

Ming Da MC368-B90 KT90 Push Pull Amplifier Re-Engineering

Introduction

A few months ago I acquired a used Chinese KT90 tube amplifier. The former owner of this amplifier sold it to my younger brother, but my sister-in-law did not like it so it was dumped in a corner. My brother approached me to see if I might be interested in it. At that point, I had no real intention to add anything to my audio system. However, the price was so attractive that I could not resist but give it a try. The amplifier was a Ming Da MC368-B90. It is a integrated amplifier equipped with a pair of KT90 as output in push-pull mode, 6SN7 as driver and phase splitter, 12AX7 as input. The volume is remote controllable. In addition, there were 2 pairs of brand new KT88 as spares. All these added up to only US\$250, a nice deal indeed.

I never owned any tube power amplifier before. My system comprises of a DIY FirstWatt B1 buffer with a DIY Nelson Pass PLH amplifier. I do have a DIY phono amplifier which is a combo-design based on Allen Wright FVP5 and TubeCad Journal (TCJ) Tetra phono. That phono stage is the only vacuum tube device in my system. Frankly I am very satisfied with all these.

Upon taking the Ming Da back home, I immediately plugged it in and checked its sound. The first impression was surprisingly good. The sound stage was wide and deep, bass was forceful and treble was very clear. Compared to the PLH, I would describe the sound of Ming Da as vibrant and colourful. It certainly provides a very exciting experience to the listener. I was not sure if this came with a tint of colouration but anyhow I was happy to keep it plugged in and used it as the main amplifier for an in-depth evaluation.

After about a month of usage, I was still happy with the sound of the Ming Da. However, a few issues did show up:

- The gain of the Ming Da is very high. I never need to turn the volume knob over the 9 o'clock mark to get the volume level I want. It was then very difficult to make fine adjustment to the volume due to this high sensitivity. The remote control was basically unusable as one key press brought substantial changes to the volume.
- There was a rather noticeable hum noise.

The idea of modifying the Ming Da came up naturally. One reason I never attempted to made a tube power amplifier before was associated with the headache in the acquisition of the components, primarily the power transformer and the output transformers. With the Ming Da, all these become on-hand.

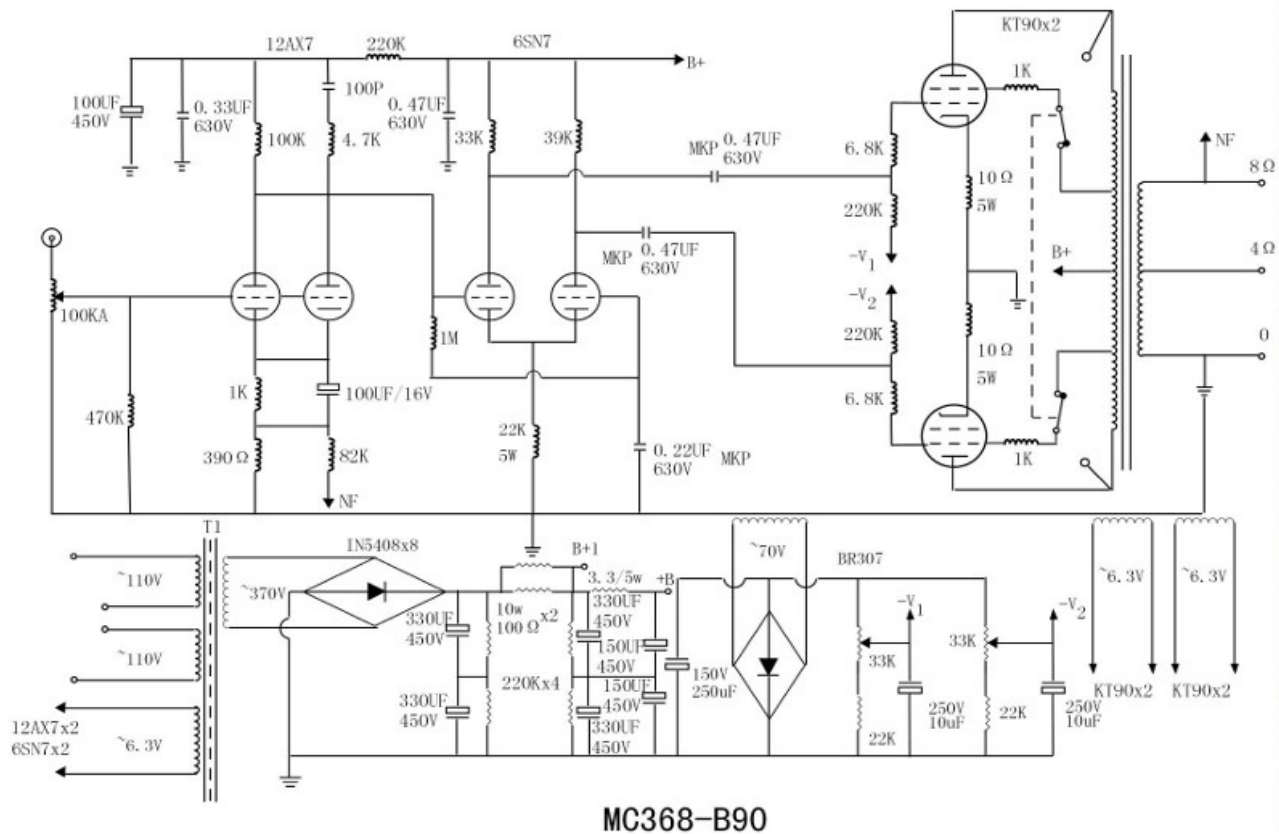
I drew up a list of requirement to find out how big the job might be:

- The major components will be re-used. These include the power transformer, the output transformers, the tubes (KT90, 6SN7, 12AX7), the power supply capacitors.
- The KT90 Push-Pull should operate in pure Class A mode. Output power level to be determined but should be higher than my PLH (10W Class A).
- Reduce the overall gain as I do not need that much, and improve the usability in volume control.
- Employ modern tube circuit ideas if possible.
- Lowest practical cost and effort.

Here is my thought process and results.

The Stock Ming Da Amplifier

There was zero documentation came together with the Ming Da. A search in the internet also did not give much. Fortunately I was able to locate a schematics.



I checked the circuit against this schematics and found that it was fairly accurate with only a few discrepancies. The circuit design is rather standard. The two 12AX7 triode sections are wired in parallel in common cathode mode. They are coupled to two 6SN7 wired as a long tail pair (LTP) phase splitter. The KT90 employs fixed bias and can operate in either Triode or UL mode. Global NFB is adopted.

A very brief specification could be found from the internet. The ones of interest to me:

Output Power:	75W UL mode
	40W Triode mode
Power consumption:	250W

The output transformer

Being the most important component affecting the design, I need to know more about the output transformers. One important parameter needed to be measured: the turn ratio of the output transformer. I made a quick test by sending a 10mV 1kHz signal to the 8 Ohm speaker terminals and measure the anode-anode voltage on the primary side. It was

about 220mV. Hence the turn ratio is about 22 for the 8 Ohm connection.

The impedance ratio is $22 \times 22 = 484$. For 8 Ohm load, the anode-anode impedance is thus $8 \times 484 = 3872$ Ohm, or 4K Ohm. With Class A PP operation, the load seen by each KT90 is half of the anode-anode load, so 2K Ohm approximately. Like it or not, this is the value I have to live with.

I had no way to determine the power rating of the output transformers. The 40W Triode mode output listed in the specification should most likely be based on Class AB1. That anyhow provides some hints on the power capacity of these OPTs.

How Much Class A Power?

Everyone want more power, but we need to tame our desire and ask how much I really need? The 10W PLH works fine in my apartment and I had no experience of any clipping so far. 10W should be fine for me. In addition, I need to consider the capacity of the hardware. In this case the power transformer and output transformers in particular.

I had no information about the capacity of the Ming Da power transformer. The product specification says overall power consumption is 250W. Hence the power transformer should be capable of delivering 250W. I made some calculations.

4 x KT90 heaters consume $6.3 \times 1.6 \times 4 = 40W$

2 x 6SN7 heaters consume $6.3 \times 0.6 \times 2 = 7.5W$

2 x 12AX7 heaters consume $12.6 \times 0.15 \times 2 = 4W$

Just these heaters already consume about 50W, leaving only 200W for the amplifier circuit. Assume the input and LTP stages consume 30mA in total for 2 channels, with 500V supply this will consume 15W. I am left with about 180W available to the output stages. Assuming 25% efficiency for Class A, the output power per stage is $180/2 \times 25\% = 22.5W$. The calculation does not account for losses in the transformers and other stuffs so 20W/channel seems to be the reasonable level.

I made a table to determine the Class A operating current with 8 Ohm load:

Class A O/P (W)	Spk I rms (A)	Spk I p-p (A)	Pri I p-p (mA)	pri idle I (mA)	Tube idle I (mA)
5	0.79	2.24	102	51	25
8	1.00	2.83	129	64	32
10	1.12	3.16	144	72	36
12	1.22	3.46	157	79	39
15	1.37	3.87	176	88	44
20	1.58	4.47	203	102	51
25	1.77	5.00	227	114	57

With 20W Class A, the output tube should be biased to 51mA. That basically defines the working point.

KT90 or KT88?

