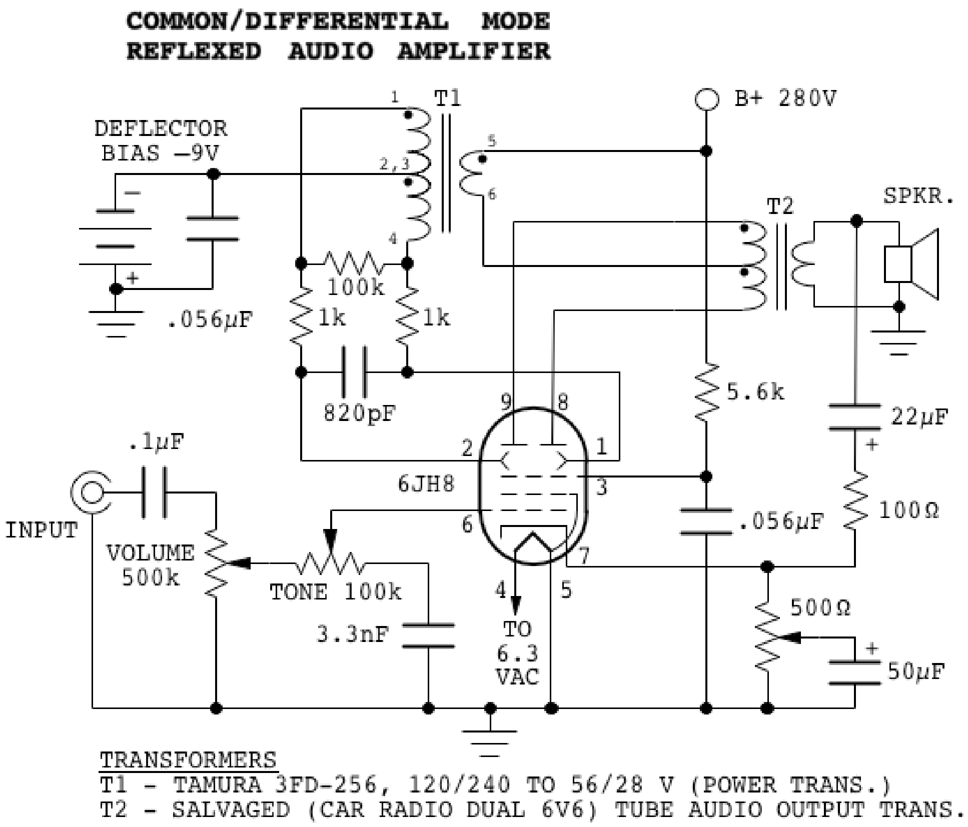
Bob Weaver (http://electronbunker.ca/Home.html) designed the common/differential mode reflexed audio amplifier circuit below for an electronics challenge in 2010 (http://www.dutchforce.com/~eforum/index.php?showtopic=31877). The single tube amplifier uses a push-pull output transformer, and a single-ended driver transformer with step-up CT secondary. The tube is a two-plate sheet-beam, or beam-deflection tube (equivalent types are 6AR8, 6JH8, 6ME8, 7360), which acts like a typical pentode but with two plates and the addition of two deflectors that control the current division between the plates (the screen electrode in the pentode is called the accelerator). The control grid transconductance is about 4,000 µmho, which is just a bit lower than common amplifier pentodes of similar plate power rating. For the allowable plate and screen voltages, and maximum cathode current, the 2-3W plate dissipation levels are a bit low and will obviously limit an amplifier's output power capability.

The amplifier input's voltage signal is passed to the control grid and amplified to a combined plate current signal passing through the driver transformer T1 primary winding, as per a normal single-ended configuration, to generate a T1 secondary side voltage signal which is used to differentially drive the deflectors to cause the combined plate current to generate a push-pull plate-plate current signal through the primary of output transformer T2, with the T2 secondary winding generating a voltage signal to drive a speaker load.



