

Adjusting Pentode Bias

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This is my preferred method of adjusting bias in guitar amplifiers with pentode output tubes that are equipped with adjustable grid bias circuitry. This method does not apply to amplifiers employing cathode bias circuits. You must at least check the bias on any new pair of output tubes installed.

Several amplifier output stage topologies exist. Some of interest to audio are class A (not discussed any further here) and class B. In class B, there are two output devices (tubes or transistors). One and only one is on at a time. One conducts with drive signals that are + and the other conducts on signals that are -. This is a very efficient configuration. However, in this configuration, crossover distortion occurs at the input zero volt point where neither device conducts.

Typical vacuum tube audio amplifiers utilize class AB which is a hybrid design closer to class B where some standing current is always present so that the output tubes are not fully off in the quiescent (no signal present) state. By properly applying a bias, a small standing current exists so that both devices are conducting at the same time. If the bias is set correctly, the crossover distortion is eliminated and the output tubes operate efficiently. If set wrong, the sound will likely be distorted, the output power may be lower than the stated specification and the lifetime of the output tubes may be shortened.

Caution: The following steps require measurements and adjustments that are made with power applied. Lethal voltages exist. You must be very careful and understand the very real risk involved. Otherwise, take your amplifier to a skilled technician and let him/her do the adjustment.

Equipment required:

An oscilloscope

A quality audio generator

A voltmeter of sufficient accuracy to measure millivolts to 4 digits.

A bias measuring device, built in, home made or commercial. It may be as simple as two resistors.

A dummy load resistor that matches the output impedance of the amplifier under test and is rated at enough power to withstand full power operation of the amplifier under test.

Optional, a Harmonic Distortion Analyzer.

Procedure:

Inspect the data sheet for the output tubes used. Under the maximum ratings table, locate the maximum Plate Dissipation value for a Pentode connection. Remember this value.

Example of 6L6GC GE Maximum ratings table:

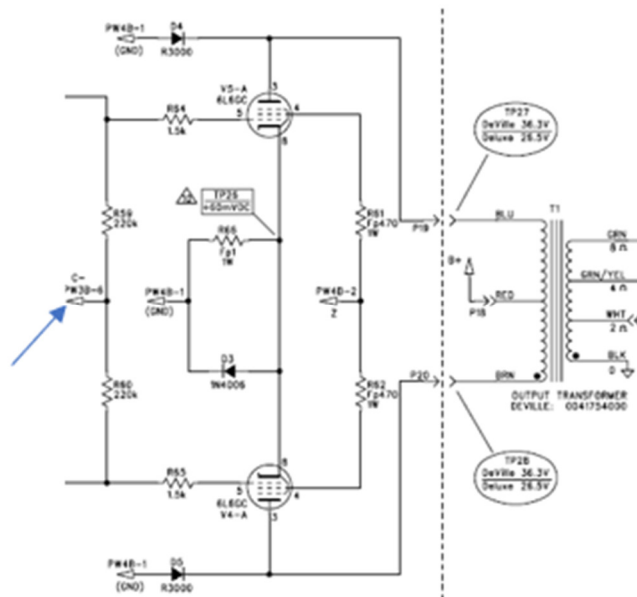
MAXIMUM RATINGS		
DESIGN-MAXIMUM VALUES	Triode† Connection	Pentode Connection
Allowable Heater Voltage	5.7 to 6.9 Volts	5.7 to 6.9 Volts
Plate Voltage	450	500 Volts
Screen Voltage	450† Volts	450† Volts
Plate Dissipation	30	30 Watts
Screen Dissipation		5.0 Watts
Heater-Cathode Voltage		
Heater Positive with Respect to Cathode	200	200 Volts
Heater Negative with Respect to Cathode	200	200 Volts
Grid-Number 1 Circuit Resistance		
With Fixed Bias01	0.1 Megohms
With Cathode Bias05	0.5 Megohms

Connect the amplifier to the dummy load for the following steps.