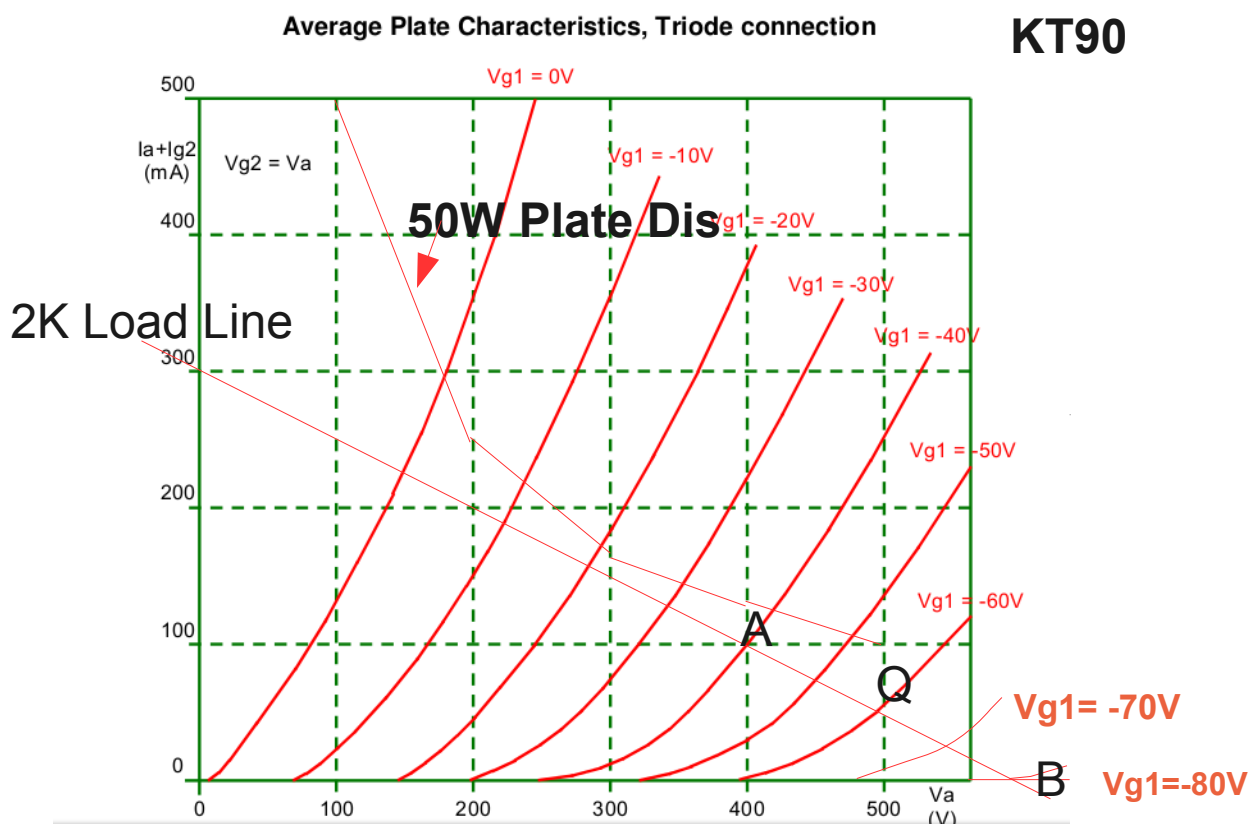
I was not aware of the existence of KT90 before taking this amplifier, on the contrary KT88 was a famous vacuum tube. A search in the internet does indicate that KT90 is not that common, datasheets are brief and rare. Furthermore, I have not yet found a DIY project using KT90, at best it is a KT88 project with hints that KT90 can be used as alternative. An idea came up: should I switch to KT88 (remember that I have 2 pair as spares)?

I constructed the load line for both KT90 and KT88 to see if there can provide useful hints. The binding conditions:

Supply voltage = 500V (fixed by the power transformer)

