

# 13 dBm Isolation / Distribution Amplifier 5 to 100 MHz

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This amplifier is based on work done at NIST, Boulder, Co. [1], [2]

I really like the design [2] because there are no supply lines necessary that could propagate crosstalk and the conversion of input voltage to current is elegant. The 24V supply voltage fits the 24V for my HP / Symmetricom 58540A GPS time and frequency reference receiver.

The only thing that I changed is the way of biasing. The motivation for the change was more just to try it and constitutes no critique to the original design.

A common collector stage is used to convert the input voltage to a proportional current ( Q2 ). The cascode has an input impedance of close to 0 (hopefully). The emitter voltage of Q2 follows the input voltage minus a diode drop, so the AC emitter current is determined by the ratio of input voltage and R4. For 13 dBm = 2.8Vpp and R4 = 39 Ohm we get an AC current of 2.8/39 of 71 mApp. (dark blue trace in the simulation). This is 25.1 mA eff.

The value of R1 determines the input impedance of the isolation amplifier. Since we want 6 outputs plus one for cascading another board, a single amplifier needs to have an input impedance of  $7 * 50 = 350$  Ohm. Choosing R1 = 390 Ohm allows us to trim the input impedance with an additional resistor. R12 = 22 Ohm was necessary to put paid to oscillations in the common collector stage. It will probably impair the noise figure somewhat, but without it there were slight oscillations at 1.2 or 2 Ghz.

A red LED D1 provides a voltage drop of 1.8V. The pnp transistor Q1 / BC860 compares this voltage to the drop across the resistor R51 plus its own BE drop of 0.6V. If the voltage across R51 is smaller than 1.8-0.6 V, the BC860 gives more base current to transistor Q2 / BFG196. Thus, the BFG196 develops a collector current of  $1.2V / 27 \text{ Ohm} = 44 \text{ mA}$  which is just right for 71 mApp of signal in class A. C4+C7 must be large against C2 to keep the regulation loop stable. But in praxi 0.1u / 0.1u were stable, too. R11= 5 Ohm damps the parallel resonance of C4 / C7. Check the voltage rating of your SMD capacitors.

The two stage cascode provides the isolation. The current gain of the cascode is close to 0.99. Output is taken from a 200 to 50 Ohm transformer. Since the source impedance of the cascode is very high, a 200 Ohm resistor is required across the primary side of the transformer to provide a 50 Ohm output impedance. Thus the load of the cascode is 100 Ohm: the resistive 200 Ohm in parallel to the transformed 50 Ohm of the external load.

For 13 dBm = 20 mW of output power we must generate 40 mW into 100 Ohm. Since  $P = I^2 * R$  this requires a current of  $\sqrt{P/R} = \sqrt{0.04/100} = 0.02\text{Aeff}$  or 56 mApp. Since we have 71 mApp, we make a little bit more gain than necessary. We can trim R4 for unity gain. Something will be lost in the transformer anyway.

The RF transistors were chosen to be SOT-223 types because of power dissipation. Instead of the Infineon/Siemens BFG196 a NXP/Philips BFG198 and others will do, too. Medium power PNPs are not that common.

