# Modern High-performance Narrowband Equipment for 10GHz

Part 4 Amplifiers

Designed by

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**Introduction**

Following on from the three previous modules in this series (G3WDG001 x4 multiplier-amplifier, G3WDG002 10GHz - 144MHz receive converter, and G3WDG003 144MHz - 10GHz linear transmit converter) a number of add-on amplifer modules have been developed to improve performance further. These all take the form of amplifiers, either power amplifiers to increase transmit power or preamplifiers to improve receiver performance. These amplifiers may well also find applications in systems other than the G3WDG equipment, such as to upgrade earlier transverters such as the G3JVL, or to improve the performance of commercial transverters eg SSB Electronics.

The purpose of this booklet is to cover the constructional techniques common to all the amplifiers in this series (present and future), as well as to describe the specific modules. The booklet will be added to as new modules become available.

As with all the modules in this series, the amplifier designs are intended for home construction without the need for either difficult constructional methods or elaborate test equipment. They have already been duplicated with relatively little difficulty by a panel of independent constructors. Wherever possible, low cost components have been identified and designed-in, but in some cases it has been found necessary to use more exotic components. It must be stressed that the specified parts must be used without exception or all the hard work put in by the designer will be wasted! All of the specialised components are available from the Microwave Committee Components Service so there should be no reason to substitute.

**General circuit features and components.**

The designs are built on ptfe-glass board and, in the main, surface-mount "chip" devices (SMDs) are used, although some more familiar "ordinary" components are also used. Microstrip circuitry is used to provide the correct operating impedances for the GaAs FETs and the circuits have been designed to cover the whole of the 10GHz band from 10.0 to 10.5GHz. A reliable method for grounding the source leads of the GaAs FETs was developed to ensure that the designs would be reproducible. Earlier attempts using copper foil "wrap-arounds" failed because the inductance of such connections was too variable.

Where high selectivity is required, this is provided by a small "pill-box" tuned cavity resonator soldered to the board. Coupling from the microstrip lines into and out of the resonator is accomplished by the use of probes, and avoids the use of critically dimensioned and spaced printed microstrip filters which are almost impossible to make with enough accuracy, using amateur techniques.

Each GaAs FET amplifier stage provides a gain of about 10dB. Matched input and output circuits are realised by the use of microstrip lines. Rather than attempt to etch very narrow (high impedance) microstrip lines, where these are necessary, easier construction results from the use of short lengths of thin wire soldered to the lines and pads on the surface of the board.

It is recommended that the PCBs available from the Microwave Committee Components Service, as part of the "mini-kits", be used for these designs. Both the board material and the dimensions of the microstrip lines are critical to the success of this type of circuit. The other critical components, such as the ceramic chip capacitors, resistors and resonator, are also included in the kit. Virtually all the other components are available from easily accessible amateur sources. ONLY the recommended components should be used and only first-grade KNOWN components employed - substitution from the "junk-box" or components "salvaged" from other microwave equipment is just not acceptable!

It is strongly recommended that the PCB is installed in a tin-plate box or an alternative, specially made sheet-metal (brass or copper) enclosure of similar size and form. By so-doing, not only is the somewhat flexible board housed rigidly, but is also well screened. The finished, boxed unit(s) should be housed in a rigid outer case to provide further mechanical and thermal stability - the "boxes within boxes" approach which has long been advocated for high performance microwave equipment.

The use of other than SMA connectors for input and output is not recommended. The 12V power supply should be well decoupled by 1nF to 10nF solder-in feedthrough capacitors or Filtercons. The power supplies must be stabilised to the voltages given in the circuit diagrams: if these voltages are exceeded the GaAs FETs can be damaged, if not instantaneously destroyed. By incorporating resistors in the drain circuits a degree of current-limiting protection is afforded. Nevertheless, it is well worth spending time on this aspect of the circuits, using only generously rated and reliable components in the bias circuits. Care and attention to detail is essential AND your soldering techniques must be good! Components should be mounted in the order given and the GaAs FET device(s) should always be the last to be soldered into place, taking the usual precaution of grounding together the constructor, the body of the soldering iron and the case/groundplane of the PCB whilst soldering them in place. In this way the risk of damage by static discharge is minimised or eliminated. Unplugging the soldering iron whilst soldering is also recommended.

