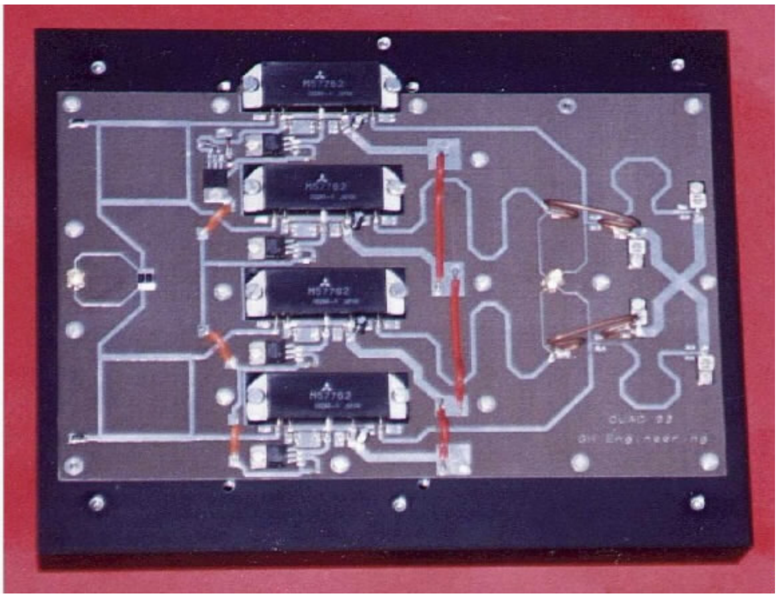
GH *Quad* Linear Amplifier

Construction and operating notes - mini-kit Version 0.6 March 2001



1…Introduction

The GH *Quad* is a high performance solid-state amplifier using 4 Mitsubishi M57762 Power Amplifier modules to deliver up to 72W in the frequency range 1.24 - 1.3 GHz. The PA modules require no tuning, being internally matched at the input and output to 50 ohms. The modules are biased from a regulated 9V supply. These features make the modules very easy to use, but the downside is that they are very inefficient, typically achieving around 30% efficiency. Therefore, for an output power of 72W, a total DC input power of around 240W is required, of which 168W is dissipated as heat.

It is imperative that the PA modules are not allowed to overheat, and for this reason a large heatsink is used with a thermal resistance of approximately 0.3 degrees C/W. This measures 300 x 250 x 48mm, and weighs 3 kg. The heatsink is a comb section aluminium extrusion which has been black anodised for extra thermal performance. The PCB is mounted to the flat surface of the heatsink.

The mechanical construction of the *Quad* is critical for good results and reliability. The *Quad* mini-kit is not supplied with a case, as many constructors are able to supply their own. The first job therefore is to plan the overall mechanical layout. Whilst it would be possible to use the *Quad* without a case, using studs or screws to support the heatsink, this is not recommended for a number of reasons. A suitable case is available from GH Engineering if required.

1.1..Safety

One of the advantages of solid state amplifiers compared to those with valves is that there are no dangerous high voltages present inside the case. However, a couple of points need to be mentioned regarding the safe use of this amplifier :-

1.2..RF Fields

A typical use of the amplifier is for ATV, where a 'bare foot' transmitter might give an output of just over 1W. Under normal operating conditions the RF fields generated are unlikely to pose a hazard to health, although obvious precautions should still be taken. The *Quad* is capable of generating 50 times the RF power of the 'bare foot' transmitter, and therefore 50 times the RF field strength at the aerial. If the aerial is mounted at the top of a mast, then the RF fields generated at ground level will be within safe limits. However, situations could occur when aerials are being used close to ground level, for example if testing the SWR of the aerial prior to installation. In this case, the operator needs to take extra care to ensure that the aerial is not being pointed at anybody within a reasonable distance whilst transmitting, as very high levels of RF energy can be present in the near field region of a high-gain antenna, and the use of the *Quad* amplifier will intensify these RF fields.

1.3..RF burns

It is not recommended to use the amplifier with the PCB exposed, as there is a possible danger of accidentally touching one of the output tracks. At full power, each of the output tracks is carrying over 0.6A of RF current; and even though this current is at 1.3 GHz any contact with skin is likely to produce burns which could be as severe as touching the tip of a hot soldering iron.

1.4..Beryllium Oxide

The power amplifier modules contain Beryllium Oxide (BeO) which has excellent thermal properties. In normal use, these modules are perfectly safe and present no danger to health. However, BeO in dust form is extremely toxic. Under no circumstances should any attempt be made to open or repair the modules. Note that the modules have a non-setting sealant around the fin and the leads - this sealant does not contain BeO.

2..Specification

Frequency Range	1240 – 1300 MHz (may be operated above 1300MHz with some loss of output power)
Output Power	72 Watts typical (4W input @1260MHz, 13.8V DC supply voltage)
Input Power	5W maximum
Input VSWR	<2:1
Output VSWR	<2:1
Power requirements	12.5 – 13.8V DC @ 23 A
RF Connectors	N-type sockets
Size	305mm x 280mm x 185mm
Weight	3.5kg

2.1.. Checking the contents of the kit

The first task is to read these construction notes carefully, and then read them again. If in doubt about any of the points in this document please feel free to contact GH Engineering for advice. The second job is to check the documentation against the documentation list, and to check the contents of the kit against the parts list. Please contact GH Engineering immediately if any parts appear to be missing or damaged. The documents supplied are :-

Construction and operating notes	This document	20 pages
Circuit diagram		1 page
Heatsink drawings	Assembly Drawings 1-3	3 pages
Semi-rigid cable drawing	Assembly Drawing 4	1 page
PCB Assembly drawings	Assembly Drawing 5	2 pages
Parts list		1 page

Note that TR1 is a static sensitive component, and so the appropriate handling precautions should be taken.

