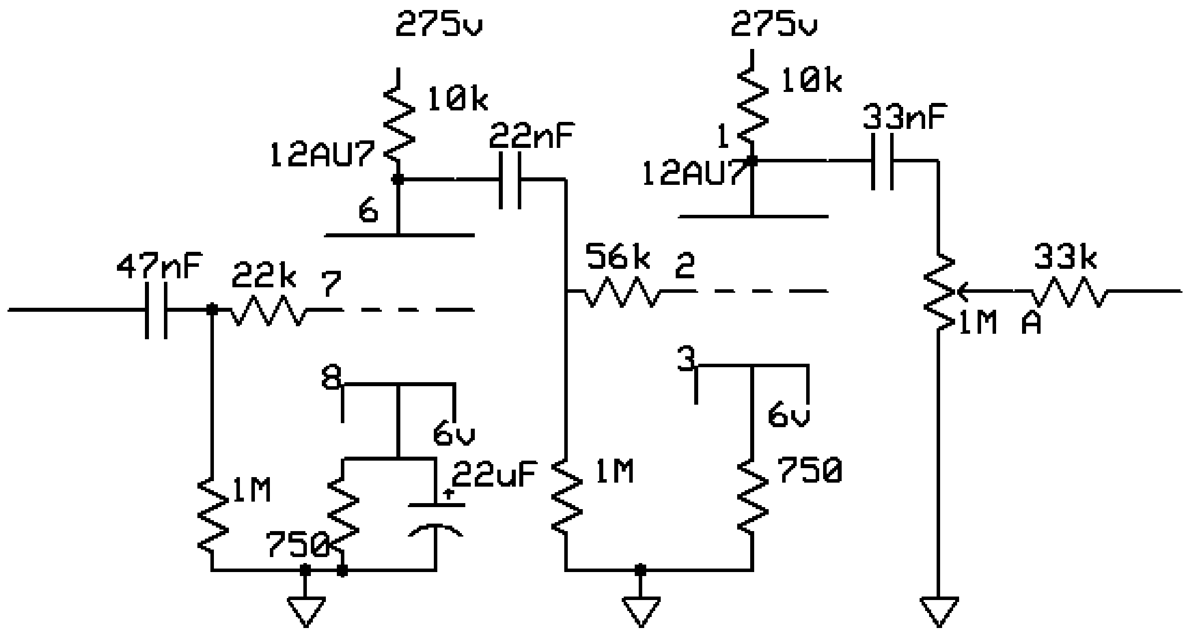
Jared Bland Tube Preamp Notes
Clean Preamps



Not-So-Bland-Amplification		
CN-100		
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Okay, let's look through this, it's got a supply voltage of 275, not too common in an amp, but not uncommon either. This design is simple, use capacitors to block DC, Direct current, from the following gain stage, this eliminates any voltage offset.

How to design a gain stage: We'll need a datasheet for the tube we want to work with. I typically use Tung-Sol datasheets, but all the brands will have similar datasheets.[1]

First, we pick our supply voltage, then we pick an anode load resistor. Using ohms law, E=IR, we can do a lot with tubes. I chose 275v since it's a nice large voltage, which is great for headroom. Pay attention to the maximum voltage on the datasheet, it's 300v for the 12AU7 tube, so we're good. Next, I chose a 10k anode load resistor, that means that for every ampere of current through the resistor, the voltage will drop by 10 thousand, to put it into perspective though, for every milliampere, mA, or 1/1000 ampere, the plate will have 10 volts dropped across it.

To find the maximum amount of current through the resistor, we use ohms law,

$E = IR$, $275 = I \cdot 10,000$ $\frac{275}{10,000} = I$ $I = .027$A or 27mA. So we look at the data sheet, find the graph that plots plate voltage versus plate current, with the control grid's voltage graphed as well. It's on the 4th page of that datasheet I linked. Then, draw a line from the 275v plate voltage to 27mA plate current. This is our anode load line.

Next, we pick a voltage for our control grid. I chose -6v with respect to cathode, this should give decent headroom, without distorting the signal much. If you look at the curves of the grid voltage, you'll notice how they aren't symmetrical, and vary slightly with the grid voltage. This means that no matter what, we will have some distortion, but fortunately, it's largely 2nd harmonic distortion, which we like in small amounts, even for clean.

But, how do we make the grid naturally rest at -6v? If you look at the graph, you'll notice that there is the plate current scale, we do just a little bit of guesswork to find where we think the -6v curve would be. Then we find where the -6v curve intersects with our anode load line. Then look directly to our left, and see that it's roughly 8mA on the plate.

