STRUCTURE

The basic structure of a xenon flashtube is as in figure 1 below.

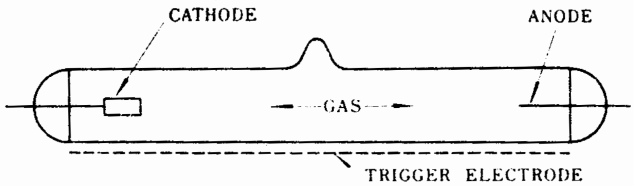


Fig. 1 Basic Structure of Xenon Flashtube

The xenon flashtube is a sort of a discharge lamp which is made of hard glass or quartz with an electrode sealed at each end. The bulb is filled with xenon gas (normally with a pressure of some 10cmHg). The noticeable feature of a flashtube, as far as the basic structure is concerned lies in a trigger electrode, a third one, attached to the external wall of the bulb.

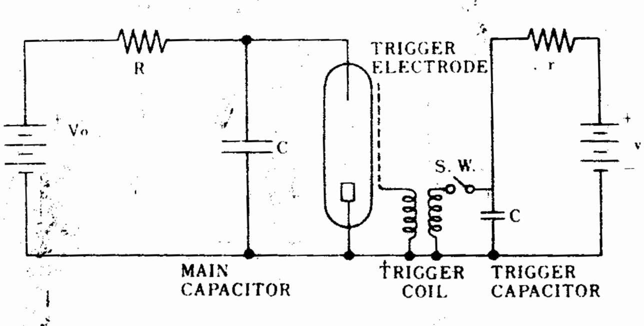


Fig. 2 Flashtube Circuit

As you can see from the above circuit, a main capacitor stores charge up to Vo through a resistor R. In this state, the flashtube does not start discharging when impressing high-voltage, high-frequency trigger into a trigger electrode by closing the switch, the inert xenon gas in the lamp partially causes insulation breakdown, thereby main discharge is induced between anode and cathode, and electrical energy stored in the main capacitor is instantly discharged through the flashtube. At the same time, the lamp emits powerful flash light.

TRIGGER VOLTAGE

The trigger voltage greatly influences ignition of flashtube. Too low trigger voltage may cause one of the following phenomena:

1. Complete failure to flash
2. Occasional misfiring
3. Normal operation until the bulb becomes warm, then misfiring.
4. Short life

In order to avoid these phenomena, it is essential to give the trigger capacitor sufficient trigger energy and to use a trigger coil of high insulation. Make absolutely certain that neither one of the two conditions is wanting. Supplying the adequate trigger coil with insufficient trigger energy may also produce one of the aforesaid phenomena, as the trigger output voltage extremely drops when connected to the lamp.
The reverse case may also cause the same result.

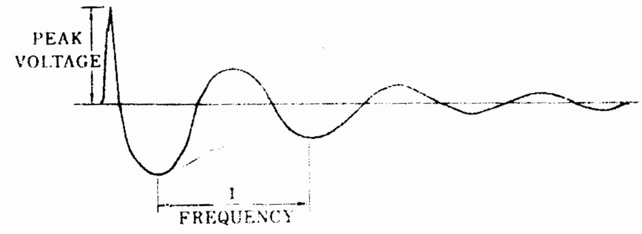


Fig. 3 Trigger Pulse

ELECTRICAL CHARACTERISTICS

The SPECTRO xenon flashtube's typical characteristics are shown in figure 4.

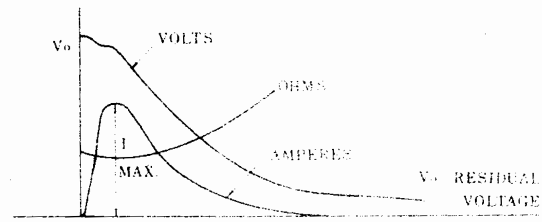


Fig. 4 Typical Characteristics of SPECTRO Flashtube.

