A 28-V, High-Current Power Supply

Many modern high-power transistors used in RF power amplifiers require 28-V dc collector supplies, rather than the traditional 12-V supply. By going to 28 V (or even 50 V), designers significantly reduce the amount of current required for an amplifier in the 100-W or higher output class. The power supply shown in Figs. 14 through 18 is conservatively rated for 28 V at 10 A (enough for a 150-W output amplifier) — continuous duty! It was designed with simplicity and readily-available components in mind. Mark Wilson, AA2Z, built this project in the ARRL lab.

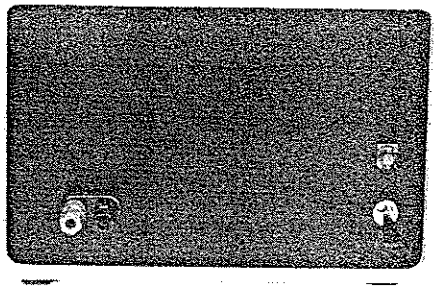

Fig. 14 — The front panel of the 28-V power supply sports only a power switch, pilot lamp and binding posts for the voltage output. There is room for a voltmeter, should another builder desire one.

Circuit Details

The schematic diagram of the 28-V supply is shown in Fig. 15. T1 was designed by Avatar Magnetics specifically for this project. The primary requires 117-V ac, but a dual-primary (117/234 V) version is available. The secondary is rated for 32 V at 15 A, continuous duty. The primary is bypassed by two 0.01-µF capacitors and protected from line transients by an MOV.

U1 is a 25-A bridge module available from Radio Shack or a number of other suppliers. It requires a heat sink in this application. Filter capacitor C1 is a computer-grade 22,000-µF electrolytic. Bleeder resistor R1 is included for safety because of the high value of C1; bleeder current is about 12 mA.

There is a trade-off between the secondary voltage of the transformer and the value of the filter capacitor. To maintain regulation, the minimum supply voltage to the regulator circuitry must remain above approximately 31 V. Ripple voltage must be taken into account. If the voltage on the bus drops below 31 V in ripple valleys, regulation may be lost.

In this supply, the transformer secondary voltage was chosen to allow use of a commonly-available filter value. The builder found that 50-V electrolytic capacitors of up to about 25,000 µF were common and the prices reasonable; few dealers stocked capacitors above that value, and the prices increased dramatically. If you have a larger filter capacitor, you can use a transformer with a lower secondary voltage; similarly, if you have a transformer in the 28- to 35-V range, you can calculate the size of the filter capacitor required. Chapter 6 contains the formulas needed to calculate ripple for different filter