2.2..Construction

2.2.1…Tools

The *Quad* mini-kit is intended for constructors who have previous experience of building UHF circuits, and therefore it is likely that that most, if not all of the tools required to build this project will be readily available :-

1.8, 2.5, 3.0, 3.3, 4.2 and 10mm drill bits
M3 taper tap and bottoming tap)
) alternatives
M3 spiral flute tap)
M4 taper tap
M4 bottoming tap
M5 taper and bottoming taps
Tap wrench (T-bar type may be more suitable for M3 taps)
Small Tri-square
Jig saw with steel cutting blade
Soldering iron with very fine tip and large tip

The mini-kit can be supplied with any amount of construction already completed by GH Engineering; for example the heatsink can be supplied ready drilled and tapped. Please ask for details.

2.3...Planning the layout

The PCB measures 281 x 184mm. The PCB is mounted on the heatsink as shown in Assembly Drawing 1. These dimensions have been chosen to allow the use of the optional N-type to SMB input lead. There is a border around the outside of the heatsink for mounting the case. Note that it is not practical to mark the location of the case-heatsink mounting bolts on the heatsink. Instead, the location of the holes should be marked on the case, and then drilled through to the heatsink after the cut-out has been made in the lid of the case.

It is highly recommended that a suitable equipment case is obtained before construction of the *Quad* is started. The case should be made of metal, either steel or aluminium. The position of the input and output connectors, DC power connectors, PTT connector and any ancillaries such as power-on LED should be considered carefully. For maximum strength, it is recommended that a cut-out is made in the lid of the case to accommodate the PCB, and that the heatsink is bolted directly to the case top in the 'border' area of the heatsink in at least six positions with M5 screws. It may be possible to use M4 screws, in which case at least 8, and preferably 10 should be used, but this has not been tried. The cut-out for the PCB should be approx. 283 x 186 mm.

The choice of RF connectors is left to the constructor. Provision is made on the PCB for SMA connectors at the input and output, and these connectors are supplied with the kit. Alternative PCB connectors are SMB and SMC as they have a similar footprint to SMA connectors, although the centre pin is slightly smaller with SMB/SMC connectors. A special input lead is available from GH Engineering which has an N-type socket at one end and an SMB plug at the other end. If this lead is used, then care should be taken to ensure that the PCB is located exactly as shown on Assembly Drawing 1, otherwise the SMB socket on the PCB may be too far away from the N type socket on the front panel.

Note that thin PTFE co-ax is fine for the input connection, but is not suitable for the output connection as it will overheat. Semi-rigid co-ax is recommended for the output connection, and is an option for the input. Short lengths of semi-rigid co-ax with SMA connectors are readily available at many large rallies in the UK. SMA connectors and semi-rigid coax are available in any length up to 3m from GH Engineering.

Also note that SMA connectors are rated to handle power levels in excess of 80W at 1.3GHz, and should present no problems, hence the recommendation that they are used on the PCB. However, it is recommended that for the majority of instances an N type socket is fitted to the case as the output connector.

2.4..Marking out the case

Once the overall layout has been decided, the case needs to be marked out with the positions of the various connectors and the PCB cut-out. The positions of the screws holding the heatsink to the case
also need to be marked on the lid of the case. The PCB cut-out can then be made with the use of an electric jigsaw and suitable cutting fluid. If a jigsaw is not available, then alternative methods are to chain drill a line of holes inside the marked-out area and file out the holes to form four straight edges in a rectangle, measuring 283x186mm. Alternatively, a lot of time could be saved by the judicious use of a cutting disc on an angle grinder, but take extra care as this could damage the case if too much metal is removed!

3…Mechanical Construction

3.1..Drilling and tapping the heatsink

This is a very time-consuming process. However, these notes have been prepared in order to guide the constructor through the various stages step by step. If these notes are followed carefully then no problems should be encountered. Do not be tempted to take short cuts or rush things. Best results will be obtained with a methodical approach. Marking, drilling and tapping the heatsink will take 4-6 hours depending on your experience and facilities, but getting it wrong will take even longer.

The smallest holes are drilled first, gradually increasing in size. This makes it easier to correct mistakes - it is easier to enlarge a hole; making it smaller is not so easy (see section ‘If something goes wrong’ for details).

The mounting plate is used as a drilling template for the heatsink. The holes have been punched on a precision CNC machine to ensure high accuracy and repeatability. Some of the holes on the mounting plate are very close together, and the drawings should be referenced very carefully before and during the marking out procedure. Most of the measuring has been eliminated by the use of the template, but care should be taken to ensure that the correct holes are being used at any given time.

There are 42 holes to be drilled in the heatsink, of which 36 are to be tapped. Because the holes are being tapped, the diameter needs to be controlled quite tightly. If the holes are too large, the threads will strip easily; if they are too small the tap may break whilst cutting the threads. For best results, the holes should be drilled blind with the use of a depth stop. This will ensure that the mounting screws are not visible on the outside of the heatsink. The use of a pillar drill will help considerably with this, and at the time of writing a suitable pillar drill is being offered for under £40 at one of the major UK DIY superstores.

