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BUILD A PREREGULATED POWER SUPPLY

Super-stable, multi-purpose supply for the experimenter's workbench

ANYONE who works with modern electronic circuits, whether he is a professional or an amateur, will eventually require a closely regulated variable power supply. While most power supplies are regulated directly from the basic rectified and filtered dc line, tighter regulation can be obtained by using a preregulated approach in the supply's design.

The preregulated power supply described here can be built for about $15 more than you would have to pay for a conventionally regulated low-current supply. It employs two inexpensive 723 voltage regulator IC's in a circuit that can deliver 3 to 35 volts dc at load currents up to 3 amperes. The design eliminates the need for massive heat sinks and cooling fans.

How It Works. The power supply's circuit shown in Fig. 1 can be functionally diagrammed as an ac source, rectifier bridge, and two voltage regulators in series. The preregulator, by means of *SCR1*, continuously controls the potential at *C1* so that the potential across *Q1* remains constant. The output regulator (*IC2*) is a high-performance circuit that is capable of providing 0.1% regulation.

Synchronized to the 120-Hz rectified ac input, preregulator integrated circuit *IC1* is connected as a time-delayed pulse generator that controls the gate of *SCR1* to trigger conduction at the exact point required during each half cycle. The bias voltage applied to the inverting input (pin 2) of *IC1* is adjustable via potentiometer *R9*; it determines the reference level for the supply.

The zener-regulated source at pin 4 of *IC1* also supplies current through *R14*, *R15*, and *R18* to *C4* and pin 3 (noninverting input). The current continues to flow until the reference voltage is exceeded. At this point, *IC1* turns on. The resulting square-wave pulse from pin 6 of the IC is limited to 9 volts by current-sensing resistors *R12* and *R13*, which is sufficient, at the gate of *SCR1*, to trigger the SCR into conduction.

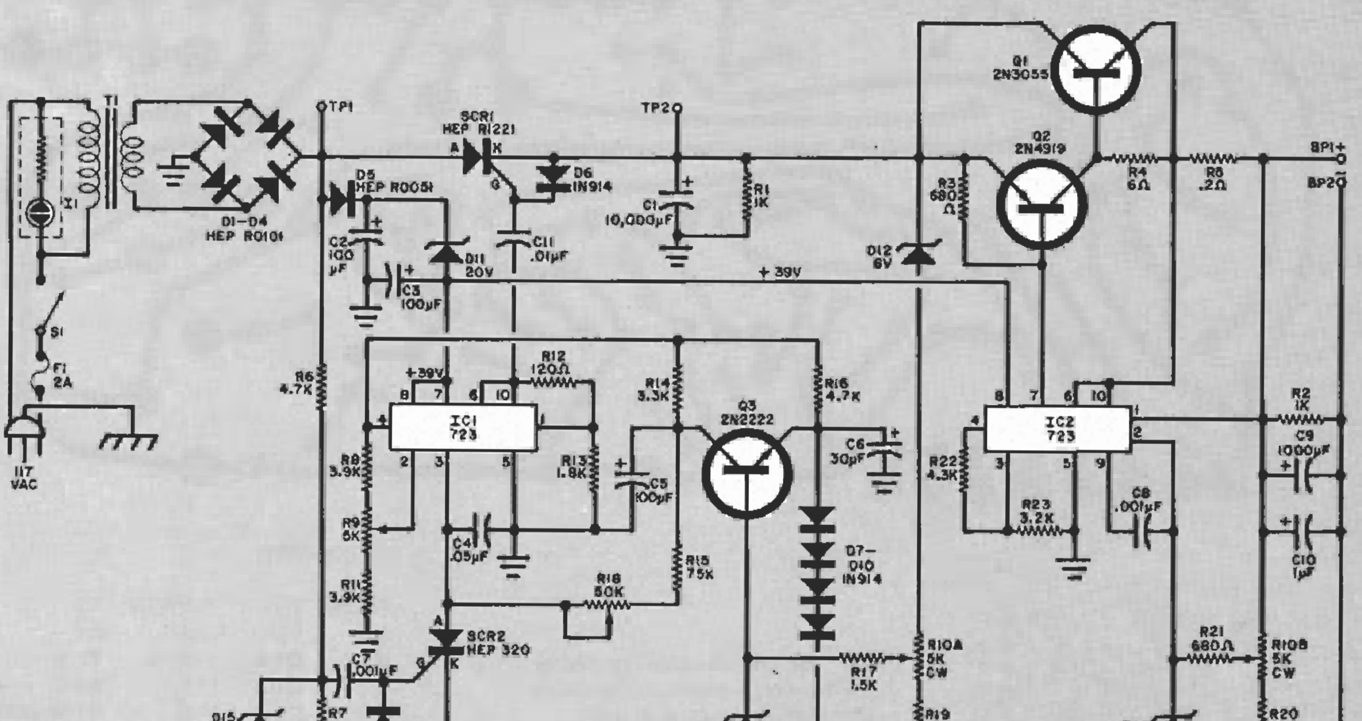
The RC time constants in the circuit are controlled by the amount of current flowing through *Q3*, which, in turn, depends on the error voltage present at the wiper of *R10A*. A voltage divider consisting of *R16* and diodes *D7* through *D10* applies a relatively constant 2.4 volts to the emitter of *Q3* so that when the transistor's base goes above 3 volts there will be a voltage drop across *R14* and a corresponding change in the RC time constant. Capacitors *C5* and *C6* stabilize the operation of *Q3* to prevent *SCR1* from firing erratically. When *R10* is rotated counterclockwise, *R17* and *D13* protect *Q3* and *D12* from damage.

