

PGA103+ Low noise, high dynamic range preamp for VHF and UHF

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Introduction

This paper describes a low noise, high dynamic range VHF/UHF preamp that uses the Minicircuits (MCL) PGA103+ P-HEMT MMIC device.

The PGA Amp achieves 0.5dB noise figure from 50MHz to 144MHz and 0.55dB at 432MHz. At 1296MHz the noise figure is 0.85dB. However the real PGA Amp advantage is its incredible dynamic range. The Input third order intercept (IIP3) is better than +10dBm at 144 and 432MHz and over +20dBm at 1296MHz! It is possible to optimise these figures for particular frequency ranges. The design, as described, is optimised for the lower VHF and 432MHz bands.

The PGA Amp requires just a single 5V supply at 84mA.

It is a broadband amplifier and this means that if it is going to be connected directly to an antenna it may be necessary to use a low loss input filter to reject the strongest out of band signals whilst minimising additional losses that will add directly to the preamplifier noise figure. A suitable filter is described, for use at 144MHz, that provides more that 20dB attenuation across the whole FM band, with over 50dB at 98.5MHz. A suitable 432MHz filter will be described in a future article.

Circuit schematic and assembly

The schematic really could not be simpler. The PCB is designed to accept 0603 size SMD parts

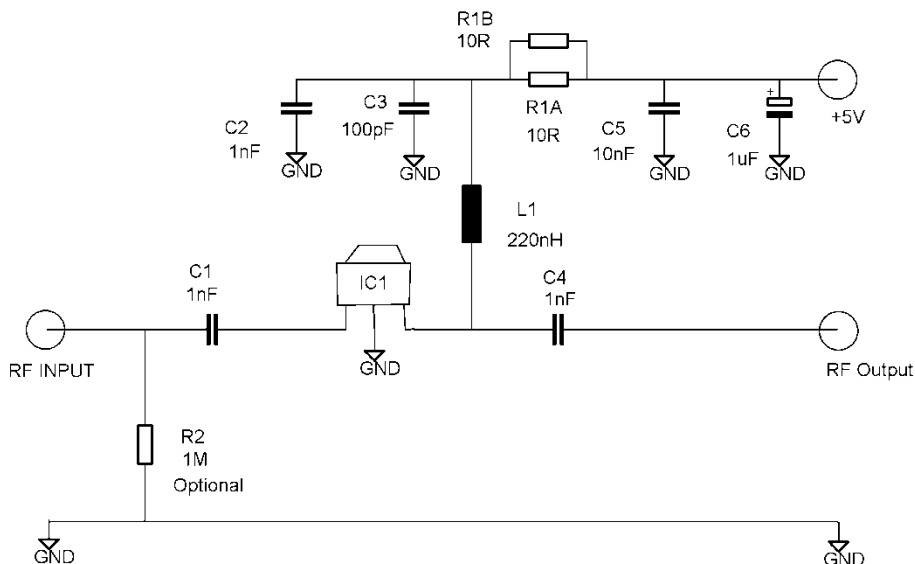


Figure 1 shows the circuit schematic of the basic PGA103+ amplifier.

