Dynaco ST-70 Series 3

The Inside Story—A Long Road

Since acquiring the legendary Hafler and Dynaco brands in 2014, Radial Engineering has been carefully working on the Dynaco ST-70 Series 3 tube amplifier. In an effort to create a truly worthy successor of one of the most successful tube amplifiers of all times, its design team has considered all the options needed to meet the expectations that come with David Hafler's work.

By
Dan Fraser
(Senior Design Engineer,
Radial Engineering, Ltd.)

As a veteran audio electronics engineer, I welcomed the news that Radial Engineering had acquired the Dynaco intellectual property and brand. I was one of the last engineers to receive a basic electronics education on tubes back in the 1960s. Then, I repaired and rebuilt Dynaco products back in the 1970s. And, although I worked for many years on Class-D PWM amplifiers, DSPs, digital audio distribution, and other leading-edge state-of-the-art technology, I immediately jumped on the ST-70 as the best introductory product for the line and something I really wanted to do. How hard could it be to bring it back, considering we already had the schematics and the sample amplifiers to measure?

Turns out, it was a lot harder than you would expect as the Dynaco output transformers are magic when it comes to high-frequency clarity and accurate build information is not to be had. When we conducted listening tests, we found that with the original tube power supply the bottom end was thin when played with modern music. And, it is the power supply in an amplifier that determines the quality of the bottom end. The power supply delivers the punch that modern music requires. Good low-frequency response is not enough.

Then, there was the question of whether to offer it as a kit. We debated this as it would save the cost of getting safety certification and reduce the costs in production. But in today's onerous legal environment, sending out products with high voltages that could potentially be used by amateurs made the legal risk too great. Instead, we chose to sell the ST-70 as a completed product and undertook the costs to have it properly safety certified.

Next, we considered the countless upgrades and modifications that were introduced by the DIY community over the years, many of which were very good. There is no sense in making a faithful reproduction of the old amplifier that would need to be modified out of the box.

Modern Parts

For the ST-70 Series 3, Dynaco has made extensive use of the most modern parts including: precision metal-film resistors, poly-composition capacitors, and miniaturized high-capacity power supply electrolytics (unavailable at the time of the original design). Newer parts are also more conservatively rated than some of the original parts. In compliance with general practices, a heavy-duty three-pin detachable grounded power cord is provided. Signal ground is the same as electrical ground and chassis. And all the signal connectors are gold-plated.

Tens of thousands of original Dynaco tube amplifiers are still in use around the world. In fact, more quality music systems have included Dynaco tube preamps and power amplifiers than any other combination. The original Dynaco Stereo 70 is a true classic still regarded with awe by audio enthusiasts worldwide. This "new ST-70 Series 3" reflects the illustrious history of Dynaco's involvement with vacuum tube designs as well as the latest advances in vacuum tube technology. We like to think of the ST-70 Series 3 as the update that David Hafler would have made if he were alive today (see **Photo 1**). Besides, there was no point in precisely recreating the old amplifier and adding some upgrades. If people wanted the old amplifier with upgrades, the aftermarket upgraders do an excellent job restoring and upgrading the old stock of Stereo 70 amplifiers at a better price than a new amplifier will cost. We feel people who are buying new want a better amplifier, but one that is still based on the work of David Hafler.

Styling

Next up…The styling came into question. The original ST-70 was a pretty utilitarian box that was okay in the 1950s. There have been many great looking replacement housings made for the ST-70 by third-party vendors, and really, the original looks pretty plain.

Today, with numerically controlled metal fabrication gear, the cost of making something look good is not a lot more than the cost of a plain box. So, we decided the case needed an update and our people created a better-looking amplifier that still retains the original "base-and-cage" design, yet brings a more modern and sexy look. We made it a little bit wider to get the necessary clearances for the high voltages based on current regulations and to match the upcoming Dynaco ST-1 tube preamp. Both are about 17" wide to follow the generally accepted standard in use by many manufacturers today.

The front panel is especially modern. It features adjustable recessed bias controls with pairing LEDs to optimize each tube and separate channel volume controls enable the user to balance the output for odd-shaped rooms. The rear panel is made with ultra-high-quality gold-plated RCA connectors and heavy-duty gold-plated "No Touch" speaker binding posts—compatible with modern safety standards. The modern IEC power cord connection is now capable of both 115 V/230 V operation with a simple rear-panel switch.

Photo 1: The new Dynaco ST-70 Series 3 tube amplifier intends to be an updated version, compliant with today's demanding global regulatory safety requirements.

