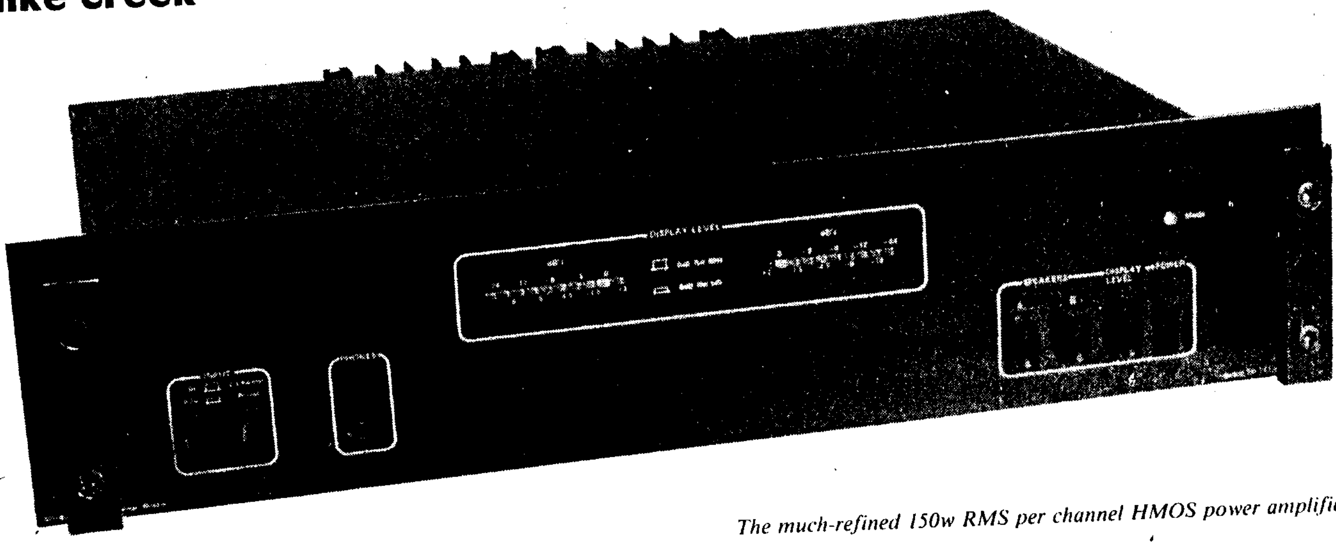
Higher Fidelity

PART II

..... following on from last month's loudspeaker protection circuit.

Mike Creek



The much-refined 150w RMS per channel HMOS power amplifier

The power supply and amplifier.

In view of the varying ideas and opinions on what constitutes the 'correct' power output for a 'Hi Fi' amplifier, it is necessary to examine the reasoning for such a large power output - when only around 10-20W average will be required.

If you need to reproduce the dynamic range (difference between the loudest and quietest sounds) and frequency information found on the latest analogue and digital recordings, then you must have an amplifier which is capable of reproducing at least 90dB, and allowing for some extra headroom so that the amplifier does not clip at that level, then an extra 10dB or more is desirable. The amp must also be able to follow fast transient information accurately, so it must also have a fast slewing (dV/dt) capability. As the power for the amplifier is derived by the power supply (minus the resistance of the output devices 'Ron') whose function is to modulate the DC power supply with an audio signal, it is essential to have a very low impedance power supply. In fact, the power supply is just as important as the actual amplifier if the full potential of the system is to be realised.

With this design, it is possible to run each channel of the amplifier with a completely separate power supply. This will give the ultimate in low and middle frequency crosstalk figures, providing that correct earth wiring is maintained. The effectiveness of the power line decoupling is rather better at the higher audio frequencies, so the the PSU does not play quite such an important role above 1kHz.

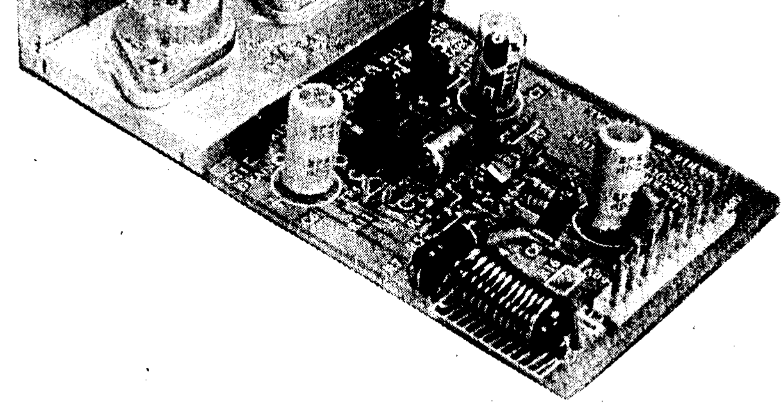
So that the design can be built 'on easy terms', a single power supply version can be expanded with a second PSU at a later stage.

As mentioned earlier the voltage drop across the output devices (*Ron*) is a significant factor in the efficiency of the power amp. MOSFET's have a higher *on* resistance than bipolar transistors, therefore more power is dissipated in a MOSFET output stage than a bipolar equivalent. However, one of the many features of HMOS devices allows you to simply parallel several pairs of devices, without the awkward side effects encountered when trying to place bipolar devices in parallel. Each additional pair reduces *Ron* and increases the current capability - making it possible to dissipate more power into the load and not into the heatsink.

The basis of this design is a compact module which has all its inputs, outputs and power rails plugged-in to one PC socket and the output devices mounted on a bracket and soldered directly onto the PCB, allowing for repeatability of manufacture and performance.

How it works

The circuit with its long-tailed pair on the input can be likened to a large operational amplifier with the positive input being the main signal input (TR1) and the negative input (TR2) being used for the negative feedback connection. Since the input will respond down to DC as well as AC, there is a requirement for a DC sensing circuit (LS1000 - see part one in last month's issue) to protect your speakers. The signal is then fed to the



