

## Introduction

Other than finding and eliminating system “hum”, the most frequent question found on our Dynaco-Doctor forum how to solve output tube bias issues (too low, too high or unstable). Therefore I thought it would be a good idea to put together a document that would discuss both the design and operation of bias current in tube output stages and include a troubleshooting guide.

I’m not going to get into the various classes of amplifiers (A thru C and beyond) since this is a subject that is only tangentially related to our purpose here plus there are plenty of articles already available that go into the theory and operation of the various amplifier classes. Rather I would like to discuss the most common output tube bias circuits and in particular the designs favored by Dynaco in their power amps.

We’ll begin by looking at the three main sections of a Tube Output Stage (Tubes & Transformer, High Voltage supply and Negative Bias supply) and examine their roles and then look into the makeup and operation of each in detail. Finally we’ll do a little troubleshooting and recommended rebuilding that will not only repair but also improve the reliability of your amp.

## Tube Output Stage Operation

The output tube bias current is really a “idle” current that flows through the output tubes when there is not audio signal present. This is somewhat analogous to your car’s engine that “idles” in your driveway or at stoplights – but the rationale is different. Power amplifier idle current is required to keep the operation of the output stage away from the zero current position where distortions are generally higher. When we “set” the output tube bias current (sometimes referred to as “setting the bias”) we are adjusting this idle current flowing through the output tubes without any audio signal present. To understand the factors that contribute to the idle current, we need to examine its operation.

The typical tube output stage is comprised of three main sections (see Figure 1):

- 1) The High Voltage Supply (the engine that drives the output stage). This is shown as a 450VDC battery in Figure 1.
- 2) The Negative Bias Supply (the section that controls the system), This is shown as a variable 65VDC battery in Figure 1, and
- 3) the Tubes, Output Transformer Primary & “BIAS” resistor (where the current from the HV engine flows).



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To begin, let's examine the current path through the output tubes. Refer to the simplified tube output stage shown in Figure 1. The "engine" that supplies the current to the circuit is the 450V High Voltage power supply. From the HV supply, the current flows into the center tap of the output transformer (primary). It then flows out of both ends of the output transformer (wire colors are blue for one tube and blue / white stripe for the other) into both output tubes – note that the current flows into the anode (plate) of the tubes. In ultralinear designs (most Dynaco circuits are ultralinear) some small current also flows into the screen grid (usually pin 4) of each tube from the transformer ultralinear tap (wire colors green and green / white stripe). All of the current entering each tube (either into the anode or screen grid) exits at the tubes cathode(s) connection (usually pin 1). In the stock Dynaco MK-4, ST-70 and MK-2/3 circuit, the current from both output tube cathodes (tied together) then flows into a common "BIAS" resistor and finally out of the BIAS resistor back to ground (which is also the same as the negative side of the HV supply). This "BIAS" resistor (15.6 ohms in the MK-4 & ST-70 and 11.6 ohms in the MK-3) is not really necessary for the circuit to function – it is there so that you (the user) can easily measure the current through it (that equals the sum of the currents flowing through both output tubes) by measuring the voltage across it (per ohms law Voltage = Current X Resistance). Note that when there is an over-current condition in the output stage (shorted tubes or too high bias current) the "BIAS" resistor is frequently sacrificed in the event.

Note that some amps (not Dynaco's) omit this resistor instead placing a jumper or connector in each output tube cathode - in this case an ammeter is needed to make the current measurement. As was customary for Dynaco, their engineers made the very wise decision to make life easy for their customers and included this BIAS resistor.

As we noted the engine that drives the output stage is the HV power supply. It is a very simple FWCT design (see Figure 2) consisting of the power transformer feeding a GZ34 dual diode tube rectifier. The rectified voltage is then feeds a 3 stage filter that consists of an electrolytic capacitor (one section of the familiar "quad cap") followed by a choke filter and then again with another electrolytic cap (another section of the quad cap). This junction is the 450V HV supply output that then feeds current into the center tap lead (RED) of the output transformer. If any of these components are weak or out of spec, this "engine" will be incapable of supplying not only the bias current (amps resting current) not to mention the higher currents needed when your amp is delivering power to your loudspeakers. Although the rectifier tube will fail on occasion, the most common component failure (and actually the major weak point with Dynaco amps) is the quad electrolytic capacitor. The 525VDC voltage rating is frequently exceeded (with today's line voltage variances) so this rating is marginal (at best). Additionally capacitor technology has significantly progressed since this capacitor was designed so replacing with the same design or new old stock (even worse) is really wasted time and money. You should only consider one of the contemporary quad cap module replacements and if you want to preserve the look of the original amp simply use a below chassis type. Transformer failures are uncommon (but do happen) and will result in symptoms that are dramatic such as immediate fuse failures or no power at all.

