Power Modifications for the ST-150-BJ-1

by Jim Boak

Since the publication of "A Family of Power Amplifier Power Supplies" (*TAA* 1/80), audio enthusiasts have asked me for help in applying the circuit to various power amps, from the DH-200 to the Dyna ST-416 Double 400. In most cases the change of diode Z_2 is all that was required to make the supply suitable for their application; but in all cases, the target amp itself required some study before the mod could be successfully applied. The general pattern of problems, and the method of their solution was similar enough to convince me that most people applying the regulator to their power amp could use an additional applications article.

The ST-416, the ST-150, and the DH-200 all use the version of the supply I originally developed for the Nelson Pass Class-A amplifier (*TAA* 1/78). This supply features heavy-duty output devices and peak currents up to 15 amps. The only change necessary for this application is to substitute the value of Z_2 indicated in *Table 1* for the value supplied by Old Colony.

However, since the ST-150 is internally limited to 9.5 amps, you may want to limit the regulator to this value also, as Pat did (see pp. 21-25).

In both the DH-200 and the ST-400 series amps, the room available inside the chassis is insufficient to allow the addition of regulators without some alteration. In addition, the DC headroom is not sufficient for a full-power regulated amp. For the DH-200 and ST-400, I recommend the removal of the power transformer, capacitors, and rectifier, along with the associated AC wiring (as we will see below, this step is not necessary in the ST-150). The 'raw' supply is then constructed in a separate chassis, with the DC run to the regulators which are to be mounted in the original amp.

Taking this route has some advantages. The AC is kept out of the amplifier (with the resulting lower hum potential). The resulting chassis is lighter, easier to mount, move, and service than the original version. And, most importantly, it is possible for us to mount the regulators as close to the power amp boards as we wish.

The only modification to be covered in detail in this article is for the ST-150. The brief outline below should be adequate for the experienced amateur to apply the same concepts to the other two designs, and I will be eager to help anyone who wishes to attempt the project. In general, then:

1. Remove power transformer, rectifier, filter caps, and associated wiring.

2. Purchase a pair of 5 amp 12.6 volt transformers (Radio Shack).
3. Wire them as shown in *Fig. 1*. The voltage across the combination from centertap should be 12V AC higher than the old value; if it is not, reverse the secondary windings.
4. Connect a 25A 400 PRV bridge as shown (the existing bridge should be adequate). The filter caps must have at least a 75V rating for the Hafler DH-200, and at least a 90V rating for the ST-400. The caps should be at least 10,000μF, and need not be larger than 20,000μF.
5. Mount the regulators (tested as per the 1/80 article, but using the test resistors specified for the Williamson version) on small heatsinks (Radio Shack, as above, are adequate) and mount the combination securely in the amplifier chassis.
6. Route the DC from the outboard supply as you see fit. Connect a capacitor bridge (as above) of at least 2200μF total value across the regulator, as close to the amp boards as possible.
7. Verify the correct output voltages.
8. Enjoy many of the same benefits as Pat describes in his article.

TABLE 1

Amp	Volts	I_{RMS}	I_{PEAK}	Z_2
ST-150	50V DC	6.5A	9.5A	33V
DH-200	60V DC	10A	15A	43V
ST-400	75V DC	10A	15A	56V

The easiest application of the regulator (electrically, and physically) was Pat Amer's incorporation of the circuit into his Dyna ST-150. The careful notes Pat took, and the thorough analysis he performed, make this modification an ideal showcase for the regulator installation procedure.

THE SKELETON

What are we starting with in the 150? The basic amp is a bipolar transistor design using a clean, minimum component layout. A differential front end feeds a level shifter which serves to set idle current. This in turn feeds a voltamp limited driver and power stage. DC offset (the DC value of the output with no signal) can be adjusted, which means the amp can be DC coupled if desired. Thermal tracking reduces the input signal if overheating occurs; while this is a clean way to avoid overdriving the amp, it is of little help in controlling an excessive idle current.

