High Performance Power Supply Modifications to an ST-35 Including Individual EFB™ Bias

—– not your mother's Dynaco ST-35 rebuild.

By Arthur Grannell

When Dave Gillespie first described his EFB™ bias circuit, it immediately caught my eye as a worthwhile improvement to the Dynaco ST-35. I read his article at least three times, to educate myself, as much as possible to the "workings" of this circuit. I decided that the amount of potential improvement to be gained from this simple modification, versus the effort and cost, made it a "must have." I was planning the complete rebuild and upgrade of an ST-35 when I read about this circuit, so I decided to incorporate it. While this was the ST-35 that I originally planned to use to evaluate his circuit, I later decided it wasn't a good idea, since I made a number of other alterations, which would make it impossible to evaluate Dave's circuit alone. Work on this amplifier was started well over a year ago, nearly completed, then "shelved", while I added his EFB mod to another "stock" factory built ST-35, the subject of another "how to do it" article that appears on the Tronola website. Meanwhile, I then became involved in a number of other audio projects, before recently returning to complete this one. This describes the on again, off again, process that led to completion of the amplifier.

Preliminary Work

The rebuild was started by completely "stripping" the amp down to the bare chassis. Before starting any reassembly, I cleaned the chassis with some "automotive", heavy duty cleaner. The brand I like is "Turtle Wax Scratch and Swirl Remover". The descriptive name doesn't apply to the Dynaco plated chassis, but does a great job otherwise. It won't remove rust or deep "digs", and I didn't try it on the outside of the bottom cover, as it could remove the printing. It takes a lot of rubbing, but the "like new" final appearance was worth it. I also didn't try it on the cage, as the dull painted surface isn't the sort of thing that will benefit from this process. The transformers were cleaned, and then sprayed with a light coat of Rustoleum "Black Night Metallic". This paint has a small amount of silver metallic in the black paint, that although it doesn't show well in the photos, the painting considerably improves the appearance of the transformers.

Because of the nearness of the high voltage wire and component leads to the bottom cover, I added strips of Teflon tape, on the inside of the bottom cover as shown **at right**. Common electrical tape could be used for the same purpose, here.

PC-13 Circuit Boards

One of the weaker physical areas of these amps are the phenolic "PC-13" circuit boards, which show the decided effects of heat and time, after only a few years of use. About 10 years ago, when I first realized that I needed to replace these boards on another ST-35, aftermarket PC-13 replacement boards were not available, as they are today. So I found it necessary to find a way to fabricate my own, but decided not to use the Dynaco etched layout, since I had planned some component and circuit changes. Starting with an original board as a pattern, I cut the boards from fiberglass-epoxy stock, and then hand cut the vents under the output tubes, using an original board as a pattern. On my first attempt at a pair of boards, I used "flea clips" in holes drilled in the board to mount components at appropriate places. These proved to be difficult to install and even worse to use, so when I built later boards, I inserted turret terminals rather than flea clips.

