flash tubes

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UNDERSTANDING AND GETTING THE MOST FROM STROBES

OPERATION & APPLICATIONS

IT IS a simple device, the flash tube; but it is often regarded with awe—perhaps because many people don't understand just how and why it operates. A flash tube is nothing but a sealed glass or quartz tube, filled with an inert gas (such as xenon) and having an electrode at both ends. The tube is unique in that it can provide a white light of high intensity for a very short time, which makes it ideal for use in vehicle and obstruction warning lights, high-speed photographic accessories, ignition timers and stroboscopes. It is also useful because it comes in a range of sizes: from a 1-inch tube for portable electronic flash attachments to 15-inch water-cooled units for pumping high-energy lasers.

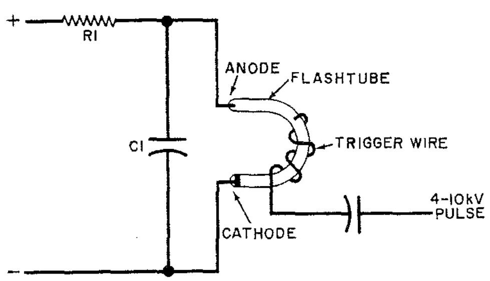

Fig. 1. In basic flash-tube circuit, C1 discharges through tube, after a trigger pulse partially ionizes gas.

So, how about the circuit that provides the driving voltage for a flash tube? It is also simple; a typical one is shown in Fig. 1. A high-voltage dc source (300 to 3000 volts) puts a charge on capacitor *C1* through series resistor *R1*. A thin wire (called the trigger) is wrapped around the tube and connected to a high-voltage pulse source. When a trigger pulse occurs, some of the xenon in the tube is ionized, allowing some electrons to flow through the gas. When this occurs, the remainder of the gas in the tube is ionized and the capacitor discharges quickly through the tube. The result is a flash of bright light.

The flash tube remains in the conducting state until the storage capacitor is fully discharged. Series resistor *R1* prevents the power supply from providing enough current to keep the gas ionized after the flash. This avoids what is called "holdover", which can destroy the tube when it occurs.

Determining Flash Duration. When the flash tube is in the conducting state, it has a very low resistance (about 6 ohms for a tube of short length) and this value is used to determine the flash duration. An approximate equation is $T = RC/2$, where T is the flash duration in seconds, C is the value of the storage capacitance in farads, and R is the equivalent resistance of the tube in ohms. The equivalent resistance of the tube depends largely on the distance between the cathode and anode electrodes, so the longer the tube, the higher the resistance.

For conventional photographic work, a flash duration of approximately 1 millisecond is required. For this application, then, a high capacitance and high flash-tube resistance are required.

When the xenon is ionized, an electron of a xenon atom is raised from its "ground" (lowest) state to some excited state. The atoms can only remain in the excited state for approximately 9 nanoseconds. When the atoms return to the ground state they radiate energy in the form of light or photons. According to Planck's Law ($E = h\nu$), the frequency of the photons is directly proportional to the energy state of the atoms. Since the excited atoms are in discrete, or "quantized" energy states, the resultant photons are of discrete frequencies.

Flash tubes are usually manufactured in three styles: linear, U-shaped, and helical. Parameters are generally specified according to: minimum-to-maximum voltage across the tube, minimum trigger voltage required to start gas ionization, maximum energy per flash, maximum average power dissipation per tube, and usable lifetime of tube. These parameters are determined by the tube's physical construction: arc length, tube diameter, type of electrodes, and gas pressure.

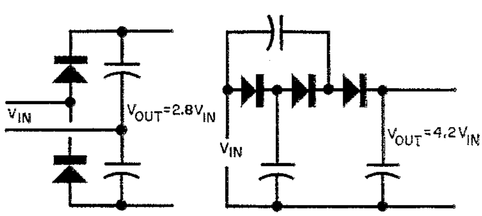

Fig. 2. To attain necessary high voltage, doubler and tripler circuits are used in the tube power supplies.

The amount of light energy released can be determined by knowing the potential energy stored in the capacitor. This can be found from the equation $E = \frac{1}{2}CV^2$, where E is the energy in joules or watt-seconds, C is the value of the capacitor in farads, and V is the voltage across the capacitor.

The total power dissipation of the flash tube is equal to the energy per flash times the number of flashes per second. However, the designer must be willing to trade off maximum energy per flash for the maximum number of flashes per second so that he does not exceed the power dissipation of the tube. If maximum ratings are exceeded, the shock waves in the gas could cause the tube to crack or shatter.

Energy Supplies. Between 300 and 600 volts dc are required to power the most common types of flash tubes. A voltage doubler (or tripler) such as that shown in Fig. 2 will serve the purpose well. Since the capacitor must discharge quickly, its internal resistance increases the flash duration and generates heat within the capacitor. Special flash-type capacitors are available, but conventional electrolytic capacitors may

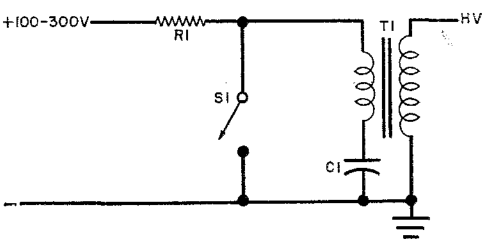

Fig. 3. When S1 is closed, C1 discharges through primary of transformer producing the high-voltage spike.

be used. (However, the latter require replacement since the heat eventually vaporizes some of the electrolyte.)

