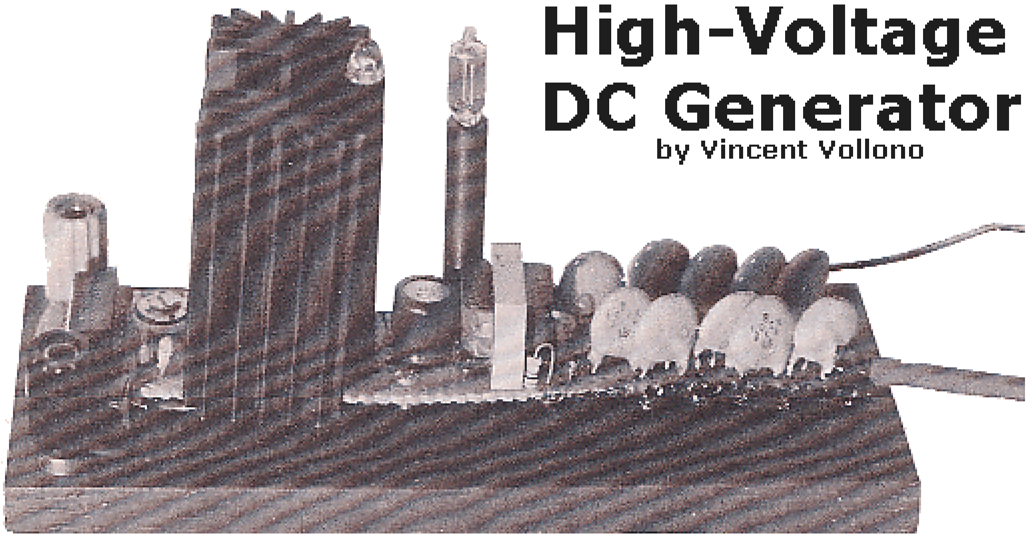


"Learn how very-high voltages are generated from relatively low power sources and apply the same techniques to your own experimental circuits."

Rewritten by Tony van Roon (VA3AVR)

Voltage, by definition, is the electrical pressure that causes current to flow through a conductor. When that pressure is sufficiently high, a high voltage is produced. But how do we define high-voltage? Is 100, 1000, or 10,000 volts considered high voltage? When compared to 10 volts, they all can be considered high voltage. As far as safety goes, high voltage can be considered any voltage that endangers human life. It's obvious that 1000 volts poses a greater hazard than does 100 volts, but that does not mean that 100 volts is safe to handle. As far as safety goes, 100 volts is still considered high voltage--and that fact must be understood.
The *Miniature High-Voltage DC Generator*, presented in this article, is capable of generating around 10,000-volts DC. So high a voltage can ionize air and gases, charge high-voltage capacitors, and also be used to power a small laser or image tube, and has many other application that are useful to both the experimenter and the researcher.