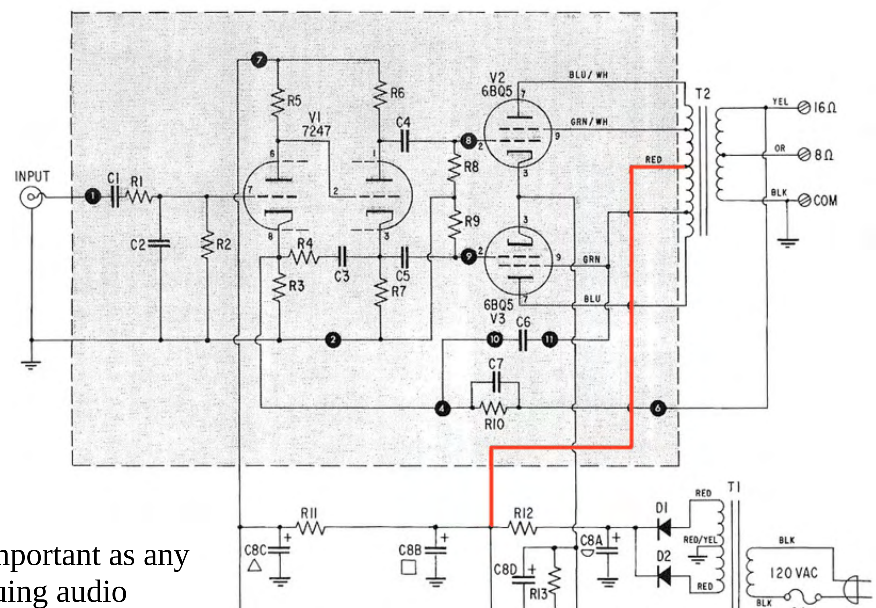
While this turret construction offers more flexibility in component selection and placement than an etched board, it is considerably more labor intensive to complete. For anyone interested in maintaining the original Dynaco circuit with nearly original component values, I'd strongly recommend using a pre-made board. There are advantages and drawbacks to each method, with the turret construction offering more choices in layout, as components can be placed both above and below the board. As seen **at left**, some turrets were installed facing upward, some downward, to better accommodate my pre-planned layout. Another advantage of turret boards is that it does allow spray painting of the board itself, before turret installation. I used black automotive lacquer to cover the "awful green-yellow" hue of some of the board material I used, improving the amplifier appearance noticeably.

The terminals that I used are made by “Keystone,” available through major electronic supply houses and are offered in a wide variety of sizes and configurations. I chose the tubular turret #1509-2 for the new PC-13 boards. These are a medium size turret with an open center hole that provides a component or wire attachment point, on the opposite side of the circuit board from the turret itself. After drilling the holes, I inserted and flared the turrets using the Keystone staking tool set in my drill press, which works well for this purpose.

Most capacitor and resistor values remain original, with upgrades to polypropylene and polystyrene caps and tight tolerance metal film resistors replacing the originals. Nearly all the wiring was done with Teflon insulated silver plated wire, not because I’m convinced that there’s any sonic advantage to it, rather, I feel it’s easier to work with, overall. Although harder to strip, it solves the troublesome “shrinkback” and melt-through issues of PVC insulation, and makes the soldering process much easier.

The minimal circuit changes on the new boards currently involve the removal of C1 and the substitution of an adjustable trimmer capacitor in place of C7 to allow adjustment of the feedback compensation for “best” square wave performance. A trimmer capacitor with a voltage rating of 50 volts or greater can be used here. The C6 feedback capacitor, which serves a different purpose, cannot be replaced in this manner as the 500 volt rating must be maintained since it’s connected to the output transformer primary.

Please note: C1 may be removed and jumpered only if it’s absolutely certain that a DC offset voltage *never* appears at the amplifier input. Dynaco PAS preamplifiers without the “X” tone controls* exhibit a DC offset at the output, as do a number of cathode-follower preamp outputs, particularly at “turn-on”. If you are unsure, it’s best to include C1, replacing the original ceramic cap with a polypropylene type of the same value (0.1mfd). The sonic penalties for doing so are very minimal.



Caution: Failure to follow this recommendation can, and has resulted in the destruction of speakers, and other damage.

Power Supply Mods

Other than the addition of EFB biasing of the output tubes, the most extensive circuit changes I made to this amplifier were to the power supply.

The power supply is about as important as any part of the amplifier when pursuing audio excellence. A look at the schematic diagram **above right**, shows that the second filter capacitor connects directly to the center of the output transformer primary, which feeds the output tubes directly, and the loudspeakers indirectly, with