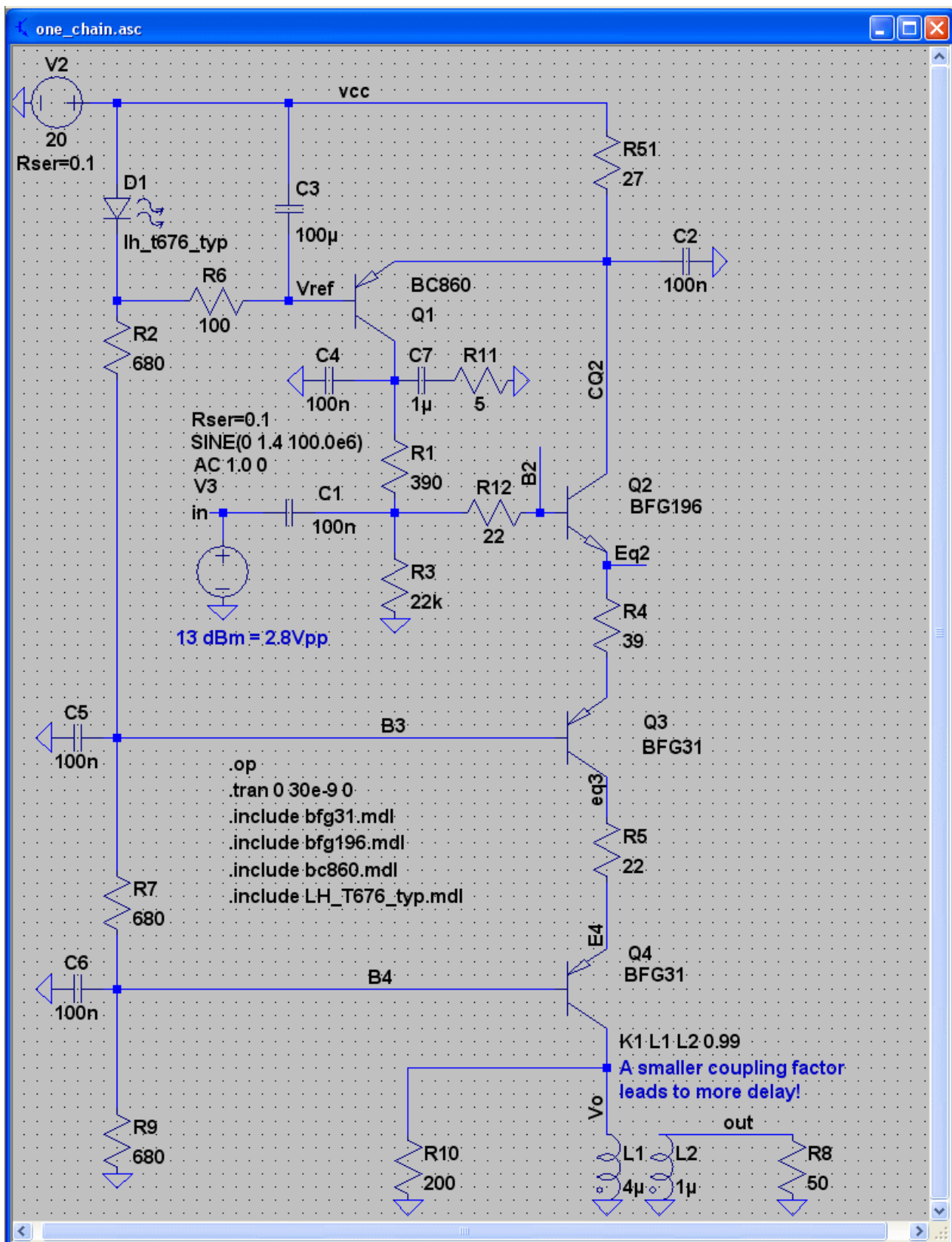
- [1] C.W. Nelson, F.L. Walls, M. Siccardi, A. De Marchi:  
A new 5 and 10 MHz Isolation Distribution Amplifier,  
1994 IEEE International Frequency Control Symposium

<http://tf.nist.gov/timefreq/general/pdf/498.pdf>

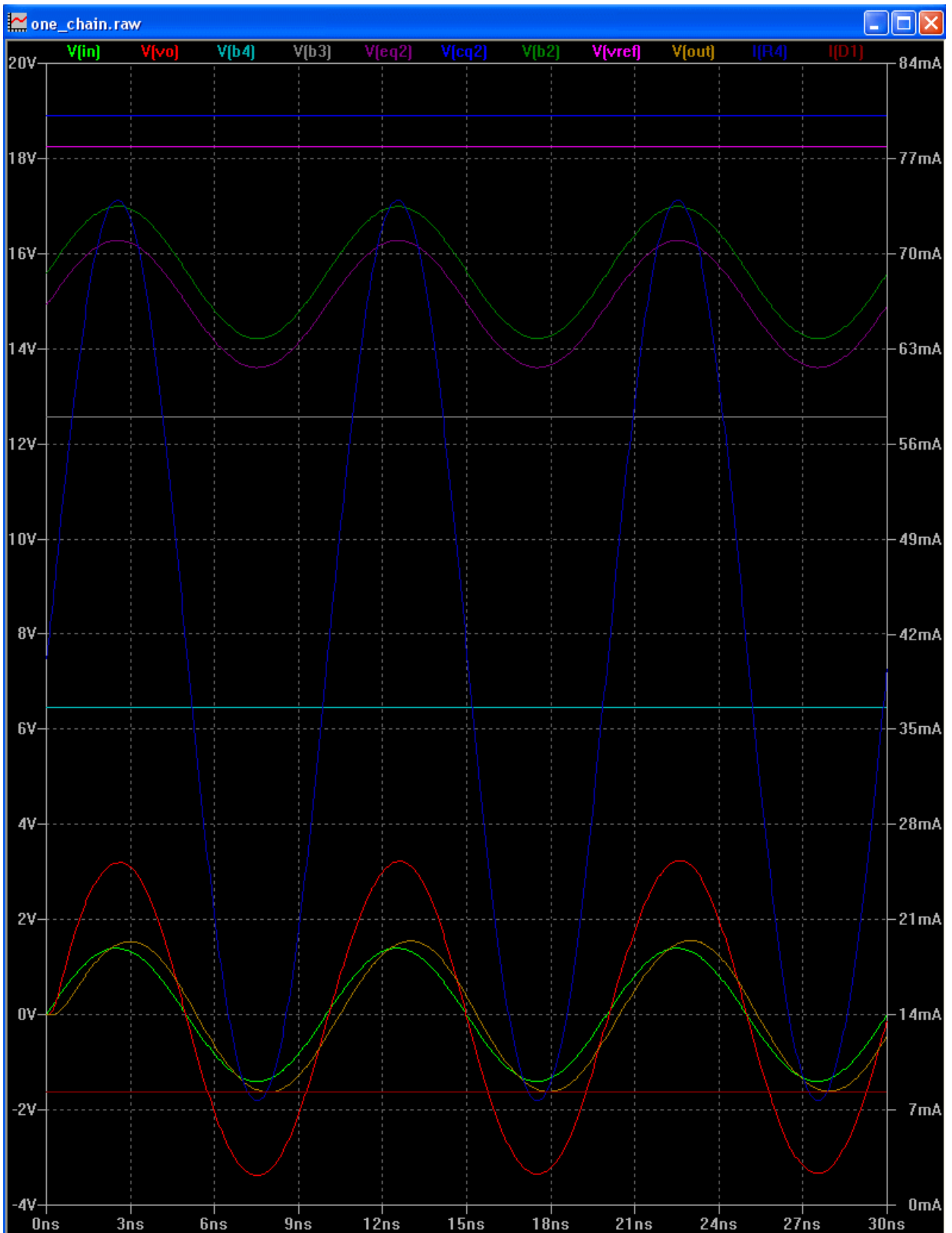
- [2] M. Siccardi, S. Römisch, F.W. Walls, A. De Marchi:  
A Low Noise 100 MHz Distribution Amplifier For Precision Metrology

