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ROCKET STROBE

BY ANTHONY CHARLTON

Now you can launch a model rocket on the darkest night, and find it in a flash no matter where it lands!

I shot an arrow in the air, it fell to earth I know not where. When Longfellow penned those words in the 1800's, he must have been thinking about my model rocketry career! The bane of a model rocket hobbyist is losing a carefully constructed and painstakingly finished model in shrubbery or trees. But those days are over.

Our *Rocket Strobe* sends out a highly visible S.O.S. for up to 2 hours, providing ample time to locate and recover the model. It also makes dramatic night launches a reality, with the blue-white flash of the Strobe visible throughout the flight sequence.

Seeing the Light. Invented in 1932 by Dr. Harold E. Edgerton, a Xenon flash lamp is the light-producing device for our Strobe. Flash lamps produce a short-duration, high-intensity pulse of light by converting energy stored in a capacitor to visible light. Each flash of the Strobe lasts about 500 microseconds. For that brief instant, the flash is as bright as a 4000-watt lamp!

It's the high intensity of the light pulse that produces long-range visibillty—yet, the Strobe requires very little energy input.

Basic Strobe Circuit. A strobe circuit has four basic parts. (See Fig. 1). The first is the power supply, which must be capable of producing about 300 volts from a 9-volt battery. That high voltage is required to sustain the arc within the lamp after triggering.

Second, we need a capacitor to store energy. The luminescence provided by the Strobe is directly related to the value of the capacitor, or to the amount of energy that the capacitor can store.

Third, we need a triggering circuit to produce a very high voltage pulse to ignite the lamp. A typical ignition pulse has an amplitude of 4000 volts, and is several microseconds in duration. The trigger pulse is capacitively coupled to the Xenon gas inside the lamp. When enough atoms are ionized by the pulse, and if the capacitor has enough charge on it, the gas fully conducts. Light output begins after conduction, and continues until the charge on the capacitor drops to about 50 volts. The lamp shuts itself off at that point, to renew the cycle after the voltage builds up again.

Last, we need a Xenon flash lamp: one is available from the supplier given in the Parts List. There are several different shapes and designs of flash lamps. We shall use a small, straight type in our Strobe.

Size and Weight. In order to be successfully lofted, our Strobe needs to be small, efficient, and light. Weight and size saving is accomplished by miniaturizing the power supply. Surplus electronics suppliers often have camera electronic flash boards left over from manufacturing overruns. Those boards contain tiny transformers that are capable of producing hundreds of volts from a battery-powered driver circuit. Suitable transformers are also available from the supplier given in the Parts List.

To drive them with maximum efficiency, we use a hex FET, and a pulse-width modulator (PWM) circuit. That combination results in maximum power output from the smallest size and weight unit, while providing an adjustable flash rate.

Strobe-Circuit Description. Referring to Fig. 2, gate U1-a (one-sixth of a CD4584 CMOS Schmitt trigger) is configured as an oscillator. With the values shown, the oscillator operates at 6 kHz. You may need to experiment with different frequencies by using the different values of C1 and R1 to obtain maximum output if you use

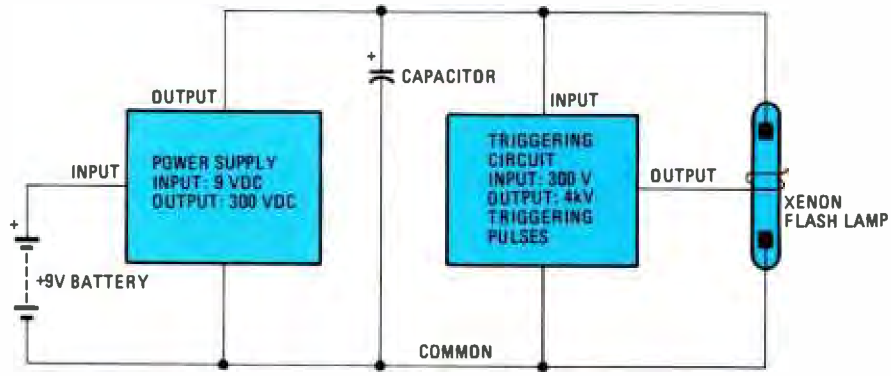

Fig. 1. Here is a block diagram of the basic strobe circuit, which consists of a power supply, storage device (the capacitor), triggering circuit, and a Xenon flash lamp.

a transformer other than the one specified in the Parts List.

