

10 March 2005

# Which Tube Shall I Use ?

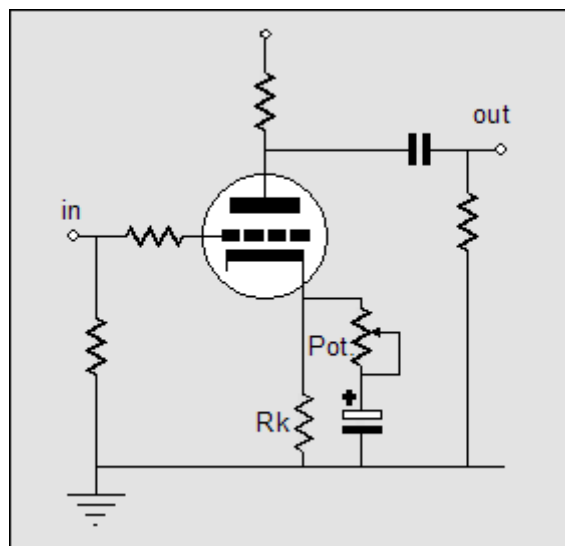
By GEORGE FLETCHER COOPER

## "Which Tube Should I Use?" Typos

A few—quite a few—typos made it into my OCR translation of Cooper's article, "Which Tube Should I Use?" Many typos were my fault, but not all of them. It turns out that a Word document that is heavily stuffed with Greek characters does not readily translate into a PDF, as the Adobe PDF Writer (version 5) will not imbed all the extended set characters in a typeface. Fortunately, Bjørn, a reader in Norway, sent me a list of errors. Thanks. The newly corrected PDF is up now, so you should download it if you had a hard time following the math.

My guess is that few tried pursuing the math to its conclusion; it did look daunting. The article's punch line was that an unbypassed cathode resistor arches a triode's transconductance curve upwards, as it lowers its slope. If the triode were perfectly linear, the resistor would only add distortion, but as the triode isn't perfectly linear (because it already bends in the opposite direction), the unbypassed cathode resistor helps to straighten the curve by reducing the 2nd harmonic while increasing the 3rd harmonic.

A key point is that too large a value will over compensate the triode. Thus, some finesse is needed. (Another example of "more, more, more" not working, not working, not working.) I recommend using a potentiometer and triangle waves to dynamically find the optimal amount of unbypassed cathode resistance needed. The circuit below shows one possible setup.



Resistor  $R_k$  sees all of the DC idle current through the triode, whereas the potentiometer and capacitor only see any current flow when AC signal is present. The capacitor is always charged to the cathode's DC value, so the bias point will not