<http://tf.nist.gov/timefreq/general/pdf/1200.pdf>

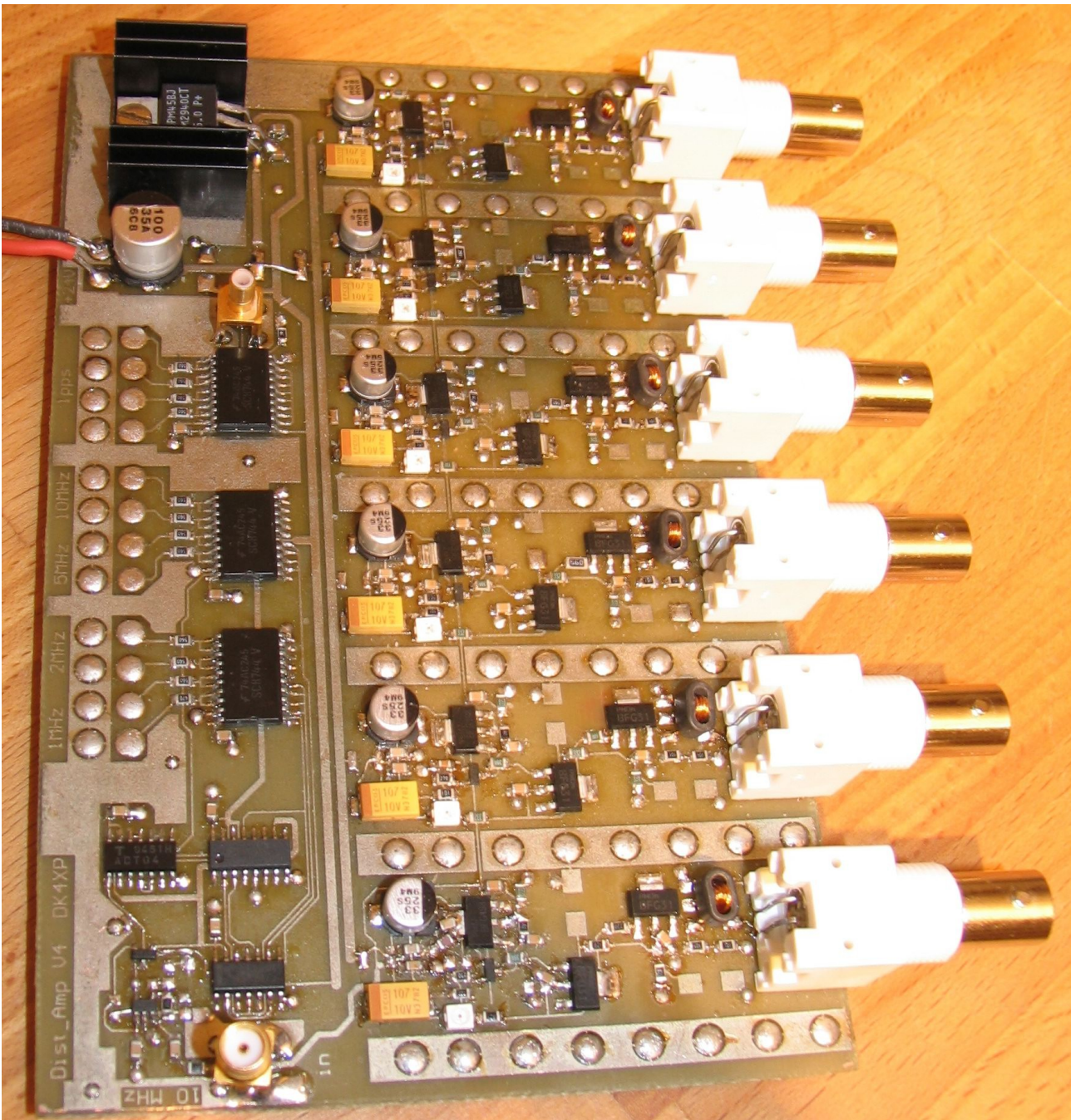
# Simulation with LT-Spice



Use as many 9s for the coupling factor of the transformer as you expect decades of Bandwidth (rule of thumb)



