A 10GHz Power Amplifier from Surplus components.

There are several very low priced (=0 cost in the best case !) GaAs transistors that can be used to make a fairly well performing 10 GHz power amplifier. By careful selection of the types used pretty good gain and reasonable efficiency can be obtained at the power level of 3 to 4 watts output. The amplifier can be built by using ready-made boards (which can be purchased from DB6NT in Germany) and using enclosures designed for these amplifiers, or you can “roll your own” pcb. This article describes how the author built a 3.5 watt amplifier, using a ready-made enclosure but a self designed pcb.

1. Selection of transistor types.

Of course the first criterion is that they should be free ! Hint: there are probably plenty of K- band (14 to 14.5 GHz) ex-satellite ground station RX/TX equipment lying around if you can find them. They are generally full of useful parts, including ceramic coupling capacitors that can be re-used at 10 GHz as well as the semiconductors. The Mitsubishi MGFK series such as 25, 30, 33, 35, 37 may be found, as well as Toshiba TIM1414 -8, -10 types. All can usually be used if removed carefully from the existing units. Note that these devices are all “internally matched” for use at 14 GHz, so of course they are not intended for use at 10 GHz. Their power output and gain may not be the same (can be better or worse !) at 10 GHz. Of course you can also use the original power amplifier modules, after tuning them as needed with copper snowflakes.

Depending on your requirements (max. power out, no limit on low efficiency) or reasonable power out, but better efficiency) you can choose the transistors. In general with these devices, the lower the power level they are designed for, the higher the gain (= less stages, and overall higher efficiency). In the authors case the parameters settled on were about 3W+ out, for less than 150 mW driving power, with reasonable efficiency. This lead to a choice of using a MGFK30 driver transistor (max. power out about 1 W with a gain of 8 db) and a MGFK35 output transistor (max. power out about 3.5 W with a gain of 6.4 db). The needed drive power in this case would be about 125 mW. The efficiency would be about 20%, if the final amplifier was run at about 0.2 Idss with no drive. Note that in the original application, where extreme linearity is needed, the transistors are run at about 0.4 to 0.5 Idss for best linear performance.Usage of this combination of devices successfully has been reported by others such as I1TEX.

2. Circuit topology.

The RF parts of the circuit are in principal very simple – the active devices, coupling capacitors and 50 ohm transmission lines, with plenty of space for adding “snowflakes” of copper for tuning the amplifier. As the devices are not specified for use at 10 GHz and there are no S-parameters or similar data available covering this frequency range, there seemed little point in adding matching sections to the original PCB artwork. The power supply, protection and bias are very much as have been used in a large number of 2 stage amps by DB6NT and others. About the only critical components are the interstage coupling capacitors, they should be special microwave porcelain types.

The schematic was captured using the Eagle CAD tool, which has been used by the author for several conventional and microwave board designs for some years. The tool can be obtained either free (for small sized boards up to 100 mm by 80 mm), low cost for boards up to 160 mm by 100 mm. and private use or higher costs with unlimited board size and unlimited use. Several PCB manufacturers accept the files from the tool directly or conventional Gerber and Drill files can be output. You can also print up the files yourself and make the boards (e.g by using direct laser toner transfer to the PCB) at home. Using the laser toner transfer process and home etching for a small board such as this power amplifier takes about 1 hour total.

Of course the tool has no microwave layout design aids. But you can make components easily. For example if you choose the PCB material (The author uses Rogers 7880 material, 15 mil (.015 inches) thickness), you can design simple objects such as 50 ohm input and output pads, transistor packages with 50 ohm pads for Gate and Drain, 10 GHz quarter wave bypass shorts and a modified 0805 capacitor package where the pad widths match the 50 ohm transmission line width. You don't need much else for this kind of amplifier, apart from the conventional parts which are generally found in the inbuilt libraries.

