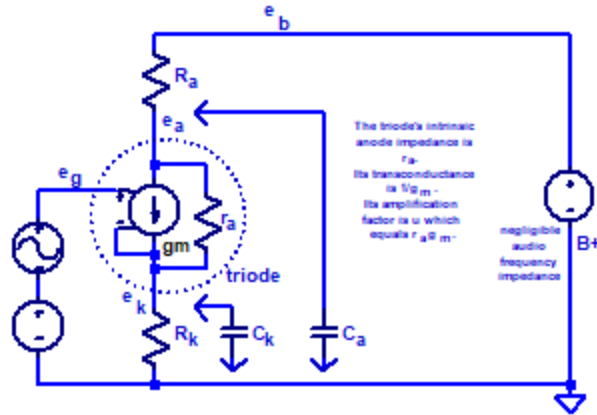


The Heart of the Article

The following is a schematic of a Common Cathode triode stage. The triode is replaced with its widely accepted model, sans parasitic capacitances. Depending on component values, it could be a voltage amplifier (VA), a cathode follower (CF) or a Cathodyne (CTHDN). Its anode, cathode or both could be connected to circuitry which could load it with resistors (not shown), and C_a (VA), C_k (CF), or C_a in series with C_k (CTHDN).



Conservation of current equations for small signals are written at the anode and the cathode. Here, we go one step further than the article and consider e_b , the B+ supply noise:

$$\frac{e_a - e_b}{R_a} + g_m(e_g - e_k) + \frac{e_a - e_k}{r_a} = 0$$

$$\frac{e_k}{R_k} + \frac{e_k - e_a}{r_a} - g_m(e_g - e_k) = 0$$

These can be solved for the anode and cathode voltages:

$$e_a = \frac{e_b[r_a + R_k(\mu + 1)] - e_g(R_a \mu)}{R_a + r_a + R_k(\mu + 1)}$$

$$e_k = \frac{R_k e_b + R_k e_g \mu}{R_a + r_a + (\mu + 1) R_k}$$

The B+ supply impedance at audio frequencies can be ignored since it is negligible in comparison with those of the resistors. So the VA output is across load R_a , the CF's is across load R_k , and the CTHDN's is across the load $R_a + R_k$. The relevant equation(s) can be rearranged into the form of a zero-impedance voltage source E driving a load R_L through a "drive" impedance R_D . The impedance of the entire circuit across the load is then $R_L \parallel R_D$. This is a simple technique to determine circuit impedances, especially those of the ever-controversial CTHDN. The method works without invoking complexities such as Thevenin's Theorem (which surprisingly, some object to applying in certain ways to the CTHDN!) or Feedback Theory. Hence, the "Oracle" equation. Sparing you the algebra,

$$\text{CF:} \quad R_L = R_k \quad R_D = \frac{R_a + r_a}{\mu + 1} \quad E = \frac{e_b + \mu e_g}{\mu + 1}$$

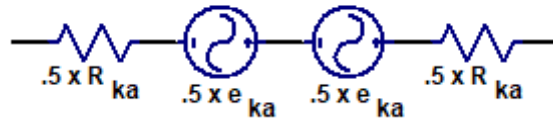
$$\text{VA:} \quad R_{Da} = R_{Lb} = r_a + R_k(\mu + 1) \quad R_{Db} = R_{La} = R_a \quad E_a = -\mu e_g \quad E_b = e_b$$

$$\text{CTHDN:} \quad R = R_a = R_k \quad R_L = 2R \quad R_D = \frac{2r_a}{\mu + 2} \quad E = \frac{2\mu e_g - e_b \left(\frac{r_a}{R} + \mu \right)}{\mu + 2}$$

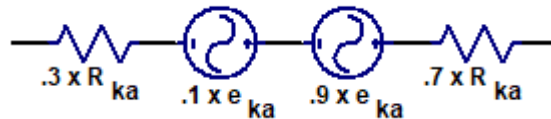
Since there are no restrictions on component values in the VA and CF calculations, their single-ended $R_L \parallel R_D$ impedances are valid even when R_a equals R_k , as is the case with the CTHDN. Because the ground-referenced anode and cathode impedances are unequal, it is clear that the CTHDN is not a balanced driver.

