144MHz Transverter-Driver Interface for the Elad FDM-Duo

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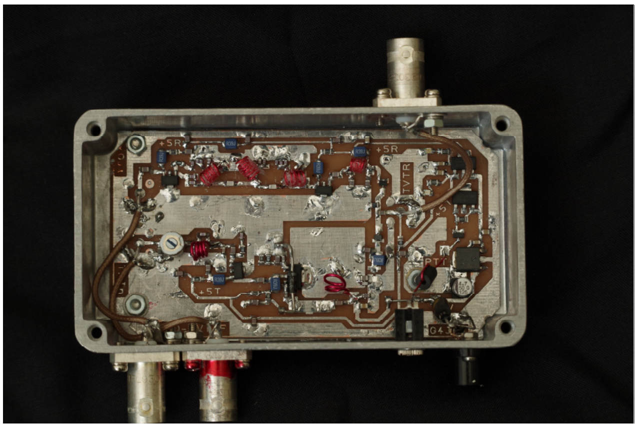


Introduction

The Elad FDM-Duo is a small fully-SDR based transceiver that can operate either in completely standalone mode or in conjunction with a PC. In normal use it operates over the frequency range from [near] zero to 54MHz where it can deliver 5 Watts on transmit. The sampling frequency is 122.88MHz on receive with the dial frequency adjustable up to 165MHz in 1Hz steps. Above 54MHz, with the input anti-alias filter switched out via menu selection item No. 2 the receiver runs with different alias products of the sampling clock. The internal software automatically compensates for the alias product in use.

On transmit a low power output can be selected via menu item No. 33 so that instead of generating the normal 5 Watts, 1mW appears direct from the SDR transmitter source from the rear-mounted SMA socket. The sampling rate on transmit is 368.64MHz, three time higher than for receive, so this low power port can output frequencies up to 165MHz without making use of alias products.

Ref [1] shows designs for add-on modules for running the FDM-Duo on-air at 144 and 70MHz. The 144MHz design, as it incorporates a 7 watt power amplifier is not suited for driving a transverter, so it was decided to build another module specifically for this task.

FT817 Lookalike

Many people use either an FT817 or the older FT290 (or occasionally the even-older-still IC202) transceiver to drive microwave transverters. These radios are usually adjusted to deliver something like 500mW on transmit, with an internal modification added to supply a few volts of DC on the antenna port for transverter Tx/Rx switching. These transmitters can deliver more than 500mW in normal operation, so any transverter must be 'safe' if accidentally overdriven with a few watts of RF.

The interface for the FDM-Duo needs to replicate this and supply a comfortable 500mW. On receive, although many transverters have plenty of gain, especially at IF, not all do so. Therefore the sensitivity of the interface on Rx needs to be about the same as these older rigs, offering a noise figure of no more than 5dB.

Module Design

The circuit diagram of the complete interface is shown in **Figure 1**. Tx / Rx changeover is controlled by switching 5V transmit and receive power rails using P-channel Mosfets. Tx input is 'ground to transmit' as provided from the 3.5mm jack on the rear of the FDM-Duo

The receive side, and specifically the anti-alias filtering requirements, are dealt with in detail in *[1]* and the same design is adopted here. Good attenuation of the first alias product which occurs at around 100MHz is essential, otherwise Classic FM will be appear all over the band! A three element top-coupled bandpass filter with nominal 10MHz bandwidth works well. The top coupling gives an asymmetric response which enhances low-end attenuation, exactly as needed here. **Figure 2** shows the measured filter response using a noise source to drive the receive chain. Although not visible on the plot due to dynamic range limitations of using noise as a test source, attenuation at 100MHz is around 73dB. Ensure there are no spurious routes for 100MHz signals picked up on connecting leads from appearing on the board. Ferrite beads should be placed on the DC input and Tx control lines and the module built into in a screened box.

As there is so much gain present in the Rx chain, there is no need to make this a particularly low loss filter so small air-wound inductors can be used. Using low-Q inductors does not significantly degrade the stopband response, but does tend to smooth out the passband and make simple "tuning for best passband response" easier. Note that the values of L and C for the filters shown on the circuit diagram are taken direct from the filter simulation package. Use a parallel combination of capacitors to get within a few percent. Tuning is performed by squeezing or stretching the coils for the wanted response. If rejection of 100MHz is still insufficient, an additional bandpass filter can be inserted in the path to the Rx output. This will need to be in its own screened box.

