Construction Notes for the N-Channel Amplifier Module

Introduction

The N-Channel Amplifier is about the simplest design one could use and still have good performance and a push pull output stage.
The n-channel is basically a two-stage amplifier, Consisting of differential error amplifier stage and Driver/Output stage. The other circuits are a 6ma current source for the first stage and a current source for the IRF610 phase splitter and temperature compensated bias voltage source for the o/p stage power MOSFETs.
It is worth noting that just about any industrial Power mosfet can be used in this amplifier. The best ones to choose are the one's with voltage ratings of 200 volts and greater.
The Gate Capacitance of these Vertical type MOSFETs doesn't appear to affect the performance of this amplifier. I have used MOSFETs with Gate C's as high as 4000pf per device without any affect on performance.
Provided that you follow these instructions to the letter. You will have no trouble getting going the N-channel amplifier. The Objective performance or sound quality of this amplifier is quite frankly second to none. There just seems to be something about amplifiers that use N-channel MOSFETS in their O/P stage.
With the new soon to be released 6 Channel MOSFET amplifier, it uses n-channel devices only in its O/P stage and the sound quality is something to be heard.

The Error Amplifier Stage

The first differential stage is made up of Q2, Q3, Q14, Q15, R4, R5, R9, and R10.
Q2 and Q3 form a differential amplifier. Q14 and Q15 form a current mirror load which forces equal current sharing in this stage. The resistors R4, 5, 9, and 10 provide degenerative gain fold back for the differential pair and current mirror respectively…
C3 provides i/p DC decoupling. R22 and C4 form a low pass filter, which sets the maximum i/p frequency at about 100khz. R25 sets the overall i/p impedance. R28 provides power ground decoupling from signal ground and helps to prevent ground loops.
Q1, Q4, C5, E2, R1, R15, and R16 form the current source feeding this stage and the current is set at 6ma.

The Phase Splitter Driver/Output Stage

The next stage could be seen as a separate stage to the output stage but is actually part of the output stage. Q13 IRF610 forms a phase splitter, where the o/p of the Source pin is non-inverting and the o/p of the Drain pin is inverting. R17, R18 having equal values ensure the splitter has the same voltage swing coming out of each o/p.
R20 ensures that at high frequencies that the o/p has better symmetry.
The o/p stage when using only n-channel devices forms an asymmetrical push pull stage, in practise this doesn't cause any problem and o/p symmetry is excellent…

The O/P Stage Biasing Circuit

The biasing circuit consists of R2, R6, R26, R19, R21, R23, P1, Q11, Q12, IC1, ZD4, E5 and E6.
Q11, R2, R6, R26 and ZD4 form a pre-voltage regulator, which drops the main supply rail voltage down to 9 volts. which then supplies the LM317T regulator. The adjust pin and the o/p pin of IC1 is connected from the output of the amplifier and the load resistor of the driver stage Q13.
P1 when it is increased in value increases the voltage from IC1 which forward biases the positive rail MOSFETs and in turn Drain current through Q13, which then forward biases the negative rail MOSFETs by increasing the voltage drop across R17. Which is connected across the Negative rail MOSFETs Gate and Source pins.
Thermal compensation is achieved by Q12 which is mounted on top of one of the o/p devices, So as junction temperature increases this heats up Q12 which turns Q12 harder on, which throttles back IC1 which in turn reverse biases the o/p stage.

The global feedback components are R24, R27, E1, C1 and C2.
The remaining components E3, E4, E7, E8, C6, C7, C8, C9 provide power supply decoupling.