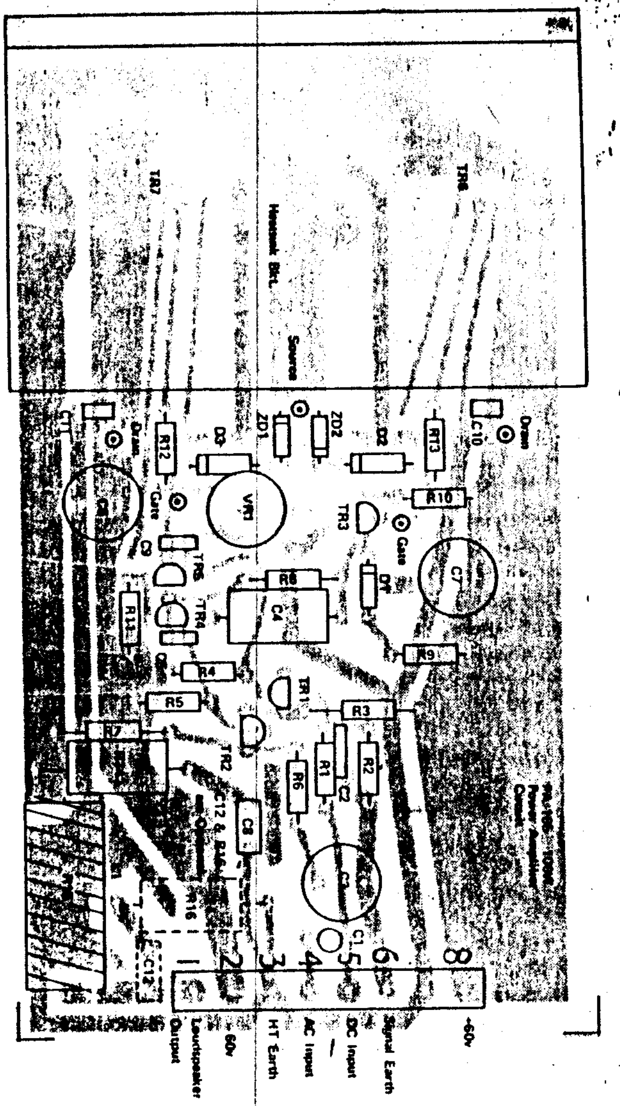


Figure 3
PC foil and overlay detail for the PA105 amplifier module

thermally protected by their negative temperature coefficient, which will actually reduce the drain current if the junction temperature rises above 75 degrees centigrade.

The MOSFET gates are provided with zener diode clamp protection to clip the drive voltage to below the 14v maximum permissible. In normal use, the gate voltage will never reach anywhere near this. However, it is in the nature of the zener diode to offer capacitance if whilst reverse biased - so it can be detrimental to the high frequency dynamic performance if the diodes are left in circuit.

No drain (emitter) resistors are required, simplifying the wiring with only a resistor of 100/200 ohms required in the gate lead to damp the input to the device and prevent parasitic oscillation from occurring. This resistor forms a low pass filter in conjunction with the device input capacitance.

It is very important to wire the various sections of the amp together in the manner described, or instability may occur due to earth loops etc.

Earth Consideration

Perhaps the most important aspect of high current amplifier design is the correct layout of earth paths. An earth is not truly an earth unless it is 0 ohms impedance, anything more than this is dicing with potential differences between one section of 'earth' and another. *Figure 2* illustrates this theory very well. Real earth leads contain finite resistance, so in the example shown the load current (1L) will be far greater than the input bias current - so V1 will follow the output voltage directly. Since the input current is basically feeding the positive side of the amplifier the result is positive audio feedback, which can very easily lead to complete instability, or at the very least, increased distortion. Thus the policy of single point earthing should be maintained at all times. The temptation to lump earth's together for the sake of convenience must be avoided.

Assembly

Solder in all the components making sure that part numbers given on the parts list match up with the legend information printed on the PCB. Make sure that all electrolytics, transistors and diodes are correctly polarised. The FET's connections are arranged with the source being the case, and the gate lead being underneath the word '*Hitachi*', which is printed on top. The Drain lead is then left.

When assembling the FET's, care should be taken not to short the case of the devices down to ground with the screws touching the heatsink bracket. Also make sure that the sources are joined together with the speaker output track on the PCB with solder tags. See *figure 4*. Wind 12 turns of enamel copper wire around the 10 ohm 2W resistor be certain to scrape off all the enamel at each each of the coil.

Test

To test this module, you need a low distortion signal generator, oscilloscope, multimeter and a dummy load. (8 ohm resistive 150W). This may be beyond the scope of most constructors, so you may need to compromise with cursory check using a multimeter. This should be done to check that the power supply rails are at the correct voltage: approx +/—60v off load for a 100W amplifier. The meter should then be connected in series with one of the HT rails (watch out for the smoothing capacitors, they bite) in a high current range. The amp module should then be plugged in, switched on and VR1

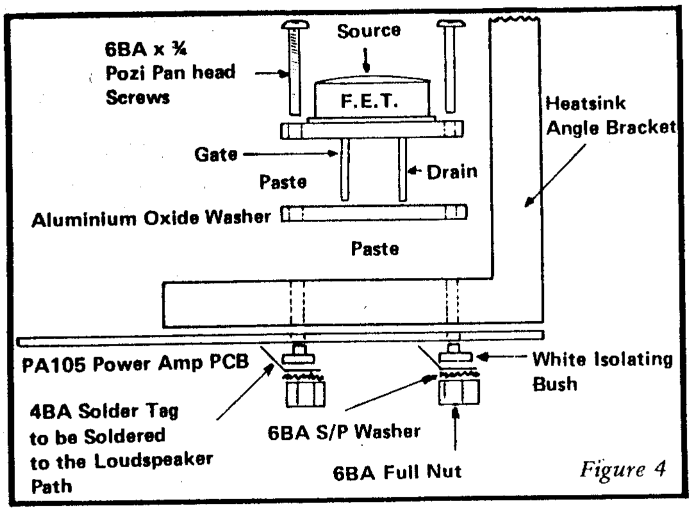
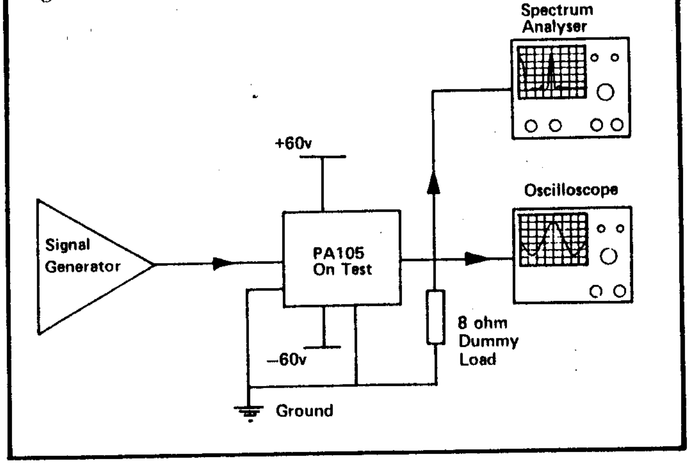


Figure 4

Figure 5 *Equipment used to Test PA105 Module*

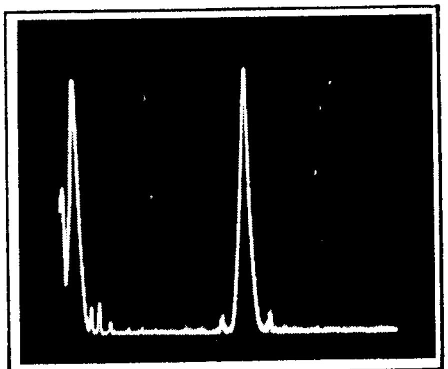


should be adjusted so that the unit draws approx 80mA. If you are still on the 30A current range of your meter and the needle has just fallen off, then after a clean set of underwear you should check for shorts on the FET's to ground (via some whiskers on the heatsink brackets), or perhaps the output devices are reversed.

