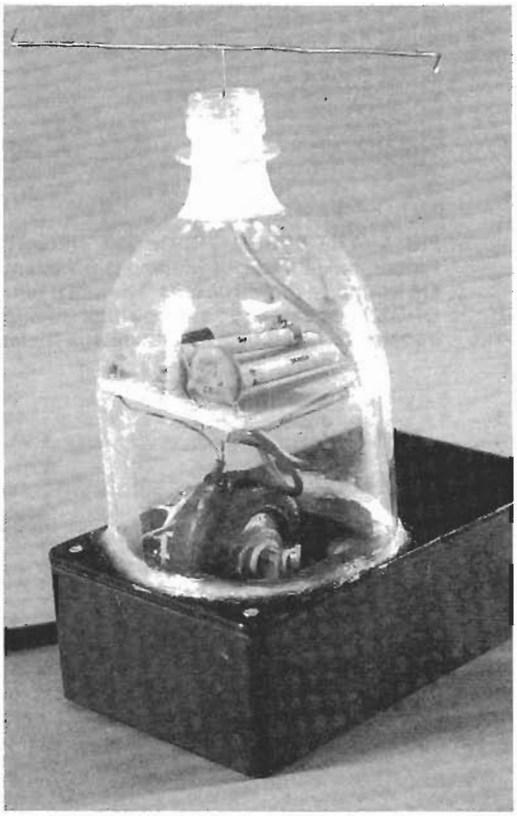
BUILD A NEGATIVE ION GENERATOR

Build this negative ion generator and put some charge in your life.

ANTHONY J. CARISTI



IF YOU'VE SEEN ADVERTISEments for negative ion generators in mail- order catalogs and wondered how they work, this project is for you. The simple version described here provides insight into their theory and applications, and is both informative and entertaining. Some of the demonstrations you can do with it will amaze you and your friends.

Many claims have been made for the beneficial attributes of negative atmospheric ions on human and plant life, especially by a Dr. Albert Krueger of the University of California. Studies have shown that negative ions promote physical and mental alertness and well-being, while positive atmospheric ions (such as in polluted air) cause discomfort and lassitude.

Certain negative ion properties can be demonstrated. For example, the surrounding air after a thunderstorm smells clean and fresh, due to generation of negative ions from lightning. The negative ions attach to smoke, dust, and pollen particles, bringing them to the ground to discharge, leaving fresh, clean air. That's why a cool room with a breeze is invigorating, compared with one that's stiflingly heated. Cool air is generally negatively ionized, whereas heated air is generally positively ionized.

Negative ions are air molecules with one or more excess electrons, produced in this case by a low-power, 9 to 14-kilovolt DC supply. The positive terminal is grounded, and the other (the emitter) is a needle exposed to air. (To generate positive ions, the polarities would be reversed.) Extra electrons on the emitter's surface produce a high local electric field owing to its pointed shape. The electrons exit the emitter needle's surface due to the polarization of surrounding air molecules between the emitter needle and ground. The electrons collide with the air molecules and produce negative ions.

A common misconception regarding high-voltage corona or arcing is that electrons are "overcrowded" on the tip, and forced off by mutual repulsion. What actually causes corona is the high electric field at the tip, which is directly proportional to the voltage, and is enhanced by sharpening an electrode tip to a fine point.

The high electric field strains the air molecules, polarizing them by a phenomenon called dipole polarization. If the electrode is positive, electrons are literally ripped off, creating positive ions, or if the electrode is negative, they're forced to accept electrons, creating negative ions.

High-voltage supplies like those in TV's need careful design, so no undesired discontinuities like sharp points or edges cause arcing. However, for the negative ion generator discussed here, the goal is to generate corona, not to avoid it, and the high electric field in the vicinity of a discontinuity more readily polarizes and ionizes air molecules.

