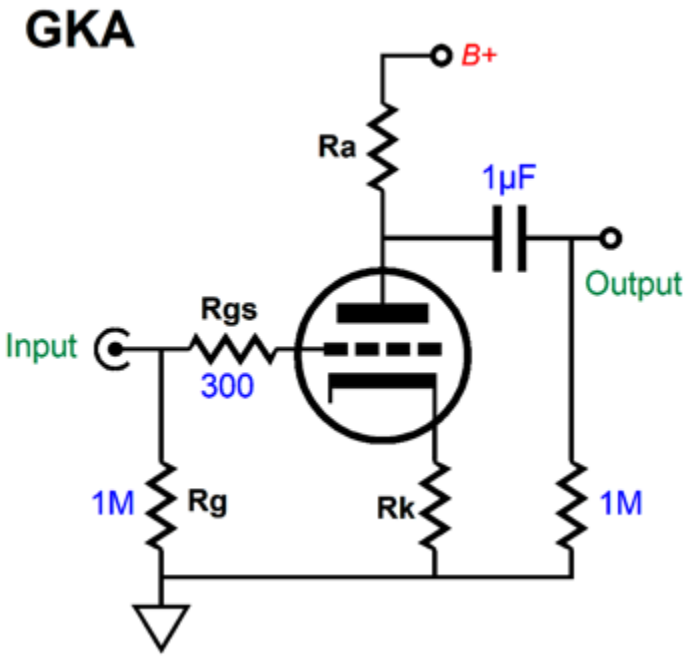
GAIN

Lowering Line-Stage Gain

In contrast to designing phono preamp, where we usually seek to squeeze all the gain we can from a triode, when designing a line-stage amplifier we do not need very much gain. My preference is for 12dB, which is a ratio of 1:4 between signal and output signals. In days past, you would simply set the negative feedback ratio so you got your desired gain. In the absence of a negative feedback loop, however, we have to work at getting less gain, especially with a medium-mu triode, such as the 6AQ8 or 6DJ8 or 6N1P. For example, a 6DJ8 in a grounded-cathode amplifier configuration can easily deliver a gain of 20 (+26dB). The same triode in an Aikido circuit will deliver a gain of 15 (23.5dB). Fortunately, workarounds exist.



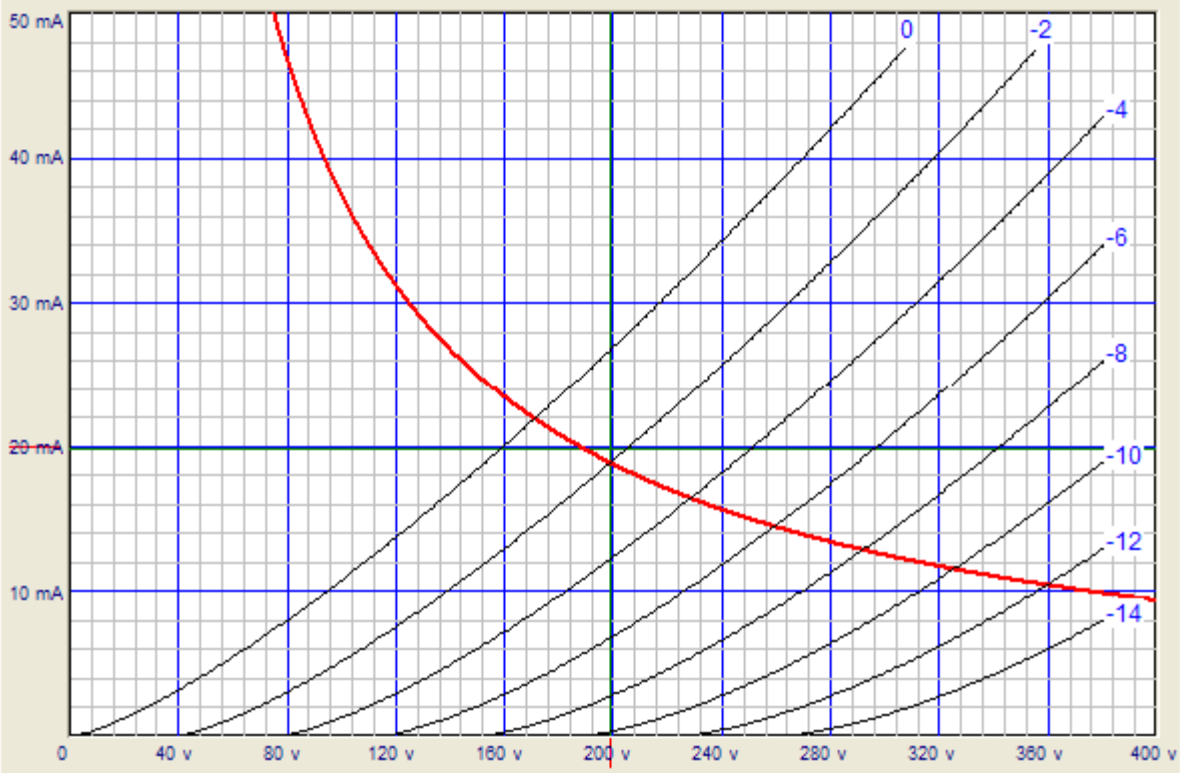
The formula for the gain of a grounded-cathode amplifier, with an **un-bypassed** cathode resistor, is the following:

Gain = mu ·Ra/(Ra + rp +[mu + 1]Rk)

If we solve for the cathode resistor (Rk), we can specify the desired gain. In other words, with the right valued cathode resistor, we can hit our target gain.

Rk = (Ra[mu/Gain – 1] – rp) / (mu + 1)

Let's use a 6SN7 with a plate resistor equal to 24k and with a target gain of 4 (12dB). The B+ voltage is 240Vdc and the desired idle current flow is 5mA, which implies a plate voltage around 120Vdc, as we will ignore the voltage drop across the cathode resistor right now. After inspecting the 6SN7's plate curves, we see that its mu is equal 21 and its rp equals 9200 ohms at the intersection of 120V with 5mA.



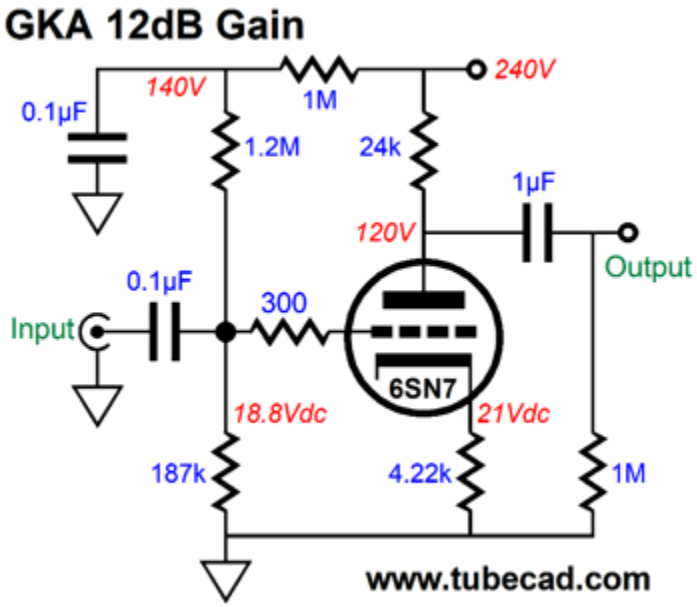
Next, we plug these numbers into the previous formula.

Rk = (24000[21/4 - 1] – 9200)/(21 + 1) = 4218

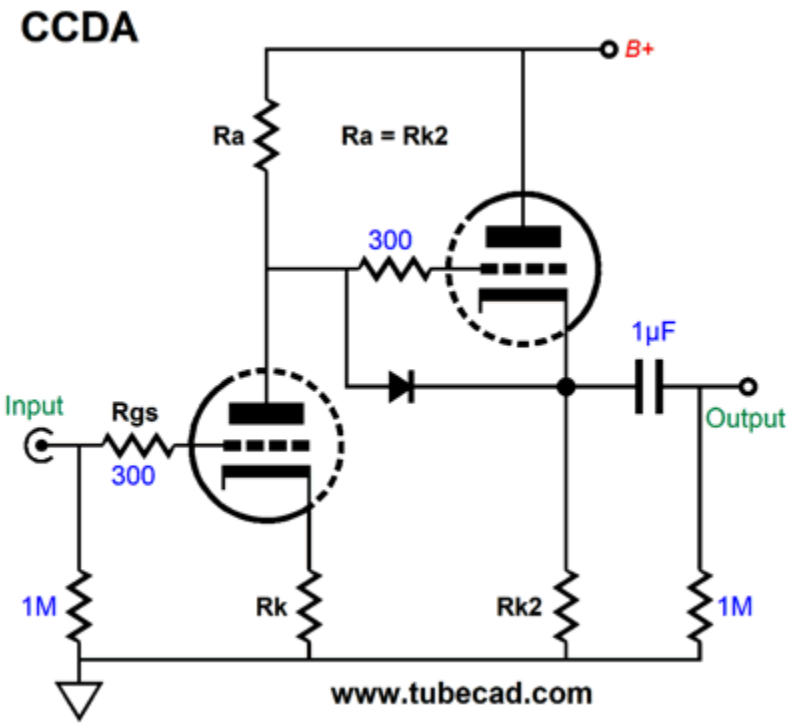
We then check our result by plugging the values into the grounded-cathode amplifier gain formula:

Gain = 21 ·24000/(24000 + 9200 + [21 + 1]4218) = 4

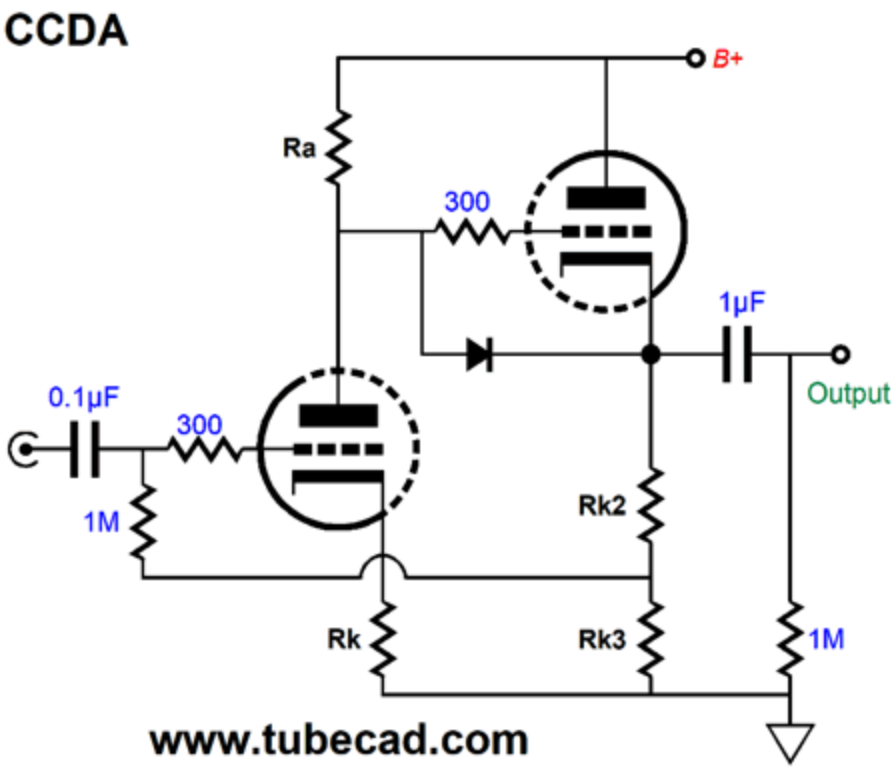
Now we face the problem that a 4218-ohm cathode resistor with a 24k plate resistor and a B+ voltage of 240Vdc does not result in an idle current of 5mA; instead, we get a plate voltage of 196V and an idle current of 1.8mA. The workaround is to add fixed grid bias to the mix. In other words, we must make the 6SN7's grid more positive to get its plate current flow up to 5mA. Okay, great, but by how much? Starting with what we know for certain, such as the plate voltage will 120Vdc, as 5mA against 24k equals 120V of voltage drop across the plate resistor and the same 5mA against 4218 ohms equals about 21V, so the 6SN7's cathode-to-plate voltage will be equal to 120V – 21V or 99V. If we inspect the 6SN7's plate curves we see that at intersection of 99V and 5mA the grid voltage is about -2.1Vdc. Thus, the needed grid-bias voltage needs to equal the voltage drop across the cathode resistor (21V) minus 2.1V or 18.9Vdc.



