

# Mixed-Technology

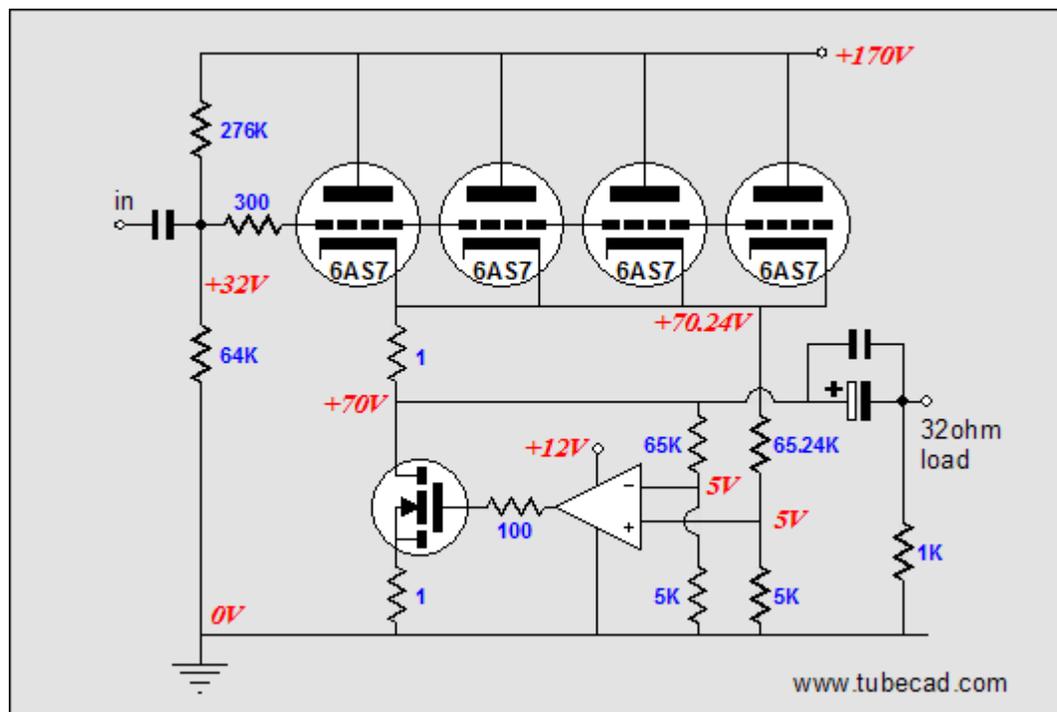
09 February 2005

## Mix-tech hybrid

Tubes! Where are the tubes? I know that it is the vacuum tube that is the star of the show and that the supporting actors, all the other parts, are not why you read this webzine/blog.

(Speaking of blogs, I understand that the word “blog” was the most looked up word at the dictionary web sites last year. To be frank, I am not altogether sure this counts as blog, as what I publish is generally too long and too infrequent. By the way, 15,000 new blogs are started each day. How many cover tube circuits.)

So, where are the tube circuits? I have been evaluating the mixed-technology hybrid amplifier, wherein the output stage holds both tube and solid-state output devices. First of all, what a curious mix this is. In the typical hybrid amplifier, the front-end is tube-based and the output stage solid-state, or vice versa. But not always, sometimes dissimilar technologies are used within a given amplifier stage, say the use of the solid-state constant-current sources to load a tube’s plate. So too, in a power amplifier, when the output devices differ in fundamental technology, one device plays a relatively passive role, acting as a constant-current source. However, in the schematic below, we see both output devices actively delivering a varying current into the loudspeaker.



A quick overview: Only a single-polarity power supply is used, one that can readily be derived from rectifying a 117-volt secondary; and no voltage doublers are used. The four 6AS7 triodes receive 100 volts of the available B+ voltage; the MOSFET,

