Experimenter's Corner

By Forrest M. Mims

HIGH-VOLTAGE DC/DC CONVERTERS

IN THIS day of low-voltage semiconductor circuits that are often battery-powered, electronics experimenters rarely use more than 10 or 15 volts for their projects. But, although vacuum-tube projects are becomingly increasingly rare, there are still many requirements for high voltages in modern circuits. For example, neon lamps require 60 to 70 volts, semiconductor laser pulse power supplies require up to several hundred volts, and xenon flash tubes require several hundred discharge volts and several kilovolts of trigger potential. Other high voltage components include photomultiplier tubes, helium-neon laser tubes, and image converters.

Some of the more exotic components that require a high operating potential are far too expensive for the average hobbyist, but many HV components are readily available. Advertisers in this magazine regularly offer such goodies as neon glow lamps, laser tubes, laser diodes, Panaplex™ displays, and assorted HV capacitors, SCR's, triacs, and rectifiers.

Several different circuits can be used to generate the high voltages required by these and other components. The most common up-converters are powered by household line current. This, of course, poses a safety problem in addition to the HV output and limits portability to the length of the power cord. For this reason miniature solid-state dc-to-dc voltage converters that operate from low-voltage batteries are very popular with both engineers and experimenters who require a high-voltage power supply.

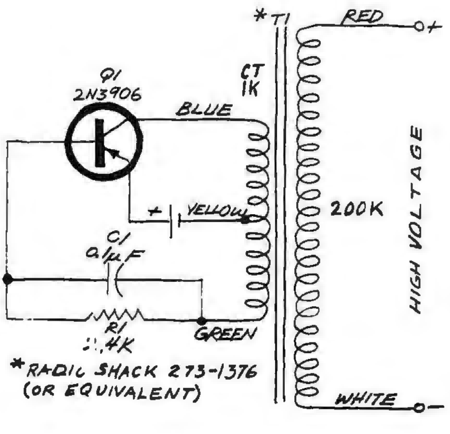

Fig. 1. Simple dc/dc converter.

Dc-to-dc Converters. Let's examine two very simple dc-to-dc converters that can be used in low-current, high-voltage applications. The first circuit, shown in Fig. 1, is ultra-simple and illustrates the miniaturization potential of a solid-state high-voltage power supply.

The circuit is a modified Hartley oscillator that uses an ordinary audio input transformer for the inductor. The low-impedance, center-tapped secondary supplies the feedback required to start and maintain oscillation. The pulses generated by the oscillator pass through the secondary winding, where they are inductively coupled into the primary. The transformer steps up the input from a few volts of steady dc to several hundred volts of rapidly pulsating current.

To give some idea of the performance of this potent circuit, here's a table of the outputs I measured for a range of input voltages:

Input (volts)	**Output** (volts)
0.5	1
1.0	200
2.0	440
3.0	625
4.0	800
5.0	900
6.0	1000

These potentials were measured under open-circuit conditions. When the converter is connected to an output device, the subsequent load will reduce the output voltage. Nevertheless, the performance of the circuit is quite impressive. Incidentally, with the component values specified, the oscillator frequency ranged from 344 to 574 Hz over the range of input voltages. The pulse width was a relatively constant 150 µs.

The current output of this circuit is minuscule, but it can easily ionize a neon lamp or power a semiconductor laser power supply. It can also operate the simple neon-lamp relaxation oscillator shown in Fig. 2. This circuit will flash about once a second with the component values shown. In operation, *C1* charges through *R1* until the breakdown voltage of *I1* is reached. When *I1* fires, *C1* discharges through *I1*, and the cycle repeats. Diode *D1* keeps *C1* from discharging back through the transformer winding.

A single 1.5-volt cell will provide enough power when using the dc-to-dc converter to operate neon lamps. Since a neon lamp requires 60 to 70 volts for operation, this provides an impressive demonstration of the circuit's high-voltage capability.

The current drain of the Fig. 1 circuit connected to the neon flasher in Fig. 2 is fairly low. The circuit draws 12.3 mA from a fresh D cell at 1.5 volts, 8.3 mA from a fully charged 1.2-volt nickel-cadmium cell, and only 6.8 mA from a 1-volt source.

The simple circuit in Fig. 1 is typical of most dc-to-dc converters in that the transformer plays an active role in both the oscillator and HV sections of the circuit. Dc-to-dc converters can also be designed so that the transformer functions strictly as a voltage converter. One possibility is shown in Fig. 3, where a unijunction transistor oscillator is connected to a high-turns-ratio input transformer like the one used in Fig. 1. The oscillator produces a series of fast risetime pulses each time *C1* discharges through the emitter-to-B1 junction of *Q1*. The pulses are passed through the low-impedance winding of the transformer

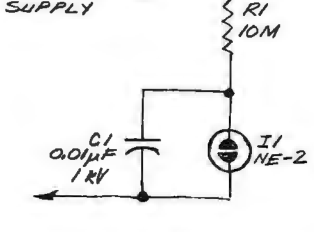

Fig. 2. Neon relaxation oscillator.

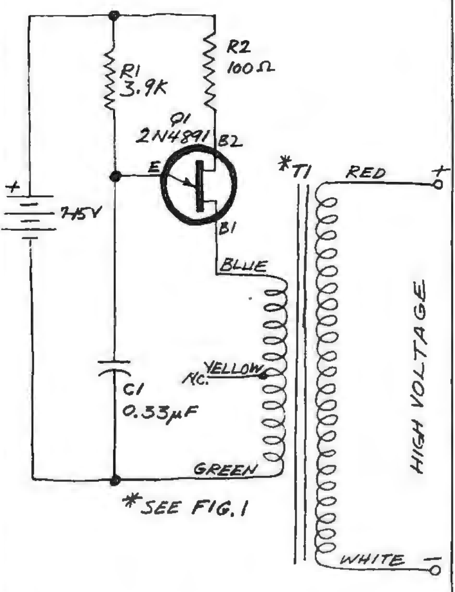

Fig. 3. UJT dc/dc converter.

and induced into the high-impedance winding as high voltage pulses.

Due to the presence of the unijunction transistor, the circuit in Fig. 3 requires a higher operating voltage (7 to 15 volts) than the circuit in Fig. 1. But at 10 volts the circuit will operate the neon flasher in Fig. 2 with a current drain of only 0.5 mA. This corresponds to a total power consumption of about 5 mW versus about 18 mW for the previous circuit.

Conclusion. The two simple dc-to-dc converters described in this column are adequate for powering neon lamps, diode-laser pulse generators, and other low-current devices. If you have access to an oscilloscope, you can watch the output voltages while tinkering with the values of *R1* and *C1* in both circuits to optimize the operating conditions. More powerful converters are required for many HV applications, and a subsequent column will continue this interesting subject with a couple of additional dc-to-dc converters.

Meanwhile, try experimenting with the circuits described here to get experience. Finally, always use care when experimenting with *any* high-voltage circuit. Small size and low battery voltage mean little when high voltage is present! A low-current shock may not harm you, but the resulting reflex jerk may injure a hand, arm, or elbow and knock items from your workbench. A high-current shock, such as from a charged capacitor, can be fatal. ◈