A Tube-Based Bench Supply for Tube Projects

Power those classic tube projects with this adjustable regulated supply.

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In the November 2012 issue of *QST*, Martin Huyette, KØBXB, reprised a classic one-tube transmitter, and Joel Hallas, W1ZR, described a power supply for it that could provide operating voltages for other tube projects.[1, 2] That supply offers one B+ voltage. A more flexible — if slightly more complicated — supply can provide a regulated high voltage that is adjustable over a useful range, like the low-voltage supplies often found powering semiconductor based projects. This article describes one example.

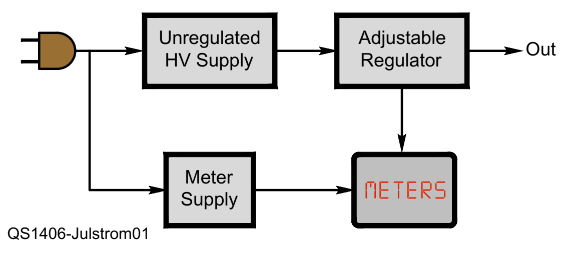

Figure 1 — Block diagram of the adjustable regulated HV power supply.

Design

I set out to build a general-purpose power supply for tube projects of moderate size. The unit would provide 6.3 V ac at several amperes for filaments, and a regulated adjustable B+ high voltage at up to about 50 mA. The regulator circuit is tube-based for robustness and vintage period consistency, but I wouldn't shy away from semiconductor rectifiers and digital meters to monitor output voltage and current.

The block diagram of the unit (see Figure 1) is the same as that of a low-voltage regulated supply. The dc output of an unregulated supply feeds an adjustable linear series regulator. The regulator places a resistance in series with the load and adjusts that resistance to keep a fraction of the output voltage equal to a reference voltage. In a low-voltage supply, that resistance and the circuit that controls it might be provided by a three-terminal regulator like an LM317. Here, the resistive element is a beam power tube. Two meters monitor the output voltage and current. They require a small low-voltage supply of their own.

The Circuit

My junk box yielded a power transformer with outputs around 600 V center-tapped winding at 50 mA, 6.3 V ac at 3 A, and 5 V at 2 A. Figure 2 shows the circuit diagram of the supply that I designed around this transformer. The unregulated HV supply uses two semiconductor rectifiers in a full-wave configuration with the usual filtering. Bleeder resistor R2 discharges the filter capacitors when the unit is turned off. The 5 V winding provides the 5 V that the digital meters require via a full-wave bridge, filter capacitors, and a 7805 5 V three-terminal regulator.

The digital panel meters are from Marlon P. Jones Associates, number 16565 ME. DIP switches set these LED meter ranges to 0 – 200 mV and 0 – 20 V, and turn on decimal points. In the supply, two resistors form a voltage divider so that one meter, set to 0 – 20 V, responds to 0 – 2000 V, of which about 0 – 400 V is used. The 1 Ω shunt, R13, allows the other 0 – 200 mV meter to report 0 – 200 mA.

The 16565 ME meter is no longer available, however several suitable replacements exist, including number 8054 ME from Marlon P. Jones. This LED meter requires a 5 V supply, as mine does, and allows mounting of scaling resistors, which are also available from the same source. I suggest scaling the voltage meter itself to 0 – 20 V to keep the high voltage away from it. You can also substitute various other LCD meters. Some operate at 9 V, which can be provided by the transformer filament winding through a voltage doubler and a 9 V regulator such as a 7809. You can also use analog meters as I did on another HV power supply project.