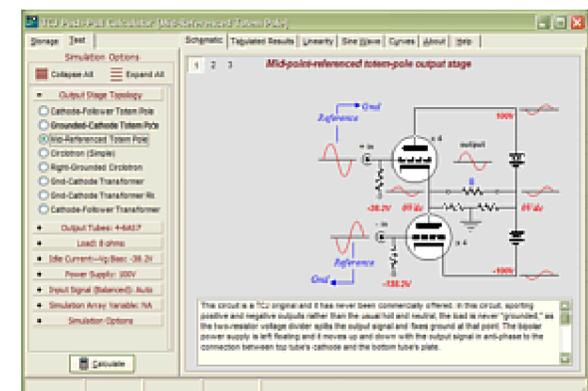
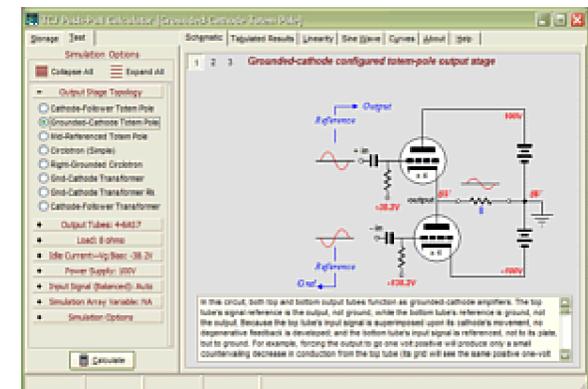
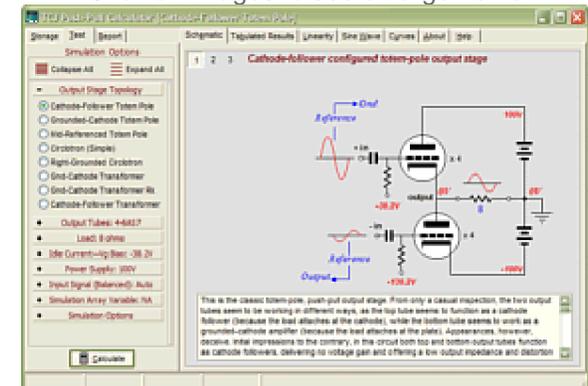
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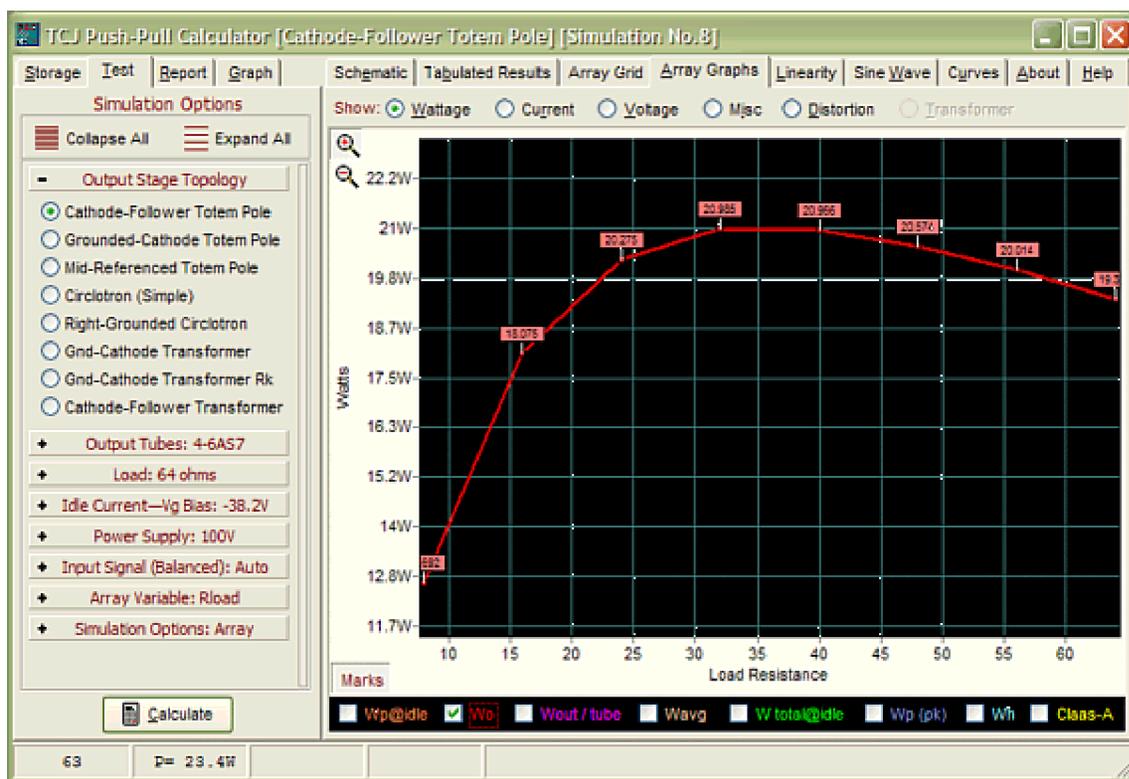
### TCJ Push-Pull Calculator

Version 2

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the remaining 70 volts. (This ratio can be readily altered to give the triodes more voltage, as the output voltage swing will never approach 70 volts (300W into 8 ohms, by the way). The heater power supply offers 12 volts to both the 6AS7 (two in series) and the OpAmp, which both drives the bottom MOSFET and controls the output stage's idle current. The output is capacitor coupled (the price we pay for having a mono-polar power supply; a good deal actually). The load is specified as 32 ohms (21W), but an 8-ohm load (12W) can be driven at a lower output power level.