Gate U1-b squares up the output of U1-a and feeds a squarewave to C2, C3, R2, R3, D1, and R4. Trimmer potentiometer R4 controls the duty cycle of the resulting pulse. When R4 is set to its maximum resistance, the maximum pulse-width and power is available from the circuit.

The remaining gates (U1-c, U1-d, U1-e, and U1-f) serve to amplify and invert the output of the PWM (pulse-width modulated) part of the circuit. The amplified pulse is fed to the IRF-Z20 hex FET, whose super low on-state resistance of only 0.07 ohm switches the primary of T1 with great force. Pull-down resistor R5 keeps the IRF-Z20 totally off during the logic-0 state of gates U1-c to U1-f. The output is rectified by D2, and is used to power the Strobe's flash-lamp circuit.

A word is needed about miniature transformers. Most units have an accessory winding used in self-oscillating circuits powered by bipolar transistors. That winding is not needed, since we have our own on-board PWM oscillator circuit. A simple test with an ohmmeter will reveal that low-resistance feedback winding. Do not confuse it with the low resistance, heavy gauge primary winding. Typical transformer configurations are shown for you in Fig. 3.

Another consideration is that lots of transformers are connected for European and Oriental active-negative circuits. (Akin to driving on the wrong side of the road to us!) That confusion is easily overcome by identifying the start of the primary and secondary windings. Connect the start of each winding as indicated in Fig. 2.

When in doubt, you may make a simple power indicator from a NE-2 neon lamp and a 220,000-ohm, half-watt resistor connected in series. Connect the lamp to the cathode of D2; and the lamp will glow much more brightly when the right combination of winding polarity is connected.

The Flash-Lamp Circuit. Previously, we mentioned that there is a relationship between lamp luminance and the size of the main capacitor. A unit rated at 33 µF will provide 2 watt/seconds (W/S) of light output. With our circuit, the flash rate is adjustable from one every 30 seconds to one every 4 seconds using R4. You may want to experiment with different capacitor values to obtain the desired light output at the desired flash rate.

For instance, a 10-µF capacitor in our circuit will produce about ⅓ of the maximum attainable light level while providing a rate of nearly one flash per second at R4's maximum setting. That rate would be better suited to night photography of the flight sequence. A slower, brighter flash is ideal for recovering the rocket in the daytime, when visibility of the flash is at its worst.

A long battery life (at a slow flash rate) is possible by setting R4 to minimum. We strongly recommend the use of a 9-volt nickel-cadmium (Ni-Cad) rechargeable battery, to save on battery costs. An alkaline battery can also be used. Regular carbon batteries work poorly because of their inability to supply the current needed for the Strobe circuit. The average current consumption of the Strobe at 9 volts was measured at 230 mA at the maximum flash rate setting, and 45 mA at the minimum setting. Nickel-cadmium batteries give a slower maximum flash rate because of their lower voltage.

The triggering circuit uses an interesting trick. (See Fig. 4). A small transformer, T2, is grounded via an SCR connected to its primary. When SCR1 switches on, the charge on C6 quickly travels through T2's primary and the SCR to ground. That induces a high-voltage pulse in T1's secondary winding, which ignites FL1. A simple and inexpensive trigger circuit kicks on SCR1 when the charge on C7 is high enough to sustain the arc inside FL1. A voltage divider, consisting of R6 and