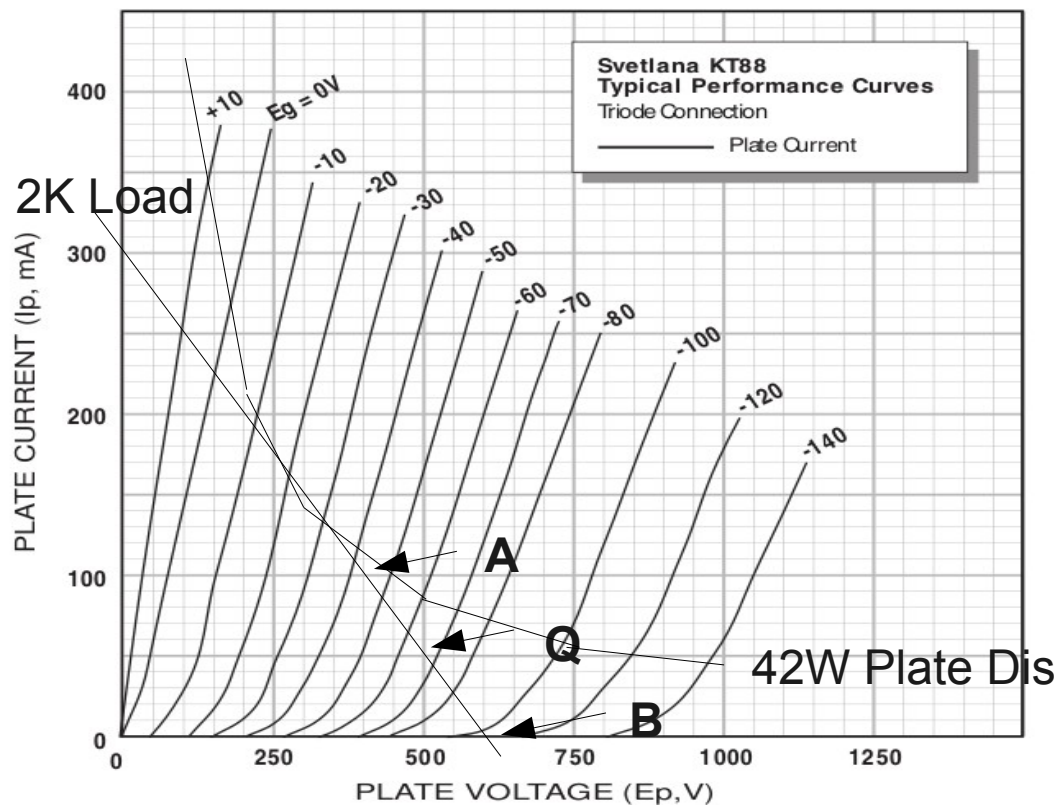
Load = 2K Ohm (fixed by the output transformer)

Bias current = 51mA (to give 20W Class A output)



The above is based on the best KT90 curves I can find. The 2K Ohm load line is drawn and AQB represents the region of operation. I also add in the -70V and -80V V_{g1} lines (by wild guess). Q is the operating point with $V_a = 500$ V, $I_a = 50$ mA, $V_{g1} = -61$ V. When signal swing to point A, $V_a = 400$ V, $I_a = 100$ mA, $V_{g1} = -40$ V. When signal swing to point B, $V_a = 600$ V, $I_a = 0$ mA, $V_{g1} = -80$ V. So the output swing a +100V/-100V with an input swing -19V/+21V. Linearity is very good. The plate dissipation "curve" of 50W is also added and load line AQB is within the safe zone.

Turning that to KT88:



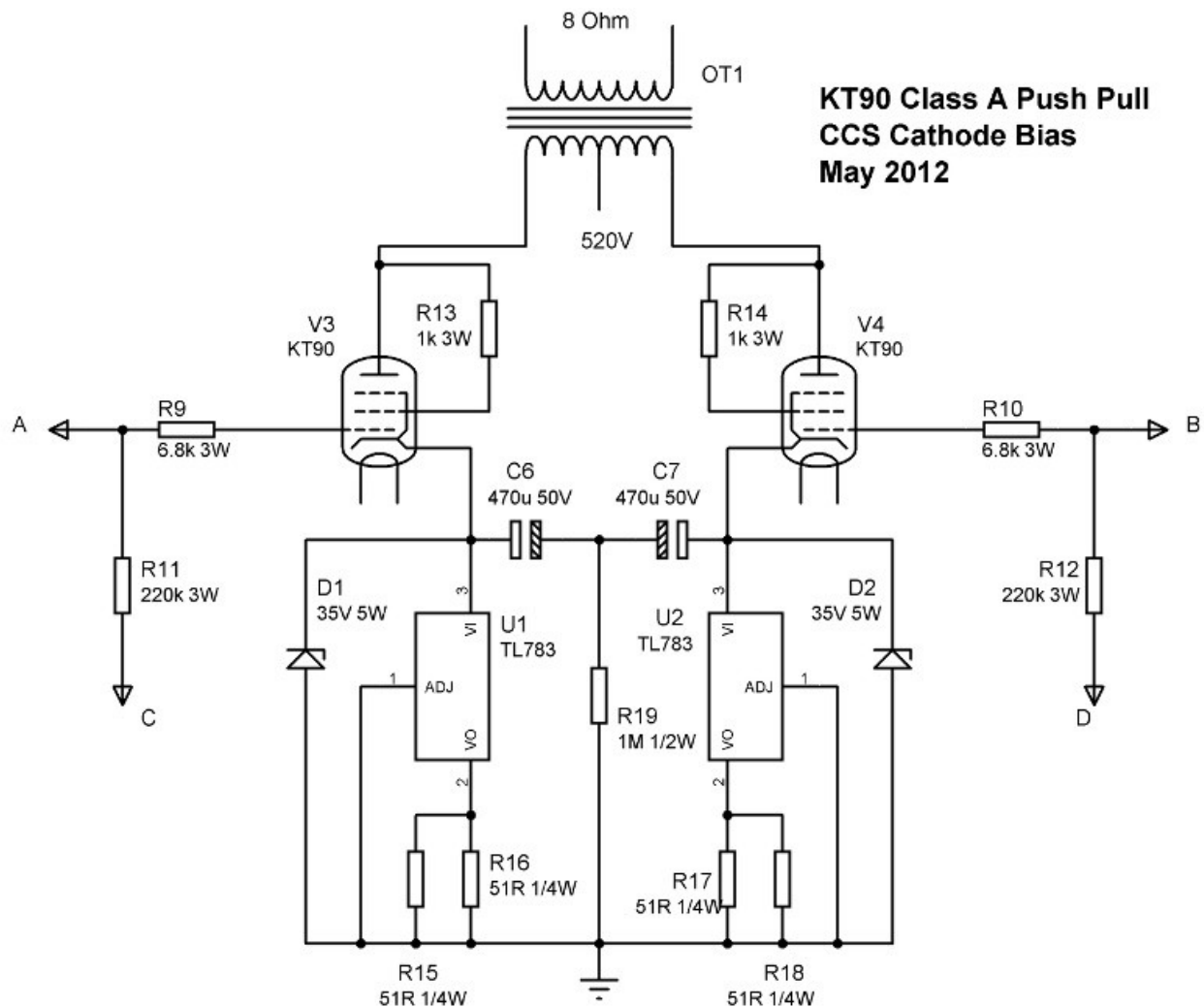
The 2K load line and point AQB are added as above. At point Q, condition is $V_a=500V$, $I_a=50mA$, $V_g=-67V$. At point A, $V_a=400V$, $I_a=100mA$, $V_g=-43V$. At point B, $V_a=600V$, $I_a=0mA$, $V_g=-105V$. So the output swing $+100V/-100V$ with an input swing $-38V/+24V$. Linearity is much worse here compared to KT90.