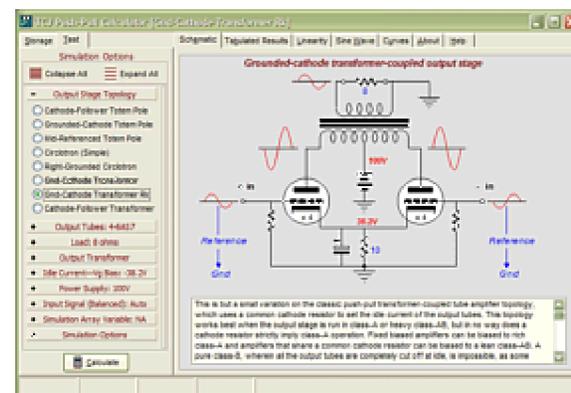
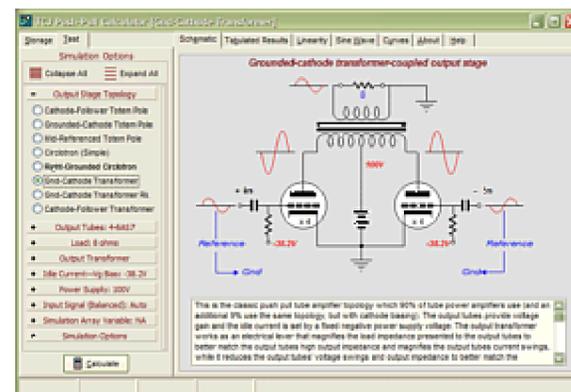
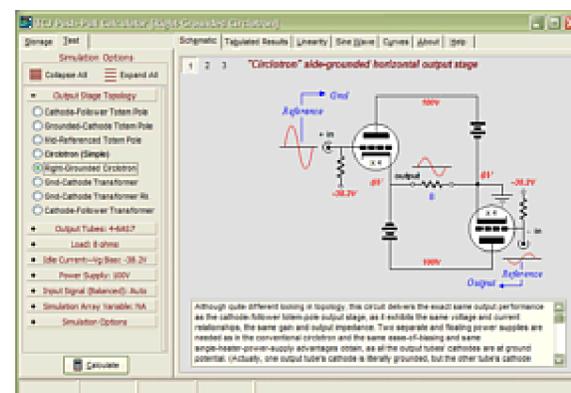
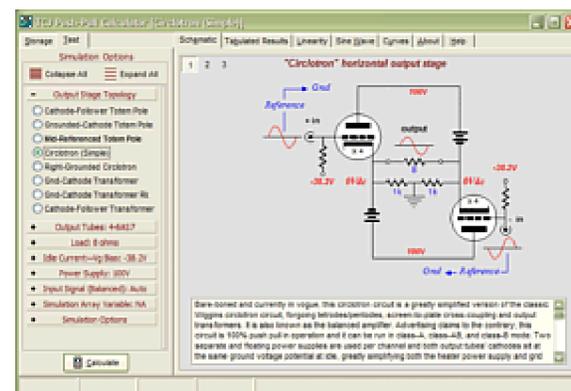


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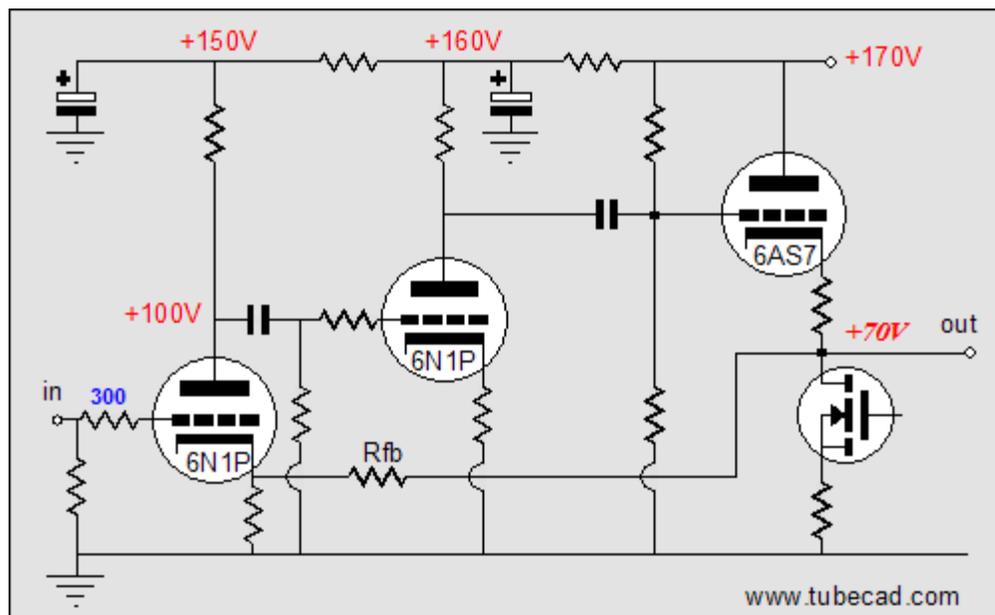
This mixed-tech output stage needs a carefully designed input and driver stage. Because the 6AS7s require so much drive voltage to deliver their maximum current swing, a solid-state front-end isn't our first choice, although one could be designed. The front-end must hold a gain of at least 80, just to drive the output tubes, assuming a 1-volt input signal; and if a feedback loop is used, a gain higher than 80 will be needed. In other words, one triode is not likely to work, but one pentode might (or two triodes cascoded). However, two triode-based grounded-cathode amplifiers cascaded would give us the most options, considering the low B+ voltage. For example, 6DJ8 type tube could easily deliver a final gain of 400 in such a circuit.

