Project 1501

Experimental negative ion generator

For those experimenters who just have to find out for themselves what the subject is all about, this negative ion generator should provide a good basis for experiment.

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THE RISE in popularity of negative ion generators, the claims made for them, and the attention they have received in newspapers and magazines recently has undoubtedly intrigued many readers with a technical background or interest, as evidenced by the deluge of letters and phone calls we've received in recent months requesting information and project material to be presented in ETI.

Having read the article presented elsewhere in this issue, undoubtedly many of you will be 'hot to trot' to experiment with an air ioniser but have been daunted by the cost of commercial units. As the electronics associated with a negative ion generator is relatively simple, generally employing readily available components, this article describes how to build a unit that can be used as the basis for experiment. The cost of commercial units, at least in part, is justified by the design and construction of the emitting head, which requires somewhat more specialised parts and construction than are available to the average constructor in order to work efficiently.

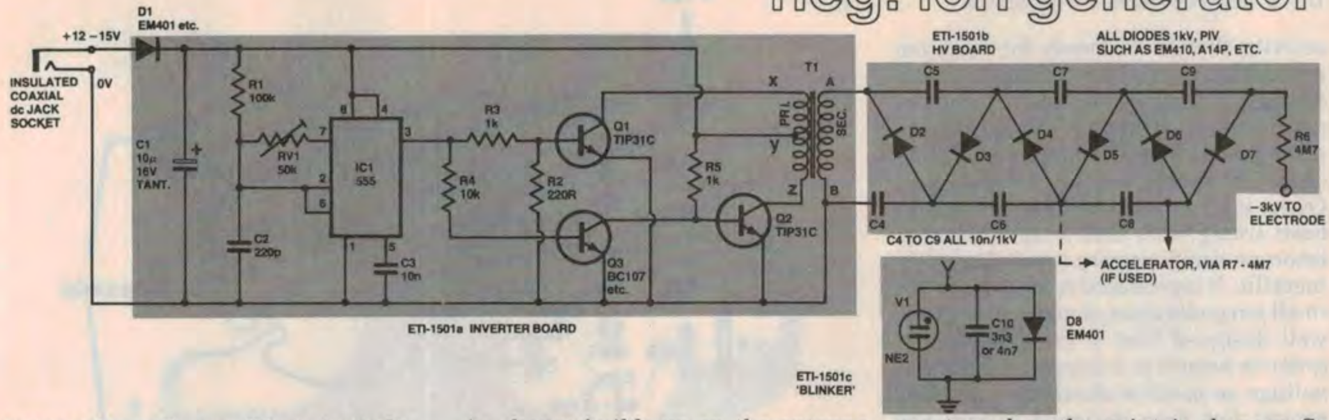
All the present negative ion generator designs that we have examined operate on the 'corona discharge' principle. This requires relatively high voltages — around 2.5 kV to 3 kV. In mains-operated units this is usually obtained by a voltage-multiplier rectifier operated direct from the 240 Vac mains. While this is economical and efficient and, in an assembled plastic box, fairly safe, it is not at all safe for anyone without a great deal of experience to tinker with on the workbench or kitchen table, etc. With this in mind, we have designed our unit to work from a 12 -15 volt supply, employing a dc-to-ac inverter and voltage-multiplier rectifier, giving a relatively safe high tension (HT) voltage to operate the emitting head. This has the added advantage that it is portable and can be used in a car or run by a plug pack from the mains. In addition, we have kept in mind that many of the victims of electrocution each year are people who should have known better. Our project design was partly motivated by the desire to avoid the necessity of having to replace design staff — who are hard to come by, expensive and cannot run the risk of being zapped like the occasional 20¢ transistor! Prime motivation behind the design was to avoid losing readers, though.

Our unit can be powered from 12 Vdc or a plug pack. The blinker testing device is at left.

Circuit design

The negative ion generator electronics can be separated into three components: an oscillator, a driver and step-up transformer comprising the dc-to-ac inverter, and the voltage-multiplier rectifier.

A 555 timer IC (IC1) is arranged as an astable multivibrator. A trimpot is included in one of the timing inputs (pin 7) to allow adjustment of the mark-to-space ratio of the output to ensure equal drive to the two driver transistors, Q1 and Q2. These two transistors alternately switch current through the



primary of transformer T1. As both Q1 and Q2 are NPN transistors, one has to receive an inverted drive signal so that it is off when the other transistor is on and vice versa. Thus Q3 is employed to invert the drive to Q2.

