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BUILD THIS SUPER STROBE

Create breathtaking stop-action photos with the Freeze Frame.

JOHN SIMONTON and TREY SIMONTON

SO MUCH OF LIFE IS A BLUR. WHEN you can slow it down and savor it, you discover the most interesting things.

Take, for example, the pictures showing a water-filled balloon being popped by a dart. You might anticipate that the burst balloon would leave a ball of water hanging in the air for a fraction of a second, but would you have guessed that the surface of the water ball would froth the way it does? What a beautiful surprise.

Our Freeze Frame strobe trigger lets you use photographic techniques that substitute a strobe flash for high shutter speeds. You can reproduce these and other stop-action shots either for serious scientific purposes or just because they make such interesting pictures. The inexpensive, easily built unit has been designed to use interchangeable sensors, so that anything that pops, snaps, flashes, or reflects or blocks light can trigger your camera's strobe.

How it works

The complete schematic for the Freeze Frame is shown in Fig. 1. Either of the sensors (phototransistor Q2 or electret microphone MIC1) acts like a variable current sink in series with R1. As light or sound levels change and more or less current sinks into the sensor, a voltage develops across R1.

The processing amplifier for the sensors is built around two stages of an LM324 quad operational amplifier (IC1-a and IC1-b). The amplifier is AC-coupled so that only changes in the triggering signal are detected. The values of the coupling capacitor between stages are intentionally small so that only changes with higher-frequency components (above about 5 kHz) pass through the amplifier. When using the microphone, that means that snaps and pops will be more likely to trigger the unit than other ambient noise, including speech.

Capacitor C2 couples the output of the processing amplifier to the rectifier- and peak-detector section consisting of D1, D5, R9, R10, and C4. The DC voltage that appears across R9 is approximately the same as the peak-to-peak voltage at the output of the amplifier.

The voltage is applied to a threshold detector, which is a

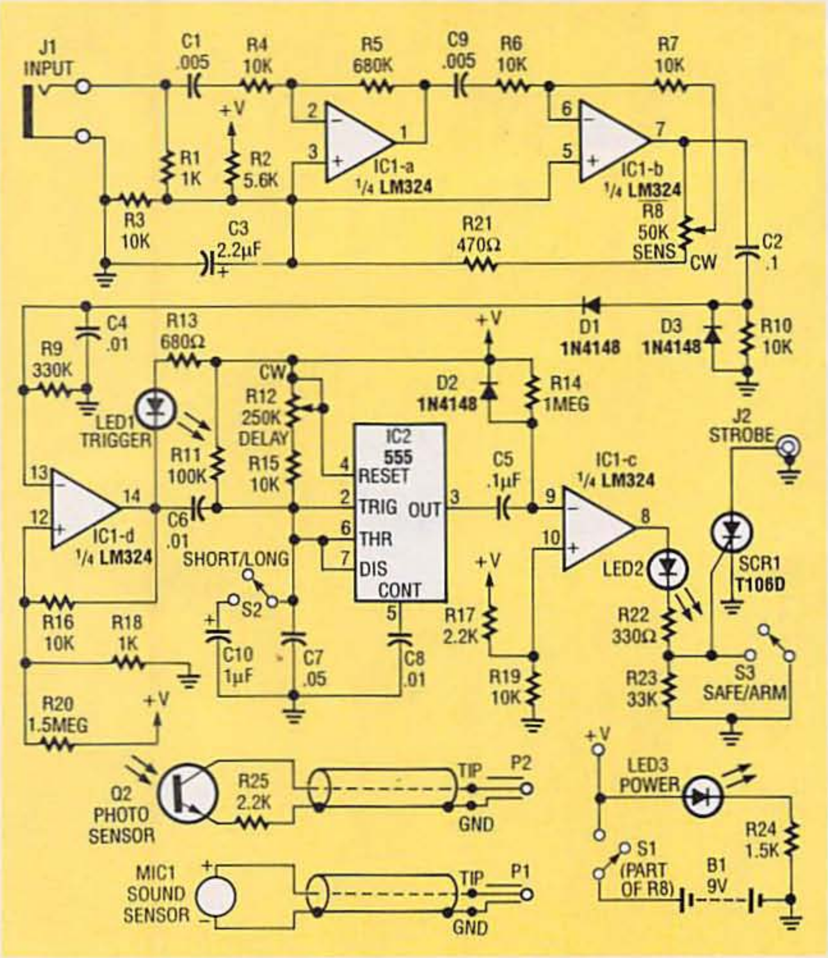
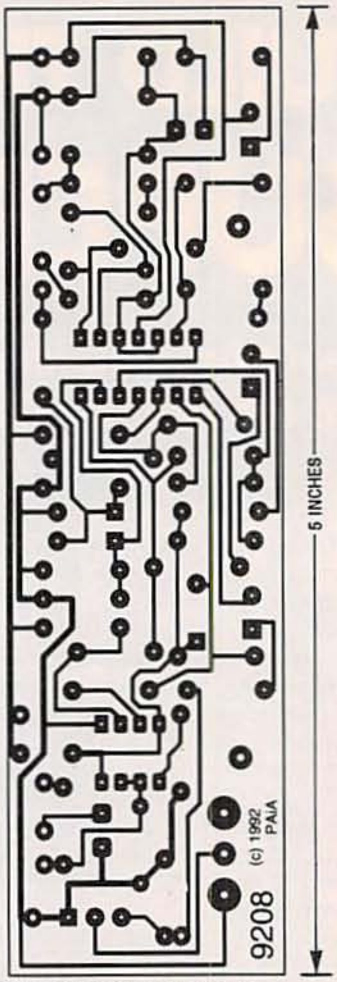