When trigger voltage is impressed into the lamp, the arc grows in an instant time (normally as short as some micro seconds or less), and the current increases abruptly, and reaches the maximum value, I max.
After that, it decreases gradually until it becomes zero. The voltage Vo charged to the main capacitor also drops gradually until it becomes residual voltage, vo. The residual voltage becomes greater as the resistance values of the lamp and its discharge circuit increases. The resistance of the lamp is not always constant as in figure 4, but varies with the time.

LIGHT OUTPUT

The total powerful flash delivered by a xenon flashtube is most easily explained by figure 5 in which the relationship between light output of a flashtube and the time is shown.

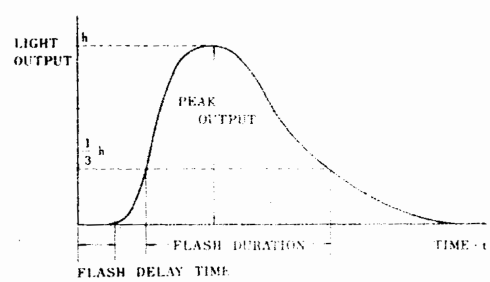


Fig. 5 Flash Characteristic Curve.

When trigger voltage is impressed into the lamp, the light output of a flashtube, after an instant flash delay time (normally as short as microseconds or less), rises sharply and reaches its peak output value (Note that there may be occasionally two peak points on the characteristic curve). After that, it falls gradually and exponential function-wise, until it becomes zero.

FLASH DURATION

Strictly speaking, the duration of flash should be defined as the total time of a light waveform. In fact, however, it is expressed in a "time width" obtained from one third of an h (the height of peak light output) in order to meet users' requirements such as motion stop ability, etc. or depending on user's various purposes. See figure 5.

In case of the circuit as in figure 2, the flash duration as a standard can be expressed in the following formula:

$$\text{Flash Duration (sec)} \fallingdotseq \frac{RC}{2}$$

R = The total resistance in ohms of a discharge circuit, which is represented by the arc resistance of a flashtube.

C = Capacitance in farads of the main capacitor.

In case of a short flash duration requirement, resistance of the lamp and capacitance of the main discharge capacitor should be as small as possible. On the contrary, a long flash duration is vice versa. Note that inserting a resistor in series to the lamp into the discharge circuit may be of help in securing a long flash duration but the efficiency deteriorates. In addition, when using a main capacitor of abnormally great charge voltage as compared with the distance between the two electrodes of the tube, inductance (L) should be necessarily inserted in series to the lamp so that instantaneous damage of the lamp is avoided. In this case, the flash duration becomes also slightly longer.

AMOUNT OF LIGHT

The amount of light per flash can be determined by integrating the characteristic curve shown in figure 5 in terms of the time. In other words, it is equal to the total light output per flash emitted by the tube, and the unit is expressed in "lumen-seconds".

EFFICIENCY

Efficiency is significantly important in expressing the characteristic of the lamp. The efficiency can be calculated by the formula:

$$\text{Efficiency} = \frac{\text{Amount of Light (Lumen-seconds)}}{\text{Electrical Energy to Lamp (Watt-seconds)}}$$

The energy given to the lamp, usually, is expressed in "electrical energy" stored in the main discharge capacitor before discharging. Therefore,

$$J = \frac{1}{2} CE^2$$

Where:

J = Energy given to the lamp (Watt-seconds)

C = Electrostatic capacitance of the main capacitor (Farads)

E = Voltage between the both ends of the main capacitor before discharge (Volts)

Strictly, the energy corresponding to the residual voltage (See figure 4), must be considered. Since it is very small, however, the energy is usually disregarded. The efficiency varies with the size and shape of the lamp, the pressure of sealed gas and electrical conditions under which the flash is fired.