## 6DJ8????

I often get grief over using 6DJ8s in the circuit examples I draw. For many there are only trees and no forest; just parts, no topology. A circuit that uses a 6DJ8 can only use a 6DJ8, never a 6AQ8 or 6BQ7. The more fanatical will claim that a circuit that uses a "Bugle Boy" 6DJ8 can never use an RCA 6DJ8. The human mind is a fascinating thing to behold. "Why do you always use 6DJ8s? Everyone knows that—fill in your favorite tube—are the only good small-signal triodes."



One reason the 6DJ8 is so often used is that it works well with low voltages, because of its high perveance. The other reason it is so often specified is that I know the tube's plate curves intimately, so I don't have to look up grid voltage or cathode resistor values. But if asked what I think of the 6DJ8 as a tube, my answer is that it can be a real pain, as so many are microphonic. Fortunately, I own a hundred of them (scores of Siemens and Amperexs) that I can hand select good ones. But, so as not to offend the overly sensitive, let us use a 6N1P instead. Below is a one possibility.

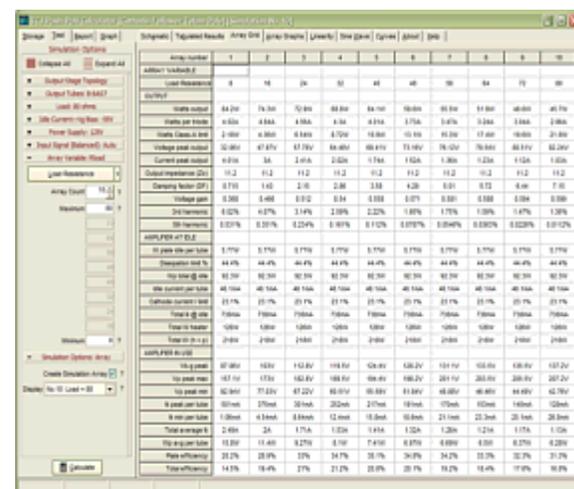
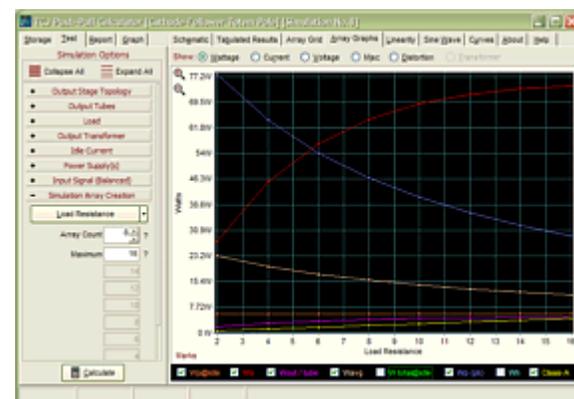
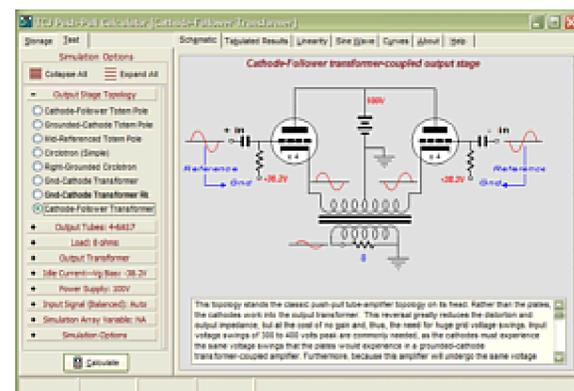