FIG. 1—SCHEMATIC FOR THE FREEZE FRAME. The sensors act like a variable current sink in series with R1. As light or sound levels change and more or less current sinks into the sensor, a voltage develops across R1.



FREEZE FRAME foil pattern.

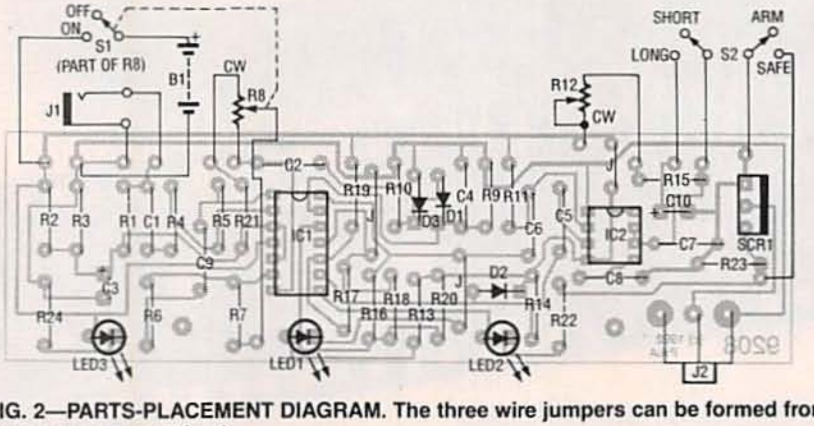


FIG. 2—PARTS-PLACEMENT DIAGRAM. The three wire jumpers can be formed from excess component lead.

Schmitt trigger built around IC1-d. The trigger level is set to a couple of volts and hysteresis is set to about one volt by R16, R18, and R20. At the output of the amplifier, LED1 indicates when a stimulus has exceeded the threshold.

When the output of the threshold detector goes low, C6 couples the transition to the input of the 555-based timer section and triggers it. The amount of delay produced by the timer is set by the DELAY CONTROL R12 and capacitor C7. Capacitor C10 is switched in by S2 when longer delays are needed.

The output of the timer is coupled by C5 to the final amplifier stage in IC1, which is wired as a comparator. At the end of the time-out, IC2's output goes low and is inverted by IC1-c to a positive transition that turns on SCR1. The current path to SCR1's gate is provided by LED2, which also indicates that the triggering signal has happened. As a convenience when setting up to take photos, switch S3 can be closed to ground the gate of SCR1 and prevent it from firing.

Building the Freeze Frame

You can build the Freeze Frame with just about any construction technique you like. A circuit board is always the neatest, quickest, and easiest way though, so we've provided a foil pattern. You can buy an etched and drilled board from the source given in the Parts List. If you use a PC board, mount and solder all of the components following the parts-placement diagram in Fig. 2. There are three

PARTS LIST

All resistors are ¼-watt, 5%.
R1, R18—1000 ohms
R2—5600 ohms
R3, R4, R6, R7, R10, R15, R16, R19—10,000 ohms
R5—680,000 ohms
R8—50,000 ohms, audio-taper potentiometer with switch (S1)
R9—330,000 ohms
R11—100,000 ohms
R12—250,000 ohms, linear-taper potentiometer
R13—680 ohms
R14—1 megohm
R17, R25—2200 ohms
R20—1.5 megohms
R21—470 ohms
R22—330 ohms
R23—33,000 ohms
R24—1500 ohms

