by Shawn Carlson

Counting Atmospheric Ions

Replenished by the thousands of thunderstorms that constantly pummel our planet, the earth's electric charge produces an electric field that is typically around 100 volts per meter of elevation and that can surge to thousands of volts per meter when a thundercloud rolls overhead. In my July column I explained how to measure these fields with a delightful instrument called a field mill. I also mentioned that we would all be electrocuted instantly were it not for the fact that the atmosphere contains very little free charge (ions and unattached electrons), and so these large fields simply cannot generate dangerous currents. In this issue I thought I would show you how to measure the density of these charges.

Every fraction of a second, cosmic rays strip electrons from some of the normally neutral molecules in our atmosphere. Ionization is also triggered by ultraviolet light, fires and the radioactive decay of certain elements. These processes leave some air molecules positively charged while simultaneously creating a diffuse mist of electrons, some of which are picked up by other atoms. The atmosphere thus contains both positively and negatively charged ions.

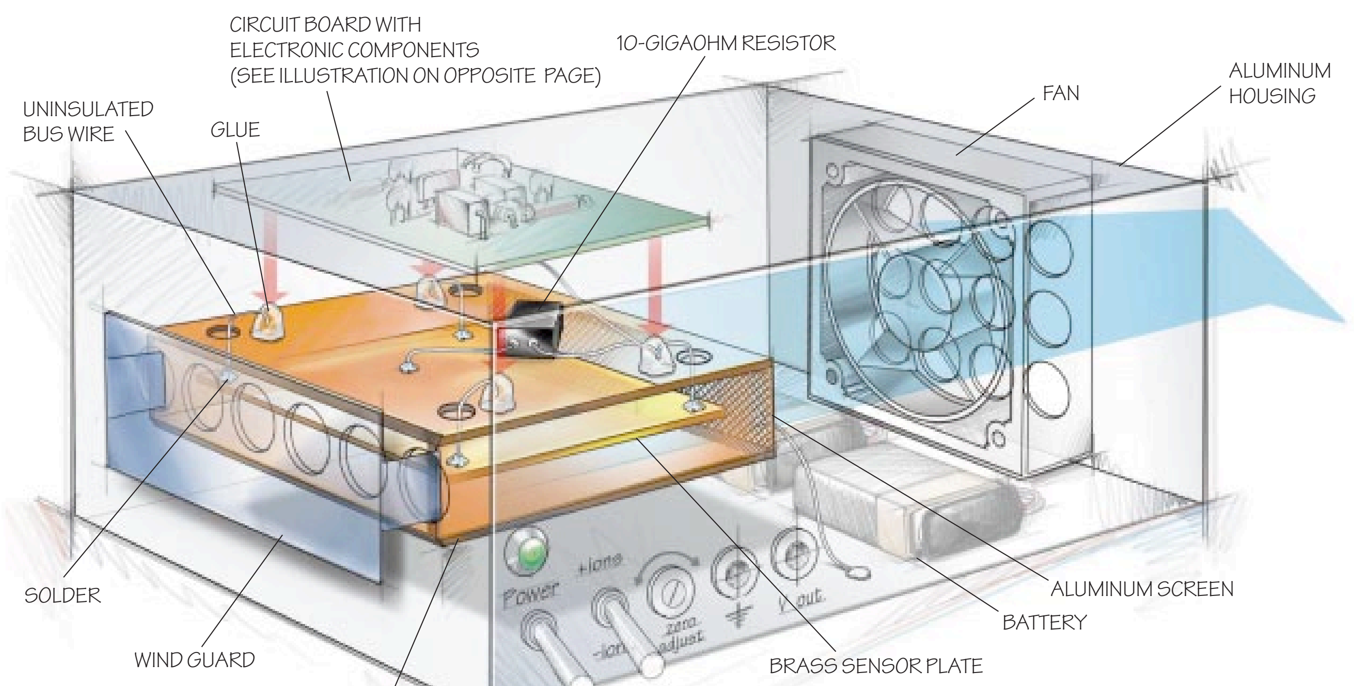
These particles are extremely scarce. Of the 2.5×10^{19} molecules that reside in each cubic centimeter of air inside your home, only a scant 200 carry an excess negative charge, whereas 250 are positively charged. (The concentrations are often higher outside.) Nevertheless, an instrument that can be built for under \$60 readily detects that tiny number. The homemade device, which owes its origin to Bill Lee of AlphaLab in Salt Lake City, is a simplified version of a sophisticated commercial unit AlphaLab (801-487-9492; www.trifield.com) sells for about \$580.