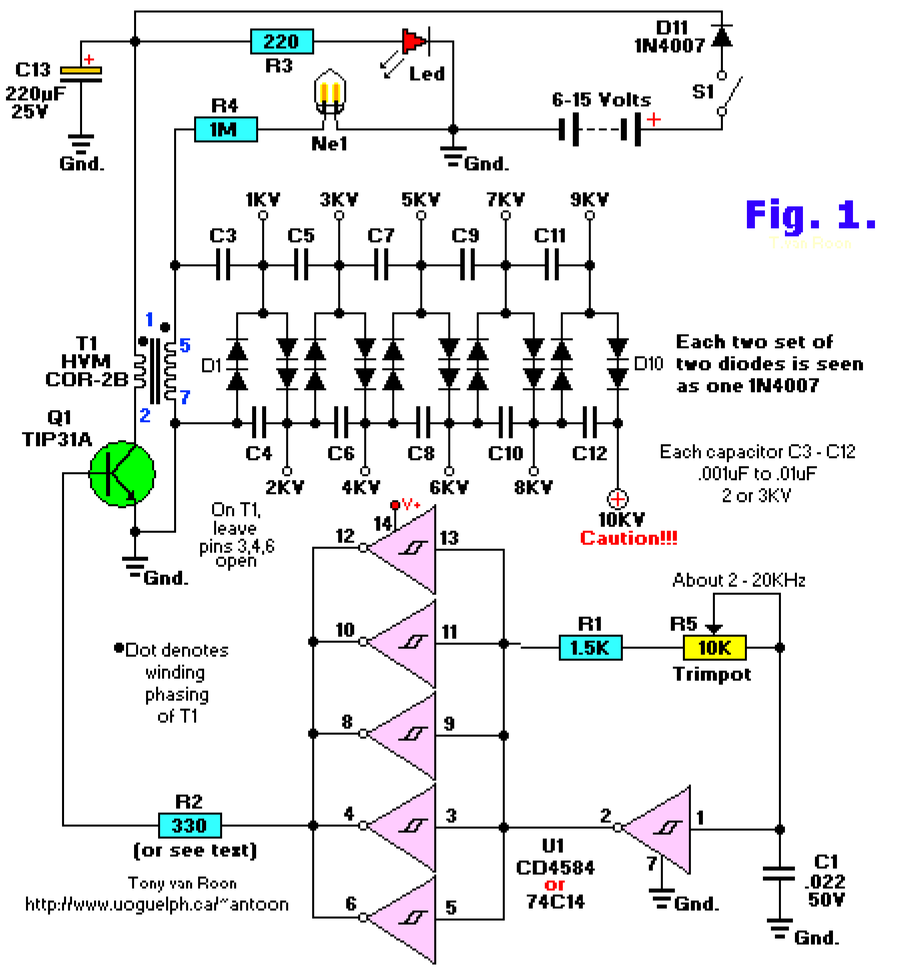
Circuit Description:
Figure 1 is a schematic diagram of our Miniature High-Voltage DC Generator. The circuit is fed from a 12-volt DC power supply. The input to the circuit is then amplified to provide a 10,000 volts DC output. That's made possible by feeding the 12-volts output of the power supply to a DC-to-DC up converter. The output of the up converter is then fed into a 10-stage, high-voltage multiplier to produce an output of 10,000-volts DC.
Let's see how the circuit works. First, let's start with U1 (a 14584 hex Schmitt trigger). Gate U1-a is set up as a square ware (pulsating DC) output. The output of U1-a is fed to the input s of U1-b to U1-f, which are connected in parallel to increase the available drive current.
The pulsating output of the paralleled gates is fed to the base of Q1, causing it to toggle on and off in time with the primary winding of T1. The other end of T1 is connected directly to the positive terminal of the battery or power supply. This produces a driving wave in the primary winding of T1 that is similar to a square wave.
The on/off action of the transistor, caused by the pulsating g-signal applied to Q1, creates a rising and collapsing field in the primary winding of T1 (a small ferrite-core, step-up transformer). That causes a pulsating signal, of opposite polarity, to be induced in T1's secondary winding.
The pulsating DC output at the secondary winding of T1 (ranging from 800 to 1000 volts) is applied to a 10-

stage voltage-multiplier circuit--consisting of D1 through F10, and C3 through C12. The multiplier circuit increases the voltage 10 times, producing and output of up to 10,000-volts DC. The multiplier accomplishes its task by charging the capacitors (C3 through C12), through the diodes (D1 through D10), the output is a series addition of all the capacitors in the multiplier.

In order for the circuit to operate efficiently, the frequency of the square-wave, and therefore the signal applied to the multiplier, must be considered. The output frequency of the oscillator (U1-a) is set by the combined values of R1, R5, and C1 (which with the values specified is approximately 15KHz).

Potentiometer R5 is used to fine tune the output frequency of the oscillator. The higher the frequency of the oscillator, the lower the capacitive reactance in the multiplier.