Capacitors
C1, C9—0.005 µF, ceramic disk
C2, C5—0.1 µF, Mylar
C3—2.2 µF, 10 volts, electrolytic
C4, C6, C8—0.01 µF, ceramic disk
C7—0.05 µF, ceramic disk
C10—1 µF, 10 volts, electrolytic

Semiconductors
IC1—LM324 quad op-amp
IC2—555 timer
D1–D3—1N4148 diode
LED1–LED3—red light-emitting diode
Q1—IR phototransistor
SCR1—T106D silicon-controlled rectifier

Other components
B1—9-volt battery
J1—Miniature phone jack
J2—RCA jack
MIC1—Electret microphone
PL1, PL2—Miniature phone plugs
S1—SPST switch (part of R8)
S2, S3—SPST slide switches

Miscellaneous: case with top panel, knobs, wire, hardware, battery snap, heat-shrink tubing, coaxial cable, circuit board, etc.

Note: The following items are available from PAIA Electronics, Inc., 3200 Teakwood Lane, Edmond, OK 73013 (405) 340-6300:

- **Etched, drilled, and silkscreened PC board (#9208pc)—$12.75**
- **Complete Freeze Frame kit including PC board, case, and all components (#9208k)—$39.75**

Please add $3.50 shipping and handling to each order.

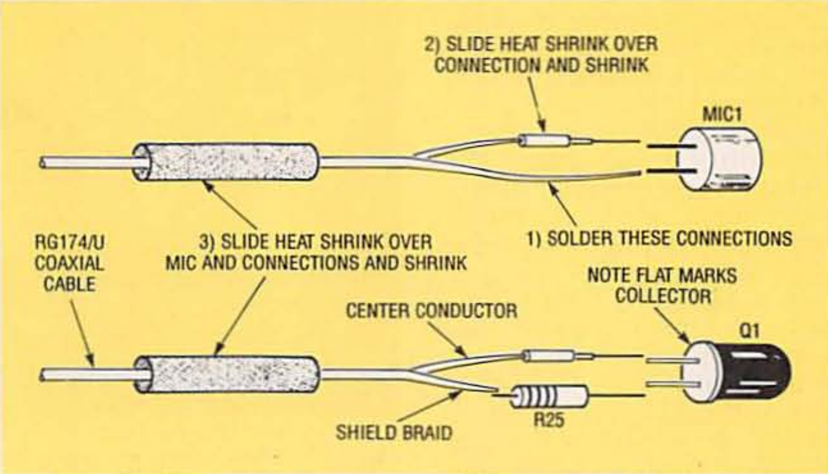


FIG. 3—MAKE THE SENSOR ASSEMBLIES with heat-shrink tubing and small diameter coaxial cable such as RG-174/U. The space between the coaxial cable and the outer heat-shrink tubing is filled with a little silicone rubber.

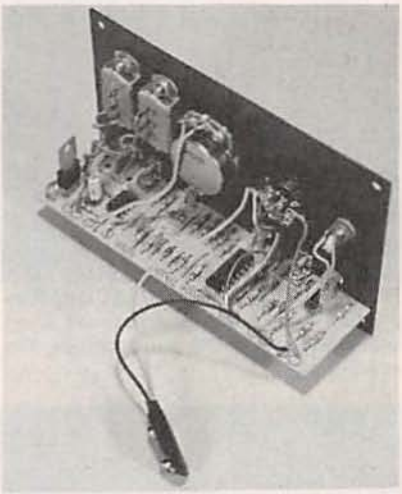


FIG. 4—THE COMPLETED FREEZE FRAME. This is one of the most attractive boards you'll ever see.

wire jumpers on the board that can be formed from the excess leads clipped from other components.

A fairly light gauge wire such as AWG 26 is appropriate for making connections between the circuit board and front-panel controls. With any electronic circuit, keeping the wiring between the circuit board and front panel as short and direct as possible is good practice, and with the Freeze Frame it is important because the high signal gains in the sensor-processing amplifier at maximum sensitivity could cause the pickup of stray signals.