If a pillar drill is not available, it may be possible to use a pistol drill mounted in a drill press attachment. However, this has not been tried, and there may be problems drilling the holes at the centre of the heatsink. It is possible that a pistol drill could also be used with an appropriate amount of care. In this case, the heatsink must be clamped firmly to a bench to prevent it moving due to vibration during the drilling operation. Due to the fact that aluminium is a relatively soft material, it is quite difficult to ensure that the drill bit enters and exists the hole without unduly enlarging the hole. It may be worthwhile to drill one or two 2.5mm test holes in an ‘unused’ area of the heatsink, for example under the voltage regulators. The diameter of these holes can be tested with the drill bit that was just used, and tapped to ensure that the thread will correctly, and that an M3 screw will fit. If the holes are too large, it would be possible to use a slightly smaller drill bit such as 2.3mm.

Note that 2 of the holes are quite close to the centre of the heatsink, and a small pillar drill may not have sufficient throat depth to be able to drill them, and so a pistol drill will have to be used. In this case, it is important to ensure that the heatsink is not able to move during the drilling operation, and the heatsink should be clamped firmly to a bench or similar whilst drilling these holes. The small drill bits should protrude just far enough from the jaws of the chuck to ensure that the holes are drilled to the correct depth - any more, and the drill bit may break or the holes could break through the heatsink.

The use of cutting fluid is highly recommended for both the drilling and tapping operations. Any cutting fluid is better than none, and there are various different types available. It has been suggested that turpentine makes a good cutting fluid for aluminium, but this has not been tested.

The PCB mounting plate also doubles as a template for marking the centres of the holes to be drilled in the heatsink. For this reason, the holes have been punched to a diameter of 1.8mm and will need to be opened out to 3.3mm AFTER the heatsink has been drilled and tapped.

3.1…Some notes about tapping holes

Two taps are required for each size of hole, the first is a taper tap and the second is a bottoming, or plug tap. Do not be tempted to just use the bottoming tap, as it is much more difficult to ensure that the tap is going into the hole vertically. Do not try to cut more than 90 degrees of thread at a time - aluminium has a tendency to 'grab', and if more than 90 degrees of thread is cut the tap could jam on the reverse cut - this could easily break the tap.

It is important to ensure that the tap is vertical. This is done by placing a tri-square on the heatsink, and repeatedly checking that the tap is parallel to the edge of the tri-square. It is necessary to check this in two orthogonal planes. The taper tap is the most critical, as the second tap will tend to follow the line of the first tap. Even so the line of the second tap should also be checked, especially for the first few threads.

Note that swarf will accumulate in the bottom of the hole being tapped, and this should be removed after using both the taper and bottoming taps.

It has been found that the 'T-bar' type of tap wrench is easier to use than the more conventional tap wrench with small taps such as M3, although this may be due to personal preference.

The use of cutting fluid is highly recommended for both the drilling and tapping operations. Any cutting fluid is better than none, and there are various different types available. It has been suggested that turpentine makes a good cutting fluid for aluminium, but this has not been tested by GH Engineering.

3.2..Drilling the heatsink with the aid of the mounting plate.

3.2.1..Stage 1

1) Locate the PCB mounting plate on the heatsink as shown in Assembly Drawing 1and clamp it in place with a welding clamp, G-clamp or similar. As an alternative, the plate can be held in position with sticky tape, but ensure that the mounting plate does not move during drilling.

2) With a 1.8mm drill, mark the location of the top right corner mounting hole (hole 'X') by drilling through the mounting plate into the heatsink.

3) Remove the mounting plate and drill this hole in the heatsink with a 2.5mm drill to a depth of approximately 6mm. The depth of this hole is not critical, but if it is too deep it will protrude through the other side of the heatsink, and if it is not deep enough the screws will not tighten fully. Tap the hole with M3 taper and bottoming taps.

4) Open up the corresponding hole in the mounting plate to 3mm, such that an M3 screw will just clear the hole. Re-locate the mounting plate as before on the heatsink, now using an M3 screw to hold the mounting plate securely in place in the top right corner.

5) Now repeat steps 2 - 4 for hole 'Y'. Ensure that the mounting plate is in the correct position on the heatsink before marking the position of the second hole.

The mounting plate is now held in place with two screws, and is now ready to be used as a template for the rest of the drilling which is done in four stages. The first stage is to drill and tap the PCB mounting holes, the second stage is to drill and tap the mounting holes for the power terminations, the third stage is to drill and tap the M4 holes for the modules and the fourth stage is to drill the two clearance holes for the input and output connectors. Note that stage 3 has to be done even if PCB mounted connectors are not used, as a clearance is required underneath the pad on the groundplane side of the PCB. Note that to avoid confusion, it is suggested that the drilling and tapping of all the holes in any given stage is finished before starting to drill the next stage.

6) With a 1.8mm drill bit, mark the centres of the 20 remaining M3 PCB mounting holes (holes A) and the 2 clearance holes for the PCB mounted RF input and output sockets (holes B). Take care that the correct holes are being used, as some of the holes are quite close together and not all the holes in the mounting plate are used.

7) Remove the mounting plate from the heatsink. Do not open up the holes in the mounting plate yet.

8) Now drill the 20 M3 mounting holes just marked in the heatsink with a 2.5mm drill bit to a depth of 6mm. De-burr the holes and tap the holes with taper and bottoming taps.

3.2.2..Stage 2

9) Re-mount the mounting plate on the heatsink using the holes XX and YY as shown on Assembly Drawing 3, and rotating the plate through 180 degrees as shown. The holes XX and YY have been pre-punched to a diameter of 3.2mm. Locate the centres of the 4 holes (C) with a 1.8mm drill bit and remove the mounting plate from the heatsink.

11) To check that the holes have been drilled in the correct place, temporarily mount the PCB on the heatsink and check that the centres just created appear in the cut-outs for the 50W terminations.

12) Remove the PCB and drill the four holes with a 2.5mm drill bit to a depth of approx 5mm. De-burr and tap these holes with M3 taper and bottoming taps.