SPECTRAL ENERGY DISTRIBUTION

Flashtubes have a continuous spectral energy distribution. Glass tubes cut off energy at about 3000 Angstroms but quartz tubes radiate into the 1800 Angstrom region. Output at the other end of the spectrum reaches about 15,000 Agnstroms.

Visible radiation is approximately equivalent to 6,000° ~7,000° Kelvin. In color photography, xenon flashtubes produce acceptable results without the use of filters.

For more critical work however, a slight warming filter is frequently used, especially with higher voltage lamps. Film manufacturers usually include proper filter recommendation with their products.

But some of SPECTRO xenon flashtubes are colored without using filter so that the color temperature is reduced to 5,400° Kelvin, for optimum results. For this type of flashtubes, "Colored Flashtube" should be indicated in your order. (Colored flashtube of quartz is not available.)

ELECTRICAL RATINGS

FIG. 6 Spectral Radiant Intensity of Xenon Flash Lamp

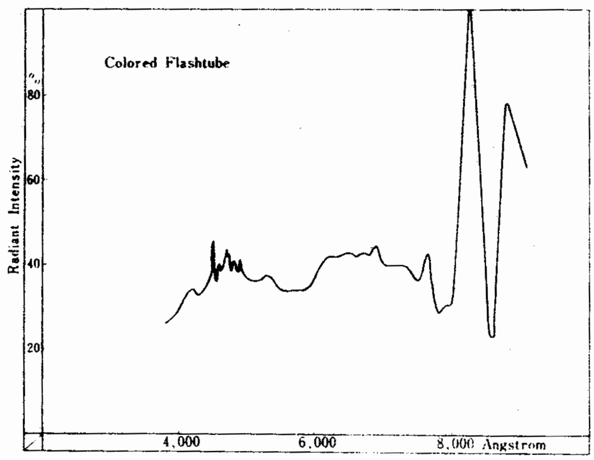
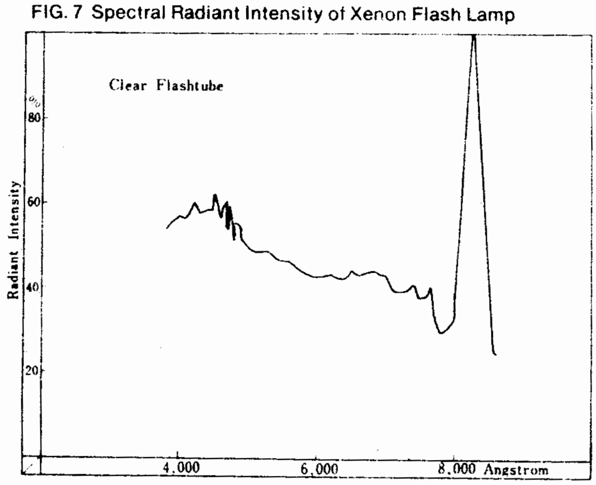


FIG. 7 Spectral Radiant Intensity of Xenon Flash Lamp



Maximum Energy Input per Flash - This rating describes the maximum energy input permissible for any one flash. Application of energy in excess of the tube's maximum watt-seconds rating may cause short lamp life, crazing or damage to the glass-to-metal seal. The energy input per flash can be calculated by the formula stated on page 6.

$$J \text{ (Watt-seconds or Joules) } = \frac{1}{2} CE^2$$

For example: A flashtube is used in a circuit with an energy storage capacitor rated at 500 microfarads and charged to 300 volts. The stored energy or input to the tube is:

$J = 1/2\ CE^2 = 1/2\ (500 \times 10^{-6} \text{ farads})(300 \text{ volts})^2$
$= 22.5$ watt-seconds or 22.5 joules.