Assembling the Printed Circuit Board

One of the first things to do is to look at the PCB and see if all of the holes on the board are of the correct size for the components you wish to insert. The holes that have been drilled into the PCB should be OK. However it

does pay to check before you start. If you find that some of the holes are not big enough then you will need to drill them out to the correct size. The standard holes sizes used for most electronic components are as follows.
¼ watt ½ watt resistors = 0.7mm to 0.8mm
1–watt resistors = 1.0mm
¼ watt to 1-watt Zener and normal power diodes = 0.8mm
Small signal transistors such as BC546 of the TO-92 pack = 0.6mm
Medium signal transistors such as MJE340 of the TO-220 and TO-126 Pack = 1.0mm
Power Output devices such as the IRFP240 require a hole size of 2.0mm

Assembling the Printed Circuit Board

Start constructing the PCB by inserting any wire links, which are shown on the component overlays. The wire links are made from spare component leads such as from 5-watt ceramic resistors or ¼ watt resistor leads.
Once the links have been taken care of the insertion of all the resistors is next, followed by the capacitors and then the small signal semiconductors. You will need to cross-reference the parts list with the white screen component overlay on the PCB to see where to insert the required component. Be careful to always insert the polarized components in the right way as shown on the screen-printed overlay. Failure to do this will most likely result in the module not functioning properly or damaging one or more of the components in the module.

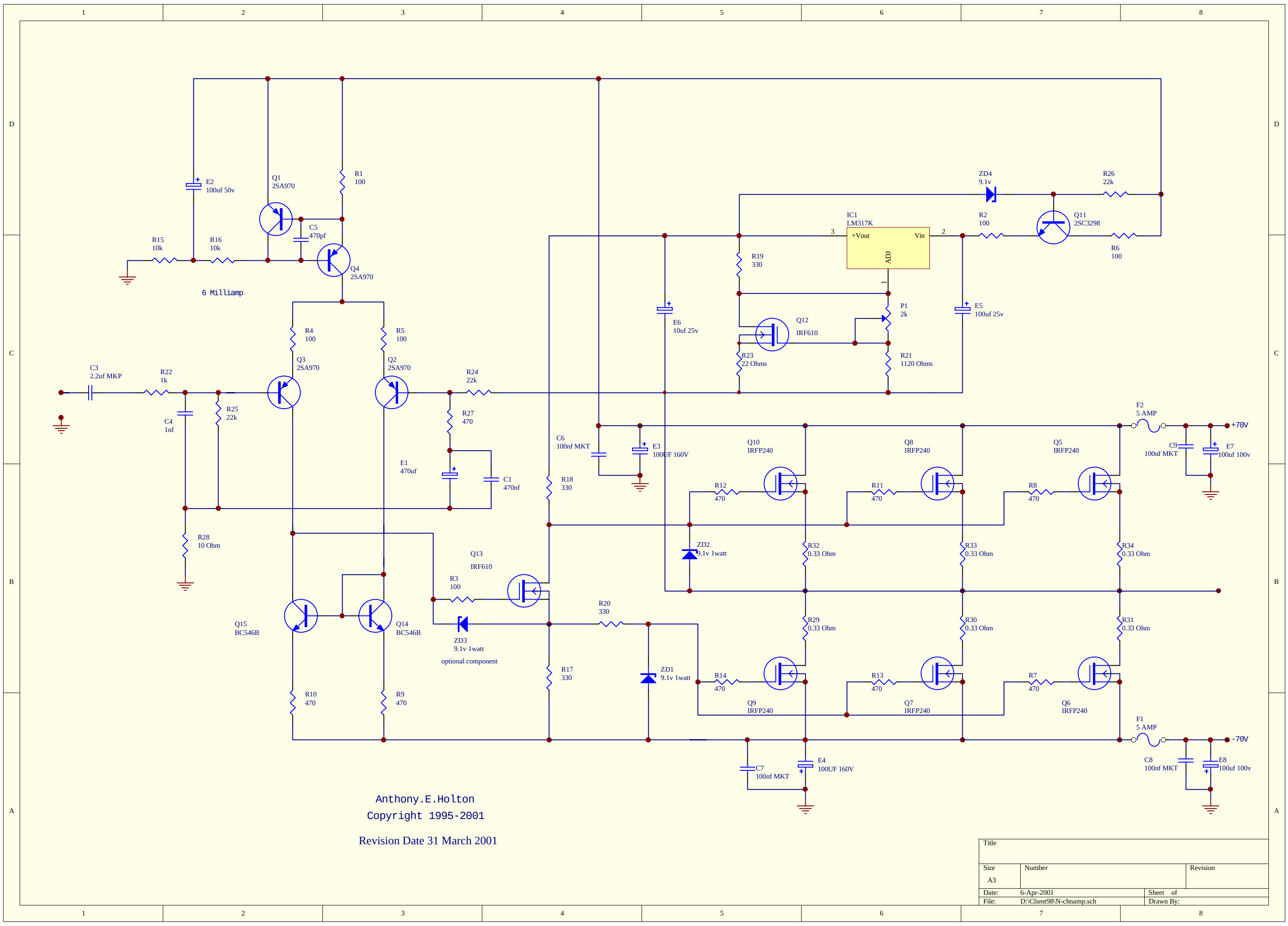
Now we have come to the soldering in of the output devices. It is assumed at this point that you have all ready matched the output stage devices as outlined in the accompanying document on
How to match Hexfet MOSFETs