3.2.3..Stage 3

13) Re-mount the mounting plate on the heatsink using holes XX and YY as shown on Assembly Drawing 3. Locate the centres of the 8 M4 holes for the modules (holes D) , again with a 1.8mm drill bit.

14) Remove the mounting plate and check that the holes are in the correct position with the PCB as previously. Drill the M4 holes (holes D) with a 3.3mm drill bit to a depth of 5mm . De-burr and tap these holes with M4 taper and bottoming taps.

3.2.4..Stage 4

15) Re-mount the mounting plate on the heatsink in the original position using the original holes X and Y. Mark the centres of the 2 holes (B) with a 1.8mm drill bit, and after checking that these two holes are in the correct position, drill them to a depth of approximately 5mm - first with a 3.3mm drill bit and then with a 10mm drill bit. De-burr the holes. These holes are simply to ensure that the centre contact of the input and output sockets to not short to ground (or generate stray capacitance to ground) on the heatsink. This drilling operation is done last deliberately - if the wrong holes had been drilled out to 10mm, it would have involved extra work in correcting the problem.

16) Drill and tap the M5 holes used to mount the heatsink to the case. These will be located in the shaded area on Assembly Drawing 1. The exact location of the holes is determined by the constructor. It is suggested that the location of these holes is first marked on the case, and pilot holes drilled. The heatsink is then mounted on the case, and the location of the mounting holes is marked by drilling through the pilot holes into the heatsink.

17) Locate the PCB and the mounting plate on the heatsink, and check that all the holes line up. Then drill out the 20 mounting holes (holes A) in the mounting plate with a 3.3 mm drill bit. Drill out the holes for the input and output connectors (holes B) with a 10mm drill bit. Note that not all of the holes in the mounting plate are used for mounting the PCB, and therefore do not need to be drilled.

3.3..If something goes wrong.....

There are very few problems that cannot be corrected, so dont' panic...

3.3.1.. Breakthrough. If a hole is drilled too deep, the drill will breakthrough into the comb section of the heatsink. This is purely a cosmetic problem; it will not affect the operation of the amplifier in any way. The use of black paint will help to disguise the shiny aluminium, and metal loaded epoxy may be used to 'fill in' the hole.

3.3.2.. Hole not drilled deep enough. Check that the swarf has been removed from the bottom of the hole before tapping. If the screw will not tighten down with the PCB and mounting plate fitted, it may be preferable to use washers underneath the screw head in preference to re-drilling the hole. Re-drilling after tapping is very risky, as the threads in the hole are very vulnerable to damage from the drill bit.

3.3.3.. Hole drilled to large. There are three courses of action that may be taken :-

(i) Do not use the hole. If the hole is a PCB mounting hole, then it is possible that the screw can be left out with no significant degradation in performance.

(ii) Drill to larger size. It may be possible to re-drill the hole and tap it with an M3.5 or M4 tap, or use a thread repair kit - see below.

(iii) Fill it and try again. Metal loaded epoxy is available from DIY stores which can be used to fill in the hole. The epoxy is left to cure, and can then be filed or ground flat and re-drilled.

3.3.4.. Broken drill or tap. If it is impossible to remove a broken drill bit or tap from the heatsink, it may be possible to grind it flat with the heatsink and simply not use that hole. Alternatively, the mounting plate can be turned around, keeping the holes at the 4 corners, and re-drilling the heatsink again. An extra hole can be drilled in the mounting plate to clear the bit protruding from the heatsink if required.

3.3.5.. Stripped thread. If a thread is stripped, it can be repaired with the use of a thread repair kit. These are available from Engineering suppliers, and although expensive, are cheaper than a new heatsink and the cost may be worthwhile compared to the time taken to re-drill the heatsink. Alternatively, the hole could be re-drilled to a larger size and re-tapped.

4…Electronics Assembly

4.1…Note on Surface Mounted components

Many of the components on the PCB are surface mounted devices (SMDs). SMDs require different soldering techniques to leaded components, and much more care has to be taken with these devices to avoid damage through mishandling or overheating. It is assumed that the constructor has had some experience with using SMDs, and so only brief notes are presented here.

The SMDs used in the GH *Quad* are fairly large by SMD standards. This is for two reasons; the first is that larger components have a higher power dissipation rating, and the second is that larger devices are generally easier to handle. Care needs to be taken when removing the backing tape, as the components can easily fall out of the individual pocket and become lost.

The use of a good quality soldering iron with a selection of small tips is highly recommended, and ideally the iron should be temperature controlled. A small tip approximately 3/32" diameter (2.4mm) or similar is required to solder the SMDs. The solder used for the SMDs should be 26SWG, and sufficient solder is provided with the mini-kit. Note that only a very small amount of solder is required for a good joint on an SMD, just sufficient for a small fillet which holds the component to the PCB. It is very easy to apply too much solder, and this is the most common mistake found in amateur construction.

A general technique for soldering SMDs is to first wet one of the PCB pads where the SMD is to be soldered with a small amount of solder. Then hold the component in the required position on the PCB with a pair of tweezers and melt the solder onto the end termination of the SMD. This is a temporary measure, which provides enough strength to hold the SMD whilst the other end is being soldered. Apply the iron tip to the pad of the second pad, on the PCB only. Melt some solder onto this pad, until the solder forms a joint with the SMD end termination. This operation should take only about 2-3 seconds. It is not necessary to touch the iron onto the termination of the SMD. Now repeat the last step for the first joint, carefully applying a little more solder to form a fillet.