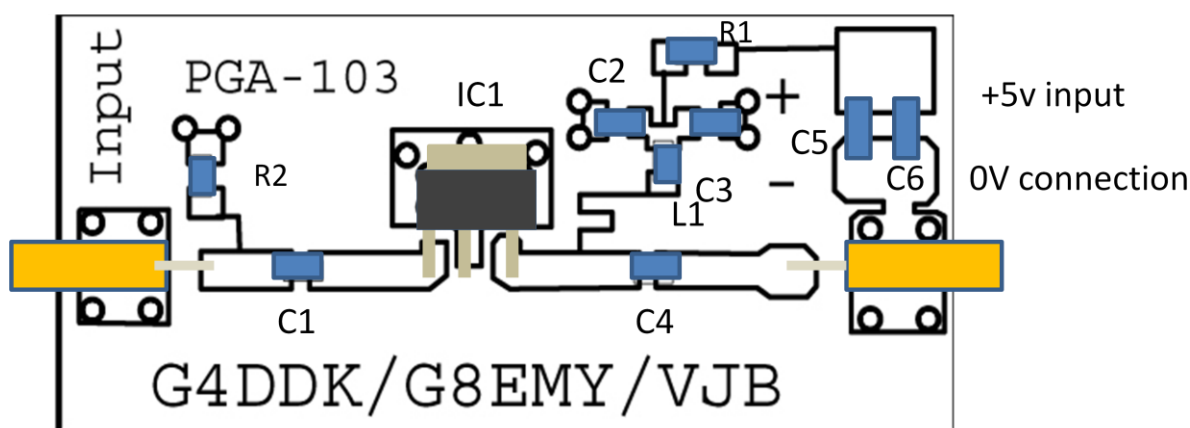


Figure 2 shows the component placement for the PGA AMP. C5 and C6 are fitted across the input power pads. R2 is an optional 1MΩ 0603 size SMD part that can be used as a static leak where static build up may be a problem. IC1 should be mounted with its leads well down the input and output tracks to prevent them shorting to the ground pad. The ground lead can be left unsoldered but the tab MUST be soldered to the ground pad once you are happy that the input and output leads are not shorting to ground.

Table 1

Component	Value	Package
R1	5Ω (two 10Ω in parallel)	SMD0603
C1,2,4	1000pF	SMD0603
C3	100pF	SMD0603
C5	10nF	SMD0603/0805
C6	1uF	Case A size
L1	220nH	SMD0603
IC1	PGA103+	SOT89
R2	1MΩ	SMD0603 optional Not supplied in the kit

Table 1 Component values for a basic PGA Amplifier.

The PCB should be populated before attempting to fit the PCB into the box.

Box

The cable termination PGA AMP PCB fits perfectly into one of the common little tin plate boxes. This is the 20mm x 20mm x 37mm size filter box (FG1) made by Schubert GMBH These boxes are available from G3NYK in the UK and from Eisch-Kafka Electronic in Germany.

Short lengths of UT141 coaxial cable with SMA connectors (either male or female) are used for the input and output RF connections. 3.5mm holes need to be drilled exactly in the centre of the box ends as shown to accept the coaxial cable pigtailed

. The coaxial cable fits through the holes and terminates on the PCB input and output pads as shown in photo 1.