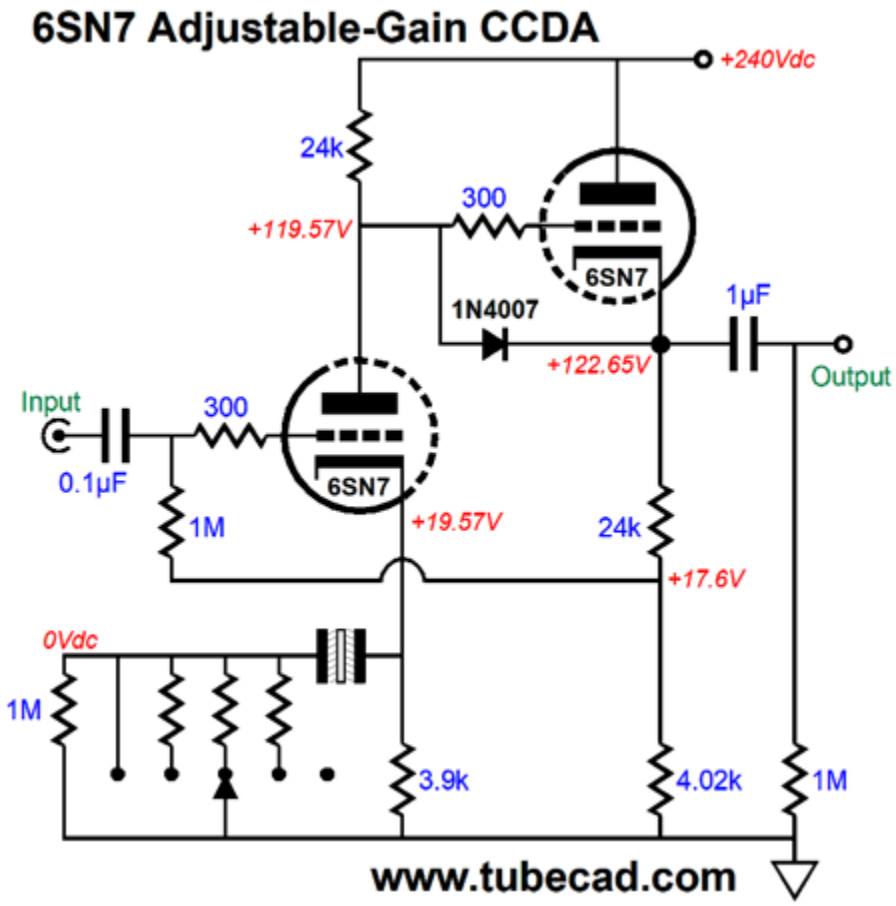
We can go for the constant-current-draw amplifier topology instead.



In fact, we can put in place a DC negative feedback loop.