At 144MHz, using the second alias product, the effective receiver noise figure of the FDM-Duo is around 30dB, made up from a combination of SIN(X)/X loss and the summation of noise in all the other alias bands. The interface therefore has to provide something like 40dB of gain to completely overcome this and dominate the overall noise figure. This was the route taken in *[1]* using a pair of PGA-103 devices operating at around 3.5V bias. The bandpass filter sits between the two gain stages. An identical line-up is used here except that an additional 6dB attenuator pad is inserted at the output of the bandpass filter.

The first PGA-103 needs to have a stabilising network added – this is the 150Ω and 1nF combination. Without this network, when presented with a certain range of input impedances, (observed when certain lengths of coax were used to connect to the transverter) the first stage could break into oscillation. A three-section lowpass filter on the input serves to attenuate strong signals from local mobile phone base stations.

On transmit a notch filter removes the 223MHz first alias product and feeds the drive signal into the first gain stage, a single PGA-103. As suggested in the data sheet, a series combination of 150Ω and 2.2pF capacitor is included on the PGA-103 input to stabilise it at GHz frequencies.

The second gain stage is a BFG591 7GHz F_T medium power bipolar device. Presenting the collector with a direct 50Ω load while running from a 12V supply rail allows a theoretical maximum P_{OUT} of 1.4 Watts. It is biased into class AB operation for decent linearity, with the device operating at a standing current of around 100mA. A breadboard of the design showed there was more than enough overall gain with this cascade, requiring just -17dBm of drive for 500mW output; saturation occurs at a little over 1 Watt. An input attenuator is included to drop the 0dBm output from the FDM-Duo to an optimum drive level. A PI network for a 17dB attenuator pad has a top-resistor value of 174Ω, so by making this a 500Ω preset, allows for drive level variation while still maintaining a good match on the input.

The BFG591 is soldered to a 300 mm^2 pad on the PCB, with heat being conducted from this, through the 0.8mm PCB substrate to the ground plane. The PCB needs to be installed without using mounting pillars, directly onto the surface of the enclosure so heat can be conducted directly away from the board. Capacitance of this pad is around 15pF and is in parallel with a 33pF output capacitor. The total C is resonated with the output inductor which should be adjusted by squeezing turns to optimise output at 144MHz. The resulting low Q tank then serves to attenuate harmonics; at 500mW output, the second harmonic was measured at -28dBC. Most transverters designed for 144MHz drive should have filters that are narrow enough to reject mixer products resulting from any harmonics in the drive, so no additional lowpass filter was deemed necessary.

PIN diodes route the Tx or Rx path as appropriate. The diagram shows BAP51 diodes, these are dual devices in a SOT23 package with both diodes operating in parallel.

Inductors and Tuning-Up

For the three bandpass filter inductors of 70nH, a good starting point is six turns of 0.5mm wire wound on a 3.5mm mandrel, then spaced out to give the right value. The transmit notch filter inductor of 32nH requires 3 - 4 turns and the 56nH Rx input filter 5 turns. The Tx output inductor of 25nH is typically 2 turns of 0.8mm wire wound on a 4.5mm mandrel.

The three inductors in the bandpass filter need to be adjusted – by squeezing or stretching turns – to give a reasonable bandpass response using either a network analyser or, as shown in **Figure 2**, by driving the receive input from a noise source and viewing the output on a spectrum analyser. Nothing is critical, the nominal bandwidth is 10MHz so provided a reasonable degree of flatness is obtained over the normal 144 – 145MHz narrowband segment it will work.

The inductor on the transmit input filter should be adjusted to give a notch at 223MHz. Adjust the output inductor for a peak in response at 145MHz. This is a low Q network so adjustment range will be very broad. With the FDM-Duo on CW and generating a carrier adjust the input preset to get 500mW output, or whatever level the transverter drive requires, but do not aim for much more than 500mW as linearity will rapidly degrade.

