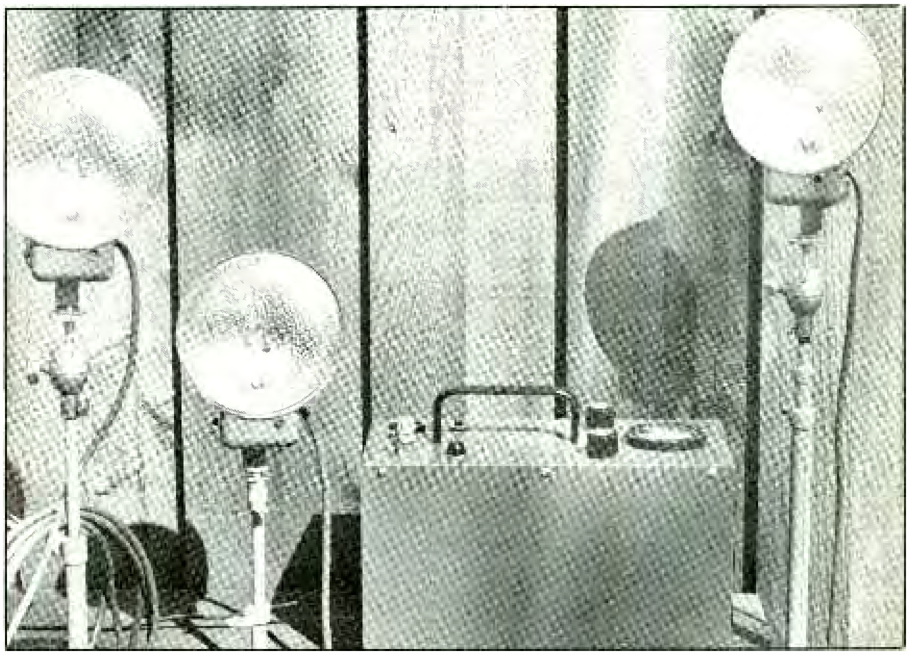
Triple-Head Photo Flash System

Gives the amateur photographer the advantages of multiple-source studio lighting systems for shooting professional-quality portraits

By Maurice P. Johnson



Regardless of the camera you use, if the flash is mounted on it, you get very restrictive illumination because light aimed at your subject from the same axis as the lens can produce flattening and very unflattering front light. This flash-on-camera arrangement is also the cause of "red eye" commonly seen in color photos of people. For effective photography lighting, you need more than one light source in locations that are off-camera.

Though use of a flash gun with a flash head that can be tilted upward to bounce light onto the subject provides a bit of improvement, it isn't a good solution. Light reflected (bounced) off the ceiling onto your subject from a direction may be more flattering, but the intensity of the light that reaches your subject is considerably reduced when compared to direct-flash intensity. Consequently, unless you use a fairly powerful flash gun, the light falling on your subject may be too weak to provide adequate exposure without a fast lens.

For effective portrait photos, what you really need is a multiple-head flash system like the triple-head design described here. Our Triple-Head Flash System is designed to meet three important criteria for good indoor studio-quality photos. One is the modeling light, which is the dominant light that establishes the direction of principal illumination and is seldom located at the lens axis. It defines butterfly, Rembrandt, 45°, etc. type light. Next is fill-in light that you use to illuminate the shadows created by the main light. This light can be located near the lens axis but is subordinate to the main light. The third and final criterion is independent background lighting that acts as a "hair" light for a degree of backlighting to separate the subject from the background. It can be used as a "rim" light or side light.

We offer here two different but similar multiple-head flash system designs. One provides 300 watt-seconds of power and features a bevy of bells and whistles. The other, more conservative system provides 100 watt-seconds of power and omits some convenience features. The version you build will almost certainly be determined by availability of certain components.

Design Considerations

A convenient per-tube power level for a home studio system lies in the 100-Ws (watt-second) range. Such a unit requires power packs that supply 450 to 500 volts dc. This is a feasible voltage for home construction and provides a very useful light level.

There's no need for miniaturization or powering from a source other than the 117-volt ac line for a studio setup. The flash heads are intended to mount on light stands, the power pack to rest on the floor.

The flash heads consist of flash tubes with reflectors and a minimum of electronics. Trigger transformers and trigger capacitors are the only trigger components in the flash heads. The remaining triggering circuitry is housed inside the power pack, which is the major element in the system, since it encompasses the storage capacitors, charging power source, control and monitor elements, and triggering circuitry.

To obtain effective energy/light conversion, a full amount of energy should be supplied to each flash tube in a multiple-head system. To achieve this, the applied potential must be at least 400 volts but not more than 550 volts for reliable firing. You must take care to avoid subjecting the flash tube to greater than 550 volts, or the tube will be irreparably damaged. From the foregoing, you can see that there's a very definite voltage "window" between 400 and 550 volts that defines power pack voltage levels. The power pack must, therefore, be designed to load the tube to a 100-Ws energy level within these voltage limits. Also, *each* flash tube should be loaded to this energy level, whether one, two or all three flash heads are in use for a particular photo session. This is accomplished with a separate storage capacitor in each flash head. These capacitors charge in parallel from a single source, but they're electrically isolated from each other for independent discharge into their respective flash tubes.