The size of the resistors (2512 size) used as the balance resistors in the Wilkinson splitter and the load resistors in the quadrature couplers are such that if 'standard' pad sizes were used for these components, the capacitance associated with these pads would shift the centre frequency of the splitters and also reduce their bandwidth. Therefore, the pads for these components have had to be made smaller than would normally be the case, and so extra care has to be taken with the soldering. The 47 ohm resistors used for the quadrature coupler terminations have only one pad at the ground end, the other end is soldered directly onto the 50 ohm track.

4.2..Printed Circuit Board

The PCB is made from 0.031" (0.8mm) PTFE-based dielectric in order to reduce the losses. Due to the thickness of the PCB, and the fact that there is an imbalance of copper between the top and bottom sides of the board, there will inevitably be some bowing and twisting of the PCB which occurs during the manufacturing process. This is no cause for concern, and the mechanical construction of the amplifier is such that the PCB is held flat against the mounting plate.

Before commencing the electronics construction, the PCB should be cleaned thoroughly with a mild degreasing agent such as isopropyl alcohol or methylated spirit.

4.3…PCB Assembly

1) With reference to Assembly Drawing 5, solder the resistors and ceramic capacitors to the PCB. Solder D1, R1 and C1, but not TR1.

2) The red wire is used to supply the DC supply to the modules and the orange wire is used to supply DC to the voltage regulators. These wires form links across the RF input and output connections to the modules, and must be formed as 'bridges' over the 50 ohm lines, clearing the lines by at least 6mm. Cut these wires to the appropriate lengths and solder to the pads on the PCB.

3) If PCB sockets are to be used for the input and output connections, solder the sockets to the PCB. Note that the sockets are mounted on the track side of the PCB, and that it is necessary to stand the sockets off the PCB by at least 2mm in order to avoid shorting out or capacitively loading the high impedance lines. This can be done by placing the PCB on a flat surface, such as the heatsink, and then placing the sockets in the holes such that the bottom of the sockets is flush with the groundplane side of the PCB. Ensure that the socket is perpendicular to the PCB before soldering. In order to avoid damaging the sockets and the PCB, heat must be applied to the socket for the minimum amount of time (consistent with producing a good solder joint). Therefore, it will be necessary to use a very large soldering iron tip and the hottest temperature setting (if applicable) in order to get the heat to the solder joints as quickly as possible. Solder the ground legs of the socket on the track side of the PCB, and then the inner connection on the groundplane side.

If co-ax connections are to be used for the RF input and output, then these can be soldered later.

4) Cut the semi-rigid cable into two equal lengths of 123mm. If a miniature tube cutter is being used for this, it may be found easier to hold the cable in a pair of pliers, protected by some cloth or similar to avoid damaging the cable, and rotate the cutter around the cable, gradually increasing the depth of cut. Remove 3mm of the outer jacket and PTFE insulator from each end of the semi-rigid cable, and form into the shapes as shown in the drawing. Note that the exact dimensions of these shapes is not critical, but that the ends of the cable must align with the ends of the 100 ohm lines on the PCB and the appropriate 50ohm power termination.

5) The cables can be bent by hand by bending around a suitable round object. The small radii can be formed by bending around an 8mm drill bit held in the chuck of a drill. It may be found easier to form the outer bends (the ones closest to the ends of the cables) first, although this is not critical.

Note that the shapes of the cables are purely arbitrary. The shapes have been given to reduce their height - other (simpler) shapes could be formed with no loss in performance. Note that the cables form a bridge over the 100ohm output lines, and it is necessary to provide a clearance around these lines of at least 6mm to avoid capacitive coupling.

Semi-rigid is a very versatile material, and can be formed and re-formed many times without loss of performance. It may be necessary to bend the cables several times to get the right fit on the

PCB. However, it is important not to kink the cable, and extreme care should be exercised if pliers are used to hold the cable.

6) When the correct shapes have been formed, the semi-rigid cables can be soldered to the PCB. The recommended procedure is to bend down the coax inner slightly at each end such that it just touches the PCB. Locate the cable centrally between the grounding holes at the ends of the cable, and solder the cable inner to the junction of the 100ohm and 50ohm lines. Solder the other end of the cable to the end of the 25ohm line along with the power terminating resistor.

7) Check that the co-ax inner conductors have been soldered properly to the PCB tracks, particularly at the junction of the 100ohm and 50ohm output lines.

8) If coax cable is used for the RF input and output connections, it can now be soldered to the PCB. Note that if semi-rigid cable is being used, it should first be formed to the required shape, before soldering to the PCB. If it is bent after soldering to the PCB, there is a possibility of damaging the PCB.

9) Now mount the PCB and the mounting plate on the heatsink, and secure in position with 18 M3 screws.

10) Locate the 50W power terminations in the PCB cut-outs with four M3 screws. It will be necessary to bend the leads down slightly to the PCB. Do not solder the leads at this stage.

11) Cut and bend the leads of the voltage regulators U1-U4 to fit the PCB pads and fit them with M3 screws. Cut and bend the leads of TR1 and fit this to the board using the M3 NYLON screw. The large pad underneath this transistor has a DC voltage, and must not be shorted to ground. Take care not to over-tighten the nylon screw. Solder the leads of U1-U4 and TR1 after tightening the screws. Solder the electrolytic capacitors to the PCB, taking care to note the polarity.

12) Connect suitably sized DC power leads to the PCB. The positive supply is soldered to the PCB, the DC ground lead can be connected to a solder terminal and located on the PCB with the screw to the right of the positive supply connection. Solder the PTT lead to the pad above D1.

Connect the DC supply leads to a 12V regulated power supply. Check that when PTT is enabled (ie grounded), 12V appears on pin 2 of the PA modules and that 9V appears on pin3.