References

[1] http://g4jnt.com/FDM-DUO_at_VHF.pdf

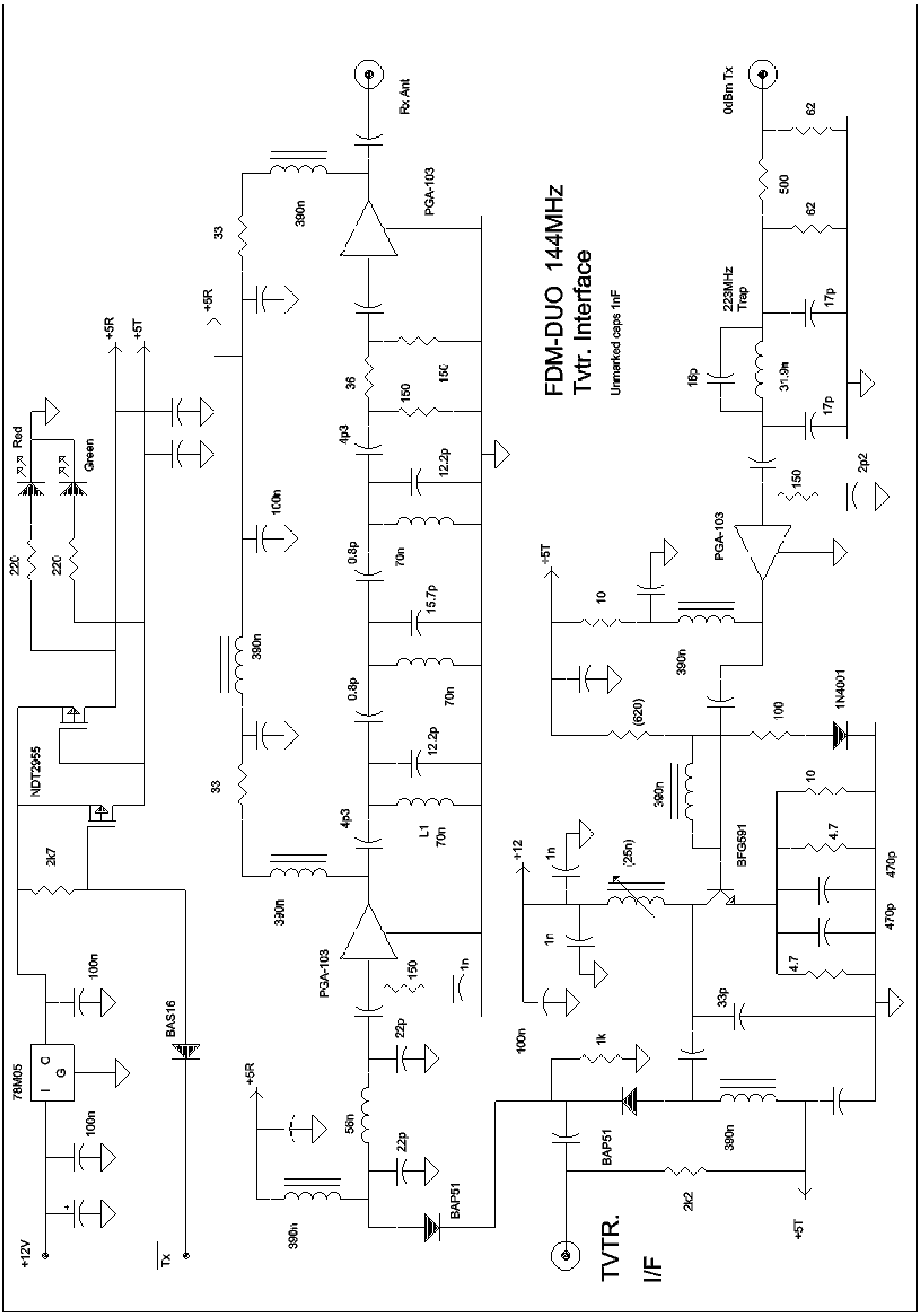

Figure 1. Full Circuit diagram of FDM-Duo 144MHz interface for driving transverters.