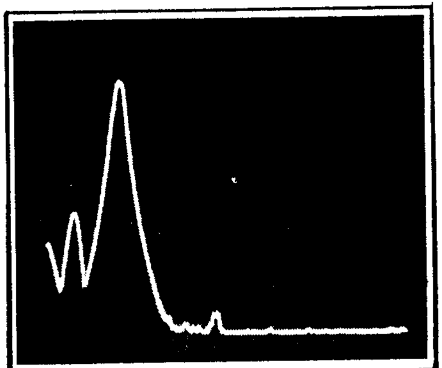
If no problems occurred on this test, then after reconnecting the HT, measure the offset voltage on the loudspeaker path. This should be below 250mV, normally as low as 5mV. You are now in a 'Go' situation, and a proper signal can be passed through to a pair of loudspeakers without fear of blowing them up. This however does not guarantee that the signal is pure and free from crossover distortion or HF instability.

This is where it is an advantage to have the rest of the test equipment, see *Figure 5* for details.

The results you should be looking for are firstly a symmetrical sinusoidal wave form, which should remain so up to approx 90 volts peak to peak on your scope or 31v RMS. This voltage into an 8 ohm load will produce in excess of 120W. No instability should be present at any level, and if you have a squarewave output on your generator, you can see if the frequency response is flat. Remember to check the test set up calibration, or like us, you may find yourself occasionally chasing your tail due to HF rolloff in the probe leads.

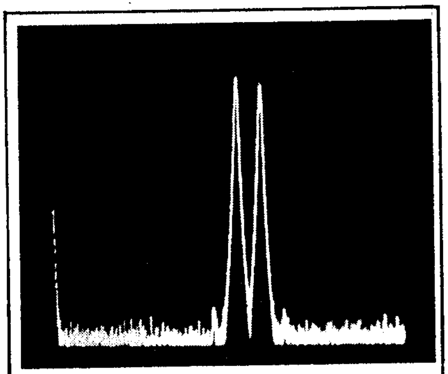


100W 8Ω
63Hz and 1kHz intermod

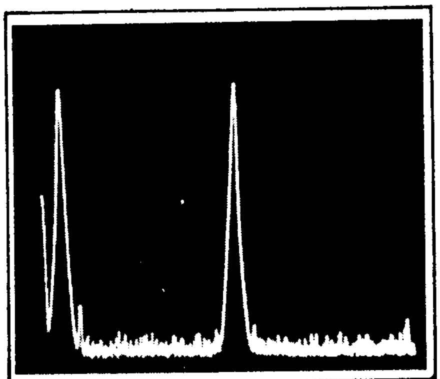


100W 8Ω 63Hz

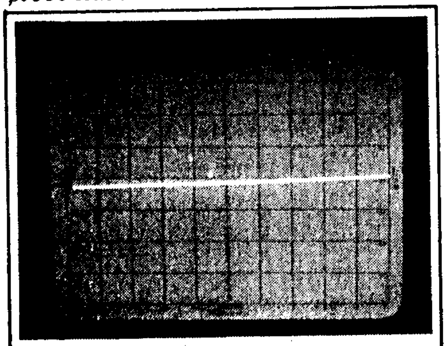
All spectrum analyser pictures: 10dB vert. 0Hz left screen



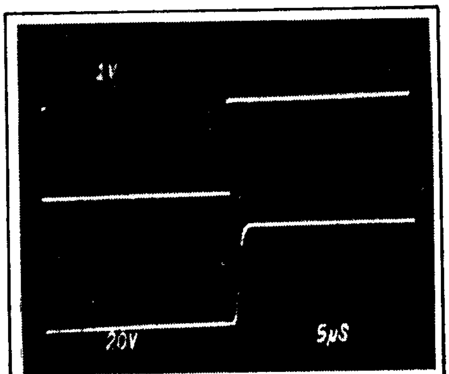
100W 8Ω
10k and 11kHz intermod



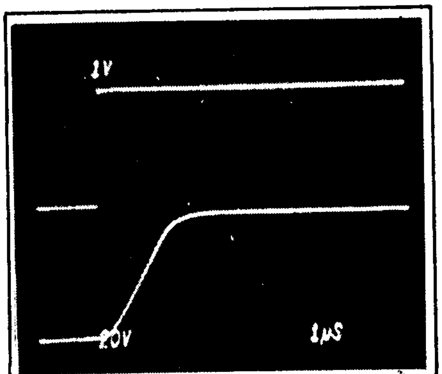
100W 8Ω
1k and 10k intermod



Bandwidth 100W 8Ω
0-200kHz



1kHz Square Wave
(input : top trace)



16kHz Square Wave
(input : top trace)

Components List

Resistors (All .25W 5% carbon film except R14, R15)

R 1	2k2
R 2	47k
R 3	56k
R 4	3k9
R 5	3k9
R 6	1k
R 7	22k
R 8	12k
R 9	100R
R10	100R
R11	120R
R12	220R
R13	220R
R14	10R 1W 5% carbon film
R15	10R 2W 5% carbon film
VR1	1k0 Min. Horizontal Cermet Preset

Capacitors

C 1	10uF 25v tantalum
C 2	33pF 100v min plate ceramic
C 3	100uF 63v electrolytic
C 4	5n6 polystyrene 100v
C 5	15pF 100v min plate ceramic
C 6	100uF 63v electrolytic
C 7	100uF 63v electrolytic
C 8	10nF 100v mylar
C 9	15pF 100v min plate ceramic
C10	47n 100v disc ceramic
C11	47n 100v disc ceramic

Miscellaneous

PCB	PA 105
1 x	8 way 0.2" connectors
2 x	Aluminium Oxide isolating washers
4 x	White isolating bushes
4 x	6BA x .75" pozi pan head screws
4 x	6BA x full nuts
4 x	6BA shakeproof washers
3 x	4BA solder tags
1 x	aluminium angle bracket
1 x	Extruded 3" long ally heatsink
45cms	16SWG enamel copper wire
3 x	No6 x .5" pozi pan-head.