13) Cut pins 1, 2, 4 and 5 of the PA modules to approximately 3-4mm long. Cut pin 3 (centre pin) to approximately 6-7mm long. Apply a very thin layer of thermal compound to the fin of the module -see note below. Place a 3mm length of sleeving over this pin.. Locate the modules on the heatsink with M4 screws and washers. Tighten the screws such that they are hand tight, and then a further 1/16 of a turn. This is sufficient to make good electrical and mechanical contact, and the wavy washers will ensure that the screws will not come undone, even with vibration or shock caused by handling (such as for contesting). Over-tightening the screws will not improve either the electrical or thermal performance, and may lead to flexing of the module substrate which could cause damage.

Note that the layer of compound should be no more than about one-thousandth of an inch thick. This is obviously impossible to measure, but is only a minute thickness. The purpose of the compound is to 'fill in' any tiny gaps between the module and the heatsink. The module is not intended to sit on a thick layer of compound. The compound has a better thermal conductivity than air, but is not as good as the thermal conductivity of the direct contact between the module and the heatsink.

14) Solder the leads of the PA modules to the PCB, taking care with the tip of the soldering iron not to touch any nearby components, or the body of the module itself.

4.4 Front Panel LEDs and switches

Most amplifiers have one or more LEDs on the front panel to indicate that the unit is switched on and that transmit has been enabled. If this is required on the *Quad*, then connect suitable resistors to the Vcc line and the Vbb line (9V regulated) and LEDs as required. As a guide, a resistor value of 1.2kÙ would be required for the Power ON LED and a resistor of value 680 Ù would be required for the Tx Vbb line. This will cause a current of approximately 10mA to flow through the LEDs when the appropriate lines are high. The connections for the resistors and LEDs are shown on the circuit diagram with dashed lines.

5…Final assembly

Locate the heatsink/PCB assembly in the lid of the case and tighten the screws. Wire up the DC supply leads and PTT leads, and any additional front panel indicators and switches that may have been added. Connect the RF input and output leads to the RF sockets on the case.

Connect a suitable 50ohm dummy loads to the RF input and output sockets.

With no RF applied, check that the bias current is approximately 3A with the PTT line low.

The amplifier is now ready for use. Note that care should be taken to ensure that a good 50 ohm load is connected to the amplifier whenever the DC is applied, even if no drive signal is present. The module is rated up to a 16:1 output SWR, but this means only that the module will not be damaged with this mis-match. In practice, instability can occur under high mismatch conditions, which could occur during Rx-Tx change-over for example.

6… Fault finding

There is very little to go wrong with this amplifier, and no tuning is required. With an input power of 1W and a supply voltage of 13.8V DC, the output power will be approximately 18-20W depending on which part of the band is being used. For SSB use, the input power should not exceed 750mW PEP, as this will drive the amplifier into it’s non-linear region. It is recommended that the input power does not exceed 1W, and the absolute maximum input power for the M57762 is 2W.

If the output power is lower than expected, then the following procedure should be followed :-

Ensure that the output power is being measured on a meter that has sufficient accuracy at 1.3GHz - don't blame the amplifier if the power meter is at fault!

Visually check all the soldered joints.

Check that the DC levels are correct on pins 2, 3 and 4 of the PA module.

Check that the input attenuator has been fitted correctly.

Measure the DC supply current - if this is low, then the problem lies with the input.

If the result of these checks is good, and the output power is still low, then contact GH Engineering for advice.

7…Circuit Description

7.1..RF

The RF input signal is applied to a Wilkinson splitter which divides the signal into two in-phase components, each 3dB lower than the input signal. The splitter consists of two quarter wavelength transmission lines of 71Ω impedance. The outputs of the splitter are connected by two resistors in parallel which give a value of approximately 100 Ω . Under normal operation, the voltages at the ends of the resistors are equal and in phase, and therefore no current flows through the resistors. In the event of an imbalance, for example due to a module failure, some of the input power will be dissipated in the resistors, and so these resistors have to have sufficient power handling capability in order to be able to cope with a fault condition.

Considering one of the two signal paths :- the signal then passes through a 90° hybrid coupler, which splits the signal into two equal amplitude components, with a relative offset of 90°. Each of the two outputs from the coupler is 3dB lower than the input. Under normal operation, there is no power dissipated across the 47Ω resistor. In the case of an imbalance, some of the power applied to the input of the coupler will be dissipated in the termination resistor. The impedance mismatch between the 47Ω resistor and the 50Ω impedance of the coupler is very small and is of no importance.

Both the Wilkinson splitter and the quadrature couplers exhibit a high degree of isolation, such that the output impedances are very close to 50Ω even if the other port has a severe mismatch.

The signals are now 6dB lower than the input signal, and the outer pair have a 90° lag relative to the inner pair. The signals are fed to the inputs of the Power Amplifier modules which have a small signal gain of around 17-18dB. The outputs of the modules are phase corrected, such that the inner signals have an extra 90° phase shift added to bring them all back in phase. This is achieved with the correct length of microstrip transmission line. The signals are then fed to a 4-

way Gysel combiner. This combiner is actually a derivative of the N-way Wilkinson combiner. The Gysel combiner consists of 4 quarter-wave transmission lines, each of 100W impedance. Therefore the 50Ω impedance of the output signals is transformed to 200Ω, which give an output of 50Ω when all four are connected together in parallel. The isolating network is somewhat more complex than for the input splitters. 3/4 wavelength transmission are connected to each of the junctions of the 50Ω and 100Ω lines. The end of these lines are terminated with a 50Ω high-power termination resistor. This is also connected to the end of another quarter wavelength line, of 25Ω impedance. These four 25Ω lines are connected together. At this point, there is a 'virtual ground', in that no current flows across the junction, but the impedance is actually very high, and approaches an open circuit. Therefore the impedance at the termination resistor is very low (approaching a short circuit) and no power flows into the resistor. Therefore, the impedance looking into the end of the 3/4 wavelength line is very high. Consequently, the 3/4 wavelength line places no load on the output, and no current flows into the isolating network.