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Now that we have examined the current path through the output tubes and the high voltage power supply that provides the current, we need to look at how that current is controlled. To control the current through the tube, a **NEGATIVE** voltage is applied between the tube control grid (pin 5) and its cathode (pin 8) – the higher the negative voltage, the less current flows through the tube (read this again). Figure 1 shows this supply as a simple variable battery – we’ll examine the bias supply in detail later. Since the output tube bias current flow **INCREASES** as the Negative Bias Voltage **DECREASES** (moves towards zero), you can hopefully see that when the negative bias supply fails (goes to zero) or has a problem (moves towards zero), the control voltage disappears resulting in excessive current in the output tubes. Note that this condition is very common and can occur when the selenium rectifier fails or weakens or if the solder connections in the connecting wires fail along the way to the output tube sockets. Another common failure is corrosion in the output tube sockets. When the negative bias supply fails to get negative voltage to the pins of the output tubes everybody in the amp gets really unhappy resulting in blown fuses (best case) or tube failures (all the expensive ones like the rectifier and output tubes) and maybe worse (like fried transformers). So it is fundamentally important to your financial health that you take the time not only repair but restore both the electrical and physical state (connections) of the negative bias supply.

Let’s look closer into the circuit that generates this negative voltage and then how it is delivered to the output tubes (since either the generation or delivery can cause problems). Refer to Figure 3 – it shows the stock ST-70 output stage (from figure 1) along with the full schematic of the negative bias supply (I’ve omitted the HV supply for clarity). The Negative Bias is generated from a basic half wave rectified design. A tap on the HV transformer secondary (the BIAS tap – the RED w/ Black Stripe lead) feeds a selenium (stacked plate) solid state rectifier. Note that in order to generate a negative voltage, this rectifier has its cathode tied to the transformer and anode as its output. This rectified negative voltage is then applied to a two stage filter consisting of an electrolytic capacitor feeding a series resistor (10K in the MK-4 & ST-70 and 1K in the MK-2/3) and then finally to the second electrolytic capacitor. In the Stereo-70 this voltage is sent to a voltage divider consisting of two 10K bias pots in parallel (resulting in an effective resistance of 5K ohms) and then a 10K resistor to ground. With the MK-4 and MK-2/3, since they are mono amps, there is of course only one pot (a 10K pot). The other side of the pot then connects to a 18K resistor in the MK-2/3 or a 10K resistor in the MK-4. These resistors on both sides of the bias pots are there to limit the voltage range of the thereby making the adjustment less sensitive. Assuming that the voltage from the rectifier is negative 65VDC (at the junction of the rectifier and first electrolytic cap), in the ST-70 the voltage at the “top” side of the bias adjust pots will be about 39VDC (negative) and 26VDC (negative) at the “bottom” side of the pots. In the MK-2/3 the corresponding voltages will be 62VDC (negative) and 40VDC (negative) and in the MK-4 the corresponding top and bottom side bias pot voltages will be 43 VDC (negative) and 21 VDC (negative). The bias adjust pots allow you (the user) to select a voltage that ranges between the ends of the pot - this output voltage from the pot appears at the pot’s wiper (center lug) that eventually finds its way to the control grid (pin5) of the output tube.

Now, notice that this negative bias control voltage from the center lug of the pot is not directly connected to the output tube control pin but instead traverses the pc board and a couple of parts before it gets there (not to mention pesky solder connections and output tube sockets). Looking again at the diagram in Figure 3 you will see that the driver pc board sits between these two points. Two possible problems can (and do) show up at the pc board: 1) oxidized solder connections and 2) leaky coupling caps. Poor solder connections are difficult to avoid since it is very difficult to properly “wet” the original Dynaco wire even with high quality 63/37 rosin flux solder (guess how we learned this) especially when the PVC insulation melts long before the metal lead is properly wetted. The solution is simply to replace the wire - don't use anything thicker than 22 ga since heavier wire is unnecessary but more importantly it will likely place torsion stress at the pad causing the pad-foil connection to crack. The best choice both sonically as well as structurally is 22 ga stranded wire with Teflon insulation. The other place for the negative bias voltage to be impacted is if current flows in the coupling caps (these are there to couple the audio signal from the driver stage into the output tube). Even a little leakage can cause problems since the impedances here are pretty high (270K) but this is not one of the common problems. Finally, assuming everything has been confirmed OK with the supply, connections and pc board what remains are the 1K resistors (at the pins of the output tubes) and the output tube socket itself. Over time the combination of heat and moisture results in corrosion at the pin socket interface. This poor connection decouples the negative bias at the output tube control pin causing the tube bias current to rise usually in an intermittent manner. Although cleaning and re-tensioning can be a short term solution it is really a good idea to change out the sockets with hi-rel ceramic types.