With power applied but no signal applied and all gain and volume controls at the CCW position, measure the plate voltage of one of the two output tubes at the socket pin with respect to chassis. Pin 3 on 6L6GC types and EL34 types. Be careful. Record this value.

Now divide the power in Watts as read from the data sheet by the measured plate voltage to obtain the maximum allowed idle plate current. If the plate voltage was 450V and the maximum Plate Dissipation is 30W, for example, this value would be 67mA. Remember this value.

Next, measure the bias voltage (a good test point is at the junction of the output tube grid resistors, marked C- in the example schematic shown below). Adjust the bias potentiometer for the most negative reading possible. This can be done in standby mode if desired.

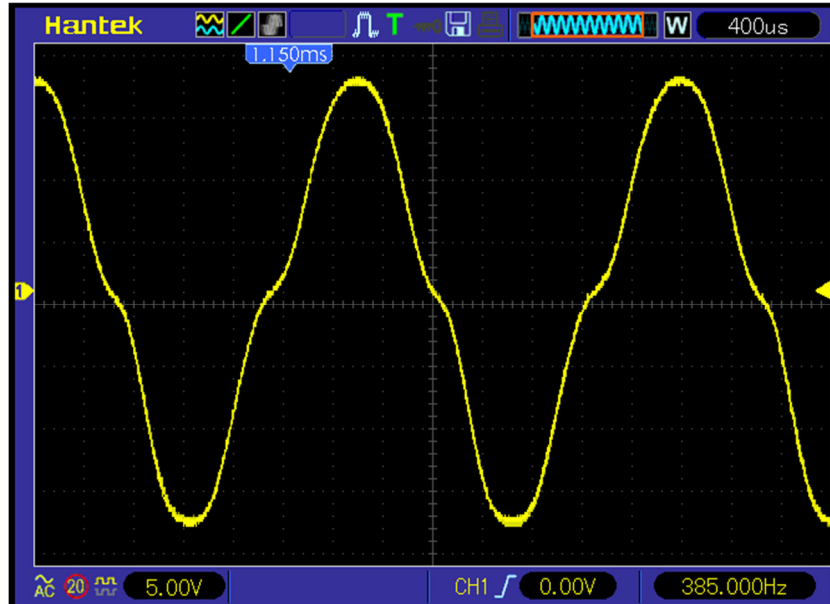


A typical vacuum tube guitar amplifier output stage.

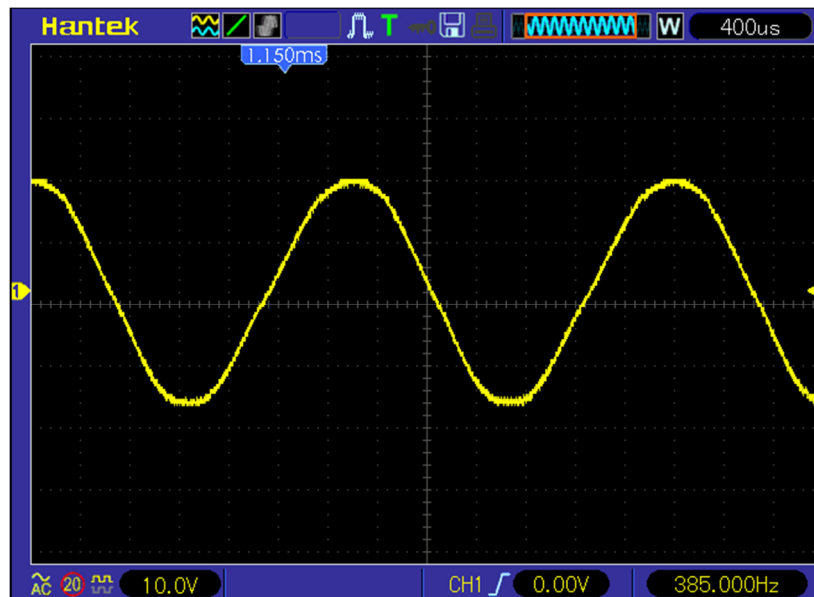
In the following steps, a method must be used to measure cathode current. Many amplifiers have a fixed 1 Ohm resistor installed in the cathode circuit of each output tube for this purpose. All Crossfire Electronics amplifiers have this resistor installed and test points provided on the chassis. If needed, you may install resistors in the amplifier to be biased (1 Ohm 1%, 1W type recommended). They may be left in place with no harm to circuit performance. Optionally, a Bias Rite or other device may be used. But two 25 cent resistors are much cheaper. I sometimes use a home brew tool (picture below). Note that the schematic above has a single resistor for this purpose (R66). In his case, the measured current must be divided by 2 to obtain the single tube cathode current.

