Construction notes for the symmetrical 400 watt amplifier

Introduction

The symmetrical amplifier is an update of one of my designs, which appeared in the Australian electronics magazine Silicon Chip in June 1994.
The main changes made in this design was, the addition of a clipping detector circuit and bias circuit modifications for the use of International Rectifier HEXFET MOSFET's.
Later modifications where made to the error amp and VAS stages which improved the overall sound of the amplifier.

Tools you will need to complete the construction of this module

A good temperature controlled soldering Iron
Resin core 40/60 solder
A mini drill or a drill press, which can handle drill, bit sizes down to 0.6mm
A small flat blade screwdriver and 1 point Philip's screwdriver.
An electric hand drill
Pre-cut and drilled Aluminium right angle bracket, 196mm long, 3mm to 5mm thick.
To mount the Mosfets onto.

The Error Amp Stage

The first stage is what I call an asymmetrical input error amplifier. It has the ability to accept an unbalanced I/P source only.
Now I will explain how each device in this stage works together.
Q2, Q3, R35- R36, form the main differential error amplifier, which then has its collectors connected to a cascode load. Q4, Q5, R4 and ZD2 form the cascode stage, which provides a constant 14.4 volts on the collectors of Q4, Q5.
Q1, R8, R7, ZD1 and C1 form a constant current source, which supplies 1.5milliamps to the first differential stage. These modules form the first stage of the amplifier and basically set up how the whole amplifier is biased from front to back.

The Voltage Amplification Stage

This next stage provides most of the voltage amplification that the next stage needs to drive the o/p stage to full power.
Q6, Q7, Q8, Q9, R15, R14, R12, R13, C3, C7, C8 form the second differential voltage amplification stage. Q7 and Q9 form what is known as a current mirror load for the second differential stage and basically force this stage to share the current supplied from R15, which is about 8milliamps.
The remaining components, namely the caps provide local frequency compensation for this stage.

The Bias Stage

As the name suggests Q10, R34, 37, 38, C12form the Bias stage. Its main purpose is to provide the MOSFET Gates with a stable and compensated supply voltage.

The Output Stage or Current Amplification Stage

Once again as the name suggests this stage converts the voltage developed in the VAS and provides all the amperes needed to drive 8 or 4 Ohm loads. 2-Ohm loads are not possible unless more o/p devices are added.

Power supply requirements for the 400 Amplifier

The power supply components for this amplifier are as follows and are expressed for Two Channels.

1 x Toroidal Transformer with a Core rating of 625VA. 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.