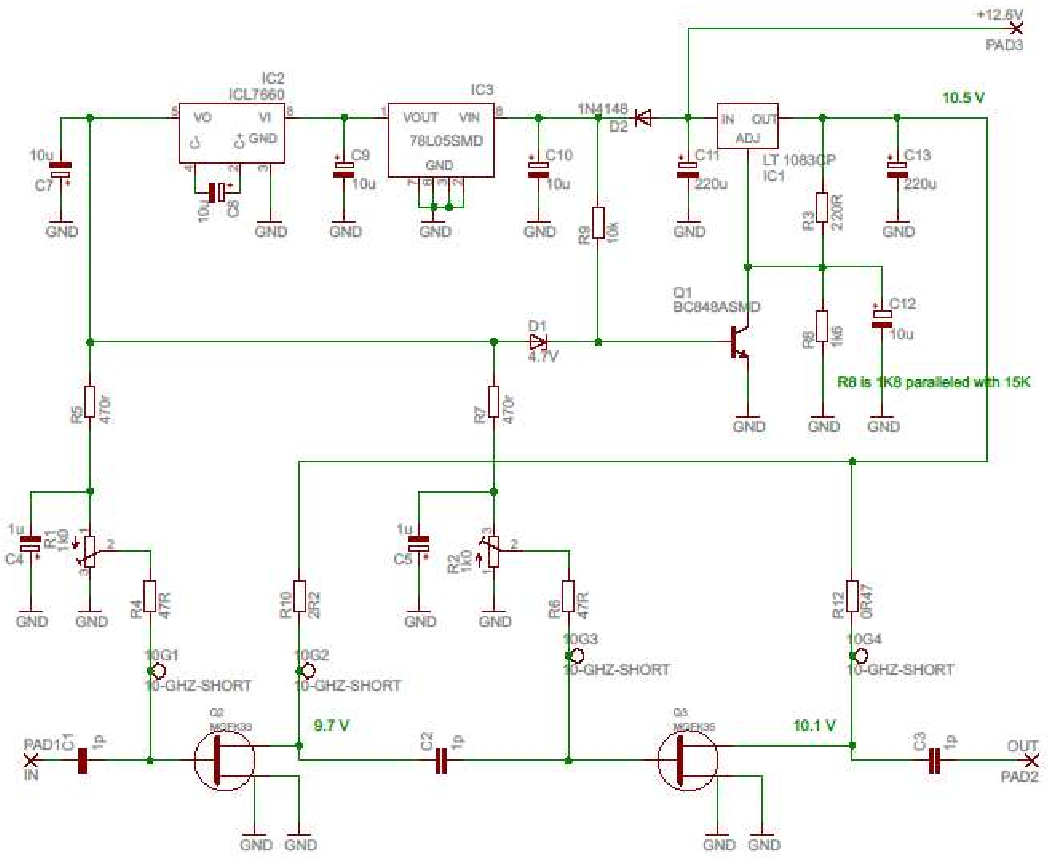

Figure 1. Schematic of 10 GHz Power Amplifier, showing nominal operating voltages.

3. Mechanics.

The milled aluminium enclosure was bought at an SHF flea market, and was designed for totally different transistors, so copper heat spreaders of the needed thickness were inserted under the transistor mounting places to make up for the depth differences.

Small pieces of 0.1 mm copper foil was bent into a "U" shape and soldered to the solid copper ground plane on the backside of the PCB to provide RF (and DC) ground for the power transistors. This was to make up for the width differences of the milled holes in the enclosure compared to the transistors used. The holes cut in the PCB for the transistors are only about 0.5 mm wider than the transistor packages, so when the foil is added there is only a 0.1 mm or so gap. This is why there is a "crinkly" appearance under the places for the power transistors in Figure 3. After the transistors have been mounted, the foil is completely flat.

The "vertical" edges of the copper foil "U" must be cut away slightly in the middle, where the Gate and Drain leads are situated, to ensure there are no shorts. A very small amount of thermal conductive paste was used under the copper heat spreaders, between them and the enclosure, and an even smaller amount between the underside of the foil and the heat spreader. None directly under the transistors.

The K25, 30 and33 transistors need 1.5 mm screws to mount them, however it is possible to slightly enlarge the slots in the mounting flanges with a very fine file and use 2 mm screws, which are easier to tap holes for in the aluminium enclosure. You may also need to reduce the diameter of the screw heads to clear the transistor case. Great fun !

