Experimenting with Electronic Flash Circuits

By Forrest M. Mims, III

THE brilliant white light emitted by a xenon flash tube has many practical applications. It's used for photographic illumination, solar simulation, and laser stimulation optical (pumping of laser materials), as well as for many kinds of safety, rescue, and warning lights.

Though specially designed high-pressure xenon lamps can be operated continously if suitable cooling is provided, most xenon-filled lamps are operated in a flash mode. Such lamps can have many different configurations. A few have envelopes of metal and glass, but most are glass cylinders or bulbs containing discharge and trigger electrodes. The cylinder configuration, the most common of all, is merely a hollow glass or quartz tube with an electrode at each end.

Cylindrical xenon flash tubes can be as small as a matchstick or, in the case of very high-power glass lasers used in fusion research, as big as a fence post. The glass tubes can be straight or shaped in the form of an L, U, or spiral.

Figure 1 is a block diagram of the essential ingredients of a circuit for operating a xenon lamp in the flash mode. A high-voltage supply simultaneously charges a large energy storage capacitor and a much smaller trigger capacitor. After the main capacitor is charged, the lamp is flashed by dumping the charge on the trigger capacitor through the primary of the trigger transformer. The high-voltage spike appearing at the secondary of the transformer is coupled to a small metal strap or wire wrapped around the flash tube.

This voltage spike ionizes some of the gas within the tube and provides an electrically conductive path for the charge in the main capacitor. The capacitor then discharges through the tube and excites the xenon atoms into emitting an intense white flash.

Figure 2 is a circuit that implements the operation of the block diagram in Fig. 1. Note that *C1*, the main energy storage capacitor, is connected directly across the flash tube. No leakage of charge occurs since the xenon does not conduct unless it is first ionized by a voltage higher than that across *C1*.

After both *C1* and *C2* are charged, the flash tube is triggered by closing *S1*. This dumps *C2*'s charge through trigger transformer *T1*'s primary. Since *T1* has a very high turns ratio, several thousand volts appear across its secondary. This voltage is coupled to the flash tube's trigger electrode where it ionizes some of the xenon gas and provides a low resistance path for the energy stored in capacitor *C1*.

The discharge of *C1* through the xenon is accompanied by a brilliant flash of light. The xenon resumes its nonconductive state immediately after *C1* is discharged. As soon as *C1* and *C2* are recharged, *S1* can again be closed to obtain another flash.

The energy in joules stored in the main flash capacitor is one-half the product of the capacitance and the square of the voltage. For example, a 400-μF photoflash capacitor charged to 350 V has a stored energy of 24.5 joules.

The duration of the flash is determined by the RC time constant of the flash capacitor and the discharge path

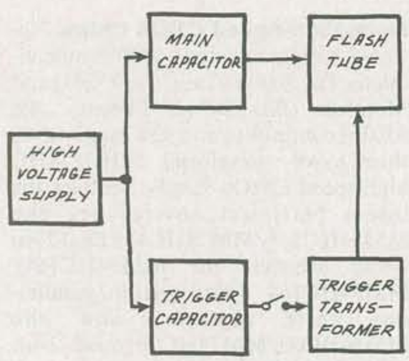

Fig. 1. Block diagram of a flash-tube trigger circuit.

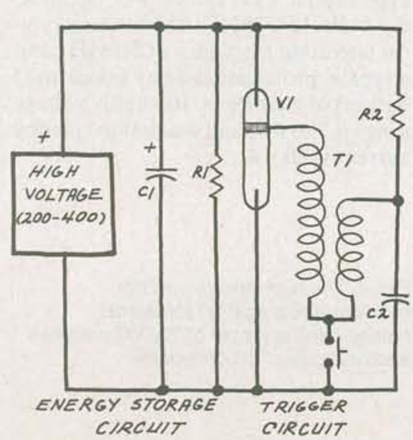

Fig. 2. Basic flash-tube circuit.

through the flash tube. Sometimes intervening networks are included to shape the discharge event into a square pulse with fast rise and fall times.

A very large C implies a long discharge time and, hence, a long flash. For short flashes it is necessary to use small values of C. To obtain equal illumination, V must then be increased. For example, to match the 24.5 joules in the preceding example, a 10-μF capacitor would have to be charged to 2.214 kV.

Alternatively, the flash can be electronically ended at almost any time by an appropriate solid-state switch. This is the method used by "computer" strobe flashes so popular with photographers. Thus, fast pulses are obtained with low energy levels. One plus is that the energy remaining in the capacitor can be used for one or more subsequent flashes, thereby extending battery life and reducing recycle time.

You may be wondering why *R1* is included in the circuit in Fig. 2 since it plays no role in the charge-discharge cycle. Its only role is to bleed the charge from *C1* should the high-voltage supply be turned off. Even if the flash tube is triggered *after* the high-voltage supply is turned off, some residual charge may remain in *C1* which will be discharged through *R1*.

The circuit will operate without *R1*, but including it is a very important safety precaution. The hazards of the high voltage required to operate xenon flash circuits are so profound that it's important to discuss them in detail before looking at some working circuits you may wish to assemble.

