PROJECT

Xenon Beacon

A visual warning device that's self-contained, compact, splash proof and rechargeable.

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If you want to attract someone's attention to a scene, a flashing light is a good method to employ. This is because the human eye is very sensitive to sudden changes in light level, particularly towards the edge of the field of view. Flashing beacons are to be found wherever attention has to be promptly drawn to a hazard, warning sign or advertisement.

The beacon to be described here emits a powerful blast of light at a rate of approximately 1.5Hz and was initially designed for visibly locating portable amateur radio stations on hilltops. It has since found refuge in the car trunk where it can be used to warn other motorists of accidents, breakdowns, etc.

Xenon beacons can be bought quite cheaply, but most of them have two main drawbacks: they are not designed as portable units and their light output is not very high. This design satisfies both these criteria and the light can be seen at a distance in excess of two miles under favorable conditions. Being moisture-proof it is ideal for outdoor use.

Other uses include mountain rescue, sea rescue (take it out with you in the fishing boat) or just for fun at discos.

Xenon Tube

The light source consists of a glass tube containing xenon gas with an electrode at each end; see Fig. 1. When the xenon atoms are excited by passing a high current through the gas, they emit an intense blue/white light. However, the gas is non-conducting at low voltages and in order to make it pass a current a potential difference of several thousand volts would be needed across the ends of the tube.

This is very inconvenient, and so a third "trigger" electrode is attached to the outside of the tube near the ends. In order to strike the gas (make it conduct) a voltage of about 350V is applied across the ends of the tube and a brief 6,000V pulse is applied to the trigger electrode. This causes the gas at the ends of the tube to ionize and conduct; this ionization very rapidly spreads along the tube and current flows from one end to the other causing the emission of light.

Radio Shack sells a strobe tube, the 272-1145, for replacement use and experimenting. You could also salvage one from a defunct photoflash, though the very small ones may overheat from the frequent flashing.

Block Diagram

The outline operation of the Xenon

Beacon is shown in Fig. 2. The circuit uses an inverter to step up the 12V supply, producing several hundred volts required for the xenon tube; an ordinary mains transformer used "in reverse" acts as the voltage- increasing component. Since transformers only work on AC, an oscillator is used to drive the primary winding.

The high voltage AC is rectified and used to charge up a high voltage storage capacitor. The voltage across the capacitor increases as the charge builds up and when it reaches about 350V a trigger circuit rapidly discharges the capacitor through the xenon tube, thus producing a bright flash.

The inverter then proceeds to recharge the capacitor and the cycle repeats.

Circuit Diagram

The circuit of the beacon, divided into three discrete sections is shown in Fig.3. The inverter is driven from a 12V rechargeable battery, protected by fuse FS1. S1 is an on/off switch which connects B1 to sockets SK1 and SK2 when the unit is switched off, thus allowing the battery to be charged *in the case..* The power supply is decoupled by capacitor C1.

NAND gate IC1c is wired to a Schmitt trigger inverter, and together with R1, VR1 and C2 it forms a relaxation oscillator. The square wave output from the oscillator is buffered by gate IC1b and used to switch transistor TR2 which controls current through one half of the primary winding of transformer T1. (Note that in this circuit the *primary* is the *low voltage winding.*)

An inverted version of the oscillator signal from gate IC1a switches TR1 so that when current flows through TR1, TR2 is switched off, and vice-versa. TR1 and TR2 are Darlington devices having the high gain necessary to drive the transformer directly from CMOS gates.

Due to self-induction in T1 primary, spikes of about 80V amplitude are produced each time TR1 and TR2 turn off. These spikes are stepped up in excess of 1,000V in T1 secondary, rectified by diodes D1 to D4 and used to charge capacitors C3 and V4.

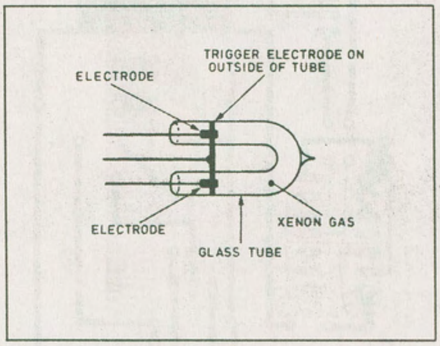

Fig. 1. The Xenon tube.

Trigger

As the voltage across C3 and C4 increases, capacitor C5 is charges via R4. R5, VR2 and R6 for a potential divider which feeds a fraction of the voltage across C5 to neon LP1 via R7. Thus the voltage across the neon increases to about 70V upon which the neon conducts and a positive voltage is applied to the gate of thyristor CSR1.