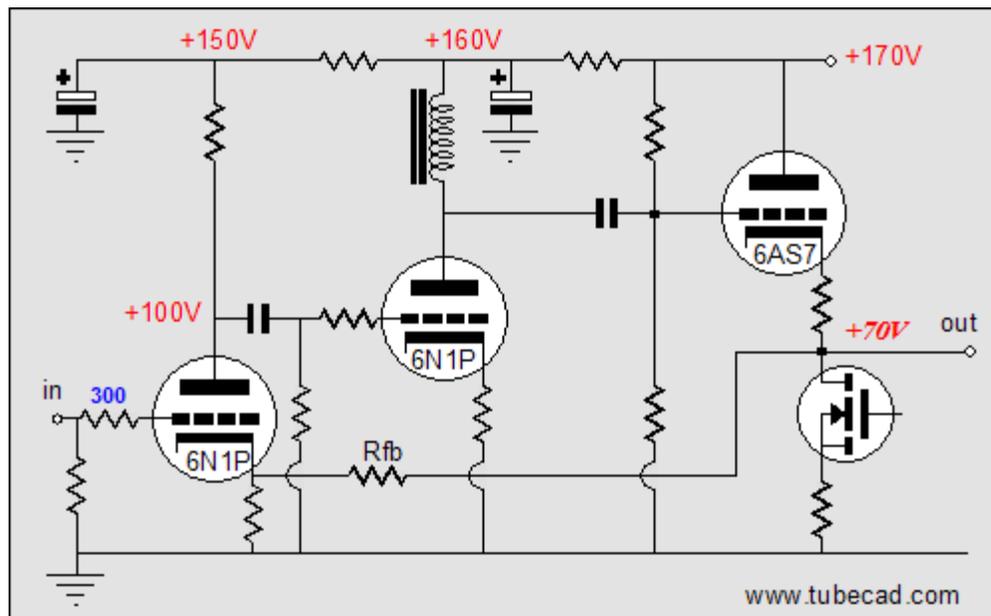
## Input stage

The input stage is most important, as its noise and distortion will be paramount. Thus, it gets its own decoupled power supply connection. If a feedback loop is used, the driver stage must be able to swing asymmetrically, as the output tubes need more voltage swing to turn off than they do to turn on fully. As the circuit stands, this stage will not cut it, as it cannot swing sufficient voltage to drive the 6AS7s to full output. The output tubes need at least  $\pm 38$  volts of grid signal relative to the cathode, which are not grounded, but move with the output. Thus,  $\pm 74$  volts of grid signal is needed (the bias voltage is  $-38V$ ; thus,  $74V = 38V + 36V$ ).

The low B+ voltage is partially setting the limit, as  $74V$  times two is  $148V$ , which barely fits in the  $160$ -volt B+ voltage. In other words, if a  $10k$  plate-load resistor were used (a typical value), the triode's rp should not exceed more than  $810$  ohms. Since the 6N1P's rp is closer to  $15k$  at  $50$  volts, a  $185k$  plate would be needed, which in turn would necessitate a miniscule idle current (never a good idea). Thus, the other limiting factor is the 6N1P itself.

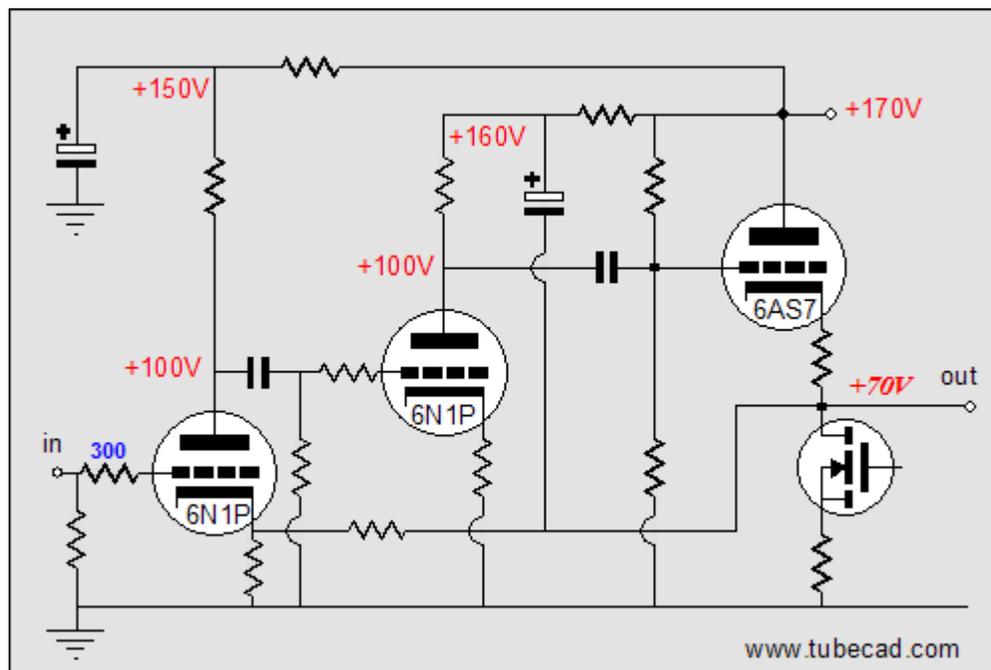
Yes, indeed, the 6N1P is a great little tube. It is quiet and it offers a fairly low rp. However, it is not a 6DJ8, 6922, 7308, ECC88 drop in replacement. It differs in **mu**, **gm**, **rp**, and **heater current draw**. Furthermore, one key difference a designer quickly finds is that it requires a higher plate voltage than the 6DJ8 type, because of its lower perveance.