To improve the amplifier's unit-to-unit consistency, we needed to eliminate the majority of the hand wiring and this meant using a PCB for the internal components and wiring to the output tubes as well. This is a modern glass-epoxy board with extra heavy traces that meet the modern standards for safety. The ST-70 Series 3 still employs 100% hand-inserted full-size discrete components—no surface-mount parts are used.

Once all the pieces were in place, Radial Engineering CEO Peter Janis unveiled the Dynaco ST-70 Series 3 at the 2016 High End show in Munich,

Photo 2: Peter Janis, CEO of Dynaco's parent company Radial Engineering, unveiled the Dynaco ST-70 Series 3 at the 2016 High End show in Munich, signaling the return of the Hafler and Dynaco.

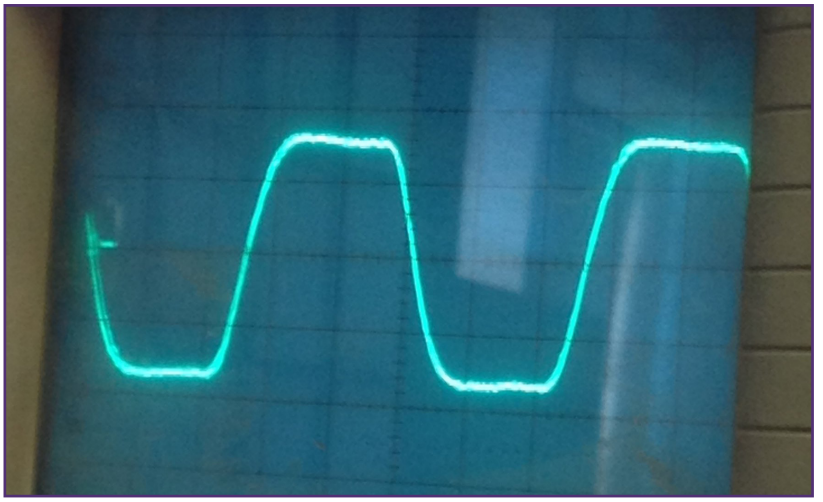


Photo 3: Here is the square wave response of the original A470 transformer at 20 kHz (1 W output).

signaling the return of the Hafler and Dynaco brands (see **Photo 2**). However, it is important to understand all the work that went into the new Dynaco ST-70 Series 3.

Power Supply

The original ST-70's power supply has long been the design area most vulnerable to legitimate criticism. We addressed this problem as follows:

- We designed an entirely new and larger dual primary power transformer with improved line regulation (due to added iron in its core). This improves bass response and enables the ST-70 Series 3 to be set for either 115 V or 230 V operation for global operation.
- The original, long discontinued 5AR4 tube has been replaced by solid-state rectifiers. This reduces the 5AR4's inherent losses while improving regulation and eliminating a failure-prone tube in the process. The benefits include more low-end impact, greater efficiency, and reliability.
- The original power supply filter capacitance has been made far larger; as large as we could fit in the space available while observing required safety clearances. This advancement has been desirable for a long time but has only recently become practical with the evolution of next generation capacitors that have been developed for computer power supplies and other switch-mode circuits. This benefits the ST-70 Series 3 with improved low-end dynamics and damping factor.
- The troublesome selenium rectifier used in the bias circuitry has also been replaced by a solid-state rectifier with additional supply capacitance. This of course improves reliability.
- The bias reference voltage is now derived from an IC voltage regulator for consistency. This improves the stability of bias settings for more consistent tube performance.
- The filter inductor has been reduced in value to complement the increase in filter capacitance with a resulting reduction of DC resistance. This makes more voltage available for use by the outputs and somewhat higher peak power output for a more impactful bottom end.
- The final filtering stage of the operating B+ voltage has been split into four streams, each with its own RC filter network to greatly enhance channel separation while lowering noise.
- The PCB has been especially carefully routed and optimized with advanced circuit development software to ensure that ground return currents from the power supply remain separate from the filtered power that operates the output stage and other separate ground returns for the driver stages. This reduces channel crosstalk, lowers overall noise including rectifier noise, and lessens overall low-level harshness or grit for more "air" when listening at low levels.