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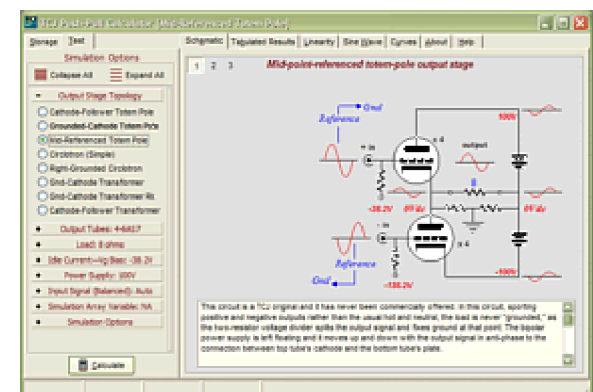
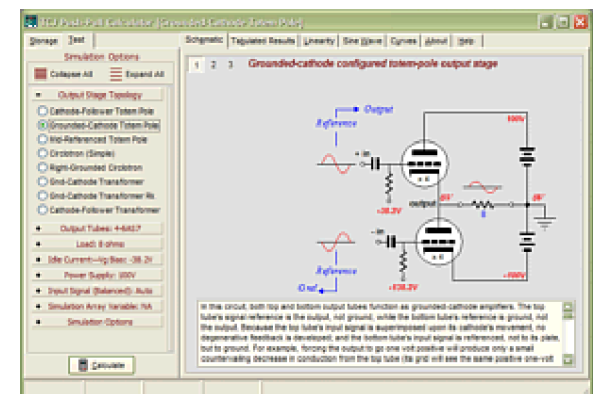
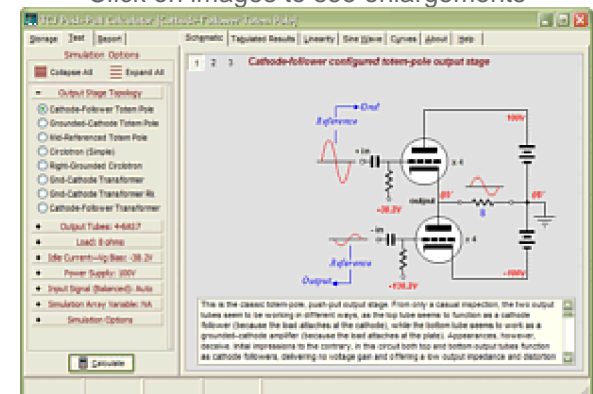
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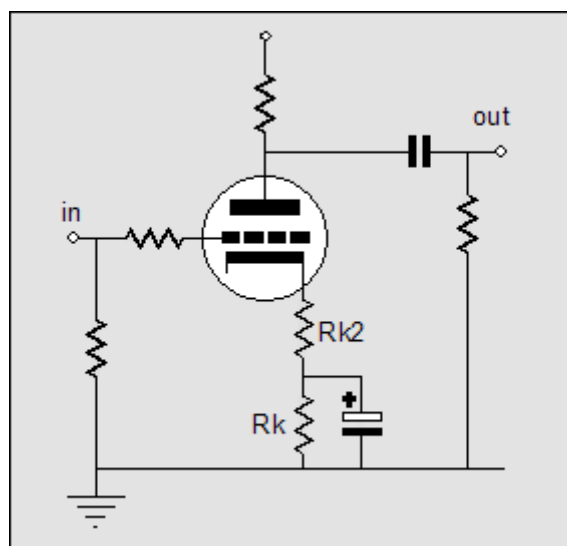
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be thrown off by adjusting the potentiometer. At one extreme of the potentiometer, the cathode resistor  $R_k$  is completely bypassed; at the other extreme, relatively unbypassed (if it were completely bypassed, the capacitor would have to pass DC current). In AC terms, the potentiometer's un-shorted resistance is in parallel with resistor  $R_k$ . (A good starting value for the potentiometer is whatever you have in your part bins that is closest to resistor  $R_k$ 's value.)