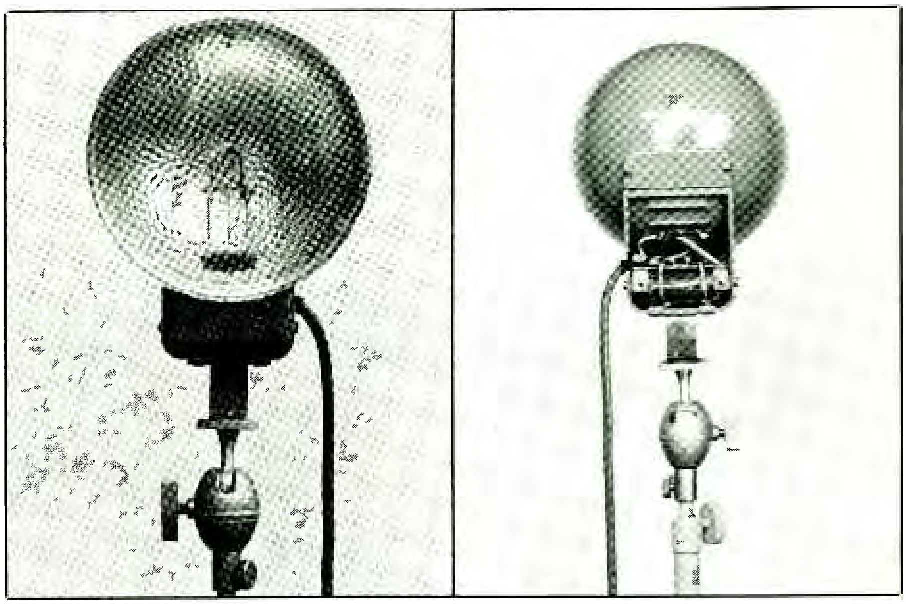


Fig. 1. Flash heads selected should have built-in flash tubes and trigger transformers. They should also be able to mount on tripods or other supports. Being able to tilt is also a plus.

When searching for suitable flash tubes, look for ones intended for 450 to 500 volts across them (GE No. FT-118 and similar types). Try to obtain heads that include tubes, trigger transformers and suitable reflectors to minimize any modifications needed to adapt them for light-stand use.

Suitable capacitor values are in the 500- to 800-μF range. These capacitors should be rated to handle 500 working volts, but in a pinch you can get away with capacitors rated at 450 volts. You can parallel-connect smaller-value capacitors to obtain the desired value if need be.

You also need a power transformer of the type used to power tube-type TV receivers, amplifiers or radios. The transformer should have a secondary winding rated at 650 to 700 volts and a center tap to drive a full-wave power-supply circuit. A transformer with no tap on the secondary winding and capable of delivering 325 to 350 volts can be substituted for a half-wave power-supply circuit. Select a transformer rated at not less than 50 mA. The greater the current rating, the faster the charging cycle for the flash-head storage capacitors and the shorter the cycle interval between shooting pictures.

To avoid confusion, we'll deal with the elements that make up this project one at a time, discussing how each works and giving construction details before proceeding to the next.

• *Flash Heads.* Only a minimum of circuitry is included inside a flash head (see Fig. 1). A three-conductor cable terminated in a plug connects each flash head to the power pack through a mating jack. This cable should be wired directly to the components in the flash head, not through a plug/jack arrangement.

Flash-tube leads shouldn't be subjected to strain. They're best secured to solder lugs or support terminals at the points the cable conductors or trigger transformer leads attach. Connect the high-voltage secondary of the trigger transformer directly to the trigger band on the flash tube. (Each flash head must be equipped with a separate trigger transformer and trigger capacitor.) One side of the trigger capacitor connects to the primary of the trigger transformer, while the opposite (input) end of the capacitor is brought back through the cable to the power pack, where it's accessible to the firing circuits.

In essence, the trigger capacitor simply connects back to the opposite end of the trigger transformer when the flash is to be fired. The primary circuit is completed so that the capacitor discharges through the transformer in only a few microseconds to generate a high-voltage firing pulse at the transformer secondary. Applied to the tube, this trigger pulse ionizes the internal xenon gas so that the capacitor, in turn, discharges through the very-low resistance of the ionized gas and produces a light pulse of very-short duration.

Nearly 500 volts dc appears across the flash tube and cable conductors when the storage capacitor is charged. The trigger capacitor charges to about 150 volts, which also appears on the third cable conductor. Within the head housing, when the tube is fired, the voltage at the secondary of the trigger transformer is a pulse with a magnitude of at least 4,000 volts and may even approach 10,000 volts with certain transformers. Consequently, component layout and cable type should be selected with these voltages in mind.

Fit the flash head with adequate hardware to permit it to be attached to a standard light stand. A tilt head is particularly useful for aiming the flash to direct light in a specific direction during use.

• *Power Pack*. This part of the system requires construction from scratch. Here we give you a choice between two versions of power pack to build—"bare-bones" and a more elaborate design, both of which can power up to three flash heads. The major difference between the two designs is the amount of loading each applies to each flash tube when the tubes are fired in parallel.

When using multiple flash heads powered by a common power pack, each flash tube should have its own trigger transformer and capacitor to ensure reliable triggering. Parallel-connected flash tubes should be of the same type if a common stored energy source is to divide equally among the tubes. Make sure that the energy discharged into any one tube never exceeds the energy (watt-second) rating of that tube.

The more-elaborate power pack contains a storage capacitor for each flash tube in the setup, each of which charges to the energy rating of a single tube. Thus, each storage capacitor charges to a 100-Ws energy level. To ensure that no tube becomes overloaded, which could happen if one tube receives the charge of more than one energy capacitor, each tube and its energy capacitor is isolated from the others via "steering" diodes. This makes for a bit more elaborate power pack and permits loading each parallel-connected tube to its full energy rating, with attendant greater total light output.

