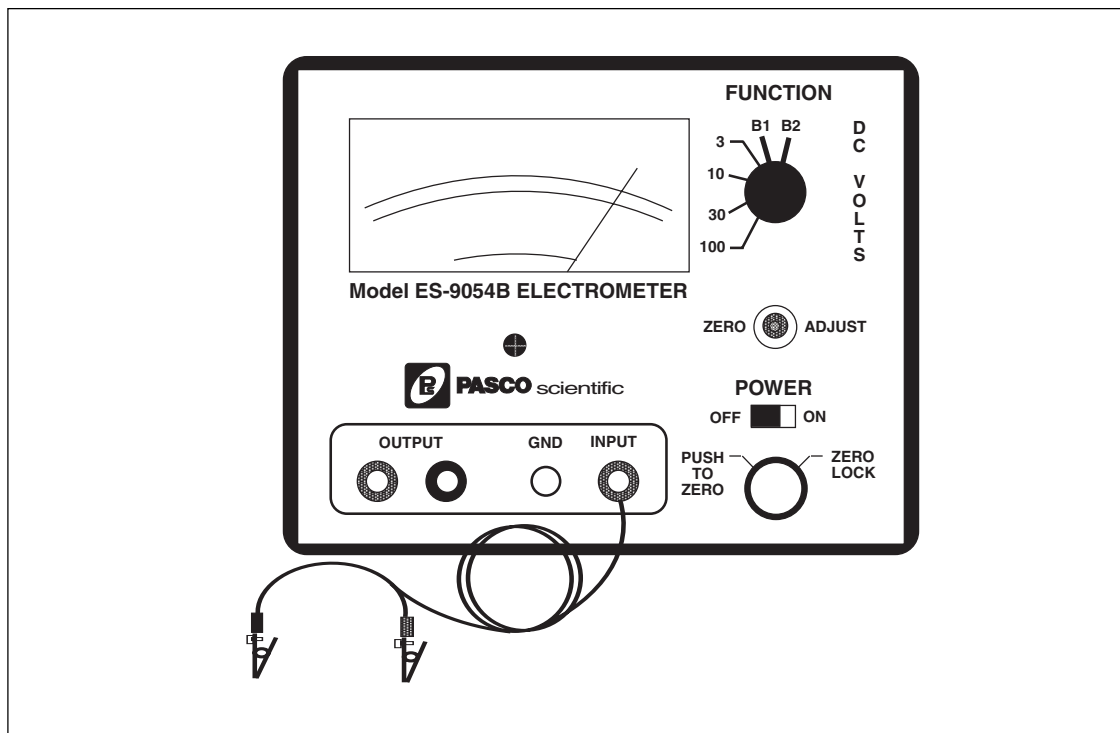


**Instruction Manual and
Experiment Guide for
the PASCO scientific
Model ES-9054B**

012-03175E
3/93

ELECTROMETER



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\$7.50

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Copyright, Warranty, and Equipment Return

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Should the product have to be returned to PASCO scientific for any reason, notify PASCO scientific by letter, phone, or fax BEFORE returning the product. Upon notification, the return authorization and shipping instructions will be promptly issued.

► **NOTE: NO EQUIPMENT WILL BE ACCEPTED FOR RETURN WITHOUT AN AUTHORIZATION FROM PASCO.**

When returning equipment for repair, the units must be packed properly. Carriers will not accept responsibility for damage caused by improper packing. To be certain the unit will not be damaged in shipment, observe the following rules:

- ① The packing carton must be strong enough for the item shipped.
- ② Make certain there are at least two inches of packing material between any point on the apparatus and the inside walls of the carton.
- ③ Make certain that the packing material cannot shift in the box or become compressed, allowing the instrument come in contact with the packing carton.

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Introduction

The Model ES-9054B Electrometer is an infinite impedance ($10^{14} \ \Omega$) voltmeter that can be used for direct measurements of voltage, and indirect measurements of current and charge. Because of its high impedance, it is especially suited for measuring charge in electrostatic experiments. It has a sensitivity nearly 1,000 times that of a standard, gold-leaf electroscope, it has a center-zero meter that directly indicates charge polarity, and it measures charges as low as 10^{-11} coulombs.

