dynaco PAS

Compatibility

Output Loading Issues

by George Ronnenkamp
Pacific Audio Regenesis

One of the more prominent criticisms of the Dynaco PAS preamplifier is that it cannot properly drive the lower impedance loads presented by more contemporary power amplifiers. Due to its unusual output impedance characteristics, it is important to consider the effects of loading, perhaps more so than with any other vintage tube preamplifier. While this subject was covered previously, within the comprehensive line stage article, it will be covered here specifically, and at a more basic level, so as to be understandable by a wider audience. It is possibly the most important thing you need to know about the PAS. We will also examine some relatively simple modifications that can significantly improve its drive capability.

PAS 2/3 Load Considerations (not 3X)

The drive capability of a preamplifier is related to its output impedance. The lower the better, and ideally, should be at least ten times lower than the load. A peculiarity of the PAS is that its output impedance cannot be considered, in the normal sense, as being a fixed value. If you were to measure it, in the traditional manner, it would be found that it varies considerably over the audio frequency range, being quite high, at over 50K, at the low end but drops to less than 1K at the high end. The output impedance, and thus the drive capability, would appear to be frequency dependant, with the low frequency end being particularly affected. This is, in fact, the actual case, although the reason it occurs is a little more convoluted that you may imagine. In any case, this would seem to be a rather significant impediment, and indeed, more recently, some have claimed it to be an outright design flaw. But was it? It must be remembered that the PAS is a vintage piece and, as will become apparent, given the loads it was expected to encounter, its output impedance anomalies were actually not much an issue. Concerns with loading really began to emerge with the introduction of solid state power amplifiers which often presented input impedances far below what the PAS was ever expected to encounter.

The reason for the peculiar output impedance characteristic is the unusual way in which the tone controls were implemented, particularly the bass control. Fig. 1 displays the PAS output circuit, and associated power amplifier load, in greatly simplified block diagram format. Amplifier stages are represented with generic symbols and, for clarity, only the bass control potentiometer is shown since the treble circuit is not a significant factor. Notice that one portion of the bass potentiometer resides within the amplifier feedback loop, while the other portion actually appears in series with the load the PAS must drive. The bass control circuit is actually an active/passive hybrid with the load forming part of the passive portion. It is the passive portion that is primarily responsible for the variable output impedance characteristic. Note that the bass potentiometer is also bypassed with capacitors, which is the path higher frequencies take, so it is primarily the low end response that is affected.

The technical details on how the bass circuit works are covered in the line stage article, but here, suffice it to say that, in order to deliver flat low end response, with the bass control centered, the bass potentiometer must be terminated into a specific “total” load impedance of about 50K. That load is comprised of two internal resistors, 62K and 510K, plus the power amplifier input impedance. In Fig. 1 the power amplifier input impedance is shown as 500K, which happens to be the ideal power amplifier load for the PAS. The total load is thus 62K || 510K || 500K = 49.8K. This specific load will result in the flattest response when the bass control is set to center. If the power amplifier input impedance is varied significantly, particularly if it is lowered, the bass response will also change. It’s as if the bass control was moved off center and, in effect, it has been, because the load is part of the tone control circuit. How could this condition possibly be considered as being acceptable?

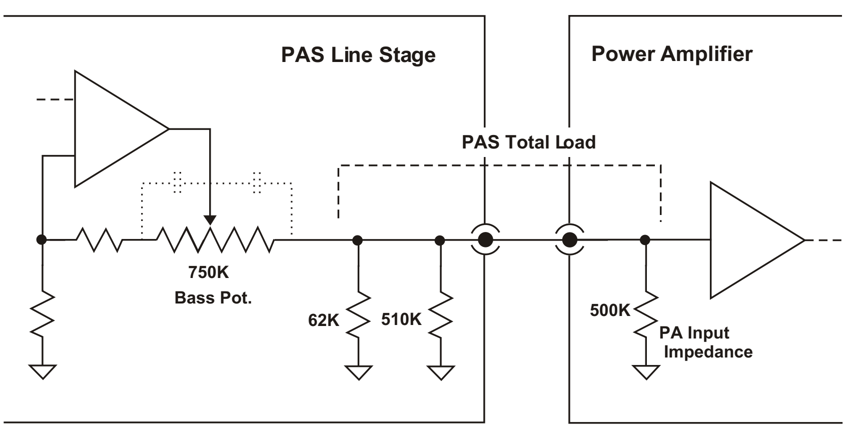

Fig. 1 PAS Load Simplified Block Diagram

Actually, this is not quite as dire as it may seem. Although 500K is ideal, a power amplifier with an input impedance of 250K would only degrade the response by about -1db at 20Hz. At this point, Dynaco recommended deleting the 510K resistor, which was located at the output jack. Doing so would restore the total load, and thus the response, back to optimal, although a change of less than 1dB would not be very audible to most. With PA impedances greater than 500K the deviation in response is even less, so no internal resistor changes were recommended. The 62K load resistor is the dominant factor and, within limits, keeps the response from deviating too far from optimum with varying "high impedance" PA loads. The PAS 2/3 was, obviously, designed to drive power amplifiers having impedances in the range of 250K and higher, which was the norm at the time. The final iteration of the PAS series, the 3X, included an innovation that did significantly improve its drive capability. More on that later.

