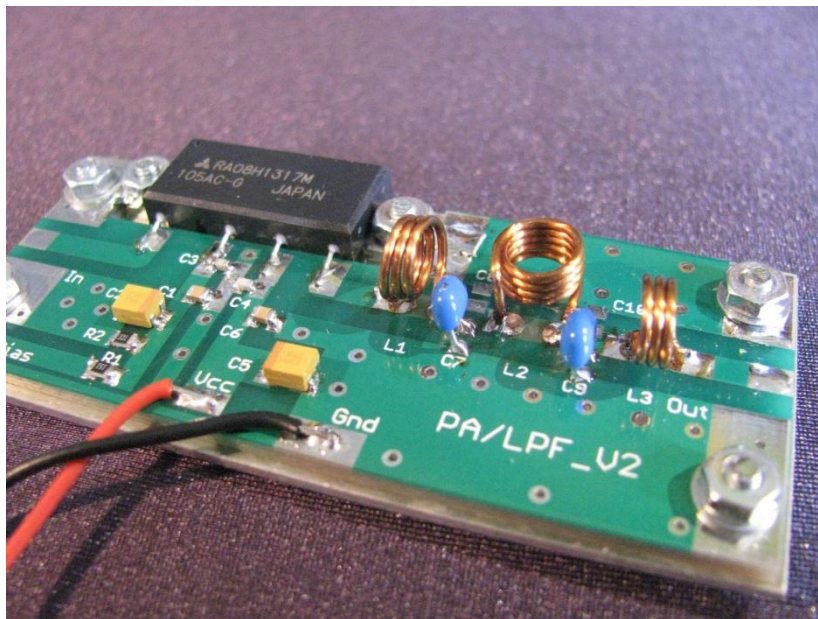


# 144MHz 8W low power linear amplifier

*An 8w linear amplifier using the Mitsubishi RA08H1317M RF MOSFET power amplifier module. This amplifier was designed for use with the Anglian 144MHz transverter.*

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*Doc V.1.1*



## Introduction

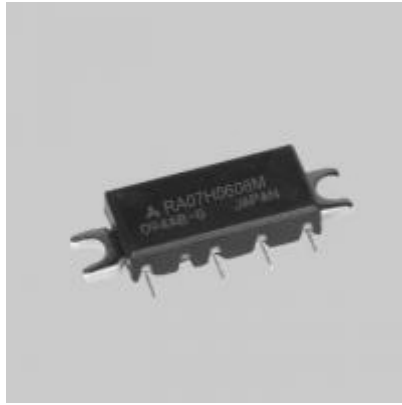
Two metre amateur band linear power amplifiers are relatively easy to design. However the ready availability of the low cost Mitsubishi RA08H1317M module makes it an attractive option for use with the Anglian and other low power transverter modules.

The two-stage Mitsubishi RA08H1317M module features very stable, low voltage ( 12.5V) operation, with high gain and low drive level requirement. It also has good linearity, especially when the output is kept below about 5W PEP. The amplifier operates in Class AB.

The 8W power level is adequate for driving most modern 50 Volt powered RF MOSFET or valve linear amplifiers to full UK legal output power. The 8W amplifier incorporates a Low Pass Filter (LPF) to reduce harmonic output. Saturated output is over 10W.

## Power Module

The Mitsubishi RA08H1317M is a small (30 x 10 x 5.4 mm) power amplifier module using RF MOS FET technology. The device number indicates it is a 8W amplifier for use between 130 and 170MHz. The amplifier module draws less than 1.5A at 13.5V at full output.