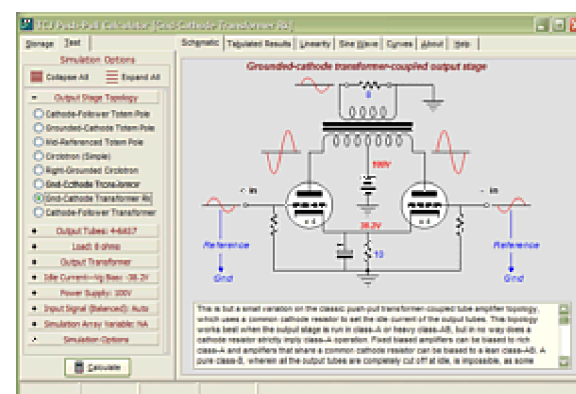
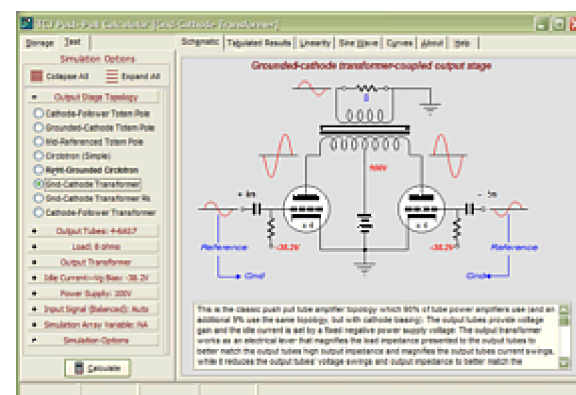
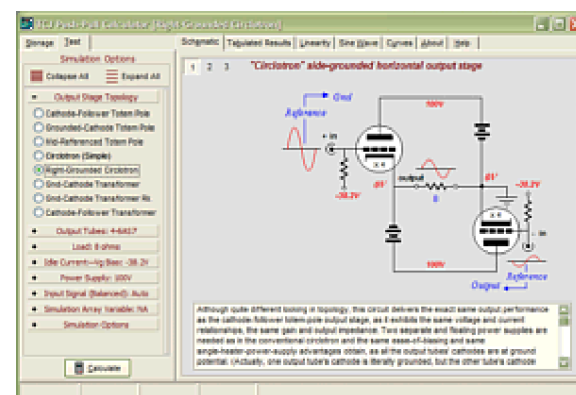
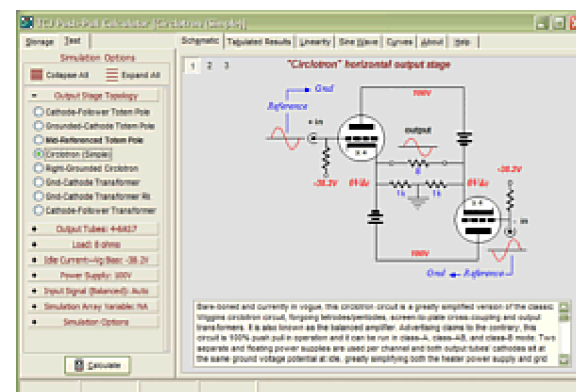
By using triangle waves instead of sine waves, we can readily see changes in linearity, as our eyes can easily see a tad of distortion in a straight line, whereas it is difficult to see a gob of distortion in a sine wave.

Once an optimal amount of cathode resistance is found, we can move on to the circuit below.



We have added an unbypassed cathode resistor in series with a bypassed cathode resistor. (I have gotten e-mail from readers jazzed by a bold new grounded cathode amplifier circuit that uses two unbypassed cathode resistors in series. Well, here is chance to actually do something worthwhile with the extra cathode resistor.) Let's say that in test setup we found that optimal potentiometer position presented a resistance of 330 ohms and that the unbypassed cathode resistor was 500 ohms in value. Now, 330 in parallel with 500 equals 200, so we have our resistor values: the bypassed resistor equals 500 – 200 ohms (300 ohms) and the unbypassed resistor equals 200 ohms.

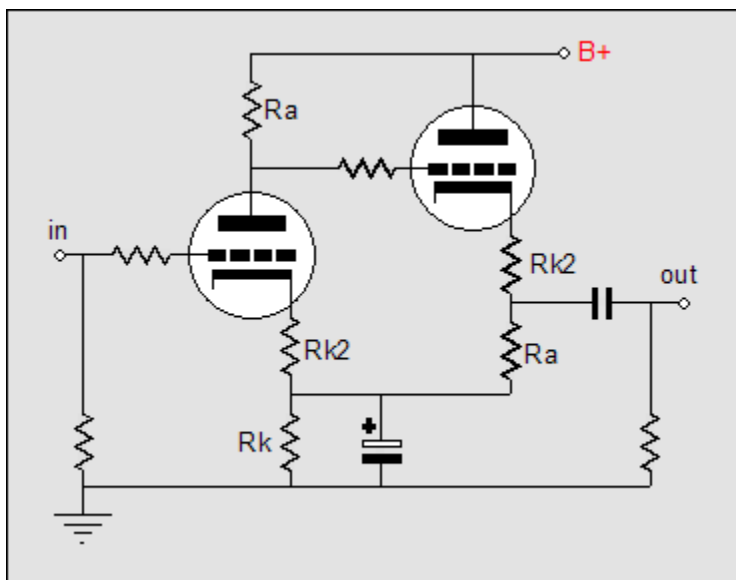
The bypassed cathode resistor can be replaced by a constant-current source FET diode or the LM134 (LM234, LM334) IC ( $I = 67.7\text{mV}/R_{\text{set}}$ ) or a zener or a rechargeable battery. In the case of the battery, the large-valued bypass capacitor can be replaced by a small-valued, high-quality film capacitor.