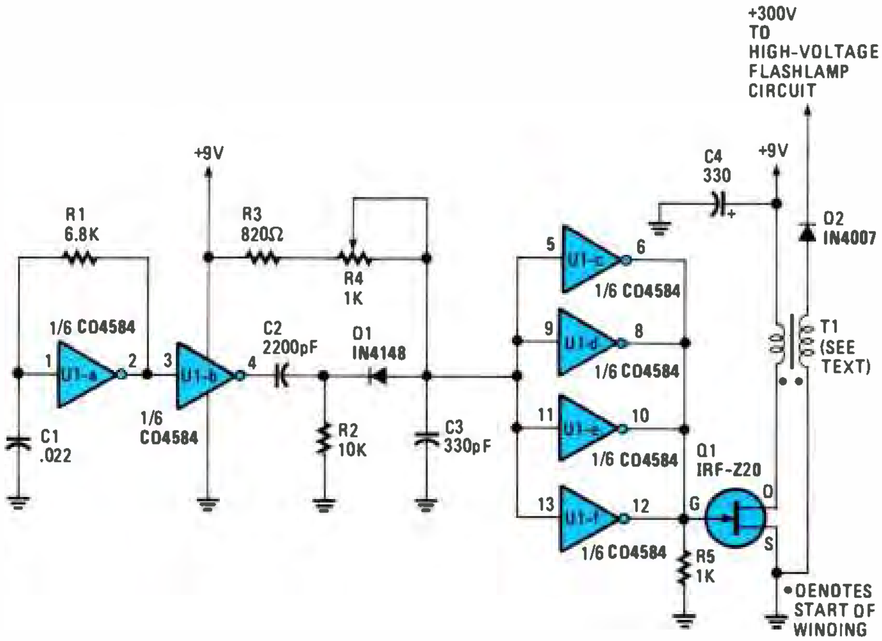

Fig. 2. Shown here is the schematic diagram of the PWM power supply for the Rocket Strobe, which produces 300 volts from a 9-volt battery.

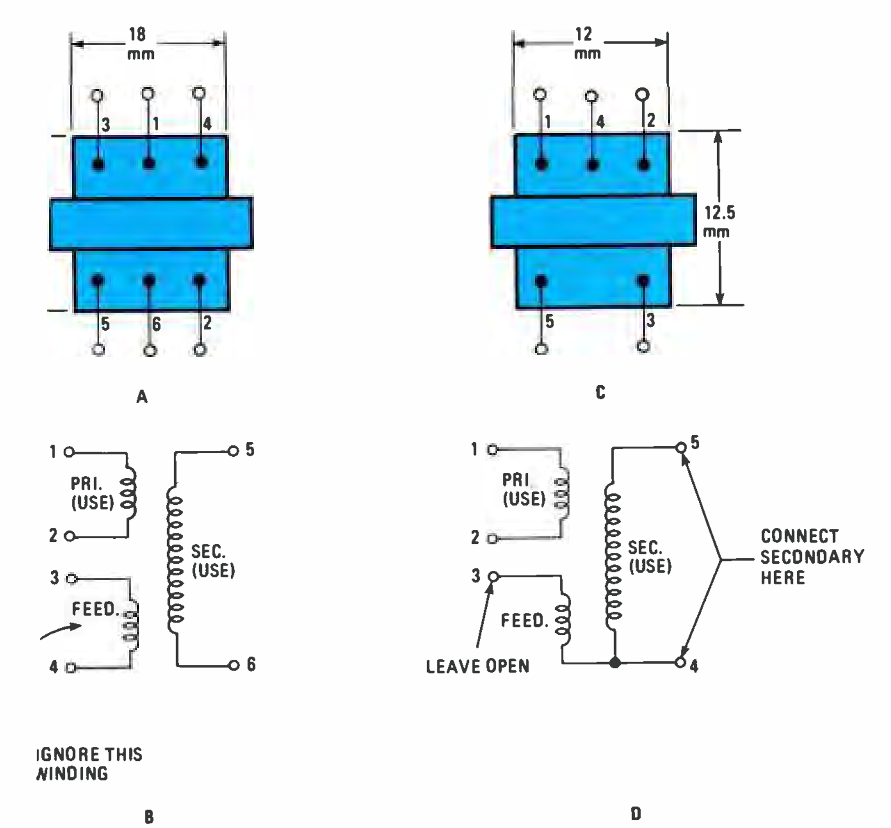

Fig. 3. If you use a miniature transformer salvaged from an old flash unit, it will be necessary to figure out the proper windings and/or connections. Shown here are two typical miniature transformer configurations.