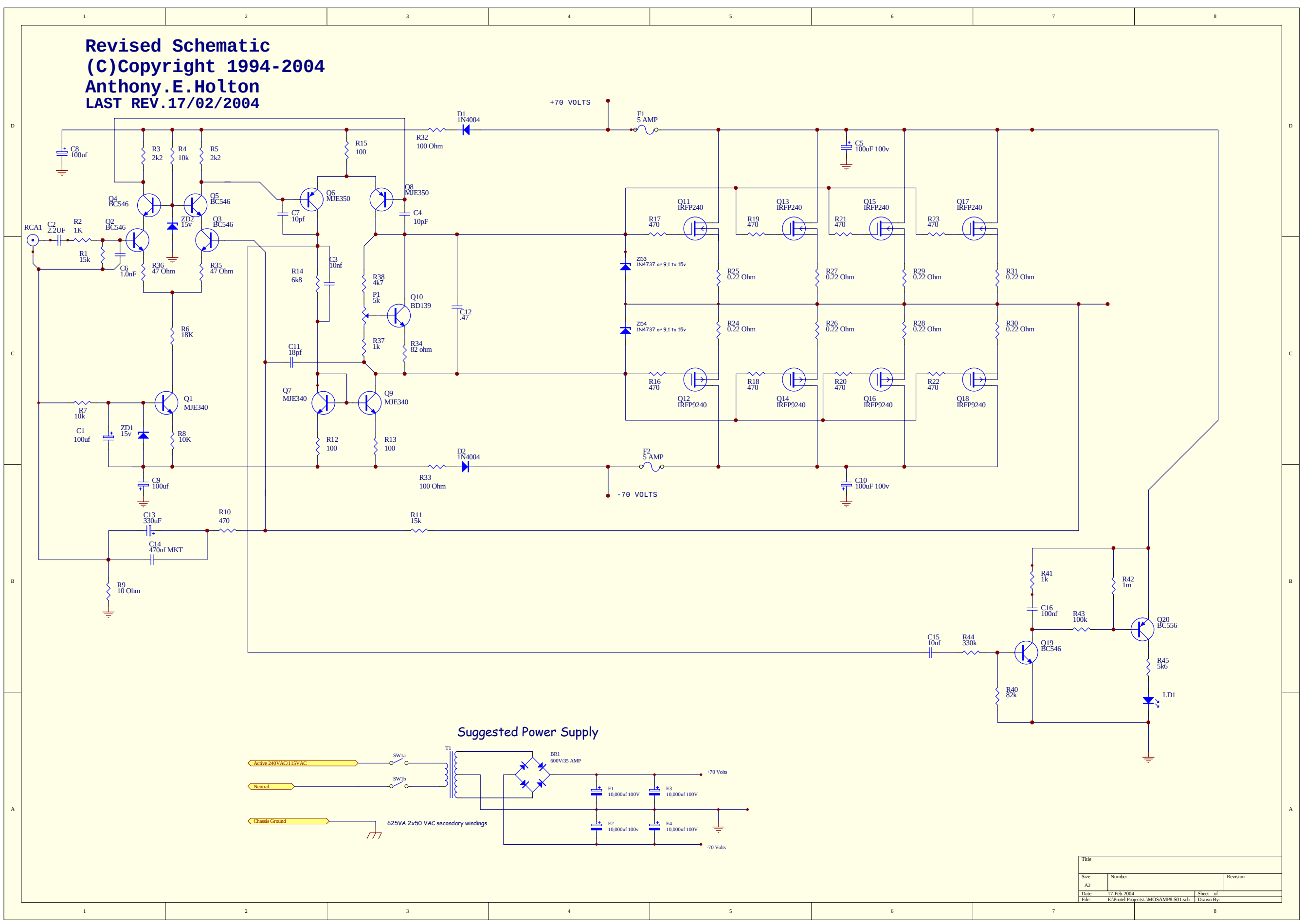
One 400 Volt 35 Ampere, bridge rectifier.

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.