The tube-based adjustable regulator is based on one in the 1963 edition of *The Radio Amateur's Handbook* that uses an 807 and a 6AU6.[3] This circuit continued in subsequent editions of the *Handbook* with a 6L6 replacing the 807. Similar circuits appeared as early as 1951 using a 6AQ5 and a 6BH7 vacuum tube.[4] Circuits like this were also described by L. Chipman,W4PRM, in 1957, by J. Meredith, K6KWX/7 and D. Roberts, W7PXE, in 1965, and by others as well.[5, 6, 7]

The choice of vacuum tubes is not critical. I've also used a 7984 Compactron beam power tube, and a 12AU6. The 7984 was designed for mobile service and has a nominal filament voltage of 13.5 V, but it does fine with 12.6 V, which is what the 12AU6 filament requires. In all the circuits mentioned above, cold-cathode voltage-regulator tubes fix a reference voltage, but I used Zener diodes. I used two that in series set a reference of 86 V. I thoroughly tested breadboards of the circuit, and I adjusted many of the parts values by trial and error to get a wide range of output voltage and to spread that range over most of the rotation of R9, the voltage adjusting potentiometer.

The potentiometer R9 is part of a voltage divider that imposes a fraction of the output voltage onto the control grid of V2, a 12AU6 tube. That, in effect, compares it to the voltage established at the cathode

[1]Notes appear on page 32.