The circuit board is laid out so that the LED's and the STROBE-TRIGGER output jack J2 are on an edge of the board

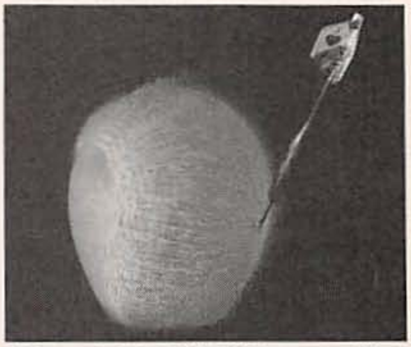


FIG. 5—A DART HITTING a water-filled balloon from an angle. The microphone sensor picked up the sound of the balloon bursting.

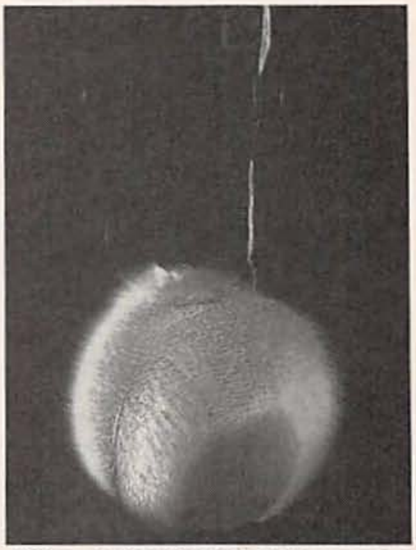


FIG. 6—ANOTHER DART hitting another water balloon, but from directly above.

where they can look out through holes in the front panel when the board is mounted at a right angle to the panel with "L" brackets.

Providing a miniature phone jack (J1) will allow interchangeable sensors. Using different style jacks for the trigger input and strobe output prevents the possibility of damaging the Freeze Frame's circuitry if a high voltage on the flash unit were suddenly connected to the input of the amplifier circuitry. Even if you're going to be using only one sensor, having it remote from the rest of the circuitry is an advantage because it makes it much easier to set up photos and to protect the trigger parts from splashes and other abuse.

Make the sensor assemblies with heat-shrink tubing and small diameter coaxial cable such as RG-174/U (see Fig. 3). Both the phototransistor and microphone are polarized components, so make sure their positive sides (the collector in the case of Q2) connects to the center conductor of the coaxial cable, which, in turn, connects to the tip of the phone jack. Note the resistor in series with the phototransistor; we mounted it at the detector end of the coaxial cable and made the heat-shrink tubing long enough to cover both it and most of the case of Q2. The space between the coaxial cable and the outer heat-shrink tubing was filled with a little silicone rubber.

An infrared photodetector is recommended because it allows a setup under limited fluorescent lighting, which is low in IR. At the same time, many of the events that will be triggering events (such as things blowing up, for instance) are high in IR.

You will need to modify a flash extension cord by replacing its normal camera-end connector with an RCA plug. There are a couple of things to be aware of here. First check the polarity of the voltage on the flash cord; the positive side must go to the anode of SCR1 (the center of the RCA jack) and the negative side to ground. Also, the voltage on those leads varies widely; on some strobes it might be only a couple of volts, while others might be over 200 volts. There is fairly low energy here in either case, so we're not talking about a lethal situation. But you'll definitely feel the higher voltage if you touch it. If you don't want to purchase an extension cord to be dedicated to the Freeze Frame, you might be able to cut your existing cord and patch the two ends together with an in-line plug and jack pair. Make sure the male connector on the end of the cord is connected to the flash. Figure 4 shows the completed unit.

FIG. 7—AIR-FILLED BALLOON hit by a pellet. The streak on the right side is the pellet.

FIG. 8—WATER-FILLED BALLOON hit by a pellet. The sound sensor was used with the report of the gun providing the event trigger.

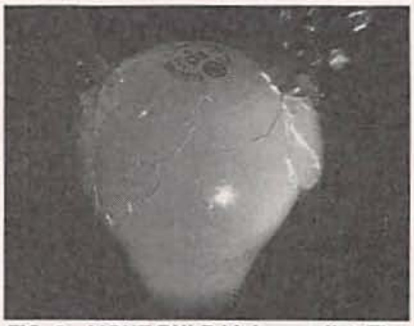


FIG. 9—LIGHT BULB hit by a pellet. The delay was set at its minimum value for this shot.

FIG. 10—THE LIGHT BULB is almost totally gone in this picture. Don't forget to wear goggles when shattering light bulbs.