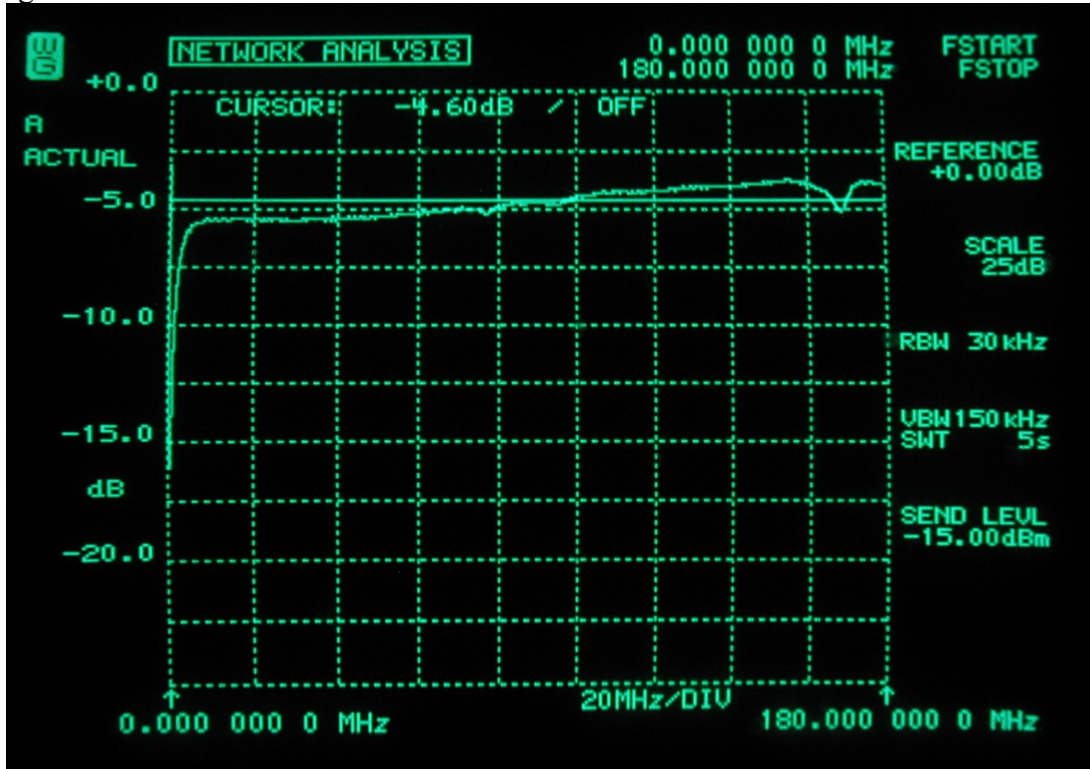
## Homebrew Experimental Board



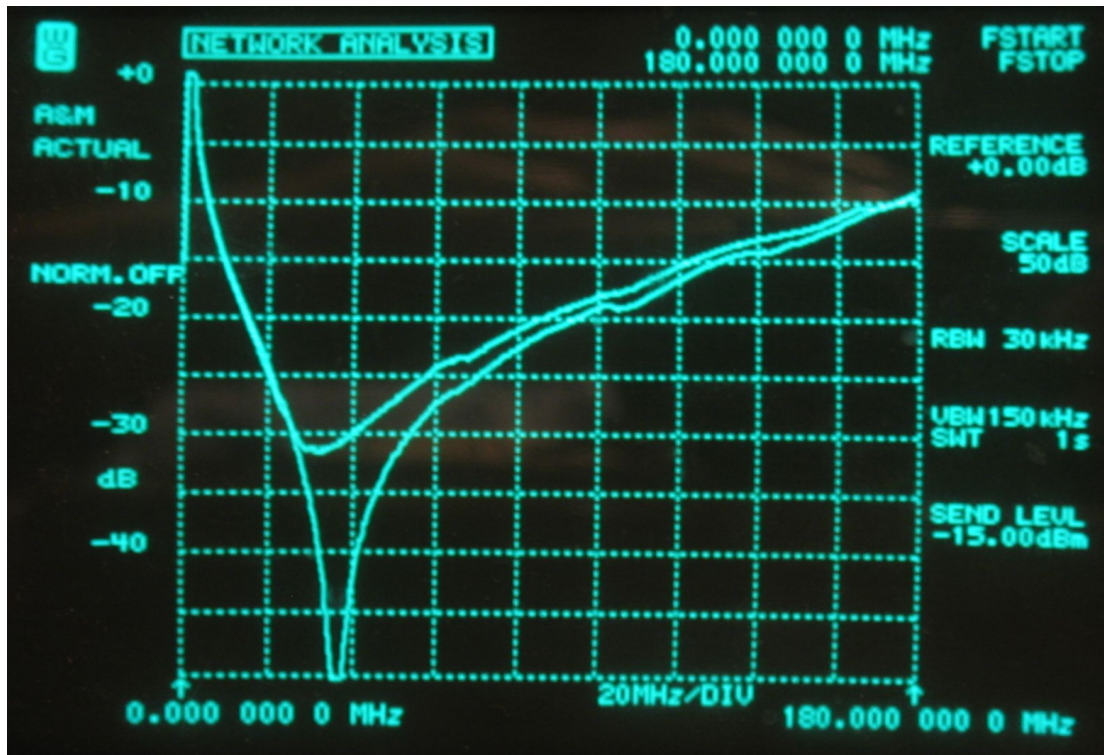
The board is a 160 \* 100 mm Eurocard. The bottom side is gnd only and unetched, so there is no issue making the top and bottom masks meet. The layout is outdated already. Especially the bottom channel has suffered a lot of optimization / experimentation. The two large empty places in each channel were reserved for fat base decouplers in the cascode. I'm not convinced that they make sense. The bird seed parts are 0805 size. The ferrite transformers have 4 turns trifilar 0.2 mm on a 7\*4.4\*4 mm core, probably from Siemens/EPCOS („Ameise“). MiniCircuits ADT4-1WT do work and fit the pads though they are rated for 30 mA DC only and we use 40. They won't burn but probably lose some bandwidth.

The left third of the board has a LVDS line receiver that converts the 10 MHz to 3.3V CMOS level and dividers that produce some useful frequencies that are available with 5V-CMOS level and  $R_i = 50 \text{ Ohm}$ . That should fit nicely to 50-Ohm-terminated 3.3V CMOS inputs. In the next revision, the

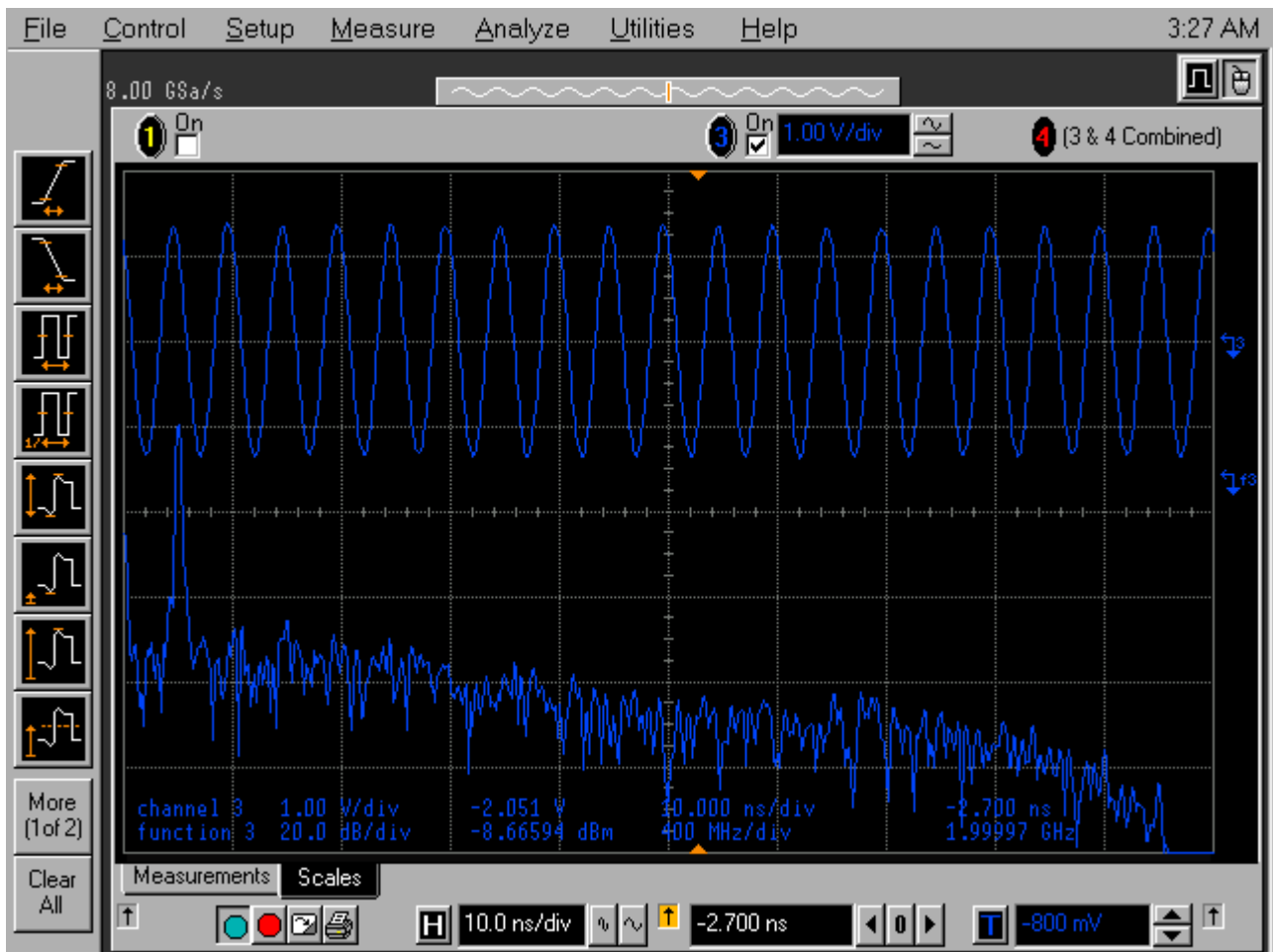
digital section will no longer be there. It will be replaced by a 7<sup>th</sup> isolation amplifier for easier cascading of several boards.