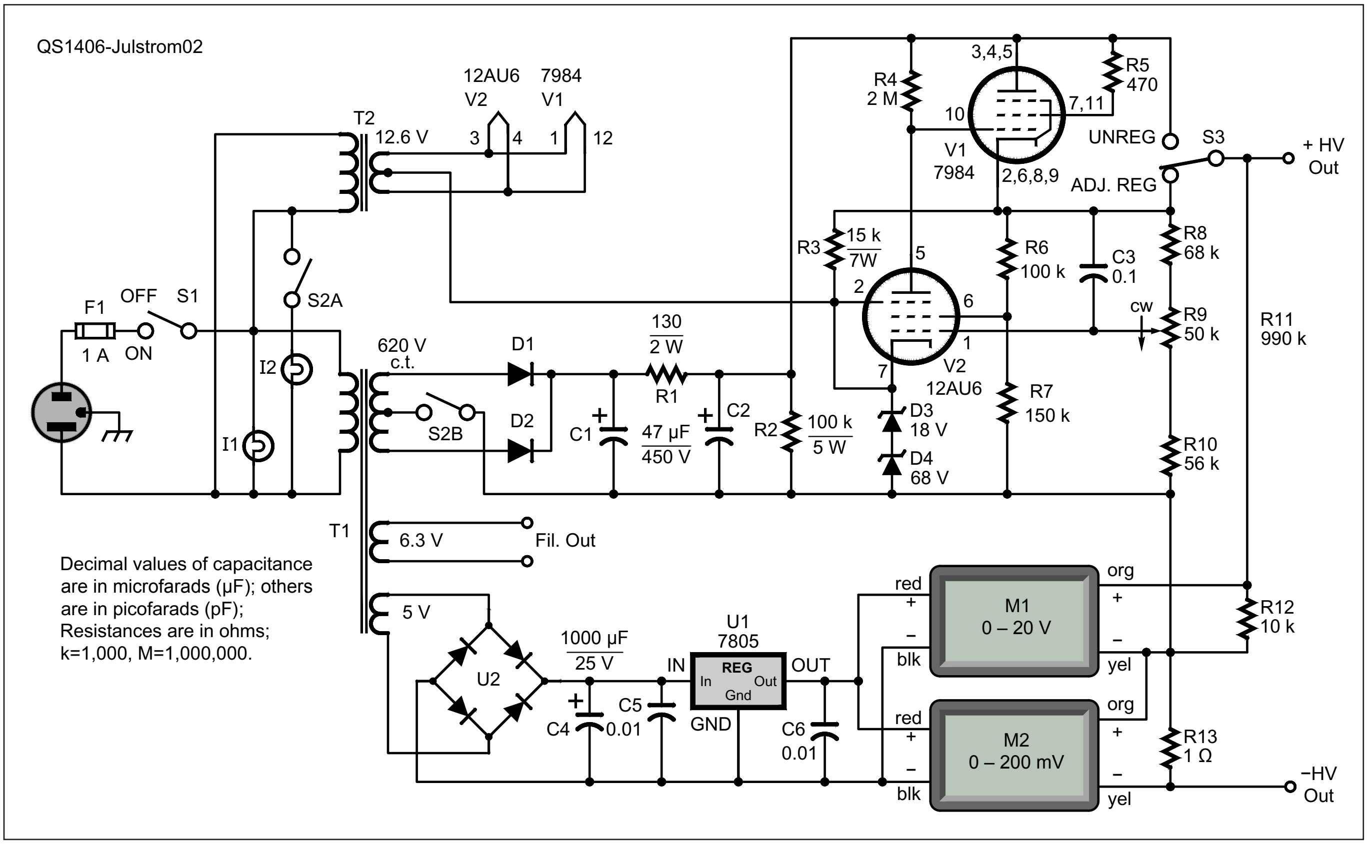

Figure 2 — Circuit of the HV supply with a tube-based adjustable regulator.

C1, C2 — 47 µF, 450 V electrolytic
C3 — 0.1 µF, 400 V
C4 — 1000 µF, 25 V electrolytic
C5, C6 — 0.01 µF, 16 V
D1, D2 — 1N4007 or similar
D3, D4 — Zener diodes, sum up to about 85 V
I1, I2 — Indicators, 120 V
M1, M2 — 3½ Digit LED Panel Meter, PM129B (8054 ME from Marlon P. Jones Associates, **www.mpja.com**)
R1 — 130 Ω, 2 W
R2 — 100 kΩ, 5 W
R3 — 15 kΩ, 7 W
R4 — 2 MΩ, ½ W
R5 — 470 Ω, ½ W
R6 — 100 kΩ, ½ W
R7 — 150 kΩ, ½ W
R8 — 68 kΩ, ½ W
R9 — 50 kΩ potentiometer
R10 — 56 kΩ, ½ W
R11 — 990 kΩ, ½ W
R12 — 10 kΩ, ½ W
R13 — 1 Ω, 1 W
S1 — SPST switch
S2 — DPST switch
S3 — SPDT switch
T1 — Power transformer; see text.
T2 — Filament transformer 120 V ac in, output 12.6 V, 1 A
U1 — 7805 three-terminal regulator.
U2 — Full-wave bridge rectifier, 1 A, 50 V
V1 — 7984 Compaction beam power tube
V2 — 12AV6 Pentode tube

by Zener diodes D3 and D4. A decrease in the load current causes the output voltage to increase, so that the voltage on the grid also increases. The 12AU6 draws more current through 2 MΩ resistor R4, so that the voltage on the 7984 control grid moves in the negative direction. This increases the resistance of the 7984 and thereby reduces the output voltage, thus regulating the output voltage. A increase in the load current does the converse, thus again regulating the output voltage.

A separate transformer provides 12.6 V ac for the tube filaments. The filament supply is not grounded but connects to the cathode of the 12AU6. This puts the filaments at the same dc potential as the cathodes, so that the maximum heater-cathode voltages are not exceeded. Overall power, S1, and the high voltage, S2, are switched separately with indicators I1 and I2 showing what's turned on. Switch S3 makes the unregulated high voltage available (and metered when S2 in on) at the output. Fuse F1 in the hot side of the line protects the unit.

Construction

I built the supply on a 5" × 7" × 2" aluminum chassis, with a front panel and top cover cut from aluminum sheet. Two aluminum brackets support the front panel and cane metal covers the ventilation hole above the 7984 and encloses the back of the unit. A small circuit board holds the rectifiers and filters of the HV and meter supplies. I used point-to-point wiring on the adjustable regulator. There are large rubber feet on the chassis bottom plate.

The front panel holds the meters and all the controls and indicators, as seen in Figure 3. I printed the panel lettering on inkjet decal paper. The horizontal stripes are 1⁄16" automotive pin-striping. I mounted a three-wire ac line connector, the fuse, and two four-pin Jones sockets for the outputs on the rear apron, as seen in Figure 4. With the back cover removed you can see the locations of the transformers and vacuum tubes. You can see why I chose semiconductors rather than additional tubes for the rectifiers and voltage reference, as there just isn't much more room there.

As always with HV circuits like this one, *respect the high voltages*. Never work on any high-voltage unit when it is plugged in, and keep your fingers out when it's on.

Performance

The unit meets my original design goals.