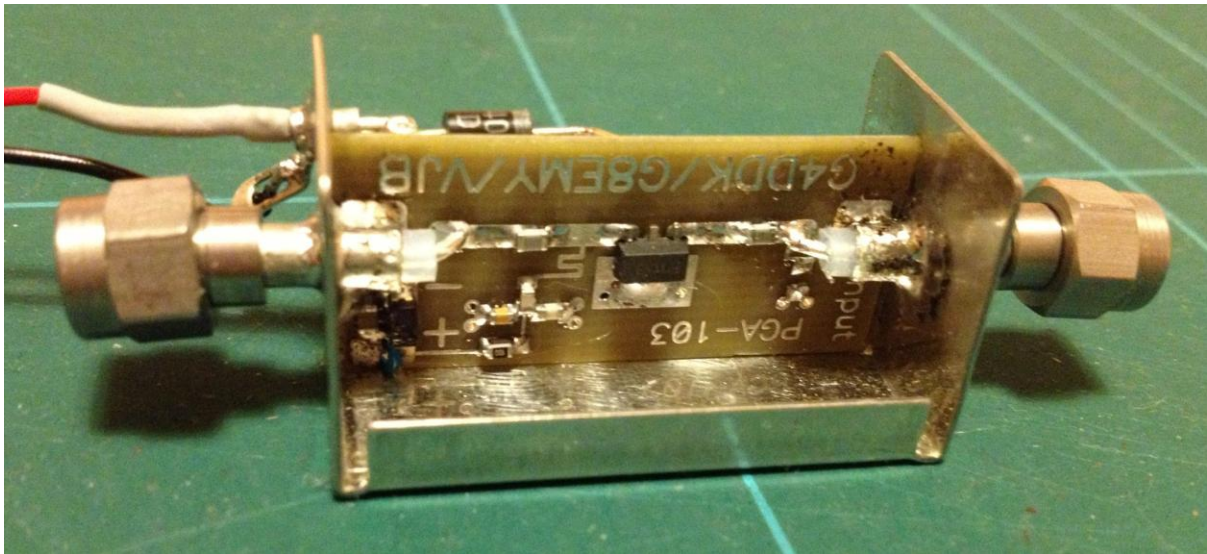


Photo 1 The PCB is soldered vertically into the box with the board input and output pads slightly offset to the 3.5mm diameter holes.

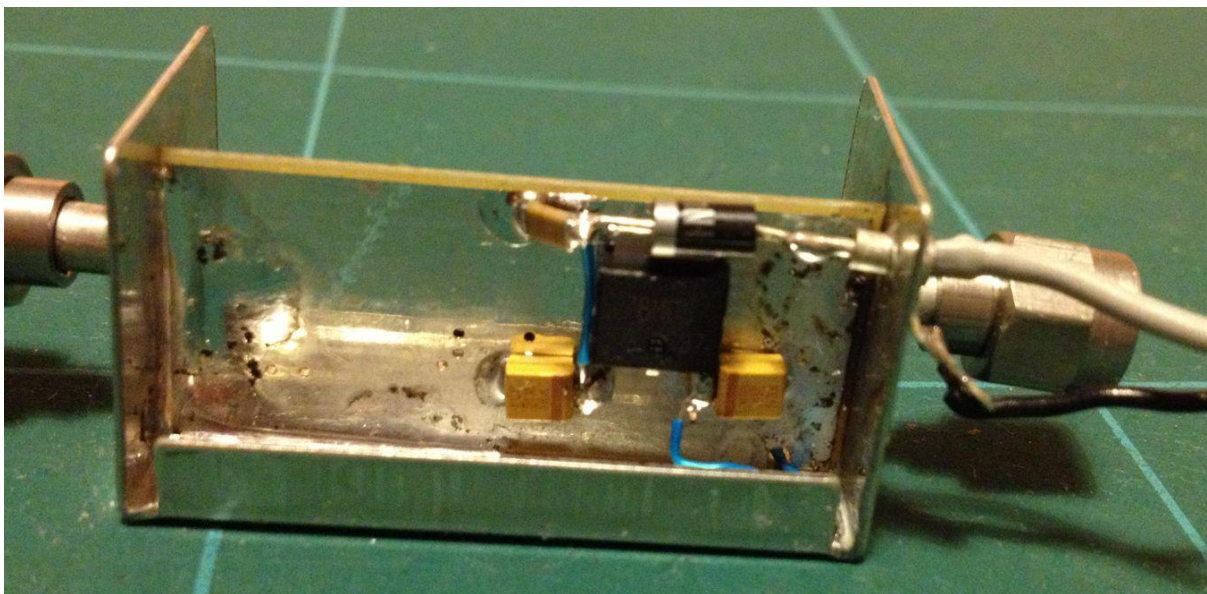


Photo 2 shows the extra 5V regulator added onto the rear of the PGA Amp PCB

I chose to solder a 78M05 5V/500mA SMD regulator to the ground-plane side of the PCB with 10 μ F/20V working tantalum capacitors for decoupling. This ensures that whatever the input supply voltage variation no more than +5V appears at the PGA AMP.

I used a Tusonix 1500pF solder-in feed-through capacitor to bring the supply into the box and then a 1N4001 as a series 'idiot diode' to prevent reverse polarity disasters.

Results

Table 2 shows the results obtained from a boxed PGA AMP. The usual caveats apply, i.e. systematic uncertainties in the measurements, particularly of the noise figures, test equipment calibration, quoting noise figures to hundredths of a dB! etc. These numbers were obtained using the newer FR4 PCB.

