## Introduction

Having been made aware that the service manuals, including complete circuit diagrams, for the Aleph Series amplifiers had been released on the PassLabs website I started looking into the possibility of building one.  After some research I decided to make the Aleph4.

I built the amplifier successfully and details were posted on the PassLabs site.  Subsequent review of the amp by a number of interested people identified some inconsistencies within the circuit and accompanying description.  Most of these were minor, had no significant impact and were easily rectified.

Nelson has since corrected the circuit.  The most significant change was the number of output devices was initially listed as '**X3**', where it now reads '**X6**'.  The effect of this for the amp I built was to run insufficient bias, i.e. with 1.5ohm source resistors @ 0.5V, the amp was running a total of about 1amp bias, c.f. the approx 3 amps intended.  This was easily corrected by reducing the source resistor to 0.68ohm with dV across this being about 0.6V, as suggested by Nelson.

This sequence of events may actually prove beneficial for some would-be-builders.  Clearly, the commercial incarnation of the Aleph4 was built in a "bullet-proof" design frame, quite understandably so!

Judging by e-mail correspondence I have received, the number, cost and matching of FETs is a major hurdle for some.  A total of 24 versus 12 devices will have a significant impact on cost.  DIY enthusiasts **may** choose to make some compromise at this point.

My amp runs with equilibrium heatsink temperatures at around 65C.  This is hot!  This temperature would likely be identical with 24 devices total, the difference would be the dissipation in watts per device.  Given there is a thermal resistance from the FET junction to case, then from the case to the heatsink, the actual junction temp will be above that of the heatsink by an amount.  With fewer devices and more watts per device, so the junction temp will be raised further with the net effect that the longevity of the devices will be reduced.

How significant is this?  OK, from the datasheet for the IRFP244s which I used, the rated continuous current is 15A and power dissipation 150W.  The increase in current bias from 0.5 to 1A per device is well within tolerance and each device will be dissipating <50W, so we have a safety factor of > 3x.  What may become significant is FET junction temperature; this is rated from –55 to 150°C.  Looking at the datasheet, junction-to-case thermal R is nominally zero, but in a worst case may be 0.8°C/W.  We have to add to this the resistance from case to sink, which may be as high as 0.5°C/W.  If we take a worst case power dissipation of 50W, then the junction temp will be 65°C **above** the heatsink temp, or 130°C in my case.

In reality the figure will be less than this because we have assumed the worst in all cases.  However, the take-home message must be, **if** you decide to build the amp with 3 devices instead of 6, then you **must** ensure there is adequate heatsink, such that the idle temp of the amp is preferably **no greater than** 60°C.

If I were starting from scratch I would use the original configuration of **X6** devices and 1.5ohm, but then the choice is yours!  My amp has done 20+ hours now and works fine.

The circuit diagram following is the corrected version.  I have included both 3 and 6-FET mounting PCBs.  The circuit PCB provided can be used for either the Aleph 4 or 5, simply install 4 or 6 resistors as required in the output section.

The basic format for your amp will likely vary from mine.  I have never seen the sort of heatsink I have used commercially available and I would be frightened to guess the cost – they weight a ton!  Use a little imagination and forward any results to Desmond for the projects gallery.

The amp sounds great.  I would encourage anyone reading this file to take the plunge and build either the Aleph4 or 5.

I am happy to be e-mailed re questions, this has proved to be to my own benefit (large grin!).

mailto:mark.finnis@adelaide.edu.au

Regards

Mark

## Construction

Building the Aleph4 I had to be a little budget minded. You can do a lot of good shopping in surplus stores, especially for power supply parts. Using second-hand here will not affect the performance of the amp one iota and can save considerable $$ for those worried about these things. For example (in $AUS ….. for USD$ simply divide by 2):

| | | |
|---|---|---|
| 1 x 10A RF mains filter | $ 2 | |
| 2 x 400VA toroids | $ 20 each | |
| 4 x 80,000uF 50V caps | $ 8 each | |
| 1 x 80Amp 400V bridge | free | |
| 2 x heatsinks (300 x 360mm) | $ 30 each | |
| 2 x high current chokes | included with heatsink, free | |
| 1 x dual 10A circuit breaker | free | (= main power switch) |
| 2 x 5A “Re-Cirk-It” breakers | free | (+ supply rail protection) |

So for a small fraction of the “new” cost I had most of the power supply! OK, so the filter caps may not last 20 years, but hell ….. at that cost I regard them as disposable.

I used a RF filter IEC socket for the mains. I mounted the power switch (dual 10A breaker) on the rear to minimize AC lead length and used an inline 5A fuse. I used Pi filters for the supply rails. Those readers who have not read Nelson’s article on Power supplies should do so ***before*** building such an amp, see:

http://www.passlabs.com/articles/pwrsup.htm

I mounted the rectifying bridge on a heatsink for 2 reasons. First it would obviously generate some heat of its own, but also I had no idea of the dissipation rating of the 2 main heatsinks, so I didn’t know if I would have enough. I had this lying around, actually it was the cut-off end of the sink I had used for the tops of the Son of Zen project. Turned-out it was the right width for my tower design.