The thyristor triggers and conducts from anode to cathode, discharging C5 through the primary winding of trigger transformer T2. This induces a very high voltage pulse in the secondary of T2 which is used to strike the xenon tube X1; C3 and C4 then deposit their charge through the tube in a fast, high current surge.

Following this, thyristor CSR1 resets to its high impedance state and the process repeats as C3 and C4 charge again.

Notice that if, as may occasionally happen, the tube fails to strike upon the discharge of C5 through CSR1, then the thyristor will reset and C5 will recharge until neon LP1 conducts and the tube is triggered again: this process is repeated rapidly until the xenon tube fires.

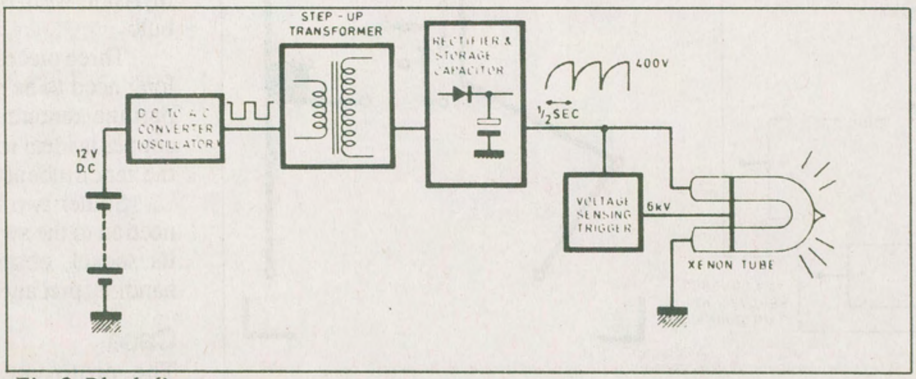

Fig. 2. Block diagram.

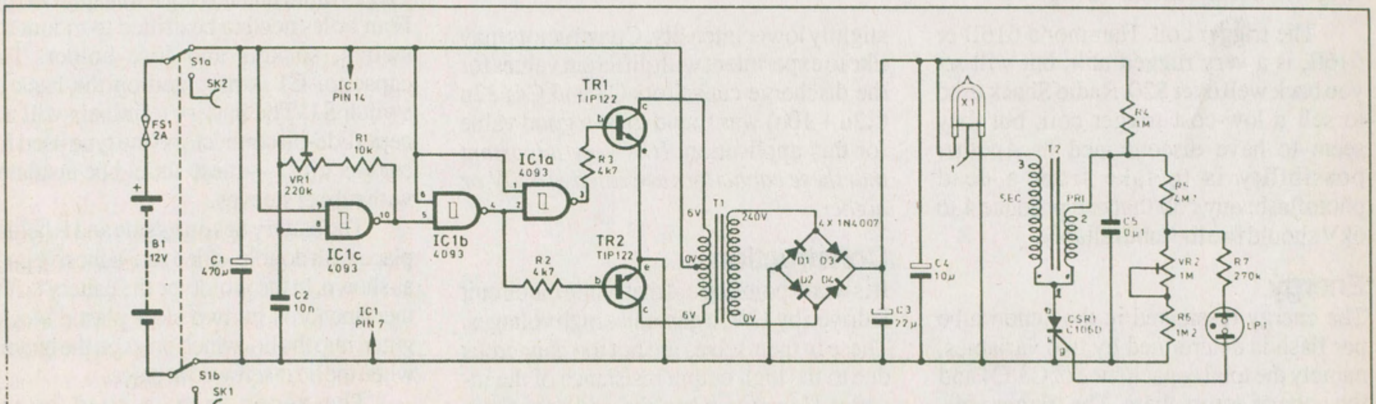

Fig. 3. Circuit diagram of the Xenon beacon. See the text for information on T1, T2 and the flash tube.