With these features, you'll find that your electrostatics demonstrations and labs are easier to perform and, with quantitative data, are more informative as well.

The electrometer is battery powered by two 9 volt batteries, and comes complete with the batteries and a shielded test lead. Instructions for inserting the batteries are at the end of this manual.

Operation

The controls on the front panel of the electrometer are explained in Figure 1. Whether you're using the electrometer to measure voltage, current, or charge, the following procedure should be followed each time you turn on the electrometer. More information on making accurate measurements is given in the sections that follow.

►IMPORTANT:

- ① **Never** use the Electrometer for measuring potentials in excess of 100 volts.
- ② **Never** connect the electrometer to an electrostatic generator such as a Van de Graff generator or a Wimshurst machine.
- ③ **Never** touch the input leads until you have grounded yourself to an earth ground. A person walking across a rug on a cool, dry day can easily pick up a potential of several thousand volts.

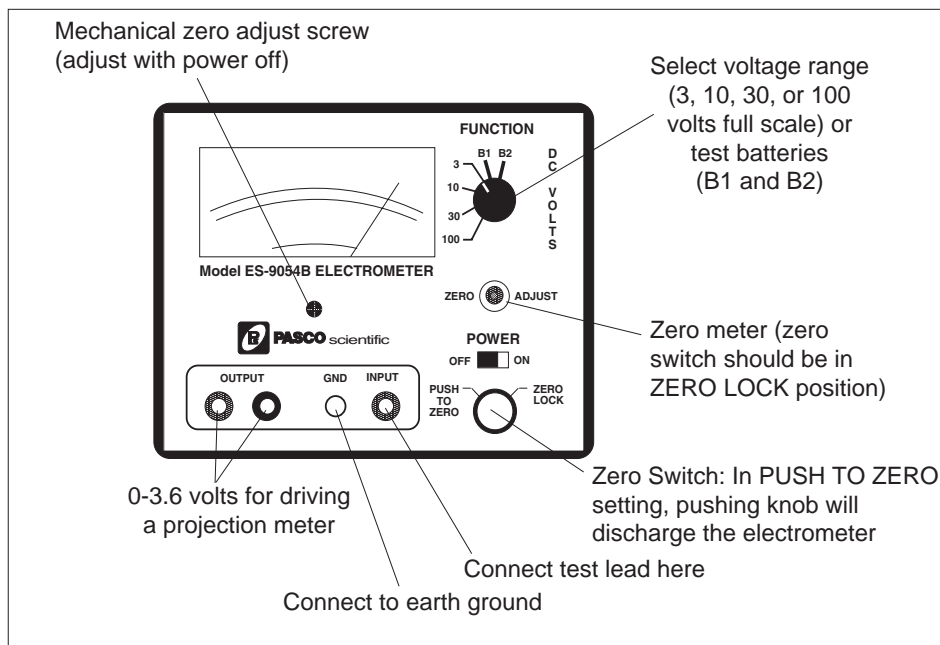


Figure 1 Front Panel Controls

Setup

- ① Before turning on the electrometer, check that the meter reads zero. If not, turn the Mechanical Zero Adjust screw, located just below the meter face, until it does.
- ② Slide the POWER switch to the ON position.
- ③ Check the batteries:
 - a. Turn the FUNCTION switch to B1. The meter pointer should read to the left of the B1 line at the bottom of the meter face. If the pointer falls within the area labeled B1, see the battery replacement section at the end of this manual.
 - b. Turn the FUNCTION switch to B2. The meter pointer should read to the right of the B2 line at the bottom of the meter face. If the pointer falls within the area labeled B2, see the battery replacement section at the end of this manual.
- ④ Zero the meter:
 - a. Turn the FUNCTION switch to 3.
 - b. Turn the Zero Switch to the ZERO LOCK setting.
 - c. Adjust the ZERO ADJUST knob so the meter reads zero volts.
- ⑤ Turn the Zero Switch to the PUSH TO ZERO setting.
- ⑥ Connect the test lead to the INPUT connector of the electrometer.
- ⑦ Connect the GND post of the electrometer to an earth ground.