amplifier's plate resistor works close enough for most applications.

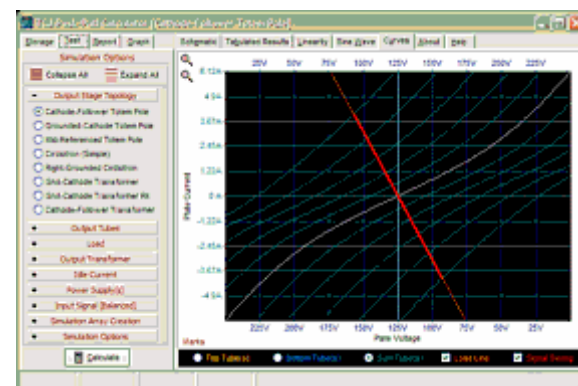
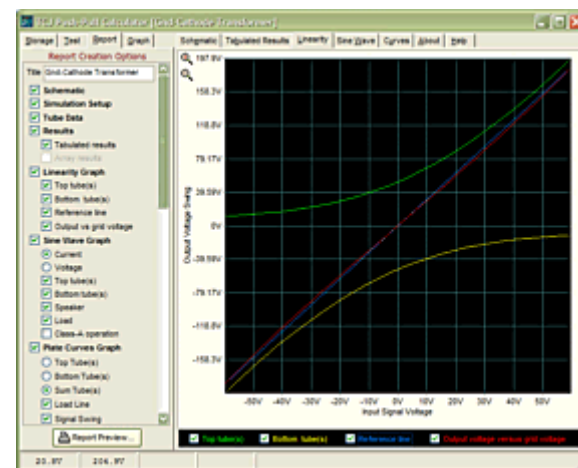
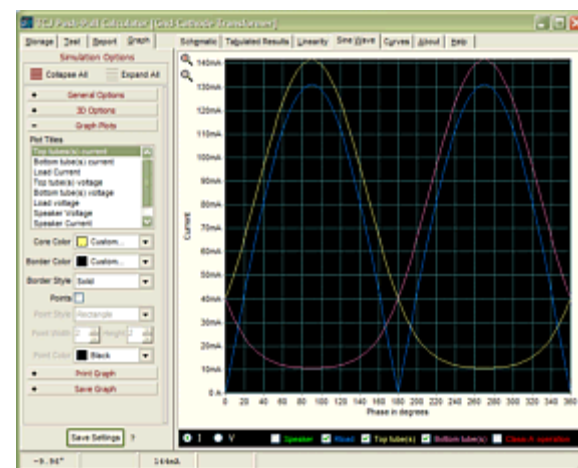
Below is the modified constant-current draw amplifier. Both the grounded-cathode amplifier and the cathode follower benefit from a small amount of unbypassed cathode resistance.



### The cheat

What if you don't have the endurance or the means to actually dynamically test for the optimal value of unbypassed resistance, is there a shortcut? I have found that using the reciprocal of the triode's transconductance usually works well. For example, 400 ohms for a 6SN7; 100 ohms, a 6DJ8; 130 ohms, 5687. (Do not forget that the triode's transconductance is not a constant, but varies with plate voltage and cathode current.)

//JRB



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