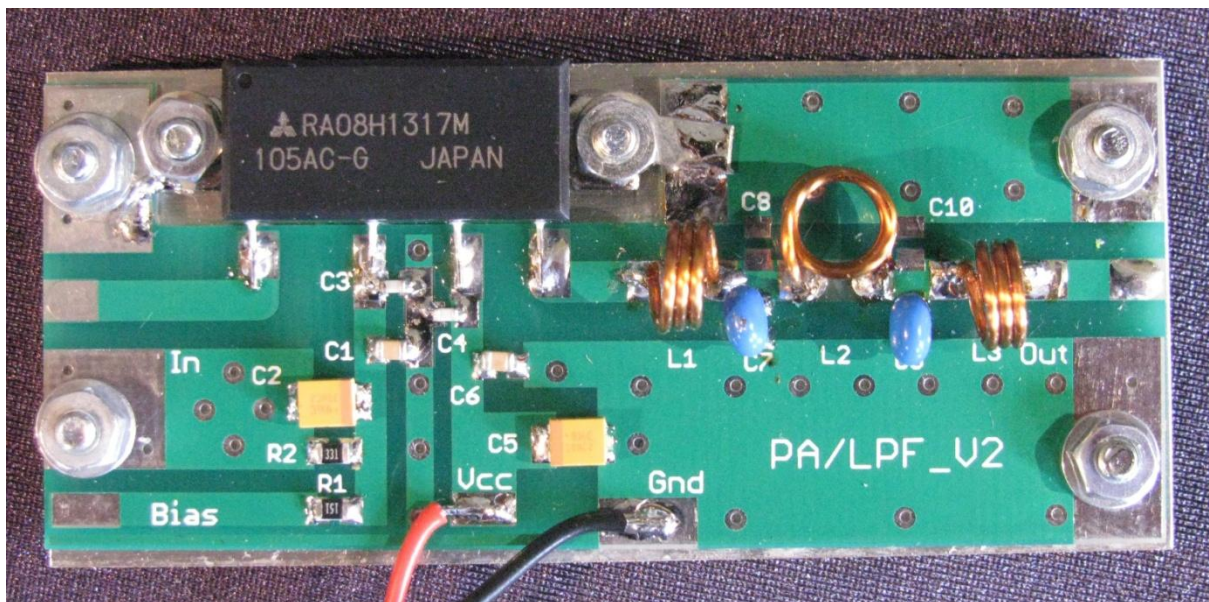


*Note that the photo shows the identical 70MHz module*

It has four connection pins plus ground (Heat-sink tabs). These connections are, from left to right:-

- |                              |                     |
|------------------------------|---------------------|
| 1 RF Input ( $P_{in}$ )      | 50mW max            |
| 2 Gate Voltage ( $V_{GG}$ )  | 5V max              |
| 3 Drain Voltage ( $V_{DD}$ ) | 13.2V max           |
| 4 RF Output ( $P_{out}$ )    | up to 10W saturated |
| & RF Ground (Case)           |                     |

According to the manufacturers RA08H1317M data sheet the drain voltage should not exceed 13.2V when running 3.5V gate bias. The gate bias voltage is purposely held at 3.4v by R1 and R2. A series-connected 3 Amp silicon rectifier diode, D1, in the supply to the amplifier, is recommended in order to drop the supply voltage from the usual 13.5V and also to provide protection against accidentally reversing the supply to the transverter and amplifier.