It makes little difference whether you use half-wave or full-wave rectification, except that the full-wave supply has a higher ripple frequency that's a bit more efficient in charging the storage capacitor(s). Availability of a specific transformer can be the guiding factor in your choice between half- or full-wave rectifier circuit. In any case, transformer voltage must be selected according to the

300-WS PARTS LIST

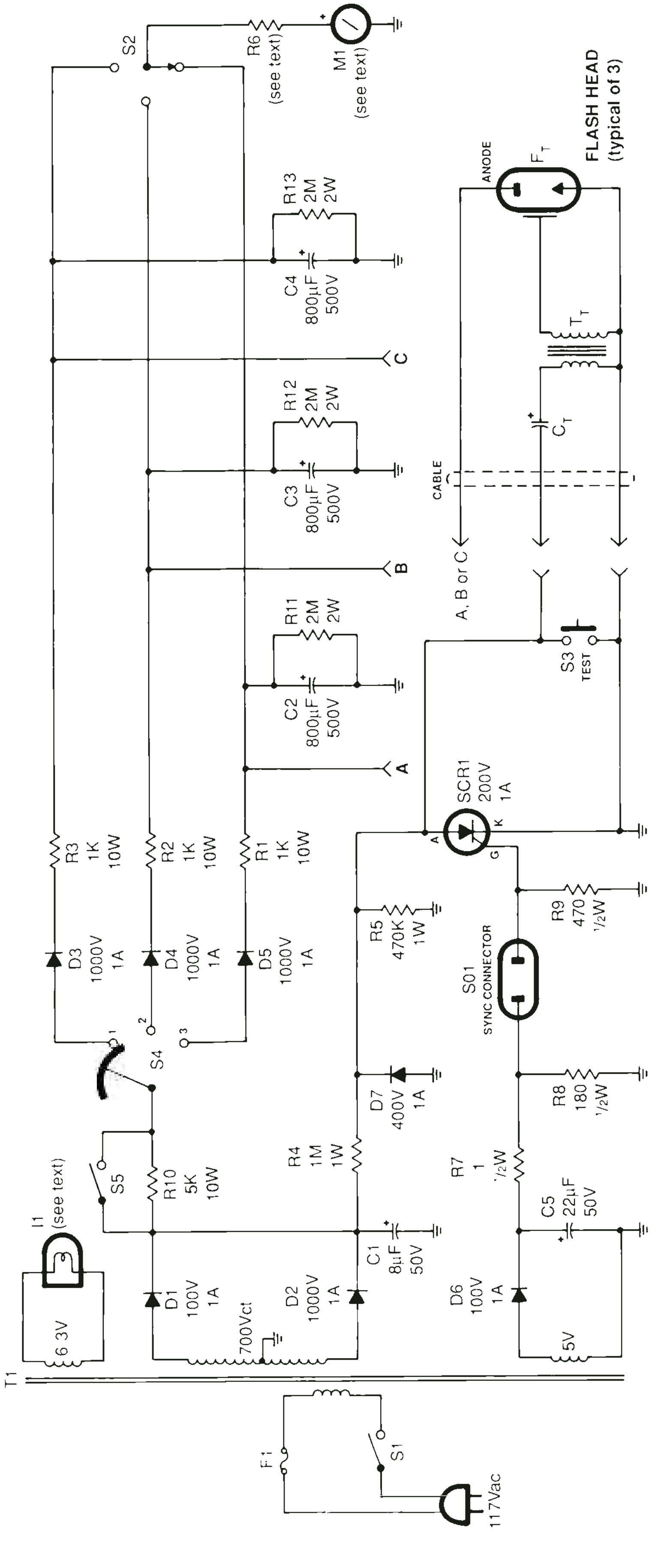
Semiconductors
D1 thru D5—1,000-volt, 1-ampere silicon rectifier diode
D6—100-volt, 1-ampere silicon rectifier diode
D7—400-volt, 1-ampere silicon rectifier diode
SCR1—200-volt, 1-ampere or more silicon-controlled rectifier

Capacitors
C1—8-μF, 500-volt electrolytic
C2,C3,C4—600- or 800-μF, 500-volt computer-grade electrolytic
C5—22-μF, 50-volt electrolytic
C_T—0.22-μF, 400-volt paper*

Resistors (10% tolerance)
R1,R2,R3—1,000 ohms, 10-watt wire-wound
R4—1 megohm, 1-watt carbon
R5—470,000 ohms, 1-watt carbon
R6—533,000 ohms for 1-mA meter movement; 5.3 megohms for 100-μA movement
R7—10 ohms, ½-watt carbon
R8—180 ohms, ½-watt carbon
R9—470 ohms, ½-watt carbon
R10—5,000 ohms, 10-watt wire-wound
R11,R12,R13—2 megohms, 2-watt carbon

Miscellaneous
F1—3-ampere slow-blow fuse
F_T—100-watt-second, 450-volt flash tube with suitable reflector and housing (GE-FT118 or similar)*
I1—6.3-volt ac panel lamp
M1—1-mA or 100-μA meter movement (see R6 above)
S1,S5—Spst toggle or slide switch
S2—Sp3t non-shorting rotary switch
S3—Spst normally-open pushbutton switch
S4—Sp3t shorting rotary switch
SO1—Polarized jack
T1—700-volt, center-tapped power transformer with 6.3- and 5-volt windings (see text)
T_T—4-to-10,000-bolt trigger transformer*
Suitable enclosure (see text); bayonet fuse holder; pointer-type control knobs for S2 and S4; C clamps for mounting storage capacitors; bayonet panel-lamp holder; sockets for flash-head cables; flash-head cables; flash heads (see text); tripods or stands for flash heads; ac line cord with plug; spacers; terminal boards (see text); dry-transfer lettering kit; spray paint and clear acrylic spray (see text); stand(s) for flash tube(s)*; suitable wire (see text); machine hardware; hookup wire; solder; etc.