With the pentode cathode-biased, the signal input voltage experiences a high transconductance gain in combined plate current signal with only a relatively minor change in grid-cathode voltage around the quiescent idle level. With a resistively loaded output transformer T2, the plates are forced by the T1 generated push-pull drive signal to swing along a T2 loadline with equal and opposite changes in plate current.

A positive control grid voltage swing will push the more conducting push-pull plate towards the saturation region, and a negative control grid voltage swing will push the same plate towards the cut-off region. The other push-pull plate in the tube is receiving effectively the same signal variation (away from idle in opposite direction) via transformer action, but the change in idle bias point is avoiding that plate from reaching its saturation and cut-off regions. This distortion characteristic is slightly different from a typical push-pull stage operating in class A.

A pk-pk differential voltage of about 40-60V on the deflectors generates a fairly linear push-pull swing in plate currents for all levels of combined anode current. The idle cathode current is set by the cathode bias voltage and screen voltage, and can be set to operate each plate at nearly max design rated plate dissipation, in which case the average plate dissipation would remain constant due to class A push-pull operation. The idle operating point should also allow a T2 loadline to extend in to the pentode knee region of the appropriate control grid voltage curve for an input signal peak positive voltage excursion, and to provide an equivalent negative current excursion for the input signal peak negative voltage excursion.

Given that the deflectors are effectively an open-circuit load, T1 can use a large step-up ratio to generate the push-pull drive voltage. A variable load on T1 secondary could be used to control the gain of the deflector voltage swing. Alternatively, a cathode resistor pot with the wiper bypassed allows the level of unbypassed cathode resistance to be varied, which can also control the single-ended cathode current signal swing, and hence the gain of the deflector voltage swing. Some loading on the T1 secondary is needed to flatten the output voltage frequency response. As the tube is designed for RF applications, stoppers may be needed on deflectors and grids, and heater pin 5 should be connected directly to 0V as it is also an internal shield. Control grid leak is preferably < 250kΩ. The recommended bias voltage of the deflectors is about -14V, which is derived from the -9V CT bias (shown as provided by a battry), plus the approximate +5V cathode bias. The valve should also not be placed near the power or output transformers or T1, due to possible magnetic field disturbance.