R7, ensures that roughly 300 volts is stored in C7 before the neon lamp, NE1, fires. Neon lamps are designed to fire at different voltages. The common NE-2 lamp used in our circuit fires at about 120-volts DC. When NE1 fires, it dumps the charge stored in C5 to the gate of SCR1. That in turn, produces a trigger pulse that is applied to flash-lamp FL1, causing it to ignite, which allows you to find your rocket in a flash!

Speaking of flashes, let's look at different ways to attach a flash lamp to your rocket, rocket stability, what type of engines can loft your "bird," and a few suggestions for multiple strobes to increase visibility.

In our prototype, the flash lamp is attached to the end of the rocket's nose cone with silicone glue. The electronics are handily located in the nose, and the battery is held by a snap-in holder designed to withstand the shock and vibration of parachute deployment without losing the battery. The author used a combination 9-volt battery snap connector and holder assembly (see Parts List for source).

A balsa-wood plug is held securely in place by silicone, which also seals the components inside the nose cone, as well as providing an anchor point for the parachute, and shock-absorbing rubber cord leading to the rocket's body.

Strong assembly techniques are needed for the nose-cone/electronics package. The nose cone must withstand considerable force at the apex of flight when the rocket engine activates its ejection charge. There is nothing gentle about the hefty charge of black powder that pops off the nose cone and deploys the parachute! Figure 5 shows the parts of a rocket engine, and their function. Be sure to use enough silicone for good strength.

Weight must be minimized to allow your bird to lift off, and attain maximum height. Soft grades of balsa wood are the lightest, and weight savings may be gained by careful assembly of the electronics on a small board, using a minimum of solder. All told, our Strobe added 3½ ounces to the rocket's weight. You may also save weight by not painting the model with too many coats of finish if it's to fly a Strobe.

If the electronics are ahead of the model's center of gravity (CG), the rocket should fly fine with the added weight. If, for some reason, you locate the electronics or battery behind the rocket's CG, a counterbalancing weight must be added to the nose to bring the CG back to its normal position. A rocket's CG is determined by its balance point with an unused engine installed. (See Fig. 6.)

A flash lamp may be attached to the rocket's nose, body, or fins. Be aware that the delicate flash lamp needs breakage protection. A rigid, clear piece of plastic tubing placed

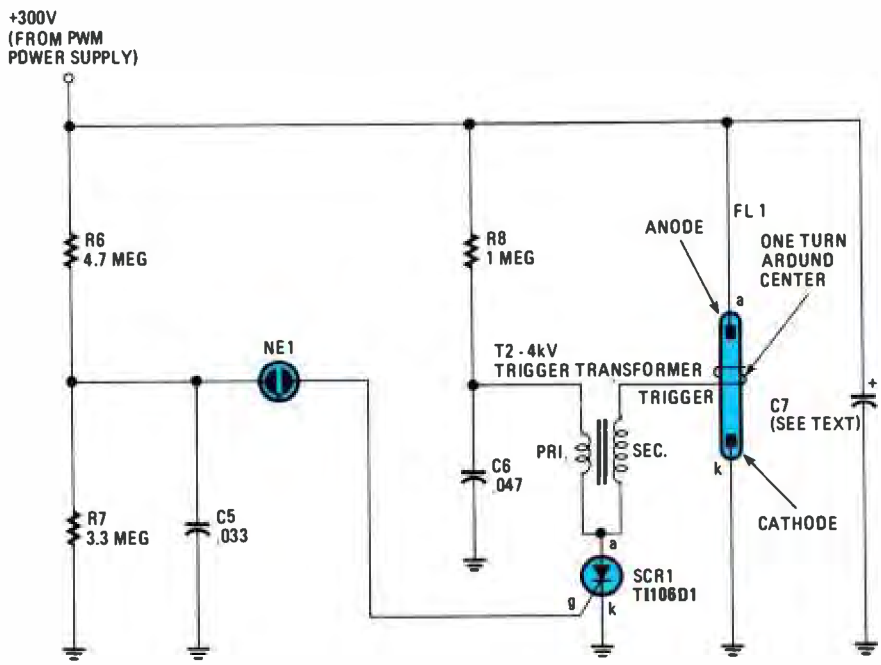

Fig. 4. The triggering circuit uses a small voltage transformer that is grounded via a SCR which, when triggered, induces the high-voltage pulse that ignites the flash lamp.