## Troubleshooting

Before you begin diagnosing your amp:

1. Pull the driver (small) tubes and run all these tests without them (you can re-insert them once you have the output tube bias up and running).
2. Turn the bias pot(s) fully counterclockwise
3. Be sure that you have confirmed that the problem is not with your power tubes (this includes the output tubes and rectifier tube). To be safe always use a fresh new set of output tubes and a new rectifier (GZ34) tube. Only after you get the amp up and running again would I suggest re-inserting the original output tubes and then only if you have had them tested. It is not uncommon that a tube failure (short) will damage the amp as well so you would just be chasing a problem circle if you continued to troubleshoot with defective tubes.
4. Important - if the symptoms only appear in one channel, the first step would be to swap the “defective” channel's output tubes with the “working” channel's tubes. If the problem moves with the tubes – congratulations, you have found the problem - it's the tubes. If there is little or no difference after you have swapped the tubes from channel to channel, continue troubleshooting with new tubes – but start with one channel at a time.

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Because the bias supply is the “control rod” that keeps the lid on overload, we’re going to confirm that everything is OK here before checking out the rest of the output stage. Remember, with a defective negative bias supply it will be impossible to set the correct output tube current flow correctly.

Remove all the tubes (rectifier tube included) set your digital voltmeter (you do have a digital voltmeter I hope) to the DCVolts Function. Turn on the amp and connect your digital voltmeter negative probe to chassis and with the positive lead, measure the voltages on both ends (outer lugs) of the bias adjust pot(s). For a Stereo-70, the voltages should be negative 39VDC on one end and negative 26VDC on the other end. For the MK-2/3 the voltage on one end should be negative 62VDC and negative 40VDC on the other end. For the MK-4, the voltages should be negative 43VDC on one end and negative 21VDC on the other end. Note, these voltages are based on the assumption that that the rectified voltage on the first filter cap is 65VDC (negative) and therefore are approximate – don’t obsess – as long as they are within about 20% everything is OK. Now check the pot by connecting your voltmeter to the center lug of the pot(s) and monitor the voltage as you rotate the pot through its entire range - the voltage measured should range from the two outer values you just measured. In the ST-70 you will need to check both pots individually. Now, write down these two end point voltages (you will need these values later).

If you get a low or zero volts reading, replace both the selenium rectifier and both bias supply electrolytic caps (these are axial lead caps mounted on the bottom of the chassis) Our bias repair kit includes these parts and the hardware needed. Pay attention to diode polarity (the band side is connected to the transformer lead) as well as the cap polarity (the positive leads are connected to ground). Don’t worry about the bias pots and resistors – they rarely fail however if you’re concerned, with the power off and the caps out, you can simply measure their resistance. Afterward go back and repeat the voltage measurements described above – if they are still not correct (or zero) measure the AC Voltage (set your DVM to AC Volts) on the power transformer RED / Black Stripe lead. If you cannot see about 50VAC your power transformer is probably defective (this is also rare).

I’ll assume that by this point you have a functioning negative bias supply so now we’ll check the delivery of this negative voltage to the output tube. Set you DVM to volts and place your DVM negative lead to ground (chassis) and its positive probe on the control grid (pin 5) of one of the output tubes. Rotate the pot across its full range and note the two voltages (and either end of the bias pot) – write down these two voltage readings. Do this again for the other (same channel) output tube (you will be rotating the same pot) and write down these two readings as well. Compare the two + two readings you measured on the output tube pins (5) to the two voltages you measured and recorded while measuring the center pin of the bias set pot (two paragraphs ago). The voltage readings at the tube pins should be slightly less (due to the finite input impedance of your DVM). If they are significantly less (more than 10 volts less) the connection from the center lug of the pot to



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the pc board is suspect. More likely and importantly, if there is more than a 10% difference, it is likely that one of the coupling caps to the driver board is leaky – to be safe, replace both on the suspect channel. Note - usually these are 0.1uF to 0.47uF caps running along the outer edge of the driver board near the output tubes. Another big problem is old oxidized solder connections. Triple check the solder connections at the pcboard from the center lug of the bias pots and both solder connections at the pc board connecting pin 5 of the output tube(s). Poor connections can be identified by a non-shiny (dull) finish. Be diligent and if you suspect a poor connection the proper remedy is to remove the original solder (you do have a solder-sucker don't you?) and re-solder with high quality (60/40 Kester or Multicore, not the overpriced and over-rated “audiophile” silver stuff). Also check the integrity of the solder connections to pin 5 of all output tubes. Again, if you suspect a connection clean up as described above. Another reliability enhancing note: say farewell to the original Dynaco solid core PVC insulated wire – nothing better than 20 or 22 ga stranded silver plated copper with Teflon insulation.

You should be feeling a lot more confident now since you have not only checked out the high probability causes but, if you have made the recommended connection and connector remediation, you can be confident that its reliability has significantly improved.