The reason for the high electric field at the tip of a needle is due to its small localized radius of curvature. A sphere has a much more uniform electric field at its surface, due to its constant and much larger radius. The audible hiss caused by a high-voltage discharge is called "corona wind," and is often heard in older large-screen color TV's, especially on humid days, when the breakdown potential of the surrounding air is reduced, making the flyback transformer arc. You can often also feel it, if the corona is strong enough.

The negative ion generator de-

WARNING!! This article deals with and involves subject matter and the use of materials and substances that may be hazardous to health and life. Do not attempt to implement or use the information contained herein, unless you are experienced and skilled with respect to such subject matter, materials, and substances. Neither the publisher nor the author make any representation as for the completeness or the accuracy of the information contained herein, and disclaim any liability for damages or injuries, whether caused by or arising from the lack of completeness, inaccuracies of the information, misintepretations of the directions, misapplication of the information, or otherwise.

scribed here is low-cost, easy to build, and uses a high-voltage flyback transformer from an old black-and-white TV. It generates high voltage, but at very low current. However, the safety precautions taken for any high-voltage device should be observed here.

The circuit

The schematic of the negative ion generator appears in Fig. 1; T2 is a TV flyback transformer with an open ferrite core partially enclosed in an aluminum bracket. The only original connections used are one low-voltage tap as ground, and the lead connecting to the flyback transformer output winding (at right).

The other low-voltage taps aren't used, and the new feedback and bifilar primary windings are wound on the ferrite core. The bifilar primary winding goes to the collectors of an astable multivibrator made up of Q1 and Q2, with the center tap driven by the +3–5 volts DC from IC1. The astable energy-storage elements are the inductances of the new feedback and bifilar primary windings.

The term bifilar means a pair of transformer windings optimally coupled by having been wound in the same direction, either adjacent to or, preferably, superposed on top of one another. The feedback winding goes to the bases of Q1 and Q2 for positive feedback, with the center tap driven by the +3–5 volts DC from IC1 through R3. The transistors are then forward-biased by the opposite ends of each half of the feedback winding.

When power is applied, the current through Q1 and Q2 is unequal, due to differences in doping, layer thickness, and base-emitter (B-E) turn-on voltage. That's what causes oscillation; if all the astable parts were perfectly balanced (nearly impossible), it might not oscillate at all. Whichever transistor carries higher current saturates due to positive base feedback, and the other cuts off.

When the sharp increase in transistor current in half the bifilar primary winding is maximized, the induced voltage reverses, so the second transistor conducts and the first one cuts off. The collector waveform