The method of synchronizing *IC1* to the rectified input is graphically shown in Fig. 2. Triggered into conduction by the positive-going voltage, *SCR1* cuts off when the gate signal ceases and *C4* discharges sufficiently to reduce to a minimum the holding current to the SCR. The diagram also reveals why the secondary voltage from *T1* must be greater than would be normal in a conventionally regulated power supply. The SCR cannot conduct until its anode is more positive than its cathode. Simultaneously, a minimum latching current must flow. Also, *SCR1* must remain conducting until the energy drawn from *C1* by the output load is replaced.

Since the potential across *C1* will be 41 volts at maximum output, the 18-volt difference allows the time interval necessary for maximum current. This also means that *SCR1* fires only near the peak or on the negative-going side of the waveform. Resistors *R1* and *R2* are bleeders that carry the minimum holding current required by *SCR1*.

Dual potentiometer *R10* establishes feedback to both voltage-regulator IC's. (A wire-wound potentiometer is best used here so that the sections will be more evenly matched. So, if an identical voltage were present across each section of the pot, the wiper voltages would be very nearly the same at any setting.) Potentiometer section *R10B* samples the output voltage and drives *IC2* in the proper direction to maintain 3 volts between wiper and ground. The A section of the pot samples the voltage across *C1* and controls the firing of *SCR1*, also maintaining 3 volts between wiper and ground.

Since the potential at the counterclockwise ends of *R10A* and *R10B* must be the same, the potential across



PARTS LIST

BP1, BP2—Five-way binding post (one black, one red)
C1—10,000-μF, 50-volt electrolytic capacitor
C2, C3—100-μF, 65-volt electrolytic capacitor
C4—0.05-μF disc capacitor
C5—100-μF, 10-volt electrolytic capacitor
C6—30-μF, 10-volt electrolytic capacitor
C7, C8—0.001-μF disc capacitor
C9—1000-μF, 50-volt electrolytic capacitor
C10—1-μF, 50-volt tantalum electrolytic capacitor
C11—0.01-μF disc capacitor
D1 thru D4—100-PIV, 3-ampere rectifier (Motorola HEP R0101 or similar)
D5—100-PIV, 1-ampere rectifier (Motorola HEP R0051 or similar)
D6, D7 thru D10, D16—1N914 diode
D11—20-volt, 1-watt zener diode (Motorola HEP Z0421 or similar)
D12—6-volt zener diode (1N429 or similar)
D13, D14—6-volt zener diode (1N1509 or similar)
D15—8-volt zener diode (Motorola HEP Z0217 or similar)
F1—2-ampere slow-blow fuse
I1—Neon panel lamp with resistor
IC1, IC2—723 voltage regulator integrated circuit (in TO-5 can)
Q1—HEP 704 (Motorola) or 2N3055 transistor
Q2—HEP 246 (Motorola) or 2N4919 transistor
Q3—HEP 736 (Motorola) or 2N2222 transistor
R1, R2—1000-ohm, 2-watt, 10% resistor
R3, R21—680-ohm, ½-watt, 5% resistor
R4—6-ohm, 1-watt, 5% resistor
R5—0.2-ohm, 2-watt, 5% resistor
R6—4700-ohm, 1-watt, 5% resistor
R7, R16—4700-ohm, ½-watt, 5% resistor
R8, R11—3900-ohm, ¼-watt, 5% resistor
R9—5000-ohm miniature pc potentiometer
R10—5000-ohm dual wire-wound potentiometer
R12—120-ohm, ¼-watt, 5% resistor
R13—1800-ohm, ¼-watt, 5% resistor
R14—3300-ohm, ¼-watt, 5% resistor
R15—75,000-ohm, ¼-watt, 5% resistor
R17—1500-ohm, ¼-watt, 5% resistor
R18—50,000-ohm, miniature pc potentiometer
R19, R20—470-ohm, ½-watt, 5% resistor
R22—4300-ohm, 1% resistor
R23—3200-ohm, 1% resistor
SCR1—HEPR 1221
SCR2—HEP 320
S1—Spst switch
T1—Transformer, 42V, 3A Secondary
Misc.—Printed circuit or perforated board; suitable cabinet; heat sink; fuse holder; sockets for IC's (2); etc.