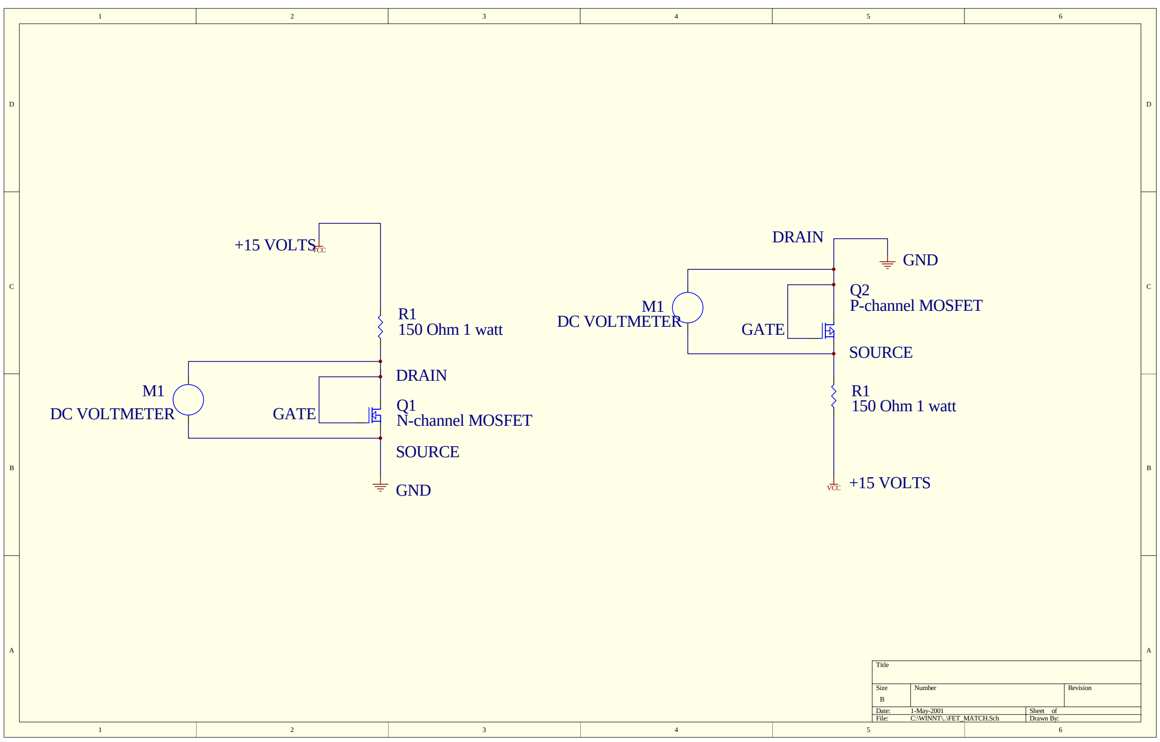
A suggested power supply schematic is shown below with the schematic of The amplifier.



How to match MOSFETs

When using this type of MOSFET in the symmetrical 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.



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-126 pack = 1.0mm
Power Output devices such as the IRFP240 require a hole size of 2.5mm
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 polarised 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.
The output stage transistors and Q10, which is the BD139 device, are to be left till last.

Pre-flight test

OK at this stage I am assuming you have populated all of the PCB except Q10 and the main output stage devices IRFP240's and IRFP9240's
For the time been temporarily wire up Q10 via flying leads. Making sure that you match up the Collector, Base and Emitter pinout's on the PCB, with the Collector, Base and Emitter pinouts on the BD139. Don't insert Q10 directly into the PCB.
It is important to test the function of the amplifier at this point in time so as to make sure it is working properly. This is achieved by soldering a 10-Ohm ¼ watt resistor across ZD3, On the screen-printed side of the PCB. What this does is to connect the feedback resistor R11 to the output of the buffer stage. In doing so it bypasses the output stage and turns it into a very low powered amplifier, which can be tested without damaging the expensive output stage. Assuming you have connected the resistor from o/p to the buffer stage. It is now time too connect the +-70 volt supply to it and power it up.
Be sure to have 4k7 Ohm 5-watt bleeder resistors across the power supply capacitors.
Now assuming that there was no smoke, with a multimeter on volts. Measure the following voltage drops across these resistors locations marked in blue and if they match to within +-10% then you can be sure that the amplifier is OK.
When you have done the checks, be sure to power down and remove the 10 Ohm resistor.

R3~1.6 volts
R5~1.6 volts
R15~1.0 volts
R12~500mv
R13~500mv
R8 ~14.6 volts
ZD1~15 volts
Offset voltage at R11 should be close to 0 volts, but can be as high as 100mv.

Completing 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 output devices.
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 pins at right angles. The same needs to be done for the p-channel devices.
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.
After completely mounting and insulating the N and the P channel devices.
Solder the devices in on the copper side of the PCB.
Now its time to get the 0.22 Ohm 5 watt resistors and bend the pins at rights on each device and using a pair of side cutters, trim the leads back so about 10mm to 12mm of lead is protruding from the body of each resistor. Then solder each resistor on the copper side of the PCB.
After completing this task the module for the most part is completed.
The only other thing you will need to decide is wether to use PCB stakes to solder the external wiring too or solder the cable directly into the PCB pads.
Now there is one device that requires some special attention. This is Q10 and this device is the Vbe multiplier or bias compensation device, which needs to be mounted off board on top of Q11 in the output stage. Q10 will need flying leads soldered from the Base, Collector and Emitter pins of the BD139 to the appropriately marked pads on the PCB shown as Q10.