**Module construction**

1. Fit grounding PCB pins and solder in place.
2. Solder filter into position (if used) . Leave the tuning screw and lock nut in position to avoid unwanted debris accidentally falling into the cavities.
3. Locate the PCB into its box and trim to a neat fit if needed, particularly in the corners of the box where there are joints. The PCB material will cut quite easily with a sharp scalpel blade and straight-edge. Locate the groundplane 17 +/- 0.5mm from the top of the open box and mark its position. (see Fig1). Locate and mark the SMA socket centre-pin clearance holes. Drill the holes and de- burr. Locate, drill and de- burr holes for any feedthrough components needed for power supplies. Tack-solder the corner seams of the box and make sure that the lids are a neat fit. Adjust as necessary. Check also that the board will fit neatly. When satisfied, solder the corner seams fully. Solder the SMA connectors and the feedthrough in position.

4. Relocate the PCB so that the input and output tracks touch their respective socket spills, tack-solder the PCB in place and, when satisfied that it is correctly located, solder all round the groundplane and solder the SMA socket spills to their respective tracks. This completes the mechanical construction of the module.

5. Fit wire inductors into position, ensuring that the wires lie flat to the board.

6. Fit all chip components using the mounting techniques described below.

7. Fit assembled power supply board and any other components on the groundplane side of the board. If a 1A regulator is used, the metal tab can be soldered to the side of the box for heatsinking.

8. Fit all components which have leads, ensuring that static-sensitive devices (ICs, FETs, etc) are put on the board last of all to minimise the risk of damage to the devices.

Note:- it is best to apply the supply voltage to the board BEFORE fitting the FETs, to check that both the drain and gate voltages are present and correct on the respective tracks/pins. On completion of this test, disconnect power and solder in the devices only if everything checks out correctly.

**Specific build operation**

1. PCB-pin grounds.

Place the PCB-pins in the holes with the pin heads on the track side and the body of the pins sticking up through the groundplane, with the exception of the three filter-locating pins (where used). Place the head of the pin on something hard and flat and press the board until the head butts up against the track side of the board. Solder by starting with the iron at the top of the pin; tin the pin generously and, while applying more solder to the joint, flow the solder down the pin and onto the groundplane to ensure good pin to groundplane contact. Trim the pin back using flush-cut cutters. Repeat until all grounding pins are fitted. Do not solder the heads of the of the pins on the track side, as this makes fitting the chip components more difficult later on.

2. Fitting the filter (if used)

This is potentially the most difficult soldering operation on the board! Note that cleanliness is a MUST for this operation and cavity should be cleaned carefully using the RS Components PCB eraser or other similar mildly abrasive pad and, if possible, degreased with an aerosol cleaner eg. RS Components Part Number 567-660 or 554-838. Details of the cavity are given in Fig 2a. First prepare and clean the PCB, then fit the three PCB-pins which mark the filter cavity position. These pins are fitted from the groundplane side through to the track side. Solder the pins to the pads provided on the track side and cut off excess pin length after soldering. Do not solder the pins to the groundplane side. The board is now ready to take the cavity filter.

Pre-heat the cavity with its tuning screw and locknut assembly in position. Heat it by placing on a hot plate (eg. a 3 to 6mm thick sheet of aluminium placed over a gas ring) and heat until 60/40 tin/lead solder melts easily on touching it to the cavity wall near the base (open end). Quickly transfer the hot cavity, using pliers to grasp the tuning screw, to the board, position it between the three guide-pin heads on the groundplane side of the board and apply fine (22 SWG or finer) solder at the junction of the board and filter to fix the cavity in place. Ensure the cavity does not jump outside the guide pins whilst soldering, ensure a continuous small fillet of solder all round the cavity, but do not apply too much solder. Allow the cavity to cool without disturbing it. When it has cooled fully, fit the two PCB-pins which probe through the board and into the cavity, having pre-cut and filed the pins to the correct length first. Pin length is critical to +/-0.1mm and vernier calipers or a micrometer should be used to measure length.