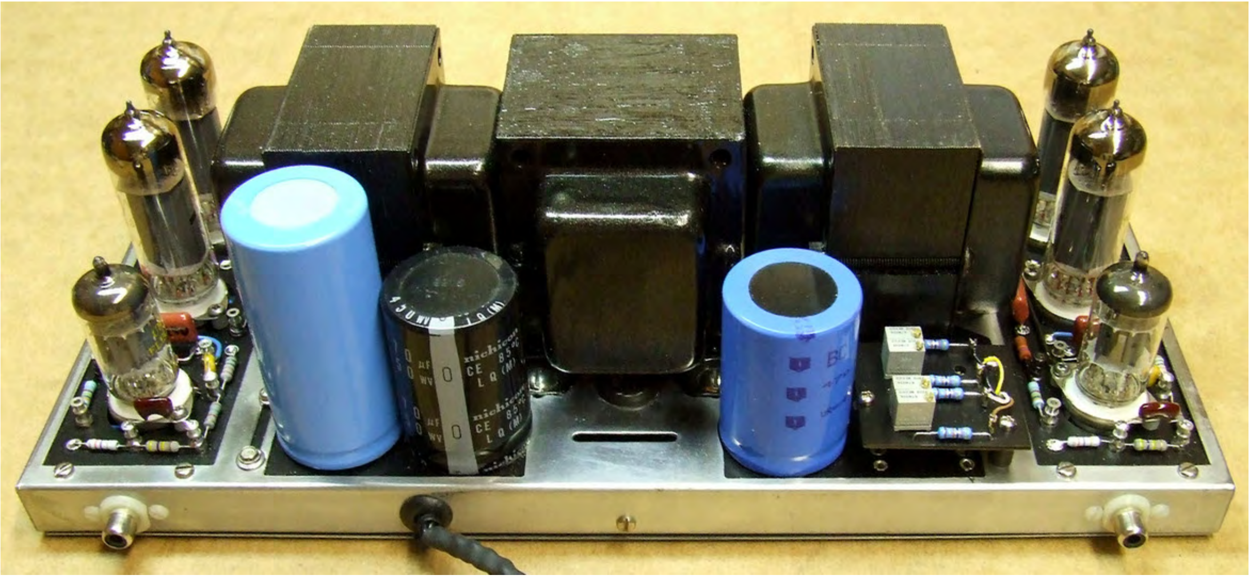
* The PAS-3X version differed from the PAS-3, in that it had tone control potentiometers which were constructed to be electrically removed from the circuit when set to their flat position.

the output transformer the only component in between. The output tubes only act on this supplied current to modulate it, providing an AC signal to the speakers, through the output transformers. The more stable the power supply, the greater the potential accuracy of the output signal, particularly at higher output levels, when the power supply has trouble keeping up with the demand.

The ST-35 output stage operates in Class AB, which is more efficient than Class A operation. This increase in efficiency means considerably more of the supplied electrical current is used to drive the loudspeakers and less is dissipated as heat, resulting in greater power output from the amplifier than would be obtained in standard Class A operation. The downside of this is that while a “pure” Class A output stage has a nearly constant “draw” on the supply, a Class AB amplifier varies the demand as signal levels change, taxing the power supply heavily at times. Because of the inherent output impedance limitations of the power supply, the voltage supplied to the amplifier circuitry instantly drops under load. A particularly interesting feature of Dave’s EFB bias circuit is that it automatically corrects the output tube operating point as the voltage from the power supply varies.

The obvious way to counter the power supply limitation is to increase the size of the power supply itself, so that it can handle the higher demands when needed. This seemingly easy approach presents a number of issues, particularly in the ST-35. A considerably larger power transformer would be required, along with heavier diodes, increased wire size, and other components. This solution is neither inexpensive, nor particularly practical, as a separate chassis would be needed to mount the equipment. Another option would be to add a “regulator” to maintain the voltage under all operating conditions. Unfortunately, a good regulator circuit for the output stage would be large, complex, costly, and probably also require a larger power transformer, in addition to the fact that such regulators have inherent inefficiencies, anyway. Regulators can work well for low current draw circuits, but are very rarely used for the output stage of a power amplifier of this type. A third and much easier way to meet this higher demand is to “store up” energy in advance, and this can be done by increasing the size of the electrolytic filter capacitors, or adding additional ones.