Important changes that must be made to the n-channel amplifier.
Since I designed the PCB for this amplifier I have made some important changes to the Bias and O/P stage to greatly improve the thermal stability of this design.
The changes are as follows and I would strongly recommend that these changes be done.
0.33 Ohm 5 watt resistors have been added to the o/p stage in the Source pins of Q5, Q8, Q10 and the Drain pins of Q6, Q7 and Q9. Q12 has been replaced with a IRF610 power MOSFET, R23 has been reduced down in value from 120 Ohms to 22 Ohms, R21 has been increased in value to 1120 Ohms, P1 10 turn pot has been reduced down to 2K from 20k and ZD4 has been reduced down to 9.1volts from 15 volts. R21 to made by connecting in series a 1k Ohm resistor with a 120 Ohm resistor.
If this is already done then you can proceed by getting the PCB and the pre-drilled alloy bracket. Now first get the N-channel devices and a pair of long nose pliers and bend the Gate and Drains pins of the devices Q5, Q8 and Q10 at right angles, facing down so they can be inserted into the PCB and mounted horizontally onto the alloy right angle bracket, while bending the Source pin at right angle upwards so you can later solder the 0.33 Ohm 5 watt resistors into place. Now get the remaining N-channel devices Q6, Q7 and Q9 and with the long nose pliers, bend the Gate and Source pins downwards leaving the Drain pin of these devices to be bending upwards. Once this is done get 8 x TO3-P insulation washers and 8 x M3 x 25mm bolts and nuts and mount the devices onto the alloy bracket and thereby clamping the alloy bracket to the main PCB.
Because of the changes made to the n-channel design additional degenerative resistors R29 to R34 as shown on the update schematic, need to be mounted into the PCB standing up. This is done be drilling additional holes into the PCB in the O/P area of the PCB and in close proximity to the output devices, Source and Drain pins.
With the holes drilled and the solder masking removed with a sharp blade, mount the 0.33 Ohm resistor vertically and solder the protruding pin on the copper side of the PCB. then bend the remaining pin at the top of the resistor at right angle and bend down so as to connect to the MOSFETs Source pin which was bend upwards. Once this is done solder the two leads together. Now do the same for Q8 and Q10
After completely mounting and insulating the N channel devices.
Solder the devices in on the copper side of the PCB.
Now there is one device that requires some special attention. This is Q12 and this device is the Vgs multiplier or bias compensation device, which needs to be mounted off board on top of Q10 in the output stage. Q12 will need flying leads soldered from the Gate, Drain and Source pins of the IRF610 to the appropriately marked pads on the PCB shown as MJE340 on the PCB with the pins marked as E C B. The MJE340 has now been replaced by the IRF610 power hexfet Mosfet. The pins E=Source C=Drain and B=Gate

Now having completed the power module. Its time now for the pre-flight test to be done, before the biasing of the o/p stage is performed. Remember that all of the o/p devices must be insulated with either silicon rubber washers or mica –washers and heat sink compound be used on both sides of the washers.
Connect a suitable power supply to the power module, making sure that the supply rails are connected to the correct terminals on the amplifier module. Now before the amplifier is powered up, adjust (P1 2k Ohm pot) so when you measure across its two outside pins that 0 Ohms is measured. Having done this and checked that there are no shorts between the MOSFETs, Gate, Drain and Source pins to the right angle bracket. You can proceed to power up the module. Now if you have access to a VARIAC. Which is a device that can vari the mains AC voltage going into the primary of the mains transformer. Then I would use one, as it can be the difference between making a mistake and getting away with it or not.