3. Inductors

The 0.2mm diameter wire inductors are assembled by firstly tinning one end and fitting to the board as shown in Fig 2c. Next, solder at position 1, then at position 2 as close as possible to the apex of the triangle, then at position 3. If any excess wire remains at 1 or 3, trim off carefully with a scalpel blade.

4. Chip components

To fit chip components across two circuit tracks or pads, adopt the following procedure for best results: (see Fig 3)

a. Lightly tin one of the tracks or pads. Silver loaded solder is recommended (see below).

b. Fit component and reflow solder to make a solder fillet at the tinned side - the tip of the tweezers may be used to hold the chip in position whilst the solder solidifies. Use as little solder as possible to form a very small fillet.

c. The component should now be secure: tin the other track and make a solder fillet on the second side of the chip component to complete the mounting.

d. Resolder the first joint if required, using a little fresh solder.

This procedure ensures that the components are flat to the board, good contact is made and the best circuit performance is achieved.

5. Static-sensitive components

Components such as ICs and FETs should always be fitted last to minimise the risk of static damage. The GaAs FETs have the gate lead bevelled for identification, as shown in Fig 2b. Grounding of the two FET source leads is via PCB-pin ground "pads" fitted as shown in Fig 4a. Cut the source leads to minimum length, but note that before handling static-sensitive devices, you should make sure that you and the handling implements (eg. tweezers) are grounded together: it is a good idea to work on a grounded sheet of aluminium foil spread on the work surface, resting the wrists on the foil, with the board and implements also on the foil when not in use. You may find, if using surplus GaAs FETs, that one source lead is already trimmed short. Cut the other to a similar length. If the device has full length source leads, the leads should be cut so that half of the veropin heads are covered by the remaining leads (see Fig 4b).

Before soldering the FET, precautions should be taken to avoid damage to the device by leakage currents from the soldering iron. Some GaAs FETs, especially HEMTs and other high performance low-noise devices, are especially sensitive to this and if you have ANY doubt as to the integrity of your soldering iron, it is best to unplug it and make the joints quickly. To be extra safe, connect a wire from the iron to the grounded worksurface to equalise potentials before touching the work with the iron.

Lightly tin one of the source grounding pins, and hold the device in position using tweezers. Make sure the FET is the right way round! Next tack the device in position by reflowing the solder on the tinned grounding pin, making sure the device is flat on the pins and not sitting up on a bump of solder. It is best for this operation to apply the iron to the side of the pin head and not to the lead of the FET (this is why the leads are trimmed short), to minimise the chance of a dry joint. Using the same technique, solder the other source applying fresh solder to the point where the cut end of the lead touches the top of the veropin, not to the iron. Then remake the first joint using a little fresh solder. The use of the Blue Rose 26swg silver loaded solder is highly recommended for this operation. Finally, bend the gate and drain leads down to the board as close to the body of the FET as possible (see Fig 4c) and solder to the tracks. Make sure that the solder fillet starts at the point where the lead touches the track, to prevent any unwanted source inductance.

**Power supply (G4FRE023)**

Fig 5 shows the recommended power supply circuit for all G3WDG 10GHz modules which use active devices. The circuit consists of a 5 or 8V IC regulator to provide FET drain bias, and a negative voltage inverter circuit consisting of an ICL 7660 and associated components to provide the negative gate bias.

The regulator is assembled on the G4FRE023 PCB included with all kits. This may conveniently be housed within the upper part of the specified tin-plate boxes. Construction of the unit is a little unusual in that the components are all mounted on the track side of the PCB (see Fig 6). NO holes are required in the PCB! The power supply board will fit inside all modules. For single stage amplifiers, it is necessary to mount the regulator IC at 90 degrees to the board.

The value of R1 is not specified in the text. It should be equal to the parallel value of the gate bias potentiometers. For example, if two 10k potentioments are used R1 is 4k7 ohms. This should provide a gate bias voltage of about -2.5V at the top of the bias pots.