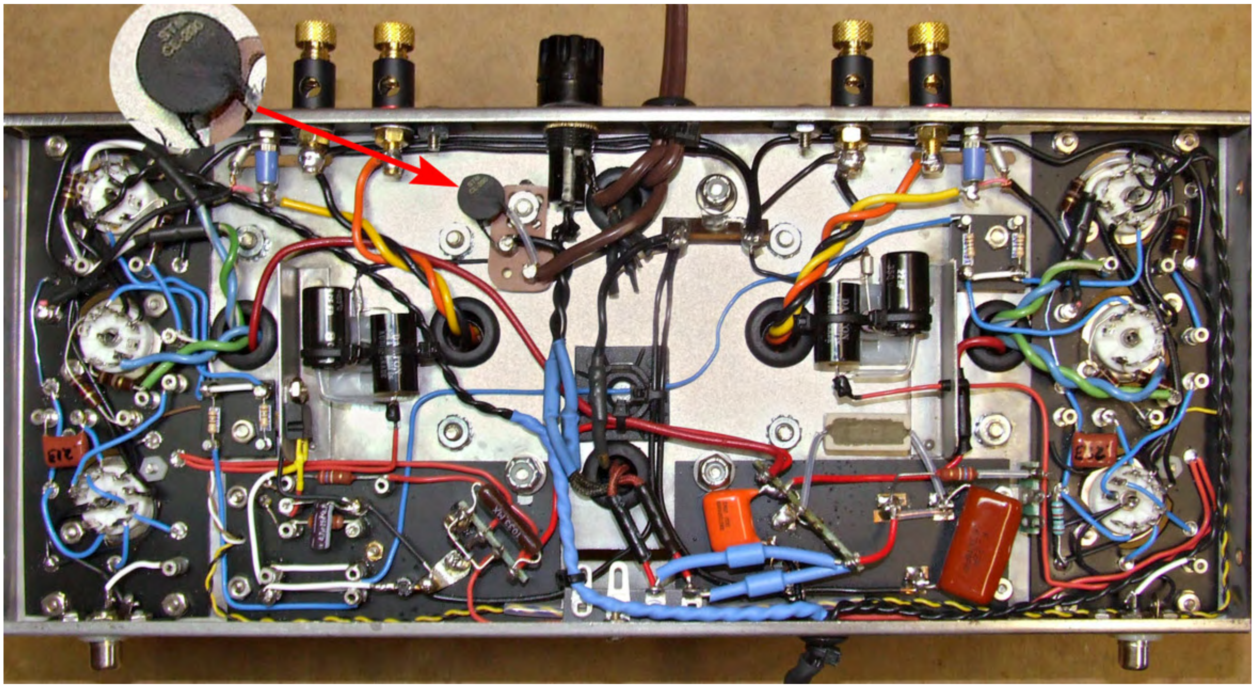
Cage removed showing filter capacitor placement.



In an article titled, “Build an Energy Storage Bank,” *Audio*, August, 1980, Walt Jung stated that “increases in electrical capacity and energy storage...in many cases dramatically improves the quality of sound reproduced by the amp. The improvements show up in such areas as increased bass separation and reproduction, greater power, and in some cases, increased clarity and definition—from top to bottom.” He was referring to solid state amplifiers in this article, but it has been my observation that these same improvements also show up in tube amplifiers. The formula for energy storage is $J=1/2(CV^2)$, where J=joules (a unit of energy), C=capacitance in Farads (multiply by 0.000001 to change to microfarads to farads), and V is the applied voltage.

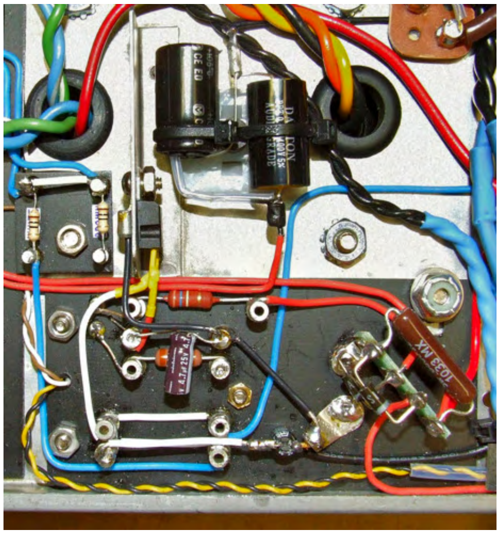
The energy storage capability of the filter capacitors of the original Dynaco ST-35 is 8.4 joules. As shown in the **photo on the previous page**, I removed the original four section can capacitor, and replaced it with an input cap of 100 mfd (it’s the large cap with two 50 mfd sections paralled), and two 470 mfd capacitors. This results in an energy storage capability of 67.7 joules. The removed 4-section “can” capacitor also contained a 100 mfd 25 volt capacitor for the output tube cathode bypass. A small replacement is installed under the chassis that could be used for either the original cathode bias, or EFB bias. While this is far easier and less costly than the first two options, however, it’s not quite as simple as just adding additional capacitors. A number of factors come into play when large electrolytic caps are added.

