

Vixen Design: Power Supply

Begin by cataloging the current demands.

Power Stage: 807 Plate and Screen Currents

88mA (Q-point)

138mA_p

5.0mA (Q-point)

16mA_p

This gives the overall averages:

$$I_{ave} = (2 * 138E-3) / \pi = 87.85mA$$

$$I_1 = \sqrt{(88E-3)^2 + 87.85E-3^2} = 124.35mA$$

$$I_{ave} = (2 * 16E-3) / \pi = 10.19mA$$

$$I_2 = \sqrt{(5.0E-3)^2 + 10.19E-3^2} = 11.35mA$$

Grid Drivers:

$$I_3 = 2(3.0E-3 + 0.2E-3) = 6.4mA$$

Preamp:

$$I_4 = 3.2 + 1.0 = 4.2mA$$

Screen Regulator:

$$I_5 = 7.0mA$$

The total current is simply the sum of these values: 153.3mA (Take this as 160mA here)

Since this is a two channel design, the total current demand is 320mA. Since there are two DC rails, use a split voltage power supply that works as two full wave, center-tapped diode sections in parallel.

Since this is a two-pole filter, it rolls off at -12db_v per octave:

$$23.84/12 = 1.99 \text{ Octaves}$$

This corresponds to a cutoff of about 30Hz, but that's much too high as it falls inside the audio passband. This would lead to "filter bounce" and that's highly undesirable. A ripple choke of 8.0H from the junk box and a 220 μ F filter capacitor has a cutoff of:

$$f_0 = (8.0 * 220\text{E-}6)^{-0.5}/2\pi = 3.79\text{Hz}$$

This gives an attenuation of:

$$\text{Octaves} = \log_2(120/3.79) = 4.98$$

$$\text{Attn} = 12 * 4.98 = 59.76\text{db}_v$$

$$V_{\text{ripple}} = 56.81/(10^{59.76/20}) = 58.4\text{mV}_{\text{P-P}}$$

This gets you well under 1% ripple. Any filter resonances will also be well below the passband so filter bounce won't be a problem here. The diodes are protected against any surges from either the AC mains or the filter choke on power down by paralleling the secondary with a vintage 0.01 μ F/5KV PiO capacitor.

I_{surge} may be calculated as follows:

$$v(t) = |V_p \sin(\omega t)| \text{ (Raw full wave output)}$$

$$V_p = 300 * \sqrt{2} = 424.25\text{V}$$

$$\omega = 120\pi \text{ rad/sec (For 60Hz AC mains)}$$

$$v(t) = 424.25 - 56.81 = 367.44\text{V}$$

The above formula can be solved for t:

$$t = (1/\omega) \arcsin[v(t)/V_p] = 2.78\text{mS}$$

Since the peak voltage occurs at the quarter cycle points, this would happen at: $(1/60)/4$, or 4.17mS.

$\Delta t = 4.17 - 2.78 = 1.45\text{ms}$ – the time it takes to replenish 2.67mC.

$$I_{\text{surge}} = 2.67\text{E-}3 / 1.45\text{E-}3 = 1.93\text{A}$$

This is well below the I_{surge} spec. It also isn't so much higher than the expected surge from hollow state diodes to present a problem for the PTX.

The 150V rail supplies the plates of the grid drivers, the first pre, and the bias chain of the LTP active tail. That comes to about 8.0mA, so figure this as a voltage divider with an idling current of about 4.0mA.

$$R_4 = 150 / 4.0\text{E-}3 = 37\text{K}5 / 10\text{W} \text{ (36K design nominal)}$$

$$R_5 = (365 - 150) / (4.0\text{E-}3 + 8.0\text{E-}3) = 17\text{K}91 / 10\text{W} \text{ (18K design nominal)}$$

$$R_4 \parallel R_5 = 12\text{K}$$

$$C_6 = ((2\pi * 20) * 1200)^{-1} = 6.63\mu\text{F} \text{ (10}\mu\text{F design nominal)}$$

Since this voltage divider does double duty as a safety bleed down, size the resistors generously. 10W is more than adequate, especially if they are mounted to the chassis with mounting brackets for added heat dissipation.

