experimenter's dual electroscope

Easy-to-build unit measures electrostatic charges; both negative and positive

By ESTEN MOEN

THE electroscope is a tool, but it has become as obsolete as the stone axe of the paleolithic era. Yet surprisingly, the one described here is an educational novelty that gives convincing proof that the face of an ordinary TV receiver does carry an electrostatic charge.

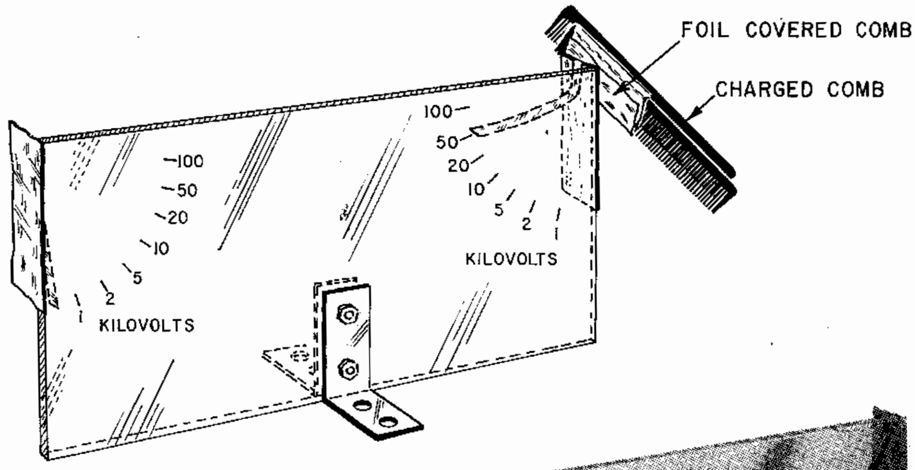
The instrument is shown in the diagram. It is a 6 x 8-inch piece of polystyrene plastic clamped between two right-angle metal brackets. In each upper corner a 2-inch metallic plate is cemented to the plastic. The plate is a piece of foil from a package of cigarettes, placed so the foil sides face each other.

The "gold leaf" or swinging vane is a strip of aluminum foil which is lifted off the cigarette wrapper. They are 2 inches long and ½-inch wide. Dip the wrapper in hot water for about 10 minutes to simplify the job and lessen the chance of tearing the foil. This strip is fastened to the foil plate with a small piece of cellulose tape. As you can see, a very rough kilovolt scale is marked on the plastic for each swinging vane.

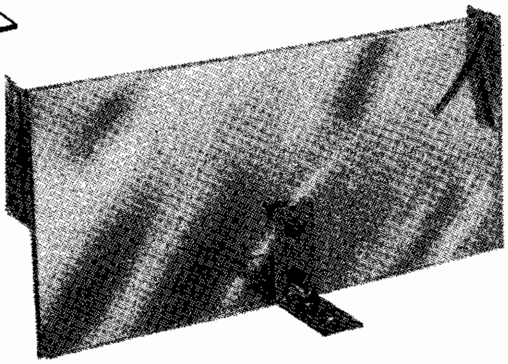
To charge the electroscope, you will need two pocket combs. Cover about an inch of the end of one comb with foil. The foil-covered comb becomes the "charge splitter," the other carries the "inducing charge."

Flick the inducing comb once through dry hair and, holding it close to the charge splitter, touch the charge splitter to the foil that contacts one of the electroscope vanes. The vane is now negatively charged. Then take the combs away and separate them. Next, take the charge splitter and touch it to the foil on the other side of the dual electroscope. You have just put a positive charge on that vane.

For proof of the polarities, set the instrument about 6 or 8 inches from your TV set screen. Turn the receiver on and, as soon as it warms up, the electroscope leaves will swing in opposite directions. Varying the brightness will cause a small swing in each leaf's position. It makes a good demonstration of some facts to which we often pay little attention. END



Charging the electroscope.