Testing

Any testing procedure should start with a close visual inspection of your work. Make sure component polarities have been observed, that all solder joints look good, and that there are no solder bridges on the circuit board.

Don't plug in a sensor yet—our initial tests won't need one. Snap in a fresh 9-volt battery and turn the unit on by rotating the sensitivity control clockwise beyond the detent; the power indicator (LED3) should light. If not, check for a dead battery, short circuits, etc.

Set the SENSITIVITY (R8) and DELAY (R12) controls to about the mid-point of their rotation, and set the SHORT/LONG switch (S2) to "short." With a wire jumper or clip lead, short the tip and ground lugs of the input jack J1 together. If everything's working properly you should see both the TRIGGER and FIRE LED's flash briefly and apparently simultaneously. If neither LED flashes, it could indicate problems in the sensor-processing amplifier, so check the circuitry associated with IC1-a and -b, the polarity and assembly integrity around diodes D1 and D3, and the circuitry associated with IC1-d. If only the TRIGGER LED lights, it could indicate problems in the timer circuitry associated with IC2 or the final comparator IC1-c.

Switch S2 to "long," and once again short the input. Now you should be able to see a discernible time delay between the flash from the TRIGGER and FIRE LED's. If you don't see an obvious delay it could mean problems with the timer or with S2 and C10.

Now plug in the microphone sensor. With the SENSITIVITY control set to about mid-range, a finger snap from within a foot of the microphone should cause both the TRIGGER and FIRE LED's to light. At maximum sensitivity, a finger snap within several yards should trigger the unit, and at minimum sensitivity you will have to be within a inch or so from the microphone. If there are no obvious differences in the sensitivity of the unit as the SENSITIVITY control is rotated over its range, check the wiring around potentiometer R8. If there is no response from the microphone as an input, check the wiring of the phone plug and coaxial cable of the microphone, as well as the polarity of the microphone.

Plug in the IR sensor and point it at an incandescent lamp (fluorescent or Krypton lights might not have sufficient infrared energy to be detected by the phototransistor), and set the SENSITIVITY control to mid-range. Passing your finger in front of the phototransistor should cause the TRIGGER and FIRE LED's to flash briefly. Striking a match or lighting a cigarette lighter in front of the sensor should trigger the unit. If there are problems here, check the wiring of the sensor, in particular the polarity of the phototransistor.

Finally, mate the RCA plug on the end of your modified flash extension cord with the STROBE jack and turn the strobe on. Set the ARM/SAFE switch (S3) to "arm" and trigger the Freeze Frame. The strobe should flash when the FIRE LED flashes. If not, check the strobe first, making sure its battery is good by firing it with its own test switch. Then check the modifications you've made to the flash's extension cord; make sure that the positive voltage from the strobe connects to the tip of the RCA plug. If there are still no results, check the SCR.

Using the Freeze Frame

The Freeze Frame helps you to get shots that would be difficult to obtain otherwise. But that doesn't mean that they're necessarily going to be easy. The quality of the pictures you get will depend to a large extent on how carefully you set up the shot.