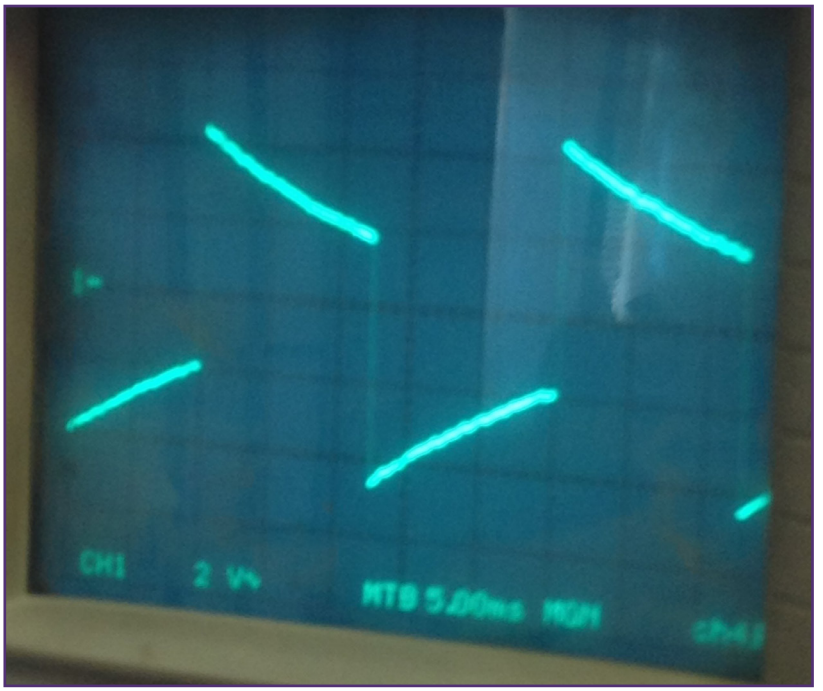


Photo 4: The bottom end is like this at 40 Hz square wave.

All of the changes serve to improve "stiffness" of the power supply by lowering the effective power supply impedance and improving regulation while increasing available voltage for maximum safe power output. This ultimately makes for a tighter bottom end. It is Dynaco's position that full electronic regulation of the plate power supply does not result

in cost-effective sonic improvement.

Output Transformer

The output transformer inside the Dynaco ST70 is often considered to be one of the primary contributors to its legendary sound. Before we set out to build a "new version," we heavily invested in the project by purchasing various ST70s ranging from the original to the updated. This laid the foundation and set the goal in finding the right transformer for the job.

We began by taking these apart and then scouring the planet to find possible solutions. After testing various "off-the-shelf" output transformers, we found that we could not find any that had the high-end response of the original David Hafler-designed A470. The square wave response of the original transformer at 20 kHz is telling (see **Photo 3**). After reviewing the test results, we were able to confirm that the response was part of what made the original amplifier so well-loved by audio fans. The image shows the square wave response at 1 W output as are all the rest of the tests herein. They are representative of the others we did at various power levels to clipping.

You can see the bottom end at 40 Hz square wave in **Photo 4**. The angle of the tilt indicates the low-end response. The less tilt the better the bottom end. Tilt is caused by both the frequency response and the ability of the power supply to deliver current at low frequencies .

Figure 1 shows the frequency response of a professionally upgraded ST70 with the original ST70 transformers in it. The amplifier that we used to obtain these results already had upgraded coupling capacitors and a somewhat upgraded power supply.

Our first attempt at a custom transformer provided the results shown in **Photo 5**. This is as good if not better than every off-the-shelf transformer we tried. Please note the vertical scales are different. The original is set to 2 V per division while this one is at 5 V per division with 20 kHz at left and 40 Hz below.

However, the bottom end was stunning in comparison (see **Photo 6**). The greatly improved power supply is a large part of the performance, but the transformer was also very important.

For our second attempt—after exhaustive work by our transformer vendor over many months including testing of the original A470—we got the results shown in **Photo 7** at 20 kHz. While the rise time is not quite as fast, that was the trade off to get the excellent bottom end. The issue is that there should be no overshoot and no ringing or distortion of the wave shape. Our listening tests confirmed that the rise time was not an issue. The lack of ringing is what makes the high-end magical. **Figure 2** shows the results we obtained with the new transformer.