You're now ready to use the electrometer to measure

charge or voltage. Set the FUNCTION switch to the desired voltage range. The range setting refers to the voltage input required to produce a full-scale meter deflection (e.g., a setting of 30 means that a full scale meter deflection indicates a voltage of 30 volts).

► Important Points for General Operation:

- ① Between measurements, always press the Zero Switch to discharge all current from the electrometer. (The Zero Switch must be in the PUSH TO ZERO setting.) Shorting the test leads together is insufficient. There may still be stray charges within the electrometer circuitry.
- ② When adjusting the zero point of the electrometer, always turn the Zero Switch to the ZERO LOCK position.
- ③ For good results, it is essential that the electrometer be connected to an earth ground (a water pipe or the ground wire from a 120 VAC socket). Only an earth ground provides a sufficient drain for excess charges that may build up during an experiment. It is also helpful if the experimenter is grounded. Just touch one hand to a good earth ground while, or just before, making measurements.

Measuring Charge

Charge measurement with the electrometer is indirect, but simple. It is based on the relationship $Q = CV$, where

Q and V are the charge and voltage across a capacitor and C is the capacitance. The electrometer can be thought of as an infinite impedance voltmeter in parallel with a capacitor, as shown in Figure 2. The capacitor represents the internal capacitance of the

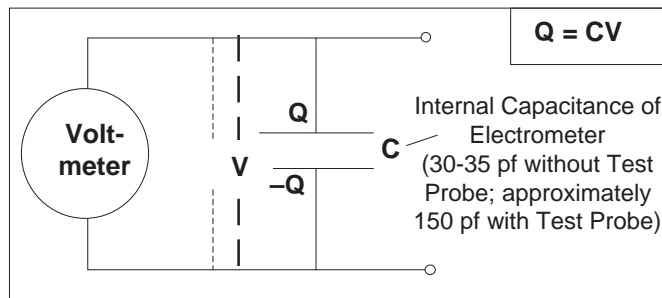


Figure 2 Ideal Schematic of the Electrometer

electrometer, plus the capacitance of the leads.

When a charge is placed across the Electrometer leads, a voltage V will read on the meter. If the value C is known, the value of the charge can be calculated as $Q = CV$. However, when you touch the Electrometer leads to another object to test a charge, the capacitance may change. If the object adds significant capacitance, the situation becomes as shown in Figure 3. The new capacitance ($C + C_{ext}$) must be determined to accurately calculate the charge from the measured voltage.

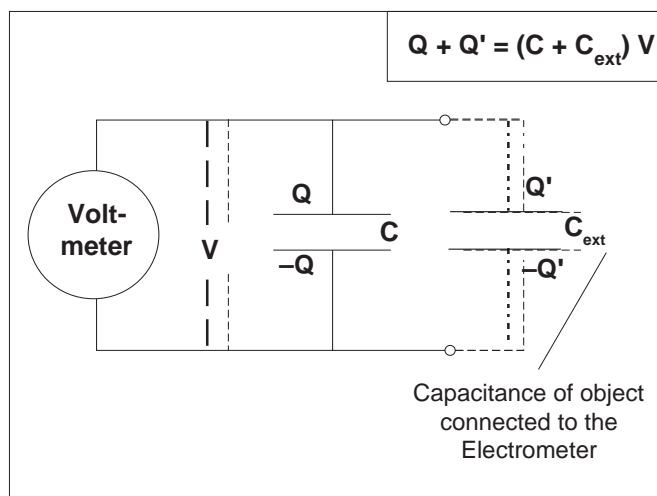


Figure 3 Change in Capacitance Due to Charged Object

Measuring Charge by Induction

Under most conditions, the best way to measure charge is by induction, using a proof plane and a Faraday ice pail such as those included with PASCO's Demonstration Electrostatics System. The proof plane is simply a small conductive disk on an insulating handle. You can make your own ice pail by mounting a conductive cylinder on an insulating support, and placing a larger conductive cylinder around it as a shield. Connect the test lead of the electrometer probe to the inside cylinder, and connect the ground lead to the outside cylinder (see Figure 4).