One issue with increasing the energy storage in this manner involves the large surge of power that occurs when turning on the amplifier. For the first fraction of a second, capacitors of this size “charge up” by drawing many times the normal power through the fuse, power transformer, and rectifiers, eventually resulting in the probable failure of one or more these components, so a method of limiting this current must be employed. The small black disk near the power cord is a CL-200 current inrush limiter, **shown below**. These limiters are designed for this exact purpose, but there are “trade-offs” in characteristics, and limits to the capabilities of these devices. So I chose to build an external device that slowly “ramps up” the AC line voltage over 30 seconds, having much the same effect as slowly turning up a Variac by hand. I added the inrush limiter



only as a backup safety device, should full 120VAC be accidentally applied. I’m not certain if it sufficient to protect the amplifier, as fortunately, that hasn’t happened!

Safety is a very important item that needs to be addressed when using large capacitors. These 400+ volt capacitors hold their high voltages for a long time after power is removed. A method of automatically discharging them is mandatory, but luckily, easy to implement, using bleeder resistors. Bleeder resistors really should be included on all high voltage tube circuits, but are notably absent on most vintage tube amplifiers. The EFB bias mod uses a voltage divider string, consisting of a 360Kohm resistor, 5Kohm adjustment pot, and another 15Kohm resistor, completing the circuit to ground. In addition to other functions, this string also acts as a bleeder resistor, but it’s good practice to have two strings, should one fail “open”. I added a second bleeder consisting of one 360Kohm, and one 56Kohm resistor in series. A general “rule of thumb” for sizing bleeder resistors is 1000-ohms per volt, drawing 1mA per string. Resistors rated at one watt or more and sufficient voltage rating need to be utilized.



Additional changes that I made to the power supply include small polypropylene bypass capacitors, at each filter capacitor section, and the electrical isolation of each 12DW7/7247 from the other, with a 1N4007 diode, and adding additional electrolytic and bypass capacitors for each channel mounted as shown in **<u>at right</u>**.

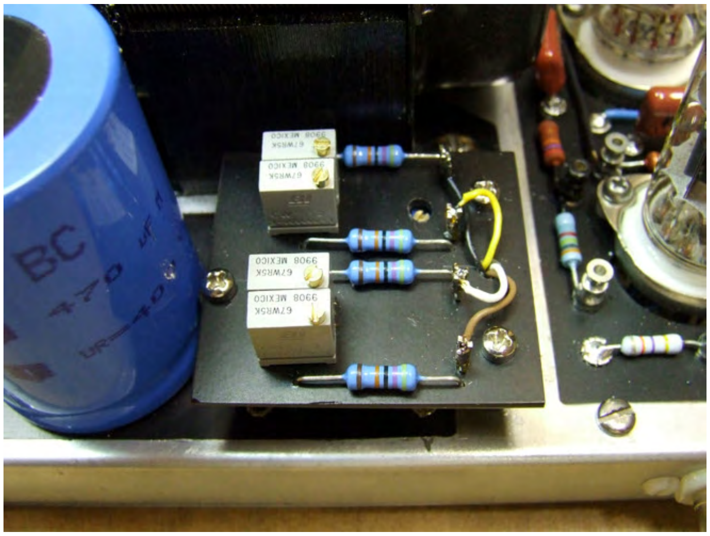
I replaced the original Dynaco one-half amp diodes with three-amp “ultrafast” rectifier diodes. One amp diodes are sufficient, but three amp diodes are only slightly more expensive than one amp diodes.