Now having completed the power module and tested the Error, VAS and Buffer stages and you are confident that it is working OK. Its time to bolt it down to a suitable heat sink. Remember that all of the o/p devices must be insulated with either silicon rubber washers or mica –washers and heat sink compound. The type, size and shape of heat sink are left up to you and the local availability of heat sinks. But be sure to have a heat sink rated at 0.5 degrees/watt or better.

Testing the module

So we have come to the point where we need to do a full test on the amplifier module.
There are a few checks that need to be done first.

- The Drain pins on all the o/p devices need to be checked for S/C to the heat sink.
- The power supply wiring has been checked for correct polarity to the PCB.
- The Multi-turn pot P1 has been turned back to 0 Ohms, so that a measurement of approximately 4.7k is measured across the Base and Collect pins of Q10 BD139.
- When wiring up the power supply, be sure to have 8 amp fuses inserted on each of the supply lines.
- Connect a multimeter on DC volt range to the o/p of the amplifier.

Ok now that you are happy that the module is setup correctly apply power via a VARIAC if you have access to one, otherwise just power the amplifier up.
Looking at the voltmeter you should get from 1mv to 50mv offset voltage.
If this is not the case then power the amplifier down and check your work.
Assuming all is well then power the amplifier down and find a small flat blade screwdriver so you can be ready to adjust P1 for the biasing of the o/p stage.
But first connect the voltmeter across one of the o/p stage Source resistors using Alligator leads.
Now reapply power to the amplifier and slowly adjust P1 while watching the voltmeter, for a reading of 18mv. This sets the bias current in the output stage to just under 100ma per device
Now check across the rest of the Source resistors and find the one, which has the highest reading, and adjust P1 till 18mv is read.
Now connect a load and signal source to the amplifier and with a CRO if you have access to one observe that the waveform is clean and free from noise and distortion.
If you don't have a CRO and Signal generator, connect a pre-amp and loudspeaker and have a good listen. The sound should be very clean and dynamic.

Congratulations, the amplifier is complete.

Best Regards

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8th February 2001
www.aussieamplifiers.com

Specifications for the symmetrical 400 watt amplifier

Power rating of 200 Watts RMS into 8 Ohms Per Channel
400 Watts RMS into 4 Ohms Per Channel.
Total Harmonic Distortion is typically 0.005%, Signal to Noise Ratio of -122dB unweighted (20Hz to 20Khz)
A-weighted -126dB, Damping Factor Greater than 200 at 8 Ohms.
1.2 volts RMS for full power O/P