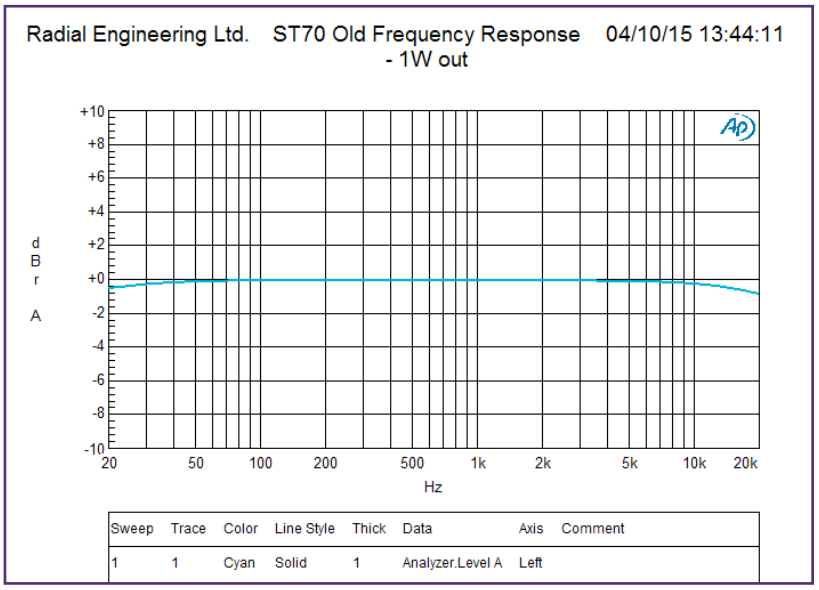


Figure 1: We obtained this frequency response for a professionally upgraded ST-70 with the original Stereo 70 transformers in it.

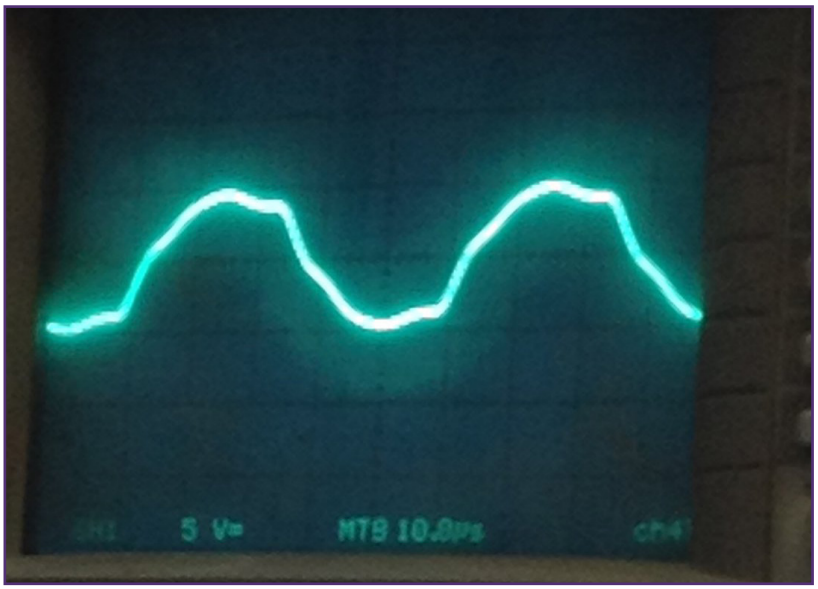


Photo 5: This was our first attempt at a custom transformer.

About the Author

Dan Fraser is one of the last electronics people to receive their basic education on tubes back in high school. A graduate of the Northern Alberta Institute of Technology, in Edmonton, AB, Canada, he has worked for more than 50 years in electronics in Alberta, California, and British Columbia. He built his first power amplifier in 1966 and has designed and built a variety of products for professional and high-end consumer audio in every technology from tubes to pulse width modulation.

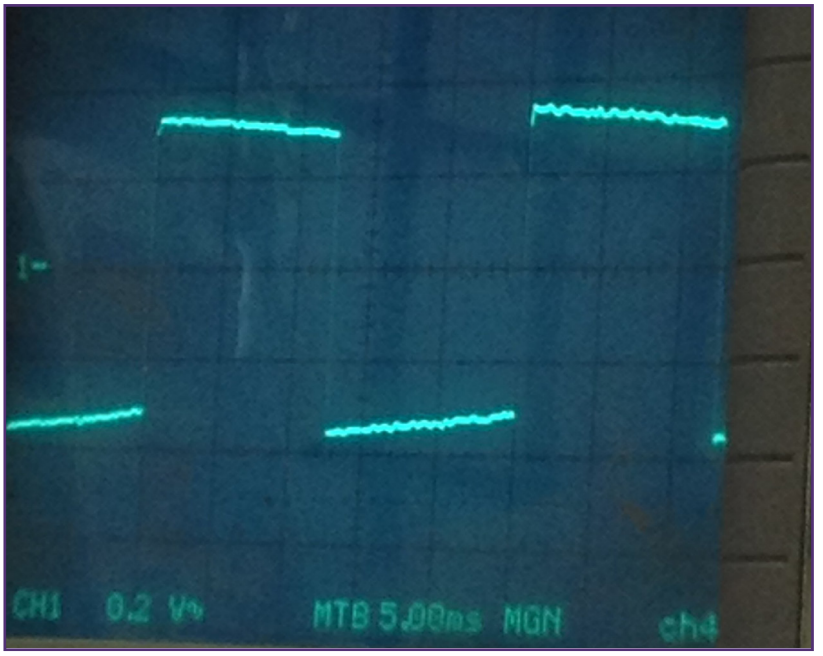


Photo 6: We achieved the bottom end shown here with our custom transformer.