## Circuit

This is very straightforward. The circuit schematic is shown in Fig 1

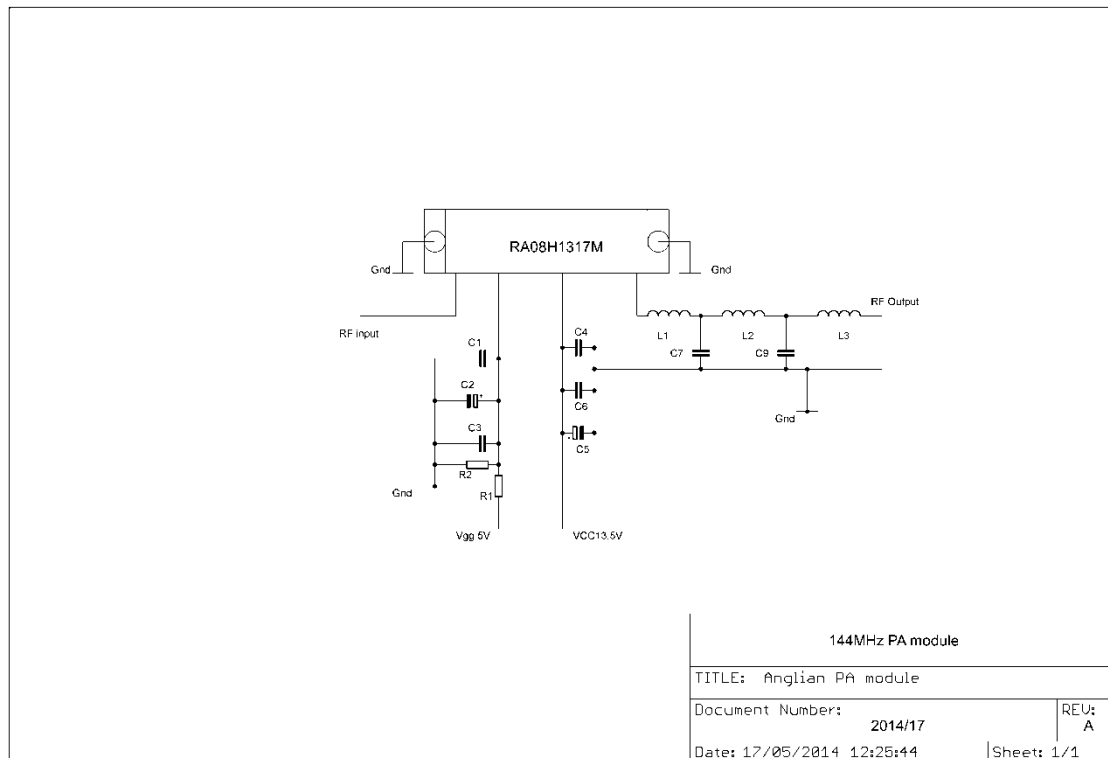


Fig 1 schematic of the 144MHz PA module and LPF

Table 1 shows the component values.

Designation	Value	Type
<b>C1</b>	10nF	0805 SMD
<b>C2</b>	10uF Tantalum 16V - 20V wkg	Case B SMD
<b>C3</b>	100pF	0805 SMD
<b>C4</b>	100pF	0805 SMD
<b>C5</b>	10uF Tantalum 16V - 20V wkg	Case B SMD
<b>C6</b>	10nF	0805 SMD
<b>C7</b>	27pF	Ceramic plate
<b>C8</b>	Not used	
<b>C9</b>	27pF	Ceramic plate
<b>C10</b>	Not used	
<b>R1</b>	150R	0805 SMD
<b>R2</b>	330R	0805 SMD
<b>L1</b>	See table 2	
<b>L2</b>	See table 2	
<b>L3</b>	See table 2	
<b>IC1</b>	RA08H1317M	PA Module

Table 1 component values for the PA and low pass filter. The low pass filter coil details are shown in table 2

The component overlay is shown, over-size, in figure 2



*Fig2 Component overlay for the 144MHz amplifier module with LPF. C8 and C10 are not used in this version of the amplifier module.*

The layout consists of a number of decoupling capacitors connected to the supply and bias pins of the PA module, with two fixed gate bias setting resistors. The low pass filter ensures that the harmonic output from the PA module meets current UK out of band spurious output recommendations for amateur radio transmitting equipment.