The stock amp in stereo mode is driven from nominal ±50V rails, which drop to ±42 volts under full load, 10,000μF 80V caps provide energy storage and filtration to the raw supply. An additional set of transformer secondary taps provides a higher AC. In actual measurements on Pat's amp, these additional secondaries provided 45V AC, which yields 63V DC no-load (65V DC at idle). This tap allows the user to strap the amps to 150W mono mode without putting the outputs in push-pull as is often done in amps where the supply or output stage is voltage limited. The switch to mono is accomplished through a fairly complex arrangement of molex connectors and wires which considerably degrade the design elegance.

Output transistors are Motorola 2N5630 and 2N6030 TO3 devices rated at 200W, 100V, and 16A. These are rugged, stable units which I have used with great satisfaction for the majority of my medium-power designs for several years. Output current into a 4Ω load is limited at 8A. peak; slightly more is available into 8Ω, due to the safe-area foldback design of the protection circuit. The amp is voltage limited at 90W into 8 Ω, current limited at 150W into 4Ω.

The first question I asked myself was, why not apply the higher secondary voltage to the amp in stereo mode and eliminate the molex connector? The output devices will see exactly the same limit protection as in mono mode, and the increased voltage should give a big power boost and increased dynamic headroom to the 8Ω load. As Pat describes, this is exactly what happens; maximum power goes up to over 170W into 8Ω.

Our only problem was our inability to set the idle current to the 75mA the 150 manual calls for. This was not insurmountable, as I prefer a 250mA bias (or higher). However, the original circuit, as designed, could never have allowed the range of adjustment required, for either the low (stereo) or high (mono) voltage settings. Worse yet, the idle current is dependent on the supply voltage. We were able to fix the problem with a simple change in the set pot and associated resistor.

The basis of the idle current adjustment circuit was a V_{be} multiplier, as it is in the majority of modern transistor designs, but the point is that in all applications, you must measure the supply voltages and idle current before the regulator is added, and be sure to set the regulated voltage as close as possible to the original supply voltage at idle, in order to keep the idle current at near the original value. If you want to change the operating voltage, be sure you fully understand how the bias circuit works, since you will probably need to alter it.

FLESHING OUT THE DESIGN

What did we hope to accomplish with regulation? Measurable distortion should be reduced, especially IM due to cross-coupling. Hum and noise should also drop; but these are not really troublesome areas in the ST-150. The real goal of an audio modification is to improve the sound.

The basic design of any amplifier assumes certain operating parameters, usually defined on a static or steady-state model. The real signals are not steady-state at all, and they impose random demands on every point in the audio chain. The more points inside the

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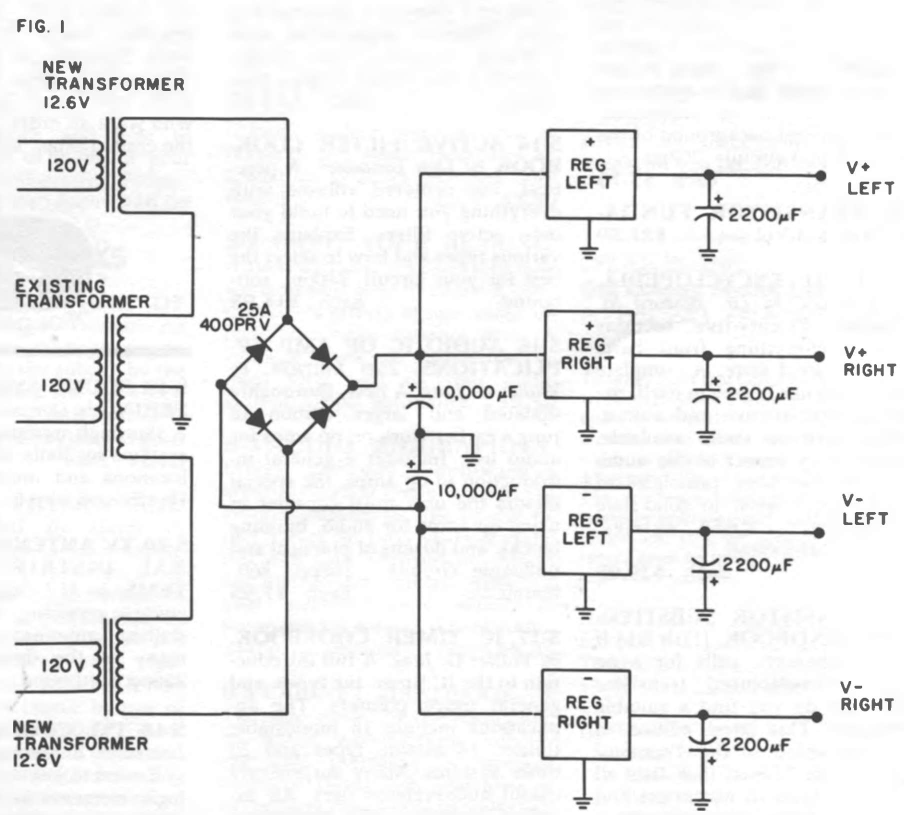