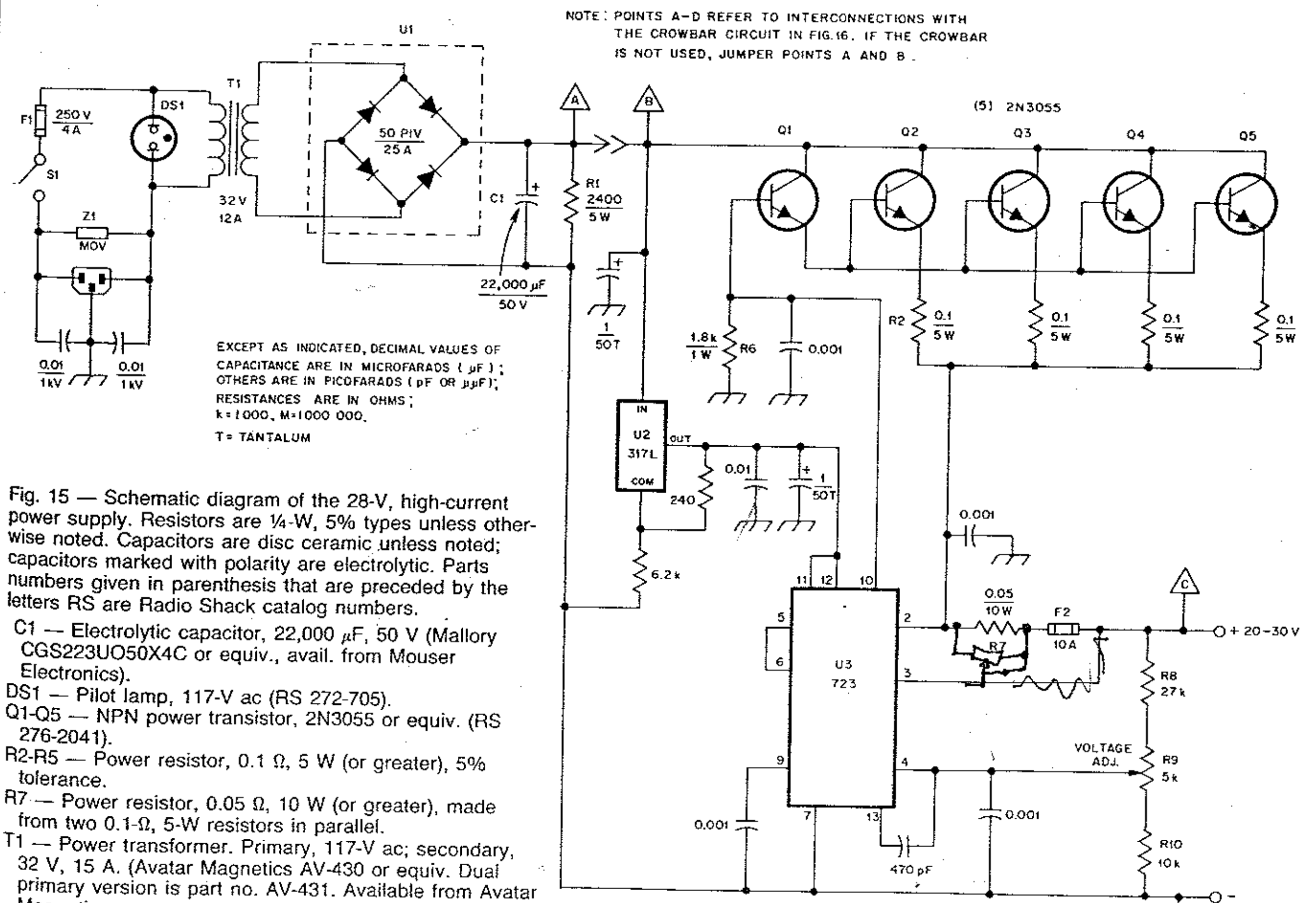

Fig. 15 — Schematic diagram of the 28-V, high-current power supply. Resistors are ¼-W, 5% types unless otherwise noted. Capacitors are disc ceramic unless noted; capacitors marked with polarity are electrolytic. Parts numbers given in parenthesis that are preceded by the letters RS are Radio Shack catalog numbers.

C1 — Electrolytic capacitor, 22,000 µF, 50 V (Mallory CGS223UO50X4C or equiv., avail. from Mouser Electronics).
DS1 — Pilot lamp, 117-V ac (RS 272-705).
Q1-Q5 — NPN power transistor, 2N3055 or equiv. (RS 276-2041).
R2-R5 — Power resistor, 0.1 Ω, 5 W (or greater), 5% tolerance.
R7 — Power resistor, 0.05 Ω, 10 W (or greater), made from two 0.1-Ω, 5-W resistors in parallel.
T1 — Power transformer. Primary, 117-V ac; secondary, 32 V, 15 A. (Avatar Magnetics AV-430 or equiv. Dual primary version is part no. AV-431. Available from Avatar Magnetics.
U1 — Bridge rectifier, 50 PIV, 25 A (RS 276-1185).
U2 — Three-terminal adjustable voltage regulator, 100 mA (LM-317L or equiv.). See text.
U3 — 723-type adjustable voltage regulator IC, 14-pin DIP package (LM-723, MC1723, etc., RS 276-1740).
Z1 — 130-V MOV (RS 276-570).

and transformer values.

The regulator circuitry takes advantage of commonly-available parts. The heart of the circuit is U3, a 723 voltage regulator IC. The values of R8, R9 and R10 were chosen to allow the output voltage to be varied from 20 to 30 V. The 723 has a maximum input voltage rating of 40 V, somewhat lower than the filtered bus voltage. U2 is an adjustable 3-terminal regulator; it is set to provide approximately 35 V to power U3. U3 drives the base of Q1, which in turn drives pass transistors Q2-Q5. This arrangement was selected to take advantage of common components. At first glance, the number of pass transistors seems high for a 10-A supply. Input voltage is high enough that the pass transistors must dissipate about 120 W (worst case), so thermal considerations dictate the use of four transistors. See Chapter 6 for a complete discussion of thermal design. If you use a transformer with a significantly different secondary potential, refer to the Chapter 6 thermal tutorial to verify the size heat sink required for safe operation.

R9 is used to adjust supply output voltage. Since this supply was designed primarily for 28-V applications, R9 is a "set and forget" control mounted internally. A 25-turn potentiometer is used here to allow precise voltage adjustment. Another builder may wish to mount this control, and perhaps a voltmeter, on the front panel to easily vary the output voltage.