Table 2

Frequency (MHz)	Noise figure (dB)	Insertion gain (dB)	Input IP3 (dBm)	Input return loss (dB)	Output return loss (dB)	Psat Output (dBm)
30	0.5	26.2				
50	0.5	26.2		3.8		
70	0.5	25.9		5.2		22.1
144	0.47	25.1	+11.8	8.7	22	22.5
432	0.53	21.0	+10.5	10.6		
1296	0.8	14.1	+20.5	14.7	15.4	24.5

Table 2 Measured performance of one sample of the PGA103+ amplifier mounted in the recommended tin plate box.

Summary

Whilst an IIP3 of +11.8dBm at 144MHz is impressive, an IIP3 of +10.5dBm at 432MHz is also pretty good for a device delivering over 20dB of gain and around 0.5dB noise figure.

At 1296MHz the IIP3 is also extremely good at over +20dBm. However, this figure could be improved significantly by careful selection of the device operating point. Potentially, it could be as high as +26 to +30dBm. These are the numbers achieved at 1.9GHz in the original cellular radio base station mast head preamplifier application of this device.

One of the advantages of this small high performance amplifier is that it is so small that it can be fitted inside many existing transceivers as an alternative receiver front end or even a replacement driver stage, possibly giving a large increase in receiver performance or restoring transmitter drive to a PA.

A concern for some

144MHz band users will be strong signal effects from Band 2 FM broadcast stations. However, unless you live or operate very close to one of these monsters, they probably don't cause the average radio amateur any problem.

Traditionally, the input selectivity provided by low loss input matching circuits has been used to reduce the effects of FM broadcast stations. These 'filters' are not always as effective as we might imagine! In the PGA AMP the very high IIP3 provides additional protection against Band 2 broadcast signals as well as against close-in paging signals and some in-band signals from the bigger contest stations.

Where additional protection from Band 2 is required a simple high pass filter can be used at the PGA AMP input. DJ7VY and LA8AK (SK) both recommended this approach as it can give extremely low losses at the preamplifier input (<0.13dB) together with 50dB rejection of the more troublesome stations in Band 2.