Fig. 1. Power supply employs two voltage-regulator IC's for super stability.

C1 will be 6 volts greater than the output because of the action of *D12*. Any change in the output voltage and/or current will affect the firing-pulse timing at the gate of *SCR1*, maintaining a constant potential across *Q1*.

Construction. The easiest way to assemble the power supply is by using a printed circuit board. (See Fig. 3 for actual-size etching and drilling and component placement guides.) Alternatively, you can assemble the circuit on perforated board using solder clips and sockets. Whichever method you use, refer to the table in Fig. 3 for instructions on how to interconnect the circuit board assembly and the com-

SEQUENCE OF EVENTS

A. *SCR2* fires as *C7* charges; *C4* then discharges and *IC1* cuts off.
B. *D15* limits voltage on *C7*; *SCR2* cuts off and *C4* begins to charge.
C. *C4* has charged above reference level at pin 2 of *IC1*, causing the IC to conduct; a trigger pulse at pin 6 turns on *SCR1* through *C11*.
D. *SCR1* current decreases as *C1* voltage increases. When voltage across *SCR1* is insufficient to maintain about 10 mA current, *SCR1* turns off.

Note: *SCR1* turns on and off at approximately C and D on the curve, when the output load is drawing 3 amperes at 35 volts. With no external load, events C and D occur near the end of the wave as indicated by the unmarked dots.

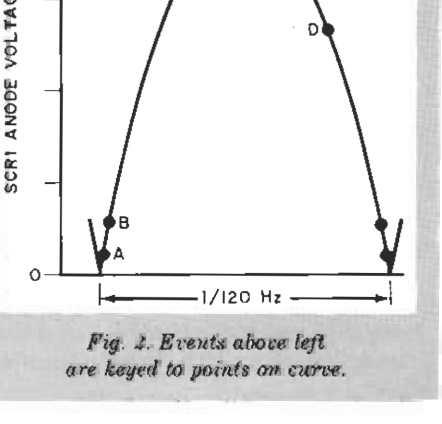
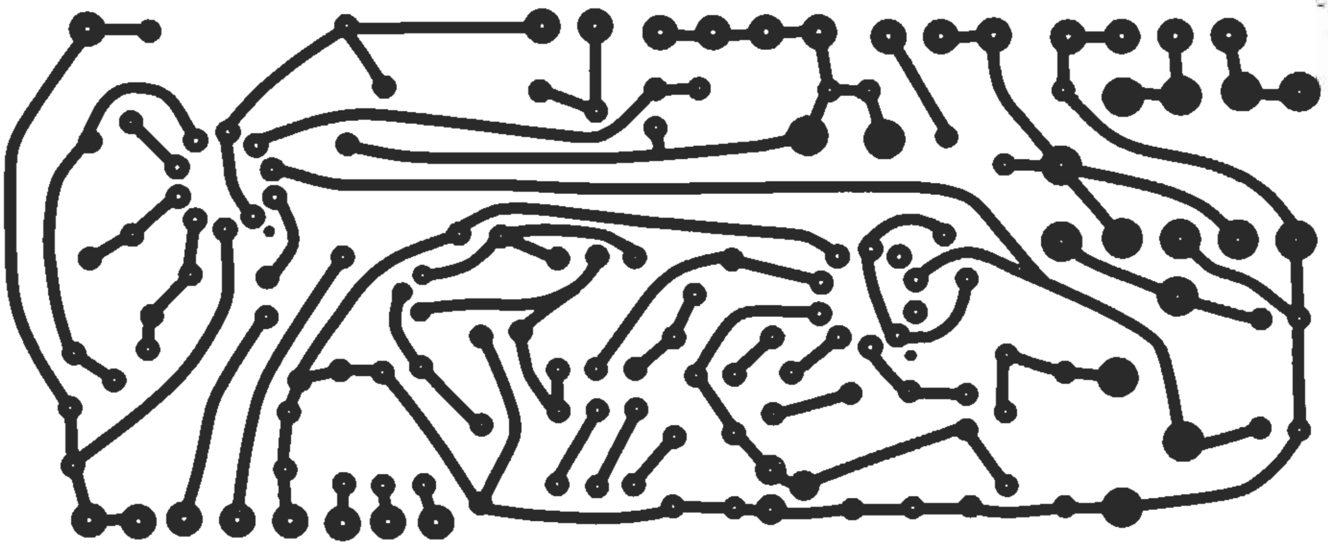
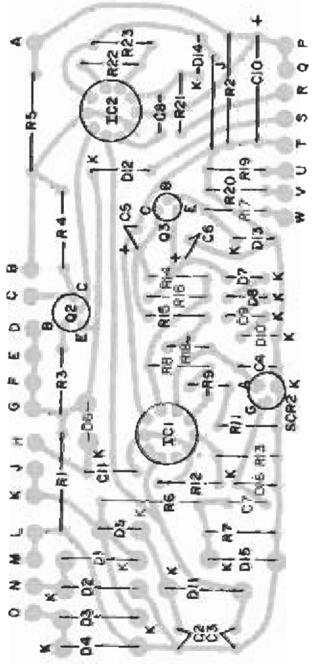