Light Emitting Diode Led serves as an input-power indicator, while neon lamp NE1 indicates an output at the secondary of T1. A good way to get the maximum output at the multiplier is to connect an oscilloscope to the high-voltage output of the multiplier, via a high-voltage probe, and adjust potentiometer R5 for the maximum voltage output. IF you don't have the appropriate test gear, you can place the output wire of the multiplier about a half-inch away from a ground wire and draw a spark, while adjusting R5 for a maximum spark output.



In the High-Voltage DC Generator, the input to the circuit, taken from a 12-volt DC power supply, is magnified to provide a 10,000-volt DC output. There's no C2.

Parts List, Fig. 1

All resistors are 1/2-watt, 5%, unless otherwise noted

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R1 = 1K5 (1.5K) (brown-green-red)
R2 = 300 ohm    (orange-black-brown)
R3 = 220 ohm    (red-red-brown)
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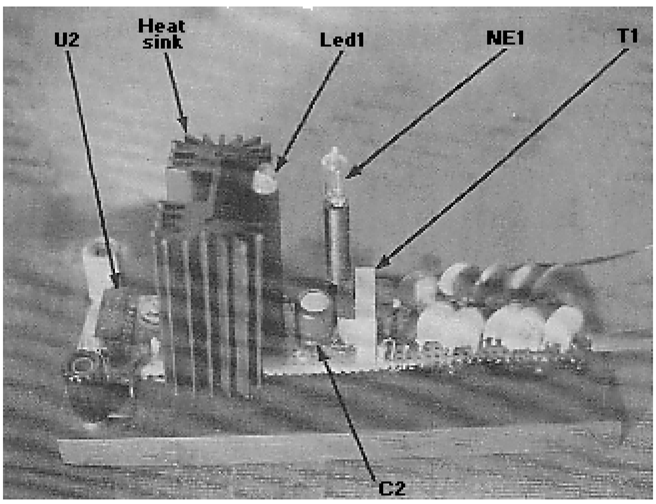
R4 = 1 mega ohm (brown-black-green)
R5 = 10K potentiometer

Capacitors
C1 = 0.022uF, 50WVDC metalized film
C2 = none, omitted.
C3-C12 = 0.001uF, 2000WVDC ceramic disc
C13 = 220uF, 25V, electrolytic
C14 = 4700uF, 35WVDC, electrolytic

Semiconductors
D1-D10 = 1N4007, 1A, 1000PIV, silicon rectifiers connected in series (see text)
D11 = 1N4007, 1A, 1000PIV, silicon rectifier
Q1 = TIP31A, NPN, Darlington transistor
U1 = MC1458BAL hex, inverting Schmitt trigger, IC
BR1 = 6A, 50PIV, full wave bridge rectifier
Led1 = Jumbo green light emitting diode

Other Components
Ne1 = Ne-2 type neon lamp
T1 = HVM COR-2B, Ferrite core step-up transformer (see text)
T2 = 12 Volt, 2A, power transformer
PL1 = 117 volt AC plug with line cord
Perfboard materials, enclosure, battery, heat sink, IC sockets, battery, wire,
Battery, Battery holder, solder, hardware, etc.

Caution:
The output of the multiplier will cause a strong electric shock. In addition, be aware that even after the multiplier has been turned off, there is still a charge stored in the capacitors, which, depending on the state of discharge, can be dangerous if contacted. That charge can be bled off by shorting the output of the circuit to ground. (In fact, its a good idea to get in the habit of discharging all electronics circuits before handling or working on them).
Also, U1 is a CMOS device and, as such, is static sensitive. It can handle a maximum input of 15 volts DC. Do not go beyond the 15-volt DC limit of the IC will be destroyed. Diode D11 is used to prevent reverse polarity of the input voltage source.
As far as the voltage multiplier goes, the diodes and the capacitors must be rated for a t least twice the anticipated input voltage, So, if we have a 1000-volt input, all of the diodes and the capacitors must be rated for at least 2000 volts each. Because diodes with that voltage rating can be hard to find and expensive, D1 through D10 are each really two series-connected 1-amp, 1000-volt rectifier diodes.