Semiconductors

ZD1-2	BZY88C12V
D1-3	1N4001
TR1-2	2SA872
TR3	2SB646
TR4-5	2SD666
TR6	2SK134
TR7	2SJ49

Specification

Power Output	2 F.E.T. per channel	120W into 8 ohms	160W into 8 ohms
	4 F.E.T. per channel	160W into 4 ohms	230W into 4 ohms
Frequency/power bandwidth		5Hz to 200kHz —3dBs at rated output	
Slew rate		40v per uS	
Damping Factor		Better than 100 at 100Hz	
Distortion		Better than 0.03% 20Hz to 20kHz at rated output	
Intermodulation distortion		Better than 0.03% 100Hz and 10kHz	
Signal to noise		Better than 110dB	
Overload recovery		Instantaneous	
Sensitivity		1.25v RMS input for rated output	

Next month...
Assembly of complete amplifier, with careful attention to the detail of the wiring layout.

Radio and Electronics World

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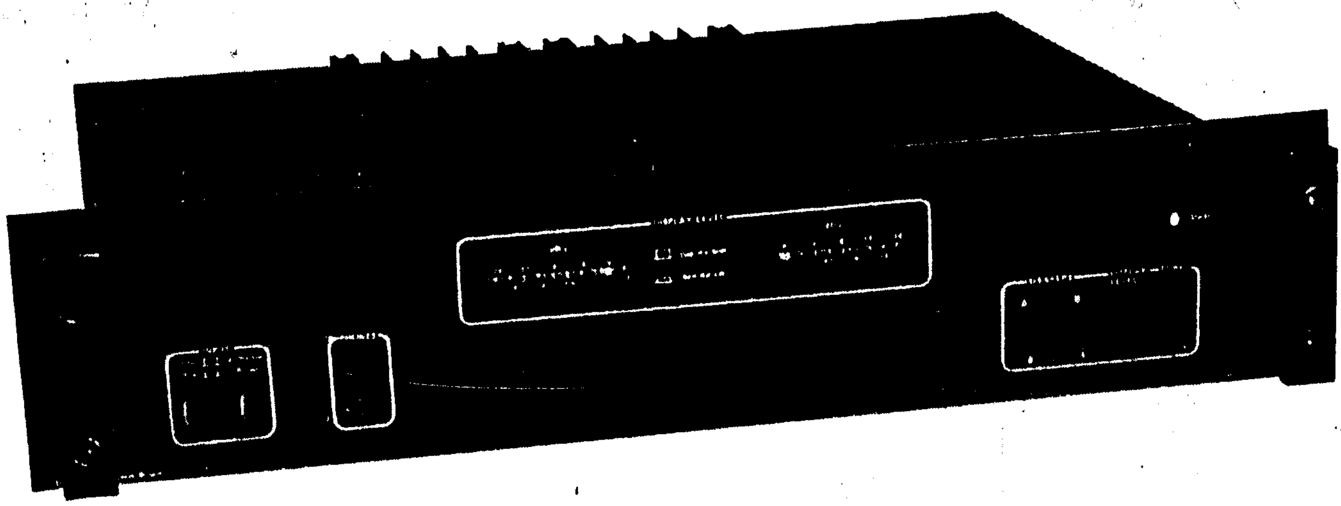
Higher Fidelity PART III

by Mike Creek



Assembly and wiring of the complete HMOS P.A.

General Description

If you are planning to build a high quality amplifier, and you have read the last two issues of R&EW, which describe the construction of the electronics involved in this project, you will be aware of the advantages of a MOSFET power amplifier compared to a bi-polar design.

The next consideration will be the packaging of such a design. You will need a substantial chassis to house the power amp modules, the power supplies, protection circuits, and several other bits and pieces, such as bar graph meters, switches, sockets, and fuse holders etc.

Cosmetics

This still leaves the problem of the front panel, which will need to have holes carefully punched or drilled in it, and will need spraying and perhaps silk screening if you are to be able to live with it in the living room. This now becomes a more daunting task, but don't despair, for help is around the corner in the shape of a ready-made, professionally finished 19" format chassis kit, which is provided with all the necessary holes and hardware to build a no-compromise power amplifier -or a less ambitious but nevertheless highly flexible approach to starting a project which allows for further improvements (funds permitting) as time goes on.

To be more specific, it is possible to build the power amplifier into the hardware using just one power supply, (transformer, rectifier and capacitors) the two power amp modules (PA105) and leave out the offset sensing until later. The requirement of bar graph meters, and bridged output will not be everyone's cup of tea, so these can be deleted also, leaving the amp without any reduction in performance but with a lot of room for refinement.

Assembly

The chassis itself is designed in several sections for ease of construction. These comprise the aluminium control panel, the inner front panel, rear panel, two side panels, middle panel, base plate, vinyl coated cover, and sundry items such as handles and blanking pieces.

For ease of construction it is best to follow a set pattern, and I shall first describe the 'complete' model, with reference to economies as I go along.

As a first step the rear panel should be fitted with its sockets. The two phono sockets should be isolated from the chassis with two plastic inserts, and the earth return should be via a solder tag mounted on one of the two holes used to secure the 600 ohm cannon socket or blanking piece.

The cannon socket is for professional use with balanced lines and will not be described here. The solder tag should also be used for an input and power supply chassis central earth point. This is important for maintaining hum and noise at a low level, *Figure 1*. It is also critical to the stable operating of the amplifier, (see last month's feature on Earth Considerations).

The loudspeaker terminals chosen for this design are screw cap 4mm instrument terminals 30A rating, allowing either twisted wires or 4mm plugs to be used. There are also facilities for two pairs of speakers to be connected, hence 8 sockets which should of course be isolated from the chassis. Next to these is an IEC chassis mounting mains plug for flying lead socket connection, above a chassis mounting fuse holder for the right-hand channel. The left-hand channel mains fuse is on the opposite end of the panel and directly above the socket for remote speaker switching.

The fuse ratings for the mains should be 3.15A slow blow, this is because the initial current surge when switching on a toroidal transformer is extremely high. If one transformer only, is used then the fuse rating may still remain the same.

The side and middle panels should be fitted with the smoothing capacitors (10,000uF 80v) through the three holes provided for mounting the capacitor clips. If one supply is used, then two capacitors only should be fitted to the right-hand side of the chassis. Make sure also that the connections to the capacitors should face each other - and be of opposite capacity, i.e. positive to negative.

The top two are to be joined together with heavy braiding, and the capacitor should then be left free to be rotated until the remaining two connections are the shortest distance away from the positive and negative wires emerging from the bridge rectifier - which is mounted directly below them on the base plate.