Maximum Long Term Average Power Input This rating is generally used to express the maximum input applied to the flashtube when repetitively flashing it at a rate of more than once per second. The energy input per flash multiplied by the number of repeated flashes per second indicates the long term average power input in watts, hich can be calculated by the formula:

$$W = J.f = \frac{1}{2} CE^2 f$$

Where:

W=Long Term Average Power Input in Watt.
f=Number of Repeated Flashes per Second

Example:

Capacitance of a Main Capacitor	2 u F
Charging Voltage	500 volts
Flash Repetition Rate*	50 flashes per second

*Will be described in a later part of this manual.

$W = 1/2\ CE^2 f$
$= 1/2\ (2 \times 10^{-6} \text{ farads})(500 \text{ volts})^2 \times 50$
$= 12.5$ watts

Setting the flash repetition rate to the maximum makes the long term average power input the maximum value. The maximum value may be determined by the temperature permissible for the tube's rating. If energy in excess of the maximum value is applied to the tube, one of the following may result:

1. Short lamp life
2. Damage to the glass-to-metal seal
3. Deformation of the bulb wall

So, when a tube is used in a small lamp housing where the heat from the tube is prevented from dissipating, or in a high ambient temperature, the maximum wattage rating must be reduced.
Unless otherwise specified, the rating in this manual is referred to the energy input applied to the tube when continuously flashing it at the maximum flash repetition rate under a natural cooling condition in the free air. If intermittently flashing the tube and the flashing term is much shorter than the non-flashing interval, application of energy in excess of our published rating can be accomplished.

Flash Repetition Rate This describes the rate of flashes continuously repeated. The flash repetition rate is usually referred to the number of flashes per second or that at regular intervals. For example: 50 flashes per second or one flash per 10 seconds.

Maximum Anode Voltage The maximum voltage to be applied to the anode for safe lamp operation. If a tube is needed to be operated at a voltage higher than this, inserting an inductance or air gap in series with the lamp is preferred.

Hold-off Voltage This rating expresses the minimum voltage allowing the lamp to begin self-flashing with no trigger voltage supplied to the flash-tube. This rating is always higher than the maximum anode voltage but extremely unstable and can be affected by the temperature as well as the number of already fired flashes of the lamp. If using a tube at a voltage higher than this rating is absolutely necessary, it is recommended that either an air gap or thyratron and inductance are inserted in series with the lamp.

Minimum Flashing Voltage The minimum anode voltage permitting a tube to be securely fired at a time when the specific trigger voltage is applied to it. The voltage applied in-between the anode and cathode of the lamp must be higher than the minimum flashing voltage.

Flashtube Life The life of our flashtube is defined as the average integrated flashing time or the average number of flashes achieved with the maximum input applied to the tube under a natural cooling condition in the free air until one of the following lamp failures is observed:

1. Complete failure to flash
2. Occasional misfiring (skipping)
3. The light output is decreased to 70% of initially attained one (other than those particularly specified in the Diagrams).

The life of the flashtube, therefore, can be prolonged according to its practical use.

BY RICHARD M. FISHER

flash tubes

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.

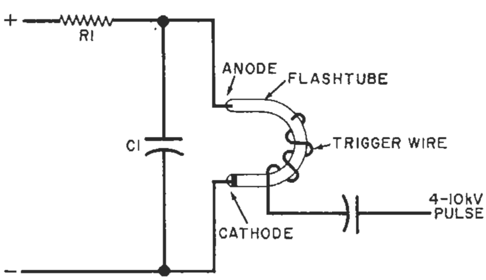


Fig. 1. In basic flash-tube circuit, C1 discharges through tube, after a trigger pulse partially ionizes gas.

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.

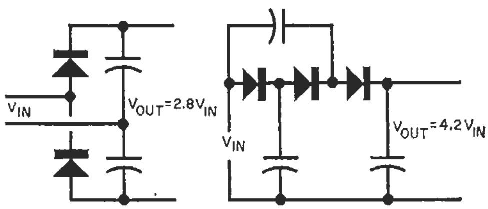


Fig. 2. To attain necessary high voltage, doubler and tripler circuits are used in the tube power supplies.