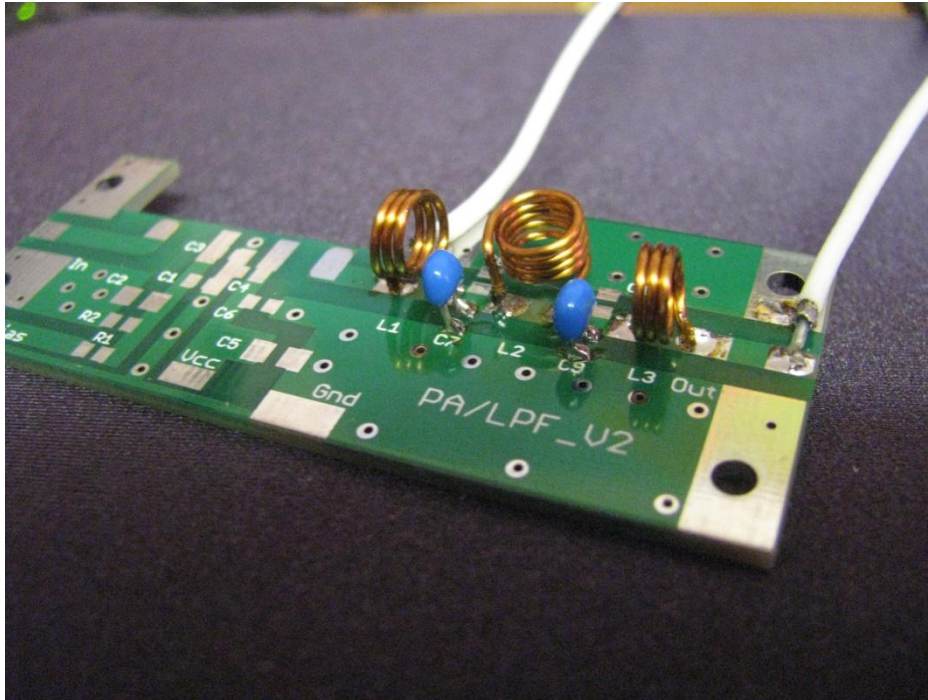
The amplifier bias current was 0.7A with 3.4V bias, rising to 1.2A at full output ( with 12.5V supply).

## LPF

This is the most critical part of the module as it must exhibit low loss at 144MHz with good matching and yet reduce the harmonic output from the amplifier to acceptable levels. The low pass filter, consisting of L1, C7, L3, C9 and L3, ( Note that C8 and C10 are not used in the 2m PA/LPF) has been carefully modelled and then tested to check that it agrees with the model design.

22SWG (0.7m) diameter enamel insulated wire is used to produce the required inductance values for L1, L3 and L3. Together with leaded capacitors these form the low pass filter. Provision is made on the board for C7 and C9 SMD capacitors but the leaded parts were found to work just as well and are easier to obtain. C8 and C10 are not used in the 2m LPF. L2 is mounted perpendicular to L1 and L3 to reduce unwanted coupling between these inductors.

The filter has less than 0.3dB insertion loss at 144MHz with over 25dB input return loss. The second harmonic, at 288MHz, is suppressed over 20dB and the third harmonic by over 50dB. Higher harmonics are suppressed over 60dB. Additional stages of filtering can be added if required, but at the expense of increased insertion loss.



*Low Pass Filter view 1*

*LPF view 2. The LPF is shown with temporary coax connections to allow testing of the filter response independently of the power amplifier module. Note that L2 has one short connection and one long connection. L2 is offset from the connecting tracks.*