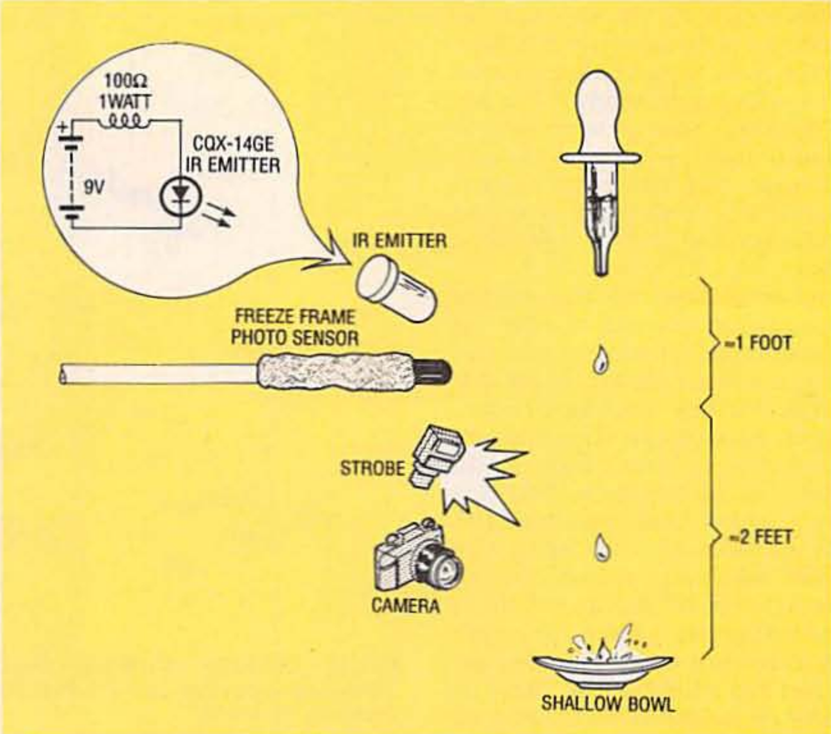


FIG. 11—YOU CAN TRIGGER A MILK DROP by pointing an IR emitter and the sensor in the same direction toward the space through which the drop will fall through.

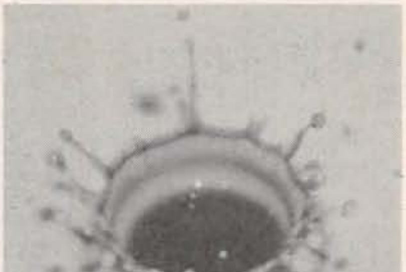


FIG. 12—THIS MILK CROWN is formed after the drop hits.

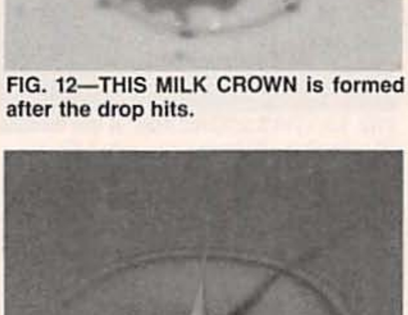


FIG. 13—THIS MILK COLUMN forms later in the sequence.

You can look forward to giving your imagination a workout as you figure out what sensor to use, how to use it, and how to light the subject—not to mention thinking up an interesting picture in the first place.

Each situation will be slightly different, but to get you started we'll cover first some basic principles on the camera side of things, and then look in detail at how the Freeze Frame produced the photos shown here.

As we said in the opening, the essential idea is that you're going to be exposing the film with a brief flash of light while the camera shutter is held open, rather than the usual way of lighting the subject and briefly opening the shutter. The first obvious implication of this is that the photography must be done in the dark—not darkroom dark necessarily, where every tiny little crack must be sealed against light, but dark—a moonless-night-in-the-country kind of dark.

Sensor selection is usually pretty obvious. If the event that you want to photograph makes a sound (like a popping balloon), use the microphone. If the event is very quiet, make arrangements for the event to interrupt a light beam. In the case of the milk drop, we found that milk was surprisingly reflective of infrared, and we were able to exploit this. Some events (like an exploding firecracker) produce a flash and pop giving you a choice of sound or light sensors.

After setting up the strobe and sensor, you will need to do some trial events to get the proper sensitivity and delay settings for the Freeze Frame. Since you won't be shooting any pictures, you don't have to do this part in the dark. You can get a pretty good preview of the photo just by watching the event when the strobe flashes. Persistence of vision will hold the image on your eye's retina for a short time, and you can get a feel for whether the delay is right or needs to be shorter or longer. The range of delay is from 0.5 millisecond to 12 milliseconds when S2 is set to "short" and 10 milliseconds to 0.25 second when set to "long."

Proper placement of the flash makes a big contribution to the quality of the photo. For example, backlighting the subject slightly (placing the strobe so that it lights the subject from behind) will keep any background clutter from showing up on film. When backlighting, make sure the strobe doesn't flash directly into the camera lens or close enough to cause lens flares, unless you want them. Strategically placed "light baffles" can make things that you don't want in the photo, such as supports for the subject, disappear by keeping them in shadow. Sheets of cardboard would be our choice material, but we used books or whatever else we could lay our hands on.

When you're trying to freeze motion, you need brief flashes of light. Strobes that are too "smart" can produce a flash that is amazingly long; we figure several milliseconds judging from the blurred results of our first shots. Switch your flash to its "dumb" (manual) mode and minimum energy settings if you get blurred results. If you are not able to do this, switch to another flash. A modern Vivitar 636AF was smarter than we were, so we wound up using an inexpensive and ancient Vivitar 253 for all of the shots shown here.