Like most light sources, the lifetime of a flash tube is limited. Each time the tube is flashed, ions bombard the cathode and cause some of the cathode material to be atomized and deposited on the inner surface of the tube. This deposited material forms a black area near the cathode; and, as the cathode element is used up, the black area grows. Eventually, the point is reached where the flash tube either does not fire or fires erratically. Depending on the tube's cathode structure, the operational life is between 5000 and 1,000,000 flashes. Of course, operating a flash tube below its maximum rating greatly increases its useful life.

Trigger Circuits. The basic trigger circuit is shown in Fig. 3. When switch *S1* is open, the high-voltage dc charges capacitor *C1*

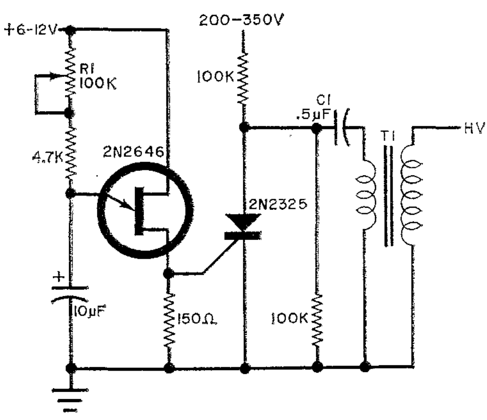

Fig. 4. Here, a UJT is used to control an SCR, which acts to discharge C1 through the primary of transformer.

through series resistor *R1*. When *S1* is closed, the charge stored in *C1* rapidly discharges through the primary of step-up transformer *T1*, generating a pulse on the secondary of 4000 to 6000 volts. An automatic pulser, using a UJT to trigger an SCR is shown in Fig. 4.

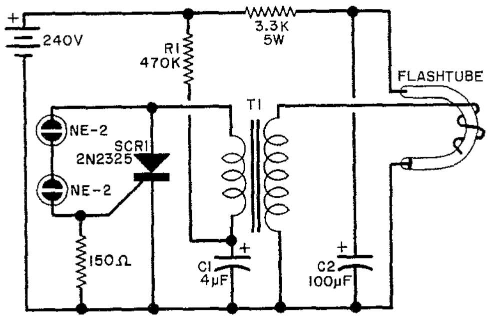

Fig. 5. In battery-operated flasher, two neon lamps flash over to turn on SCR. C1 and R1 set the firing rate.

The design of a portable strobe can be greatly simplified if a high-voltage battery is used instead of the line-operated supply. A #491 battery, rated at 240 volts, is used in the circuit shown in Fig. 5. This battery will last for several hours of flashing.

The triggering rate is determined by the time constant of *R1C1*. As the charge on *C1* approaches 240 volts, the combined ionization voltage of the series-connected neon lamps is eventually reached so that they turn on, thus triggering *SCR1*. This

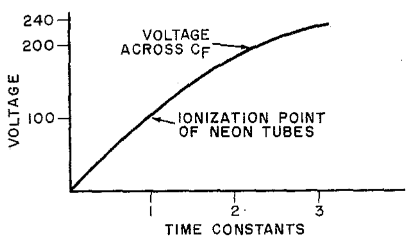

Fig. 6. Voltage across capacitor increases with time constant until the firing point of neon tubes is reached.

causes *C1* to discharge rapidly through the primary of *T1*. The pulse on the secondary of *T1* triggers the flash tube.

The energy input to the tube is $E = ½CV^2$ or $½(100 \times 10^{-6})(240)^2 = 2.88$ joules. The time constant of *R1C1* is 0.47 × 4 or 1.88 seconds. As shown in Fig. 6, after a period of about 1 time constant, the voltage on the neon lamps is sufficient to turn them on, thus firing the SCR.

A typical camera strobe circuit is shown in Fig. 7, while Fig. 8 illustrates an ignition timer lamp.

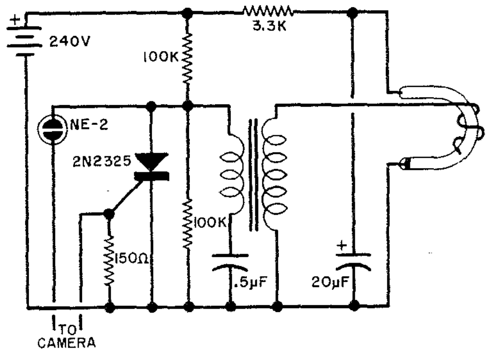

Fig. 7. Typical electronic flash for camera. Closing camera leads causes SCR to conduct, thus triggering tube.

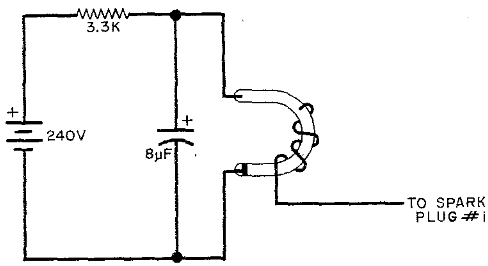

Fig. 8. In this simple engine timing light, the high-voltage pulse at the spark plug triggers the flash tube.

Caution. There is some medical evidence that exposure to strobe rates of from 6 to 10 flashes per second could cause an epileptic fit, even in a person without a previous history of epilepsy. Therefore, extreme caution must be used in building and operating strobes—not only by the builder but by any other observers as well.

From the electrical standpoint, caution must be used due to the high voltages involved in most strobe circuits. Be sure that all capacitors are fully discharged before making any circuit modifications or other changes in a piece of strobe gear. ◈