In the event of an imbalance, the situation changes. Some of the output power from the remaining modules will be dissipated in the terminating resistors, although most will still flow to the output connection. However, each module will still have an impedance of very close to 50Ω presented to it, and so the effect of failure or instability of one module will not be seen by the other modules. Note that the load resistors do not dissipate this power evenly; if for example module 1 failed, then approximately 18% of the power from the three remaining modules would be dissipated in the termination resistor associated with module 1, and approximately 5% of the power would be dissipated in each of the other 3 resistors. This power split is irrespective of the nature of the failure; i.e. regardless of whether the module fails with an open circuit, a short circuit or something in between. The Gysel coupler has a bandwidth and isolation similar to that of a Wilkinson splitter.

This feature can be used for diagnostic purposes - if the output power is somewhat lower than it should be, then the voltage across each of the terminating resistors can be measured with a high impedance probe or an RF millivoltmeter. One resistor will have significantly more voltage across it than the other 3, and the fault will lie in the corresponding module. As an alternative to an RF millivoltmeter, each of the terminations can be removed in turn, and replaced with a length of thin coax cable, which is connected to a power meter.

Note that the 'classic' Gysel coupler uses 1/4 wave line lengths throughout, but this is difficult to implement on the PCB, and so 3/4 wave sections were chosen. The outer two 3/4 wavelength lines are printed on the PCB as microstrip transmission lines. The topology of a Gysel coupler is such that is effectively a 3-dimensional structure, and cannot be fully implemented on a 2-layer PCB. The 3/4 wavelength line for the inner modules have to cross the outer lines, and for this reason are constructed from 0.086” semi-rigid cable.

7.2..DC and switching

The DC supply (Vcc) to the PCB is connected via a fuse. This is then applied to the Vcc1 and Vcc2 pins of the modules. Note that in the Rx/standby mode, the modules will conduct only a very small amount of leakage current.

TR1 is a P-channel MOSFET switch. In the Rx/standby mode, the PTT signal is floating, and R5 ensures that there is no voltage between the drain and source, which keeps the FET switched off.

When the PTT line is taken low, the combination of R5 and R6 form a potential divider which takes the gate voltage to approximately half of the supply voltage. This causes the FET to turn on, and the supply voltage appears at the input of the voltage regulators. The regulators provide a stable 9V which is required to bias the modules. C2 de-couples the gate of the FET to prevent accidental switching due to stray RF fields or glitches.

De-coupling is provided on each of the module pins. Note that only relatively low-frequency de-coupling is provided - no attempt is made to de-couple the pins at the RF frequency, as this is done internally within the modules.

DC blocking of the input and output signals is performed internally within the M57762 modules.

7.3…Reverse Polarity Protection

A 20A quick-blow fuse and a fuseholder are supplied with the mini-kit. This fuse should be connected in series with the positive supply to the amplifier inside the case. D2 acts as a reverse-polarity protection diode, such that if the supply is accidentally reversed, the diode will conduct and blow the fuse. Under these conditions, the reverse voltage will not exceed approximately -0.8V which should be a safe condition.

8…Operating the amplifier

An input power of 1W will give an output power of approximately 50W with a DC power supply of 13.8V. The DC current drawn will be approximately 15-18A. Increasing the drive level will increase both the output power and the DC current, but the amplifier will no longer be linear – i.e. a 1dB increase in input will give less than 1dB increase in output. The DC current drawn is approximately proportional to the input power, so even when the amplifier is close to saturation, the DC current will still increase as the input power is increased. The consequence of this is that the efficiency decreases, and the amount of heat generated increases. Therefore, it is necessary to ensure that the modules do not overheat, and the use of one or two small axial fans on the heatsink is recommended if the amplifier is being driven at power levels of greater than 1W, especially for continuous (FM) use. A suitable fan kit is available from GH Engineering.

Note that the input power should never exceed 5W under any conditions. If the amplifier is being driven from a source that is capable of delivering more power than this, for example a multi-mode Transceiver such as the FT736 or the TS790, then it is recommended that an attenuator is used at the input to the amplifier. Although these transceivers have adjustable power controls, there is a possibility that the drive control could accidentally be set too high. The M57762 modules are very susceptible to excess drive levels, and could be damaged or destroyed if too much input power is applied. A suitable attenuator can easily be made from a length of thin coaxial cable; for example 2m of RG178 cable has a loss of 3dB at 1.3GHz. Ready-made cable assemblies can be supplied by GH Engineering if required.

8.1…Heat Dissipation

The heatsink has been designed to allow the amplifier to be used continuously for SSB or CW operation. Under these conditions, the heatsink will reach a steady-state temperature of around 60°C after approximately 45 minutes of operation with an ambient temperature of 20°C. This is a safe condition for the module. Note that at 60°C, the heatsink will be very hot to the touch - care must be exercised to ensure that the operator does not suffer a mild burn from the heatsink.

For FM/ATV use, it is recommended that two axial fans are used to assist cooling of the modules. A fan kit is available from GH Engineering which consists of a pair of 93mm fans and all the associated mounting components.