That brings us to the cathode resistor. This is what we'll use to "lift" the cathode by 6 volts, afterall, we don't need the grid to be negative with respect to ground (0 volts DC), we just need it to be more negative than the cathode. If we have 8mA running through the tube if its grid is at -6v with respect to the cathode, we can easily find out the value of the resistor needed. E=IR, 6=.008*Rk therefore Rk= 6/.008=750 ohms. The closest standard value you can find will suffice, this isn't hifi afterall. Another trick you could use is set-up a 1k trimmer pot, and play with it until you find the tone you like.

I just duplicated the resistors for the second triode, it will give the same results.

But wait, what's the capacitor for? The Capacitor from the cathode to ground is a cathode bypass capacitor, it literally bypasses the resistor for AC since capacitors only allow a change in current to flow. This allows us to keep the DC bias of -6v while effectively boosting the signal to allow more gain, this also slightly distorts the signal, but for one stage, you wouldn't notice anything other than the increased gain. If you use a smaller capacitor, you won't get a full A.F. spectrum boost, you can create a treble boost by limiting the capacitor to 1nF-100nF with small values boosting less bass, and can create midrange boosts as well as treble.

If you look at the datasheet, on the first page, there is maximum circuit resistance, this allows us to set the input impedance to almost any value we would like, since tubes have a larger output impedance that solid state, it helps to have a large input impedance. Typically a 1M is used, but lower can be used as well, this resistor also has a purpose of why it must be there, as electrons flow, the grid can get hot and emit electrons, the 1M resistor allows these electrons to flow to ground. It also keeps the grid at 0v bias, unless using a negative grid bias power supply. (We'll get into negative grids without a cathode bias later, this is called fixed bias.)

Whenever driving something, the source should have an output impedance well under the input impedance of what you are driving. Tubes are high-ish impedance, the output impedance of an average 12AX7 stage is about 40k ohms. The output of a 12AU7 is lower, but still not nearly as low as solid state. When driving a low impedance with a high source impedance, you can lose a good deal of treble. This is why we use a higher input impedance than source.

Next, we have the resistor that is attached to the grid, 10k to upwards of 1M is used for this. We can tailor the frequency response with this resistor, the input capacitance is relatively easy to figure out.

$C_{\text{in}} = C_{ga} \cdot A + C_{gk}$

Where

C_{in} is the input capacitance, C_{ga} is the grid to anode capacitance, A is the gain of the stage, and C_{gk} is the grid to cathode capacitance.
The grid to anode capacitance is amplified by the gain of the stage since the anode voltage is changing much more rapidly than the cathode.

The gain of the first stage is 12, so
$C_{\text{in}} = 1.5 \cdot 12 \cdot 10^{-12} + 1.6 \cdot 10^{-12}$
$= (1.5 \cdot 12 + 1.6) \cdot 10^{-12}$
$= 19.6$ pF, which we can round to 20.0 pF
Next, we pick a frequency to attenuate at
$$R = \frac{1}{2 \cdot \pi \cdot f \cdot C_{\text{in}}}$$
We can also manipulate the equation to find the frequency from a known source resistance.
$f = \dfrac{1}{2\,\pi \cdot R \cdot C_{\text{in}}}$ π~3.14 and R is the grid stopper's resistance value plus the source resistance.
$= \dfrac{1}{6.28 \cdot 20 \cdot 10^{-12} \cdot \left[22k + Z_{out}\right]}$ The resistance of a passive guitar pickup can vary a lot, put to simplify things, let's call it 100k.
$$= \frac{1}{6.28 \cdot 20 \cdot 10^{-12} \cdot [22000 + 100000]}$$
$$= \frac{1}{6.28 \cdot 20 \cdot 10^{-12} \cdot [122000]}$$
$= 65$ khz

With this, even a large impedance signal like a piezo pickup could have no noticeable treble loss, a piezo pickup can have an output impedance of several Megohms.

$$f = \frac{1}{\left(6.28 \cdot 20 \cdot 10^{-12} \cdot 2022000\right)}$$
$f = 3.6$ khz, which is which will attenuate the upper harmonics of the pickup.

The next reason we have for that grid stopper, the resistor in series with the signal, attached to the grid, is to prevent blocking distortion. Blocking distortion happens when the changing voltage is too much for the capacitor to discharge properly. Unless the following stage is being overdriven, this isn't of much concern, but most modern amps distort more than older designs did, and you should always include grid stoppers on all of your stages. Small values may not prevent blocking distortion, and large values will attenuate treble just as the last equation proved. So a value of 10k-100k will suffice. Notice that even with a volume potentiometer, we still use a grid stopper, the proceeding grid must always have series resistance to prevent blocking distortion.

References: [1] http://tubedata.tigahost.com/tubedata/sheets/127/1/12AU7.pdf