Gain. The horizontal cursor at -4.6 is unity gain. The output transformer still could use some work. W&G TSA2 with minimum loss pads.

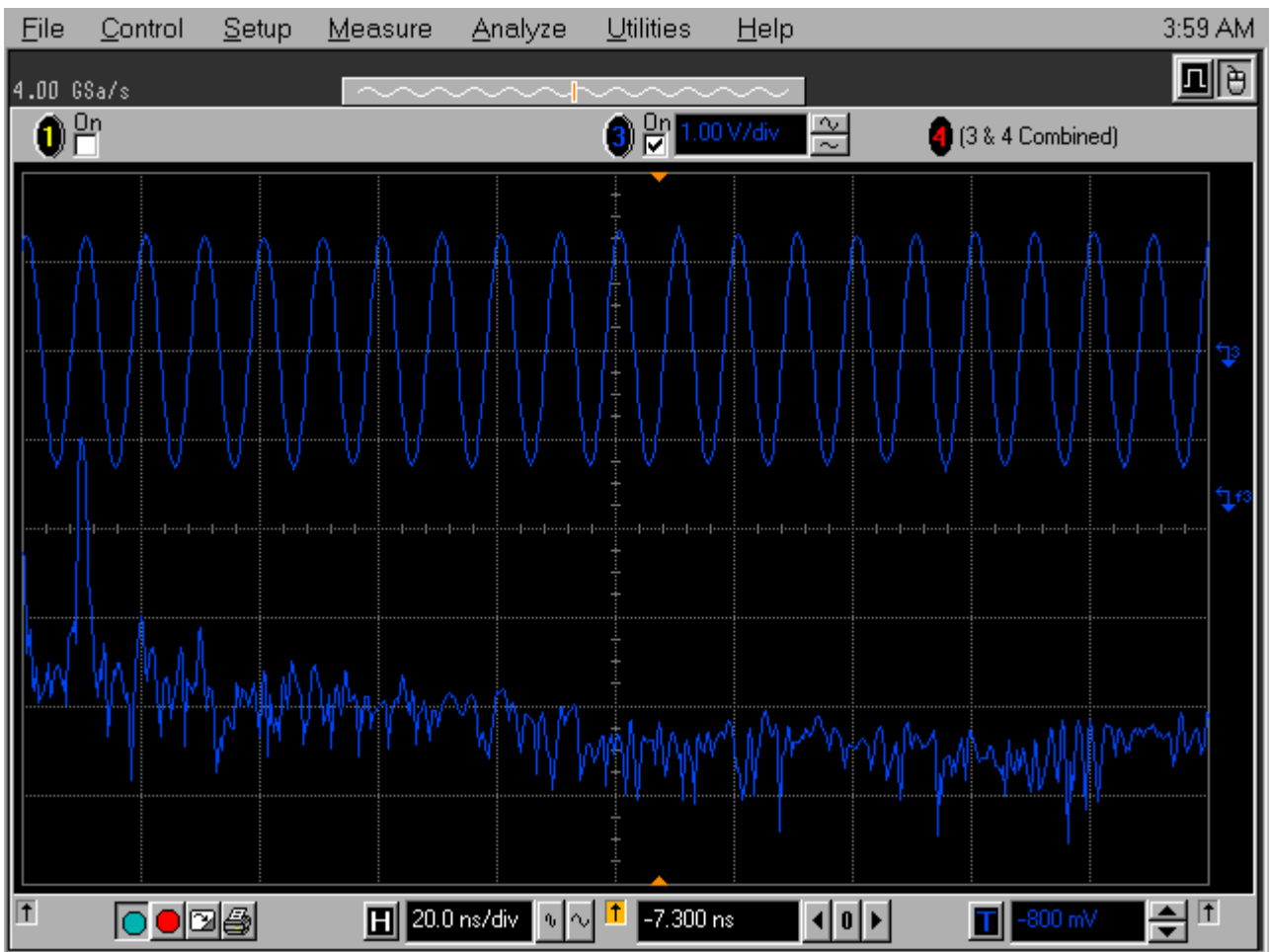


Output return loss. Upper trace: termination resistor = 220 Ohm, lower trace 236 Ohm. The optimum termination resistor is larger than 200 Ohm because of the transformer