Transformer T1 steps up the drive applied to its primary, providing a 500-600 V peak-to-peak output at the secondary (depending on the supply voltage).

As about 3 kV dc is required to operate the emitter head, a Cockcroft-Walton voltage multiplier circuit is employed, multiplying the secondary voltage of T1 six times. A large value series resistance, together with the inherently poor regulation of the rectifier circuit, ensures that the output short-circuit current is very low to reduce shock hazards.

To enable you to test the operation of this unit a 'blinker' has been provided. This simply consists of two large 'pads' on a piece of pc board with a diode, capacitor and neon connected between them. With the pad to which the diode cathode connects held with your thumb, the other pad acts as an 'antenna' or 'collector' when held in front of the emitter head of any negative ion generator.

As charge builds up on the antenna pad, the capacitor will charge up. When this reaches a voltage that exceeds the breakdown voltage of the neon, the neon will conduct briefly while the capacitor discharges and you will see a flash. The charge will build up again and the whole process will be repeated.

The 'blinker' thus provides a crude measure of the ion production of the generator being tested. The closer the blinker is held to the emitter head, the faster it will flash. Alternatively, if held a fixed distance from the emitter heads of different air ionisers in turn, the one in front of which it blinks fastest will have the greater ion output.

Design of the emitter head

The object of the emitter head is to take in the HT, in our case about 3 kV, and produce a stream of negative ions flowing forwards into the room in which the generator is placed. The ions are produced by a very intense field gradient, which is induced by the high voltage and the geometry of the head assembly. This ion flow is a corona wind. It is a basic principle of electrostatic physics that the field gradient is stronger in the immediate vicinity of a point projection, the gradient being greater when the point is sharper. So most ion generators employ some combination of sharp projections and high voltage. A number of other matters affect the choice of head geometry. Firstly, the design should expel the ion stream away from itself to allow more ions to be emitted. Secondly, it should achieve its aim with a minimum of ozone production. Thirdly, it should employ points made of a hard metal to resist cathode stripping and hold their edge, without being too hard to work or too expensive or exotic to get easily. We will briefly discuss these aims and the relevant principles behind their realisation, then give you a couple of examples to act as a guide for experimentation.

If the point is spaced well away from other parts of the unit the ions will naturally repel themselves away from the region of emission. However, if the point or points are partially enclosed in the case of the device there may need to be either a chimney-shaped assembly around the emitters or some sort of accelerator electrodes to help eject the ions from the emitter head.

Wherever there is ion production there will be ozone production. Ozone, O_3, is a product of higher energy ▶

HOW IT WORKS — ETI 1501

One board contains a dc-to-ac inverter, a second board a high voltage multiplier rectifier and a third a 'blinker' test unit.

The dc-to-ac inverter on board ETI-1501a consists of a 555 astable multivibrator, the output of which is used to drive two transistors operated in push-pull, the collectors of which switch current through each side of the transformer (T1) primary in turn. Diode D1 prevents any damage from a supply connected with reverse polarity. Capacitor C1 is a bypass. IC1 oscillates at around 25 kHz, determined by R1 and C2. The exact frequency is unimportant. The mark-to-space ratio of the output of IC1 (via pin 3) may be adjusted by RV1, which is connected in series with pin 7 of IC1.

The output of IC1 drives the base of Q1 directly, via R3 and R2. Q1 turns on when the output of IC1 goes high. Resistor R3 is there principally to limit the base current supplied to Q1, while R2 serves to discharge the base-emitter junction capacitance so that Q1 turns off quickly when the output of IC3 goes low.

When pin 3 of IC1 goes high, Q3 also turns on, preventing Q2 from turning on. When pin 3 of IC1 goes low, Q1 and Q3 turn off and Q2 will turn on as base bias will be supplied via R5.