The negative rail supplies the grid drivers and the bias chain. Since this rail is shared, the total current demand comes to about 12.4mA. Use a 47 μ F reservoir and a design nominal load of 15mA.

$$\Delta Q = 15\text{E-}3 / 120 = 125\mu\text{C}$$

$$\Delta V = 125\text{E-}6 / 47\text{E-}6 = 2.67\text{V}_{\text{p-p}}$$

This isn't a hard job, and one could easily use an RC ripple filter here. Active filtration is also attractive here as well. The latter utilizes the isolation provided by the drain of a MOSFET.

An RC filter could use a 4K7 resistor as this gives a 70.5V drop at 15mA, and comes quite close to the design nominal –300V.

$$f_0 = (4700 * 100\text{E-}6)^{-1} / 2\pi = 0.34\text{Hz}$$

$$\text{Octaves} = \log_2(120/0.34) = 8.46$$

$$A_v = -6.0 * 8.46 = -50.78 \text{ (First order filters roll off at } -6.0\text{db per octave.)}$$

$$\Delta V = 2.67 * 10^{(-50.78/20)} = 7.7\text{mV}_{\text{P-P}}$$

This gives good ripple suppression here, and this isn't a complicated solution here. The filter resistor should be 5W or more.

The alternative is active filtration that uses a power MOSFET. This is simply a Source Follower, and the suppression mechanism is the insensitivity of the drain to voltage variations. This is desirable since the filtering can be done at the gate. For faster start-up, use 5.0mA of draw on the voltage divider:

$$R_9 = 300/5.0\text{E-}3 = 60\text{K}$$

$$R_7 = 65/5.0\text{E-}3 = 13\text{K}$$

$$R_7 \parallel R_9 = (1/60\text{E}3 + 1/13\text{E}3)^{-1} = 10.68\text{K}$$

For 50db of ripple suppression you need: $50/6 = 8.33$ Octaves:

$$f_0 = 120/2^{8.33} = 0.37\text{Hz}$$

Since this is an AC voltage divider problem, the cutoff frequency is:

$$\omega_0 = (1/C)(1/R_1 \parallel R_2)$$

Solving for C gives $40.26\mu\text{F}$ ($47\mu\text{F}$ design nominal)

When using MOSFETs, include a gate stopper: 1.0K. Polarity and gate protect diodes are also included as well to prevent transistor poofage from reversed polarities.

The DC neutral is returned to the chassis safety ground by means of a 50PRV/30A integrated bridge connected so the diodes are connected anti-parallel. This provides a ground loop breaker to reduce the possibility of external ground loops that can introduce noise and 60Hz hum. This is paralleled by a 10R/10W resistor bypassed with a $0.1\mu\text{F}$ capacitor to bypass RF noise to ground.

You should never operate this (or any other equipment) without a safety ground where there is a possibility the end user could come into contact with a hot chassis.

The heater PTX is sized by total current demand. From the spec sheets, the heater currents are:

807: 0.9A

6J5: 0.3A

6SL7: 0.3A

6SN7: 0.6A

$$I_{\text{total}} = 2(0.9) + 0.6 + 0.3 + 0.3 = 3.0\text{A}$$

Since there are two channels, you would need twice the power handling capability. Here, the heaters of both channels are operated from a center tapped secondary, so this PTX needs to be a 12.6V_{CT} rated for 3.0A as this is effectively a series/parallel connection. The PTX doesn't need any extra current capability as the load here is purely resistive where VA is equivalent to watts.

To finish off, include some panel LEDs. For the high voltage supply, an unused 6.3V heater winding is used. A 1.5K resistor sets the peak current at about 5.0mA for the HV diode, and 3.0K works across the heater secondary.

The heater supply is separated from the HV supply since the HV will come up very fast, much faster than cathodes can warm. This way, the heaters can be powered up first, the tubes allowed to warm, before the HV is applied. This is especially important since DC coupling is used here. The correct voltages won't be applied unless the tubes are drawing their plate current.

The schemo shows an interlocking connection that prevents switching on the HV without heater power. It's not exactly fool proof, but does help in reducing the chance for errors here.

The primary of the HV PTX includes a MOV to add surge protection for the power diodes. It is essential that the MOV be connected after the switch and fuse since these devices tend to stick on once triggered by a high voltage transient riding in on the AC mains.