stray inductance. SWR bridge R&S ZRB2 is usable > 5MHz only.

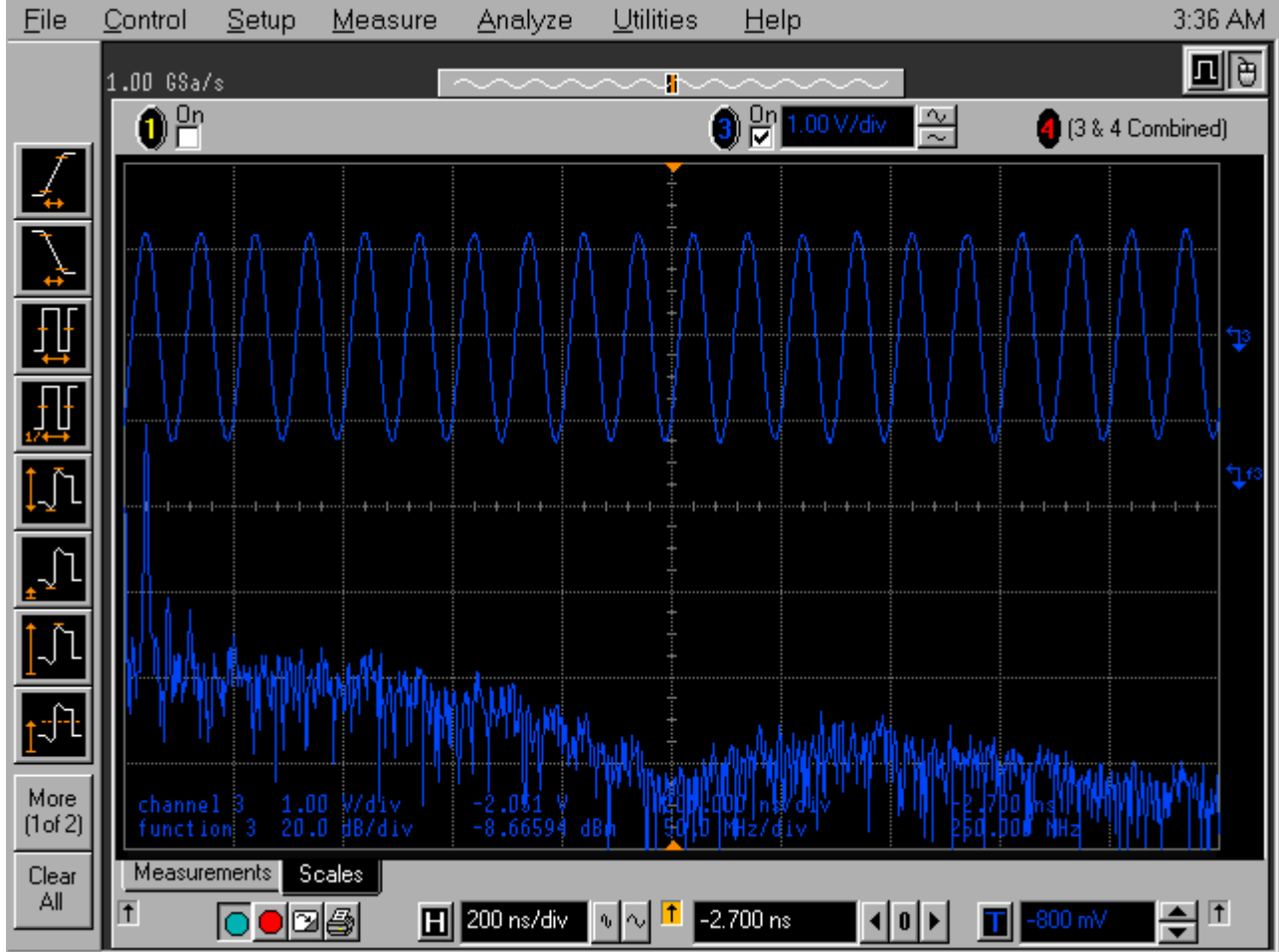


Supply = 24V, output +13 dBm at 200 MHz, harmonics < 45 dBc

Agilent 54846B scope, 50 Ohm direct / no probe, bandwidth 2.25 Ghz, 8 Gsamples/s real time  
 Signal generator R&S SMPD, +13 dBm.  
 The noise floor is given by the scope.