Instrument constructed by I. Queen of the Radio-Electronics staff.

A Science Fair Project for Your Youngster:

THE ELECTRONIC ELECTROSCOPE

Indicates when strong electrostatic field exists

BY KEITH KUNDE

PRIOR to 1792 and Allesandro Volta's development of the chemical battery, nearly all electrical experimentation and research involved static electricity. Such static charges are generated on many nonconducting materials through friction with a complementary material, with combinations such as glass and silk, sealing wax and wool, and solidified sulfur rubbed by hand, leading the way in early experiments. Of course, the early experimenters had no means for directly measuring their static charges, but they did observe the forces of attraction and repulsion produced by charged objects. These observations led to the introduction late in the 16th century of the earliest form of electroscope by William Gilbert, who used a pivoting metal pointer to demonstrate the presence of static charges.

Another early form of electroscope used small balls of pith or cork suspended by fine insulating threads so that the forces of attraction and repulsion could be observed through the motions of the charged balls. In 1787, Abraham Bennet invented what became the most familiar form of the device—The Gold-Leaf Electroscope, which consisted of a small brass box having glass windows on two opposing sides, inside of which two strips of very thin gold leaf were suspended face-to-face from a metal rod. The rod passed through a cork in the top of the box and was terminated with a brass disk on its outer end.

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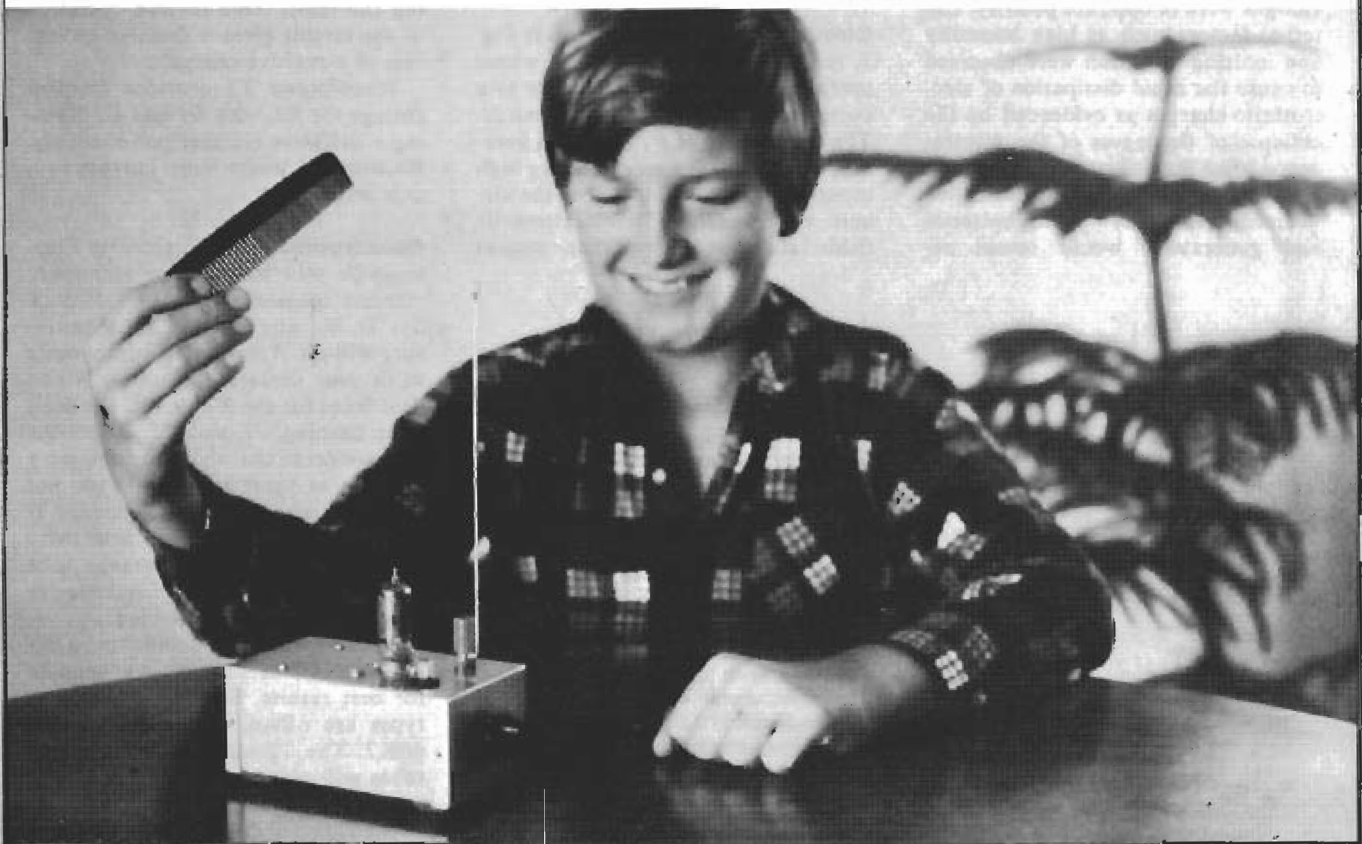