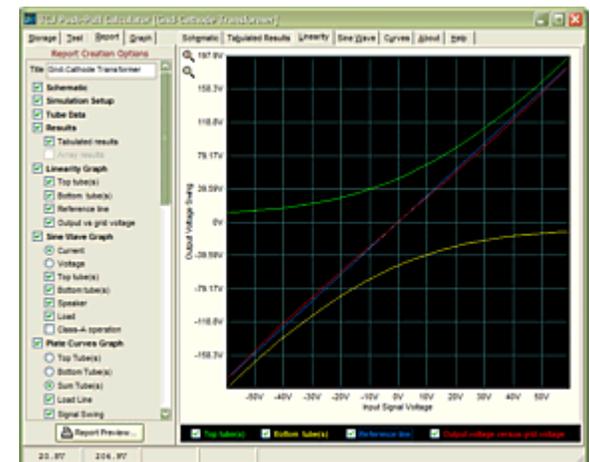
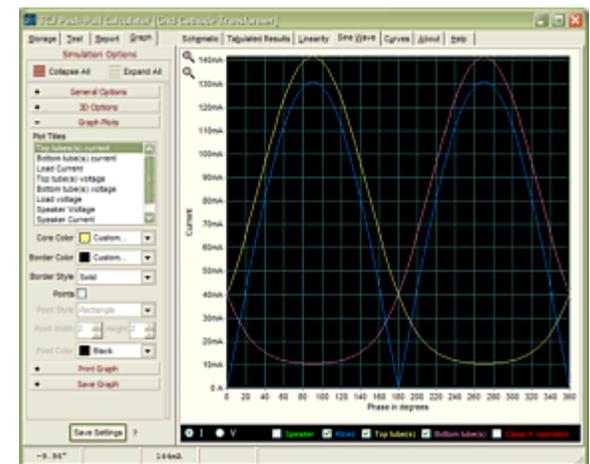
One workaround would be to replace the plate resistor with an inductor, which would effectively double the B+ voltage. Such a replacement would give the 6N1P plenty of voltage to work with, as almost the full 160 volts would be available. However, such a move is dangerous when a global feedback loop is added to the mix, as the inductor brings its own set of problems, such as resonance and phase shifts, which can easily turn an amplifier into an oscillator.

Thus, in this circuit, with this limited B+ voltage, it should be obvious that the 6DJ8 is a better choice, but let us see if we cannot make the 6N1P work through a special technique.



### Bootstrapping

The circuit above may not look that different from the first version, as it holds the same number of parts, but it is wired differently. The driver stage's plate resistor is



## TCJ PPC Version 2 Improvements

- Rebuilt simulation engine
- Create reports as PDFs\*
- More Graphs 2D/3D\*
- Help system added
- Target idle current feature
- Redesigned array creation
- Transformer primary & secondary
- RDC inclusion
- Save user-defined transformer definitions
- Enhanced result display
- Added array result grid

\*User definable

TCJ Push-Pull Calculator has but a single purpose: to evaluate tube-based output stages by simulating eight topologies' (five OTL and three transformer-coupled) actual performance with a specified tube, power supply and bias voltage, and load impedance. The accuracy of the simulation depends on the accuracy of the tube models used and the tube math model is the same True Curves™ model used in

bootstrapped to the output stage's output, which effectively boosts the B+ voltage by the amount of peak output swing, which in this case is about 36 volts. So effectively, the B+ available to the driver stage is not 160 volts, but 196 volts, at the top of the grid swing. This means that we can set the idle plate voltage 36 volts higher than with a fixed 160-volt B+ voltage. In other words, we can use  $196 - 74$  volts, which equals 122 volts; instead, of  $160 - 74$  volts, which equals 86 volts. The result is that the lowest plate voltage swing will only extend down to 48 volts, not 12 volts. So, how well will the 6N1P work with this setup?

GlassWare's SE Amp CAD and Live Curves programs, which is far more accurate than the usual SPICE tube model.