ICL 7660 and 5V regulators may be obtained from a number of sources including RS Components, Farnell, STC Components (ESD) and Maplin. 8V regulators are available from STC Components and Cirkit.

**Typeset and graphics**

By G4DDK.
Text was prepared with Word for Windows on a 386.
Graphics was prepared using MACDRAW on a Macintosh IIci.

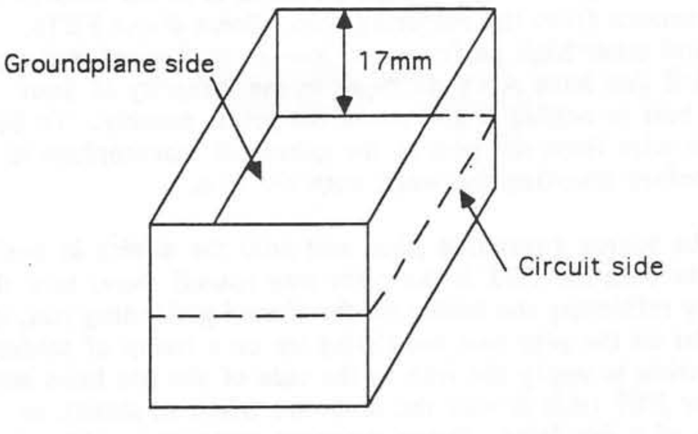



Fig 1. Location of PCB in box

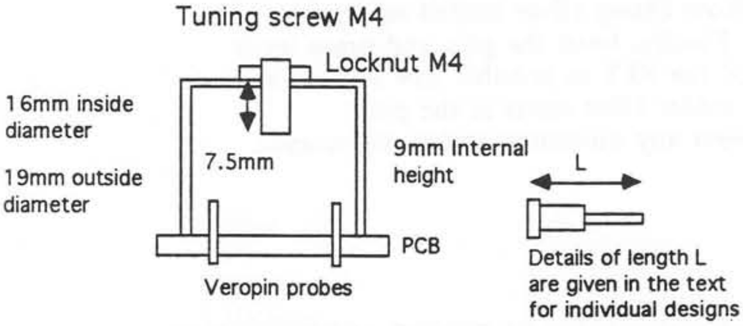



Fig 2a Details of the cavity resonator filters

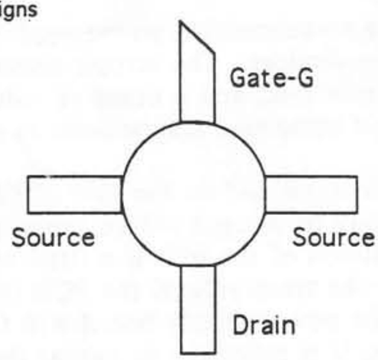



Fig 2b Details of FET connections

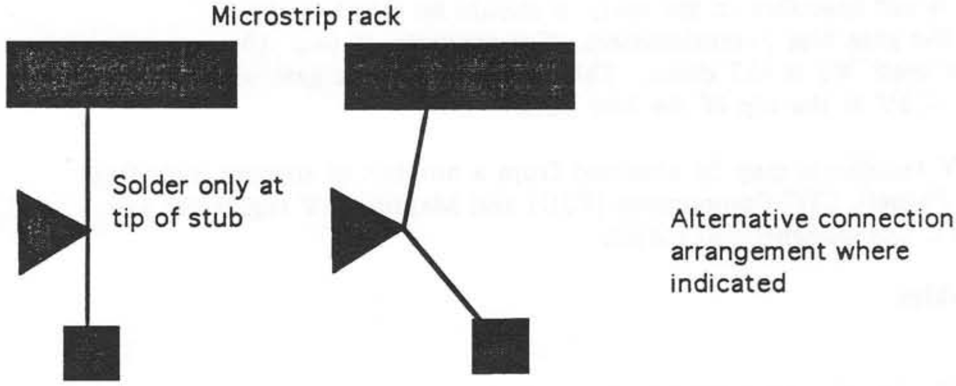