PARTS LIST FOR ROCKET STROBE

SEMICONDUCTORS
Q1—IRF-Z20 hex FET (Digi-Key IRF-Z20-ND)
D1—1N4148 or equivalent general-purpose diode
D2—1N4007, 1-A 1000-PIV, general-purpose rectifier diode
U1—CD4584 hex Schmitt trigger, integrated circuit
SCR1—TI106D1, C106D1, ECG5457 (or equivalent) 400-volt, 4-amp, sensitive gate silicon controlled rectifier

RESISTORS
(All fixed resistors are ¼-watt, 5% units, unless otherwise noted.)
R1—6800-ohm
R2—10,000-ohm
R3—820-ohm
R4—1000-ohm, trimmer potentiometer
R5—1000-ohm
R6—4.7-megohm
R7—3.3-megohm
R8—1-megohm

CAPACITORS
C1—0.022-µF ± 10% stable temperature coefficient (Digi-Key P1016 or equivalent)
C2—2200-pF ± 2% stable temperature coefficient (Digi-Key P3222 or equivalent)
C3—330-pF ceramic disc (Digi-Key P4106 or equivalent)
C4—330 to 680-µF, 16-WVDC miniature electolytic
C5—0.033-µF, 250-WVDC (Digi-Key E2333 or equivalent)
C6—.047-µF, 400-WVDC (Digi-Key E4473 or equivalent)
C7—33-µF (or value to suit, see text) 350-WVDC miniature electroytic

ADDITIONAL PARTS AND MATERIALS
FL1—Xenon flash lamp
NE1—NE-2 120-volt neon lamp
T1—See text
T2—4kV trigger transformer
Printed circuit or perfboard materials, 9-volt nickel-cadmium battery, snap-in battery holder (part number 16064, from Sintec Electronics, 28 8th St. Box 410, Frenchtown, NJ 08825 or equivalent), wire, solder, hardware, etc.

Note: The following parts are available from Allegro Electronic Systems, 3 Mine Mountain Road, Cornwall Bridge, CT 06754. A kit containing T1, T2, and FL1 with data sheets is available for $5.75 postpaid. Connecticut residents, please add appropriate sales tax.
Free technical assistance is available by writing Allegro Electronic Systems at above address or calling (203) 672-0123 weekdays from 9 AM to 1 PM in the afternoon.
Model Rockets are available from local hobby shops, or by mail-order in kit form from Estes Industries, PO Box 227, 1295 H Street, Penrose, CO 81240. Catalog: $1.

TABLE 1—ROCKET/ENGINE COMBINATIONS

Model Name	Engine Type	Weight w/Engine	MLW	Weight Margin
Phoenix™	D12-3	8.1	14	5.9
Mercury Redstone™	C5-3	3.9	8	4.1
Jupiter C™	C5-3	3.9	8	4.1
Black Brant II™	D12-5	3.8	10	6.2
Pathfinder™	D12-5	4.7	10	5.3
Mega Sizz™	D12-5	4.7	10	5.3
Ranger ™	D12-5	3.1	10	6.9
Der V-3™	D12-3	5.9	14	8.1
Der V-3™	D12-5	5.9	10	4.1
Eggspress™	C5-3	3.4	8	4.6
D.A.R.T.™	C5-3	2.7	8	4.6
Transtar Carrier™	C5-3	2.8	8	5.2

Note: All weights are given in ounces.
Courtesy of Estes Industries. Material used by permission.

around the lamp affords additional breakage protection. Plug the open end with a tapered balsa or plastic plug to preserve the rocket's aerodynamic sleekness. Use of a short, sturdy flash lamp, cushioned in Silicone, may work fine, as it did with our model.