It is very clear from the load line study that the KT90 is a much better choice in my application.

Output Stage

Having decided to stay with KT90, the output stage design follows. Here I take the risk to employ a non-conventional approach to use the concept of constant current sourced cathode bias described in TCJ (13 Aug 2011). The TCJ website provides a detailed discussion of this configuration. In simple terms, the idea is to place a constant current source (CCS) at the cathode of the output tubes instead of the normal resistor. TCJ provides a cascade of design options with this approach but I do not go all the way to the end. I only put a zener in parallel with the CCS, and that means I must always stay within Class A. I do however employ individual CCS for each KT90 as this will ensure each KT90 be biased equally at about 50mA.

The output stage schematics is shown here. The CCS is formed around a TL783 regulator. Two 51R resistors in parallel define the current ($1.27/25.5 = 49.8mA$). With 2 resistors in parallel, the deviation in resistance can be statistically reduced and hopefully the bias current in all KT90 will be matched more tightly. The 35V zener diode prevents the cathode voltage to rise excessively due to overdrive. The 470uF capacitors provide AC coupling between the 2 cathodes. The KT90 always works in Triode mode.



The grids are tied to negative voltages to reduce the voltage drop across the TL783. The target voltage levels of the cathodes are +10V.

Reading from the Load Line diagram, the grids will be biased at -51V. The gain is about 10X (+100V/-100V output swing from -19V/+21V input swing, and doubled due to push pull action). With 22X turn ratio, the overall output stage voltage gain is $10/22 = 0.45X$ (-6.9db).