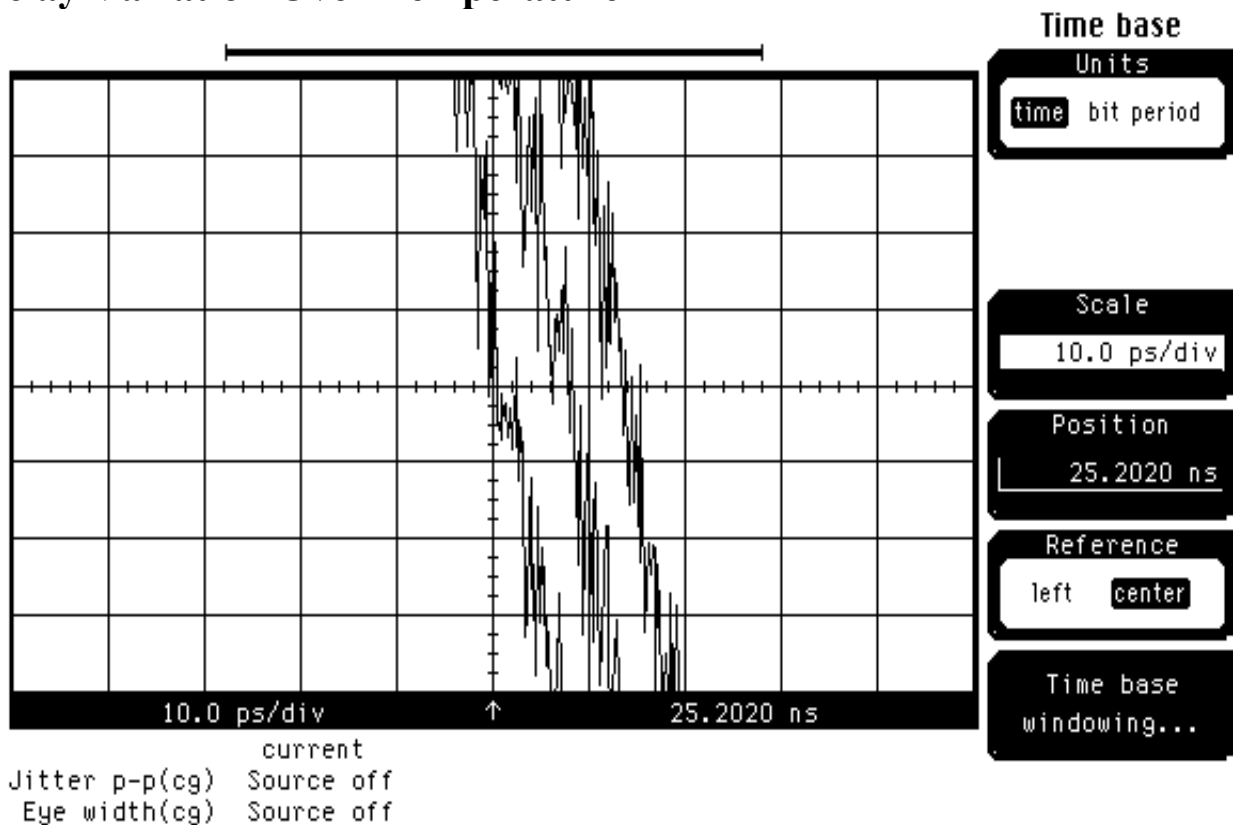


Output 13 dBm at 100 MHz, harmonics < 40 dBc



Output 13 dBm @ 10 MHz, harmonics < -40 dBc

## Delay Variation Over Temperature



This was measured with +13 dBm @ 200 MHz from the R&S SMPD. That is the maximum level of the generator. This power was divided by a resistive splitter Suhner 4901.19.A. One splitter output was fed to the trigger input of a HP54751A dual 20 GHz plugin in a HP54750A mainframe. The other splitter output was fed to the DUT input. The output of the DUT was connected to channel 1 of the 54751A.

V/div was cranked up to the max to get a usable fall time in the visible window. Bandwidth was reduced to 12.5 GHz to minimize noise.

The middle trace is the board laying open on the table after warm up. The right trace results when the amplifier is hit with hot air from a hairdryer. If applied directly to the skin for some time, this would result in injury.

The left trace is a good load of freeze spray „Kälte 75“ that claims to reach -52 °C. I did not measure the actual temperatures, but 15 psec delay change from really cold to really hot seems quite OK.

Touching the Gore Coax cables can easily bring the trace off screen. If you press your wrist against the cable, you can see your heart beat.