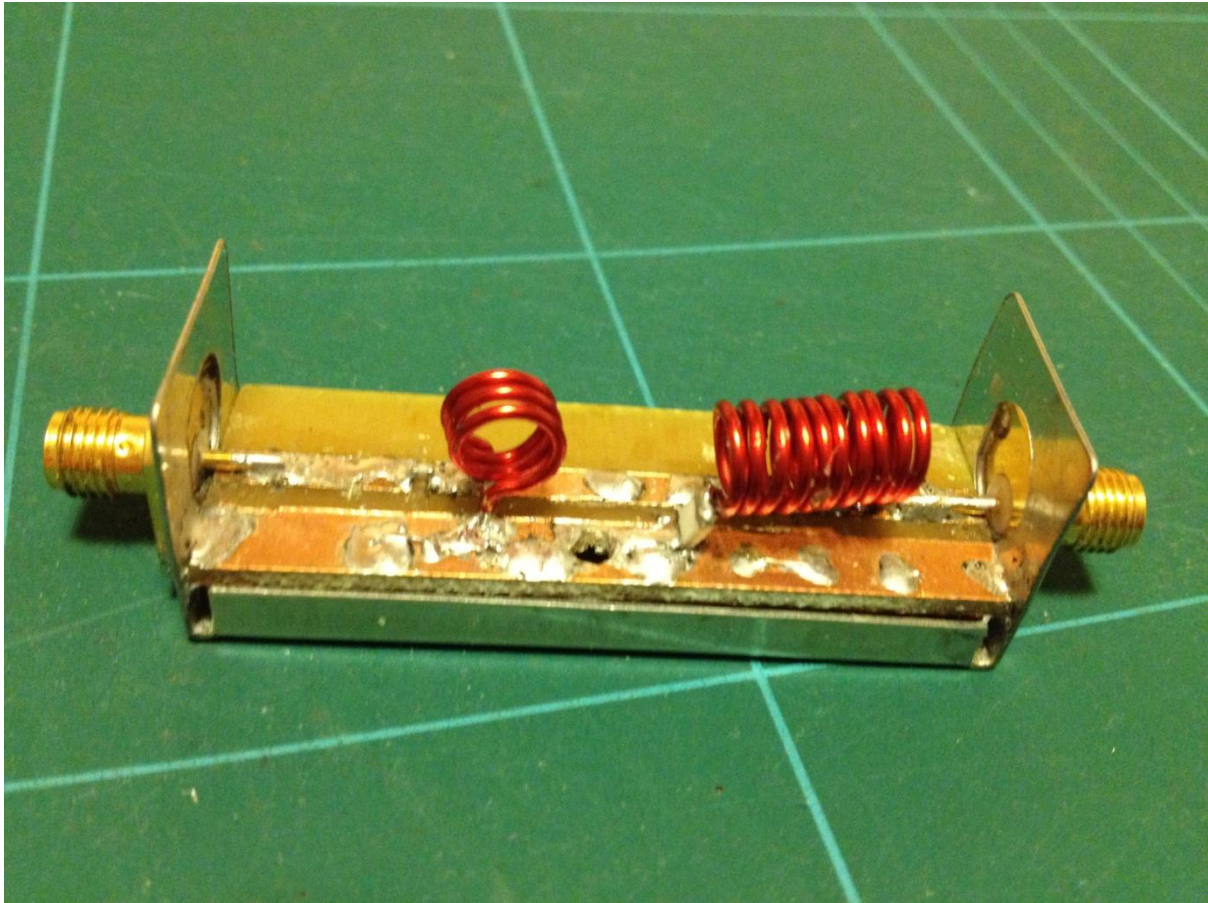
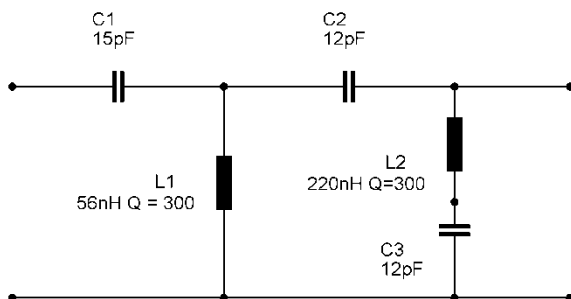


Photo 3 The G4SWX 130MHz low loss HPF built into a Schubert 20 x 20 x 57mm tinplate box with input and output SMA connectors. Note that this is a no-tune filter. Build it as described for best performance.



Low loss 130MHz HPF

L1

3 Turns of 1mm enamelled wire
5.5mm inside diameter, length 4mm

L2

10turns of 1mm diameter enamelled wire
5.5mm inside diameter, close spaced

Fig 3 Circuit Schematic for the 130MHz HPF filter developed by G4SWX and tested by G4DDK

The filter has been specially designed to give the lowest insertion loss at 144MHz whilst giving a large attenuation across the Band 2 FM broadcast band. If it is built exactly as described it will require no tuning. Do NOT be tempted to replace the enamelled, annealed copper wire with silver plated wire or even a larger gauge wire.

The filter should be constructed as shown. The three capacitors should be low loss, High Q, Low ESR microwave SMD types. The filter insertion loss will increase if cheap multilayer ceramic capacitors are substituted. The ones used in the photo are a mixture of AVX and Johanson ceramic capacitors.

1mm diameter enamel insulated annealed copper wire is wound as shown. The wire diameter and winding details are critical if you don't want to spend a long time tuning the filter. It is important to orientate the two coils at approximately 90° in order to minimise unwanted coupling.

To check that the filter is working correctly it should be swept and the deep notch will be located at 98.5Mhz +/- 1MHz. Minimum insertion loss will be across 143 - 146MHz and should be between 0.13 - 0.14dB

The filter was built into a separate box from the preamp and is only connected if it is required. Most 144MHz operators should not find it necessary to use the filter.

Filtering above 144MHz is probably best left to a low loss bandpass filter located at the preamplifier output, although an input 400MHz HPF might also be practical.

A suitable 432MHz HPF will be published later.

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