Other Models - The Twin-Twin / Multi-Multi

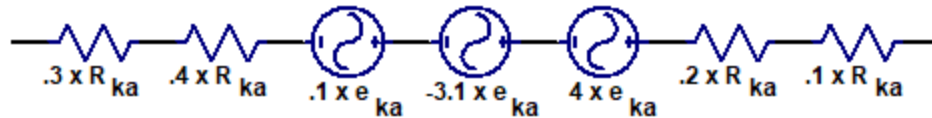
There is a model that I'll refer to as the "Twin-Twin" because it's equivalent to dividing the CTHDN Oracle's voltage source and drive impedance each into equal halves and arranging them as follows. (The suffix k_a refers to cathode-to-anode):



Since the voltages and resistances each add up to the Oracle CTHDN voltage and resistance, both models will give the same results. (I suspect that the proponents of this model wish to (incorrectly) assert that the CTHDN is a balanced driver¹.) The following models make use of this principle. Here's a "Dual-Dual" with unequal voltages and resistances:



The prior two models are members of a "Multi-Multi" family, another example of which employs a voltage source with a negative value and more than two sources and resistances:



None of the component values in any of the Multi-Multis can be directly measured, since no component exposes more than one terminal. I can think of no reason to prefer one Multi-Multi over another, unless our polestar is simplicity. But in that case, the Oracle's "Single-Single" is the clear winner, with the added benefit that all its components are directly measurable.

Other Models – Those employing Effective Impedances

Another model employs a parameter named "effective impedance." It is asserted that CTHDN cathodes and anodes each have effective impedances equal to half the circuit's anode-to-cathode impedance.

Unfortunately, effective impedance is undefined. And I use the word "model" loosely here because I can find no schematics which incorporate effective impedance. And so what drives effective impedances is a mystery. Only one terminal of each effective impedance is specified, and so it is impossible to directly measure any. With no definition, no accompanying schematics, and no way to directly measure the values of effective impedances, I will argue that references using this term in an attempt to explain CTHDN operation in fact explain nothing.

¹ Since the Cathodyne's ground-referenced anode and cathode impedances are distinctly different (as revealed by Voltage Amplifier and Cathode Follower Oracle equation arrangements), this driver cannot be balanced. In contrast, a long-tailed pair with identical loads driven by the terminations of a center tap-grounded transformer winding is a balanced driver.

Provenance

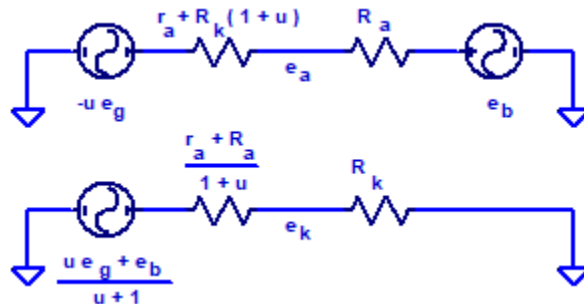
The Oracle Equation-derived models are simple rearrangements of that equation's defining relationship between the grid and anode or cathode voltages of all common-cathode triode stages. I am unaware of any disclosures of how the Multi-Multi or Effective Impedance models are derived analytically.

Are these Models Conceptually Correct?

Nope, not a single one. Not even the Oracle-derived one. Why? All common-cathode stages have anode and cathode single ended and differential power supply rejection ratios, voltages, and impedances. But no model discussed so far specifies all these parameters at once or even tries to. However, there is one model that does succeed in this...

The Conceptually Correct Common-Cathode or Quad-C Model

Let's return to the first page of this paper with a schematic and associated equations defining the anode and cathode voltages. Each of these two equations defines a circuit of its own as shown below:



How to use the Quad-C model? Well, if your interest is a VA, ignore the e_k circuit. Parallel R_a with the external load, capacitive or resistive or both if that's what you're driving, and you're good to go. The strategy for a CF is similar – ignore the e_a circuit and parallel R_k with the driven external load. For a CTHDN, R_a equals R_k and an external purely differential load (one for which e_k remains equal to $-e_a$) is placed in parallel with instances of r_a in both the e_a and e_k circuits.

Conclusions

Provenances are in question for the Multi-Multi and Effective Impedance models. Ignoring the VA and CF, they focus exclusively on the CTHDN and yet ignore its power supply rejections and its single-ended, ground-referenced signal voltages and impedances. On the other hand, the set of three Oracle models suffer no such flaws or limitations.

A case could be made that the Oracle set affords a conceptually correct understanding of the operation of all common cathode stages, something which the Multi-Multi and Effective Impedance models fail utterly at. But such a claim would be a stretch. It is the Quad-C model that supplies both a utilitarian tool and a complete and proper understanding of the entire collection of VA, CF, CTHDN circuits.