DDS Generator Filter

Contents

With the low cost **DDS Generator AD9850** (Direct Digital Synthesizer) from company Analog Devices, it is now easy to build an wide range oscillator for measurement purpose. For the **data sheet** please look at the Links.

Especially interesting are the low cost modules from China you can get for about $10 at Ebay. Search for **AD9850 module**. The only **problem** is the **output filter**. It **looks like**, that the filter was designed for an AD9851, and the output impedance is 200 Ohm. So, you have to built you own output filter, if you want to have a **clean signal** for measuring with **50 Ohm matching**.

Following I will explain, what solutions about an **output filter** I found, and I want to have.

Because it is not so easy to figure out the frequency response, I like to show in simulation (LTspice 4) what is the **frequency response** of some popular **DDS output filters**.

The **AD9850** was designed for an **output frequency** of up to 40 MHz at a **clock rate** of 125 MHz.

The **AD9851** was designed for an **output frequency** of up to 70 MHz at a **clock rate** of 180 MHz.

The output filter from the **Analog Devices data sheet** has the draw back of not having a 50 Ohm output impedance (200 Ohm), please look at the Links.

The output filter from the **PHSNA group** looks good, but needs an amplifier, which is not so easy to build, please see at the Links.

The output filter from the **VNA group** looks good, but was designed for the **AD9851**, please see at the Links.

The **wobbulator** project does not have an impedance matching at all, and the original 200 Ohm filter (China module), please see at the Links.

I want to have a low cost filter, which is easy to build, with 50 Ohm output impedance. There should be also some protection against **impedance mismatch**.

Because none of the proposed solutions fitted my needs, I designed my own output filter.

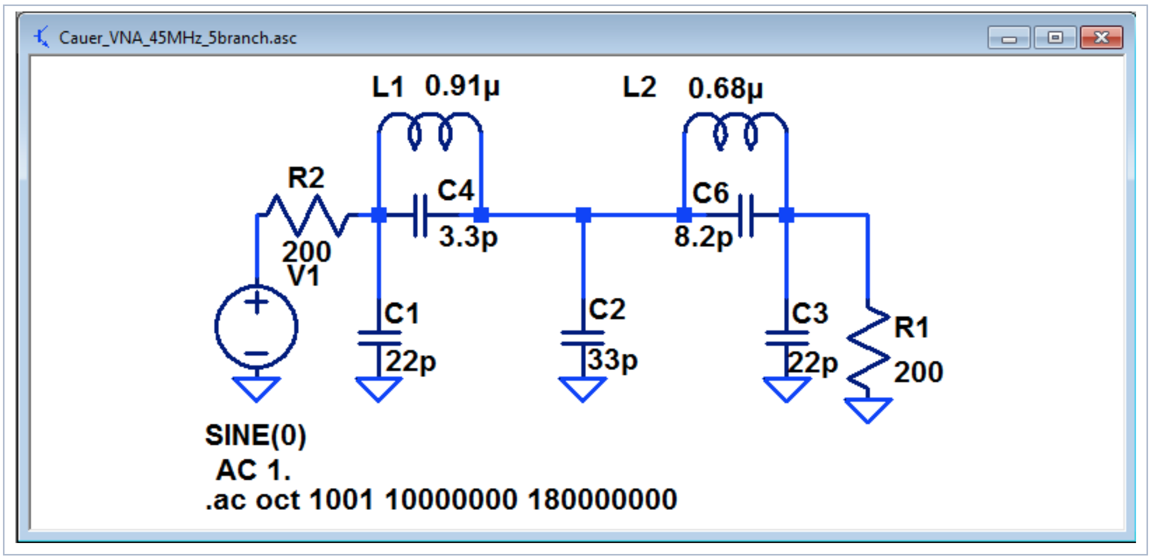
Tools

The most important tool is the circuit analyzing program **LTspice** from Linear Technology. You get it free for Win32 and Mac OS X, please see at the Links. The actual Mac OS X version has the drawback of not showing a grid pattern.