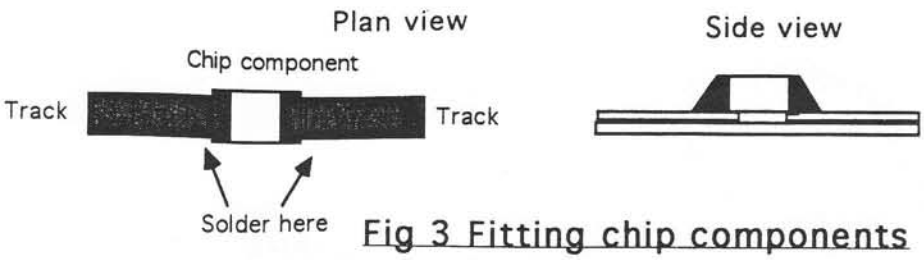
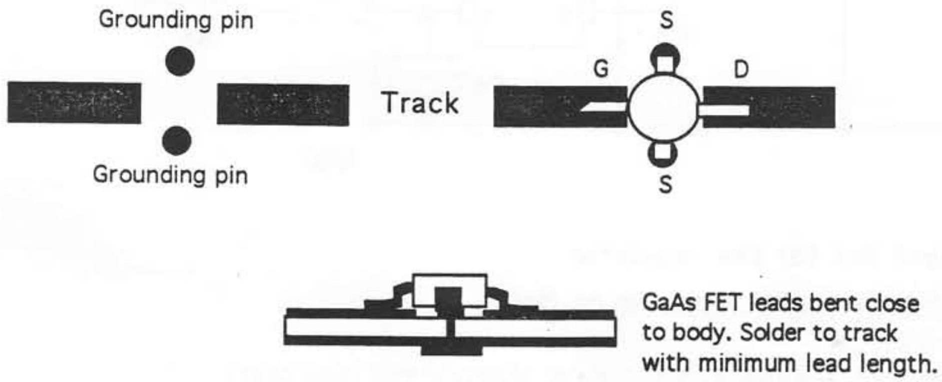


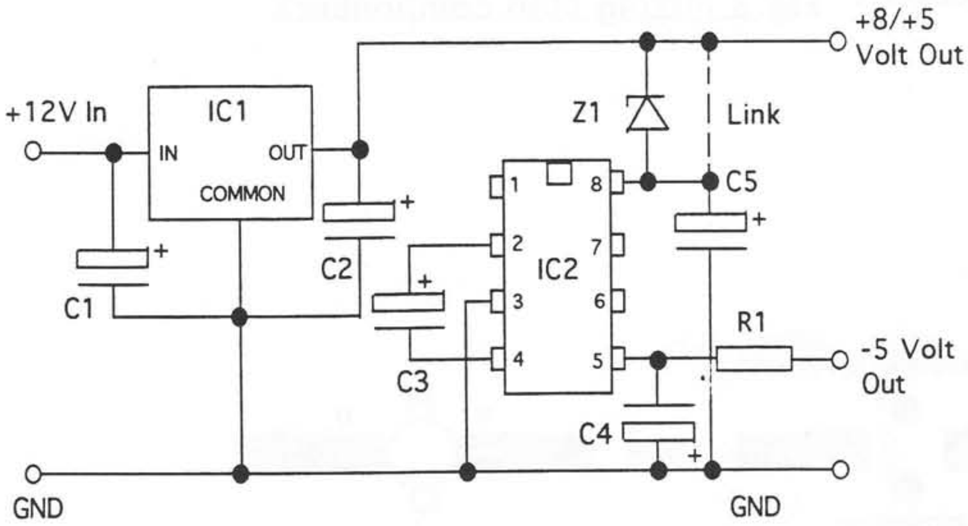

Fig 2c Details of the radial stub connections to the bias chokes




## Fig 3 Fitting chip components




## Fig 4 Mounting GaAs FETs




**Component list for the regulator**

IC1 uA7808 (8V) or uA7805/78L05 (5V)
IC2 ICL7660PCA
Z1 3V0 or 3V3, 400mW Zener diode or shorting link (see text)
R1 See text
C1 1uF Tantalum bead 16v wkg
C2 0.1uF Tantalum bead 10v wkg
C3 22uF Tantalum bead 10v wkg
C4 22uF Tantalum bead 10v wkg
C5 10uF Tantalum bead 10 vwkg
PCB G4FRE-023