Modifying the PAS 2/3 to Drive Lower Impedance Loads

When confronted with questions related to compatibility, once it is learned that the PAS is driving something other than a vintage tube power amplifier, resident online "experts" will often proclaim that an external buffer stage is needed, or that the PAS should be discarded in favour of something more suitable. While this may be true in some cases, there are actually a number of easily performed modifications that will allow the PAS to drive loads well below what was intended.

Load Resistor Changes

Knowing that the *total* load the PAS wants to see is about 50K, it is apparent that, within limits, the internal load resistors could be altered to maintain that value for a lower than anticipated power amplifier impedance. In fact, this what Dynaco recommended to make the PAS 2/3 compatible with their own ST-120 solid state power amplifier, as described within the ST-120 manual. Theoretically, the lower limit for power amplifier impedance would be 50K, at which point both the 62K and 510K load resistors would be removed and the power amplifier alone would provide the optimum load. For PA impedances above 50K, the internal load resistors could be altered such that their value, in parallel with the PA impedance, results in a total load near 50K. In practice, a single resistor of the closest standard 1% or 5% value (whichever is closer) will suffice.

To demonstrate that this is, indeed, the case, a stock PAS 2, in good working order, was modified to drive a PA load of 50K, the lower theoretical limit. Before modification, the tone controls were calibrated for the flatest response using instrumentation. To establish the stock, baseline performance, the frequency response was measured at 30 points from 20Hz-20KHz (relative to 1KHz) into the ideal PA load of 500K, as well as into 50K. The PAS was then modified by removing the internal load resistors, as would be required to drive a PA load of 50K, being careful not to disturb the previously calibrated tone controls. The response was then measured again driving a 50K load. In all cases, the resistive, simulated PA test load was terminated into a 3 ft interconnect cable of mediocre quality (on purpose) to best reflect the results that may occur in the real world. The total combined capacitance of the cable and measurement instruments was 232pF. The results were plotted and are displayed in Fig. 2.

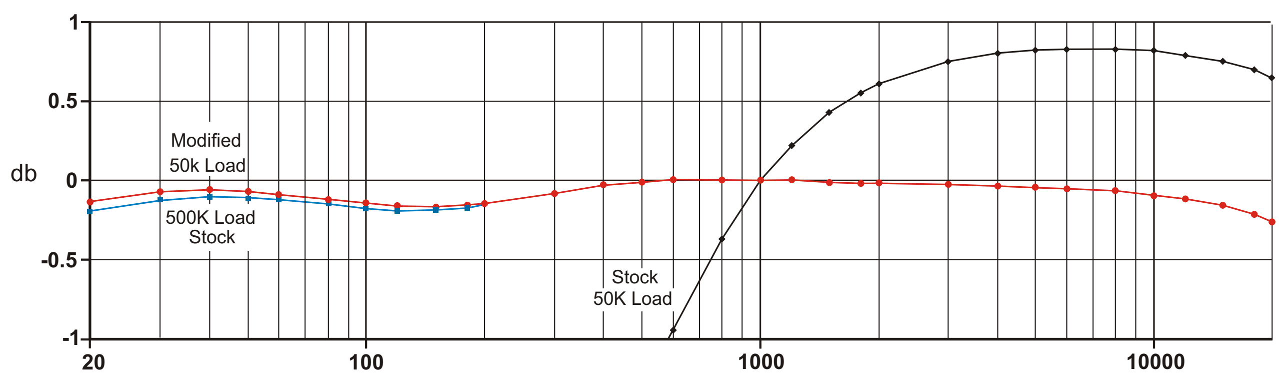

Fig. 2 PAS Internal Load Modification for 50K PA

It can be seen that the plots for the stock case into a 500K load , and the modified case into a 50K load, are virtually identical. This is the logical, expected outcome since the *total* loads are, essentially, equal and ideal in each case. In comparison, the response of the stock circuit driving a 50K PA load is dismal. Had the graph in Fig. 2 been extended, taking much of the page, it would reveal the response as being down over -4db at 20Hz. If you're wondering about the slight dip in the ideal response below 1KHz, this is typical for the PAS 2/3 and is due to interaction within the tone control circuitry. In the "real" world, the deviation will likely be more than the fraction of a db exhibited in Fig. 2. This is primarily due to the fact that the tone control flat positions are determined by eye, not with instruments. But also, flattest response does not correspond exactly to the center of potentiometer rotation, a condition that is described in the assembly manual. The tone control knobs must be installed exactly as indicated to achieve the flattest response when positioned to indicate such. This could be overlooked during assembly, but more often, was not realized as the PAS changed hands, and was tinkered with, over the years.