8.2…Testing with a Signal Generator

If a signal generator is being used to provide an input signal for test purposes, great care must be taken to ensure that the output level from the generator does not exceed the maximum safe input level for the module. Some signal generators, especially older ones, can generate 'spikes' in the output level when the output attenuator is adjusted. This is accompanied by a 'click' from the generator as the relays change state. As the relays are changing over, the output attenuator can be in an indeterminate state, and it is possible that a much higher level is present at the output socket than is indicated, albeit for a brief period of time. For most purposes, this is of little consequence, but when testing amplifiers this could cause a problem. One solution is to connect a fixed attenuator of the appropriate value to the output of the generator, which ensures that the signal will not exceed the maximum safe level for the amplifier..

Appendix A - PTT operation

The GH *Quad* is provided with a PTT facility which may or may not be required depending on how the rest of the system is to be used. The PTT facility is provided in order to disable the amplifier during receive periods, which has two main advantages :-

If an antenna changeover relay is being used, a high SWR will be presented to the amplifier on receive periods, which is highly undesirable. The amplifier should not be on in this state.

The amplifier dissipates DC power even when no input signal is being applied due to the bias current of the PA module. It is advantageous to keep the PA module cool whenever possible.

PTT stands for Press To Talk. It is a term that is used in all SSB and FM speech transmitters, and refers to the operator pressing a switch in order to change a transceiver system from receive to transmit for half-duplex operation. The switch is usually on the side of a handheld microphone, although operators using headsets often use foot switches to allow both hands to be free for logging and tuning.

If using a self-contained SSB/FM transceiver, the PTT line will be a direct connection to the transceiver, either via the microphone connection or via a separate PTT input connector on the rear panel. If the transceiver is being used with an external amplifier, then the amplifier needs an external PTT input, such that the amplifier is enabled only during transmit periods. This PTT signal can either be taken from the microphone/PTT switch, or alternatively from a PTT out connection at the rear of the transceiver. If a Transmit/receiver sequencer is being used (see separate note on sequencers below), then the amplifier's PTT input will be taken from an output from the sequencer. This allows system is flexible enough to allow multiple amplifiers to be cascaded, which is often the case at VHF and UHF.

For ATV use, the situation is not so straightforward, for a number of reasons :-

Some ATV operators use a full duplex system.
Some ATV systems use a microphone with no PTT facility.
The vast majority of ATV transmitters have no provision for a PTT output.
Unlike SSB systems, there is no 'standard' for the polarity of a PTT line - some systems use ground on transmit, some use +12V on transmit.

If a half-duplex system is used, then the PTT facility should also be used. It would be possible to connect the PTT line to be permanently on, such that the amplifier is enabled whenever power is applied. However, this has the disadvantage that the full DC current of 23A will have to be switched at power on. Using the PTT line, the main DC power can be left switched on and the PTT line used to enable the amplifier only during transmit periods.

N.B. If an input signal is applied with the PTT off, then the amplifier may be driven into class C operation. If this occurs, the amplifier will produce a considerable amount of output power, even though the PTT is not enabled. This is a highly undesirable state, and care should be taken to ensure that no drive signal is applied unless the PTT is enabled.

PTT Line polarity

The PTT line polarity is Ground on transmit. D1 acts to prevent high voltages reaching the rest of the amplifier if other amplifiers are connected to a common PTT line. In the receive mode, the PTT line can be either floating or connected to the positive supply.

If +ve on transmit operation is required, an inverter will need to be used. This can be implemented with an NPN transistor and a series resistor in the base. The collector of the transistor is connected to R2 in place of diode D1. Contact GH Engineering for more details.

Appendix B Sequencing

Sequencing only applies to half-duplex systems. Sequencing refers to a system whereby certain delays are introduced into the control lines for the transmitter, power amplifier and masthead pre-amplifier. The purpose of the delays is to ensure protection for the antenna changeover relay and the pre-amp (if used) and transmit power amplifier.

Systems with relatively low levels of transmit power do not generally require sequencing. However, as power levels increase, the risk of damage to the system components also increases.

If sequencing is not employed, then the system changes over from Tx to Rx and vice versa at the same time. The problems associated with this are due to the fact that any antenna changeover relay needs a finite time for the contacts to move from one position to the other. This occurs on both states - Transmit to Receive and Receive to Transmit. There are thus two separate cases :-

1) Transmit to Receive. As well as the relay needing time to change over, the Tx carrier needs a finite amount of time to decay. This decay time will depend on the type of transmitter, amplifier and power supply being used. If the antenna changeover relay starts to change over at the same time as the Tx PTT line is removed, then there will still be a certain amount of RF power flowing through the relay contacts as the contacts start to open. This will cause arcing of the contacts and could quickly lead to a deterioration in performance of the change-over relay. A sequencer will keep the relay in the Tx position until the RF power has been removed. There is a second problem involving the use of a masthead preamplifier. If no sequencing is employed, then the DC power to the preamplifier will be applied before the change-over relay has completed the switch to receive. Thus the preamplifier may see be presented with a very high input SWR, which may cause it to become unstable.

2) Receive to Transmit. If the transmitter is activated at the same time as the change-over relay starts to switch to transmit, then the relay contacts could arc for the same reason as given above, as the transmitter power could be present at the transmit port of the change-over relay, before the contacts have had time to complete the switch to transmit . Furthermore, due to the fact that it may take some time for the de-coupling capacitors in the preamplifier to decay, the preamplifier may still be on as the relay changes over and the transmitter is brought up to power. Under these conditions, the isolation of the change-over relay could be a lot less than in the steady-state. There is then the possibility that a much larger amount of Tx power is presented to the pre-amplifier, whilst it is still on, which could cause the preamplifier to be damaged or even destroyed.

A sequencer will eliminate these conditions, and many designs have been published over the years. At the time of writing, GH Engineering is not able to offer a suitable sequencer, but it is hoped that this situation may change in the future.

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