Input Stage and Phase Splitter

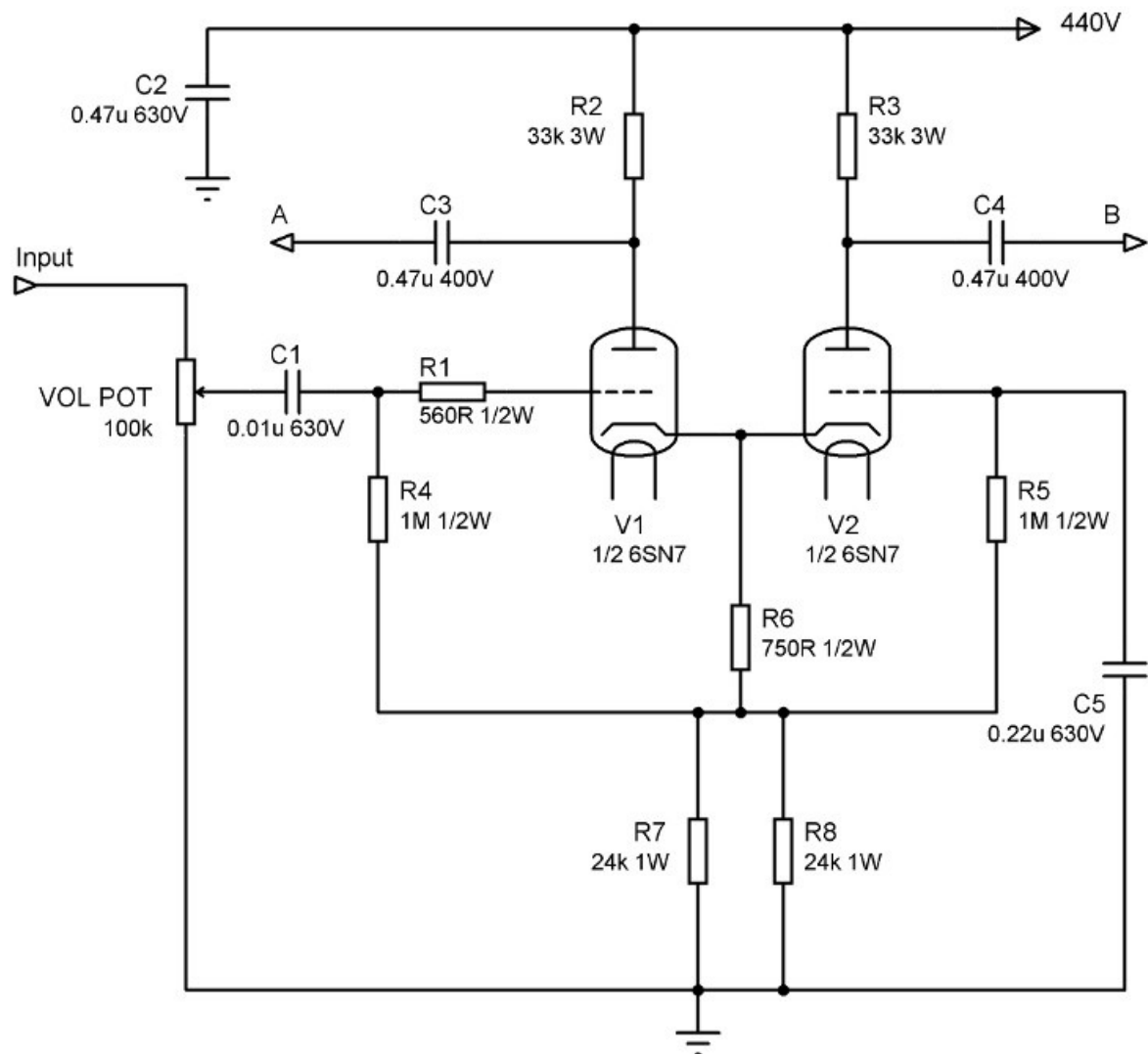
The stock Ming Da amplifier employs 3 stages. As noted above, the gain of the stock amplifier is too high in my application. It makes a lot of sense to cut this down to 2 stages. Not only the gain will be tuned to a more practical level, but 1 less stage means 1 less set of distortion. Just to be sure there will be sufficient gain left, the global NFB is also eliminated.

I selectto redesign the 6SN7 LTP phase splitter and made it also function as the input stage. Essentially I followed the steps outlined here:

<http://www.aikenamps.com/LongTailPairDesign.htm>

I kept the anode resistor at 33k, which is the stock Ming Da value. I made both anode

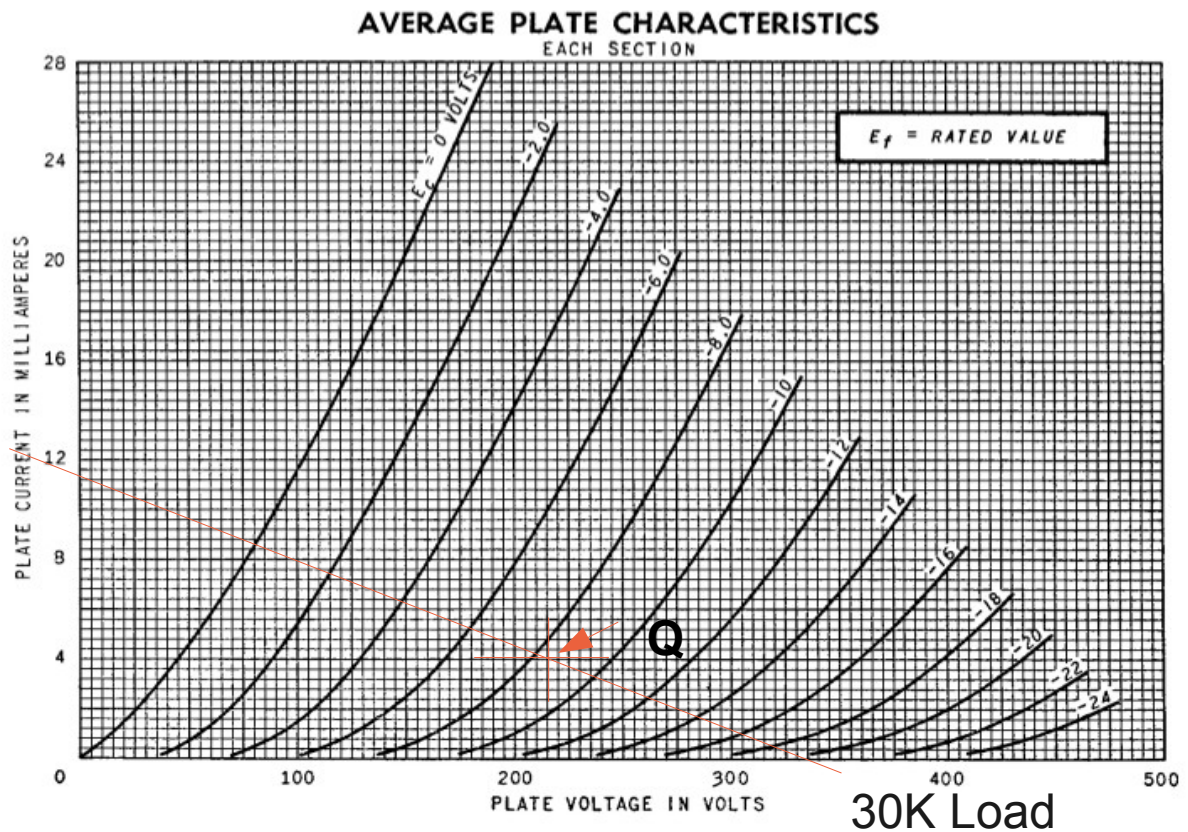
resistors the same as the tail resistor value is high (12k). A 560R grid stopper is added to the grid of the input valve.



