12AU7 to 6CG7/6FQ7 conversion

Posted by **Michael Samra (D)** on July 14, 2009 at 21:14:40

is a necessary improvement for any amp using a 12au7 such as all your Macs,Heath W5ms,Piliot 232's and the list goes on and on..In the preamp,I usually just sub 5814s or black plates but in Amps with 12au7s,6cg7 no question!!
Williamson Tube Amplifier Modifications
The Williamson Amplifier â€“ Notes on Improving the circuit â€“ DCB, Chimera Laboratories

The importance the Williamson Amplifier had on audio amplifier design can be best judged by its popularity. Just about every audio amp manufacturer built â€œWilliamsonâ€ amplifiers. In most cases they copied the circuit exactly, choosing the 6SN7, 6CG7/6FQ7 or 12AU7 for the voltage amplifier, phase inverter and push-pull driver stage.

Today the amplifiers are still highly regarded and rightfully so. In fact you can still buy kits and commercial amplifiers that are exact copies of the original circuit. Its circuit(with simple modifications is even used in Single Ended amplifiers.

Some audio enthusiasts have noticed that the amplifiers sound better when they are connected to efficient speakers. In fact when they are connected to less efficient speakers, two design flaws surface. At higher output levels they exhibit high levels of distortion and instability. In 1961, Talbot M. Wright published an insightful analysis of the circuit in Electronics World, highlighting these two problems. Fortunately he also told us how to fix them and his recommendations form the basis of this article.

When the modifications are implemented, the â€œWilliamsonâ€ circuit is capable of outstanding performance at any power level. It is also capable of driving just about any push-pull pair of power tubes you care to employ. In many respects, this timeless â€œclassicâ€ elegant circuit is really hard to beat.

Before we get into the circuit itself, I would like to share an opinion about tube selection. Of the three tubes commonly used the 12AU7s are not as linear as the 6SN7 or 6CG7/6FQ7s. If your amplifier uses the 12AU7 tubes, you should consider converting to 6CG7s or 6FQ7s. The 12AU7 uses a 9A Base and the 6CG7/6FQ7 uses a 9AJ Base. The only difference is the connection of the filament voltage. In the 9A base one leg of the filament voltage is connected to the number 4 and 5 lugs and the other leg is connected to the number 9 lug. To convert to the 9AJ base, simply move the 4 and 5 leg to the number 4 lug and move the number nine leg to the number 5 lug. Vintage RCA 6CG7/6FQ7s are very good. EI in Yugoslavia was making a nice sounding tube if you can still source it.

The reason that the stock Williamson circuit is higher than 2% at over half rated power output is that the 6SN7, 6CG7 and 12AU7 Tubes are badly under-biased. Fixing this just requires the change of a few resistor values to bias the tubes properly. These changes produce more drive voltage and the driver stage stays in Class A operation.

I sort of take a try one step at a time and listen to it approach to making any changes. I make a change in one channel and compare the change to the stock channel by listening in mono. This also catches any mistake I made such as a bad solder joint or installing something to the wrong terminal. I donâ€™t do that often any more but I like to hear the difference each change makes.

1. Letâ€™s start at the input of the amplifier. Most â€œWilliamsonâ€ amplifiers have a series of grid resistors and a DC blocking capacitor in the input circuit to the first tube stage. If you are concerned about DC offset coming out of your preamplifier, leave them in. If you are interested in better sound performance pull them out. Leave the 470K grid to ground resistor and install a 330 ohm to 500 ohm grid resistor between the 470K resistor and the input pin of the tube(lug 2 or 7). Keep the lead on the tube base side as short as possible(1/8â€-1/4â€).

2. The bias resistor on the cathode of the first tube stage(lug 3 or 8), is usually 470 ohms. This should be replaced with a 1000 ohm resistor(metal film if you please, Roderstein is the best). This raises the bias voltage to around 3 volts. It also changes the grid cathode bias on the next stage, the phase inverter, but we can fix that by making the following changes. These changes will reduce the supply voltage to the first stage and increase the voltage to the phase inverter stage.

The average Williamson circuit uses a 15000 to 33000 ohm isolation resistor to decouple the first stage from the 450 Volt power supply. This resistor should be changed to around a 47000 ohm resistor. This will cut the current through the first stage and your bias voltage will be around 2.5 volts.

The stock power supply decoupling resistor of 22000 ohms to the phase converter stage should be reduced to 3900 ohms. This increases the current through the phase inverter and raises its cathode bias. When all these changes are made you should measure around 2.5 Volts at the cathode of the first stage, and about 5.5 to 7 volt bias from the grid to cathode voltage of the phase inverter. Due to you mains line voltage or some variations in power supply voltage you may measure these exact voltages, but it should be close enough to allow these two stages to bias each other correctly.