### Coil orientation details

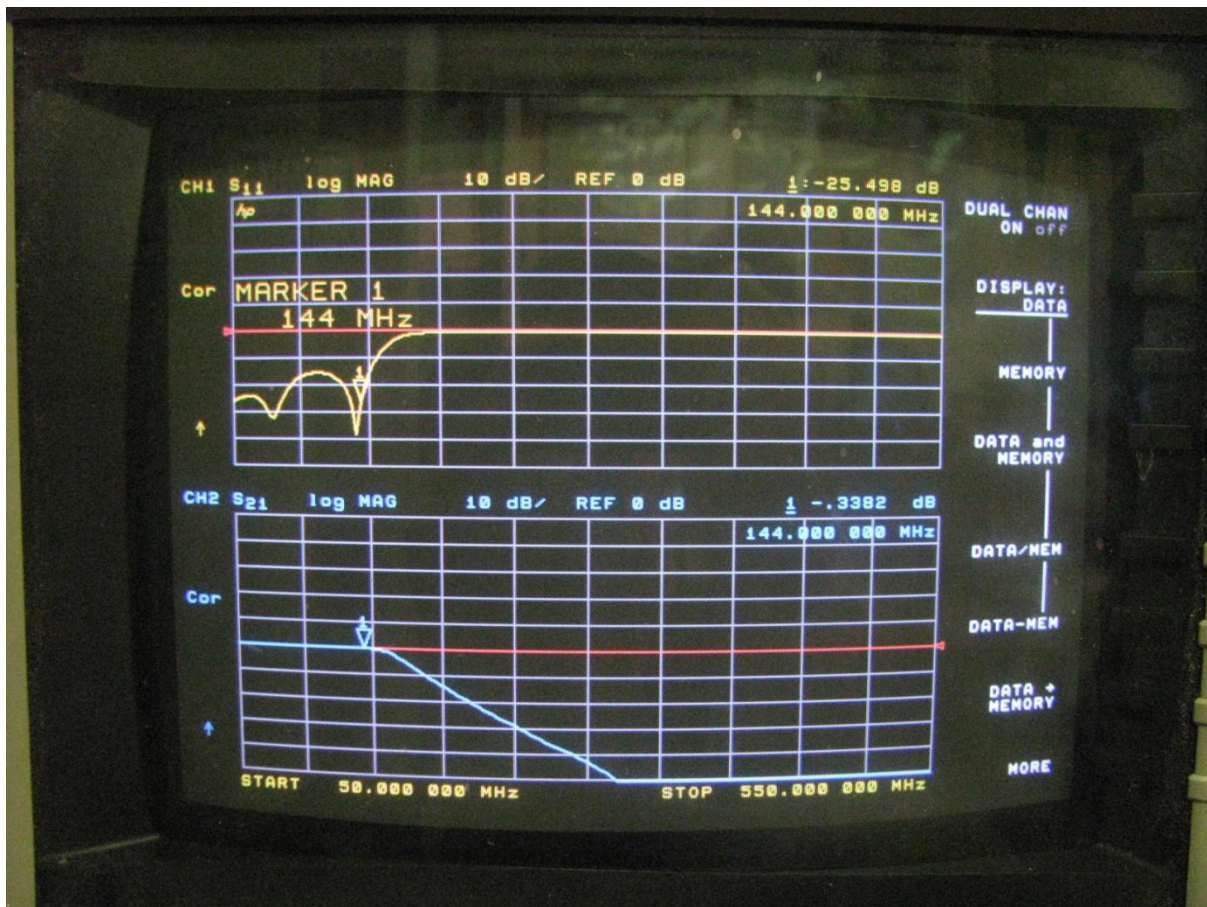
Coil	Turns	Coil orientation
<b>L1</b>	3	Horizontal
<b>L2</b>	4.5	Vertical
<b>L3</b>	3	Horizontal

*Table 2 Low pass filter coil details*

All coils use 22SWG ( 0.7mm) enamel covered copper wire, close wound on a 5.0mm diameter former such as a 5.0mm drill shank. Remove the former after the coil is wound!

At the end of the coils carefully bend the wire tails down from the coil as shown, cut to about 1.0mm long and then tin with a VERY hot soldering iron to remove the insulation coating for approximately 0.7mm. L2 requires that the top tail is cut longer, as shown, so as to contact the same pad as C7. It may be necessary to 'tune' the coils for optimum low loss and return loss performance. L2 may be opened out **very slightly** by bending the top turn away from the rest of the coil. It should not be necessary to touch L1 and L3.

## Frequency response and return loss of the LPF



Frequency response ( yellow trace) and Return loss ( blue trace) of the 144MHz LPF. Vertical scale is 10dB/Division. The 144MHz insertion loss includes the thin coax and the two connectors.

## Amplifier performance

The Output performance is shown in Table 3. below.

Input level dBm ( 144.2MHz)	Output power dBm/W	Harmonics (2nd/3rd)
-10	+27dBm/0.5W	
-5	32dBm/1.5W	
0	34dBm/4W	
+5	+38dBm/7.4W	-60/-60dBc
+10	39.5dBm/9.5W	

Table 3 Output level performance of the amplifier module

The Intermodulation performance is shown in table 4

Power output level	IMD 3rd	IMD 5th
4W PEP	-30dBc /Tone	-64dBc/Tone
7.4W PEP	-24dBc/Tone	-56dBc/Tone

*Table 4 Two tone ( 50kHz separation) IMD performance at two PEP output levels at 144.150 and 144.200MHz*

The amplifier was accidentally tested at 70.2MHz and a saturated output of 5W was seen!