I made a load line study for the 6SN7 stage. The load is 33k in parallel with the input impedance of the output stage. I do not know how to calculate the input impedance so I make a guess and take 30k as the approximate load. I picked 4mA as the bias current. From the chart, at Q, $V_a=215V$, $I_a=4mA$, $V_g=-8.3V$. With a $\pm 20V$ anode voltage swing (to drive the output stage to full swing), the corresponding input swing is -6.9V to -9.9V (-1.6V/+1.4V). The gain is about 13.3X (22.5dB).

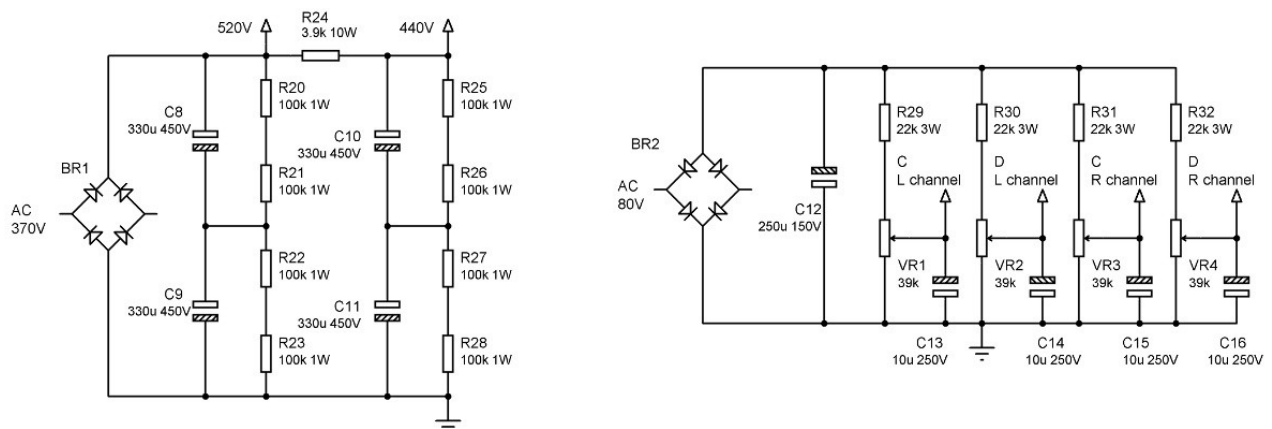
The overall gain of the 2 stages = 22.5dB – 6.9dB = 15.6dB. This is slightly lower than the PLH (20dB). That should be OK as I normally turn my volume knob to the 12/1 o'clock mark with PLH. There is quite some margin here.

The signal now come directly to the grid of 6SN7 after passing through the volume pot. The coupling capacitor is 0.01u, which followed the hint from www.aikenamps.com to avoid “blocking” distortion.



The Power Supply

Essentially I used the stock power supply with minor changes.