The instrument uses a small fan, like the ones used to cool personal computers, to draw air through a conducting rectangular tube. Inside the tube the air travels over a thin brass plate that is fixed at ground while the tube's electrical potential is set to either +5 or −5 volts. The former repels positive ions toward the central plate, where they pick up electrons and are neutralized. The latter drives negatively charged ions to the plate, where they deposit their excess electrons. Either action causes a current to flow through a resistor, creating a proportional voltage drop that a simple circuit can amplify for you to measure.

You can construct the conducting rectangular tube, measuring 7.6 by 7.6 by 1 centimeters, from four plates of double-sided copper-clad circuit board. The inner surfaces should all be connected electrically so that they can be energized with either +5 or −5 volts. The topmost outer surface must be held at ground, however, and needs to be isolated electrically.

For the brass sensor plate, almost any hobby shop sells sheets of the alloy that can be cut. You'll need a 6.4-centimeter square, but purchase some extra to construct a small wind guard for outdoor operation of your instrument.

To prevent stray electric fields from ruining your measurements, cover the



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ATMOSPHERIC-ION COUNTER *relies on a fan to draw air through the instrument. A thin brass plate inside a conducting rectangular tube then detects either positive or negative ions in the airflow.*

downstream opening with an aluminum screen that is electrically connected with the inside of the tube. Note that just a 9-volt battery runs the 12-volt fan.

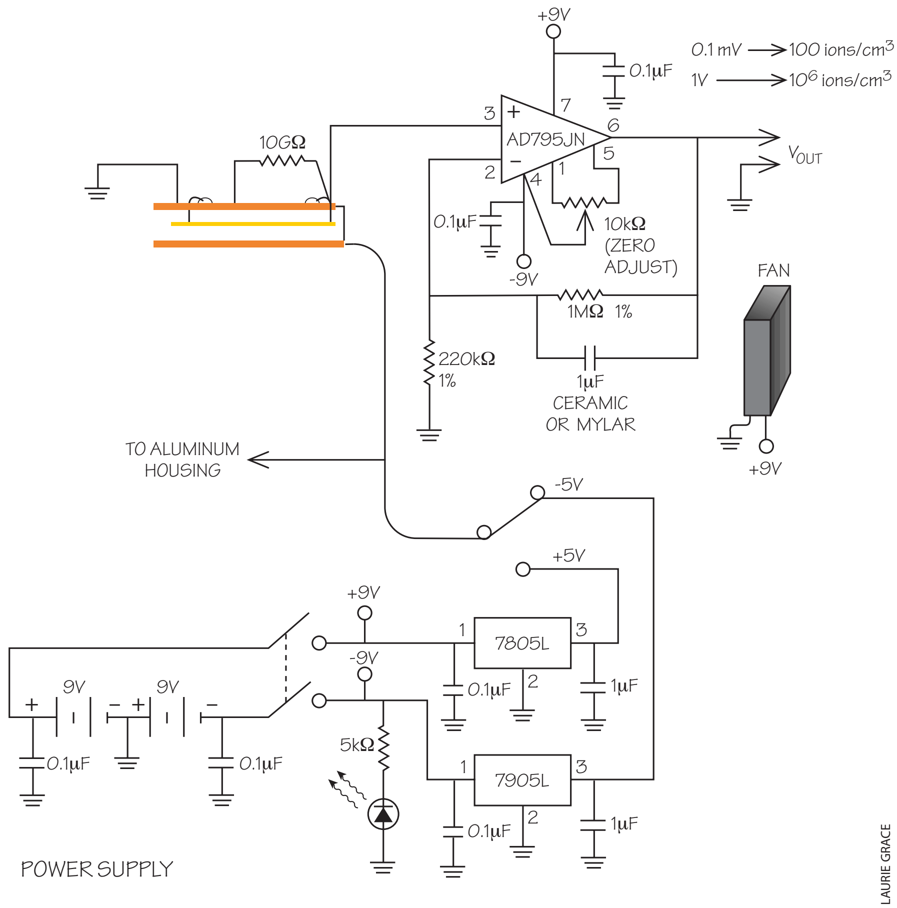
The signal current will be fantastically small—the ions in the air inside your home might generate only 10^{-15} amps. (Outside sources should produce a somewhat larger current.) To become a detectable signal, such a tiny current must pass through a huge resistance—in our case, about 10 gigaohms. Ohmcraft in Honeoye Falls, N.Y., sells such monster resistors for about $10 each.

