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Oggetto: **SRPP design data**

The following is reposted from several previous posts on the subject (DejaNews is a good source for things like this):

For those who would like some design on totem-pole amplifiers:

Assuming identical triodes and no bottom-tube cathode degeneration,

$$Zo = rp \left(\frac{rp + R}{2rp + (u + 1)R} \right)$$

$$Av = \frac{-u(rp + uR)}{2rp + (u + 1)R + (rp + R)(rp/Rl)}$$

The effective plate load resistance supplied by the upper tube is given by:

$$rp + (u + 1)R$$

and the "current gain" (effective transconductance) is:

$$-gm \left(\frac{rp + uR}{rp + R} \right)$$

where:

Zo = output impedance
Av = voltage gain
rp = dynamic plate resistance of the tubes at the operating point
u = mu, the amplification factor of the tubes at operating point
gm = tube transconductance at the operating point
R = value of the upper-tube cathode resistor
Rl = load resistance

Maximum +/- output current conditions:

output DC voltage = 1/2 B+ and R = 1/gm

(a good way to do this is with equal cathode resistors; bypass the bottom one if you need to maximize gain)

Maximum gain conditions:

R = approximately 3/gm

The great value of the totem-pole connection is that it loads the lower tube with a quite high effective resistance (thus good voltage gain and linearity) but at the same time has a quite low output impedance and high current gain. It behaves very well into reactive loads and load impedances lower than one would normally use with the tube.

The circuit is discussed briefly in Valley & Waldman, _Vacuum Tube Amplifiers_, v. 18 of the Radiation Lab series.

The first place I saw the circuit was driving the (line) output transformer of the Ampex 351.

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Some *calculated* figures (load resistance assumed 10k):

12AT7 w/ R = 1.5k, rp = 15k, u = 60: Zo = 2.0k   Av = 43
6SN7 w/ R = 600, rp = 6.7k, u = 20: Zo = 1.9k   Av = 12
12AU7 w/ R = 750, rp = 6.5k, u = 18: Zo = 1.7k   Av = 11
6DJ8 w/ R = 300, rp = 2.7k, u = 33: Zo = 0.5k   Av = 25
6SL7 w/ R = 2k,   rp = 44k, u = 70: Zo = 8.8k   Av = 30

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Here are the measured data for a 12AT7/6201 in totem pole operation:

B+ = 310 V (this is non-critical)

Bottom tube cathode resistor = 1 K ohm

Bottom tube cathode bypass capacitor = 1000 uF/6.3 V
  (figures in parentheses are with unbypassed cathode)

Top tube cathode resistor = 1.5 K ohm

Output network: 5 uF coupling capacitor with 100 K ohm resistor to ground

Feedback for closed-loop figures: the bottom-tube grid is used as a summing junction. 100 K ohms from the signal source to the bottom grid, 470 K ohms from the load side of the output coupling capacitor to the bottom grid. (This configuration makes a nice line amplifier, bearing in mind that it inverts absolute polarity so the speaker leads must be reversed.)

Open loop gain: 36 = 31 dB   (25 = 28 dB)

Open loop output impedance: 3 K ohms, resistive

Closed-loop gain: 4.7 = 13.5 dB

Closed-loop output impedance: 300 ohms, resistive   (1.1 K ohms)

Closed-loop bandwidth: -3 dB at 110 Kc   (105 Kc)*

Distortion: driving 10 K ohms to +10 dBv, IMD = < 0.1 %
            driving 10 K ohms to +30 dBv, IMD = < 1 %

Maximum output: greater than 100 V p-p (> +33 dBv)

Capacitive loading: using 2 Kc squarewave signal, drives 1000 pF without visible change; 2500 pF produces just visible rounding; 10,000 pF (.01 uF) produces definite rounding but still very good shape.

* Note that the closed-loop bandwidth reflects the rather high effective source impedance of the summing operation. Fed from a lower source impedance (even the plate of a 12AX7 is substantially lower) the bandwidth is correspondingly higher.

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SRPP output impedance is higher by a factor of 5-10 than a cathode follower, and the effective plate resistance seen by the lower tube is a little lower (not too much in practice, all things equal) than it would be if the upper tube were operating as a constant-current source.

So, using three tubes (voltage amp loaded by constant-current source driving a cathode follower) instead of the SRPP's two, you can seemingly have the best of both worlds.

There are two reasons I like the SRPP better than the three-tube circuit:

(1) It draws less power supply current, all things equal.

(2) Although the cathode follower has lower small-signal output impedance, it has much higher large-signal output impedance. When you are driving a reactive load (cables, the grid of a power triode), a non-linear load (following tube operating near the grid-current region), or just a low-impedance load, the large-signal impedance is important.

When a cathode follower is sourcing current to a load, it has to supply the load current and the pull-down resistor current. As the load current increases (the follower pulls it more positive), the resistor current increases as well -- the opposite of what we want. When the follower is sinking current, the pull-down resistor is all that supplies load current, and the harder it needs to pull the less able it is (because there is less voltage across it). All this can work fine if the follower is made very class A, but there is still distortion inherent in the "backwards pull-push" nature of the circuit.

(One change someone might think to make would be to add a fourth triode section as a pull-down current source or to turn the cathode follower into a White follower. This sends its "kludge factor" over the top IMO. The White follower is an interesting beast, but not recommended for real-world design)

The SRPP, on the other hand, is a real push-pull circuit -- the tube that is not supplying the load current decreases its current demand as the load current increases. It can also pull down (sink current) with as much authority as it pulls up.