The IMD and harmonic performance was NOT measured at 70MHz but the results suggest that it MAY be possible to use this module at 70MHz as part of a dual band transverter. Just saying.....

## Amplifier construction

The first thing to do, even before soldering any parts onto the PCB, is to cut a small, flat, sheet of thin aluminium, the same size as the PCB, but WITHOUT the cut out for the module. This is the heat spreader plate (HSP) that goes between the PCB and the case. The Mitsubishi module is also screwed to this plate. An ideal thickness is about 0.8 - 1mm.

Offer the PCB up to the HSP and mark the position of the four PCB mounting holes through, onto the HSP. Do not mark the holes for the module at this stage.

Drill four 2.5mm diameter mounting holes in the HSP.

Bolt the PCB to the HSP using short M2.5 nuts and bolts. Ensure the edges are square.

Offer the module up to the PCB ensuring that the four connecting leads line up with the four tracks on the PCB. as shown in the photo below. Carefully mark the positions of the two mounting holes for the module. **DO NOT SOLDER THE MODULE TO THE PCB AT THIS STAGE.**

Remove the module and place safely on one side.

Unbolt the PCB from the HSP.

Drill the two 2.5mm mounting holes for the module by drilling through the HSP.

Bolt the PCB to the HSP.

Ensure the edges are square.

Offer up the module to the HSP and PCB. **DO NOT SOLDER THE MODULE TO THE PCB AT THIS STAGE!**

Bolt the module temporarily to the HSP.

Check everything is square and that the module pins still line up.

Before going any further it would be wise to mark where you need to drill mounting holes for the amplifier in the case. This is best done by marking the (Hammond) case from the outside, using the

HSP as a template, making sure that you have drilled 6 holes; four for the HSP and two for the amplifier module.

Temporarily assemble the amplifier inside the case to check all the holes are in the right places.

Out of the case, again bolt the PCB to the HSP.

Spread a VERY THIN layer of heat sink compound on the bottom of the module.

Bolt the module to the HSP ensuring that the pins line up. You should use a longish solder tag on each of the two module mounting bolts as shown below. These tags should be soldered to the adjacent areas of tinned copper PCB to ensure a good, low inductance, grounding to the PCB. Do not use an excessive amount of heat sink compound on the bottom of the module. A thin, consistent, layer is adequate.

*Note that the HSP shown above is slightly bigger than described.*

If you want to test the 8W amplifier with the rest of the Anglian transverter then see the wiring information in the next section. Note that the amplifier 'Bias' is 3.4v and comes from the Anglian 5.0v TX out connection. If you don't have a Anglian you will need to provide a suitable 5V bias externally. If the amplifier is tested without bolting into the case, a small fan can be used to blow cool air over the HSP.

## Anglian transverter wiring

There are several ways to interconnect the transverter module with the PA/LPF depending on what you want to achieve. The method shown in figure 3 allows the Anglian transverter **+5v on transmit** output to provide the gate bias for the power amplifier module. The Vcc supply is left connected to the RA08H1317M whilst the transverter is switched on. The switched bias enables the PA for transmit.

The two 1N5401 silicon diodes provide reverse polarity protection if the supply is accidentally reversed. Also, D1 drops the supply voltage from 13.5 to 12.8V for the RA08H1317M module, whilst D2 additionally drops the voltage another 0.7V for the Anglian transverter module, thus reducing the dissipation in the on-board voltage regulators. A third diode may be connected in series with D2, to the transverter module VCC input to further reduce the transverter module supply, if felt necessary.

It is HIGHLY RECOMMENDED that a 6dB attenuator be used between the Anglian transverter module and the PA/LPF as the output from the transverter module is quite capable of overdriving and destroying the PA/LPF if too much IF drive is applied. A suitable Pi attenuator can be made with two shunt 150Ω 0805 size resistors and one series 39Ω 0805 size resistor. These can be mounted on the PA/LPF PCB by cutting the PA/LPF PCB input track and inserting the 39Ω resistor across the cut and the 150Ω resistors to the ground plane at either end of the 39Ω resistor.