Besides preserving the original transformer's high frequency and square wave responses, our transformer makers have extended the low-frequency response to do justice to current music, recorded with modern recording technology. As far as we can tell, we feel these may be the finest output transformers made for any tube amplifier ever anywhere near this price point.

Two output impedances are now offered, 4 Ω and 8 Ω with a selector switch, and feedback is taken from whichever impedance tap is selected with the switch. Everyone we surveyed felt that a 16 Ω tap was not required and the space that was freed up in the transformer allowed for heavier wire on other windings.

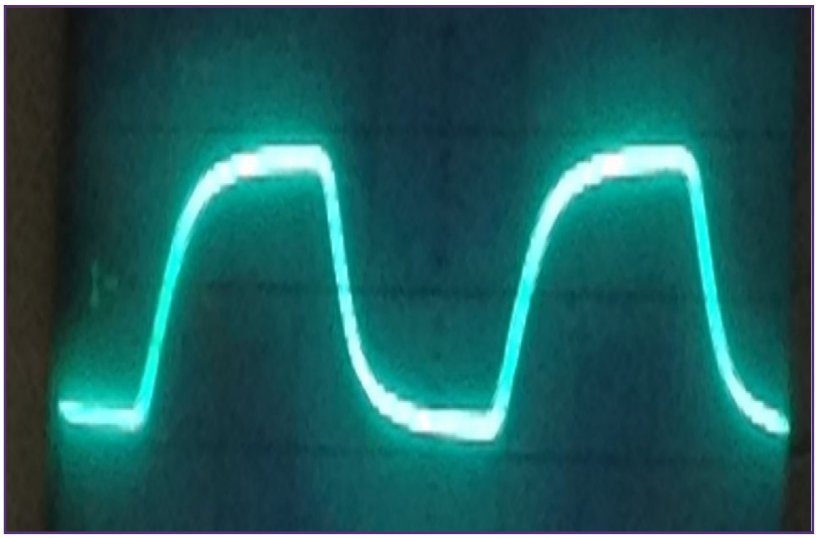


Photo 7: This is the results of our second try with new transformer.

Driver Stage

It is important to reiterate the philosophy behind the development of the ST-70 Series 3. When conceptualizing the product, we asked ourselves a simple question: What would David Hafler do if he were in our shoes today? The answer is simple: He would use the very best components, try to keep the costs under control, and deliver good value.

At this point, we ran into a brick wall. The original 7199 driver tube with pentode and triode sections that was serving as both the preamp and the phase splitter has long been out-of-production and unavailable as are all triode-pentode types except for expensive or hard to come by new old stock (NOS) tubes. David Hafler's approach would have been to find a solution that would enable the ST-70 to be produced without part shortages, while delivering the very best possible sound. So we searched and tested various options until we uncovered the best overall solution.

We recreated the design using a pair of EF86 pentodes and a 12AU7 dual triode as the phase splitter. This worked reasonably well. However, we discovered that the EF86 is only available from a single vendor and we felt the supply source was not secure and without competition, quality and price could be called into question. We built a prototype anyway and called it the 2T.

Upon further digging, we felt that it was likely that that this driver circuit was developed by David Hafler to meet a target price point based on the available parts that were obtainable 50 years ago and may not reflect what he would have done today. During his illustrious design history, David Hafler had developed a number of more advanced designs—many of which were never commercially produced.

In fact, we discovered a design that used three dual triode tubes with a 12AX7 as a voltage amplifier and a pair of 12AU7 tubes as a long tail pair to act as a phase splitter. This configuration cost little more than the original design and had very good sound quality. However, the long tail pair phase splitter has unequal gain on the two phases, which then required a trimmer to balance the phase for lowest distortion. To adjust this in the field is difficult so we would need to make sure it has been set correctly. We built one and called this the Triple Triode (3T) design.