The parachute's size must be increased to compensate for the added weight: 40 square inches of parachute area per ounce of weight is recommended. All told, our rocket weighed 13.5 ounces, so 540 square inches of chute area was needed. We replaced the 18-inch chute that came with the model with two 24-inch ones. That gave about 900 square inches, which gently delivers the model to Earth.

If you need to use more than one chute, attach each chute's shroud lines to a snap swivel (which can be found at tackle shops). Those handy little gizmos reduce the chance of the line tangling (which can lead to disaster) and enables you to clip on or remove chutes in a jiffy. More than one parachute means you will have to pack each carefully. Try not to wind the lines too tightly around the chutes, and use plenty of flame-proof recovery wadding between the chutes and engine. Dusting the chutes with plain talcum powder lets them slide out freely during the engine's ejection phase, and they unroll quicker when in the air.

The finished model's weight is an important consideration in engine selection. To launch successfully, the model must be less than the maximum lift weight (MLW) of the engine type selected. Weight can really creep up on you (as all dieter's know!). Our model, called the Phoenix, weighed 11.6 ounces, with the engine and Strobe installed. After it was painted, the paint added 1.9 ounces! That put total weight at 13.5 ounces., very close to the MLW of the engine we used.

Table 1 is a listing of some rocket/engine combinations that will lift off with the Strobe onboard. Each model was selected to provide a reasonable weight margin, and a body size large enough to hold a 9-volt battery. The weight margin is what's left over for the Strobe, paint, battery, and so forth. The rockets are sold in kit form, and manufactured by Estes Industries. Other designs may work, provided that you use lightweight batteries, and build the rocket and Strobe using minimal-weight methods.

Multiple strobes add a very interesting touch. We used up to six flash lamps, strung in parallel, all operating from the same power supply. The light output appears to be equally divided among multiple lamps if they are all of the same type. To get the same brightness per lamp, you'll have to increase the value of C7 (see Fig. 4). For instance, with 3 lamps, C7 would need to be three times larger to provide each lamp with a high brightness, but the total light output would be tripled. Increase C6 to 0.1 µF when using more than one lamp in parallel. The higher capacitance causes a greater charge to be dumped across T1's primary (and hence, a larger secondary current), which guarantees the ignition of all lamps.

Construction. Well, by now you are an expert on power supplies, strobes, rockets, and aerodynamics; so let's roll up our sleeves, and get to work!

You may make a PC board, or wire the electronics on perfboard (which we did). A universal printed-circuit board worked fine. As you assemble the circuit, be mindful of the need to minimize weight. Use just enough solder to make a good joint. Trim away excess space on your mounting board.

Wherever possible, use miniature components. A Ni-Cad battery will save you quite a bit of weight (1.25 ounces vs. almost 2 ounces for an alkaline unit). The Ni-Cad gives a good 15 minutes of flashing at high rate, and over 1 hour on slow.

The power-supply layout is not critical, but you must pay attention to the high-voltage output of the trigger transformer. That little guy puts out over 4,000 volts, and while it does not look too dangerous it packs quite a nasty wallop!

Dress the secondary leads away from other components; a half inch is recommended. The wires leading to capacitor C7 and the trigger transformer should be short, and if on the outside of the rocket, glued flat to avoid excess air drag. If you run the wires inside the body, make sure that they won't become tangled in the recovery system! Also, the ejection gases will quickly rot the insulation on wires; if they are in an exposed area, jacket and seal them in heatshrink tubing or the kind of plastic tubing sold for aquarium air lines.

Wire size is not critical; we had fine luck with #26 stranded hook-up wire. Make sure flash-lamp polarity is observed. The end with the large round electrode is the cathode, which is always connected to ground. Some flash lamps have a trigger wire already attached to one end, but on those that don't, one wrap of bare wire around the lamp's center will do the trick. Secure the wire with a tiny dab of epoxy or Crazy glue to the glass.