The 723 features current foldback if the load draws excessive current. Foldback current, set by R7, is approximately 14 A, so F2 should blow if a problem occurs. The output terminals, however, may be shorted indefinitely without damage to any power-supply components.

If the regulator circuitry should fail, or if a pass transistor should short, the unregulated supply voltage will appear at the output terminals. Most 28-V RF transistors would fail with 40-plus volts on the collector, so a prospective builder might wish to incorporate the overvoltage protection circuit shown in Fig. 16 in the power supply. This circuit is optional. If you choose to use the "crowbar," make the interconnections as shown. Note that R11 and F3 of Fig. 16 are added between points A and B of Fig. 15. If the crowbar is not used, place a wire jumper between points A and B of Fig. 15.

This crowbar circuit is taken from Motorola application notes for the MC3423 overvoltage sensor IC. The chip contains a 2.5-V reference and two comparators. When the voltage at pin 2 (sense terminal) reaches 2.5 V, the output goes high (from 0.0 V to the positive bus voltage) to drive the gate of Q6, a high-current SCR. Q6 turns on, shorting the supply output terminals. This circuit is inexpensive and easy to implement, yet it allows the builder to precisely set the trip voltage. It provides excellent gate drive to the SCR, and is somewhat quicker and more reliable than

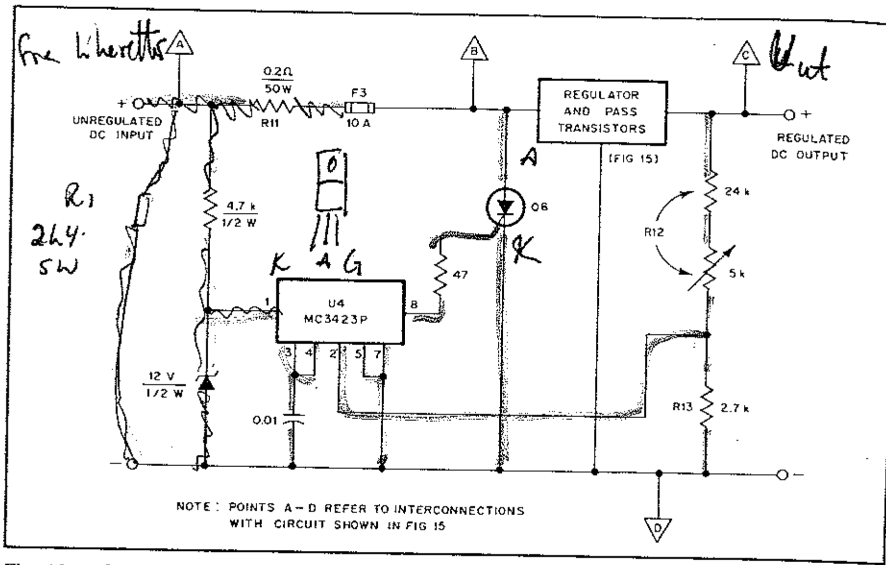

Fig. 16 — Schematic diagram of the over-voltage protection circuit. Resistors are ¼-W, 5% carbon types unless noted.

Q6 — 20-A, 100-V stud-mount SCR (RCA SK6502 or equiv.).

R12 — 5-kΩ, 10-turn potentiometer in series with a 24-kΩ, ¼-W resistor.

U4 — Overvoltage sensor IC, Motorola MC3423 (RS 276-1717).