3. The push-pull driver stage usually has 47000 ohm plate load resistors and the original cathode resistor is 560 ohms. This produces a bias of slightly over 5 volts with about 175 volts on the plates, a very poor operating point for these tubes. Some vintage amps will have higher resistance values installed, since this design flaw was caught early on. You want to use a resistor with a value of 1200 ohms or higher. The correct bias is approximately 9 volts and there will be around 250 volts on the plates of the tubes.

4. Since the value of the bias resistor on the first stage is doubled you have significantly increased the global negative feedback of the amplifier. To compensate you need to double the value of the feedback resistor to reduce the feedback back to its original level. You may want to try increasing the feedback resistor even more to reduce the feedback to a value that sounds best to the speaker you have the amplifier connected to.

The net result of these last three changes is to almost double the drive voltage available to the input grids of the output tubes. A 450 volt supply you will get over 100 volts to each grid. Even with as little as a 350 volt supply you will still get about 80 volts of drive per grid. Now any Williamson amplifier should not produce 1% distortion until it reaches overload. If the drive voltages to the grids of the output tubes are balanced the distortion should be well below 0.5%.

All of the above changes have cut distortion dramatically, but there are still some other opportunities. The high frequency response of many Williamson amplifiers can be improved. The RC network bypassing the plate load of the first stage is not critical. The value that must be carefully selected is the capacitor across(in parallel) with the feedback resistor. Usually about 50pf to 250pf is found in this network. The only way to optimize the value is to use an oscilloscope. Fortunately the low-frequency transient response is easier to improve.

5. Most Williamson amplifiers(actually most tuber amplifiers) sound soft when they try to reproduce high levels of bass information. This is due to the poor decoupling of the B+ power supplies. In the Williamson amplifier. The first tube stageâ€™s power supply capacitance should be increased from 20uF to at least 40uF to 60uF. The phase splitter stage capacitance should be increased to 80uF to 100uF. The push pull driver stage capacitance should be increased to 60uF to 80uF. Finally the capacitance to the center tap of the output transformer should be increased to at least 100uF, better yet 200uF. Do not increase the 20 uF capacitance value of the filter capacitor/s between the rectifier tube and the choke. Doing so will cause premature failure of the rectifier tube.

The stiffer and better isolated power supplies will not only improve transient performance, but improve the stability of the amplifier. The amplifier will handle difficult loads and high peak power requirements with ease.

The final changes to consider are the use and size of bias capacitors on the first stage and output stage of the amplifier. The use of a cathode bias capacitor on a bias resistor of a tube stage has been a misunderstood and contentious subject. I must admit when I read Talbot Wrightâ€™s analysis on this, I was somewhat skeptical. I have always felt the only way to find out whether anything works in Audio is to try it. It works! I have taken the liberty to quote his analysis verbatim:

â€œThe capacitor bypassing the cathode resistor of the output stage(of the Williamson amplifier) is somewhere between 20uF and 250uF. Use of the 250uF capacitor bypasses the stage to around 6 cycles, that is, the stage is flat to about 10 cycles. Low-pitched musical wave shapes contain near-DC components and in order to handle these adequately you must have the output stage bypassed to approximately 1/10th of the lowest frequency you wish to reproduce.

If you want to have good transient response below 60 cycles, you have to bypass the output stage more heavily than 250uF. Capacity of 500-600uF will bypass the output stage to about 3 cycles and will give good transient response to around 30 cycles.â€

6. Well my listening evaluations in my opinion have proved him right. A capacitance value of 660uF to 820uF provides superb performance. Be careful not to go overboard using large bypass values may lead to instability and instead of an amplifier you have an oscillator your loudspeakers will not appreciate.

7. Finally, I recommend you install a bypass capacitor on the cathode of the first stage tube. In fact, I have found you can voice the amplifier to work best in your system(after all the above modifications) by selecting the right capacitance value of this bypass capacitor. It should be somewhere between 100uF and 470uF.

You should use good â€œAudio Gradeâ€ bypass capacitors on the output stage and the first tube stage. I recommend the Nichicon Muses or the Elna Cerafines or Silmics. Sanyo also has some very good sounding capacitors(solid types). I have not had much personal luck with the Black Gates. I preferred the sound of the other types, but if your ears tell you they are superior, by all means use them.

Certainly you can also consider better connectors, capacitors, resistors and hook-up wire. I like the Rel-Cap tinfoil and polystyrenes for signal capacitors. Continuous Cast copper for hook-up wire and copper content solder. For resistors, I use the Mills Wire Wounds for power supply and high wattage bias resistors, 2 Watt carbon film for plate resistors and Roderstein 1 and 2 Watt resistors for everything else.

Once you are done with the changes, you will find you have an amplifier that will do a wonderful job of reproducing music. One that will compare favorably with any push-pull design tube design, either vintage or current â€œhigh endâ€ products.

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"For every complex problem there is an answer that is clear, simple, and wrong" H. L. Mencken

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