The front panel should be fitted with the DC offset sensing board (LS1000), by passing two 3mm (blue) screws through the panel and then through two 9mm metal spacers. The switch bracket is tapped and easily accepts the two screws. At the other end of the chassis there is provision for two switches, which if connected to the BR1000 PCB allow for switchable input sensitivity and bridged output (for those of you who require four times power output in mono). If this is not required, then only fit the switches to give the push buttons a home - and fill the holes in the control panel!

Bar Graphics

Offset each side of the middle of this panel, are large holes for mounting the bar graph meters (BGM1) which gives an inertialess power output indication which has switched dynamic range via the LS1000 PCB. (10W and 160W FSD.)

These are mounted with the highest 'power' LED of each meter in the centre of the panel. This is achieved on one type of PCB by assembling the LED's of the LH meter on the track side and mounting

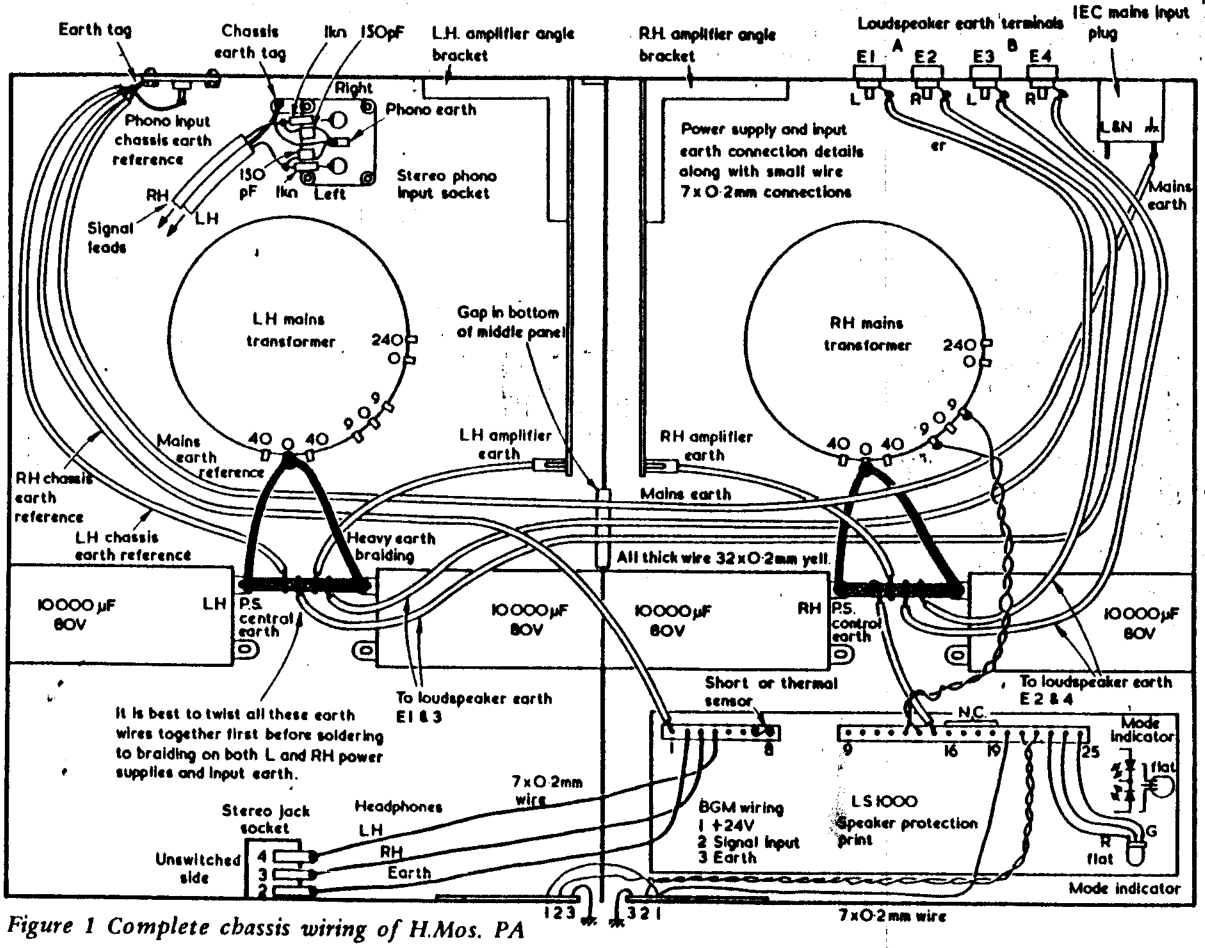


Figure 1 Complete chassis wiring of H.Mos. PA

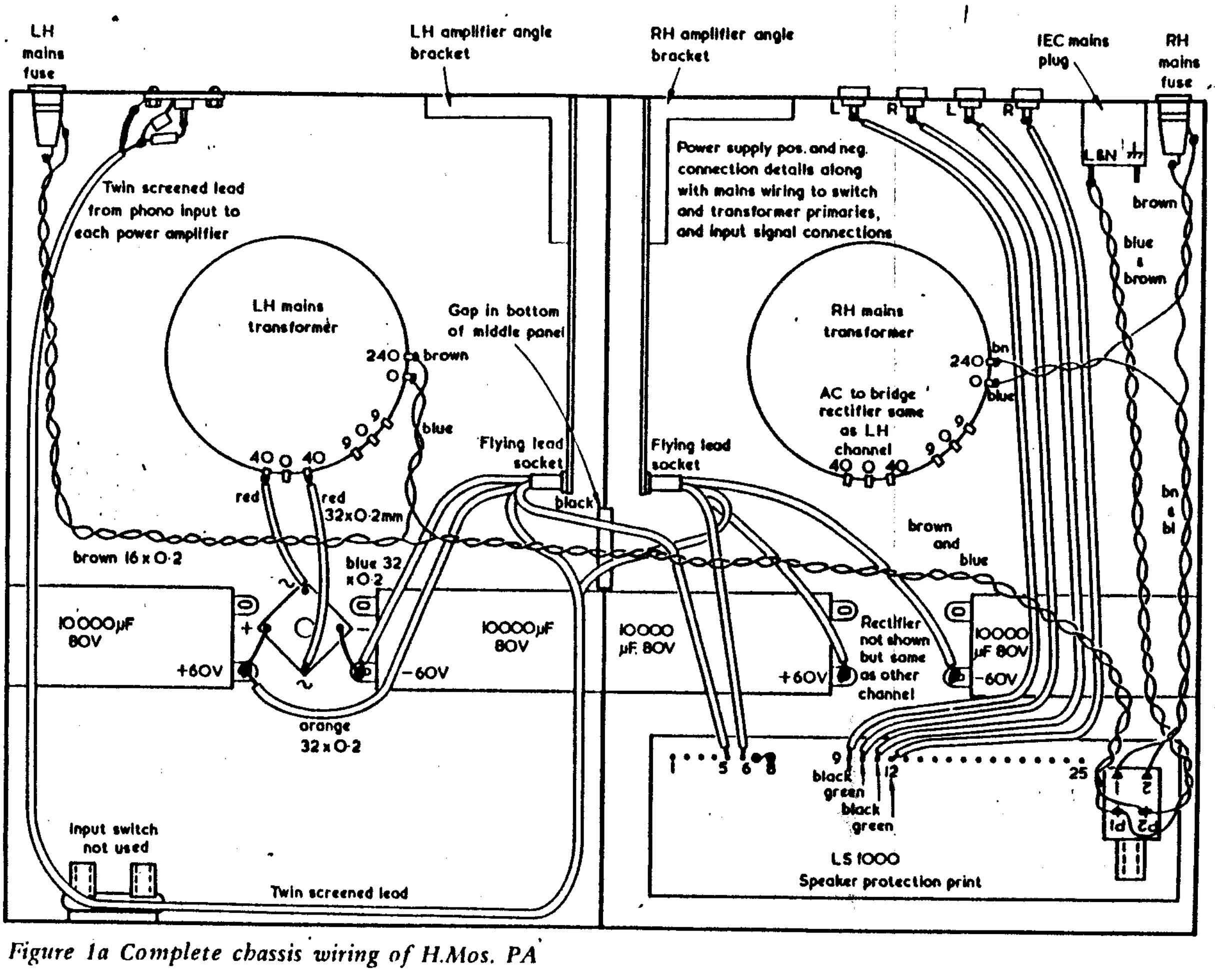


Figure 1a Complete chassis wiring of H.Mos. PA

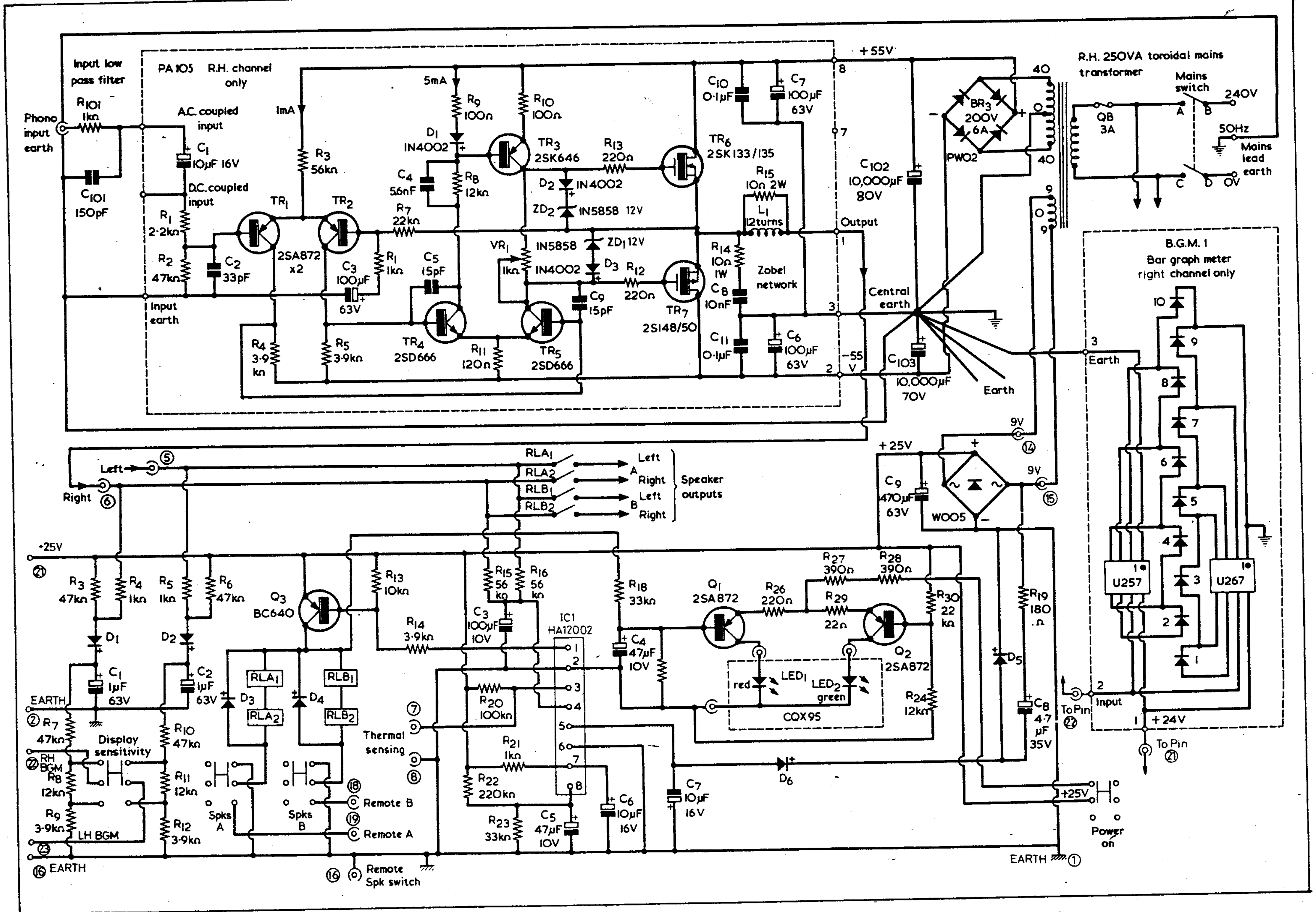


Figure 2 The complete circuit of final amplifier

it inside out on the front panel. Power to the display boards is derived from the LS1000 PCB.

If that is not used, the 25v DC should be sourced separately. Next to the BR1000 there is a hole for fixing a stereo jack socket for headphone connection.

Get It together

At this stage, it is a good idea to screw together all the panels, leaving the base plate until later, as this will facilitate easier wiring of the unit up to the point where the transformers and rectifiers are to be fitted. Nevertheless, the wires to these devices can be prepared and soldered at the 'other' end i.e. mains switch and fuse holder.

For the correct layout of the internal wiring it is advisable to follow the two diagrams *(1&1a)* which have been split for the purpose of simplifying the drawing. It is very important that the correct wire thicknesses are used, as some of the currents involved in the circuit would be severely restricted by too small a conductor, leading to poor performance and reliability.

All loudspeaker leads and earth returns, HT, and high current earth leads should be at least 32/0.2mm type and preferably in various colours. Mains wiring to transformers switch and fuses should be with wire of no less than 16/0.2mm and in different colours (brown and blue).

Apart from the heavy braiding used for the power supply earth and the twin screened lead for the input - the rest of the wires can be 7/0.2mm type in different colours. (see diagram for details).