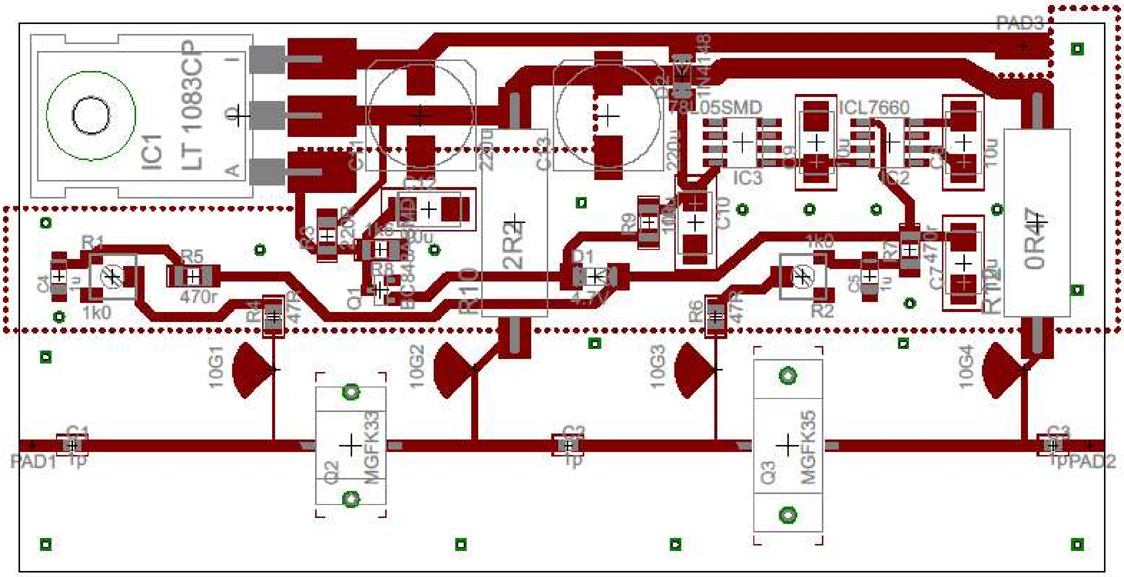

Figure 2. Final layout of the amplifier, without the “poured copper” ground plane shown.

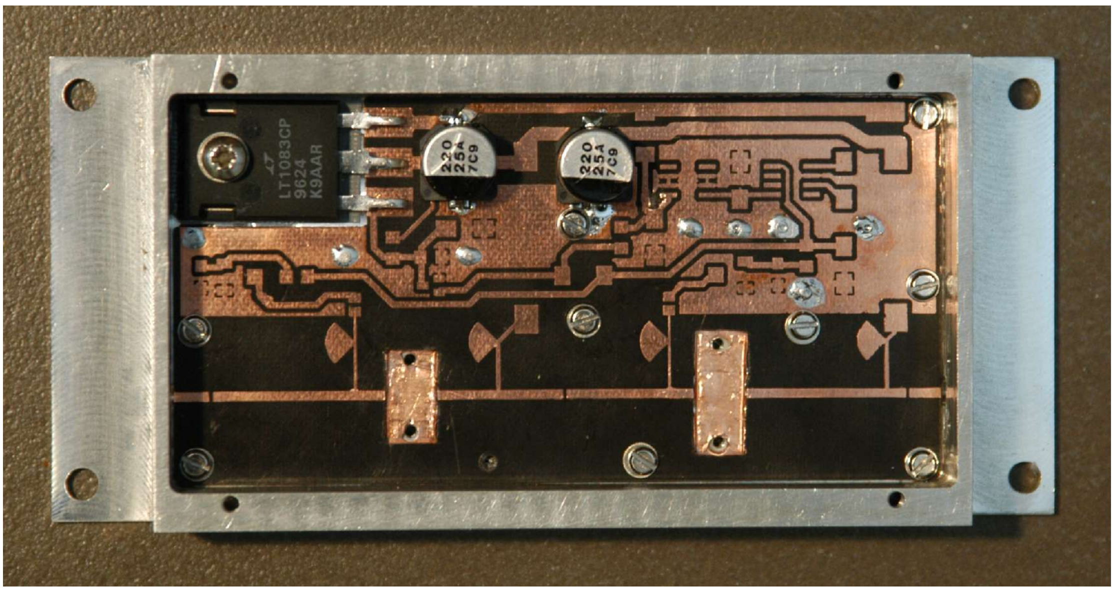

Figure 3. PCB mounted in milled aluminium case and with a couple of “impossible to solder when in the box” electrolytic capacitors mounted.

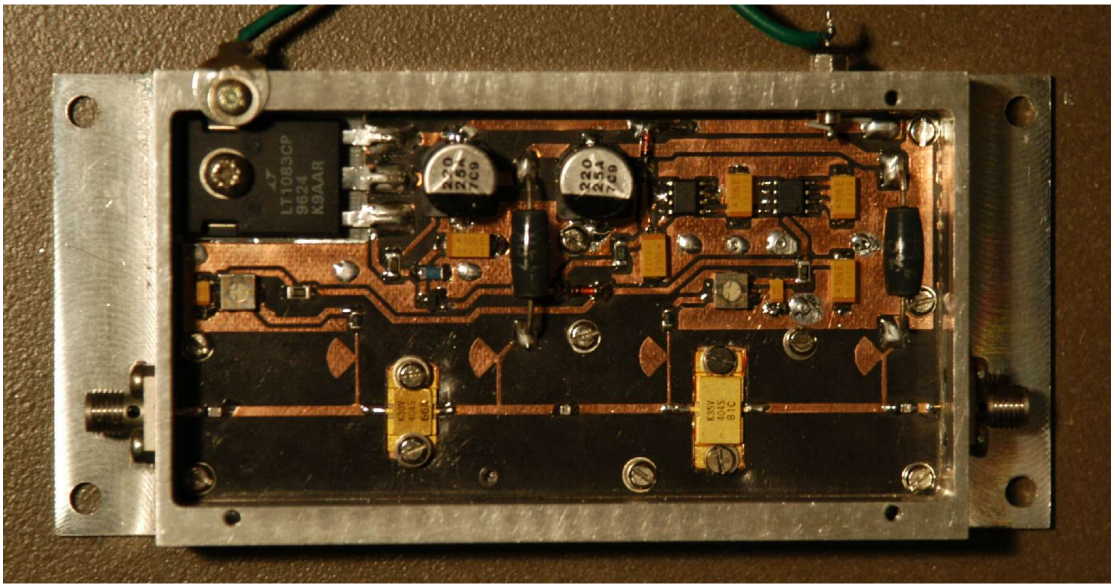

Figure 4. Completed amplifier, ready for mounting on heatsink and tune-up.