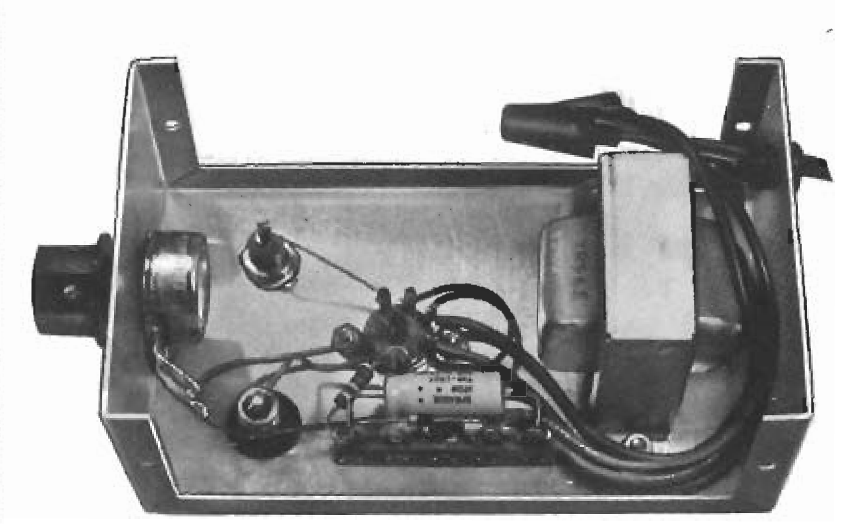


Photo showing how the author assembled his prototype of the electronic electroscope on an aluminum chassis.

induced on the leaves of the electroscope. Since like charges repel, the equally charged gold leaves would repel each other and move apart, with the degree of divergence a function of the strength of the charge. The polarity of a charge could be determined by bringing another charged object near the disk. If the leaves remained diverged, both charges were of the same polarity. However, if the leaves collapsed and then diverged again, the charges were of opposite polarity. External factors such as high humidity and ionizing radiation were observed to cause the rapid dissipation of electrostatic charges as evidenced by the collapse of the leaves of the electroscope when these factors were present.

Later experiments, with so-called "current electricity" from batteries and generators, would reveal responses by the electroscope similar to those produced with static electricity. Eventually, the brass enclosure originally used by Bennet was supplanted by a simple glass jar or flask, and the fragile gold leaves found substitutes in thin foils of tin or aluminum. Since the price of gold prohibits the duplication of the gold-leaf electroscope, we can turn to vacuum-tube technology to create an electronic counterpart of the static electricity detector.