Given there is a total of 320,000 uF to charge, the inclusion of power thermisors (Th1&3) was essential (unless you want to have to click the main breaker 2-3 times to get the amp turned-on). On power-up I get a healthy buzz from the toroids due to the high current drain, which decays exponentially over 5-8 secs as the caps charge leaving near silence. There is a discernable 50Hz hum from the amp, but you have to place you ear up against the speaker grill for this to be just audible.

From the circuit, Nelson did not include fuses on the supply rails, only the mains. I think doing both is sensible and it cost me nothing except the time to cut the holes in the rear panel. I used 5A breakers as I had them available.

I did not include the 75°C thermal protection switches. A bit lazy on my behalf. Given the subsequent alteration to the design (3 vs 6 FETs) I wish I had done this and may add this later.

A major stumbling block for me was PCBs. I did a little hunting on the WWW and decided to make my own using positive resist board and PC artwork.

Main points:

1. Use a bubble-jet or ink printer, **not** a laser. Lasers will leave gaps in the solid track lines when printing onto overhead transparency material.

2. Buy purpose bubble-jet overhead film. It is quite expensive relative to standard OHT film, but the results are miles superior. Given the effort involved, $1 for a sheet of film is nothing.
3. Check the printed PCB positive against a strong light before using it for exposure, in case there has been a line missed by a blocked jet. Use a permanent OHT pen if required.
4. I used commercial positive resist board from Farnell, along with their developer and etching solution (granules). This comes with a black plastic peel-away covering on the treated side.
5. Buy a couple of cheap plastic “lunch boxes” for the solutions.
6. Get some thin (1-2mm) plastic sheet (**not glass**) to place over the film on the board so it lies flat and does not move. Obviously you don’t want refraction around the edges and a fuzzy result.
7. For exposure I used midday sunlight. Now, living in Australia this is easy. Make a small test film. I used a simple text message “Testing” at 12 point and trial exposed at various times on small pieces of PCB prior to doing the main boards. Turned-out 5minutes in the sun was perfect, but then it was a 38°C day (around 100°F!). On another day for the FET boards it took 8 mins.
8. Place in the developer solution for as long as it takes to clear the unwanted protective film. This is quite quick and is aided by rocking the solution slowly.
9. Make your etching solution as per the pack instructions. Please don’t ignore the safety instructions re eyes etc !!!!! Place the boards in and rock the solution gently. I found using a cheap plastic disposable paintbrush helpful.
10. If you use FR4 based board, standard drills will blunt quickly. I bought a cheap set of tungsten tipped drills for the purpose.
11. Try to find a drill press, it makes the task a lot neater and easier.

Having never done this before I was very pleased with the end quality of the boards and I would encourage any would-be-builder to try this if they don’t have access to proper facilities. In fact, it was the success with the main boards which prompted me to make the custom mounting PCBs for the FET sets.

All parts are obvious, except for C1 across Q3. The listed value is ‘103’. Many have asked me what is this. I have **assumed** it is standard labeling for a film cap, ie:

| | | | |
|---|---|---|---|
| 1 | = | 1 | |
| 0 | = | 0 | |
| 3 | = | 000 pF | = 10,000pF (0.01uF) |

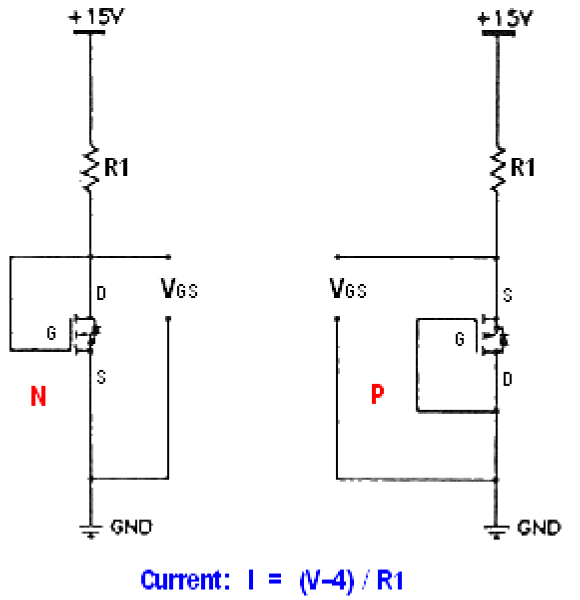
Another point of confusion is the value of R29. This is different on the 2 circuit diagrams in the service manual. Nelson has stated, “the value of R29 has varied over the production life of the amp, personally I prefer the higher value”, so I went for 620ohm.

FETs are a major issue judging by the e-mails I have received. The circuit uses IRF244s (TO-3 casing) which are now superceded. You can substitute IRFP244s which come in a TO247 case which are what I used, or, if I had my time again IRFP240s, which are what Nelson uses frequently now and recommended (alas, after I had ordered my 244s …… never mind she cried). The 9610s are common enough and shouldn’t be a problem.