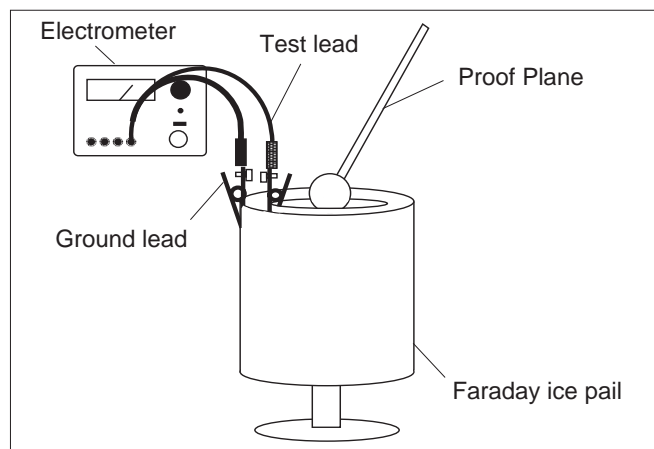


Figure 4 Using a Faraday Ice Pail

To sample the charge distribution on a charged object, simply touch it with the proof plane, then place the proof plane inside the inner cylinder of the ice pail, without touching the cylinder. A charge is induced on the inside cylinder that is equal but opposite to that on the proof plane. You can now read the voltage on the electrometer. By always using the proof plane and the ice pail, the capacitance will be the same for all your measurements and the charge on the proof plane will always be proportional to the voltage reading of the electrometer. However, in experiments for which you want to know the absolute charge on the proof plane, you need to know the total capacitance of the electrometer, plus the test probe, plus the ice pail with the proof plane inside it. Fortunately, this is easily measured, as described below. Once you know the capacitance, you can calculate the absolute charge for any measurement as $Q = CV$.

To measure the total capacitance:

- ① Turn on the Electrometer and zero the meter. Clip the test lead of the probe to the inside cylinder of your ice pail and the ground lead to the outside cylinder (see Figure 4).
- ② Use a DC power supply or a statically charged object to charge your proof plane.
- ③ Place the proof plane inside the inner cylinder of the ice pail and adjust the FUNCTION switch to get a meter reading near full scale. (For convenience, you may want to touch the proof plane to the inside of the ice pail and then remove the proof plane. The effect on the voltage reading should be negligible.) Record the voltage as V_e . Do **not** discharge the Electrometer.
- ④ Take a capacitor of known capacitance, C_k . Ground the leads of the capacitor to be sure it is fully discharged, then connect the capacitor between the inner and outer cylinder of the ice pail. With the proof plane still inside the ice pail, record the meter reading as V_k .
- ⑤ The capacitance of the Electrometer, C_e , can now be calculated as:

$$C_e = C_k V_k / (V_e - V_k).$$

► **EXPLANATION:** This measurement is shown schematically in Figure 3. First the Electrometer is charged with an unknown charge Q , that must satisfy the equation $Q = C_e V_e$, where C_e is the total capacitance of the system and V_e is the Electrometer reading. Then the second capacitor is connected in parallel with the capacitance of the Electrometer. The total capacitance is now $C_e + C_k$. The charge Q has not changed, but now satisfies the equation $Q = (C_e + C_k)V_k$, where V_k is the new Electrometer reading. Combining the two equations gives, $C_e V_e = (C_e + C_k)V_k$, or $C_e = C_k V_k / (V_e - V_k)$.

If you want to use the Electrometer with a different set of test leads, or a different ice pail, or even a different proof plane, the capacitance may be different, and you will need to repeat the above procedure to measure the new capacitance.

► **NOTE:** The capacitance of the Electrometer is 30-35 pf. With the test probe, the total capacitance is approximately 150 pf. For best results, measure the total capacitance.

Measuring Charge by Contact

Charges can also be measured by contact. You'll find, for example, that if you touch the charged proof plane to the

inside cylinder of the ice pail, the Electrometer reading will generally remain relatively unchanged. This is because the total capacitance is only negligibly affected by the proof plane. This may not always be the case, however.

In general, contact measurements can be carried out in much the same way as inductive measurements using the ice pail. Touch the object with the test probe, record the voltage V , and use $Q = CV$ to calculate the charge. However, if you suspect the object for which you are measuring the charge appreciably affects the total capacitance of the system, you will need to remeasure the capacitance as described above.