Fig. 1. Schematic of the adapted power supply for the Dynaco ST-150 with added Boak regulators.

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circuit we can hold absolutely at their design points, the closer we can come to the steady-state design centers, even under random signal conditions.

This goal we hoped to approach to using the regulator. The unregulated supply has a DC impedance of about 1Ω and an AC impedance which runs from about .8Ω at 20Hz, dropping at a rate of 6dB/octave. The regulated supply has DC impedance of .005Ω, and the AC impedance runs from about .005Ω at 20Hz up to .009Ω at 100Hz, where it flattens out and stays flat to 30kHz. If this is still not low enough for you, Walt Jung offers suggestions which I have

WALT JUNG'S REGULATOR SUGGESTIONS

WALT JUNG POINTS OUT several possible changes in the regulator circuit which significantly improve the performance. Since it is easy to make these changes on the stock board (*TAA* 1/80), I will detail them here for those who want to go the last yard.

The more feedback an amplifier has, the smaller the output error. In a voltage regulator, "error" is the change in voltage with load. This is the same as output impedance. The regulators are built with a standard internal circuit; the gain of an internal reference amp determines the multiplication of an internal voltage source to provide the desired output voltage. Thus, the lower the output voltage, the lower the required gain. Less gain implies more feedback which in turn should give lower output impedance.

Experimental results bear this out. A typical 5 volt regulator, the LM340T-5, measures about 30 milliohm at 100Hz, less than half the 65 milliohm impedance of the 15 volt LM340T-15.

The impedance of the regulator is further divided by the gain of the resistor network R4/R5, which sets the regulator's overall current gain. With a 5 volt regulator and a gain of 5.6 (as in the recommended Pass configuration), impedances as low as 5 milliohms can be achieved.