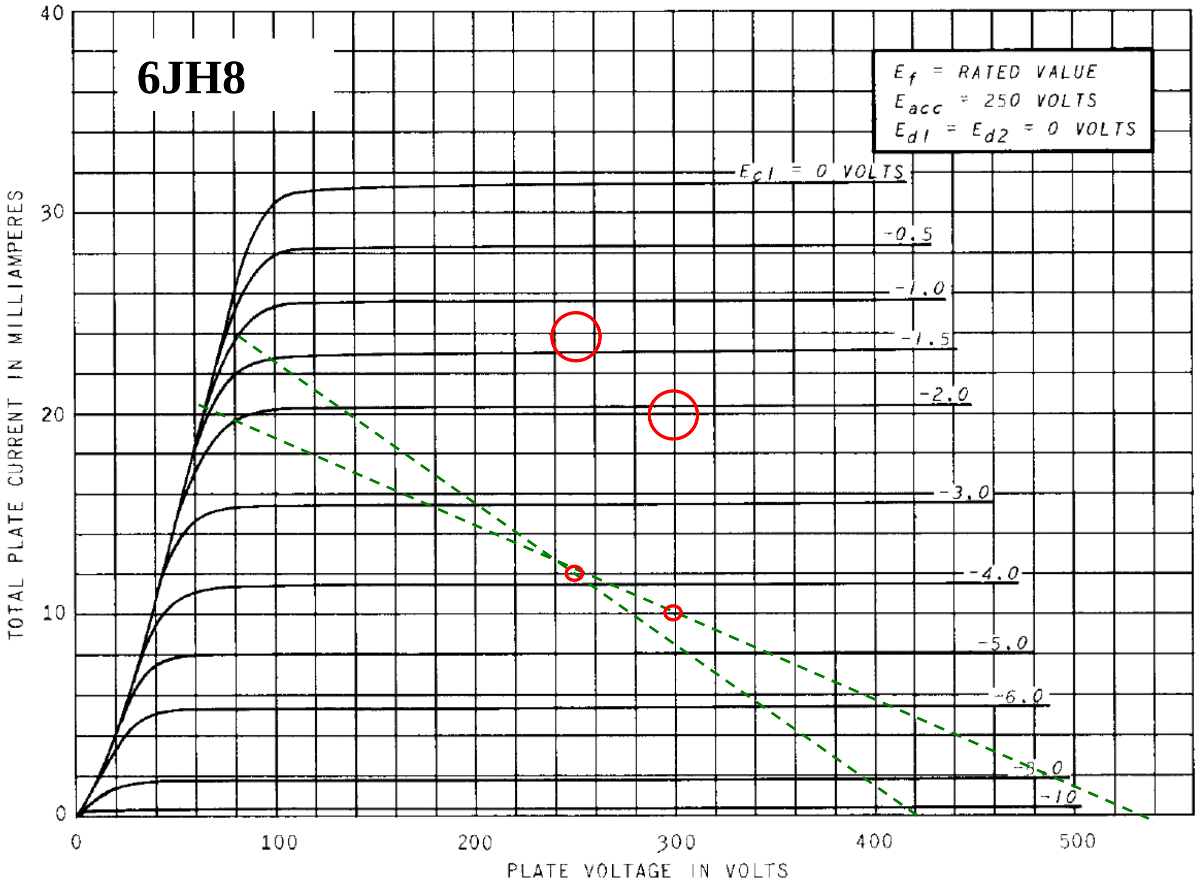
As a design example using a 6JH8 with about 250V plate and screen voltages (see plots below), a per plate idle point of 12mA (3W) results from about -1.4V grid, with the aim to drive the plate loadline towards 24mA at input signal peak positive excursion, and to 0mA at peak negative excursion. The driver differential deflector voltage should linearly transfer the combined plate current to that driven plate over the same input signal voltage swing. At this low bias voltage level, the transconductance is effectively close to its maximum level. A loadline swing in to the pentode knee region would require a (250-80)/(24-12) =14kΩ class A loadline, or 28kΩ PP impedance for T2, and a cathode resistor of 1.4V/24mA = 58Ω.

Operating at a higher idle current would require a lower supply and screen voltage, and a smaller bias voltage, but this may not allow sufficient grid voltage swing before grid conduction becomes significant. Operating at a lower idle current would require a higher supply and screen voltage (for same max power dissipation), and would increase bias voltage, but also increase T2 PP impedance. As grid voltage swing increases, the saturation region would be met by the loadline further above the knee, and so a higher OT PP impedance would be more appropriate.

A 6JH8 tube operating at 300V anode and screen can have a per plate idle current up to 10mA (3W), with estimated cathode bias of about -2.5V, and cathode resistor of 2.5V/20mA = 125Ω. A loadline swing in to the pentode knee region would require a (300-80)/(20-10) =22kΩ class A loadline, or 44kΩ PP impedance for T2.

Using negative feedback from the speaker output to an un-bypassed cathode resistor will require a larger control grid voltage change to generate the same level of cathode current change, and the same output power. Without feedback, the gain of the amplifier may be sufficient to use a guitar input to drive maximum output power, especially if the T1 step-up is sufficient.

A dual gang feedback pot could be used to increase feedback, and at the same time increase the input signal applied to the control grid, in order to maintain a constant amplifier gain. The feedback could go to just the unbypassed cathode resistance by taking the pot wiper bypass capacitor to the top of the pot, and taking the feedback to the wiper.



AVERAGE TRANSFER CHARACTERISTICS