Important Flash Tube Precautions. Though the power supplies of some specialized xenon flash units may deliver several thousand volts, most produce from 150 to 500 V. You should, therefore, exercise considerable caution when working with such circuits. *Always* keep one hand well away from the circuit to prevent a potentially dangerous or even lethal through-the-body shock.

You can eliminate the shock hazard of a high-voltage supply simply by disconnecting the power. But this alone will *not* eliminate the hazard posed by capacitors that may have been charged by the supply. For example, in Fig. 2 the high voltage is stored in both *C1* and *C2*.

Capacitor *C2* usually has a capacity of a few tenths of a microfarad, but *C1* may have a capacity of several *hundred* microfarads. Therefore, *C1* poses far more of a hazard than *C2*. A charge of several hundred volts on a capacitor of several hundred microfarads is enough to vaporize and melt away a small crater in a steel screwdriver tip! Since considerable residual charge can be retained by such a capacitor for hours, days or even weeks, it is imperative that you treat all photoflash capacitors with the respect due a loaded gun. *Never* handle this kind of capacitor without first discharging it by bridging across its terminals the blade of an insulated screwdriver, or a power resistor with well insulated leads. Use only one hand to bridge the capacitor terminals and be sure the capacitor is *fully* discharged before handling it.

Charged photoflash capacitors are so hazardous that even taking precautions sometimes does not help. For example, ten years ago I was experimenting with a voltage divider I had assembled from a string of 10-μF, 450-V capacitors. The input to the multiplier was connected to a 350-V miniature power supply powered by a 3-V battery. The output from the multiplier was about 1000 V.

Because of the shock hazard, I followed the traditional safety practice of keeping one hand in my pocket. All went well until the springy ladder of capacitors and diodes suddenly slid from the workbench and into my lap. I grabbed one end of the multiplier with my free hand just as its high-voltage output lead touched my pants. Suddenly there was a loud pop and a puff of smoke, and a terrific jolt threw me to the floor. I was not only "shocked," but got a bad burn on my leg to boot. Suffice it to say that this unsettling experience left a lasting impression on me about the hazards of charged capacitors.

A Single-Shot Flash Circuit. Figure 3 shows a single-shot flash circuit designed around commonly available components. Transformer *T1* is a standard filament transformer. Transistors *Q1* and *Q2* form a simple oscillator. In operation, the fast-risetime pulses from the oscillator are directed through the 6.3-V winding of *T1*. When powered by a 1.5-V dry cell, the initial part of the output pulse appearing at *T1*'s 120-V winding has a peak potential of about 170-V and a duration of about 40 ms. The pulse amplitude then falls to about 100 V for the remainder of the 110-ms pulse.

The high voltage from *T1* is stored in *C2* and *C3*. Diode *D1* prevents these capacitors from discharging through *T1*. Resistor *R3* is a bleeder resistor that discharges *C2* and *C3* should the power supply be turned off.

The very high voltage required to ionize the xenon in flash tube *V1* is provided by *T2* and *C4.* Capacitor *C4* is charged through *R2* to the power-supply voltage. When *S2* is closed, *C4* is discharged through *T2*'s primary. A spike of several kilovolts then appears at *T2's* secondary and ionizes the gas in *V1.* Capacitors *C2* and *C3* are then discharged through *V1.* After *C2, C3* and *C4* are recharged, closing *S2* will initiate a second flash.

The only specialized components in this circuit are *T2* and *V1,* both of which can be purchased from various electronic parts suppliers. Various kinds of flash tubes and trigger transformers may have different pin orientations, so none is shown in Fig. 3. Be sure to follow any pin outlines provided with the components you purchase. The high-voltage output of *T2* is often indicated by a red dot and the primary is of heavy wire.

If you build this circuit, be sure to observe carefully all relevant safety precautions. *Never* touch any connections or leads in the boxed high-voltage section shown in Fig. 3.

An Automatic Flashing Strobe. The circuit in Fig. 4 automatically discharges a pair of capacitors through a flash tube every 1 to 2 seconds. In operation, the output from a 555 oscillator is directed through the 6.3-V winding of *T1.* When powered by a 9-V battery, a 200-V square wave appears at *T1*'s 120-V winding. Components *D1, D2, C2* and *C3* form a voltage doubler that rectifies, increases, and stores this voltage.

Resistor *R6* charges *C4* to the power-supply voltage. When the voltage reaches neon lamp *I1*'s turn-on point (80 to 100 V), *C4* begins to discharge through the primary of *T2* and *I1.* Simultaneously, *SCR1* is turned on by the voltage appearing across the lamp. *SCR1,* which should be rated for 400 or more volts, provides a very low-impedance path between *T2* and *C4.* The resulting high-voltage spike across *T2*'s secondary ionizes the gas in *V1,* thus providing a low-impedance path for discharging *C2* and *C3.* After the resulting flash, *C2, C3,* and *C4* begin recharging until the trigger cycle is repeated.

Because the flashes are bright enough, this simple circuit can be used as a warning light. For brighter flashes, *C2* and *C3* can both be increased. The flash rate, however, will be reduced.