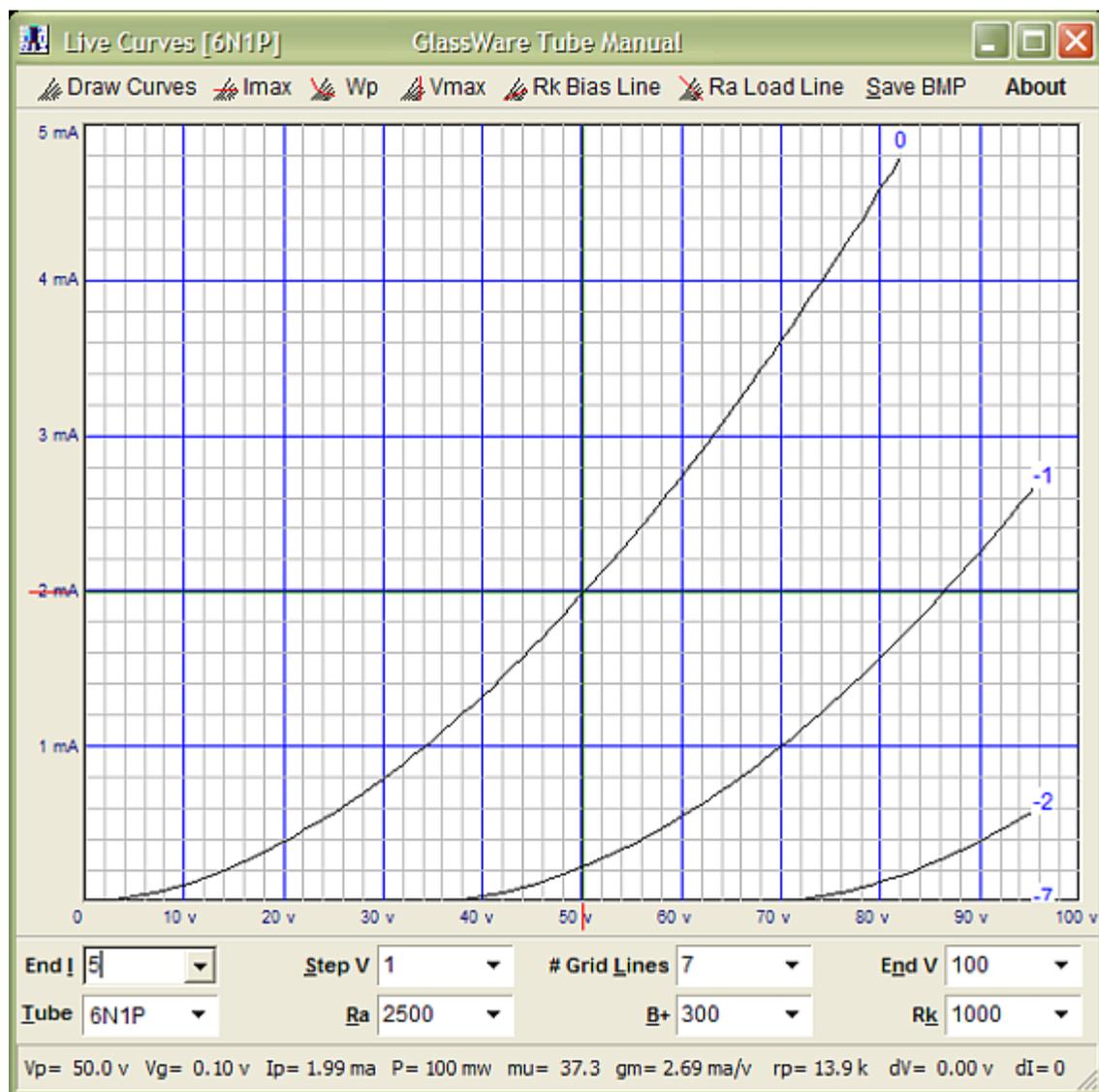
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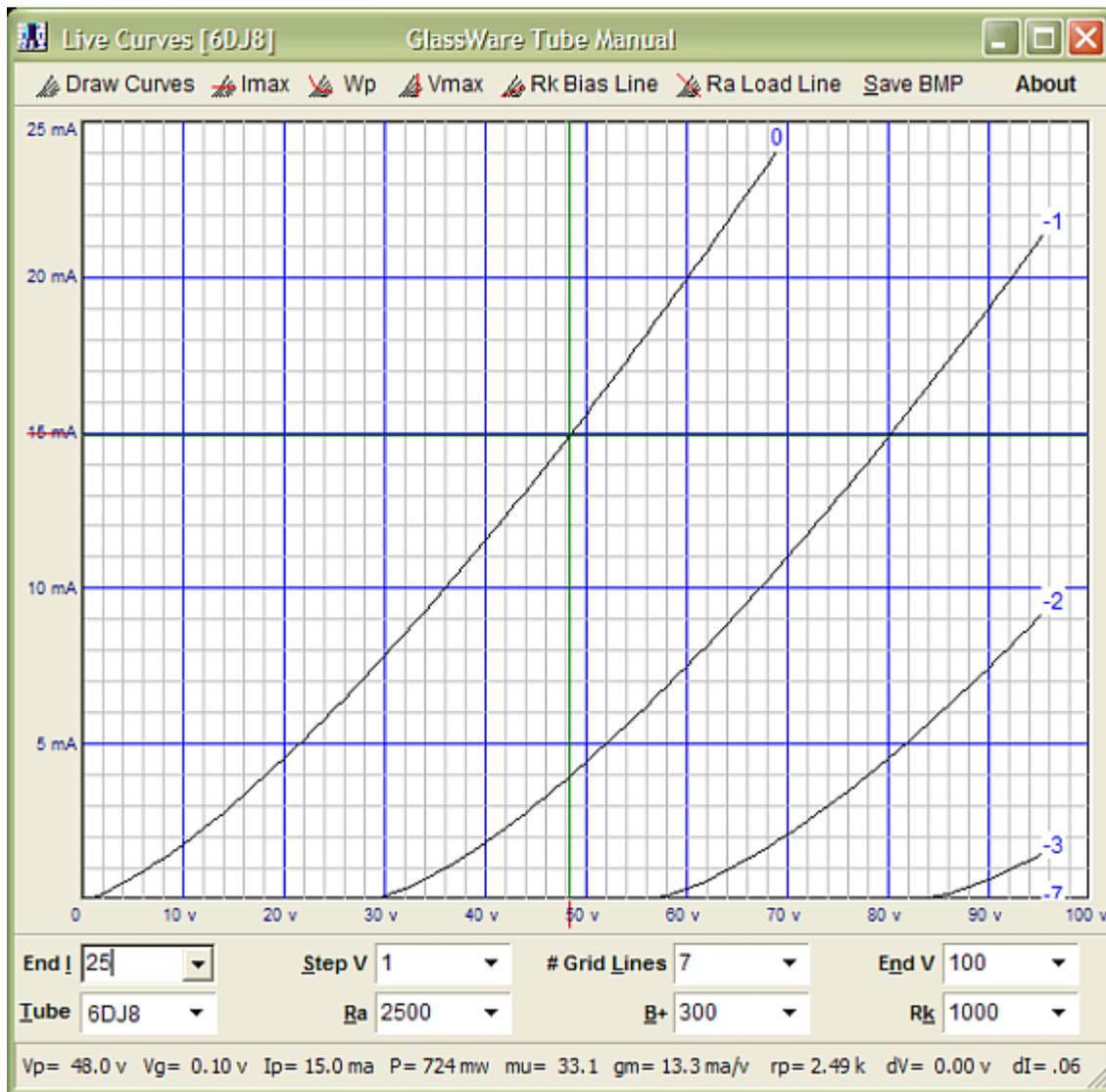
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With a 37k plate resistor and an idle current of 1mA, the 6N1P would work, but this is still a trivial amount of current. Now, let's see how well the 6DJ8 works.