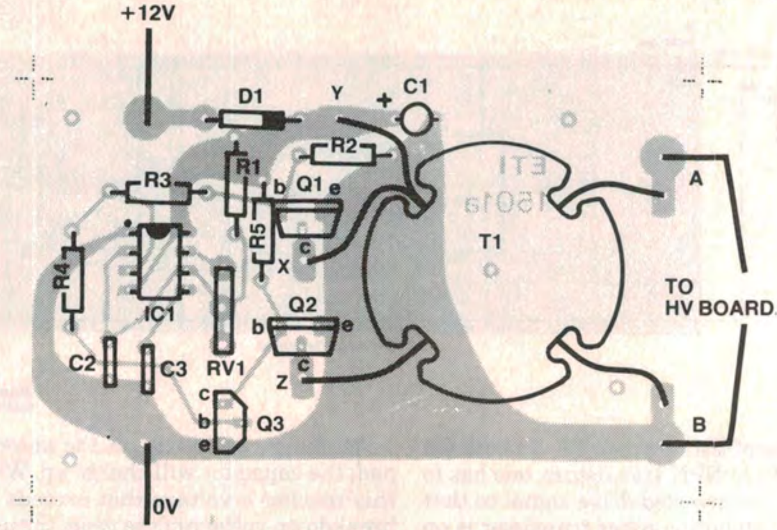
Thus current is alternately switched through each side of the primary of T1. The secondary provides a voltage step-up of 25:1. If the supply voltage is 12 Vdc, then the peak-to-peak output from the secondary of T1 will be 600V. The voltage-multiplier rectifier, on board ETI-1501b, employs the well-known Cockcroft-Walton circuit, where the output of successive half-wave rectifiers is connected in series with the previous one. This circuit provides a multiplication of six times. Thus, with a 12 Vdc supply, the output will be about −3.6 kV. With a 10 Vdc supply (as can be obtained from a 9 Vdc plug pack), about −3 kV is obtained. An output for an 'accelerator' is provided.

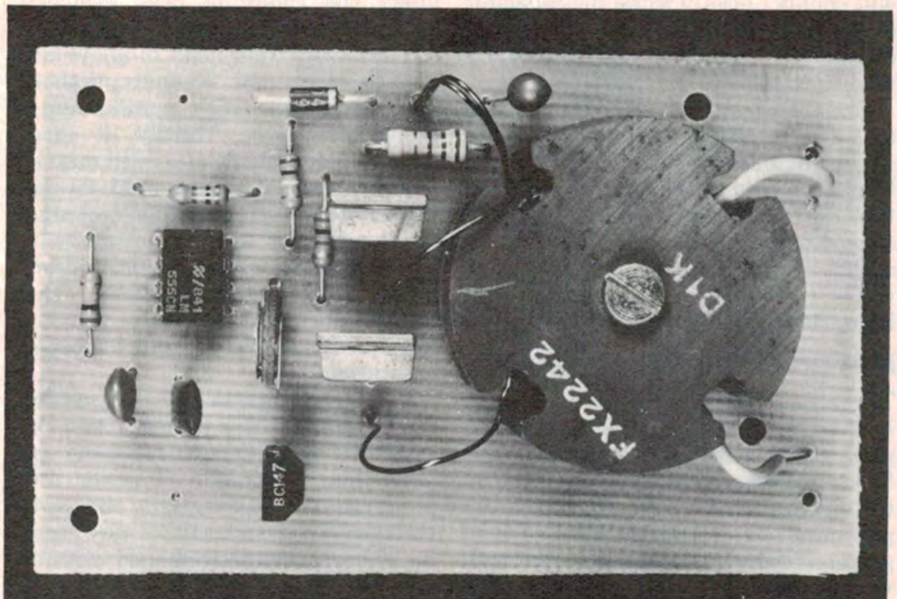
The high voltage output to the emitter head is taken via a 4M7 resistor to ensure that only low short-circuit current occurs if the emitter head is accidentally contacted or excessively humid air causes 'flashover' from the emitter.

The blinker is simply a crude relaxation oscillator. When a charge builds up on the 'antenna' pad, it will charge C10. When the voltage on C10 reaches the breakdown voltage of the neon, V1 (about 70 V), the neon will conduct. This will discharge the capacitor, the voltage across it falling until it reaches the extinguishing voltage of the neon (about 30-40 V), which will then cease conducting. While the neon conducts, it will emit light, but as it discharges C10 fairly rapidly, all you will see is a brief flash from the neon. Diode D8 ensures only negative charges operate the blinker.