*These items are for the flash-head assemblies. You need one of each per assembly.



voltage rating of the storage capacitor(s) and flash tube(s).

There are some interesting aspects to the interrelationship between the power supply and flash head. The power pack charges the storage capacitors between flashes fairly rapidly so that you can snap another photo again quickly. A time constant related to the charge time involves the value of the storage capacitor and series resistance in the charge path: T = kRC. From this, you can see that larger-value capacitors take longer to charge through a given resistance. A smaller resistance speeds up charging but results in heavier current flow. However, current flow must be limited for safe repetitive delivery without excessive heating.

Similarly, discharge of the storage capacitor through the flash tube (which has been ionized by the trigger pulse) may see a low-resistance path of, say, 3 to 6 ohms or so. Discharge can then occur in only a few milliseconds, depending on the value of the capacitor. A large-capacity storage capacitor takes longer than a small one to discharge. Flash units with electrolytic capacitor values in the hundreds of microfarads produce a flash that lasts a few milliseconds.

Since the power supply generally runs continuously during a photo session, the charging circuit constantly attempts to charge the storage capacitors, even during the flash discharge period. Therefore, the series charging resistance must also keep the power supply from attempting to keep the flash tube alive by supplying current directly to the tube. If this occurred, the tube would quickly be destroyed. Hence, the series charging resistance assures that discharge current comes from only the storage capacitor and *not* directly from the power supply.

Fig. 2. Complete diagram of more-elaborate power-pack circuit design.

The time required to recharge the storage capacitor is a determining factor in the rate at which flashes can be repeated. Another factor is the need to limit the number of flashes per unit time that the flash tube experiences because each discharge generates heat in the tube that must be dissipated between flashes. However, the charge time of the power pack is more of a limitation than the allowable repetition rate of the flash tube. So the power supply itself will be the determining factor for flash repetition rate.

• *Storage Capacitors.* Having established that a transformer secondary potential of 350-volt rms (or a full-wave 700-volt center-tapped secondary winding) will provide a peak potential near 500 volts, the next step is to select suitable storage capacitors. So-called computer-grade electrolytic capacitors of good quality (low internal series impedance) are suitable. Your objective is to operate the flash tube near its full watt-second rating for maximum energy-to-light output efficiency.

Loading is related to the voltage across the capacitor and its value in microfarads by the equation Ws = ½ CV, where *Ws* is the energy in watt-seconds, *C* is capacitance in microfarads and *V* is the charge voltage in kilovolts (kV). With 500 volts available, Ws = 0.125 C. Thus, 500 μF delivers 62.5 Ws; 600 μF provides 75 Ws, and 800 μF supplies 100 Ws. A 1,000-μF capacitor is a bit large, delivering 125 Ws, which is the absolute maximum rating of the tube. However, 1,000 μF capacitor could be effectively used if the power pack voltage turns out to be a bit lower than the 500-volt peak being discussed.

300-Watt-Second Design

The power-pack circuitry for the more-elaborate design is shown schematically in Fig. 2. This version has a center-tapped transformer and two diodes for full-wave rectification.

In addition to the impedance of power transformer *T1*, series resistors limit the charging current. Independent storage capacitors are used, one per flash head, to permit each flash tube to be fired at maximum energy. Yet, any tube will never be over-stressed, since steering diodes *D3*, *D4* and *D5* isolate the capacitors from each other. If one flash tube fails to fire, its associated capacitor doesn't discharge. The other capacitors won't be effected, nor will the unfired capacitor "dump" into those that do discharge. This keeps any flash head from ever being over-stressed, while full energy is supplied to each tube.

For convenience, shorting switch *S4* permits one or two of the storage capacitors to be disconnected from the charging path if only two or one flash heads are needed during a photo session. Doing this can speed up charging time, resulting in shorter cycling intervals between shots.

Meter *M1* monitors the voltage on any selected storage capacitor. You can select the storage capacitor to be monitored with *S2*. The series resistance of the meter was selected so that a reading 90% of full-scale represents full capacitor charge. The slight overvoltage scale allowance can be useful if high line voltage is ever encountered.

Momentary-action pushbutton TEST switch *S3* permits firing the charged flash heads to test the system. Pressing *S3* grounds the trigger capacitors of all connected flash heads to fire the tubes. The current that flows in this trigger line is a bit high for camera shutter sync contacts, especially when several flash heads are fired with a common sync switch. A simple way to upgrade the firing circuit is to use an SCR to complete the discharge path of the trigger capacitor(s). With *SCR1* connected as shown, its anode-to-cathode circuit absorbs the current that flows through the very-low resistance trigger-capacitor return path when firing the system. In turn, *SCR1* is triggered by the much lower voltage delivered to its gate from the camera shutter contacts.