Part	Used	PartType	Designators
2	1	0.47uf	C12
3	8	0.22 Ohm	R24 R25 R26 R27 R28 R29 R30 R31
4	1	1.0nF	C6
5	1	1K	R2
6	2	1N4004	D1 D2
7	2	1N4737	ZD3 ZD4
8	2	1k	R37 R41
9	1	1m	R42
10	1	2.2UF	C2
11	4	IRFP9240	Q12 Q14 Q16 Q18
12	4	IRFP240	Q11 Q13 Q15 Q17
13	2	2k2	R3 R5
14	1	4k7	R38
15	2	5 AMP	F1 F2
16	1	5k	P1
17	1	5k6	R45
18	1	6k8	R14
19	3	10,000uf 100V	E1 E3 E4
20	1	10,000uf 100v	E2
21	1	10K	R8
22	1	10 Ohm	R9
23	2	10k	R4 R7
24	2	10nf	C3 C15
25	2	10pF	C4 C7
26	2	15k	R1 R11
27	2	15v	ZD1 ZD2
28	1	18K	R6
29	1	18pf	C11
30	2	47 Ohm	R35 R36
31	1	82k	R40
32	1	82 ohm	R34
33	2	100	R12 R13
34	2	100 Ohm	R32 R33
35	1	100k	R43
36	1	100nf	C16
37	2	100uF 100v	C5 C10
38	3	100uf	C1 C8 C9
39	1	120	R15
40	1	330k	R44
41	1	330uF	C13
42	9	470	R10 R16 R17 R18 R19 R20 R21 R22 R23
43	1	470nf MKT	C14
44	1	600V/35 AMP	BR1
45	1	625VA 2x50 VAC secondary windings	T1
46	5	BC546	Q2 Q3 Q4 Q5 Q19
47	1	BC556	Q20
48	1	BD139	Q10
49	3	MJE340	Q1 Q7 Q9
50	2	MJE350	Q6 Q8

Part Cross Reference Report For : C:\WINNT\Profiles\aholton\Desktop\My Documents\MOSAMP8_BOM.XRF 2-Mar-2001 11:45:59

C1	100uf	E:\SCH\MOSAMP8.S01
C2	2.2UF	E:\SCH\MOSAMP8.S01
C3	10nf	E:\SCH\MOSAMP8.S01
C4	10pF	E:\SCH\MOSAMP8.S01
C5	100uF 100v	E:\SCH\MOSAMP8.S01
C6	1.0nF	E:\SCH\MOSAMP8.S01
C7	10pf	E:\SCH\MOSAMP8.S01
C8	100uf	E:\SCH\MOSAMP8.S01
C9	100uf	E:\SCH\MOSAMP8.S01
C10	100uF 100v	E:\SCH\MOSAMP8.S01
C11	18pf	E:\SCH\MOSAMP8.S01
C12	.47	E:\SCH\MOSAMP8.S01
C13	330uF	E:\SCH\MOSAMP8.S01
C14	470nf MKT	E:\SCH\MOSAMP8.S01
C15	10nf	E:\SCH\MOSAMP8.S01
C16	100nf	E:\SCH\MOSAMP8.S01
D1	1N4004	E:\SCH\MOSAMP8.S01
D2	1N4004	E:\SCH\MOSAMP8.S01
E1	10,000uf 100V	E:\SCH\MOSAMP8.S01
E2	10,000uf 100v	E:\SCH\MOSAMP8.S01
E3	10,000uf 100V	E:\SCH\MOSAMP8.S01
E4	10,000uf 100V	E:\SCH\MOSAMP8.S01
BR1	600V/35 AMP	E:\SCH\MOSAMP8.S01
F1	5 AMP	E:\SCH\MOSAMP8.S01
F2	5 AMP	E:\SCH\MOSAMP8.S01
LD1	Yellow LED	E:\SCH\MOSAMP8.S01
P1	5k Multiturn	E:\SCH\MOSAMP8.S01
Q1	MJE340	E:\SCH\MOSAMP8.S01
Q2	BC546	E:\SCH\MOSAMP8.S01
Q3	BC546	E:\SCH\MOSAMP8.S01
Q4	BC546	E:\SCH\MOSAMP8.S01
Q5	BC546	E:\SCH\MOSAMP8.S01
Q6	MJE350	E:\SCH\MOSAMP8.S01
Q7	MJE340	E:\SCH\MOSAMP8.S01
Q8	MJE350	E:\SCH\MOSAMP8.S01
Q9	MJE340	E:\SCH\MOSAMP8.S01
Q10	BD139	E:\SCH\MOSAMP8.S01
Q11	IRFP240	E:\SCH\MOSAMP8.S01
Q12	irfp9240	E:\SCH\MOSAMP8.S01
Q13	irfp240	E:\SCH\MOSAMP8.S01
Q14	irfp9240	E:\SCH\MOSAMP8.S01
Q15	irfp240	E:\SCH\MOSAMP8.S01
Q16	irfp9240	E:\SCH\MOSAMP8.S01
Q17	irfp240	E:\SCH\MOSAMP8.S01
Q18	irfp9240	E:\SCH\MOSAMP8.S01
Q19	BC546	E:\SCH\MOSAMP8.S01
Q20	BC556	E:\SCH\MOSAMP8.S01
R1	15k	E:\SCH\MOSAMP8.S01
R2	1K	E:\SCH\MOSAMP8.S01
R3	2k2	E:\SCH\MOSAMP8.S01
R4	10k	E:\SCH\MOSAMP8.S01
R5	2k2	E:\SCH\MOSAMP8.S01
R6	18K	E:\SCH\MOSAMP8.S01
R7	10k	E:\SCH\MOSAMP8.S01
R8	10K	E:\SCH\MOSAMP8.S01
R9	10 Ohm	E:\SCH\MOSAMP8.S01
R10	470	E:\SCH\MOSAMP8.S01
R11	15k	E:\SCH\MOSAMP8.S01
R12	100	E:\SCH\MOSAMP8.S01
R13	100	E:\SCH\MOSAMP8.S01