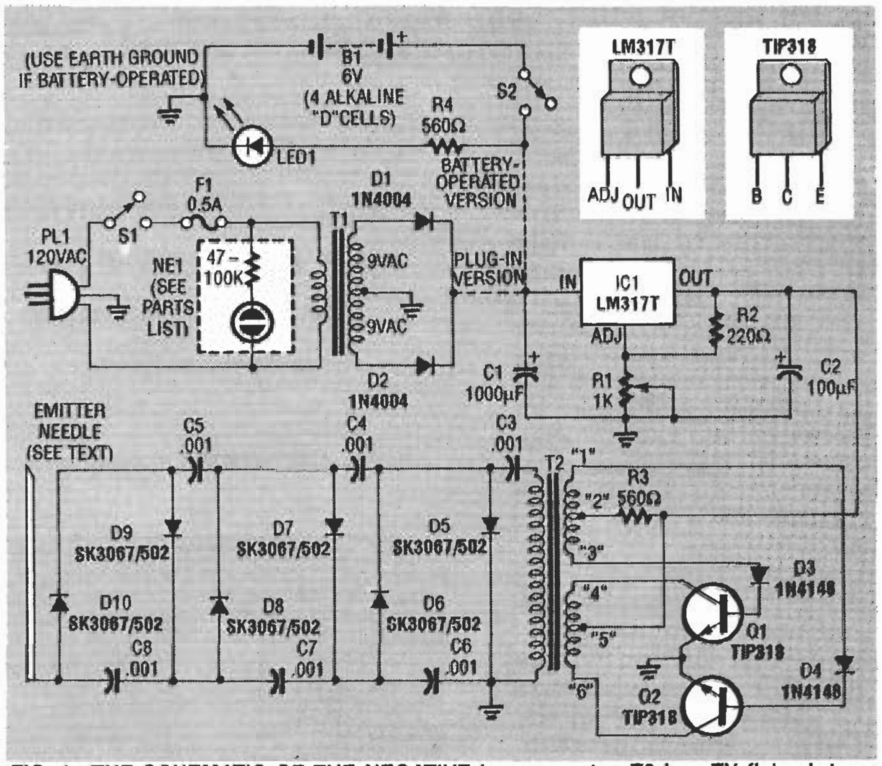


FIG. 1—THE SCHEMATIC OF THE NEGATIVE ion generator. T2 is a TV flyback transformer; only its output winding is used, and new feedback and bifilar primary windings are wound on the ferrite core. The bifilar primary winding goes to the collectors of astable Q1-Q2. Its square wave induces high voltage into the flyback transformer output winding, boosted followed by a ladder voltage-tripler −9 to −14 kilovolts.

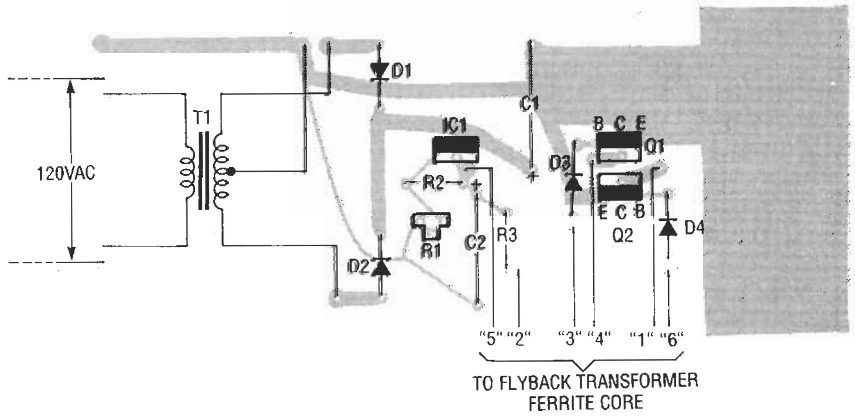


FIG. 2—THE PARTS-PLACEMENT DIAGRAM for the main PC board; Q1, Q2, and IC1 have U-shaped 1×1-inch copper heatsinks, with silicone grease for heat transfer; each goes on the main PC board without insulators. In the prototype, S1, S2, F1, and NE1 were omitted, and T2 was salvaged from a small-screen TV; note the new feedback and bifilar primary windings. Pin 7 had the highest resistance relative to the flyback transformer output lead, so it becomes ground.

fundamental frequency was 23.26 kHz, although higher harmonics greatly extend the total bandwidth. Also, the peak-to-peak bifilar primary winding voltage is four times that of the supply.

The astable square wave induces voltage into the flyback transformer output winding, proportional to the transformer turns ratio. A flyback transformer bifilar primary winding is normally quite small, while the flyback transformer output winding normally has about 2000–2500 turns, inducing −3 to −4 kilovolts.

Since the negative ion generator needs to produce −9 to −14 kilovolts DC, a ladder voltage-tripler with six diode-capacitor rungs is used to half-wave rectify and multiply the flyback transformer output voltage. Its operation is best understood in

PARTS LIST

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

R1—1000 ohms, PC-board mounted potentiometer
R2—220 ohms
R3, R4—560 ohms (the former for the astable-flyback transformer combination, the latter optional for the battery-operated version)
R5-R6—200- and 40-megohm series high-voltage focus divider, RCA SK3868/DIV-1, used for an optional high-voltage range extender for a conventional high-impedance (10-megohm) voltmeter (see text)
R7—2.7 megohms

