Using Your Amplifier for Tube Matching -- Such as a Dynaco ST-70

By Doug Criner

There are many schools of thought about the necessity to match vacuum tubes used in push-pull audio output stages. Some people don't worry about tube matching while others think it's important. And then there are tube vendors who charge extra for matched tubes, but may or may not do a good job of matching.

The basic idea is to operate each push-pull tube close to the same point on its characteristic curve so that clipping or distortion will not occur on one tube before the other. If one tube's characteristics, such as emission or transconductance, are markedly different, and both tubes a biased alike, then they will not be matched; one tube will draw more plate current than the other even at the same operating point (control grid voltage). Some people feel that just matching those characteristics is insufficient, advocating that each tube's characteristic curves should be plotted and compared. I offer no judgment on these debates, but will suggest a simple way to match tubes using your stereo amplifier itself.

Normal Procedure for Bias Setting

Before introducing the method for matching tubes using an amplifier, let us first consider a typical procedure for setting the grid bias of a push-pull amplifier. Many vintage tube-type amplifiers, such as the ubiquitous Dyanaco ST-70, have an adjustable potentiometer to set the fixed grid bias for the output tubes (as opposed to a cathode resistor that self-biases the grid). The ST-70 has a separate DC power supply to provide the grid bias; the bias voltage is adjusted with two potentiometers, one for each channel (left and right). Each channel's pair of output tubes have a shared 15.6-ohm cathode resistor. (This is a much smaller value resistor commonly used for self-biased amplifiers.) The purpose of the cathode resistor is to allow convenient measurement of the cathode current (which is essentially equivalent to measuring the plate current) for setting the grid bias voltage. The specified cathode current for the EL34 output tubes is 50mA, so a pair should have 100mA. At 100mA, the voltage drop across the 15.6-ohm resistor will be 1.56V; when setting the bias, the potentiometer is adjusted to give 1.56V. This arrangement for setting the grid bias for each channel also provides a simple way to check tubes for matching.

Tube Matching

Pick one of the four output tube sockets to be used for testing purposes; the tube in the other socket on that channel should be removed. The other pair of output tubes, on the opposite channel, should be left installed in their sockets.

One at a time, plug in tubes to be matched into the socket you've chosen to use for testing. Measure and record the voltage across the cathode resistor. Since only one tube is plugged into that channel, the cathode current will be about half the normal value for two tubes. So, the voltage across the resistor will be about 1.56V / 2 = 0.78V. Don't touch the adjustment potentiometer during testing—it has to be left at the same position for all the tubes being tested.

Now pair the two tubes with the highest readings on one channel and the tubes with the lowest readings on the other channel. You're done.

Additional Comments

It's best to have output tubes plugged into the channel that isn't being used for testing. This will minimize the boost in B+ voltage that would otherwise occur.

During the testing, there should be no audio input to the amplifier. It's probably a good idea to have speakers connected to the amp. Of course, the power to the amp should be turned off when changing tubes. For each tube under test, allow a few minutes for it warm up and for the cathode current to stabilize.

Using this matching procedure, we are essentially requiring that each pair of tubes have one point on their characteristic curves be nearly the same. That point is the cathode current at idle. Of course, the shape of the curves may differ, but we have matched each pair of tubes as closely as possible with just one test point.

Repeatedly plugging and unplugging tubes into a socket for testing can cause wear and tear on the socket. Therefore, each time you run a pair or quad of tubes through testing, rotate the socket selected for testing. Better yet, you can build an extender cable from an octal tube socket and base; that allows tubes under test to be plugged into the extender cable's socket.

I recently purchased a quad of new-manufacture EL34s that supposedly were matched. Using the above matching procedure, the lowest tube had a cathode current of 57mA and the highest had 68mA. Not very good.

Q&A

I have received several questions and comments about this method for tube matching. Some of these questions were posted on the Antique Radio Forums website.

Q1. I do a similar type of matching for plate current using an adapter I made to use my meter to measure the plate current. I use three other tubes to replace the ones in the amp since I have a lot of EL-34 tubes. The reason is I would think the B+ could be rather high with only 1 tube in the amp and might stress your filter caps a little. Lou deG.

A1. My original procedure removed all four output tubes except the one being tested. I revised my write-up to leave installed the two output tubes on the other channel. I think the B+ boost will be minimal, no more than when a single tube burns out.

Q2. Doug's method...is a very good one for selecting tubes to be used in his amplifier, but would not necessarily select tubes suitable for use in an amplifier of a different design. Brian McA.

A2. Matched tubes should have characteristics that are close; I don't think that tubes that are effectively "matched" should become unmatched in a different amplifier. When you buy matched tubes, you don't have to specify the type of amp that they will be used in.

Q3. You would have to put a lot of confidence into any amplifier used for the purpose of matching audio output tubes. You would have to be able to claim that all components in that amplifier were precision matched.... Doug VanC.

A3. I don't agree. Using my procedure, the same tube socket is used for each of the tubes being tested, i.e. measured for cathode current. Nothing in the circuit is changed between tubes being tested. Looking at the ST-70 schematic, I can't visualize an out-of-tolerance component that would affect the validity of the test procedure. If something was way out of whack, you probably couldn't adjust the grid bias in the first place.

Q4. Doug's method measures cathode current and equates it with plate current. The discussions of tube matching I've seen only mention plate current. Are cathode current and plate current always directly correlated? Or could two tubes have equivalent cathode current and differing plate currents?... Steve W.

A4. For a pentode, the plate current and cathode current aren't equal, but differ only by the screen grid current. The difference is not important for our purposes. The screen grid current is a relatively small percentage of plate current and is often assumed to vary linearly with plate current. This is why Dynaco and other manufacturers were able to use cathode current to set the grid bias. I think cathode current is considered a little easier to measure.

Q5. Here now! Unmatched output tubes is what contributes to much of a tube amp's "mojo". Especially in a guitar amplifier. Ed.

A5. OK, Ed, maybe you can try using my simple procedure for pairing tubes that are the most unmatched!

Q6. If all you have is a simple emission tester or no tester Doug's test will be a real world test of how much cathode emission your tube will give at the plate voltage and bias the amp is using. Even good testers don't use 400 to 500v DC plate voltage at 30 to 40 ma. So the idea is if you have 4 tubes you can at least pair up the ones that are closest and that's a good thing. Your are testing only 1 tube at a time in the same socket so it matters not what the rest of the amp parameters are, you just want to pair up similar tubes. If you have 2 that are around 30 ma and 2 that are around 40 ma then at least you know who goes with who, simple but still a good idea. And all it requires is a basic voltmeter, a $3.95 Harbor Freight will do. Lou deG.

A6. A $3.95 Harbor Freight meter? Lou, are you poking fun at my fancy Fluke meter shown in one of the photos, above? For the price of my Fluke, I could have bought maybe 40 Harbor Freight meters--and still have a couple of them left. :>) Doug Criner 2007