Measuring Voltage

Voltage can be measured as with any voltmeter.

Connect the leads to the circuit, set the range (3, 10, 30, or 100 volts full scale), and read the voltage on the meter.

Measuring Current

The Electrometer can be used for indirect current measurements in many situations, though it is no substitute for a good ammeter. Connect the Electrometer leads across a known resistance in the circuit and measure the voltage. Use Ohm's law (Voltage = Current x Resistance) to determine the current. The effect of the Electrometer on the circuit will be negligible in most circuits due to its exceedingly high input impedance. However, the voltage drop across the resistor must be within the voltage range of the Electrometer.

If it is not convenient to hook the Electrometer across a known resistance in the circuit, a precision resistor can be connected between the input leads of the Electrometer. The circuit can then be broken, as for connection to a standard ammeter, and connected in series with the precision resistor. Again, measure the voltage across this resistor and calculate the current. (The problem with this technique is that the resistance must be high enough so the voltage drop is easily measured, but low enough so it doesn't significantly affect the current through the circuit.)

Using a Projection Meter

The OUTPUT connectors on the ES-9054B Electrometer provide an output signal for driving a projection meter, oscilloscope, or other monitoring device. The output is proportional to meter deflection (within 10%) with a

± 3.6 VDC output corresponding to a full scale deflection. (The OUTPUT voltage depends only on meter deflection. It is independent of the range setting of the FUNCTION switch.)

PASCO's Model ES-9065 Projection Meter can be used with an overhead projector to display the Electrometer readings for the whole class. The Projection Meter connects directly to the OUTPUT jacks, red to red and black to black.

To calibrate the Projection Meter:

- ① Set the FUNCTION switch to 3, and the Zero Switch to ZERO LOCK.

- ② Turn the ZERO ADJUST knob until the meter on the Electrometer reads as close to full scale as possible (either positive or negative).
- ③ Adjust the CALIBRATE knob on the Projection Meter so that the Projection Meter reads the same as the Electrometer.
- ④ Turn the ZERO ADJUST knob until the Electrometer and the Projection Meter read zero.

Maintenance

Checking Out Your Electrometer

- ① Follow the setup instructions on pages 2-3 of this manual to check the batteries and zero the Electrometer. If the batteries are low, see "Battery Installation." If the meter cannot be zeroed, see "MOS-FET Replacement."
- ② **Calibration Test:** Set the FUNCTION switch to 30 and connect the input to an accurate 30 VDC source. If the meter does not read 30 volts $\pm 5\%$, see "Calibration."
- ③ **Input Impedance Test:** Set the FUNCTION switch to 30 and connect the input to a 30 VDC source. Disconnect the input cable at the front panel input connector. Record the meter reading and the time. If the input impedance is sufficient, it will take 15 minutes or longer for the meter reading to decrease to 30% of its initial value. If the input impedance is low, see "Repairs."
- ④ **Zero Drift Test:** With the meter zeroed, short the leads of the input cable together. Turn the Zero Switch to PUSH TO ZERO and depress the knob, then release it. The meter should read zero volts and should drift by no more than 75 mV/minute. At any time, depressing the Zero Switch should bring the meter immediately back to zero. If the zero drift is excessive, see "Repairs."

► **IMPORTANT:** A zero drift test is best performed after the Electrometer has been left unused with the Zero Switch in the ZERO LOCK position for at least four hours. During use with high voltages, or during battery replacement or other maintenance, charges may be produced on the insulators of the input circuit. The bleeding off of these charges may appear as excessive zero drift.

► **CAUTION:** Whenever you open your Electrometer, do not touch any of the components on the printed circuit board other than the battery holders or the trim potentiometers. The printed circuit contains the high impedance MOS-FET input which can be damaged just by touching the wrong lead.