SYNC CONNECTOR *SO1* can be any polarized socket for connection from the camera to the power-pack trigger interface. One side of the sync cable goes to the gate voltage source, the other to the gate of *SCR1*. Because the amount of current flowing in this path is very low, no arcing or sparking will occur. Therefore, no significant wear of the camera sync contacts will result.

Power transformer *T1* selected for this version of the project has two additional secondary windings. The 6.3-volt winding permits use of POWER indicator *I1*, while the 5-volt winding is the source for the SCR gate voltage. Transformers that don't have these secondary windings can be used, but you must obtain the voltages for the POWER indicator and SCR trigger from the main secondary winding (we'll show you how this is done later, when we discuss the minimal power-pack circuitry).

Construction

Before you can decide on what size enclosure to use for the power-pack circuitry, collect the major components that must go into it and from their physical sizes determine the dimensions of the enclosure you need. Typical computer-grade capacitors measure 2½ inches in diameter by 5 inches high. The power transformer may occupy a similar volume. These components dictate enclosure size, especially since three storage capacitors are involved.

The prototype of this power pack, shown in the lead photo, was built into a 12 × 7 × 6-inch aluminum utility box, which nicely accommodated the power-pack circuitry. Note that this enclosure provides ample volume for the components and a satisfactory control-panel layout. Removable 7 × 12-inch panels serve as the sides of the enclosure, and all

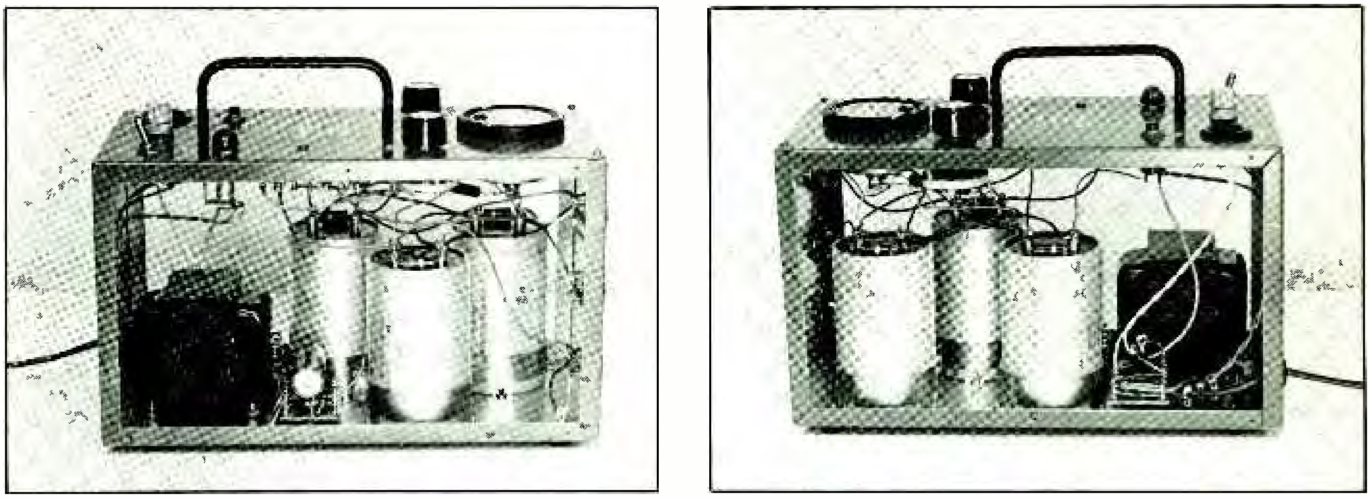


Fig. 3. These two views of author's prototype of the 300-Ws unit show the zig-zag pattern you should use to fit the power transformer and storage capacitors on a minimum of enclosure real estate.

components attach to the box itself.

One side wall (*not* removable side panel) accommodates the controls and indicators for the project and serves as the top panel of the enclosure. Most major components mount on the other side wall, which also serves as the floor of the enclosure. On one end of the enclosure should go the sockets for the cables that connect the flash heads to the power pack. No actual chassis is needed, since all components mount to either the enclosure walls or on small terminal boards.

If you use the utility box described above, position the storage capacitors and power transformer in a zigzag pattern (see Fig. 3) to fit the available area on the bottom panel. Plan on using ring clamps for mounting the capacitors and ½-inch spacers to support the transformer so that its leads can fan out under the transformer and obviate the need for drilling extra holes.

Plan your layout so that two small terminal boards mount near enough to the power transformer so that its leads reach the appropriate points on the boards without requiring you to extend them with wires.

Mount on one terminal board the components associated with the high-voltage rectification section, namely the rectifier diodes, filter capacitor *C1* and resistors *R4* and *R5*. On a second terminal board that will mount near the transformer, mount *D6*, *C5*, *R7* and *R8*, with *SCR1*, *R9* and *D7* at one end of the board. Mount on a third terminal board *D3*, *D4*, *D5*, *R1*, *R2* and *R3*. The resistors on this last board are 10-watt units that operate at nearly 500 volts. Use a high-quality board material and leave ¼ inch of space between the resistors and the surface of the board.

Machine the enclosure as needed, including drilling a hole for entry of the ac line cord. Plan on mounting a carrying handle on the top control panel near the center of gravity. Don't drill the holes for the handle until after you've assembled the power pack and can better judge where this point will be. Because the power transformer is a bit heavier than the storage capacitors, this point will be a bit to the rear of enclosure center. Arrange the holes for the POWER indicator, POWER switch and fuse holder at one end of the control panel and those for the sync cable socket and TEST switch in the other corner.