Biasing the MOSFET Output Stage and final testing.

Before applying power, connect with alligator leads a multimeter set to 300mv range across Q10 (0.33 Ohm) Source resistor. So you can measure the adjustment of the O/P stage MOSFETs.
If you have a variac then apply power and slowly adjust the voltage into the amplifier while looking at the millivolt meter reading. If you see a reading of 33mv or greater. Then power down and recheck the adjustment of P1.
Assuming all is OK, adjust the voltage level so +-70 DC appears at the supply terminals of the amplifier.
Now adjust P1 slowly so you see the voltmeter reading increase to 38mv. When reaching this reading stop adjusting and allow the amplifier to heat up for about 30 mins. After this period time the reading should have dropped down to between 33mv and 30mv depending on the size of your heat sink and ambient temperature.
One other thing that needs to be checked is the rest of the current settings through the remaining O/P stage MOSFETs. This is done by measuring across the remaining 0.33 Ohm 5 watt resistors. The readings should be fairly close to Q10s readings if you have matched the MOSFETs well enough…

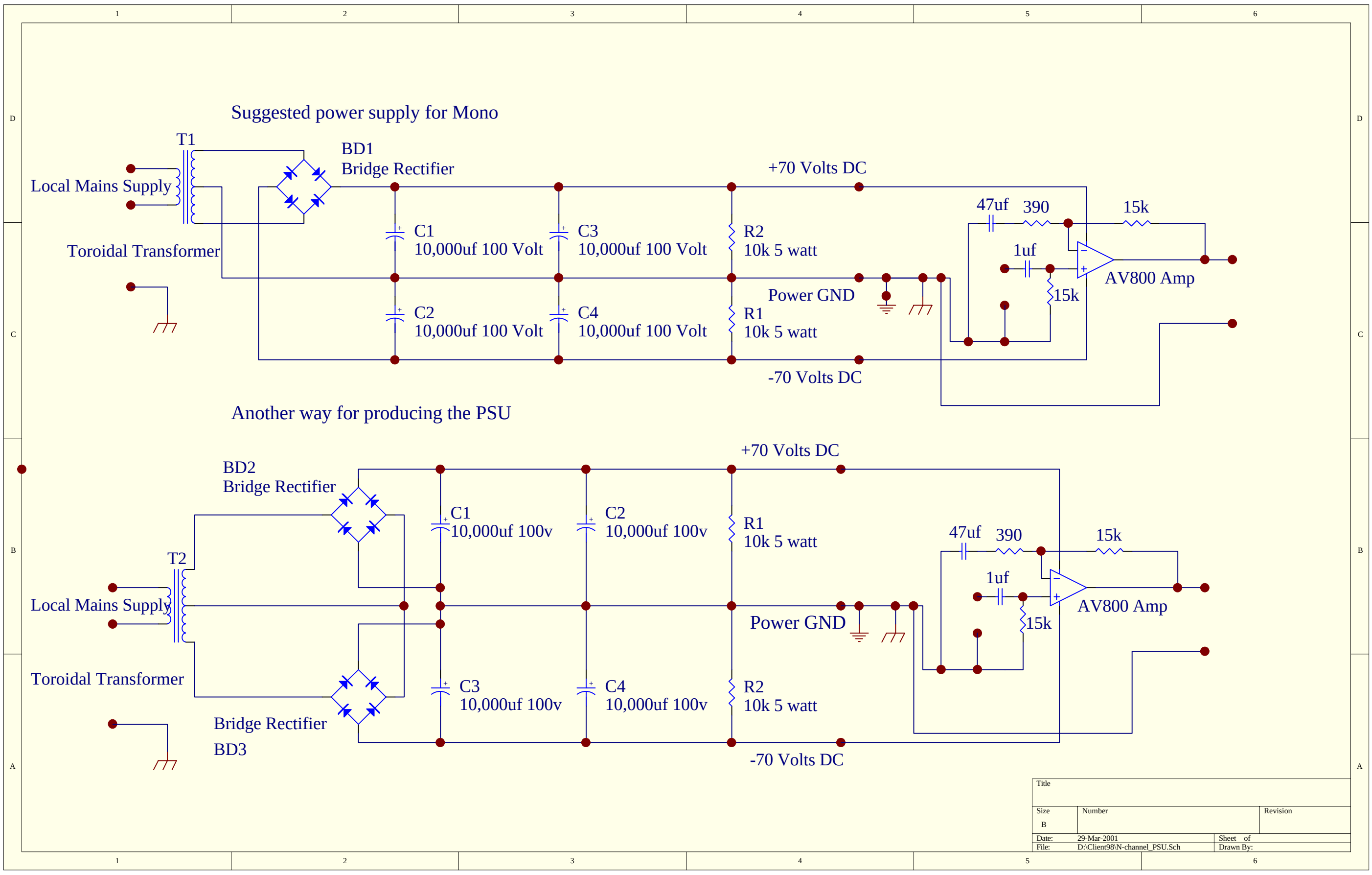


Bill of Material for N-channel Amplifier

Used	Part Type	Designator	Footprint	Description
1	10 Ohm	R28		
6	100	R1 R2 R3 R4 R5 R6		
2	10k	R15 R16		
1	22 Ohms	R23		
1	1.1k	R21		
1	1k	R22		
1	20K	P1		
3	22k	R24 R25 R26		
4	330	R17 R18 R19 R20		
9	470	R10 R11 R12 R13 R14 R27 R7 R8 R9		
1	2.2uf MKP	C3		
1	1nf	C4		
4	100nf MKT	C6 C7 C8 C9		
2	100uf 100v	E7 E8		
2	100UF 160V	E3 E4		
1	100uf 25v	E5		
1	10uf 25v	E6		
1	100uf 50v	E2		
1	470nf	C1		
1	470pf	C5		
1	470uf	E1		
2	5 AMP	F1 F2		
4	9.1v 1watt	ZD1 ZD2 ZD3 ZD4		
4	2SA970	Q1 Q2 Q3 Q4	TO-92	
1	2SC3298	Q11	TO-126	
2	BC546B	Q14 Q15	TO-92	
2	IRF610	Q12 Q13	TO-220	
6	IRFP240	Q10 Q5 Q6 Q7 Q8 Q9	TO-247	
1	LM317K	IC1	TO3	