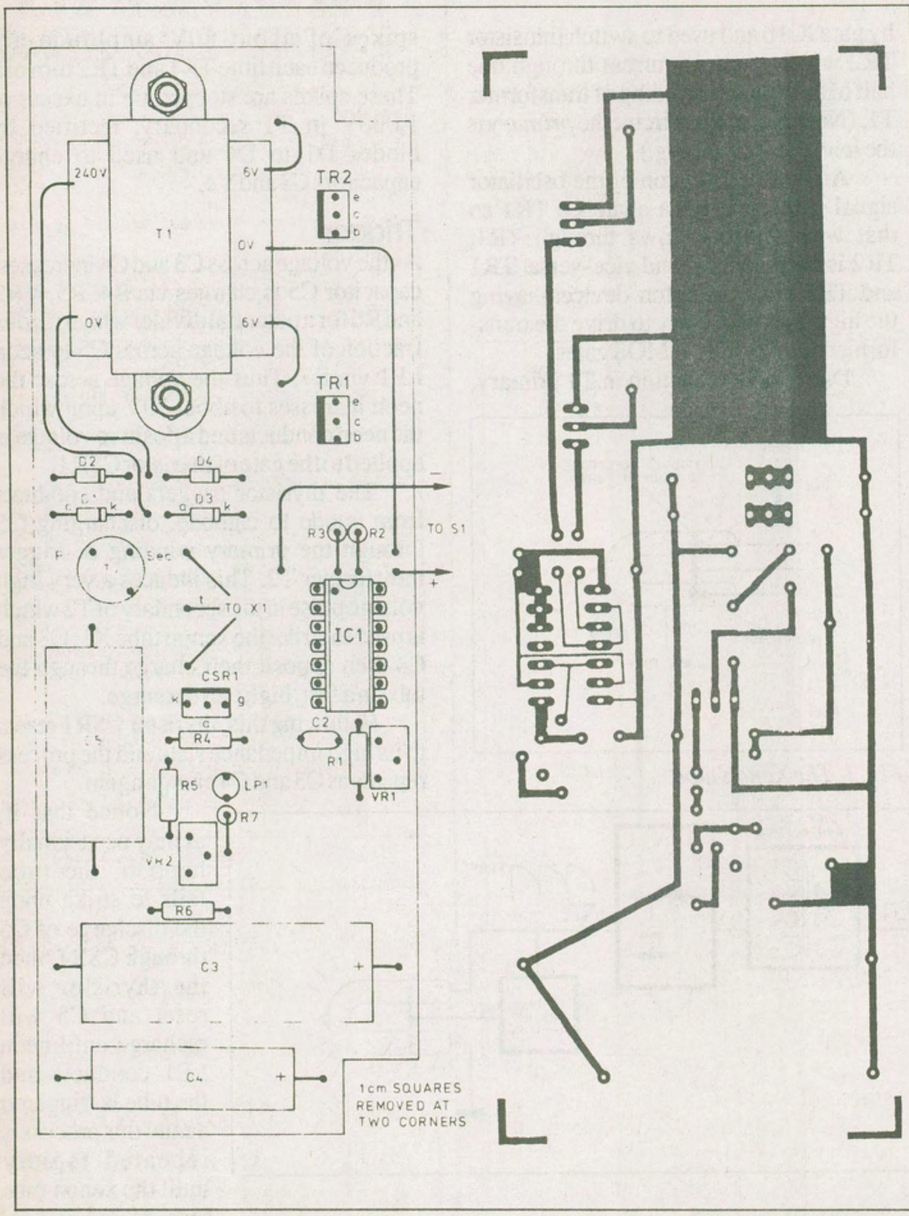

Fig. 4. PCB layout and wiring.

The trigger coil, Hammond 616B or 616E, is a very rugged unit, but will set you back well over $20. Radio Shack used to sell a low-cost trigger coil, but they seem to have discontinued it. Another possibility is to take from a dead photoflash; any coil that can produce 4 to 6kV should fire the tube reliably.

Energy

The energy dissipated in the xenon tube per flash is determined by two variables, namely the total capacitance of C3/C4 and the voltage across them. The trigger voltage is adjustable from about 220V to 340V by altering VR2; setting this to a high value results in one bright flash approximately every two seconds. Reducing the trigger voltage will give more rapid flashes of slightly lower intensity. Constructors may like to experiment with different values for the discharge capacitors C3 and C4; 32u (22u + 10u) was found to be a good value for this application. *It is very important that these capacitors are rated at 450V or higher.*

Construction

It is worth pointing out that while the circuit is driven by 12V, it generates high voltages. These in themselves are not too dangerous due to the high output resistance of the inverter. However, when charged, capacitors C3 and C4 can deliver a very nasty shock or burn if shorted out by, for example, a ring or other piece of jewellery — take care when testing.

All the main components are mounted on a single-sided printed circuit board, the full size foil pattern of which is given in Fig. 4. Notice that two holes need to be drilled to mount T1 and two 1cm square pieces have to be removed at the corners if the recommended case is used.

Using the layout diagram in Fig. 4 as a guide, solder the small components into place first: the resistors, presets, capacitor C2, neon and diodes, observing the polarity of the latter. Insert the trigger transformer T2 — the recommended transformer will only fit the PCB in the correct orientation. If a different type is used, check the connections before soldering.

Fit the remaining capacitors checking that C3 and C4 are inserted the correct way around and then bolt transformer T1 into place, nuts uppermost. Solder the transformer connections to the circuit board.

The transistors should be fitted with small clip-on heatsinks and these are probably best attached before the devices are soldered into place. Insert the transistors with their tabs facing T1 and fit the thyristor with its *front* facing the neon bulb.