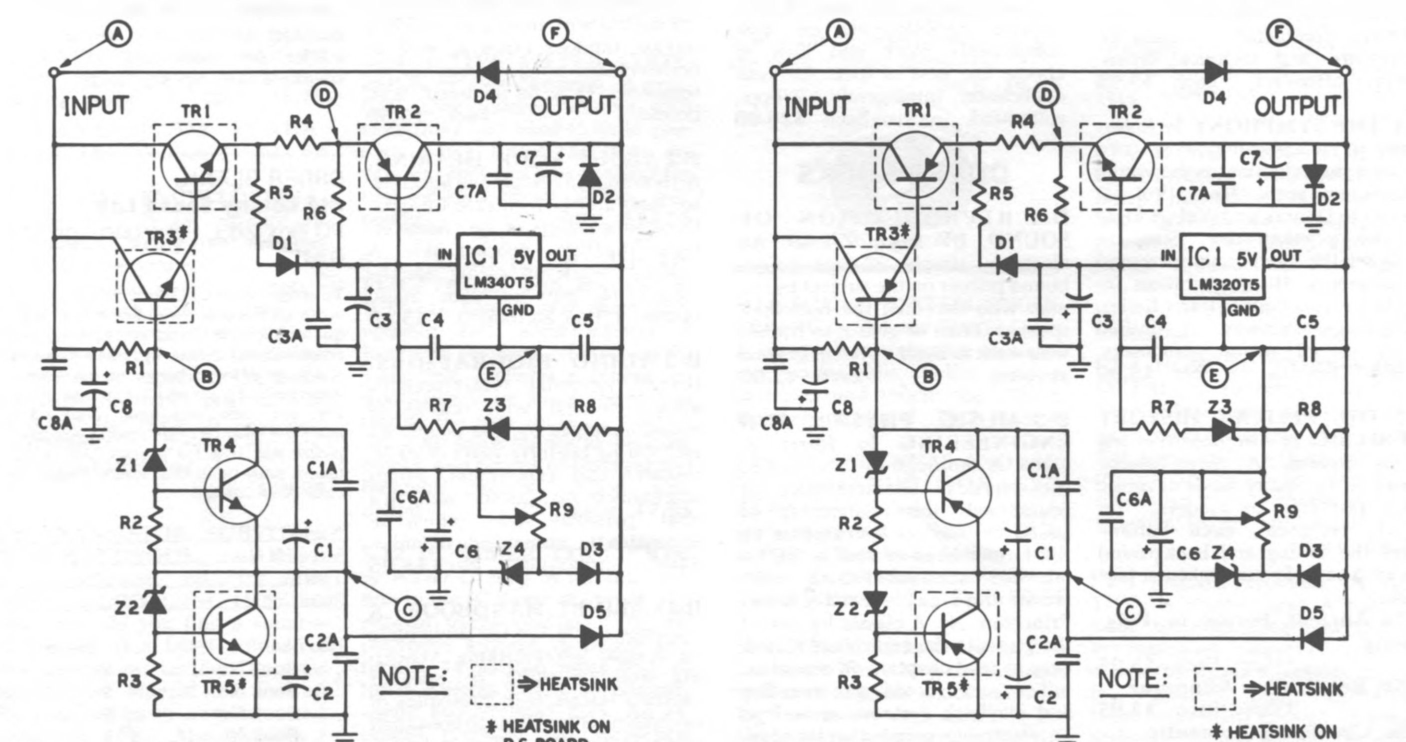
Refer to the positive regulator schematic below, which shows the changes Walt and I agreed upon. The use of a common voltage reference (Z_2) on the 1/80 regulator made it easy to scale the output voltage for different applications, but it allows input voltage variations to be coupled to the output through changes in the supply current to Z_2. This coupling is determined exactly by the ratio Z_{Z2} (the zener impedance of the combination Z_2-TR_5 etc) over R_1; whatever changes are coupled by this ratio will be level shifted by the IC and the drop across R_9, and thus pass directly to the output.

In the new scheme, we add another zener (z_4) to provide an isolated reference for the regulator IC_1. First cut the trace between C_2-C_{2A} and the trimmer R_9: this separates the pre-regulator reference. To preserve the short-circuit protection, add a 1N4004 diode (D_5) from point C (the C_2-C_{2A} side of the cut trace) to the output. In the positive regulator, the cathode of this diode points to the output; the anode points to the output in the negative regulator.

Next remove the leads of C_6 and C_{6A} which connect to the center lead of R_9 (the cut trace); the removed leads should be connected to ground (C_6 now stabilizes the new reference Z_4). Connect a new zener (Z_4) from ground R_9 (use the holes where C_6-C_{6A} were removed). In general, select Z_4 to be a one watt (or larger) type, about 9–12V higher than Z_2. For example, the Pass regulator, with Z_2 of 15V, would use a Z_4 of 27V. The Williamson version, with Z_2 of 47V, would use a 56V Z_4. R_9 still trims the final output voltage to compensate for component variations.

Last, replace the LM-340T-15 (LM-320T-15 in the negative version) with a LM-340T-5 (LM-320T-5); the 5-volt regulator IC has a lower output impedance. R_8, at 1k provides 5mA bootstrap. This, combined with the 5-6mA class-A supply current from IC_1 provides clean, stable bias current for the reference.

The improved version has an output impedance about half of the 1/80 regulators, for equivalent conditions. The input voltage variation rejection is improved to 80dB, or a factor of 10,000. These changes are easy to make, especially on an unassembled kit, and inexpensive, and they really do add a substantial edge in regulator performance. □



The Boak regulators altered for use in the Dynaco ST-150 and other amps.

tried (see box), which will reduce output impedance and improve input variation rejection by a factor of two, or more.