When forced through such a large resistance, the tiny signal will generate about 10 microvolts, which a high-impedance operational amplifier, such as the reliable AD795JN, can magnify. Unfortunately, other circuit components do not perform as well, so to achieve the necessary level of precision you will have to take a few precautions.

The circuit board you use to mount the electronic components must be kept clean of surface contamination; otherwise excess current could flow about. Cleanse the board with alcohol and thereafter wash your hands thoroughly with soap before touching it.

Also, tiny currents can pass directly through the smidgen of circuit board that separates the operational amplifier's pin 4 (connected to the power supply) from pin 3 (the input signal). Because these currents can swamp a delicate signal, bend up pin 3 to keep it from touching the circuit board. You will need to connect the sensor wire from the 10-gigaohm resistor directly to this pin. Finally, to prevent any stray electric fields from forming between the aluminum housing of the device and the tube, connect the two electrically.

For your ion counter to work properly, you must ground the brass sensor plate through the 10-gigaohm resistor. Solder four pieces of uninsulated bus wire (20 gauge or thicker), one to each of the four corners of the plate. Then drill four oversize holes in the top surface of the tube so you can pass the wires through them. Secure three of the wires well above the conductive surface of the tube by encasing them inside a mound of glue from a hot glue gun [*see illustration on opposite page*]. The glue is a surprisingly good electrical insulator, but if any of the adhesive comes in contact with the metal on the inside surface



ELECTRONIC CIRCUITRY
for the ion counter must be able to detect a minute current, just 10^{-15} amp. To do so, a 10-gigaohm resistor forces the tiny signal to generate about 10 microvolts, which a high-impedance operational amplifier can then magnify.

of the tube, enough current will flow to destroy your measurements. So be careful to keep it well away from the holes. Next, solder one end of the 10-gigaohm resistor to the top surface of the tube and the other end to the remaining fourth wire. Also solder the signal wire to that junction and secure it onto the tube's top surface with hot glue, as shown in the illustration. Last, attach the other end of the signal wire to pin 3 of the operational amplifier.

When you are ready to use your device, first block the opening so that no air gets through and adjust the potentiometer in the circuit until your voltmeter reads zero. Then turn the fan on and let indoor air be drawn into the instrument. Your voltmeter should indicate about 0.2 millivolt, which corresponds to roughly 200 ions per cubic centimeter, and the reading should jump if you hold a flame near the inlet. Your device should detect about 66 percent of the ions present. (To learn how to measure the detection efficiency and to calibrate your instrument precisely, check out the Society for Amateur Scientists's Web site.)

With this device, you can observe how the ion count changes during the day, throughout the course of the year and during big storms. And because radon gas increases the number of ions in an enclosed space, you can use this detector as a presumptive test for this dangerous element. As always, please share your findings on the society's Web page. SA

As a service to the amateur community, the Society for Amateur Scientists is making the electronic components (but not the mechanical ones) for this project available until September 2000 for $35. For more information about this and other projects from this column, check out the Society for Amateur Scientists's Web page at www.thesphere.com/sas/WebX.cgi. You may write the society at 4735 Clairemont Square PMB 179, San Diego, CA 92117, or call 619-239-8807.