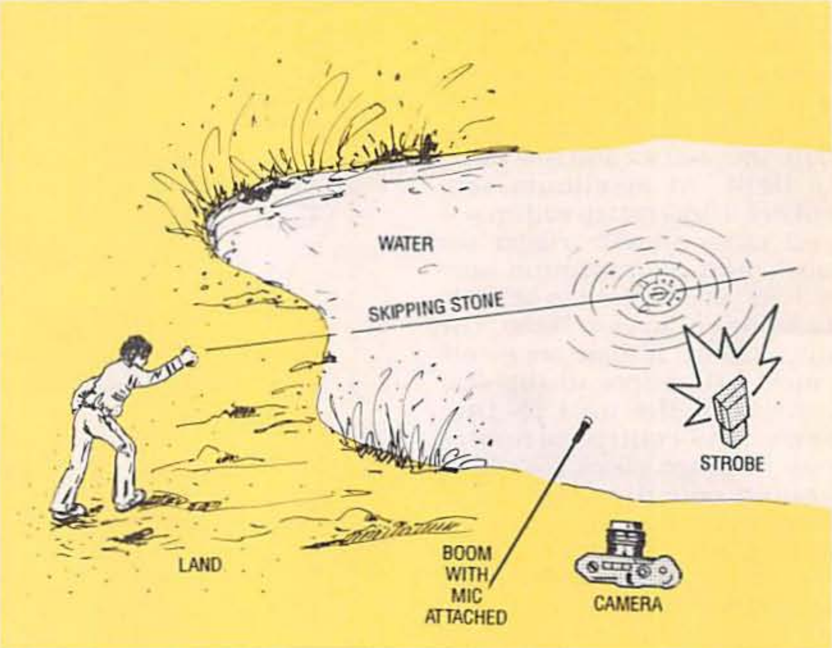


FIG. 14—TO CATCH A STONE SKIPPING ACROSS WATER, we set up the camera on shore, and supported the flash and microphone sensor out in the water to get them closer to the action.


FIG. 15—THIS STONE was in the middle of skipping when we "caught" it.

You can use whatever film you're used to; these shots were done on Kodachrome 64 with aperture settings ranging from f8 to f11. We used a fairly long lens (35–80mm zoom) because taking some of these shots was a messy proposition and we wanted to keep the camera as far away as possible. Remember, the larger the f-stop, the greater the depth of field. That is important when you're not completely sure where all the pieces of a subject will be when the shot is taken.

A tripod was used to free up hands needed elsewhere, but the camera can be handheld without much fear of blurring because the strobe will stop the action. A cable or other remote release can be used to open the shutter, but our Minolta Maxxum 7000 had a self timer that we used instead. We found that a 2-second exposure was long enough to let us take a picture without rushing, and short enough to keep the film from being exposed.

As the battery in a strobe ages, it takes longer for the unit to charge high enough to fire again. That can become an annoying delay if the flash is inadvertently fired during setup. The ARM/SAFE switch keeps that from happening. Leave the switch in the "safe" position until you're ready to shoot a picture, then switch it to "arm."

Once we finished setting and adjusting the camera, strobe and subject placement, delay times, sensitivity, and other adjustments, the general sequence for all shots was the same:

1) Arm the Freeze Frame and activate the self timer

2) Darken the scene
3) Pray while waiting for the shutter to open
4) Do the event
5) Wait for the shutter to close and relight the scene
6) Figure out what went wrong and do the next one

Balloons and darts

Figures 5 and 6 were shot with the microphone sensor to pick up the sound of a water-filled balloon bursting. The microphone was placed close to the subject, just out of the frame. No protection against splashes was needed in the case of the water balloon because splashing is minimal—most of the water just falls and forms a puddle.

In the case of the water-filled balloons, the SENSITIVITY (R8) setting was important because the event didn't generate much more noise than the self-timer opening the camera shutter. (With too much sensitivity, the strobe triggered when the shutter opened.) With air-filled balloons, the SENSITIVITY is not as critical because the balloons generate a louder sound when they pop.

The SHORT/LONG switch (S2) was set to "short" for those shots with the DELAY control (R12) set for a very short period. In fact, it was the shortest possible delay in most of the photos. The balloons were all sitting on an up-ended spray-can lid for support. Light baffles kept the support from being lit.