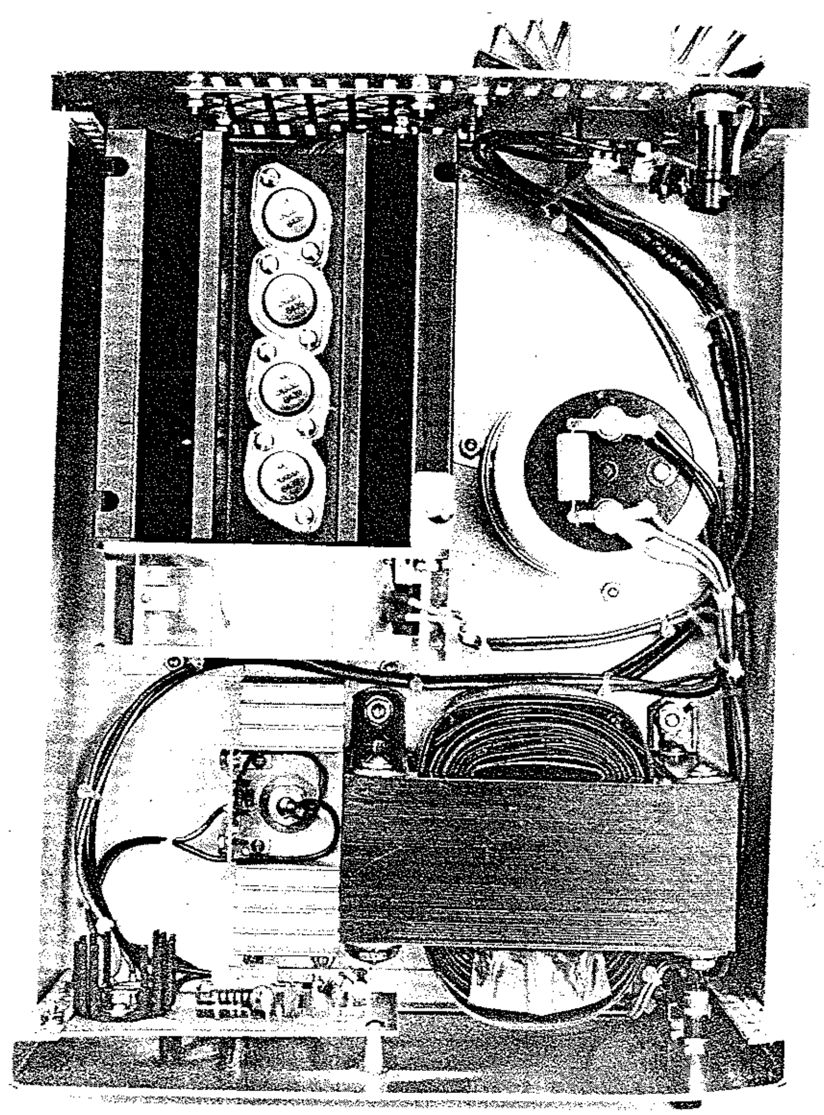

Fig. 17 — Interior of the 28-V, high-current power supply. The cooling fan is necessary only if the pass transistors and heat sink are mounted inside the cabinet. See text.

crowbar circuits that use Zener diodes. R11 and F3 protect the pass transistors from damage in case of high-current transients.

The trip voltage is determined from the equation

$$V_{TRIP} \approx 2.5\left(1 + \frac{R11}{R12}\right)$$

The application notes recommend that R13 be less than 10 kΩ for minimum drift and suggest a value of 2.7 kΩ. In this version, R12 is preset with a 24-kΩ resistor, and a 5-kΩ, 10-turn potentiometer dials in the precise trip point.

Construction

Fig. 17 shows the interior of the 28-V supply. It is built in a Hammond 1401K enclosure. All parts mount inside the box. The regulator components are mounted on a small PC board that is attached to the rear of the front panel. See Fig. 18. Most of the parts were purchased at local electronics stores or from suppliers listed in Chapter 35. Many parts, such as the heat sink, pass transistors, 0.1-Ω power resistors and filter capacitor can be obtained from scrap computer power supplies found at flea markets.