Then, there was the advanced Williamson circuit that Hafler had drawn (see **Figure 3**). This Williamson design used a dual triode as a voltage amplifier and cathodyne phase splitter. Another dual triode is used as an additional voltage amplifier and output tube driver. The cathodyne phase splitter used here and in the original ST-70 had the advantage of being as accurate as the resistors used in the circuit. With today's proliferation of high tolerance 1% resistors,

this made investigating this option completely viable. We called this version the Quad Triode. (4T)

The next step was to build prototypes of all three designs (2T, 3T, and 4T) for comparative listening. To ensure fair testing, all three designs used the same output transformers and power supplies. We set them up for blind testing and conducted multiple tests. To ensure there would be no listening bias or sonic memory to contend with, we built a switcher that instantly switched between amplifiers and carefully made sure each had the exact same output level.

In measuring, we found after warm-up and bias adjustment the triple triode (3T) unit with the long tailed pair phase splitter had the lowest distortion by a very tiny margin, but it had to be laboriously set up with an Audio Precision test system.

The quad triode and pentode-triode designs required no balance adjustment. The quad triode design measured a slightly higher distortion through the critical 500 mW to 5 W range. The pentode-triode design measured to have about twice the distortion of the quad triode design.

In the listening phase of the testing process, we found the sound quality of the pentode-triode design to have the lowest sound quality. Still good but not as good as the other two.

Between the triple triode and the quad triode, they seemed indistinguishable in the mid and high end. Both were excellent. However, the quad triode with the cathodyne phase splitter was felt to have a punchier low end. Likely because the dedicated drivers were able to feed the EL34 grids from identical lower impedances, giving it more punch.

Our listening panel decided that while the quad triode design cost a little more to make the improved sound, the quality was worth it. All of the variations followed the original design philosophy, which is still valid today. The low open-loop gain philosophy was maintained, thereby minimizing Transient Intermodulation Distortion (TIM). TIM distortion is regarded in many circles as the type of distortion to which the ear is most sensitive.

This is why we use the lower gain 12AU7 tubes for all four driver circuit tubes as the 12AX7 had too much gain and the dynamic distortion levels seemed higher. While this approach of lower open loop gain is controversial in some circles, listening tests show a sound quality closer to true tube sound by minimizing the effect of the feedback.

Output Stage

The output tubes remain the fine EL34/6CA7, using the Ultra-Linear principle David Hafler and Herb Keroes developed under US Patent 2,710,312. However the troublesome cathode resistor originally used is now a separate high-quality metal film part for each cathode.

A further improvement in distortion, particularly in the higher frequencies, was achieved by moving the feedback point from the 16 Ω tap of the output transformer to the actual loaded tap by the double pole impedance selector switch. The switch uses one side of the switch to direct the 4 Ω or 8 Ω tap to the output terminals. The other side directs the feedback point to the tap selected and changes the feedback divider ratio so the overall gain remains the same whichever tap is selected. Transient response is improved.

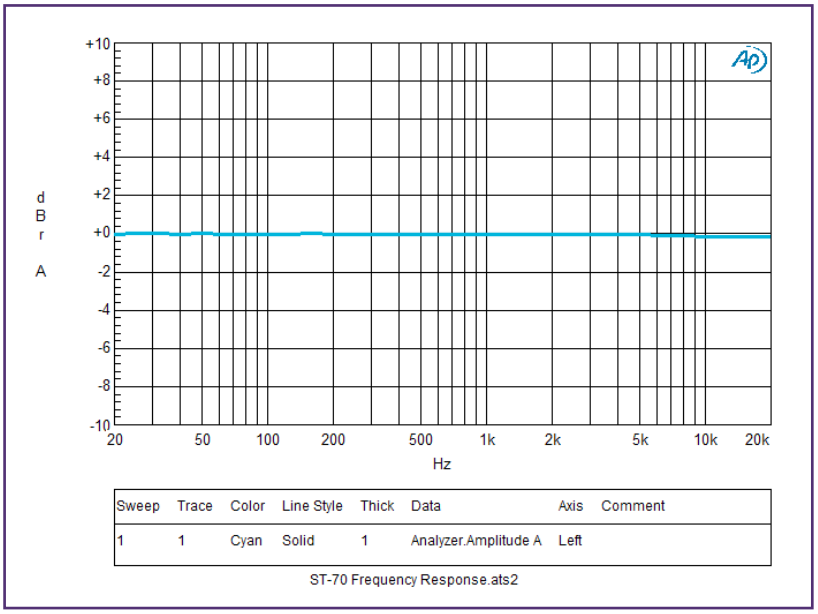


Figure 2: We obtained this frequency response with the new transformer.