Three pieces of stout wire about 8cm long need to be soldered in place to support the xenon tube X1. 20-gauge tinned copper is ideal for the purpose. Do not fit the xenon tube at this stage.

Solder two insulated wires for connection to the switch and then fit IC1 into its socket, observing the usual CMOS handling precautions.

Case

The prototype unit is housed in a waterproof plastic case measuring 150 x 110 x 70mm and having a transparent top. Four holes need to be drilled to mount the switch, sockets and fuse holder. The capacitor C1 is mounted on the back of switch S1. The battery terminals will accept slide-on connectors (the type used for car electrics) — these should be insulated with rubber sleeves.

The battery lies on its side and is held in place with double-sided self-adhesive pads as shown. In the prototype the battery is further anchored by two clear plastic blocks glued into the lid, which press on the battery when the lid is screwed in place.

The xenon tube is sited in the transparent lid above a reflector made from a piece of cardboard covered with aluminum cooking foil. The reflector is shaped to fit in the case and a slot needs to be cut to pass the wires to X1. It can be fastened to the side of B1 with double-sided tape or similar, allowing it to be removed for servicing.

Using pliers, and being careful not to strain the glass, bend the wires of the xenon tube at right angles to the plane of the tube about 1cm from its ends. slip three 3cm lengths of sleeving over the tube support wires on the PCB and solder X1 to these wires so that the tube is positioned mid-way between the reflector and the lid of the box, trimming off surplus wire as necessary. Slide the sleeving up to the top of the vertical section of the wires and hold it in place with glue.

Adjustments

Set both VR1 and VR2 at mid-position and apply power. Transformer T1 should be heard to whine and the xenon tube should flash at approximately 1.5Hz.

If a frequency counter or oscilloscope is available, connect it between 0V and pin 3 of IC1 and adjust VR1 until the inverter oscillator runs at a frequency of about 1.5kHz. If such equipment is not on hand, leave VR1 set at mid-position. The trigger voltage/flash rate is set as required by adjusting VR2.

The PCB can now be fastened into the case with adhesive pads and the lid screwed into place. Four rubber feet will improve the durability of the unit.

Battery

The battery used in the prototype is a rechargeable 12V 1.2Ah sealed lead-acid type. It has a mass of 600g and fits snugly into the recommended case along with the PCB It will give over three hours of continuous use.

These batteries are available in a variety of sizes/capacities and constructors wishing to leave the beacon running for long periods may like to consider using a battery with a higher capacity, although size and weight must be taken into account if the unit is to remain portable.

Indeed, the xenon beacon could be very successfully run from a car battery, via the cigarette lighter for instance.

It is possible to operate the unit from a 6V supply, the only modification being to replace transformer T1 for a type having a 3-0-3V "secondary" winding. The current consumption is increased and, due to inefficiencies in the transformer, the highest flash rate will probably be around 1Hz. The benefit of using a 6V supply is that smaller and lighter batteries may be used.

Finally, 12V sealed lead-acid batteries should be charged at a constant voltage of 13.5V although the maximum charging current should be restricted to 1A.

Failure to keep to these limits will cause the battery to expel excess hydrogen gas inside the box. In any case, the box should not be entirely sealed — a small vent hole around the sockets will prevent a pressure build up without affecting the moisture- proof characteristics. Ideally, the box lid should be removed when charging.

PARTS LIST

Resistors

R1 10k
R2,3 4k7
R4 1M
R5 4M7
R6 1M2
R7 270k
All 0.25W carbon

Potentiometers

VR1 220k
VR2 1M
Both vertical mounting presets

Capacitors

C1 470u 16V elec.
C2 10n ceramic
C3 22u 450V elec.
C4 10u 450V elec.
C5 0.1u 450V

Semiconductors

TR1,TR2 TIP122 *npn* Darlington

D1 to D4 1N4007 1000V prv silicon diodes

IC1 4093 CMOS quad 2-input NAND Schmitt trigger

CSR1 C106D thyristor

Miscellaneous

T1 filament transformer, 120V/6.3VCT at 250mA or more, such as Hammond 166G6 or 166K6

T2 xenon tube trigger transformer, Hammond 616B or 616E.

X1 xenon tube

LP1 miniature neon bulb

B1 12V 1.2Ah sealed lead-acid battery

FS1 20mm 2A fuse and holder

S1 DPDT toggle switch

14-pin DIP socket; clip-on heatsinks for TR1 and TR2 (TO220 case); waterproof plastic case, internal dimensions 150 x 110 x 70mm; connectors for B1; feet; 20 s.w.g. tinned copper wire; sleeving; materials for reflector.