Fig 5 Circuit diagram of the 5 and 8 volt regulator, together with component list

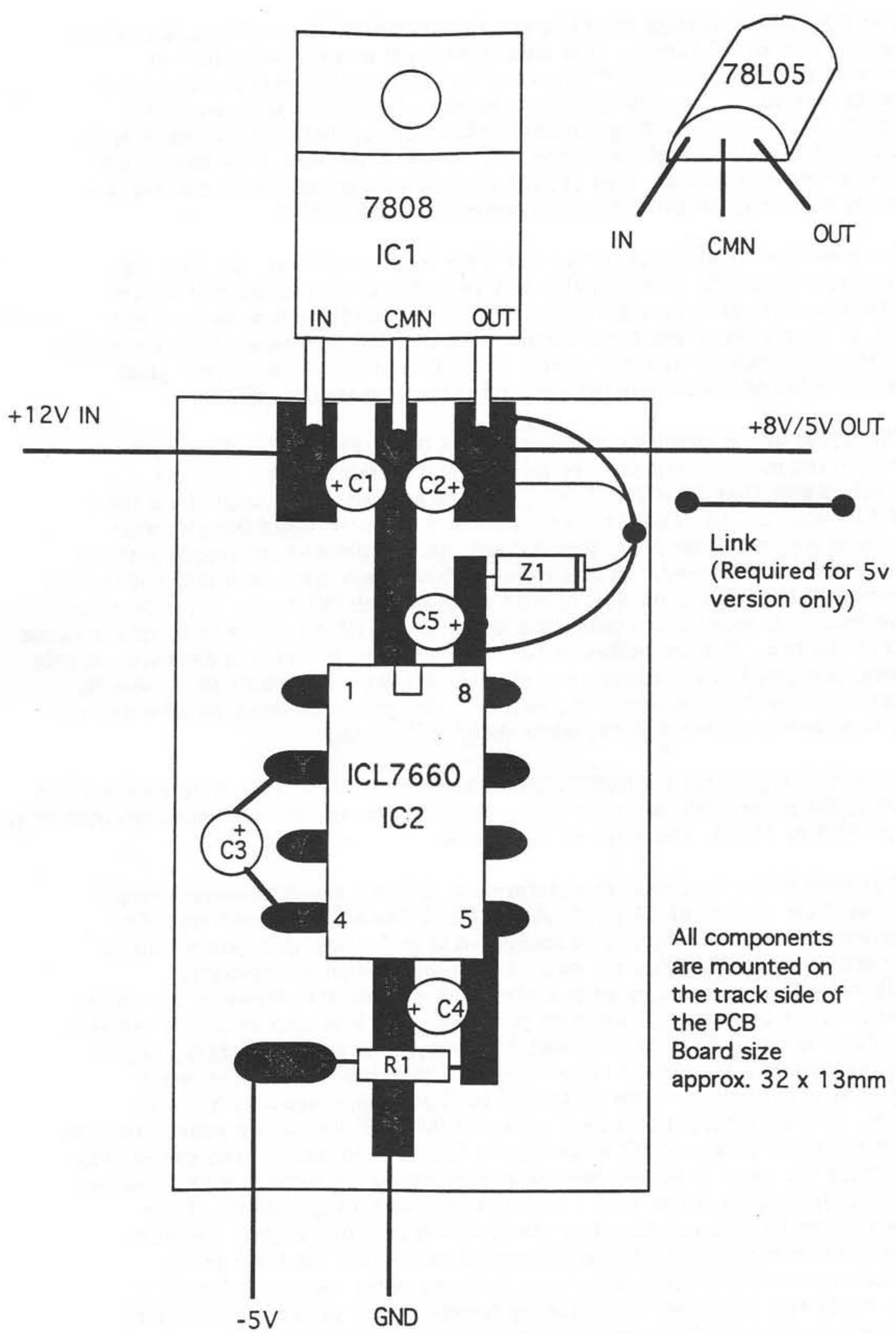



Fig 6. Regulator layout