The third terminal board will mount on the underside of the panel, beneath the carrying handle. This makes for short leads between capacitors, steering components and output sockets. The two rotary switches and meter movement holes should be drilled and punched through the top control panel.

Switch *S5* should mount under the top panel on a small L bracket. This switch isn't an operating control. You open it only to insert *R10* into the charge path during initial forming of the storage capacitors. You then close it to short out *R10* for normal power-pack operation.

By mounting components on the three terminal boards, you can use point-to-point wiring to make all interconnections when you're ready to wire together the components and assemblies. Since the currents involved in charging average less than 1 ampere, ordinary hookup wire will do for these portions of the circuit. However, the discharge path from storage capacitors to sockets to flash heads carry current pulses of 75 to 100 amperes for a few milliseconds, necessitating use of heavier wire—No. 18 or heavier-duty and well-insulated, at the minimum.

Locate the holes for the three sockets into which the flash-head cables plug in one end wall of the enclosure.

When you finish machining the enclosure, deburr all holes drilled and punched to remove sharp edges. Thoroughly clean all exterior surfaces of the enclosure with scouring powder and fine steel wool. Then thoroughly rinse the enclosure and dry it. The scouring powder and steel wool will have left behind a fine "tooth" to which paint will adhere.

Spray a *light* base coat of enamel paint in your choice of color on all exterior surfaces and allow it to completely dry, preferably two or more days. Then lightly rub the painted surface with dry steel wool and wipe away all dust. Spray onto the first two or more light coats of the paint, allowing each coat to thoroughly dry before spraying on the next.

When the paint has completely dried, use a dry-transfer lettering kit to label appropriate legends at the control, connector and indicator locations. Follow up with two or three *light* coats of clear spray acrylic to protect the legends. Again, allow each coat to dry before spraying on the next coat.

Mount the various components and subassemblies in their respective location. Then refer back to Fig. 2 to wire together the circuit. Take care when doing this to properly polarize the electrolytic capacitors and diodes and properly base the SCR. Make certain that the connections to the sockets into which the flash-head cables plug are properly polarized.

Wire the ground and trigger-capacitor feeds in parallel. Be sure to feed the high-voltage leads independently to each storage capacitor, since each flash head has its own separate storage capacitor.

A word of caution: Electrolytic capacitors that have been sitting around unused for a long time have a tendency to lose storage capacity and must be re-formed before they behave properly. An unformed capacitor won't fully charge and may heat internally if excess current is applied to it. Forming isn't difficult, but it must be performed *before* you try to put the power pack into service.

Your wired power pack includes everything you need to form the storage capacitors as follows. Resistor *R10* at the input of switch *S4* is included just for the forming procedure. Opening *S5* inserts *R10* into the charge path to limit charging current when forming the capacitors.

Forming is a straightforward process. With the flash heads disconnected from the power pack, open *S5*, plug the line cord of the power pack into an ac outlet and set the POWER switch to "on." You can set *S4* so that all three capacitors are connected to the charge line. Monitor the voltage across each of the switched-in capacitors in turn and note that one or more may not charge to more than, say, 200 or so volts after a minute or more of charging time. This is characteristic of unformed capacitors.

Turn off ac power to the power pack and allow the capacitors to discharge through their bleeder resistors. You can accelerate discharge by shunting a 500-ohm, 10-watt power resistor from the + terminal to ground. *Don't* just short the capacitors to ground with a screwdriver or other very-low-resistance path. Remember to observe all applicable safety precautions when working around the storage capacitors and voltages involved!

Repeat this charge/discharge several times and you'll notice that each time you do the capacitors should charge a bit faster to a slightly greater voltage. Depending on the history of the capacitors, it should be possible to reach a charge of about 400 volts on each capacitor. A capacitor may need more cycles before it charges to this voltage. If so, continue the process until all capacitors reach this level or more.

You can now connect the flash heads to the power pack to continue the forming process. It's now possible to discharge the capacitors by firing the flash heads as the discharge load. Close *S5* and continue to charge and fire the heads until the capacitors can be charged to at least 450 volts in a reasonable amount of time (20 to 30 seconds). The capacitors have now been formed and should accept full charge.

It's a good idea to cycle capacitors of the electrolytic type, even if unused, by charging and firing a few times every month or so. This keeps the capacitors fully formed and obviates having to go through the re-forming process again. To form capacitors from scratch or after unknown periods of time on the shelf may take hours to accomplish if internal heating is to be minimized. This is the reason for using at least 5,000 ohms of charging resistance in the initial forming steps. The operating circuit uses only 1,000-ohm values for charging resistors *R1*, *R2* and *R3*. These resistors limit the charging currents applied to fully formed capacitors. They also limit the maximum current drawn from the power supply and keep the flash tubes from suffering "hangover" from current coming directly from the power supply instead of from only the storage capacitor.

After you secure the side panels to the enclosure, there's little chance for electric shock from the power supply or flash system. Of course, completely enclose the flash heads, since high voltages appear at the tube terminals. The interconnecting sockets for attachment of the heads to the power pack are polarized to be female on the power pack and male on the flash head cable. The trigger circuit, as brought to the camera, carries only 3 or 4 volts and, thus, avoids any problems in camera handling relative to the higher pack voltages.