Capacitors
C1—1000 µF, 25 volts, electrolytic
C2—100 µF, 16 volts, electrolytic
C3–C8—0.001 µF, 10 kilovolts, ceramic disc
C9—0.001 µF, 500 volts, ceramic disc, optional for aluminum can/neon bulb experiment (see text)

Semiconductors D1, D2—1N4004 silicon diode
D3, D4—1N4148 silicon diode
D5–D10—RCA SK3067/502 high-voltage diode, 12 kilovolts PIV
LED1—light-emitting diode for the battery-operated version
Q1, Q2—TIP31B NPN transistor
IC1—LM317T adjustable voltage regulator

Other components
F1—0.5-amp slow-blow fuse with holder
NE1—120-volt AC neon-bulb assembly with 47–100K built-in series resistor for the plug-in version (Radio Shack 272-712)
NE2—neon bulb, type NE2 (not the part number), optional for experiment (see text)
S1—SPST toggle switch
S2—SPST toggle switch
T1—18-volt center-tapped transformer (Radio Shack 273-1515)
T2—standard TV flyback transformer (see text)

Miscellaneous: Plastic case (7.5 × 4.25 × 2.25-inches, Radio Shack 270-224), enamel magnet wire, three-wire line cord, emitter needle (made from either straight pin or sewing needle), RTV silicon rubber, heat sinks, four alkaline "D" cells (optional for battery operation), 2-liter plastic soda bottle, and a sewing needle.

NOTE: The following are available from Anthony J. Caristi, 69 White Pond Road, Waldwick, NJ 07463: Two etched and drilled PC boards (one each for the main and voltage-tripler sections) for $15.95, IC1 for $3.25, Q1 and Q2 for $2.75 each. Please add $2.00 for postage and handling with each order; NJ residents please add 7% sales tax.

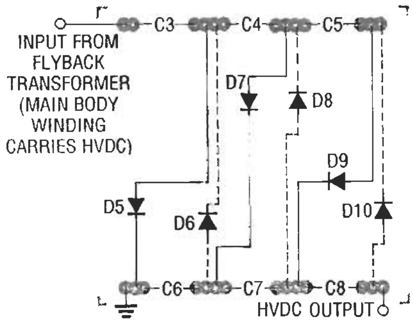


FIG. 3—THE PARTS-PLACEMENT diagram for the high-voltage PC board. The parts shown include high-voltage ceramic disc capacitors C3–C8, and selenium rectifiers D5–D10. D5, D7, and D9 go on the component side (solid lines), while D6, D8, and D10 go on the foil side (dashed lines).

segments. The AC waveform from the transformer is coupled to D5 and D6 via C3, charged through D5 acting as a clamp.

The peak-to-peak magnitude of the AC waveform at the anode of D5 equals that of the flyback transformer output winding, with a negative DC component of half the peak-to-peak value. The AC output waveform from the flyback transformer is coupled to the anode of D7 via C3 and C4, where D7 charges C4. The action is repeated again via D9, which charges C5. The DC potentials on C3–C5 add, tripling the voltage from the flyback transformer winding. The anode of D10 is the output of the negative ion generator, and should be at −9 to −14 kilovolts DC.

Power is supplied by either a standard full-wave rectifier followed by variable voltage regulator IC1, or four series "D" cells producing 6 volts DC. Although S1, S2, F1, and NE1 are shown in Fig. 1, they were omitted in the prototype. IC1 controls the DC voltage fed to the oscillator via R1. Since the negative ion generator output must be −9 to −14 kilovolts, and the exact flyback transformer turns ratio is normally unknown, adjusting R1 is mandatory. Once R1 is set, the negative ion generator output voltage will be stable.