When the neon ceases conducting, the charge on C10 will build up again and the whole process will be repeated.

activity than is necessary for more ion production. It is a corrosive as well as a strong antibacterial agent, and is poisonous in sufficient concentration. About 0.025 to 0.05 parts per million (ppm) is recognised as a safe level. Ozone is what you smell after there has been arcing, such as in a motor commutator; an acrid, coppery smell, distinctly metallic. It is produced in some quantity in all ion generators, though some are so well designed that it is negligible. In order to keep it to a minimum, as low a voltage as possible should be used. Our project has been designed to give the lowest voltage compatible with adequate ion production. The design should be such as not to allow any arcing or





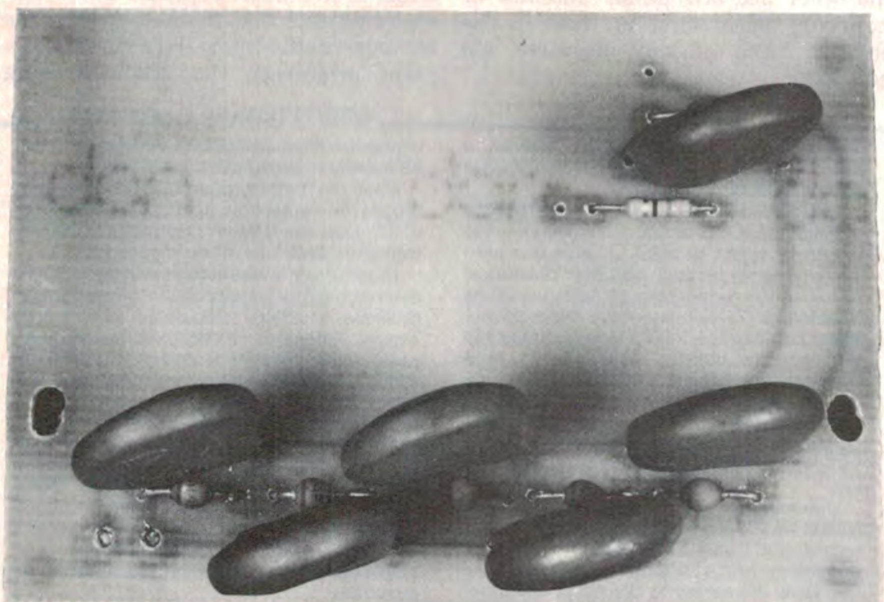
The inverter board, ETI-1501a. Compare this to the overlay above.

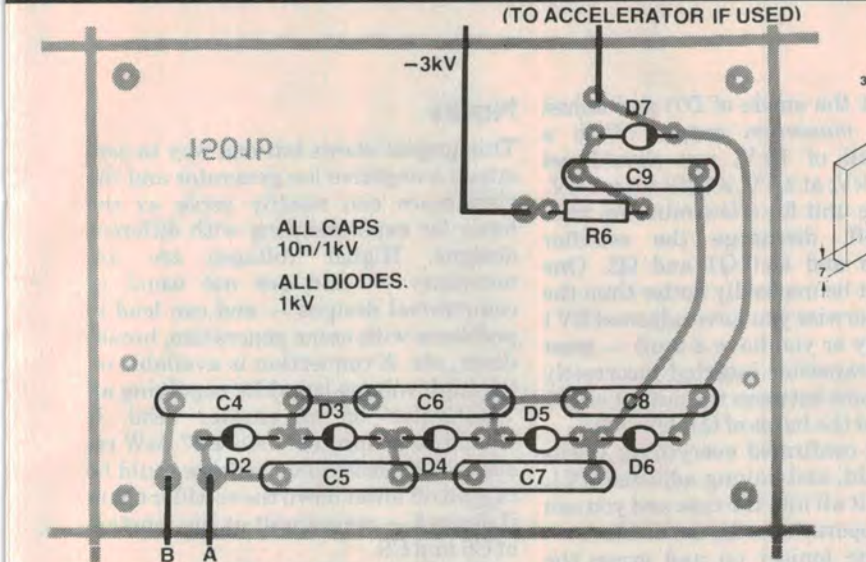
serious breakdown. This is really only likely if you try using an "accelerator", as there will be no metal in close proximity to the emitter otherwise.

The best metal for the points which is easily obtainable is steel, preferably stainless. This is hard enough to hold an edge, and will resist the effects of cathode stripping. The latter is undesirable both because the fine point will be eroded away, and also because the heavy metal ions which are ejected are undesirable agents in the air we breathe (stick to getting your minerals from cornflakes).