External Heater Supply

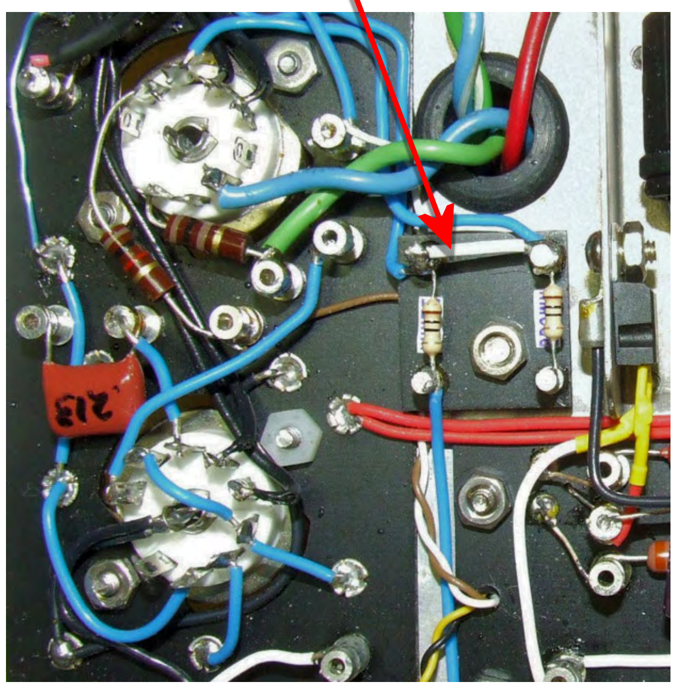
The tube heaters in the ST-35 consume over 25% of the power used by the amplifier, so I decided to power the heaters from an external DC supply. This results in a noticeably cooler running power transformer, and possibly better B+ regulation. The use of DC on the heaters of a power amplifier won’t offer much improvement in hum and noise, but the source that I used, a converted “computer” SMPS (Switch Mode Power Supply) provides excellent voltage regulation, high efficiency, and a low noise output. A description of the modification of a computer power supply for tube audio use may be the subject of a future article, if there’s interest.

Later Changes

When I originally built this amplifier, I incorporated the additional EFB mod components in the available space on the added right side filter capacitor board, with a single trimmer to adjust the bias for all four output tubes. As a late change, before installing the amp in my system, however, I decided to install individual bias pots for each output tube, allowing for the minor differences that appear in matched tubes, as well as normal changes that may occur as the tubes “age”. Faced with a choice of removing that board and completely redesigning it, or finding an add-on solu-



tion, I chose the latter, and constructed a small board to mount on spacers above the original. As seen **<u>at left</u>**, I drilled a small hole in the new board to permit access to the original trimmer, for the initial range adjustment. Additionally, I mounted the four 470Kohm grid resistors on the same board, which, on this amplifier, simplified the (re)wiring. I then ran small wires to the grid swamper resistors on each EL84. Small wire sizes can be used for this purpose as only a tiny amount of current is carried. This change also requires the use of four 10-ohm cathode resistors, rather than two 5-ohm resistors used for both the single, and two channel EFB mod. I constructed a small mounting board for each pair of resistors for each channel and fastened the boards on an output transformer mounting screw on the respective channel, as **<u>shown below</u>**.



After completion, I installed four new, but “unmatched” output tubes and attempted to set the bias to the 0.27VDC specified for each tube. I was surprised to find that the adjustment needed was beyond the range of the trimmers, despite the fact that the tubes “seemed” to match well on my tube tester. So, I ordered and installed four new “well matched” EL84s, and found that these tubes allowed the cathode current to be easily set near the center of the adjustment range.

Dave advised that he deliberately specified a limited adjustment range, to require tubes with similar, rather than greatly varying characteristics. That will ensure better AC (signal) balance, and therefore, lower distortion than would otherwise result. The procedure for setting the bias on the four individual output tubes is given in Appendix A.

The remaining changes to the amplifier are fairly standard, with improved output binding posts replacing the original “screw type” loudspeaker connections, which are far too easy to short together (a big no-no) for my tastes. New input jacks are isolated from the chassis, and all ground leads are connected to the chassis at one point of a small terminal strip. I found some small size, but low capacitance cable that I used for the feedback line from the 16-ohm output to the R10/C7 feedback pair. The shield of this cable is an attached at the chassis end only, with a turret terminal mounted on the chassis.