Adjust the audio generator to provide about 90mV Pk-Pk, sine wave (400 HZ suggested). Connect it to the input jack. Power up the amplifier. Connect the oscilloscope to the dummy load resistor (make sure to connect the scope probe ground lead to the side of the resistor that is tied to the case, the tip should be tied to the “hot” side of the resistor).

Adjust the volume and or level controls for an observed signal that is just below clipping. The example amplifier output signal image is shown below. Notice the distortion near the zero crossings. This is crossover distortion.



Now turn the bias adjustment (usually CW) slowly so that the bias becomes more +. As you adjust the bias, the crossover distortion will disappear (see picture below). Stop adjusting at this point.

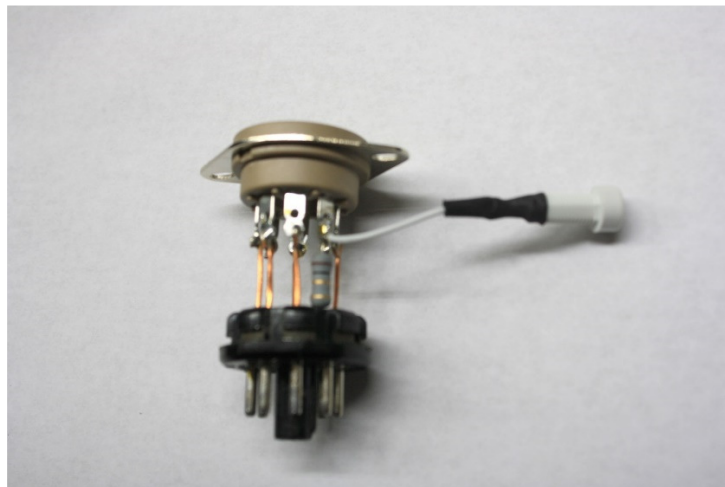


Turn the volume and or gain controls fully CCW. Measure the voltage drops across the cathode 1 Ohm resistors. Note the higher value. Each millivolt represents one milliampere of cathode current. This is the resting or quiescent current. Compare this reading to the maximum value calculated above. It should be less than 80% of the calculated maximum value. If so, your amplifier is biased properly and the lifetime of the tubes is maximized. In the example amplifier, the voltage drop across the common resistor was 65mV. This is 32.5mA per tube, well below the 80% rule value. This amplifier will perform well for years to come.

Optionally, you can re-apply the sine wave and adjust the output signal across the dummy resistor to about the half voltage point and measure the total harmonic distortion. You may then increase the bias (more +) slightly (hotter) and re-measure the THD to see if it improves. Then re-check the resting current so as to not exceed the 80% criteria. Note that the higher the cathode current, the shorter the life span of the output tubes. Rarely have I seen any improvement in THD by biasing hotter than the initial point.

For you purists out there, note that we have been measuring cathode current and not plate current. Cathode current is convenient to measure and is always larger than plate current. It is the sum of plate current and screen grid current. Screen grid current is small with respect to plate current so it is reasonable to measure cathode current in lieu of plate current. The error will always be in the safe direction. If desired, the resting drop across the screen grid resistors may be used to calculate screen currents. It then may be subtracted from cathode currents to obtain more accurate plate current readings. This might be a good time to inspect these screen grid resistors as they are high failure rate items. If they are old carbon composition types, replace them with modern metal oxide types.

If done, put the chassis back in the case, plug the speaker back in, and enjoy your properly biased amplifier.



A home made bias measurement tool.