Circuit Operation. As shown in Fig. 1, remote cut-off pentode, *V1*, whose operating bias is set by *R2*, acts as a switch connected across neon lamp *I1*. The control grid of *V1* (pin 1) is floating, thus producing an extremely high input impedance. This makes the circuit very sensitive to electrostatic fields such as those that appear around objects charged with static electricity. These fields are then picked up by a "sense antenna" connected to the control grid.

When the control grid is not under the influence of an electrostatic field, it has little affect on the flow of current through *V1*, thus the tube conducts. The degree of conduction is determined by the setting of bias potentiometer *R2*. When *V1* conducts heavily, it reduces the voltage across *I1*, forcing the lamp to turn off.

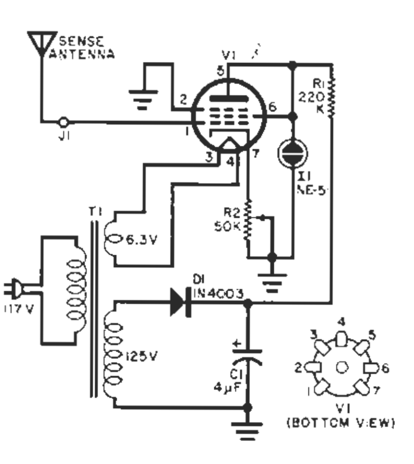
If a negative voltage is induced on the control grid by an external negative electrostatic field, *V1*'s conduction is reduced thus allowing more voltage to reach the lamp so that it glows brightly. Since only a small voltage swing on the control grid is required to control the tube, the circuit is quite sensitive. (Note: Although the neon lamp requires about 65 volts to strike, it will remain glowing until the voltage across it falls to less than approximately 50 volts.) The relatively high resistance of *R1* reduces the hysteresis of the circuit, which improves circuit sensitivity.

To detect a positive charge, *R2* is set near maximum resistance. This reduces the shunting affect of *V1* (which is still conducting somewhat) and allows *I1* to glow. When a positive charge is induced on the control grid, *V1*'s conduction increases, dropping the voltage across *I1* and extinguishing the lamp. This reverse operation of the circuit gives a decisive indication of a positive charge.

Transformer *T1* provides filament voltage for *V1*, with *D1* and *C1* forming a halfwave rectifier power supply. Resistor *R1* limits lamp current to a safe level.

Construction. The Electronic Electroscope was built in an aluminum minibox measuring 5¼"L X 3"W X 2⅛"D, but any suitable metal enclosure will do. Arrange the components to fit your enclosure, then mark and drill holes for the *V1* socket, the neon lamp bushing, *J1*, and *R2*. Orient the tube socket so that the lead from pin 1 to *J1* is as short as possible (do not route this wire close to the chassis). If you want the ultimate in sensitivity and low leakage, use a ceramic tube socket and feed-through insulator for the sense antenna connection.

Vacuum tube *V1* should be a remote cut-off or variable-mu pentode for best results. Some representative types are 6BA6, 6BD6, 6SG7, and 6SK7. The 12-volt versions of these tubes will also work if a transformer with a 12.6-volt filament winding is



PARTS LIST

C1—4-µF, 200-V electrolytic
D1—1N4003 or similar rectifier
I1—NE-51 or NE-2 neon lamp
J1—5-way insulated binding post (see text)
R1—220-kΩ, ½-W resistor
R2—50-kΩ linear-taper potentiometer
T1—125-V, 15-mA; 6.3-V, 0.6-A transformer (Stancor PS-8415, Triad R54X, or similar)
V1—6BA6 or 6BD6 (see text)
Misc.—7-pin tube socket, line cord, terminal strip, knob for R2, neon-lamp rubber grommet, metal enclosure (LMB 780, Radio Shack 270-238, or similar), rubber feet, wire, mounting hardware.