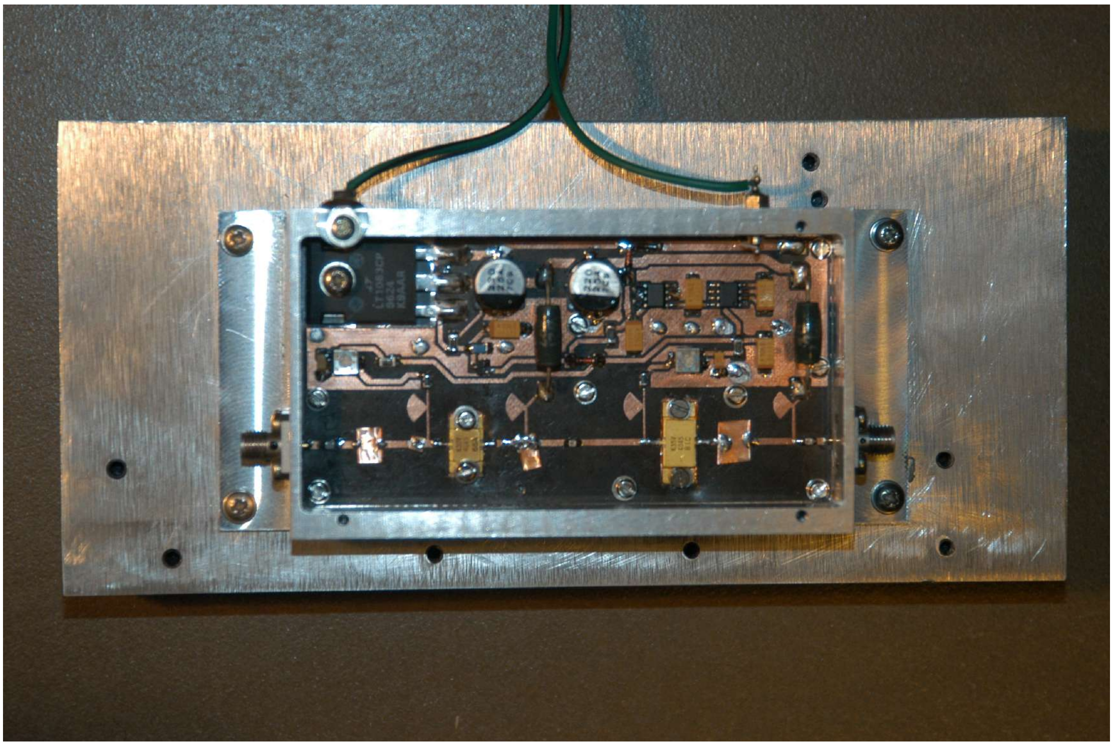

Figure 5. Amplifier mounted on heatsink, with copper snowflakes added during the tune-up.

5. Results.

The final measurements of the PA after tuneup, with the cover attached to the enclosure, are as below:

Power Output at onset of saturation was 35.8 dbm (3.8 watts).

DC current drain at max signal out (Quiescent was 1.25A) was 1.70 A at the 12.6V supply.

This gives an overall efficiency of about 18 %, including the losses in the series regulator, at max power output.

The amplifier input was 20.7 dbm (117 mW), giving a gain of 15.1 db. (The computed gain based on the 14 GHz typical figures for the transistors used was 14.4 db.)

The linearity of the amplifier was excellent over several decades, and there were no oscillations or non-harmonically related outputs seen between “DC” and 21 GHz..

6. References and Acknowledgements.

The author wishes to thank Michael, OH2AUE and Tomas, OH6NVQ for the many discussions, stimulating ideas and “junk parts”. Without their assistance and enthusiasm this project probably never would be started.

Ideas used in the design of the amplifier came also from many others such as the products of DB6NT, webpages of PA0PLY, and ARRL publications such as the UHF handbooks. There is not much here that has not been seen before.

1. PA0PLY / I1TEX “10 GHz RF Amplifier”.

http://www.pa0ply.nl/10ghz_rf_amplifier.htm

2. Ken Schofield, W1RIL, “2W 10 GHz Amplifier”, published in ARRL UHF/Microwave Projects Manual, Volume 2.

3. Mitsubishi data sheets for MGFK3x series of GaAs FETs.