In the author's prototype, Led1 and NE1 were mounted to 1-1/2 inch stand-offs, and the entire circuit (minus the powersupply) was mounted to a block of wood. The wood block helps to isolate the circuit board from any metallic objects

Construction:
The unit can be assembled on perfboard, as is the case with the author's prototype shown in the photo.
Transistor Q1 must be properly heat sinked or it will overheat quickly and self destruct.
The multiplier must be assembled in such a way so as to prevent any ion leakage. When a high-voltage source is terminated at a sharp point, the density of charge is concentrated at that point. The ions both on the point and near the point are like charges, so they repel each other and quickly leak off. So it is very important when soldering he multiplier to keep all connections rounded by using enough solder to make a smooth, ball-like joint.
The solder-side of the multiplier should be insulated to

prevent contact with any metallic object. On the author's prototype, a high-voltage insulating compound was used on the solder side of the board. High-voltage putty can also be used. Also in the prototype, the output of the circuit is simple a heavily shielded wire, like that used to feed high-voltage to the anode on a TV picture tube. That type of wire can safely handle voltages in the 15,000-to-20,000 volt range, and will also help to prevent leakage.

Positive and Negative Ions:
The polarity of the diodes in the multiplier will determine the polarity of the ions. In the author's prototype, the multiplier is set up to generate positive ions. If the diodes were reversed, negative ions would be reproduced.
In a positive-ion generating multiplier, like that used in the author's prototype, which generates approximately 10,000 volts DC, the output is a shock hazard. A negative-ion generating multiplier with a -10,000 volt DC output, offers the same shock hazard as the positive +10,000volt output.

Experiments:
If you place the high-voltage output wire about 1/2 to 3/4 inch from a ground wire, you will draw a spark of 10,000 volts. But remember, the oscillator is built around a CMOS device, which is static sensitive, and any high-voltage kickback will toast the unit. So when experimenting with the spark, do not use the circuit ground. A more reliable method would be to draw a spark to an **earth ground**.
Flash Lamp Electric Storm. When the output of the Miniature High-Voltage DC Generator is connected to a small flash tube, the high voltage ionized the Xenon gas in the tube, creating small electrical storm within the tube's glass envelope.
Getting Different Voltages. By tapping the multiplier circuit at various stages you'll get output voltages ranging from 1,000 volts to 10,000 volts DC. For instance, by placing a tap at the cathodes of D2, D6, voltage of 2000 and 6000 volts are made possible.

Troubleshooting:
If you get no output or a low output from the circuit, check that the input to logic gates is below 15 volts. The application of an input voltage exceeding that limit will blow out the IC. Also check the signal (with an oscilloscope) that you get a square-wave output of approximately 12KHz at pin 6 of U1
The switching transistor must be mounted on a heat sink or it will over-heat. Make sure the heat sink is of a suitable size to keep the transistor cool.
If a 2-KV diode is placed at the output of transformer T1, you should get an unloaded output of approximately 800 to 1000 volts DC. If you have a problem with the output of the unit, it is best to disconnect the multiplier from the oscillator and check the output of the transformer. In that way you will know if the problem lies in the oscillator of the multiplier.
The multiplier components must be rated for at least twice the input voltage. The diodes and capacitors used in the multiplier circuit should be rated at 2000volts. However, you may choose to do as the author did; use two series-connected 1-KV units for each diode in the multiplier to five an effective rating per pair of 2KV.

Safety:
The output of the circuit is high-voltage DC, which will cause an electric shock if touched. So use caution. Also with the circuit turned off, the capacitors in the multiplier are still charged, and will discharge through the path of least resistance--your body--if you come in contact with the circuit. So discharge the circuit by connecting the output lead to ground with the power off.
The Miniature High-Voltage DC Generator emits a fair amount of ozone. If the circuit is to be operated for a long period of time, make sure that you do so in a well ventilated room. Ozone is harmful in moderate to large quantities.
When drawing a spark discharge, the circuit emits radio and television interference (RFI). That can be seen as static lines on your television set or heard as noise on your AM radio.

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Re-written and re-drawn by Tony van Roon.

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