Make sure that the leads to the lamp are well insulated at the splices. A connector is handy to have in the circuit leading to the lamp. That way, the electronics can be quickly disconnected for testing or adjustment. Eventually, the lamp burns out and will have to be replaced, but only after many flashes. The author calculates the lamp listed in the Parts List will last

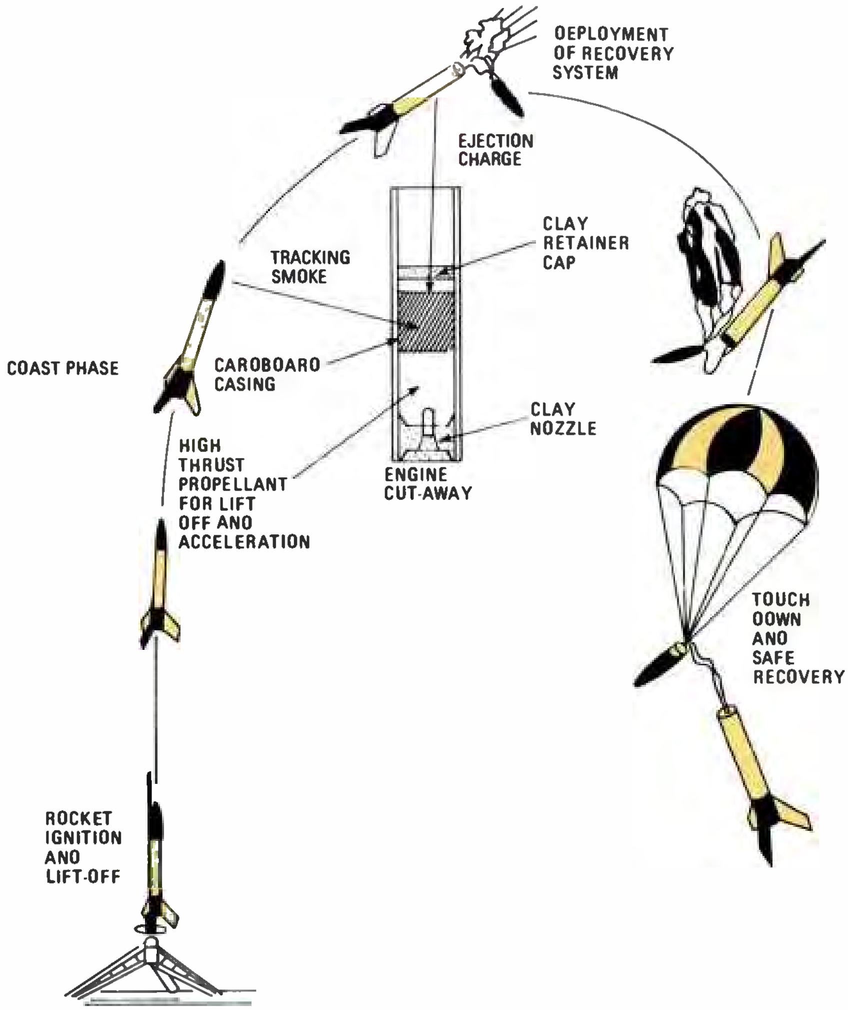

Fig. 5. Here is the flight sequence of the rocket along with a cutaway showing its engine components and their function.