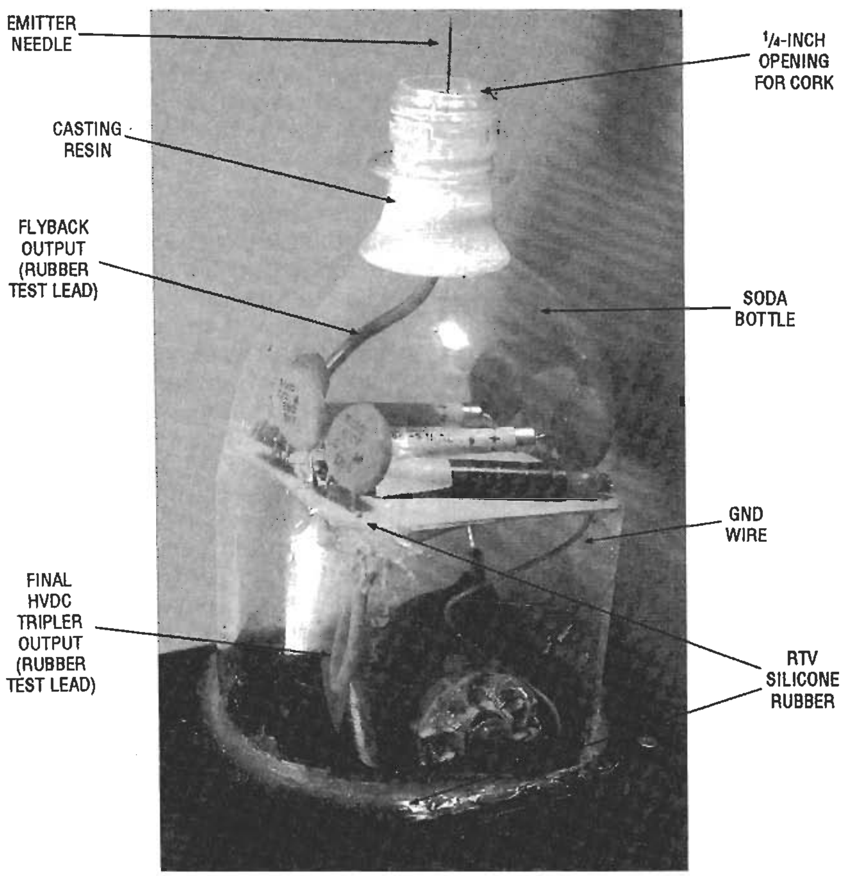


FIG. 4—THE NEGATIVE ION GENERATOR, showing the case, T2, plastic soda bottle, and the top of the high-voltage PC board, with D5, D7, D9, and C3–C8. Both the plastic soda bottle and high-voltage PC board are held in place with RTV. The neck is sealed with casting resin to within ¼-inch of the top; cover the needle with a cork when unused.

Construction

Next, we'll discuss construction, focusing on the main and voltage-tripler PC boards, the plastic cover for the voltage-tripler PC board made from the top third of a 2-liter plastic soda bottle, the emitter needle, and the cutout in the lid of the plastic case for the flyback transformer. Figure 2 shows the parts-placement diagram for the main PC board, and Fig. 3 the ladder voltage-tripler section. Remember to add S1, S2, F1, and NE1 off the main PC board, as shown in Fig. 1, if you want them.

The main section includes the regulated supply, oscillator, and flyback transformer, and goes on the single-sided PC board mentioned in the parts list, with the foil pattern shown here. The high-voltage PC board contains the ladder voltage tripler, connected to the main PC board by two leads, and the emitter needle is above the high-voltage PC board. In Fig. 2, Q1, Q2, and IC1 need heatsinks; you can buy them, or make them from 1×1-inch copper bent in a "U," with silicone grease for heat transfer.

The heat sinks go on top of the PC board without insulators. Neon lamp assembly NE1 acts as an indicator, and has a 47K–100K resistor in series with it. For battery operation, use LED1 in series with R4; use alkaline batteries, not carbon-zinc. Use a 3-wire cord with ground, or an earth ground in battery-operated versions. The voltage-tripler section is built to avoid arcing and shock. Cut the top third off a 2-liter plastic soda bottle, as shown in the lead photo, or use 4-inch diameter plastic PVC plumbing pipe.