## Back to the 6DJ8

The 6DJ8 draws 15mA at 48 volts with 0-grid volts. 148 volts divided by 0.015A equals roughly 10k, which means an idle current of 7.5mA would allow a symmetrical swing of 74 volts on the plate. Much better. Now, we add frosting to the cake.

The 6AS7 is not linear a tube. —I have been told that some believe that it is a close relative to the 2A3. How so? Well, it looks like a 2A3 and the same company that created the 2A3 created the 6AS7. Sure, just as George Bush is a close relative to John Kerry, as both are white men that went to Yale. I would love to know who started this nonsense. The 2A3 is nothing like a 6AS7, as they differ in every key electrical characteristic and even in fundamental construction, as one holds a directly heated cathode and the other indirectly heated cathode.— And its nonlinearity shows with a brutal 128-ohm load-line (32 times 4, as there is four triodes working into a 32-ohm load). In other words, it only takes 38 volts (from grid to cathode) to completely turn on the 6AS7, but it would take closer to 50 volts to turn it off. A feedback loop will work to create this asymmetrical drive signal in the process of straightening out the 6AS7.

A 6N1P is definitely not a drop in replacement for

Using a 6DJ8 with a plate resistor of 16k and an idle current of 5mA allows us to lower the plate voltage at idle to 116 volts, which will allow the 6DJ8's plate to swing +80 volts and -96 volts relative to ground and +54 volts and -60 volts relative to the output, because of the bootstrapping.

the 6DJ8

Therefore, in this circuit, a 6N1P is definitely not a drop in replacement for the 6DJ8. Of course, if we use a higher B+ voltage for the input and driver stage, then a 6N1P could be profitably used.

//JRB

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