I have received a dozen e-mails asking if I matched these. Answer is **yes**. I ordered 25 each (discount price and remember, I saved a lot on the power supply!) of both the IRFP244 and IRF9610 from Newark, as I planned on building a second amp for a friend. Those of you out there should think about “group purchase” to attain both discount and ability to match well. How close did I get these …… 9610s easily to the 0.01V and the 244s to 0.05V.

To make life easy, I have adapted this text from the A75 construction article from the Pass site: http://www.passlabs.com/projects/A75_2_7.htm

“The test is simple and requires a power supply, a resistor, and a DC voltmeter. Figure 12 shows the test hookup for N- and P-channel types. The supply source resistance (R1) is nominal, and is found from I = (V -4)/R1. Consistency is the most important thing here.”




I used a precision 24V/25A regulated supply. Nelson states the input pair are biased at 20mA and the output at "slightly greater than 3 amps".

For the 9610s, I = (V-4)/R1 we wanted a R1 = 20/0.02 = 1K.

Given there are 3 devices in the output, each must be biased at about 1 amp, so this is where I wanted to match them. R1 = (V-4)/I = 20ohm.

Fortunately I had a Dale 50W 20 ohm power resistor lying around which was perfect. However, this was going to generate some heat, so I made a small test heatsink and secured the FET in question with a strong "bull-dog" paper clip on a rubber insulting washer. This is important, because as you power-up the VGS will exponentially decay to an equilibrium value as the FET heats and you need to leave each one idling for a while before taking the measurement (I used VGS at 5 minutes). Continuing on .....

> “Keep in mind the caveats about electrostatic discharge: touch ground before you touch the parts.
> Matching input MOSFETs is critical, because they must share equally the 20mA of bias current from the current source, and they will not do that unless their VGS is matched.
> If you are unable to find input devices matched to within 10mV, you must insert resistance in the source to make up the difference. The resistance is calculated by the difference of the two values of VGS divided by 10mA. For example, if the difference in VP1GS is 100mV, then 0.1/0.01 = 10ohm. You would then place 10ohm in series with the MOSFET source having the lower VGS.
> We use the same test setup for the MOSFETs in the TO-247 packages ....
> ..... we like to see the load shared, and recommend that you group the outputs by VGS as closely as possible. Matching within 0.2V will work, and O.1V is even better. Within a population of 150 transistors, you can easily get 12 sets matched to O.1V VGS.”

The results for my FETs were:

| No | IRF9610 | | No | IRFP244 |
|---|---|---|---|---|
| 12 | 3.490 | | 15 | 4.33 |
| 13 | 3.490 | | 13 | 4.34 |
| 2 | 3.500 | | 10 | 4.35 |
| 18 | 3.500 | | 16 | 4.35 |
| 3 | 3.520 | | 19 | 4.36 |
| 23 | 3.520 | | 23 | 4.36 |
| | | | 24 | 4.36 |
| Min | 3.49 | | 25 | 4.36 |
| Max | 3.76 | | 14 | 4.36 |
| | | | 17 | 4.37 |
| Min(244) | 4.07 | | 2 | 4.38 |
| Max(244) | 4.42 | | 18 | 4.38 |

For interest the DC offset of the final amp is <10mV.

If you plan on using the small FET mounting PCBs you will need to solder the FETs in place prior to mounting them on their heatsink. This can be tricky because they need to be soldered in a perfect plane to allow final mounting (if they are not you may get compromised heat transfer). First bend the FET leads at 90° at the boundary where the lead changes width. If you have a narrow pair of “long-nose” pliers you can grab all 3 leads at once in a straight line. This allows for a neat result and effectively shorts the 3 leads preventing accidental static to the gate. I used 2 pieces of acrylic and 2 small clamps. Place the FETs in a line along the edge, place the second piece on top so the FETs are “sandwiched”. Align the FETs so they fit through the PCB holes and are straight, then clamp in place. Turn the sandwich over then solder in place.

I noted on the Aleph4 stuffing diagram that the 9610s were given heatsinks, which were not present on the Aleph3 diagram even though the input bias current was the same. Alas, as I had started designing the PCBs on the A40 format and the 9610s were too close together to mount proper heatsinks, however you can get small “snap-on” heatsinks which are better than nothing and these are what I used. Clever folk may want to redesign the PCBs to allow for mounting heatsinks and I may do this one day if I have time. On running the amp the input FETs are hot, but certainly within limits and can be touched albeit briefly.

The remainder of the construction is straight-forward for anyone likely to attack such a project. I followed Nelson’s input wiring arrangement right down to the shorting plug in the XLR socket. I used gold-plated RCA sockets and speaker terminals. Wiring was with appropriate gauge OFC wire. The central earth point is a 2mm thick, 150x80mm piece of aluminium, isolated from the mains with a thermistor as described.

The base, top, front and back I had made in 1.6mm mild steel by my local metal shop, this cost around $50AUS and is a lot easier than trying to bend sheet-metal yourself, unless you have access to the correct tools. I spray painted this myself, but given it is living inside I may have this stripped and have the front/top powder-coated for a more professional finish.