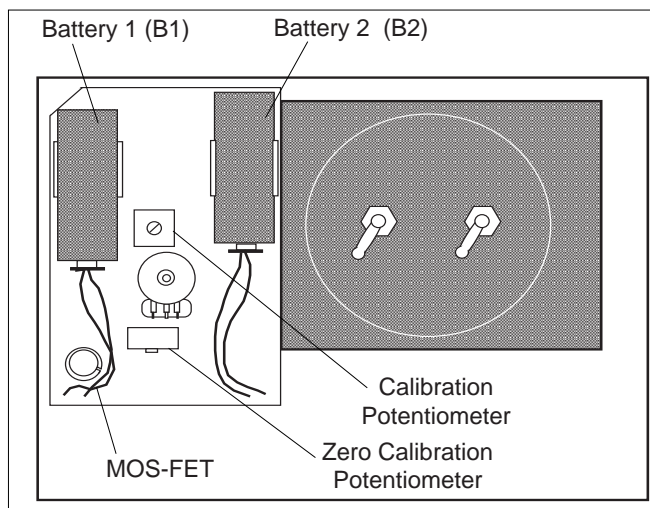


Figure 5 Inside the Electrometer

Battery Installation

To install or replace the batteries, remove the four screws that fasten the front panel to the case, then gently lift the front panel out of the case. Install the batteries as shown in Figure 5. When removing and installing the batteries, be careful not to bend the battery clips or pull the battery wires out of the circuit board. Place the new batteries in the clips with the positive terminal closest to the printed circuit board. Before replacing the front panel, test that the batteries are good and the connections are secure by flipping the FUNCTION switch first to B1 and then to B2. The meter pointer should be deflected out beyond the areas labeled B1 and B2, respectively, at the bottom of the meter face. Replace the front panel.

Calibration

- ① Remove the four screws that fasten the front panel to the case, then gently lift the front panel out of the case.
- ② Turn the POWER switch to ON.
- ③ Set the FUNCTION switch to 3.
- ④ Flip the Zero Switch to ZERO LOCK. With the zero adjust knob midway between its extreme cw and ccw positions, adjust the Zero Calibration Potentiometer to zero the meter.
- ⑤ Set the Function Switch to 30, zero the meter using the zero adjust knob on the front panel, then connect the INPUT of the Electrometer to a known, accurate 30 VDC source.
- ⑥ Flip the Zero Switch to the PUSH TO ZERO setting.
- ⑦ Adjust the Calibration Potentiometer (see Figure 5) until the meter reads 30 volts.
- ⑧ Press the Zero Switch, then release it. The meter should still read 30 volts. If it doesn't, readjust the Calibration Potentiometer until it does.

MOS-FET Replacement

If the meter can't be zeroed using the ZERO ADJUST knob with the Zero Switch set to ZERO LOCK, the MOS-FET has probably failed. (MOS-FET is an acronym for Metal Oxide Semiconductor-Field Effect Transistor). You can order a replacement from PASCO scientific (Part # 422-001). When ordering a replacement part, be sure to include the model number of the Electrometer.

To replace the MOS-FET:

- ① Turn the Electrometer off.
- ② Remove the four corner screws that fasten the front panel to the case, and gently lift out the front panel.
- ③ Gently pull the MOS-FET out of its socket (see Figure 5). Avoid yanking or twisting it, as this may damage the transistor socket.

- ④ The replacement MOS-FET will probably come in an anti-static bag or may be wrapped in aluminum foil. The leads will be protected by a thin ring or spring that is wound around the leads near where they protrude from the base of the transistor. Gently remove the MOS-FET from the bag or foil, but do not remove the thin wire ring that is around the leads. Leave this wire ring in place until after the MOS-FET is seated in the socket.
- ⑤ The MOS-FET has a small metal tab protruding from one side (see Figure 6). The lead directly below the tab (as seen from the top side of the transistor) is lead number 8. Count back to lead number 5, as shown, and gently bend the lead up.
- ⑥ Insert the leads of the MOS-FET, except for lead 5, into the socket so that the metal tab lines up with the notch on the side of the socket as shown in the figure.
- ⑦ Insert lead number 5 into the socket that is connected to the adjacent binding post. This may be done by inserting the lead through the slot in the end of the socket, and then bending the end of the lead back and crimping it tightly. Now gently pull off the thin ring of wire that is wound around the leads. This may require thin nose pliers or "tweezers".
- ⑧ Replace the cover.