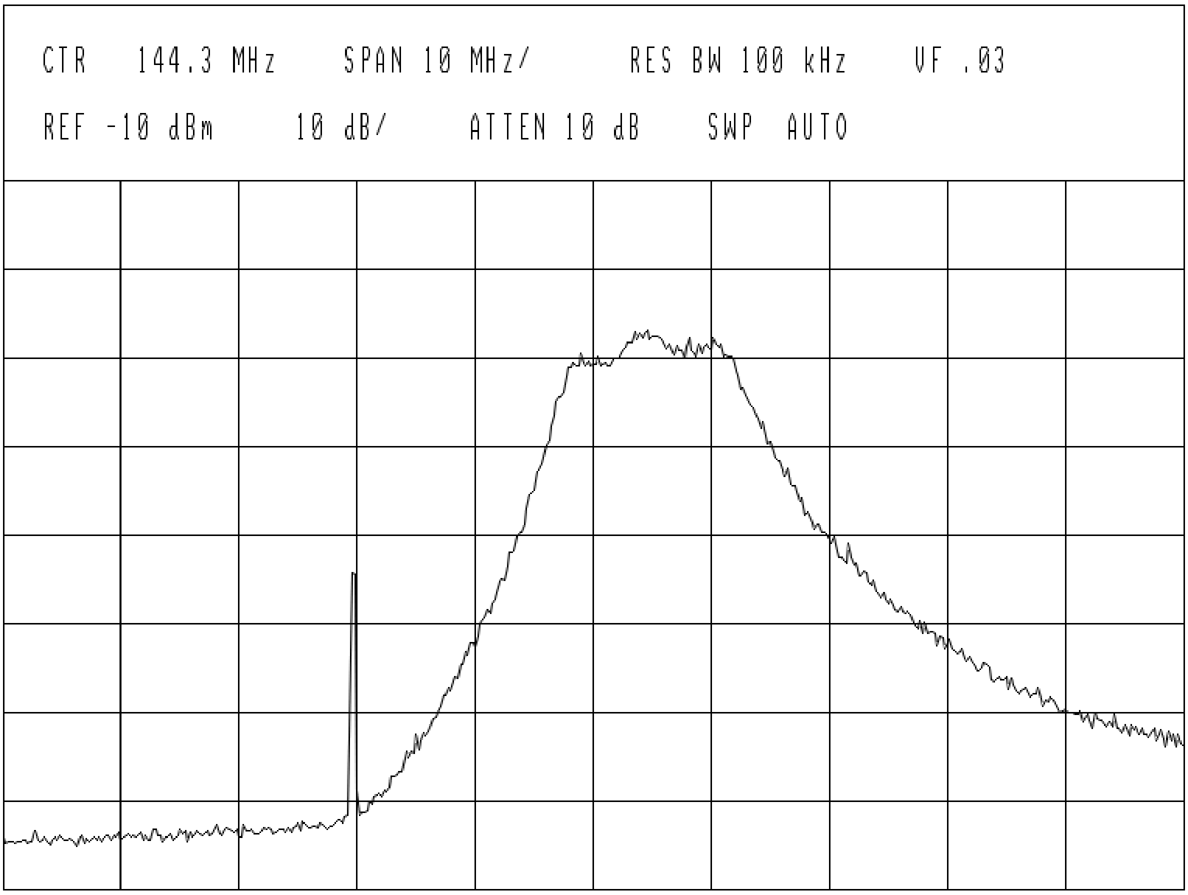

Figure 2. Measured receive chain response using a noise source on the Rx input. The spike at 125MHz is the noise generator clock. Gain at 145MHz is 33dB. Attenuation of the first alias product at 100MHz is around 73dB

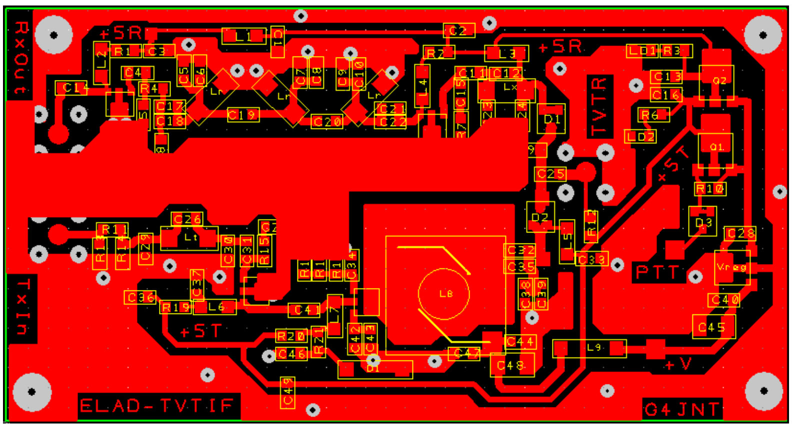

Figure 3 PCB Layout (approx. full size)