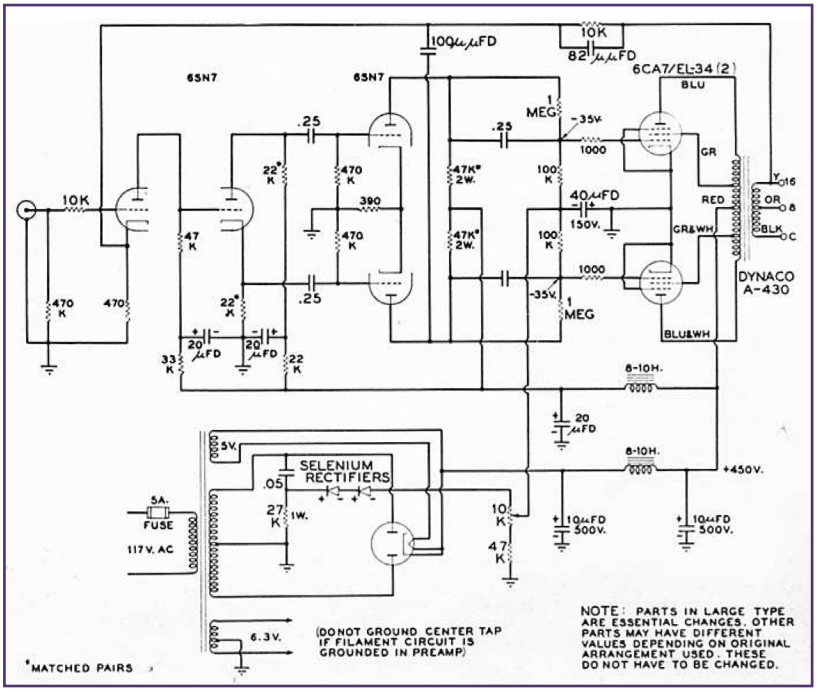


Figure 3: David Hafler drew this advanced Williamson circuit drawing.

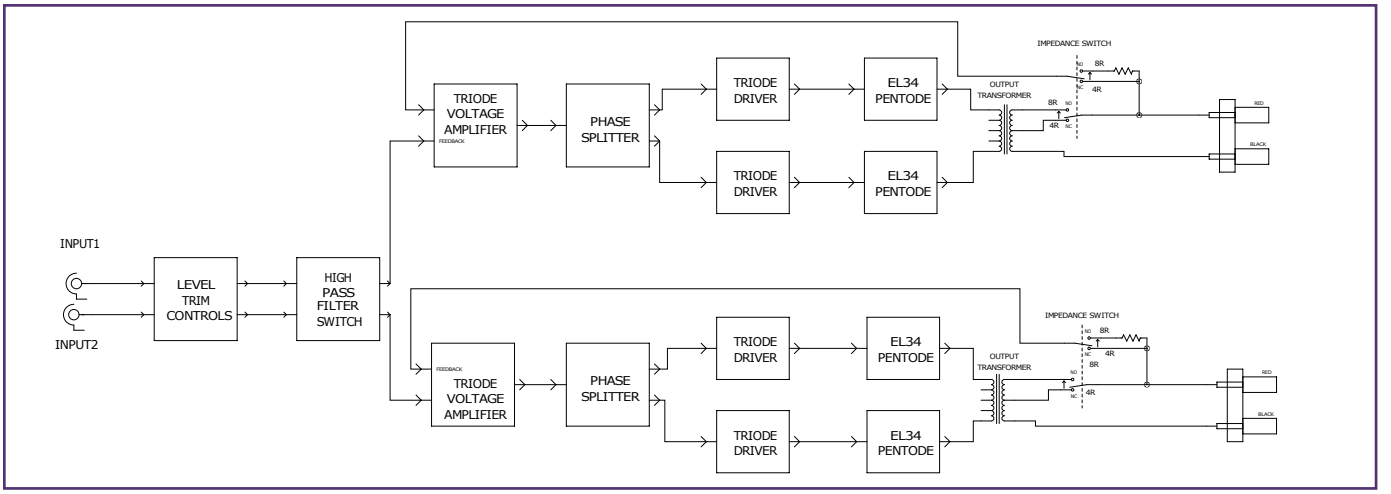


Figure 4: The block diagram details how the Dynaco ST-70 Series 3 functions.

Input Filter

reduction resulted in the characteristic distortion increase at the frequency extremes in the original Due to the extended low-frequency response the improved power supplies and the inherently lower damping factor tube amplifiers provide, operation with acoustic suspension speakers may result in an exaggerated low-frequency response. Hence, a passive high-pass, three-position filter switch is provided with a bypass position and two different frequencies of gentle 6 dB per octave roll-off. As well, there is a passive radio frequency filter well above 30 kHz to prevent picking up AM radio signals.

For best performance, the driving device should have an output impedance of 5 kΩ or lower. Operation with older equipment with very high output impedance, such as the PAS-3X, may experience some high-frequency roll-off, especially with longer connecting cables.