Use 18-gauge rubber-coated test leads to connect the high-voltage PC board to both the flyback transformer output and the needle, to withstand high voltage, but not until indicated (more below). The heavy voltage-tripler output lead is soldered to the emitter needle, which goes upward through the plastic soda bottle and projects out of the neck, which is filled with casting resin. Don't fill the neck with resin all the way to the top; leave ¼ inch of the neck open, so you can cap the needle with a wine bottle cork when not in use.

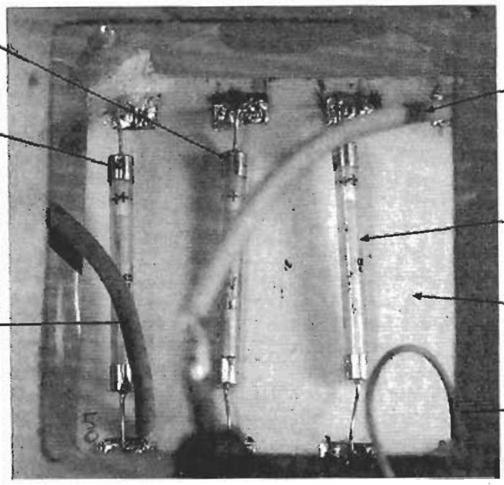


FIG. 5—THE BOTTOM OF THE HIGH-VOLTAGE PC board, showing D6, D8, and D10, and the attachment points of the ground lead and both high-voltage leads.

The voltage tripler shown in Fig. 3 consists of ceramic disc capacitors C3–C8, and high-voltage selenium rectifiers D5–D10. Note that D5, D7, and D9 go on the component side of the PC board, while D6, D8, and D10 go on the foil side. They're common to most TV's, so most TV repair shops should stock them; see the parts list.

Figure 4 shows a photo of the negative ion generator, with the closed case, flyback transformer, plastic soda bottle, and top of the high-voltage PC board showing D5, D7, D9, and C3–C8. The high-voltage PC board is held in place inside the plastic soda bottle top using RTV silicone rubber, and the plastic soda bottle goes on the top of the case the same way, for a water-tight seal that avoids condensation, and has good high-voltage attributes.

The markings and sizes of the high-voltage TV diodes used in the voltage tripler differ from those on standard diodes. They're much larger, and have a very high peak-inverse voltage (PIV) rating. Also, on a conventional diode, the cathode is normally marked with a band, whether a white band on a black body for such low-voltage rectifiers as the 1N4001, or a red band on a clear glass body, as with the 1N4148 or 1N914.

In high-voltage TV diodes, the body is generally either white, black, or see-through. In Fig. 4, D5 and D7 are white with a band of black "+" signs on the right end, while D9 is black with a dashed band of white "–" signs on the right end. The ends with the bands are the cathodes, for both diode body types; the reason for the "+" signs on D3 and D5 is that circuit power is normally considered as being extracted from the cathode ends in TV, and is called B+. In Fig. 5, D6, D8, and D10 all have bands of "+" signs on the cathodes.

A 3×3-inch hole was made in the case top for the flyback transformer; adjust yours as needed. Don't connect the voltage-tripler PC board to the main PC board until the final checkout below; put it aside and let the RTV dry overnight. The soda bottle and the high-voltage PC board are held in place using RTV. The rubber-coated test leads connect the flyback-transformer output to the voltage tripler and the voltage tripler to the emitter needle; the thin wire is the ground.

A flyback transformer is also called a tuned transformer, and consists of a ferrite core surrounded by a metal bracket, with a large coil of windings coated in plastic or ceramic with an *extremely* high dielectric breakdown voltage. Often, as with the flyback transformer used in the prototype, there are additional low-voltage output winding taps (seven, in that case) placed around a plastic ring on one side of the transformer coil, that have equally high-voltage breakdown characteristics.

That's all we have room for. Next month we'll finish up this project. **R-E**