So, the internal load modification is a possible option if the input impedance of your power amplifier is 50K, or higher and you want to retain the tone controls. An obvious drawback is the fact that the PAS would be suited to drive only the power amplifier for which it was modified, or one with very similar input impedance. This could be a problem if you have a collection of different power amplifiers you wish to drive with the PAS.

Note:

In the practical sense, when employing load resistor modifications, it is recommended that an additional 1uF output coupling capacitor be added to the circuit as indicated below. The reason for this will become apparent in the following paragraphs.

Tone Control Bypass

If you can live without them, bypassing the tone controls altogether is the better way to extend the drive capabilities of the PAS while flattening the overall response at the same time. Fig. 3 displays the modification applied to the left channel. The bass potentiometer is bypassed by shorting both legs to the wiper. This has the dual affect of eliminating the offending high series resistance as well increasing the negative feedback at lower frequencies. The treble potentiometer is bypassed by simply removing the connection to the wiper. Disconnecting the treble control does not affect the output impedance, which was always quite low for higher frequencies anyway, however It does ensure flat high frequency response.

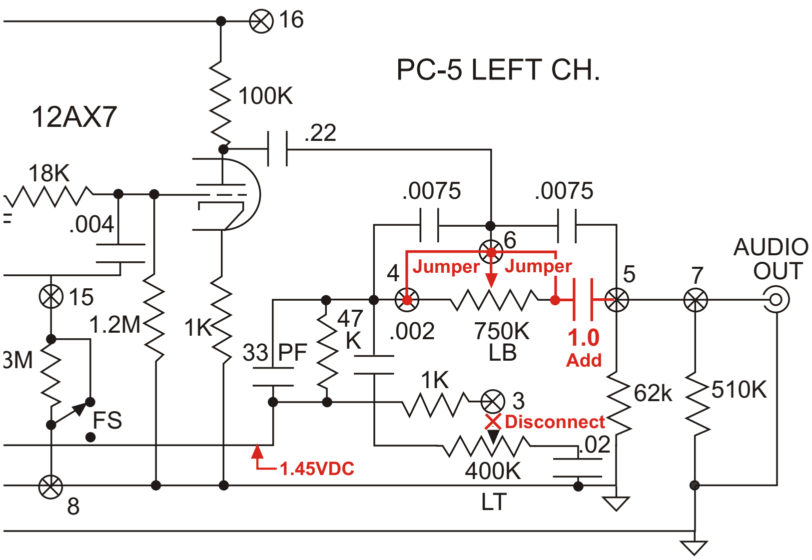

Fig. 3 Tone Control Bypass Modification

Of special note is the 1uF capacitor that is not present in the original circuit. An oddity of the PAS 2/3 (not 3X) is that a small DC voltage, of about 100mV, is present at the output. Its origin can be traced back to the cathode of the first stage of the line amplifier where it begins at about 1.45V. From there, it passes through the 47K feedback resistor and 750K bass potentiometer then appears at the output at reduced voltage due to the voltage divider action of the 62K and 510K resistors to ground. When the bass potentiometer is bypassed, a major portion of the voltage divider is eliminated and the DC voltage appearing at the output rises to over 800mV. While it is common for power amplifiers to be AC coupled at the input, this is not always the case. In fact, some of Dynaco's own tube power amplifiers were DC coupled. While they would tolerate 100mVDC at the input, increasing that to 800mVDC could result in stability issues, thus the additional coupling capacitor to block the DC. The coupling capacitor also became a necessity in the PAS 3X, as we'll see, and Fig. 3 shows where it was implemented. It is also advisable to include the coupling capacitor when performing the internal load resistor modification described above, since the DC voltage appearing at the output will also rise as the load resistors are increased in value, or removed altogether.

To confirm the performance of the bypass modification, the same PAS 2 test amplifier was modified as indicated in Fig. 3. The response was measured at 30 points from 20Hz to 20KHz using the same test setup that was used during the load resistor modification tests. Test loads included 100K, 50K and 20K. The results were plotted and are displayed in Fig. 4.