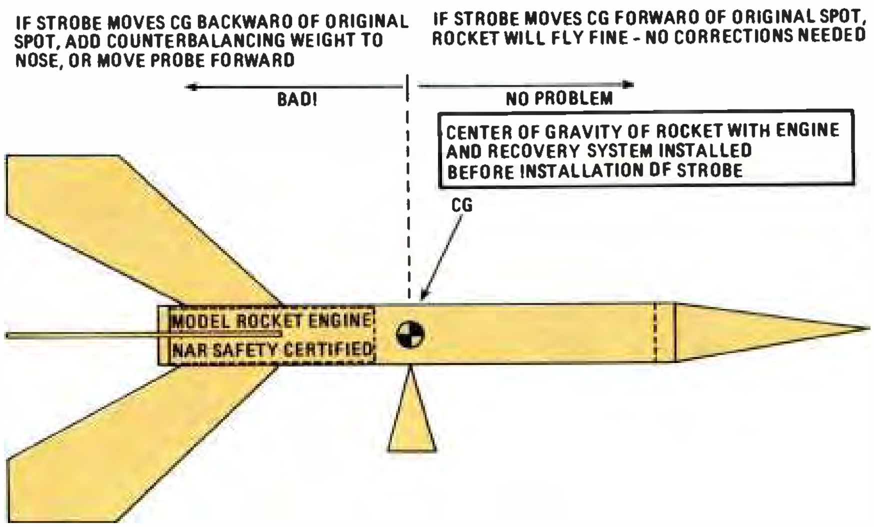

Fig. 6. If the electronics are forward of the model's center of gravity, the rocket should fly fine with the added weight.

around 20,000 flashes. That's over 20 hours continuous at a high flash rate, and represents many rocket flights.

To get the best efficiency, it's necessary to keep C4 close to Q1 (see Fig. 2). That ensures a "reservoir" of current to draw from as Q1 switches. Usually, Q1

(Continued on page 96)

ROCKET STROBE

(Continued from page 33)

does not need any heatsink. Different types of mini transformers and component tolerances may necessitate a small heatsink on Q1 if it gets too hot to comfortably hold. Sometimes, due to winding differences, you will need to increase C4 to 470 µF or 680 µF in order for the PWM circuit to work efficiently. A 16-volt capacitor is satisfactory for use with a 9-volt battery.

Build the PWM part of the circuit first. You should test it before installing the hex FET and T1. That is easily accomplished by using a small speaker with a 10-µF capacitor attached to one lead. Connect the other lead to ground, and the free end of the capacitor to pins 6, 8, 10, and 12 of U1. By adjusting R4, you will be able to hear the volume of the tone getting louder or quieter as R4 varies the pulse width. Once the PWM circuit works, attach the mini transformer, using Figs. 2 and 3 as a guide to polarity. Use proper precautions to minimize static, and install Q1. The +300-volt output may be tested with a neon lamp. Resistor R4 varies the brightness of the lamp somewhat.

Put together the strobe section of the circuit (see Fig. 4) keeping in mind the high-voltage output of T2. Once you have all the parts assembled, it is a good idea to give the finished board and components several light coats of an insulating spray to prevent shorts and high-voltage arcing. A product such as "Acrylic Coating" (which has a dielectric strength of 2,000 volts per .001 inch) or other material for coating printed-circuit boards works well. Don't coat R4, or it won't work anymore! Also, don't spray anything on the flash lamp, although you may insulate the ends to prevent arcing outside the flash tube.

Testing. Before installing the electronics in the rocket, and gluing everything down, check to see that the Strobe is operating correctly. With a 9-volt input and using the parts specified, you should see a flash every 4 seconds on the high setting, and about every 30 seconds on the lowest setting of R4. You'll note the first flash takes quite a while to appear—usually, about 10–15 seconds on high, and a few minutes on low.

The reason for that is that C7, the large electrolytic that stores the energy to light the flash lamp, has to "polarize" if it has been sitting idle for long while. Leakage within the capacitor is maximum when voltage is first applied, and it has to charge and discharge several times before leakage subsides and absorbs less power. If that problem exists, run the Strobe from another 9-volt battery before launch, and wait until the flash rate goes up. Then, you may install your flight battery, and let 'er rip.

If you can get accurate specifications, select C7 for low leakage. Most miniature, recent-style capacitors work fine. In our prototype Strobe, we left out an on/off switch, opting instead to simply install the 9-volt battery when launching. You may install a switch, or leave it out as desired.

Finally, remember to observe sensible practices when flying your rocket. If it gets caught in a power line, or high in a tree, leave it! No project is worth risking one's life! Fly in clear areas, especially for night launches, and observe wind direction, launch angle, expected trajectory, and landing site to optimize your chances of successful recovery. Happy Flying! ■