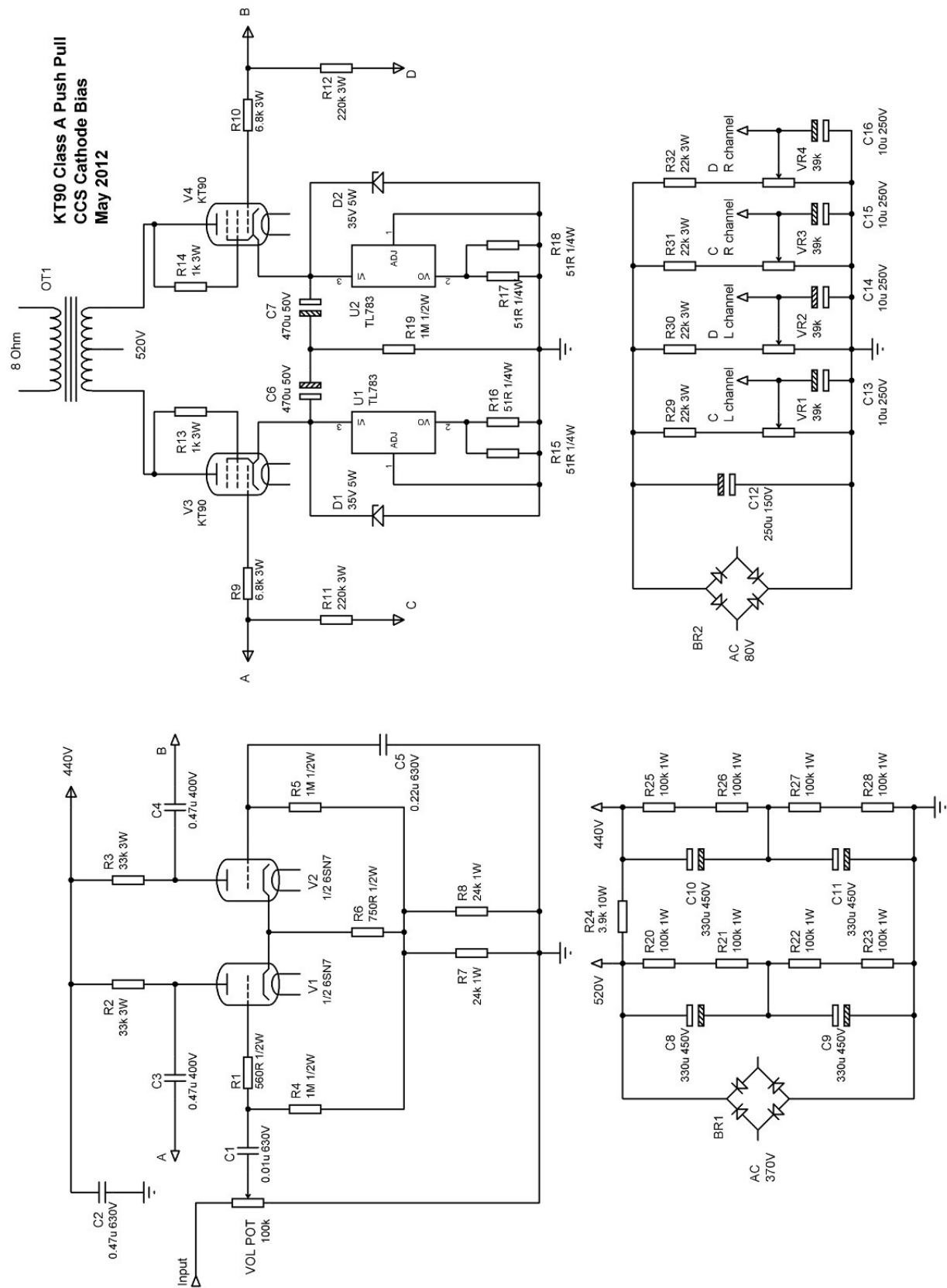


Bleed resistors 2 x 100K Ohm are added to each large filter capacitors. This provides a safer setup, and also ensure the high voltage is equally splitted between the 2 capacitors wired in series. 1 more change was made as a mistake. I swapped the positions of the 22k and 39k pot in the grid bias power supply. That was based on a mistake in drawing the load lines and I was under the impression that the pot could not cover the desired voltage range with the stock arrangement. That is not true but luckily, with this arrangement I am still able to adjust the bias points without any problem.

One more point I forget to draw in the schematics. The filament supply of 6SN7 is tied to the cathode via a high resistance to observe the limitation of the cathode/heater voltage

rating.

The Full Schematics



Construction

The quality of the skeleton of the stock Ming Da amplifier is pretty good. Most of the construction work involve desoldering old components and mounting new ones. Point-to-point wiring is used in most cases except 2 small PCBAs are used to mount the CCS, one for each channel.

Even though this is my first tube amplifier project, the tasks flowed through smoothly without any big issues. The only adjustment needed is to try to tune the cathode voltages of KT90 to +10V. This is not easy as the pot sensitivity is very high. I turned my focus to match the cathode voltages of the same channel. It might be a bit off +10V then, which really does not matter.

First Impression

This is subjective so I am not going to write too much. The first point to say is that the circuit works.

The first thing to notice after I connected the speakers was that all hum noise were gone! Maybe the CCS and the large tail resistor in LTP really help to block the hum. Or the 12AX7 stage was the one that picked up most hum and now it was eliminated. This certainly is a success.

The amplifier now sounds a bit different from the stock. It is less colourful and vibrant, but the bass is still very nice and forceful, the treble seems to be a bit dull compared to the stock version but it is still clear and nice. I would say the sound is now under very good control.

More listening will reveal more.