100-Watt-Second Design

The elaborate power pack discussed above includes operating convenience features and maximizes the energy directed to each flash head,

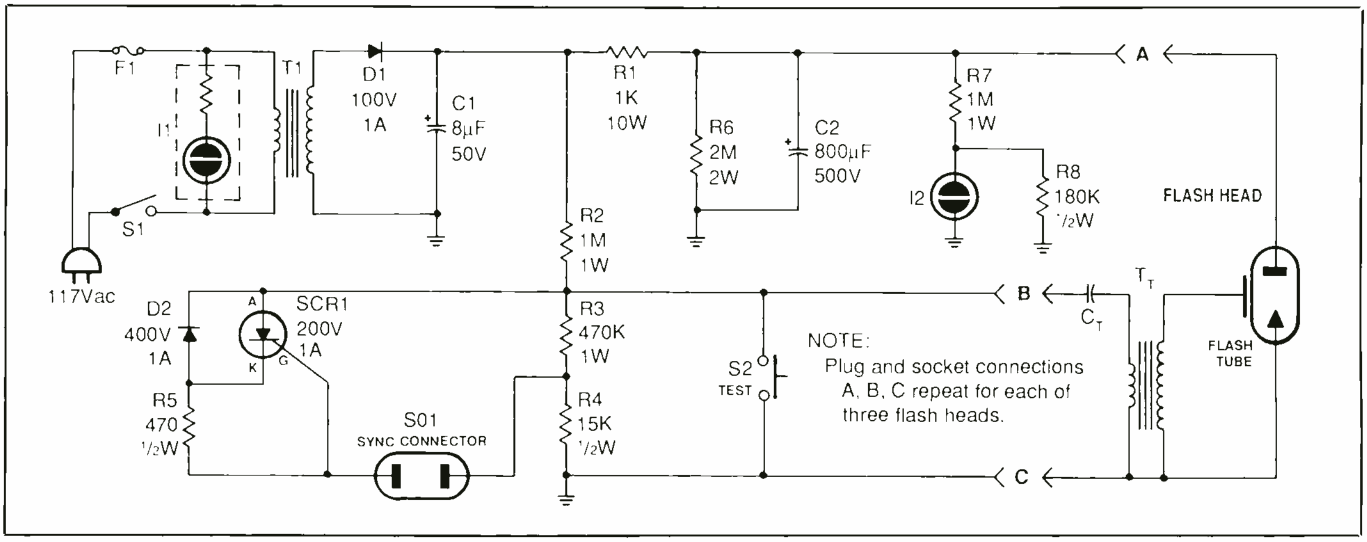


Fig. 4. Complete schematic diagram of minimal power pack circuit design.

whether one, two or three heads are used for a photo session. The minimal power pack, shown schematically in Fig. 4, is less versatile but still useful. It can apply 100 Ws total energy to flash heads and can fire two or three heads, provided the charge energy is divided among the heads for a *total* of 100 Ws. With this arrangement, one head could be fully loaded, two heads fire with 50 Ws each and three heads share the charge at 33 Ws each.

Many simplifications are made in the Fig. 4 circuit, though some features of the Fig. 2 300-Ws power pack can be included, if desired. For example, you might add a voltmeter circuit to monitor charge status, as in the more-elaborate design.

100-WS PARTS LIST

Semiconductors
D1—1,000-volt, 1-ampere silicon rectifier diode
D2—400-volt, 1-ampere silicon rectifier diode
SCR1—200-volt, 1-ampere or greater silicon-controlled rectifier

Capacitors
C1—8-μF, 500-volt electrolytic
C2—600- to 800-μF, 500-volt computer-grade electrolytic

Resistors (10% tolerance)
R1—1,000 ohms, 10-watt wire-wound
R2,R7—1 megohm, 1-watt carbon
R3—470,000-ohms, 1-watt carbon
R4—15,000 ohms, ½-watt carbon
R5—470 ohms, ½-watt carbon
R6—2 megohms, 1-watt carbon
R8—180,000 ohms, ½-watt carbon

Miscellaneous
I1—Neon panel-lamp assembly with built-in limiting resistor
I2—Neon lamp
S1—Spst toggle or slide switch
S2—Spst normally-open pushbutton switch
SO1—Polarized jack
T1—350-volt power transformer
Suitable enclosure; ring clamps for capacitors; terminal boards; bayonet fuse holder; ac line cord with plug; materials for flash heads (see 300-WS Parts List); carrying handle; spacers; machine hardware; hookup wire; solder; etc.

In Fig. 4, power transformer *T1* has a single untapped secondary winding that drives half-wave rectifier *D1*. Because a 6.3-volt winding isn't available for a pilot light, neon lamp *I1* and its series resistor connect across the ac-line after POWER switch *S1* and fuse *F1* to serve as a POWER indicator.

Also note that the 150 volts for charging trigger capacitor C_T is taken from bleeder resistor *R2*, as is done in the Fig. 2 circuit. However, an additional voltage tap is made in this divider, between *R2* and *R3*, to supply gate bias to *SCR1*.

The SCR trigger circuit is included in this minimal power pack to avoid having 150 volts and high trigger currents appear at the camera shutter contacts, as would occur if the camera shutter was directly used to short the trigger capacitor(s).

The half-wave rectifier circuit charges storage capacitor C_T to 100 Ws, somewhere beyond 450 volts. READY lamp *I2* shunted across part of the resistive voltage divider made up of *R7* and *R8* indicates when C_T is charged but doesn't indicate voltage as charge progresses. It lights only when a preset charge is reached.