If the circuit fails to flash, *I1* may be switching on at a voltage below that required to prove sufficient ionization potential across *V1.* Try another neon lamp. You may also try connecting two or more neon lamps in series to increase the ionization potential. Another cause of circuit malfunction is low-impedance leakage paths between ground and the high-voltage output from *T2.* These paths may be direct ones between exposed or poorly insulated wire leads, or may be formed by moisture and contamination on circuit boards. Even the glass surface of the flash tube itself may act as a leakage path.

Be sure to follow the safety precautions given for the previous circuit. Remember that the boxed portion of the circuit is potentially hazardous.

Going Further. After you have experimented with the basic flash circuits in Figs. 3 and 4, you may wish to replace the bulky filament transformer (*T1*) with a more compact dc-dc converter transformer like those used in photographer's strobe units. You can buy such transformers, but you can also salvage them along with flash tubes, trigger transformers, photoflash capacitors, etc. from defective or surplus flash units.

I have a stock of a dozen such flash units purchased for a few dollars each at the camera department of a discount store. Using the oscillator circuit and other components salvaged from these units, I have built half a dozen miniature automatic flashers.

A typical unit is installed in a plastic case measuring about 1″ × 2″ × 3″. The reflector assembly and xenon lamp are protected by a yellow plastic filter. The unit's AA NiCd cells are recharged by a homemade solar battery. This unit clips on my bicycle shorts or bike packs and has accompanied me on many long distance cycling trips over the past five years.

Should you attempt to build such a flasher or work with salvaged flash units, be especially careful of the high voltage generated by these units. It is *essential* that you discharge the main capacitor *and* turn off the power before attempting to disassemble or modify such a device. Make sure the batteries are disconnected or removed before beginning work. For automatic flasher units, you will want to replace the large photoflash capacitor with one that is no more than 10 to 20 μF and rated for the proper voltage (usually 450 V). ◇

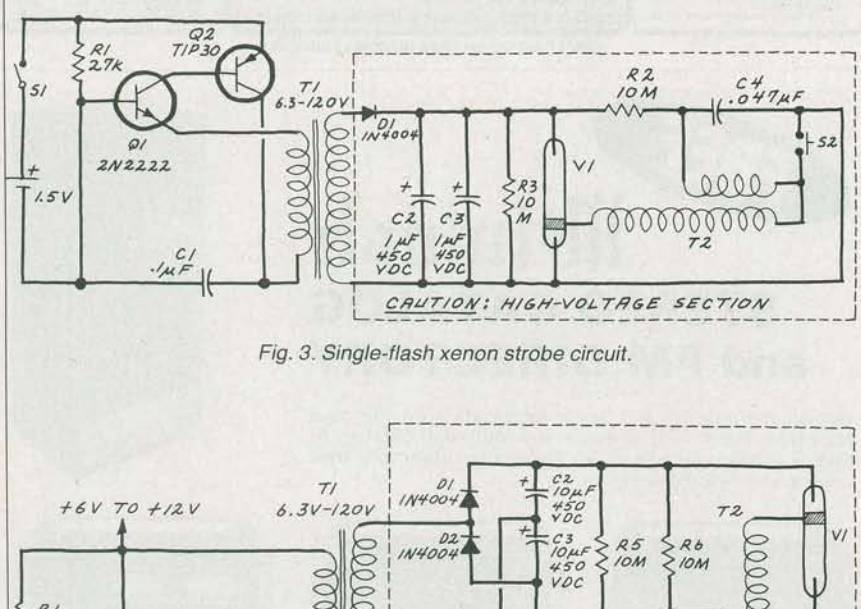

Fig. 3. Single-flash xenon strobe circuit.

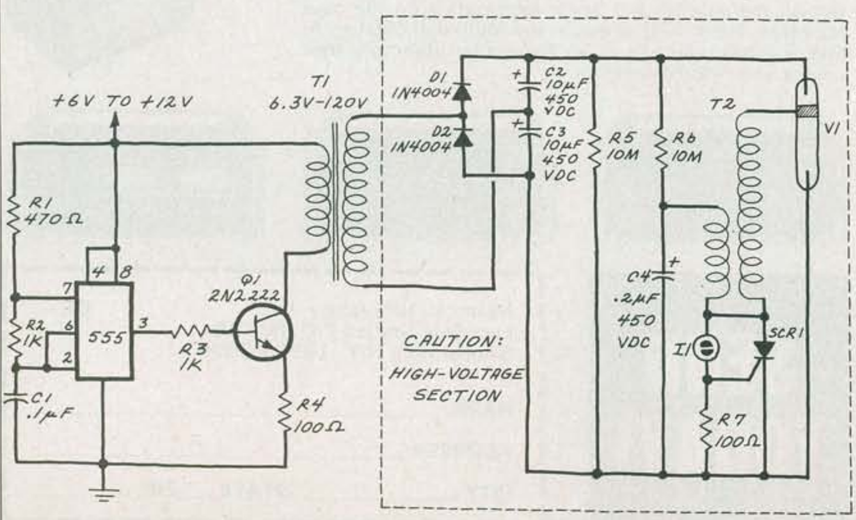

Fig. 4. Xenon strobe flasher circuit.