Block Diagram

Each channel features a dual triode device operating as a voltage amplifier and "cathodyne" phase splitter. Feedback is applied to the Triode Voltage Amplifier. Following is a second dual triode acting as a driver stage and providing additional open-loop voltage gain (see **Figure 4**). Each channel drives a pair of EL34/6CA7 power pentodes operated in the classic Hafler Ultra-Linear mode. The power pentodes drive a custom made output transformer with both the extended high frequency response of the original transformers and extended low-frequency response. The impedance taps on the transformer are selected with a rear panel switch.

The original Stereo 70's PCB material was exposed economical phenolic, which deteriorated with age, creating unpredictable electrical changes that resulted in sonic differences. The ST-70 Series 3 unit uses military-grade, double-sided epoxy fiberglass PC material and shields the recessed PCB with a solid metal chassis above it. The board is populated by

Photo 8: Adjusting the bias on the new Dynaco ST-70 Series 3.

Never Compromise on Transformers

The only parts David Hafler never skimped on were his transformers. Other than that, he used the cheapest parts he could find. Ed Dell always said that Hafler really didn't believe that quality parts mattered—carbon film resistors were just as good as metal film and ceramic disc caps were just as good as polypropylenes. I'm sure cost played a role, as well. Either way, this is a good part of the reason why Dynaco and Hafler products have been vehicles for so many modifications over the years. They were good, basic designs that usually benefited from parts upgrades. Of course, many of those modifications also involved design changes, as well.

All that said, based on what I have learned about the new ST-70 Series 3, it should be a significant improvement over the original (which was one of the highest-value audio products ever made).

—Gary Galo

Photo 9: The ST-70 Series 3 is the first Dynaco product to be relaunched since the brand was acquired by parent company Radial Engineering.

high-grade modern parts. Sensitivity to internal wiring placement is eliminated since wiring to the output tubes is accomplished via the PCB. In fact, nearly two-thirds of the trouble-prone original point-to-point wiring has been eliminated! The bias adjustment is now done with indicator LEDs (see **Photo 8**). After a warm up period and with no signal playing, all that is required is to set a pair of LEDs to equal brightness. To accommodate unequal aging between initially matched pairs of output tubes, separate adjustments are provided for both tubes of each pair.

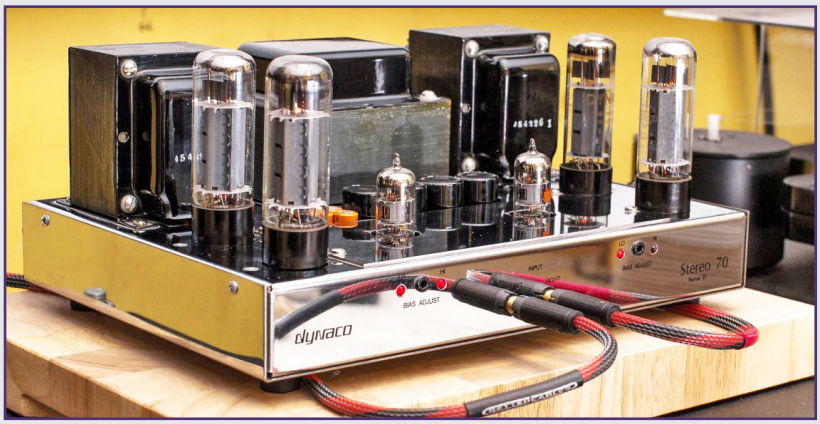
Conclusion

Recreating and improving a classic is a lot more work than any of us expected (see **Photo 9**). Our goal was to do justice to the original product, add the necessary improvements, project the vision of the original designer into a modern version that will be just as successful as its predecessor.

Is the New Dynaco ST-70 Series 3 Really Class A?

audioXpress asked this question to Dynaco's engineering team that was responsible for the new Dynaco ST-70 Series 3. In response, they agreed the Class A/Class AB issue is controversial. Dan Fraser, the engineer who led the project said, "The original was Class A up to about 10 W and Class AB above that. The Series 3 is the same."

Still, Dynaco admits that only half of the audiophile community will echo Fraser's comments. The other half will say that it's only fair to define an amplifier's class at full output (i.e., right before clipping), in which case the ST-70 Series 3 is running Class AB. Even Radial's own team doesn't agree on the classification. The Dynaco Series 2 manual called it Class A, but there's no mention of Class A or AB in the Series 1 documents.



An original Dynaco Stereo 70 Series II is shown. (Image courtesy of the Steve Hoffman Music Forums)