Figure 1 shows the emitter head assembly of our prototype. The plastic we used was clear perspex, but this is purely to show you what is inside the gizmo. We recommend some aesthetic colour for your version if you use perspex. There was found to be no need of an accelerator as the points actually protrude beyond the slot in the faceplate. If they are to be recessed an accelerator may be necessary, as the ions soon collect on the plastic parts and build up a field, inhibiting further ionisation or ejection. There is no shock hazard as the unit is not mains powered and there is a very large series resistance between the points and the multiplier output. At most, there results something between a nip and a tickle if you touch the emitter points. The points are steel needles soldered to a brass rod; the needles are probably sharp enough normally, but we struck them against a fine whetstone to sharpen them further. This enhances ion production a little.

Figure 2 shows one commercial unit's layout. It employs an accelerator and points of phosphor-bronze. It has a similar voltage potential to ours, but is physically smaller, due to custom plastic components. The points are


The high voltage board, ETI-1501b. Compare this to the overlay above right.



partially recessed. This unit derives the HT directly from the mains.

Perspex for the emitter head may be obtained from plastics suppliers, such as Cadillac Plastics (where we bought our piece) and you'll find them listed in the Yellow Pages of the telephone directory. We used a piece with a thickness of 5 mm.

ETI-1501 NEGATIVE ION GENERATOR

Resistors .... all ½W, 5%

R1	100k
R2	220R
R3, R5	1k
R4	10k
R6, R7	4M7
RV1	50k

Capacitors

C1	10u/16 V tantalum
C2	220p ceramic
C3	10n greencap
C4 to C9	10n/1kV ceramic
C10	3n3 or 4n7 greencap

Semiconductors

D1, D8	EM401 or similar
D2 to D7	A14P, EM410, BYX80 or sim. 1 kV PIV diodes.
IC1	NE555
Q1, Q2	TIP31C
Q3	BC547, BC107 etc

Miscellaneous

Three pc boards — ETI-1501a, b and c; T1 — FX2242 potcore and former; coaxial dc jack socket; 9 V 200 mA or 300 mA plug pack (if required); V1 — NE2 70 V neon; piece of perspex about 100 x 100 mm, 5 mm thick; five needles; about 80 - 100 mm of 6 mm diameter thin-walled brass tubing; Horwood case type 34/7/DS; nuts, bolts etc.

Price estimate

We estimate that the cost of purchasing all the components for this project will be in the range:

$35 - $42

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel (if used) supplied etc — whether bought as separate components or made up as a kit.

Suitable steel needles can be obtained from your family sewing drawer! Failing that, any sewing accessories supplier can help you.

The brass tubing you'll find in hobby and toy stores. The thin-walled variety is best, as it is easy to solder to and easy to cut. We used a piece measuring 6 mm outside diameter.

Construction

The ioniser electronics are contained on two circuit boards — designated ETI-1501a and ETI-1501b respectively. The first contains oscillator, driver and transformer, while the second contains the high voltage rectifier. We housed both of these in a small Horwood extruded box, type 34/7/DS, the emitter head being designed to fit in one end.

First stage of construction is to assemble the components on the pc boards. Commence with the 'a' (inverter) board. Insert the resistors, capacitors, IC and transistors before assembling the transformer to it. As usual, take care with the orientation of the diode, IC1 and the transistors. Next, wind the transformer — details are given in the box on page 34. The transformer employs a potcore and this can be held on to the pc board with a nylon bolt — do not use a metal bolt. Cut the transformer coil wires to length, scrape off the insulation and solder them in place. The TIP31C transistors, Q1 and Q2, do not actually require any heatsink, though they do get warm in operation.

The high voltage board ('b') may be assembled next. Take care with the orientation of the diodes. Stand the capacitors erect on the board so that they do not touch each other or you may have arc-over problems between these components.