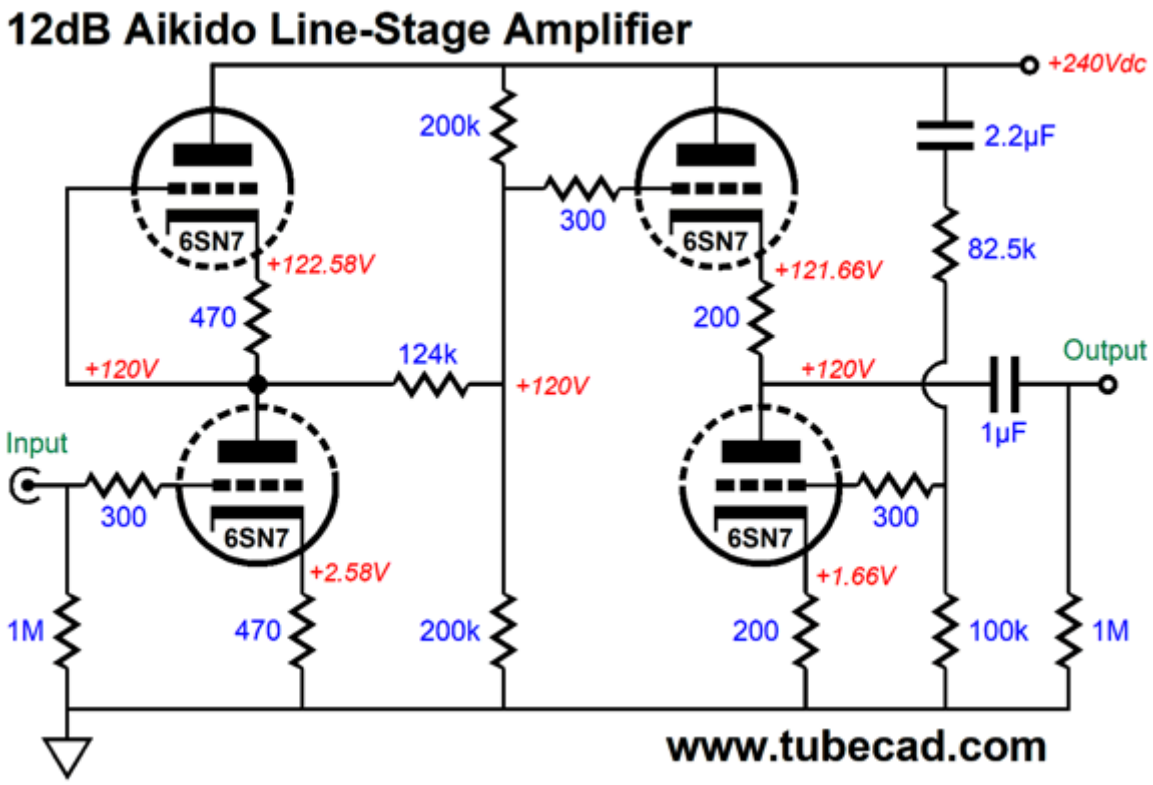


The input grounded-cathode amplifier DC couples to the cathode follower and the cathode follower DC couples back to the input triode's grid. The DC negative feedback keeps the two triodes in tight idle-current alignment. Note that we can add a selectable-gain feature to this circuit.

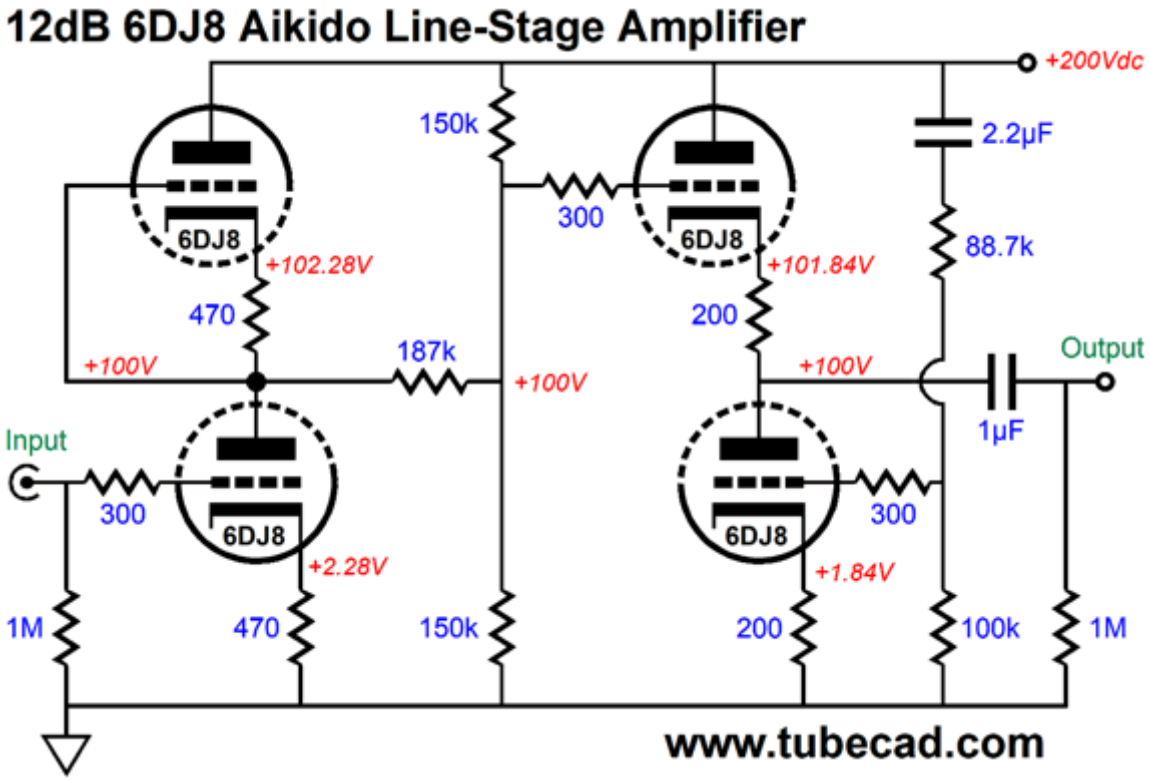


What we have here is a CCDA line-stage amplifier with selectable gain through a five-position rotary switch. Of course, more or fewer positions could be used just as easily. The 1M resistor is needed to be the non-polarized electrolytic capacitor constantly charged up, which will prevent output jumps as we rotate the gain-selector knob. Imagine each increment being 3dB in increased gain.

Over the years, I have received emails complaining of too much gain from their Aikido line-stage amplifiers. Here is the workaround.



The two 200k resistors are effectively in parallel and equal 100k of resistance, which then forms a two-resistor voltage divider with the 124k resistor. The result is a gain 4 (+12dB) with 6SN7s. If we use a 6DJ8 instead, we will need to impose greater attenuation.



Note the lower B+ voltage, 200Vdc, and that the 200k resistors have been replaced by 150k resistors, while the 124k resistor is replaced by 187k.