Repair

Should your Electrometer have problems that are not covered in the preceding sections, we strongly suggest you return it to PASCO scientific for repair.

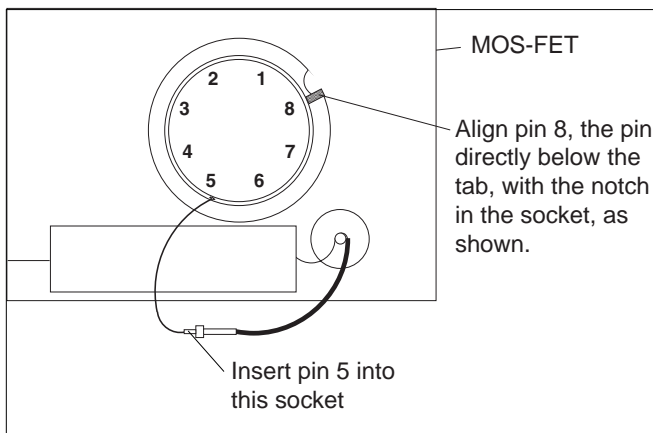
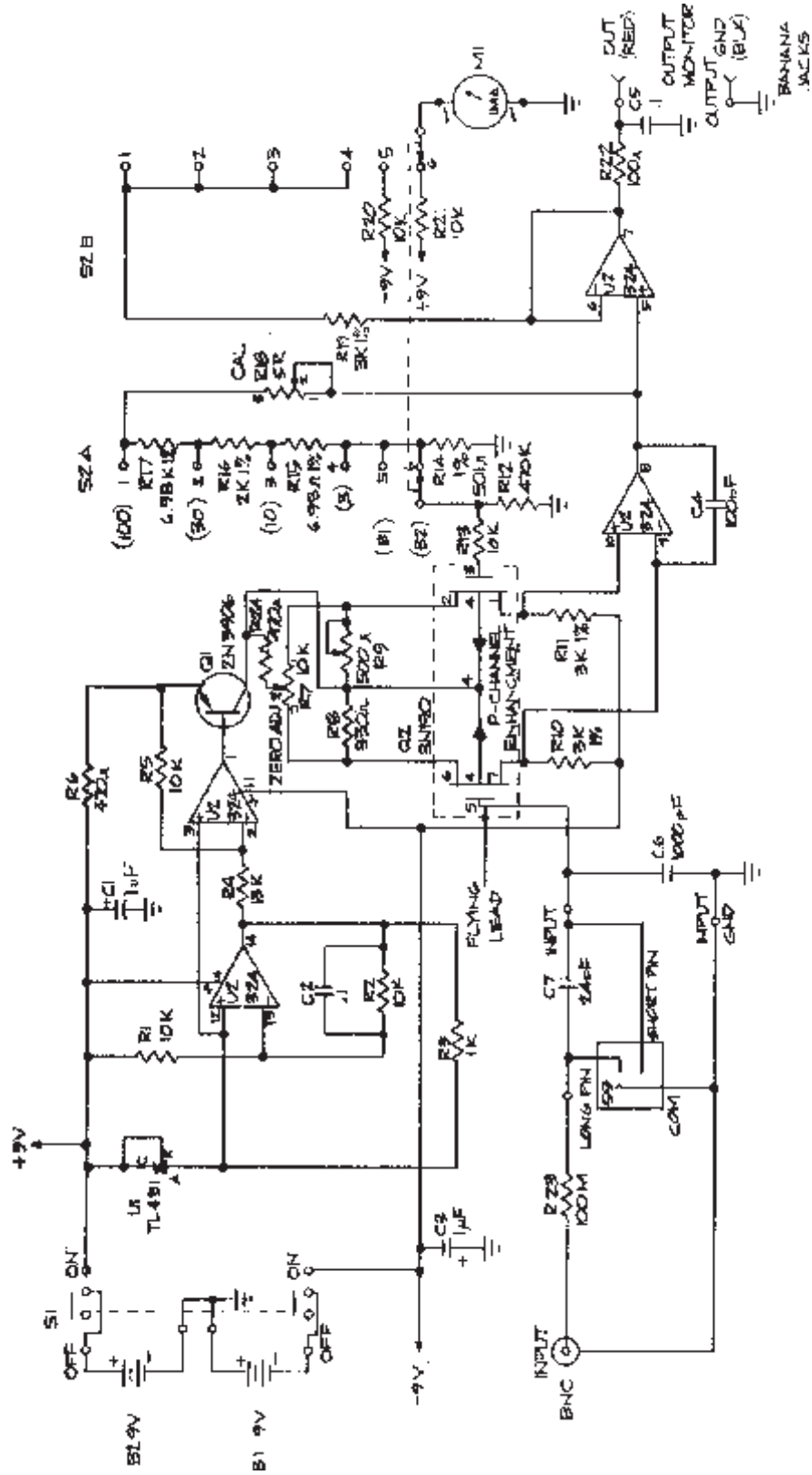