1	Aluminum Right angle bracket pre-drilled to suit the holes on the PCB.			
6	Mica or Silicon rubber insulating pads.			
6	M3 Nuts, bolts and shake proof washers			

The Suggested Power Supply

The power supply components for this amplifier are as follows and are shown for Two Channels.
1 x Transformer, with a Core rating of 500VA. Primary windings are made to suit your local mains supply. Eg: for Australia One single primary winding with a 240VAC rating. For USA, 110VAC, 115VAC and I believe there is a 220-Volt AC mains supply in some areas of the United States. For the UK it would be 220 VAC to 240 VAC.
The secondary windings are as follows.
2 x 50 volts AC at full load.
One 400 Volt 35 Ampere, bridge rectifier.
2 x 4.7K 5 Watt ceramic resistors
Minimum filter capacitor requirements would be 2 x 10,000uf 100 volt electrolytic.
Ideal capacity would be 40,000uf per voltage rail.



How to match Hexfet MOSFETs

When using this type of MOSFET in the n-channel amplifier is strongly recommended that the output stage devices be matched. As it has been found that if this is not done then there is no guarantee that they will share the current under load.
The Source resistors provide only a bit of local feedback and don't in any way force the devices to current share.

The best method I have found to work very well utilises just a 150 Ohm 1 watt resistor and a +15 volt DC power supply.
If you look at the schematic below it shows how to connect and measure the N-channel devices and the P-channel devices.
With the devices connected, as shown measure across the Drain and Source pins with a multimeter set to DC volts and measurement of between 3.8 volts and 4.2 volts will be shown. Simply match the device in-groups to a tolerance of +-100mv.
Please note that you only have to match the n-channel to the n-channel devices and the p-channel to the p-channel devices, not the N-channel devices to the P-channel devices.