To check out the HV supply, it needs to be supplying some real world current since many times it will appear to be perfectly OK but collapse once real world currents are required. So first we're going to check out the output stage itself.

Other than the tubes only the BIAS resistor (and of course electrical connections) can interrupt the current flow in the output stage. So first we'll check out the bias resistor. To do this, with all tubes out and with your DVM set to resistance, measure the value of this resistor. A stock ST-70 will measure 15.6 ohms, the Mk-4 measures 13.5 ohms and the MK-2/3 will measure 11.6 ohms. The exact value you measure will be affected by your DVM lead resistance – just look to be sure that the measurement is within 20% of the correct value. If the resistor is defective (nearly always open) replace it. You will have a difficult challenge finding the original value(s) – don't worry – just use a 10 ohm (3Watt) resistor as a sub and when you finally set your bias make note that the spec setting will change from 1.56VDC (as specified by Dynaco) to 1.0VDC (ohms law again).

You can also perform a simple continuity measurement of the output transformer primary – measure the dc resistance from the center tap (Red) lead to both all of the secondary leads (Blue, Blue/ white stripe, Green, Green / white stripe). Don't worry about the exact reading – just be sure that there is continuity that is less than 200 ohms.

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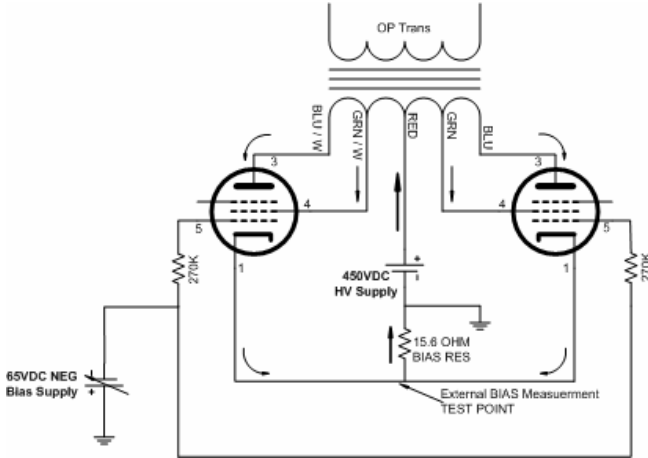
Finally, if you have confirmed or corrected any problems up to this point, we can check out the HV supply. Insert the GZ34 rectifier tube, power up the amp and measure the voltage on both sides of the choke. This voltage should be pretty high (since there is no load current flowing) in the 475V to 550VDC range. Power down and insert the output tubes. Before you power up – be sure that your bias pots are fully counter-clockwise. Now power up and constantly monitor the voltage across the bias resistor. If at any time it exceeds 2V, shut down the amp. More than likely, if there is a problem with the HV supply, the bias current will be too low and you will not be able to set it up to it's specified level (BTW, I like to run the bias current below the Dynaco spec in the 1.0 VDC range – this is with the original bias resistor values).

If you find that you cannot reach the set the bias voltage (across the bias resistor) measure the HV voltage (at the power transformer RED lead) – it should be in the 425 to 500 VDC range. If not, and assuming that you are using new tubes as initially suggested, the problem is likely the quad capacitor.

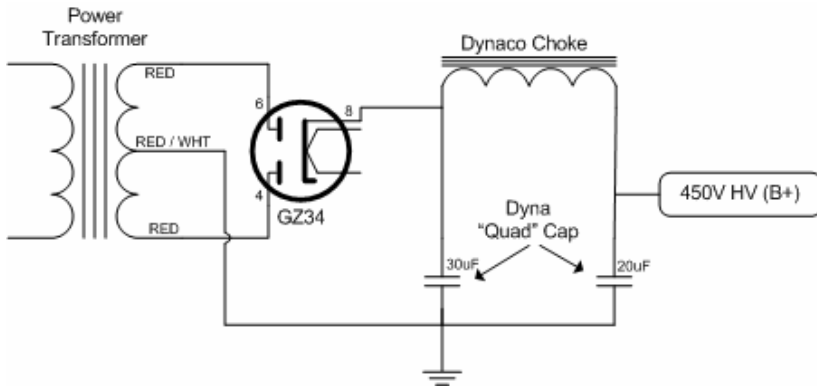
In this case, we recommend that you use a quad cap module – these have higher voltage ratings and therefore are more robust and reliable.

Well – that's it. After going through this series of tests and corrections, if you have accepted our recommendations you should be confident not only that your amp is working but that operation should be consistent and reliable over time.

**Figure 1 – Simplified Output Tube Circuit**



**Figure 2: Dynaco Tube Amplifier High Voltage Supply**



**Figure 3: Dynaco Negative Bias Supply w/ Connections**