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

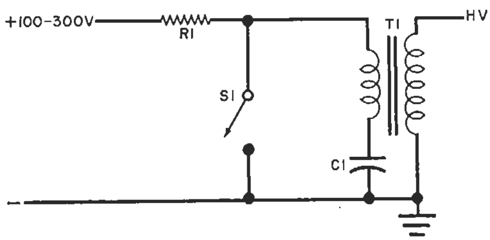


Fig. 3. When S1 is closed, C1 discharges through primary of transformer producing the high-voltage spike.

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*

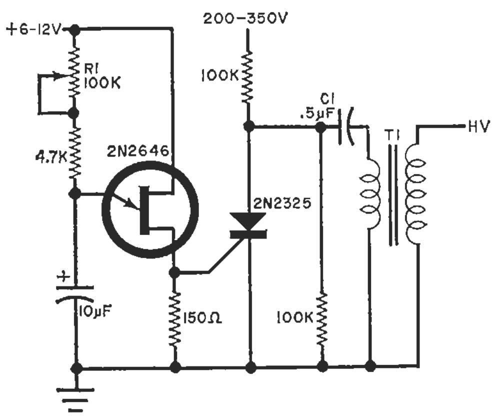


Fig. 4. Here, a UJT is used to control an SCR, which acts to discharge C1 through the primary of transformer.

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.

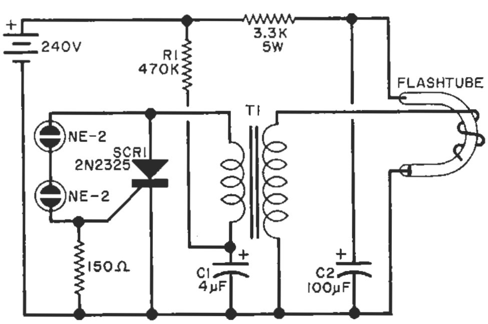


Fig. 5. In battery-operated flasher, two neon lamps flash over to turn on SCR. C1 and R1 set the firing rate.

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

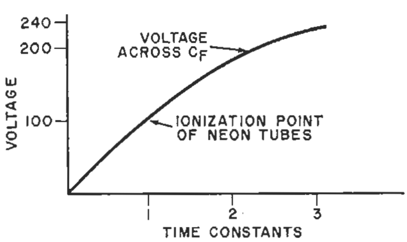


Fig. 6. Voltage across capacitor increases with time constant until the firing point of neon tubes is reached.

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 $E = \frac{1}{2}CV^2$ or $\frac{1}{2}(100 \times 10^{-6})(240)^2 = 2.88$ joules. The

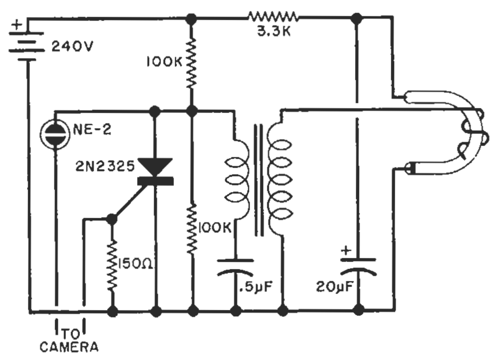


Fig. 7. Typical electronic flash for camera. Closing camera leads causes SCR to conduct, thus triggering tube.

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.

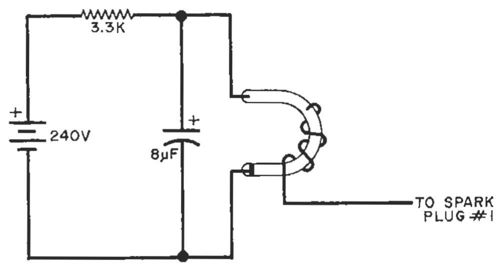


Fig. 8. In this simple engine timing light, the high-voltage pulse at the spark plug triggers the flash tube.

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. ◈