Mount the appropriate components on the 'blinker' board ('c') next, as you'll ▶

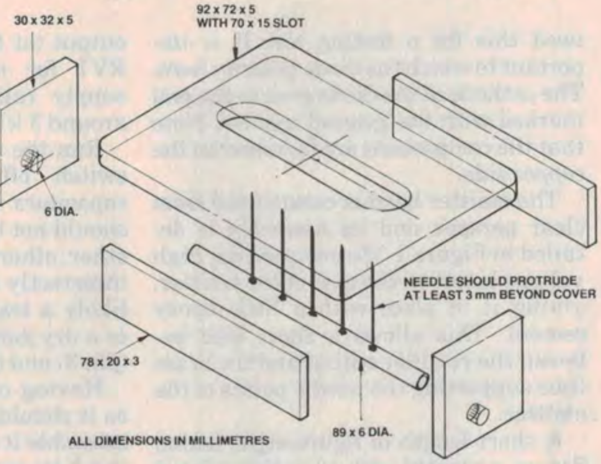
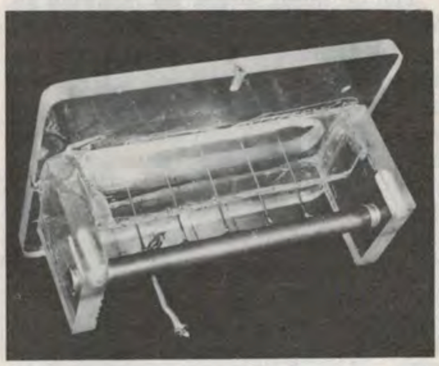
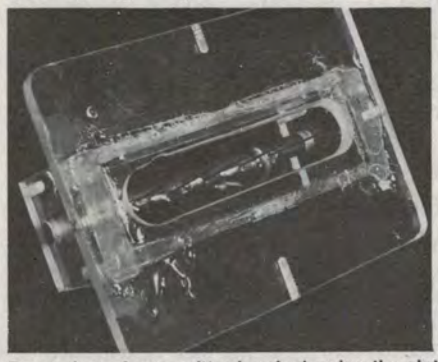


Figure 1. **Exploded view of our emitter head assembly. We used 5 mm and 3 mm thick perspex, but it could all be made from 5 mm perspex. The two pictures below show the completed head. Brass tubing supports the needles, which are soldered to it.**



Rear view of our emitter head, showing general construction of the perspex 'chimney' and assembly supporting the needles.



Front view of our emitter head, showing the slot and positioning of the needles. Note that the needles protrude about 3 mm beyond the front face.

Figure 2. **Picture of a commercial air ioniser's emitter head, showing construction.**

need this for a testing aid. It is important to watch the diode polarity here. The cathode of the diode goes to the pad marked with the 'ground' symbol. Note that the components are mounted on the *copper* side.

The emitter head is constructed from clear perspex and its assembly is detailed in Figure 1. We mounted our high voltage board on the rear of the emitter, gluing it in place with a little epoxy cement. This allows a short lead between the rectifier output and the brass tube supporting the needle points of the emitter.

A short length of figure-eight mains flex or a twisted pair of well-insulated hookup cable links the rectifier input (A and B) to the inverter board. This board we mounted on the end plate of the Horwood box using four nuts and bolts and short spacers.

The dc input socket we mounted on one side of the box, as can be seen from the photographs. Exactly how the dc coaxial jack socket is wired will depend on how your plug pack output plug is wired. Some have the outer connector connected to positive, while others have it connected to the negative. Watch the wiring of this socket if you plan to operate your unit in a vehicle. The outer connector is electrically connected to the socket's mounting and this automatically connects the case to that side of the supply. If your plug pack has the outer of its dc connector connected to positive then you will not be able to operate your ioniser project in a vehicle that has the battery negative connected to the vehicle chassis, without running the risk of shorting the supply if the ioniser's case comes in contact with vehicle ground.

With everything assembled, you can proceed to test it.

Getting it going

You will need a multimeter and a supply of between 9 Vdc and 14 Vdc. It would be handy, but not essential, to have a high voltage probe for your multimeter, having an impedance of 10M or more.

If you do not have a high voltage range on your multimeter to enable you to measure voltages greater than 3 kV, switch it to the current range to read 300 mA full scale or more, and connect it in series with the dc supply input.