TEST switch *S2* across the 150-volt trigger bus lets you test the flash system, as in the Fig. 1 circuit. Three output sockets are included in this design to permit you to connect multiple flash heads to the power pack, with the same head circuit as used in the more-elaborate design. However, the total 100-Ws charge on a single storage capacitor is all the energy available and is divided between flash heads. Hence, there's no need for steering diodes. This supply could be implemented with a full-wave rectifier circuit, with a bit better charging efficiency.

Construction

The minimal-design power pack can be built into a much smaller enclosure than was recommended above. A "double-U" shaped utility box measuring 8 × 6 × 3½ inches is suitable. Again, you should collect all the components to be used before settling on a given-size enclosure.

No chassis as such is needed for building the power pack. The top of the enclosure serves as the control panel on which you mount the POWER switch, POWER indicator lamp, READY indicator lamp, fuse holder, SYNC connector and a handle.

One of the 6 × 3½-inch ends of the enclosure accommodates the three sockets for connecting the flash heads to the power pack. Secure the power transformer to the underside of the control panel, and attach the single energy-storage capacitor to the other end of the box with a ring clamp. Use terminal strips to mount the few circuit components, and wire together the components using the point-to-point scheme.

Compared to the more-elaborate design, this minimal-design power pack is much simplified. Nevertheless, it's an easy and inexpensive way to get involved with multiple-head lighting setups. If you go this route and later wish to upgrade to the more-elaborate design, the components can be directly salvaged and reused in it.

Using the Project

Operating either of the flash units is almost instinctive. The flash heads plug into the power pack and a sync cable attaches between the camera and the pack. Two of the flash-head units should have 10- to 15-foot-long cables and be fitted with tilt heads for use as modeling light and background/rim/hair light. Locate these flash units at a distance from the camera. Tilt heads let you aim light at a subject from various angles.

The third flash head gets a 6-foot-long cable. Positioned close to the camera, this flash head provides fill-in light. It doesn't need a tilt head, because you'll usually direct its light straight onto your subject from essentially camera position. If you wish, you can fit to this flash head a normally-open pushbutton switch that can be used to short across the trigger capacitor line so that you can test fire the heads from camera position instead of having to reach for the TEST switch on the power pack.

Whenever you connect and disconnect the flash heads to and from the power pack, always power down the power pack. A flash head may fire on its own when being connected if its capacitor is already charged.

It's a good practice to energize the system and make a few test firings before actually starting to take pictures. This will assure you that the capacitors charge properly and even do minor reforming before a shoot-

Cautionary Notes

Storage capacitors must be able to hold a high-energy charge and not leak or discharge over long periods of time. Internal losses must be very low. These desirable factors for a good storage capacitor also contribute to making it a potentially lethal device! Even a computer-grade electrolytic capacitor can hold its charge for many hours, even days. Another mark of a good capacitor is low internal resistance, which means that there's nothing internal to limit the discharge current if the terminals are shorted together.

The factors that go into making a good storage capacitor in its intended application can also make it dangerous. A capacitor charged to 75 to 100 joules (watt-seconds) contains considerable energy. When discharged in the normal manner into a flash tube you'll hear a very audible "snap" as the tube fires, and a very noticeable amount of heat will be radiated from the flash tube. This is because the 100 joules of energy are being "dumped" into about 6 ohms of tube resistance at a current of 75 to 100 amperes for a few milliseconds.

The discharge current can vaporize the tip of a screwdriver if a charged capacitor were to short it with such an essentially zero-resistance shunt. Shorting the capacitor with zero resistance can tear it apart internally and create destructive internal heating. Don't *ever* attempt to discharge a capacitor in this manner.

The proper way to discharge a capacitor is to shunt its terminals with a power resistor, carefully avoiding personal contact with the leads or terminals. Experienced personnel who work around high voltages, keep one hand in a pocket or behind their backs to avoid injury and death when working around high-voltage, high-energy storage capacitors. You should adopt this as a working rule as well.

When discharging capacitors, use well-insulated clip leads attached to a 10-watt resistor of, say, 500 ohms resistance. Attach one clip to one terminal of the capacitor. Then carefully touch and hold the other clip to the remaining terminal for several seconds. Repeat the procedure several times to make sure the capacitor is fully discharged, even if you're working on a circuit that hasn't been powered for hours or several days. Work with one hand only (remove any rings and watches before you start) and an alert appreciation of what charge can do. And always handle any capacitor as if it's fully charged to a lethal voltage!

ing session. Test fire the system with the TEST button on the power pack or on the fill-in light head, before starting to trigger the system with the camera sync contacts.

When you're done taking pictures, always fire the heads to discharge the capacitors and trigger circuits before stowing your gear. Do this by firing the system with the TEST button and immediately switch off ac power.

If at any time you must gain access to the interior of the power pack, exercise extreme caution. Bear in mind that the storage capacitors may have potentially injurious charges on them. So exercise care when the unit is open. Discharge all capacitors *before* you do any internal testing.

An integrating flash meter is a very useful accessory and is highly recommended when using this project. Place the meter at the location of your subject and aim it toward the camera while you test fire the system. The meter will indicate the correct f-stop for proper exposure as a function of film speed. It will result in correct exposures, saving you time and film. Shutter speed doesn't have any effect on exposure because the flash is only about a millisecond in duration. With focal plane shutters, however, speeds must be slow enough to ensure that the curtains are fully open when the flash does fire. This means you must use "X" sync, usually at 1/60 second or slower. **ME**