When wiring up the power amp modules it is possible to either hardwire to the PC plug or make up a flying lead socket which can be assembled before the modules are actually installed into the rear panel. The wires should be cut and stripped to length, trimmed and crimped into large .2" connector pins, finally soldering until perfect high quality connections have been made. They are now ready to be inserted into a vacant ·way socket strip, making sure that they click home fully.

The base plate can now be fitted and the bridge rectifiers can be soldered into the smoothing capacitor lugs. Fastening the bridge rectifier to the base plate, which will act as a heatsink. The smoothing capacitor clips can now be tightened to secure the whole assembly.

Heave Ho

The mains transformers should be left until now, as they are obviously very heavy and make the task of moving the partly assembled amplifier around more difficult. They also make it difficult to wire around them as they take up a lot of space. It is an advantage to have the connecting wires to the primaries ready to solder, so that when you lower the transformers into place, it is just a simple matter to attach the mains wiring.

Pass the M6 x 75mm coach bolt through the base plate and through the middle of the transformer locating the square section with the square hole, and then fit the 25mm plain washer and 6mm nut - tightening up to a point where it can just be moved round. Final alignment and tightening should be carried out after the secondary connections have been made. Follow *Diagram 1* for details of connections.

Serious hum problems can occur if these instructions are not followed.

Having wired the system completely, install the PA modules. The best technique is to mount the extruded black heatsink onto the bracket that holds the PA105 PCB and FET's. It may be that you have chosen to use the four FET version in which case it is advisable to join the channel bracket to the heatsink first, before hardwiring the second pair of FET's to the PCB.

Unscrew the rear panel so that it can be folded backwards enabling easy access to the eight heatsink fixing holes. Having secured them, refit the rear panel with its PA modules and make the final preparations before switching on. Make sure the LED mode indicator is positioned in a visible position and remove the fuse from the left-hand mains supply.

Test Procedure

Check that the power supply voltage on the right hand PSU is approximately 60v DC on the capacitors, and +25v on pin 19 of the LS1000 PCB. The same should be done for the left-hand supply. **NB** These measurements should be taken with the PA modules disconnected in case anything is wrong.

If all is well, proceed to test the LS1000 circuit. The mode indicator will light - initially glowing red, and in a fault condition change from green to red. The relays will not be switched on while the LED is glowing red. Whilst the PA modules are disconnected, the resistors R4 and R5 (1k) will be floating at about 10v, due to their connection to the +25v rail via R3 and R6 (47k). This will indicate to the HA12002 that there is a DC offset on the PA module, which is false, since it is not connected. To simulate a properly running pair of PA modules' short pins 5 and 6 (LS1000) to ground via pin 8.

(This procedure is slightly different to that given in part I)

After a period of approximately 4 seconds, the red LED should turn green -indicating that all is set to go. **NB.** The relays will only engage if the green LED is 'on', and either the speaker selection switches have been pressed - or pins 17 and 18 have been grounded via pin 16, the remote selector switch.

Taking the heat off

It is also important to make sure that if you are not using the thermal sensor position (low is off, high is on), pin 7, then this should also be grounded via pin 8 - otherwise it will offer a fault condition to the HA12002. If all tests check out on the LS1000, you can pass on to the PA105. The test procedure for this was described in Part II, but briefly: check the modules one at a time without a speaker or load connected, and make sure that the quiescent current is adjusted with pre-set VR1 to approximately 80mA. Start with the preset in minimum resistance configuration (minimum current), and work 'up'.

The LS1000 will obviously not function properly until both PA modules have been connected and shown that there is an acceptably small amount of DC offset present at their outputs. The bar graph meters are supplied with audio via the LS1000. This is rectified and smoothed, and presented to the U257/267 as a variable DC voltage. The ICs used are of logarithmic law, and the scale on the control panel is calibrated accordingly -with OdB being calibrated as 5W and 80W on the low and high level ranges respectively.

Are you getting enough?

The sensitivity of the amplifier at 120W into 8 output is 1.25v RMS. (3.5v peak to peak - but if this is too low, then the BR1000 circuit can be used to boost this to 0.5v RMS. (1.4v peak to peak).

The other function it performs is to phase-split the input signal, so that the positive half cycle goes to one channel and the negative to the other. Providing the loudspeaker is connected across the left and right 'live' terminals and **not** earth, then the unit can be used as a mono-amplifier with approximately 4 times power output potential, i.e. 120W stereo becomes approx 400W mono.

For the 4-FET version run into a 4 load, a potential in excess of 600W is available. This is only designed to handle transient information and not continuous output levels.

Tests have shown that most modestly rated loudspeakers can withstand short term transients, but will give up the ghost if used with small power amps which are run into clipping frequently.

The End is Nigh...

Finally, if everything seems to be working satisfactorily, then proceed to fit the front panel. Line up all the LED's on the bar graph and fitting the panel over them before attempting to fit the push buttons.

Secure the control panel with the bolts running through the handles, fit the push buttons and insert the mode LED into place and glue in if it is not a 'tight' fit. Fitting the vinyl cover is made easier by standing the unit on its handle and putting the cover on from the rear. When the cover reaches the inner front panel, look up the middle so that it can continue to be flush with the control panel. When screwing this to the rest of the chassis, make sure there is a good electrical connection between the two, by scraping a small piece of the vinyl away from the fixing hole if necessary.

Full construction details are supplied with the hardware kit if there is any doubt.

Final Tips

When connecting to your pre-amp, make quite sure that the phono connections are of high quality, and that they are a tight fit. It may be necessary to remove the mains earth lead if a hum loop is occurring (check for hum with the volume control backed completely off) in which case make absolutely sure that the pre-amp is correctly earthed via the mains.

Good Listening. ■

Your Reactions........	Circle No.
Immediately Applicable	290
Useful & Informative	291
Not Applicable	292
Comments	293

differential pair (TR4 & 5) where the positive and negative half sine waves are amplified by TR3 and 5. These transistors need only be modified TO92 package devices, as very little driver power is needed to overcome the capacitance effects of the FET's gate.

The HMOS FET's are complementary P and N Channel devices and are connected in a source follower mode. This is similar to the conventional push-pull emitter follower method as used in bipolar designs, which provides a wide transfer bandwidth and good stability.

Whilst the forward transconductance, *Yfs* of power MOSFET's is as large as 1 S (Siemens or 'Mho') - this is only a fraction of that of a bipolar transistor, which leads to higher open loop distortion. Since the power MOSFET produces an open loop distortion of about 20dB greater than a bipolar device, it is necessary to use larger open loop gain and more negative feedback. Purists who have listened to the arguments about the efficacy of negative feedbcak with respect to *TIM* may consider this a bad thing - but the speed of the MOSFET makes up for increased NFB.