The Anglian's **+12v tx out** can be used to operate a suitable 12v coaxial relay for transmit/receive antenna changeover whilst the **EOT** (Earth On Transmit) can be used to enable an external high

power linear amplifier. There should be a 'catcher' diode, D3, such as a 1N4148 connected as shown in fig 3 in order to avoid relay coil back EMF damaging TR4 on the Anglian board.

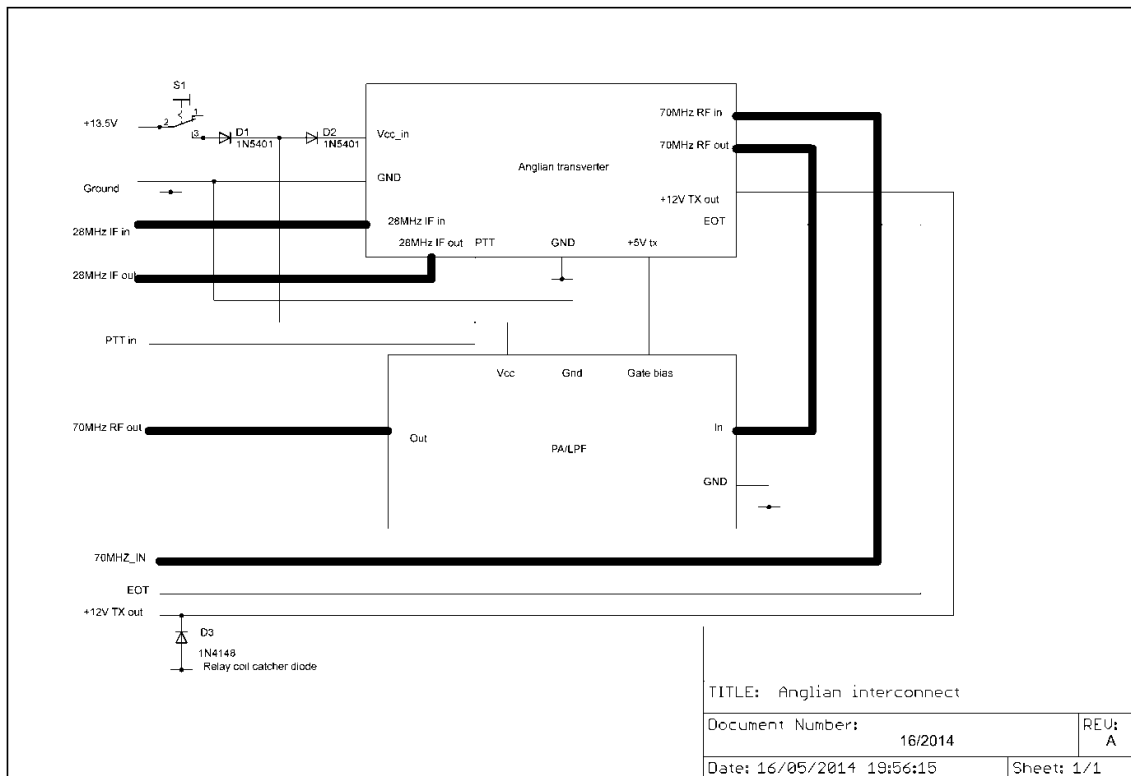


Fig3. wiring interconnections for the Anglian transverter module and the PA/LPF module. Note. This diagram was taken from the 4m PA article and shows the transmit and receive ports as 70MHz. They should be 144MHz, of course!

### PCBs for the PA/LPF

PCBs and components for the PA/LPF can be purchased from G4DDK. Please contact me at sam@g4ddk.com for details of price and availability

### Document history

Date	Issue	Changes
17/5/14	V0.1	Initial 144MHz PA module document
29/5/14	V1.0	Document ready for web page
30/5/14	V1.1	Fig. 3 comment added Page numbers added