Figure 6 MOS-FET Installation



SCHEMATIC
Model ES-9054B Electrometer
(Drawing #956-02859)

Parts List

Reference	Description	PASCO Part #
R1,2,5,13, 20,21	Resistor, 10 k Ω , 1/4 W, 5%	113-103
R3	Resistor, 1 k Ω , 1/4 W, 5%	113-102
R4	Resistor, 13 k Ω , 1/4 W, 5%, C.C.	113-133
R6,24	Resistor, 470 Ω , 1/4 W, 5%	113-471
R7	Potentiometer, 10 k Ω , 1/4 W, 30%	140-006
R8	Resistor, 330 Ω , 1/4 W, 5%	113-331
R9	Trimpot, 500 Ω	142-031
R10,11,19	Resistor, 3.01 k Ω , 1/8 W, 1%, MF	124-007
R12	Resistor, 470 k Ω , 1/4 W, 5%	113-474
R14	Resistor, 301 Ω , 1/8 W, 1%	124-004
R15	Resistor, 698 Ω , 1/8 W, 1%, MF	124-005
R16	Resistor, 2 k Ω , 1/8 W, 1%, MF	124-006
R17	Resistor, 6.98 k Ω , 6.81 k Ω , 1/8 W, 1%	124-008
R18	Potentiometer, 5 k Ω , 10%	142-018
R22	Resistor, 100 Ω , 1/4 W, 5%	113-101
R23	Resistor, 100 M Ω , 1/2 W, 20%	150-007
C1,3	Capacitor, 1.0 μ f, 10%, 35 V, Axial	220-004
C2,5	Capacitor, 0.1 μ f, 25 V, Monolithic	210-018
C4	Capacitor, 100 pf	210-014
C6	Capacitor, 0.001 μ f, 5%, 600 V	216-013
C7	Capacitor, 24 pf, 5%, 600 V	216-003
Q1	Transistor—2N3906	420-003
Q2	Transistor—MOS-FET 3N190	422-001
U1	IC—TL431 Voltage Regulator	430-083
U2	IC—LM324N	430-027
S1	Switch—Slide, 2 Pole, 2 Position	512-007
S2	Switch—2 Pole, 6 Position, Rotary	510-019
M1	Meter	525-00682

Technical Support

Feedback

If you have any comments about the product or manual, please let us know. If you have any suggestions on alternate experiments or find a problem in the manual, please tell us. PASCO appreciates any customer feedback. Your input helps us evaluate and improve our product.

To Reach PASCO

For technical support, call us at 1-800-772-8700 (toll-free within the U.S.) or (916) 786-3800.

fax: (916) 786-3292

e-mail: techsupp@pasco.com

web: www.pasco.com

Contacting Technical Support

Before you call the PASCO Technical Support staff, it would be helpful to prepare the following information:

- ▶ If your problem is with the PASCO apparatus, note:
 - Title and model number (usually listed on the label);
 - Approximate age of apparatus;
 - A detailed description of the problem/sequence of events (in case you can't call PASCO right away, you won't lose valuable data);
 - If possible, have the apparatus within reach when calling to facilitate description of individual parts.
- ▶ If your problem relates to the instruction manual, note:
 - Part number and revision (listed by month and year on the front cover);
 - Have the manual at hand to discuss your questions.