R14	6k8	E:\SCH\MOSAMP8.S01
R15	100	E:\SCH\MOSAMP8.S01
R16	470	E:\SCH\MOSAMP8.S01
R17	470	E:\SCH\MOSAMP8.S01
R18	470	E:\SCH\MOSAMP8.S01
R19	470	E:\SCH\MOSAMP8.S01
R20	470	E:\SCH\MOSAMP8.S01
R21	470	E:\SCH\MOSAMP8.S01
R22	470	E:\SCH\MOSAMP8.S01
R23	470	E:\SCH\MOSAMP8.S01
R24	0.22 Ohm	E:\SCH\MOSAMP8.S01
R25	0.22 Ohm	E:\SCH\MOSAMP8.S01
R26	0.22 Ohm	E:\SCH\MOSAMP8.S01
R27	0.22 Ohm	E:\SCH\MOSAMP8.S01
R28	0.22 Ohm	E:\SCH\MOSAMP8.S01
R29	0.22 Ohm	E:\SCH\MOSAMP8.S01
R30	0.22 Ohm	E:\SCH\MOSAMP8.S01
R31	0.22 Ohm	E:\SCH\MOSAMP8.S01
R32	100 Ohm	E:\SCH\MOSAMP8.S01
R33	100 Ohm	E:\SCH\MOSAMP8.S01
R34	82 ohm	E:\SCH\MOSAMP8.S01
R35	47 Ohm	E:\SCH\MOSAMP8.S01
R36	47 Ohm	E:\SCH\MOSAMP8.S01
R37	1k	E:\SCH\MOSAMP8.S01
R38	4k7	E:\SCH\MOSAMP8.S01
R40	82k	E:\SCH\MOSAMP8.S01
R41	1k	E:\SCH\MOSAMP8.S01
R42	1m	E:\SCH\MOSAMP8.S01
R43	100k	E:\SCH\MOSAMP8.S01
R44	330k	E:\SCH\MOSAMP8.S01
R45	5k6	E:\SCH\MOSAMP8.S01
RCA1		E:\SCH\MOSAMP8.S01
SW1a		E:\SCH\MOSAMP8.S01
SW1b		E:\SCH\MOSAMP8.S01
T1	625VA 2x50 VAC sec	E:\SCH\MOSAMP8.S01
ZD1	15v	E:\SCH\MOSAMP8.S01
ZD2	15v	E:\SCH\MOSAMP8.S01
ZD3	1N4737 or 1n4744	E:\SCH\MOSAMP8.S01
ZD4	1N4737 or 1N4744	E:\SCH\MOSAMP8.S01