Fig 1. The circuit uses a variable-mu pentode whose operating bias is set to make the control grid extremely sensitive.

used. The tube socket connections shown in the schematic are for types 6BA6 or 6BD6 or their 12-volt equivalents. Refer to any vacuum-tube manual for information on alternative tube types.

Mount the neon lamp in a snugfitting rubber grommet. Connections to the lamp are made by soldering directly to the base shell or leads, as appropriate. Neon lamp types other than those called out in the parts list can also be used; but they will probably require an adjustment in the value of *R1*. As a starting point, make *R1* equal to the resistor recommended for operation of the lamp on 115 V ac. This information is usually shown in the catalogs. Also, *R1* may have to be adjusted if a transformer supplying other than 125 volts rms is used.

Diode *D1* and capacitor *C1* must both have voltage ratings of at least one and one-half times the transformer rms voltage. Mount them on a terminal strip near the tube socket, being sure to observe correct polarity.

No power switch was felt to be necessary so the line cord was connected directly to the transformer primary leads. You may choose to leave the transformer leads uncut in case you want to use it again.

The sense antenna can be made of a piece of stiff wire about 8″ long. This length has good sensitivity and permits fast response to electrostatic fields. Form the end of the wire into a loop to remove any possible hazard. Longer antennas, or a metal plate mounted just above the chassis, will store a charge for a longer time than a short wire. However, this slows down the response time (which of course, may be desirable).

Operation. Turn the power on and allow the tube to warm up. The neon lamp should light immediately, but it may go out as the tube begins to conduct. Rotating *R2* throughout its range should cause the lamp to turn on and off as you adjust the control. If the neon lamp remains glowing at all settings of *R2*, you may be carrying a static charge caused by rising from a chair or from walking about the room. This may be verified by stepping a few feet away from the sense antenna. If the lamp persists in remaining lighted, try reversing the line cord plug in the socket or connecting the metal chassis to a good earth ground. If the lamp still cannot be controlled by *R2*, increase the resistance of *R1*. When the circuit is operating properly, the lamp will light when *R2* is set toward the high-resistance end of its range and it will go out as *R2* is adjusted downward.

Set *R2* just below the point where the lamp lights. This is the most sensitive position for detecting negative static charges. Pass a plastic comb through your hair and bring it near the sense antenna. The lamp should light, possibly while the comb is still several feet away. If you continue to approach the antenna, the lamp will get brighter, but avoid actually touching the antenna with the comb. Although contact with the antenna does no harm, it may take several minutes for the charge to dissipate from the grid circuit. If this happens, normal operation may be quickly restored by momentarily grounding the antenna to the chassis. Do not touch the antenna with your hands, as you may only add to the charge. Instead, connect a wire to the chassis and touch the antenna with the other end of the wire for a second or two. The circuit should now operate normally again. Alternatively, a 15- or 20-megohm resistor can be connected permanently from the sense antenna to chassis ground allowing rapid dissipation of heavy charges. To experiment with positive electrostatic charges, adjust *R2* just above where the lamp first lights.

A good way to get a positive charge is to vigorously rub a glass rod (or any clean glass object) with a silk cloth. Bring the glass near the Electronic Electroscope and the lamp will go out. Note that, because a positive charge causes grid current to flow in *V1*, the grid impedance is much lower and it will be difficult to keep the lamp turned off using the charge stored on the sense wire. If you want to store a charge for a longer period, try connecting a good-quality capacitor from the antenna to the chassis ground. Polystyrene or mica capacitors have low leakage and should give good results. You can experiment with different values to get the results you want. Of course, the traditional Leyden Jar Capacitor often employed in experiments with static electricity can also be used, but avoid connecting heavily charged capacitors.

If you work with MOS-type semiconductors, or if you are troubled by static sparks zapping your personal computer when you touch it, this gadget can give a warning that you are carrying a static charge. Set the unit up to detect negative charges for this application. Your family and friends will also find it amusing to see who can turn on the lamp at the greatest distance or to test various materials for their static properties. ◇