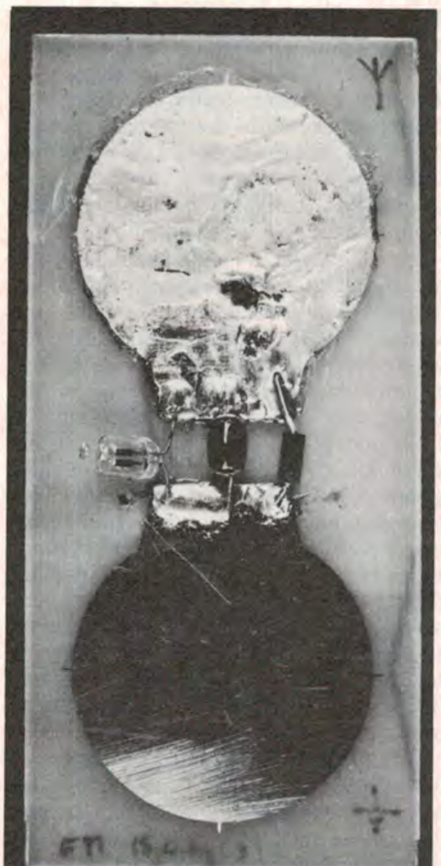
Switch the supply on and, assuming all is well, adjust RV1 on the inverter board for *minimum* current. This could be between about 220-280 mA.

Alternatively, measure the rectifier output (at the anode of D7) and adjust RV1 for *maximum* output. With a supply rail of 10 V, you should get around 3 kV; at 14 V, a little over 4 kV.

Run the unit for a few minutes, then switch off, discharge the rectifier capacitors and feel Q1 and Q2. One should not be markedly hotter than the other, otherwise you have adjusted RV1 incorrectly or you have a fault — most likely a transistor inserted incorrectly or a dry joint between the output of IC1 (pin 3) and the bases of Q1, Q2 or Q3.

Having confirmed everything works as it should, and having adjusted RV1, assemble it all into the case and you can check its operation with the blinker.

Turn the ioniser on and grasp the blinker so that your thumb is in good contact with the pad marked by the 'ground' symbol. Hold the blinker such that the 'antenna' pad is about 10 mm in front of the emitter. You should be able to count around one blink per second if all is well and this is a good 'bench mark' for successful operation when you experiment with different head designs and geometries.



Our 'blinker'. Components are positioned as per the circuit diagram on page 31. Cathode of D8 is at the bottom.

Notes

This project shows but one way to construct a negative ion generator and the electronics can readily serve as the basis for experimenting with different designs. Higher voltages are unnecessary — and are not usual in commercial designs — and can lead to problems with ozone generation, breakdown, etc. A connection is available on the high voltage board for supplying an 'accelerator' on an emitter head. It should be connected via a 4M7, ½W resistor. The accelerator voltage could be tapped off lower down the rectifier chain if desired — we suggest at the junction of C6 and C8.

The high voltage board may be mounted separate to the emitter head and four bolt-hole positions are provided on the board.

The exact value of capacitors C4 to C9 on the high voltage board is not important and may be any value between about 1n and 22n or so, but should not be lower than 1n. The voltage rating of these capacitors should not be less than 1000 volts.

The dc supply should not be greater than 15 volts, otherwise insulation breakdown within the transformer may be experienced. Likewise, more turns should not be wound on the secondary of T1 or you may experience insulation breakdown. ●

ETI-1501 WINDING DETAILS FOR TRANSFORMER T1

Potcore: FX2242
Secondary: 125 turns of 0.2 mm dia. enamelled copper wire.
Primary: 10 turns, centre-tapped, of 1.0 mm dia. enamelled copper wire.

The secondary is wound on the potcore bobbin first. Wind it in five or six neat layers. Slip thin plastic spaghetti over the start and finish leads so that the spaghetti is held well inside the bobbin. As you finish winding each layer, insulate it with 1 mm mylar sticky tape (if you can obtain it) or electrical insulation tape (a bit heavy, but it will do the job). Wind the next layer on the insulation of the previous layer, etc, until you finish the winding. Wind several layers of insulation over the completed secondary. Leave the start and finish wires protruding from different sides of the bobbin so that they exit via different slots of the assembled potcore.

Wind the primary over the secondary; it can be wound bifilar (two wires together, five turns, connect finish of one to start of other to provide centre tap) or in one winding — but don't forget the centre tap. Wind the primary so that its wires exit the potcore opposite the secondary wires.

In operation, if you have breakdown problems (arcing sounds inside the potcore) it means you have not wound or insulated your secondary carefully enough and you'll have to rewind the transformer.