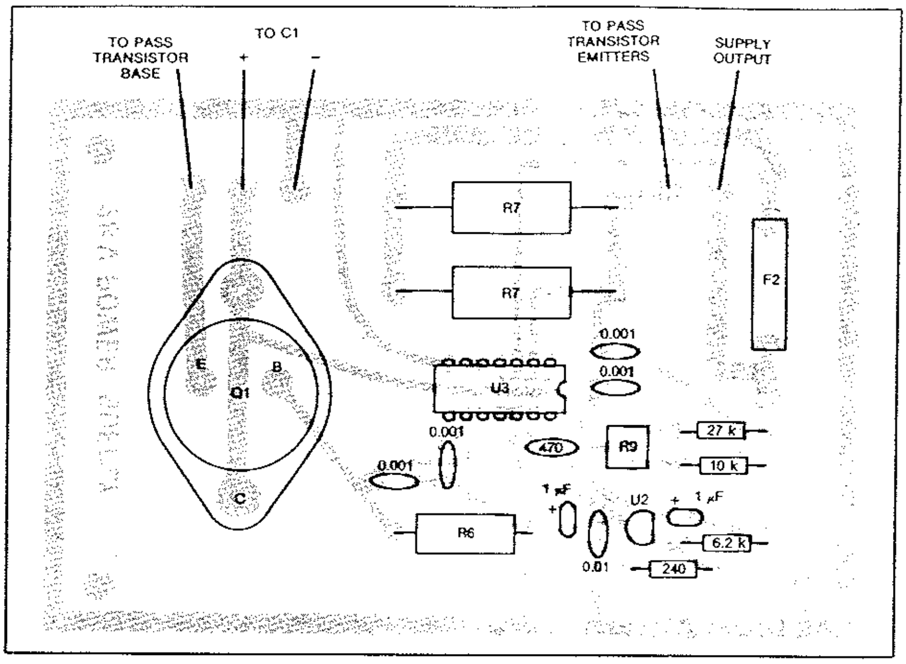

Fig. 18 — Parts-placement diagram for the 28-V power supply. A full-size etching pattern appears at the back of this book.

Q2-Q5 are mounted on a Wakefield model 441K heat sink. The transistors are mounted to the heat sink with isulating washers and thermal heat-sink compound to aid heat transfer. Radio Shack TO-3 sockets make electrical connections easier. The heat sink surface under the transistors must be absolutely smooth. Carefully deburr all holes after drilling and lightly sand the edges with fine emery cloth.

A five-inch fan circulates air past the heat sink inside the cabinet. Forced-air cooling is necessary only because the heat sink is mounted inside the cabinet. If the heat sink was mounted on the rear panel with the fins vertical, natural convection would provide adequate cooling and no fan would be required.

U1 is mounted to the inside of the rear panel with heat-sink compound. Its heat sink is bolted to the outside of the rear panel to take advantage of convection cooling.

U2 may prove difficult to find. The 317L is a 100-mA version of the popular 317-series 1.5-A adjustable regulator. The 317L is packaged in a TO-92 case, while the normal 317 is usually packaged in a larger TO-220 case. Many of the suppliers listed in Chapter 35 sell them, and RCA SK7644 or Sylvania ECG1900 direct replacements are available from many local electronics shops. If you can't find a 317L, you can use a regular 317 (available from Radio Shack, among others).

R7 is made from two 0.1-Ω, 5-W resistors connected in parallel. These resistors get warm under sustained operation, so they are mounted approximately 1/16 inch above the circuit board to allow air to circulate and to prevent the PC board from becoming discolored. Similarly, R6 gets warm to the touch, so it is mounted away from the board to allow air to circulate. Q1 becomes slightly warm during sustained operation, so it is mounted to a small TO-3 PC board heat sink.

Not obvious from the photograph is the use of a single-point ground to avoid ground-loop problems. The PC-board ground connection and the minus lead of the supply are tied directly to the minus terminal of C1, rather than to a chassis ground.

The crowbar circuit is mounted on a small heat sink near the output terminals. Q6 is a stud-mount SCR and is insulated from the heat sink. An RCA replacement SCR was used here because it was readily available, but any 20-A or greater SCR that can handle at least 50 V will work. The other components are mounted on a small circuit board that is attached to the heat sink with angle brackets. U4 is available from Radio Shack.

Although the output current is not extremely high, no. 14 or no. 12 wire should be used for all high-current runs, including the wiring between C1 and the collectors of Q2-Q5; between R2-R5 and R7; between F2 and the positive output terminal; and between C1 and the negative output terminal. Similar wire should be used between the output terminals and the load.

Testing

First, connect T1, U1 and C1 and verify that the no-load voltage is approximately 44-V dc. Then, connect unregulated voltage to the PC board and pass transistors. Leave the gate lead of Q6 disconnected from pin 8 of U4 at this time. You should be able to adjust the output voltage between approximately 20 and 30 V. Set the output to 28 V.

Next, set the crowbar to fire at 29 V or whatever trip voltage you desire. Set the potentiometer of R12 for maximum resistance. Connect a voltmeter to U4, pin 8. The voltmeter should indicate 0.0 V. Increase supply voltage to 29 V and adjust R12 until pin 8 goes high, to approximately 28 V. Back off the supply voltage; pin 8 should go low again. Connect the gate lead of Q6 and again increase supply voltage to 29 V. The crowbar should fire, shorting the supply output. Slight adjustment of R12 may be necessary. Remove power and turn R9 to reduce supply voltage below the trip point. Apply power and reset the output voltage to 28 V.

Next, short the output terminals to verify that the current foldback is working. Voltage should return to 28 when the shorting wire is disconnected. This completes testing and setup.

The supply shown in the photographs dropped approximately 0.1 V between no load and a 12-A resistive load. During testing in the ARRL lab, this supply was run for four hours continuously with a 12-A resistive load on several occasions without any difficulty.