Fig. 2. Events above left are keyed to points on curve.





Note: Components shown from foil side of board.

Fig. 3. Actual-size etching and drilling guide is shown above; component-placement diagram is at left; table at right details hookups between board and off-the-board components.

CONNECT

FROM:	TO:	FROM:	TO
A	C9 +	M	C1 −
B	Q1 E	N, O	T1 S
C	Q1 B	P	BP1
D	Q1 C	Q	R10B CCW
E	TP2	R	R10B WIP
F	C1 +	S	R10A CCW
G	SCR1 K	T	BP2
H	SCR1 G	U	R10A CW
J	SCR1 A	V	R10B CW
K	TP1	W	R10A WIP
L	C9 −		

ponents located off the printed circuit board.

Select a cabinet for the supply that is large enough to accommodate all components without crowding. Machine the front panel for potentiometer *R10*, lamp/resistor assembly *I1*, and binding posts *BP1* and *BP2*. Mount the components in their respective holes.

Next, mount *Q1* and *SCR1* on a 4" × 2½" × 1" (10.2 × 6.4 × 2.5-cm) finned heat sink. Drill mounting holes for this assembly, the line cord, and fuse holder through the rear panel of the cabinet. Mount the fuse holder and heat-sink assembly in place. Line the remaining hole with a rubber grommet for the line cord.

Mount the off-the-board components, followed by the circuit-board assembly inside the cabinet. Then refer to the table in Fig. 3 and Fig. 1 to complete wiring the system.

Test and Use. To balance out component tolerances, *IC1* must be initially aligned. To accomplish this, you will need an oscilloscope, high-impedance multimeter, and an improvised load. Rotate *R10* counterclockwise, set *R18* to maximum resistance and *R9* for maximum voltage gain at pin 2 of *IC1 before* applying power to the supply. Connect the scope from *TP1* to ground and the multimeter from *TP2* to ground. Turn on the power.

There should be a small voltage present at *TP2*, but the scope should indicate that *SCR1* is not conducting. Keeping the voltage reference as high as possible at pin 2 of *IC1*, adjust *R18* and *R9* until *SCR1* fires regularly and the meter indicates 9 volts at *TP2*. When *R10* is rotated fully clockwise, the meter should indicate 41 volts at *TP2*.

Temporarily short out *R5* and momentarily connect a 12-ohm, 120-watt resistor (or an equivalent combination) across the output via *BP1* and *BP2*. If the TP2 reading drops more than 0.2 volt or *SCR1* fires intermittently, adjust *R9* only enough to correct. Then, with no load connected to the output of the supply, rotate *R10* counterclockwise. The reading at *TP2* should slowly decrease to 9 volts. If it does not, adjust *R9* for a higher voltage at pin 2 of *IC1* until it does.

Rotate *R10* again and apply the load, compensating for the voltage drop by adjusting *R18*. There will be some combination of the two adjustments that will permit *Q3* to retain control over *IC1* throughout the specified voltage and current ranges. To do this, *Q3* must always be forward biased. If at any time *Q3* does not draw the proper current from *R14*, it has lost control.

Correct alignment will be achieved when the voltage at the wiper of *R10A* is the same at any output. As a further test, connect the meter across *Q1* and note the voltage change when *R10* is rotated clockwise. Any difference would correspond with *D12's* zener voltage characteristics at bias currents of from 1 to 7mA. ◈