meter reacts only to the immediate ion population.

To balance the ion meter, adjust R7 and R8 until equal readings on each side of zero are obtained for both settings of S1. They may or may not be full scale, but should be adjusted to be within scale using R7. When the ion polarity under observation is changed by switching S1, the detector takes about 20 seconds to stabilize, by bleeding off ions of opposite polarity. A little readjustment of balance vs. sensitivity should let you zero the ion ratio for both polarities, a basic reference level. When adjusted, carry the ion meter rapidly from room to room, and watch M1 swing. **R-E**



ION METER FOIL PATTERN.