This input voltage variation rejection is a good reason to add regulation to each channel independently. Even a husky supply will show several volts of

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signal across the *power supply caps* when driven hard; this signal is the combination of both channels of load, and it couples the two channels together, resulting in a variety of distortion products. The stock regulator reduces this signal by 60dB (a 1-volt signal is reduced to 1 millivolt at the regulator output); Walt's additions to the circuit reduce it by 80dB (1 volt is reduced to 100 microvolts at the output). Either way you are going to see a substantial reduction in problems from this source.

IMPLEMENTING CHANGES

Pat used the Old Colony kit for the Pass ±32V supply as the basis for his regulator; he wanted a 50 volt output, so he substituted a 33V zener for the 15V zener supplied at Z_2 (see *Table 1*). Pat changed the value of R_5 to 0.33Ω to give the regulator a 9.5A max current (see my *TAA* 1/80 article for details). He also added a 2200μF cap to the output to flatten the impedance curve at a low frequency. The Old Colony kits turned out to be quite a bargain, as Pat ordered two kits and received two complete plus and minus regulators in each kit. The kits all contained LM340T regulators, however this is the result of my own drawing error in the 1/80 article which showed an LM340 regulator on the negative schematic, where an LM320T-15 should have been. *[Present kits include LM340T and LM320T regulators. —ED.]*

We swapped the ST-150 output transistors with the regulator transistors (TR_2) because the TCG180 and 181's supplied by Old Colony are 200W, 100V, 30A devices, and the amplifier output transistors will see larger power products than the regulator pass elements. This change just gives a little margin to the design and was not really necessary. Watch the lead length on the transistors themselves if you swap, however. The ST-150 heatsink is so thick that the leads barely make it into the sockets, and some brands of transistor make marginal contact. If in doubt, use the old devices.

Pat's listening comments are more than supported by my own experience; I think the combination of changes covered in his article turned a rather lackluster, low/medium power amp into an open, dynamic, exciting high/medium (140W/chan) amp which is sonically the equal of anything I have heard. The photos show the care and craftsmanship Pat has applied to the changes, and demonstrate that the ST-150 was indeed an ideal candidate both physically and electrically for the addition of full regulation.

RESULTS AND SIGNIFICANCE

The test results show something even more interesting than low distortion or high power. The distortion of the regulated amplifier is nearly constant at all power levels, and across the entire audio bandwidth. Let me stress the importance of this finding.

The normal pattern of transistor amplifier designs, and of the unmodified ST-150, is to have the THD measurements fluctuate by 50% of their 1kHz values, or more, at various points in the frequency spectrum. Also, the variations get more pronounced at higher power levels, since the output impedance of the unregulated supply is fairly high, and also strongly frequency dependent.

The fact that we can control sine wave steady-state distortion with regulation almost certainly means that operating-point-dependent distortions which are the result of supply variations, such as dynamic compression and some types of TIM, are being controlled as well. We have solid, measurable evidence that regulation of the supply can make a significant contribution to overall sonic performance.

TEST RESULTS

We performed tests into an 8Ω noninductive load, both channels driven, after a 1 hour warmup period at 25W and 1kHz signal. Unregulated readings are taken from Dyna supplied charts.

IM vs. POWER

POWER (W)	REG. AMP IM %	UNREG. AMP* IM%
.1	.01	.011
1	.01	.018
10	.014	.022
50	.016	.040
75	.017	.050
100	.018	n/a
140	.020	n/a

THD vs. FREQUENCY, SEVERAL POWERS

Power / Freq.	Regulated Amp .75W	7.5W	75W	140W	Unregulated Amp .75W	7.5W	75W
20Hz	.030	.030	.030	.033	.035	.035	.045
100Hz	.030	.030	.030	.033	.035	.035	.045
1000Hz	.030	.030	.030	.033	.030	.030	.040
10kHz	.030	.030	.030	.033	.031	.031	.035
20kHz	.030	.030	.030	.032	.035	.035	.040