Applying negative feedback in relatively slow bipolar amplifier designs will cause a large phase shift to occur, forcing a compromise in frequency/gain characteristics in a phase compensation circuit. With a single MOSFET device in source follower mode, much feedback can be applied over a wide bandwidth, to reduce distortion to lower levels than those achievable in a bipolar design, and with a good deal less complication.

The MOSFET does not require a conventional class B driver stage. Therefore, the frequency compensation 'poles' of the amplifier can be reduced, and a large and stable DC negative feedback can be formed which does not compromise the amplifier's dynamic performance (transient). R7-22k and R6-1k form the feedback attenuator, and allow for 23 times voltage gain i.e. 1.25v RMS input will give 120 watts output into an 8 ohm load, using separate 250VA transformers and a single pair of output FET's. If two pairs of FET's are used -then approximately 160W into 8 ohms is possible using the same power supply.

C3 is the feedback ground reference and effects the low frequency 3dB 'roll off' point. In theory the larger the value the lower the frequency and vica versa. With C3 at 100uF, the 3dB point is approximately 5Hz.

Since the amplifier is designed for Class AB operation, it is necessary to bias the output stage into its most linear region. A high quality cermet preset is used between the gates of the two FET's and should be adjusted to make the amp draw a standing (quiescent) current of approx 80mA - although this is not particularly critical. If sustained high power is required, then a lower current may be desirable to keep the temperature of the heatsink lower.

A Zobell network at the output is necessary to prevent HF instability when looking into reactive loads - which encompasses just about everything that isn't a pure resistance. The 3dB point of this low pass filter is at 1.5MHz, so it will have no effect on the audio performance. This also applies to the output coil which is designed primarily for stopping RF from such things as adjacent radio transmitters getting into the feedback path, as this also has its 3dB point at 1.5MHz.

A complete kit of parts for making a mono amplifier module is available - with optional heatsink mounting bracket or 'U' channel that can be used for mounting either two or four FET's, and soldering two directly to the PCB and hardwiring to the other pair. HMOSFETs are inherently

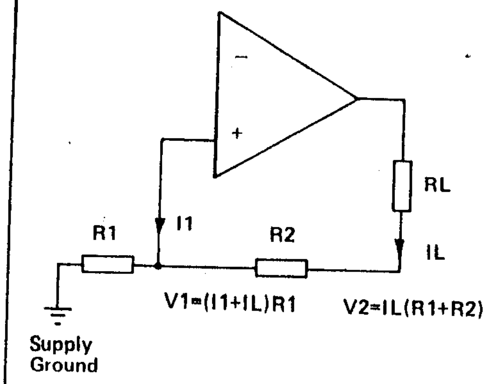


Figure 2 : Ground Loop Example

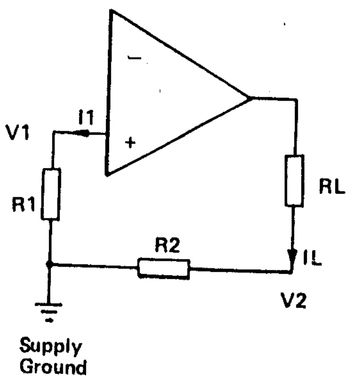


Figure 2.2 : Single Point Ground System

tie up 2 to op 1

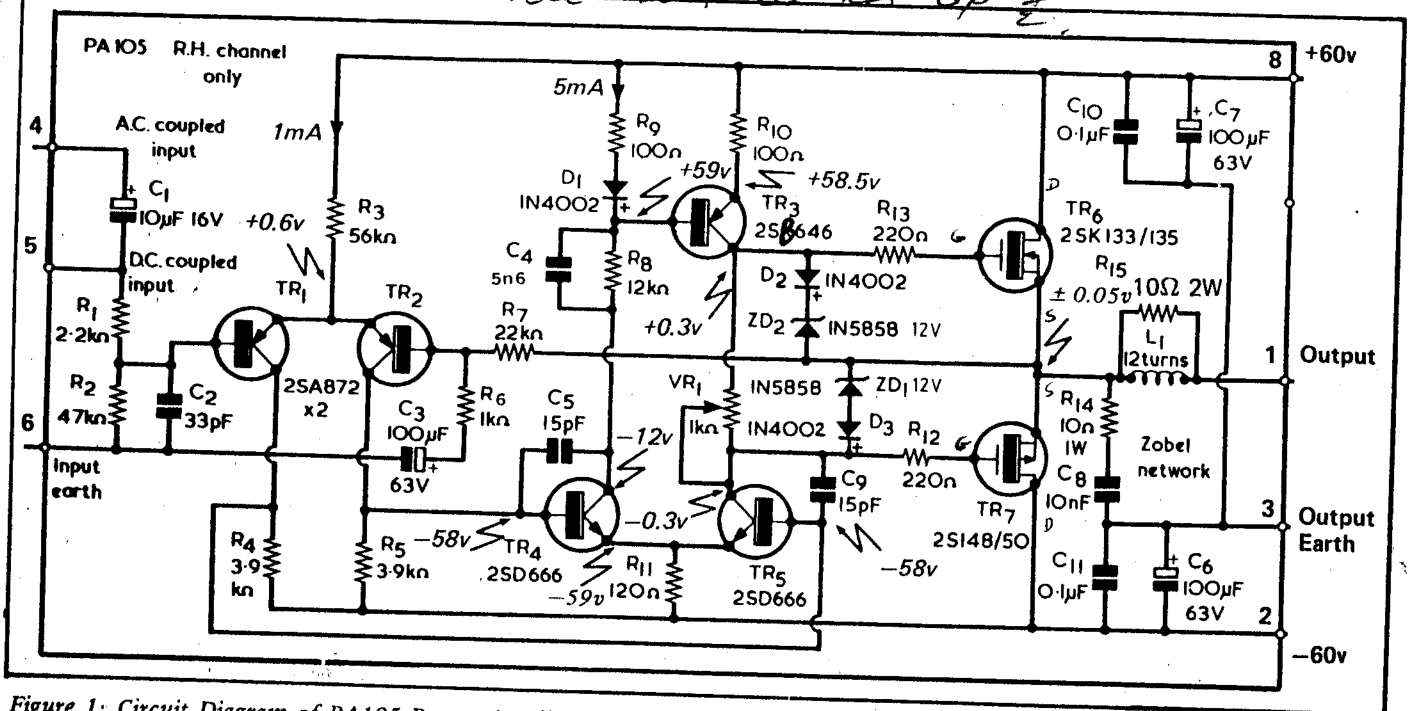


Figure 1: Circuit Diagram of PA105 Power Amplifier Module.