Final Thoughts

I think this project represents, nearly the limit of the mods to an ST-35 that can be incorporated on an original chassis. Even so, tradeoffs were necessary. The power supply capacitor bypass scheme is less than optimal, but is limited by available space. Every component's position had to be carefully evaluated in advance; even then I had to make compromises in location, and occasional unplanned changes during assembly. I have plans for another build of the ST-35 in the future, but it will be on a much larger chassis.

Is it worth it? I think so. It's a superb sounding amplifier, and the results certainly justify the effort necessary to rebuild it with modern components and techniques. It was a very good amp to start with, and the modifications described have certainly resulted in an even better sounding one.

Appendix A:
EFB Bias Adjustment with Individual Adjustment Potentiometers for Each Output Tube

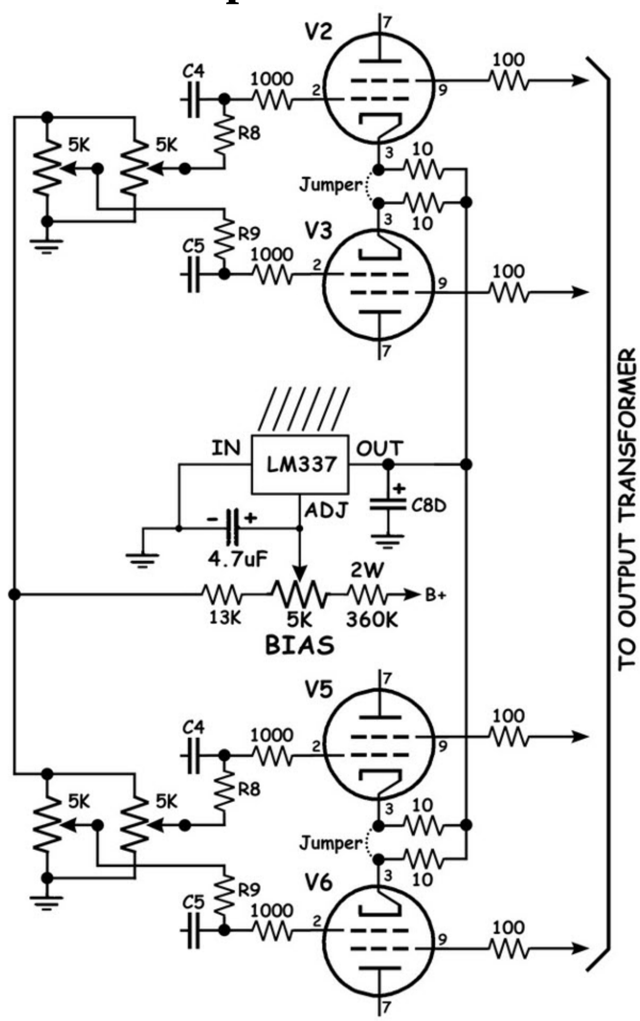
1. Center all five trimmers or pots by measuring the resistance from the center terminal to an end terminal, before installation.

2. Short (or jumper or switch) both of the output tube cathodes of one pair, together. Do the same for the other pair. This creates a 5-ohm resistor in each cathode pair by paralleling the two 10-ohm resistors of each cathode circuit.

3. Power up the amplifier and allow a short warm-up time.

4. **Preliminary Range Adjustment**—Set the main "BIAS" pot (connected to the ADJ pin of the LM337) to 0.27VDC as measured across one of the 5-ohm cathode resistors created in the above step. Measure the other (created) 5-ohm resistor of the other channel. Set the main trimmer to provide the closest average to the desired 0.27VDC in each channel.

5. Remove the short or jumper mentioned in Step-2.



Above: Schematic of EFB bias for individual output tube adjustment

6. **Individual Adjustment**—adjust each “grid” 5K trimmer by measuring the voltage across its respective 10-ohm cathode resistor at each output tube. Set each trimmer for a reading of 0.27VDC.

7. Complete this procedure by shorting the output tube cathodes, of each pair, as described in step-2.