Balloons and pellets

Figures 7 and 8 were produced by shooting at a balloon with an air rifle (the balloon in Fig. 7 is filled with air and the one in Fig. 8 is filled with water). The sound sensor was used, and the report of the gun provided the event trigger. The SENSITIVITY control was set to minimum. The rifle was securely clamped to a tripod about 4 feet from the target and carefully aimed during set-up. Several sheets of corrugated cardboard were used as a back-stop for the pellets. We chose a pump-type air rifle rather than a cartridge-powered one because, by pumping it the same number of times for each event, we found it had a more constant muzzle velocity.

Because air balloons are not as messy as water ones, we used them for setup. Simply place a balloon, arm the strobe, shoot the balloon, and see what happens. Don't blink, or you'll miss the part of the event illuminated by the flash. If what you see by the light of the flash is the balloon just sitting there, increase the delay. If you don't see any balloon, decrease the delay. If you're not sure what you saw, shoot a picture anyway. (There is such a thing as serendipity.)

It's interesting to notice the difference between water balloons burst with a dart and those hit with a pellet. While the dart simply slides in, leaving the water in the balloon almost undisturbed (Fig. 5), the energy from the impact of the pellet sets up a shock wave like that shown in Fig. 8. In some of the photos you can see the pellet as a streak in the right-hand side of the frame.

FIG. 16—A CAPACITOR EXPLODING is really quite a spectacle if you can really see what happens.

Light bulbs and pellets

Shooting at light bulbs with a pellet gun (Figs. 9 and 10) is set up the same way and with similar SENSITIVITY and DELAY settings as shooting at balloons with pellets. Safety first here: Don't forget your protective safety goggles.

Milk drops

This is the "classic" stop-action photo, with a tip of the hat to strobe photography's pioneer, Dr. Harold Edgerton. Since the splash produced by the drop is pretty quiet, the phototransistor is the sensor of choice. We tried the microphone, but couldn't keep the camera shutter from pre-triggering the strobe. This common picture is usually taken by having the drop fall between a collimated light source and photodetector. We tried that with our somewhat less-than-laboratory-grade stands and supports. It was difficult to get the eyedropper we were using as a drop source in just the right position to break the beam. After playing around for a while, we found that milk is surprisingly reflective of infrared. By placing an IR emitter and the sensor facing in the same direction pointing toward the space through which the drop would fall, we got very reliable triggering (see Fig. 11). The SENSITIVITY control was set nearly to maximum.

In these pictures we used the long delay range. By adjusting the DELAY control, we were able to get shots of both the familiar milk "crown" (Fig. 12) and the reaction column that forms later in the sequence (Fig. 13).

To help visualize the distribution of flow vectors induced by the momentum imparted to the resting fluid by the fluid in motion, we dyed the medium—just kidding. We thought it would look interesting to put some food coloring in the drops; nevertheless, it shows that the fluid that was in the drop winds up in the crown of the splash.

Skipping stones

These were fun. We set up outdoors by the side of a small country lake on a moonless night. A convenient wall gave us a dry place to put the camera and throw rocks from, but the support for the flash was put out in the water to get it closer to the action (see Fig. 14). The microphone was used as a sensor to trigger from the splash of the stone hitting the water. After en-

continued on page 87

SUPER STROBE

continued from page 37

countering some trouble with false triggering by the sound of the shutter opening, we put the microphone on a tree limb to get it closer to the splash while being careful not to get it in the frame. We covered it with a plastic bag to keep it dry. The SENSITIVITY ended up being set about mid-range. Figure 15 shows one of our efforts at catching a stone skipping across water.

Exploding capacitors

When the editor speculated on what an exploding capacitor might look like, we decided to find out... despite our better judgment. Do not try this at home! The fumes that are generated are noxious and toxic. A fire extinguisher, proper safety clothing and eye-protecting goggles are essential precautions.

We learned that there's not much more to be seen of an exploding capacitor with the strobe than without it. However, the picture that we chose to illustrate what happened (Fig. 16) is slightly more dramatic because the smoke, which would not have shown up otherwise, was illuminated by the strobe. To try to get a more interesting shot, we even piled a group of electronic components on top of the cap thinking we could get a picture of them flying into the air. That might have worked eventually, but when our eyes started to water from the smoke we decided to take a break, and we just never got back to this experiment.

Your turn

These photos and the explanations of how they were set up and shot should get you started. The only rule is that there are no rules; you really get to make them up as you go along. We have a standing bet about how much a golf ball deforms when it's hit. If you find out before we do, let us know. **Electronics Now** will be happy publish the best Freeze Frame pictures we receive. R-E