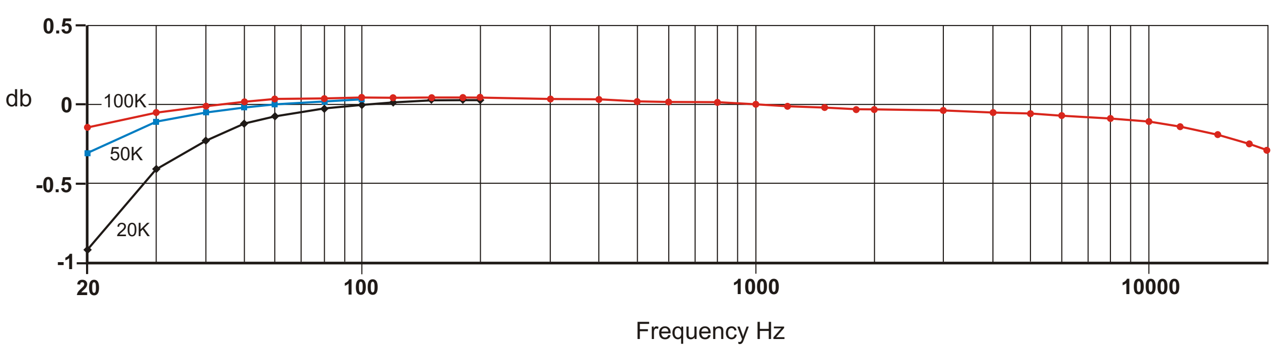

Fig. 4 Tone Controls Bypassed

With the tone controls bypassed, the power amplifier is driven directly by the output of the PAS line stage with no offending resistance in between. It no longer needs to see a specific load impedance. The output impedance of the line stage, itself, is quite low at less than 1K due to the negative feedback it employs, thus the improvement in drive capability is substantial. Test loads of 100K and 50K presented little challenge, the response being down only -0.15db and -0.3db respectively at 20Hz. Even with the 20K load the response was still within -1 db at 20Hz. These results are typical when the tone control bypass is implemented in its most common form, as depicted in Fig 3. but can be further improved upon. At lower frequencies, the reactance of the 1uF coupling capacitor, which is outside the feedback loop, becomes more of a factor than the output impedance of the line stage. For example, doubling the value to 2uF will make the response, with a 20K load, about the same as it was with a 50K load and a 1uF coupling capacitor. As well, the 62K and 510K resistors are not actually required any more, and only serve as an additional load burden. They could also be removed further extending the drive capability while lowering the capacitance required for the coupling capacitor.

Note:

The tone control bypass modification is commonly employed to maximize the performance of the line stage even when loading is not particularly an issue. It is likely the simplest modification that can be done that results in a measurable, and often audible, improvement in performance.

What About the PAS 3X?

The 3X was the final iteration of the PAS series and the circuitry is pretty much identical to its predecessors, with one important exception. The tone control potentiometers were of a special design resulting in them being out of circuit when set to the center position. Essentially, the potentiometers, themselves, performed the bypass function, in a manner much like that shown in Fig. 3, resulting in the same improvement in drive capability and linearity. The additional coupling capacitor is also included in the 3X and, in fact, became a necessity so that the elevated DC did not appear at the output when the bass control was set to the bypass position. The 62K and 510K internal load resistors are still present and are required for proper operation of the bass control when it is moved off center and a portion of the potentiometer is, once again, in series with the load. The magnitude and sensitivity of the adjustment is load dependant. This may be the reason Dynaco recommended a minimum power amplifier impedance of 100K, *in stock form,* even though the 3X was much more capable when the tone controls were set to center, effectively bypassing them. It is interesting to note that Dynaco recommended removing the 62K load resistors to make the PAS 3X compatible with their own ST-150 solid state power amplifier, which had an input impedance of only 35K. As it happens, in stock condition, with a 100K PA load, the *total* load is also about 35K. So, generally, the load resistors should remain in place, and not deviate too far from stock values if you want the bass control to work properly. It is still possible to increase the value of 1uF coupling capacitor further extend the low frequency drive capability, in the bypass position, if you feel you need it.

Note:

There are some technical differences in the way the tone controls operate compared to the PAS 2/3, related to the construction of custom potentiometers. This is described in detail in the line stage article. However, the bypass function is, essentially, the same as that indicated in Fig. 3.

Summary

It is important to remember that the PAS is a vintage piece and was well suited in its role when mated to power amplifiers of the period, or more current tube amplifiers with similar input impedance characteristics. If this is the environment in which your PAS lives, you need not be concerned. However, if that is not the case, then you must be aware of the affects of loading and understand what the options are to achieve compatibility.

There are, of course, other tube preamplifers, both vintage and more current, that do posses greater drive capability than the PAS. You may want to consider one of these if your intent is to drive lower load impedances, especially if you do not already own one or are unwilling or unable to undertake any modifications. On the other hand, if you already own a PAS, or really do want one, the drive capability can be improved considerably if you are able to perform some relatively simple modifications, as described within this article. Modifications such as alleged upgrade boards are not included here, not because they are unviable, but because, once installed, the PAS ceases to be a PAS. Of course, an external buffer stage has always been an option for those capable of implementing it, and will also allow the PAS to remain a PAS.