Figure 3 — A completed adjustable HV supply.

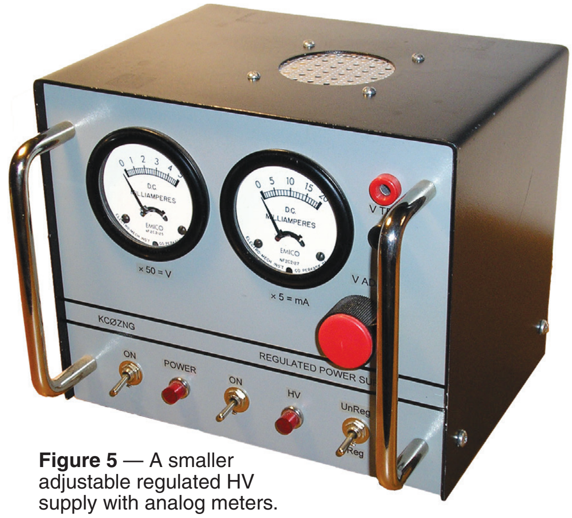

Figure 5 — A smaller adjustable regulated HV supply with analog meters.

When set to any voltage between 160 V and 260 V, it holds that voltage under loads up to about 50 mA. Higher currents exceed the transformer capacity and the output voltage falls. Voltages up to 300 V can be set, but with less available current. The filament current supply can adequately support multiple-tube circuits.

I have used this supply to power a variety of breadboards and completed tube-based projects including a 6T9 transmitter, various regenerative receivers, a 20 meter band transmitter using a 2E26 final amplifier, and an 80 meter superheterodyne receiver.

A Second Supply

For many tube circuits a B+ of 160V is too high, so I built a second supply, similar to the first one but using a lower voltage power transformer. A 6BF11 Compactron furnished both the pentode and the beam power tube for the regulator. A 39 V Zener diode sets the reference voltage. Because I already had them, I used a pair of analog meters rather than digital ones. I also included banana jacks on the front panel for an external voltmeter. The supply, shown in Figure 5, provides up to 60 mA of current between 75 V and 175 V and up to 2 A at 6.3 V for filaments.

Variations and Improvements

Many variations on this theme are possible. You can use different tubes; just be sure that the resistive element — the beam power tube — can dissipate the power that the supply does not deliver to the load. For example, if the input voltage to the regulator is 330 V, and the output is set to 180 V, with a load current draw of 40 mA the beam power tube dissipates $(330 - 150)\ \text{V} \times 0.04\ \text{A} = 7.2\ \text{W}$.

Any convenient, safe connector can be used for the supply outputs. Metering is optional but handy. A regulator portion of the circuit could be built alone and used as an accessory with an existing unregulated HV supply; it will still require its own filament transformer.

After using these supplies for several months, a number of improvements suggested themselves (sometimes forcefully) to me. The most important — more output power sockets. Other improvements include switching the output filament voltage as well as the high voltage, using six-pin rather than four-pin connectors to make both the unregulated and regulated voltages available simultaneously; using rocker switches for smoother operation; and metering the output voltage even when it is not turned on at the sockets.

Figure 4 — The supply with the cover off, viewed from the rear.

Notes

[1]M. Huyett, KØBXB, "Have Fun Building the Simplest Transmitter," *QST*, Nov 2012, pp 46 – 48.
[2]J. Hallas, W1ZR, "Power Supply Options for the Simple Transmitter," *QST*, Nov 2012, p 48.
[3]*The Radio Amateur's Handbook*, 40th Edition, ARRL, 1963.
[4]R. Pickett, "The 'Minipak'," *CQ*, Dec 1951, pp 17 – 19, 66.
[5]L. Chipman, W4PRM, "Combination Regulated Power Supply," *QST*, Oct 1957, pp 16 – 17.
[6]J. Meredith, Jr., K6KWX/7, "Simple Adjustable Voltage Regulator," *QST*, Sep 1965, p 65.
[7]D. Roberts, W7PXE, "A General-Purpose Voltage-Regulated Power Supply," *QST*, Dec 1965, pp 42 – 43.

Photos by the author.

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