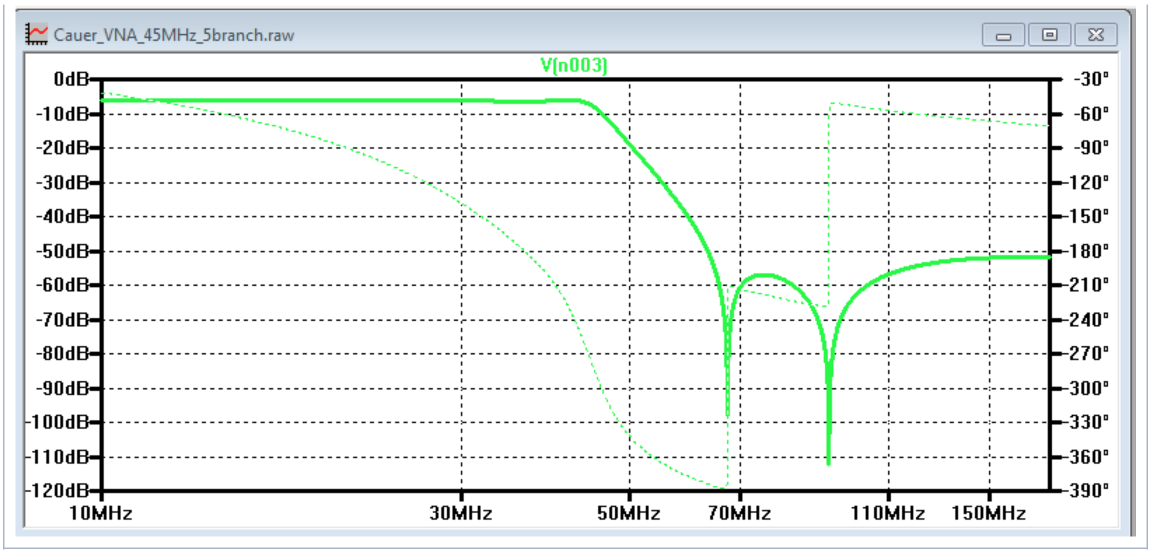
For developing your own filter there is a good program, **Elise**, please see at the Links.

Filter from AD9850 data sheet

This filter comes from the **AD9850 data sheet**, page 17. It is a 5branch Cauer (elliptic) low pass filter with 200 Ohm input and output impedance. The **LTspice** data file is here for download.



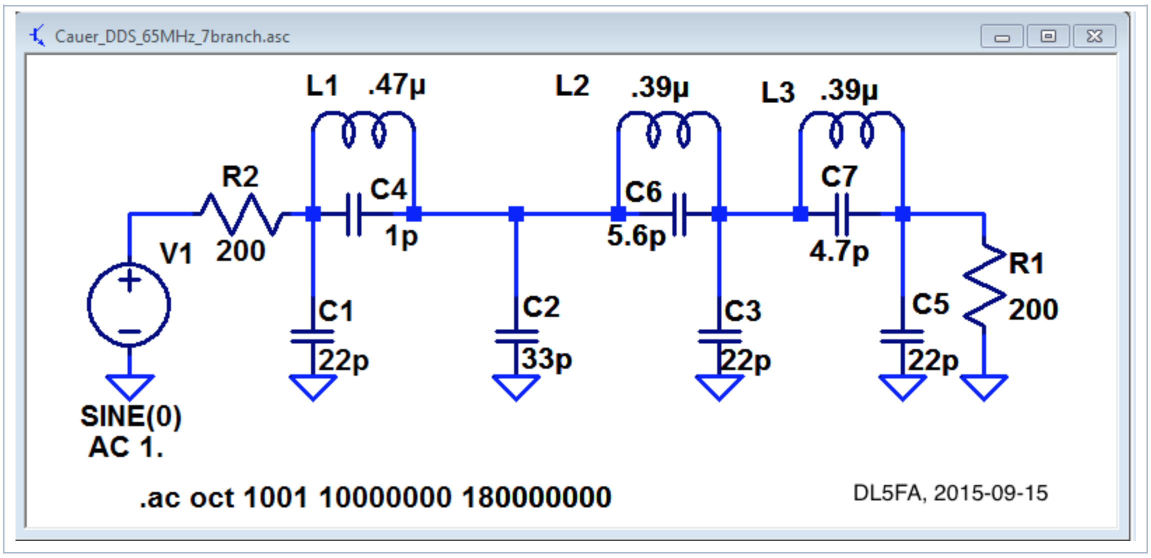
The frequency response is:



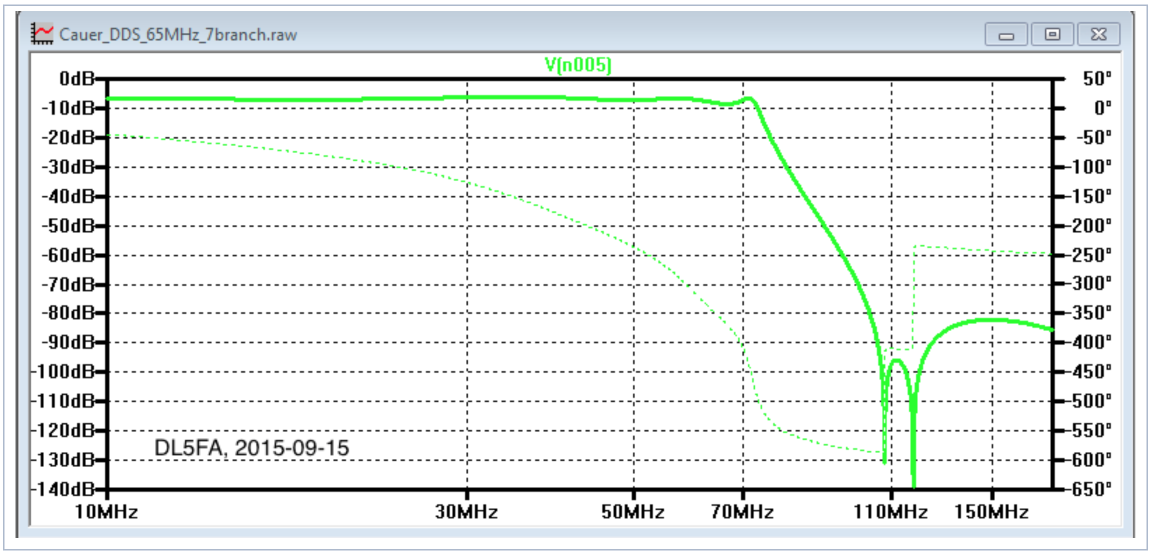
The **-3dB cut off** is at 45 MHz and the **stop frequency** 65 MHz with 50 dB attenuation. At 125 MHz (clock) you have also 50 dB attenuation.

Filter from AD9850 module

This filter comes from the **AD9850 module** from China. It is a 7branch Cauer (elliptic) low pass filter with 200 Ohm input and output impedance. The **LTspice** data file is here for download.



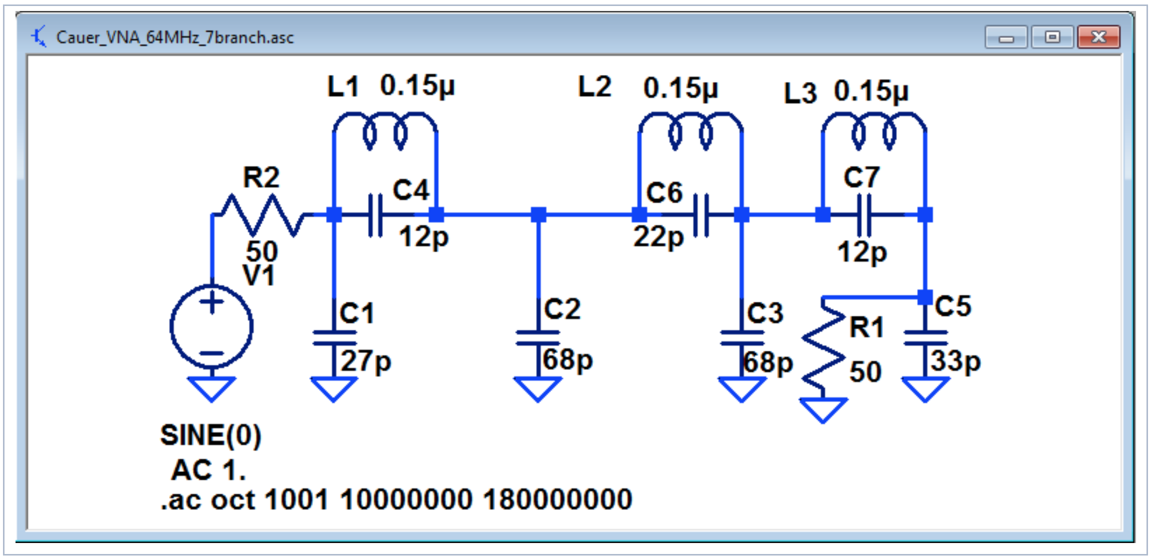
The frequency response is:



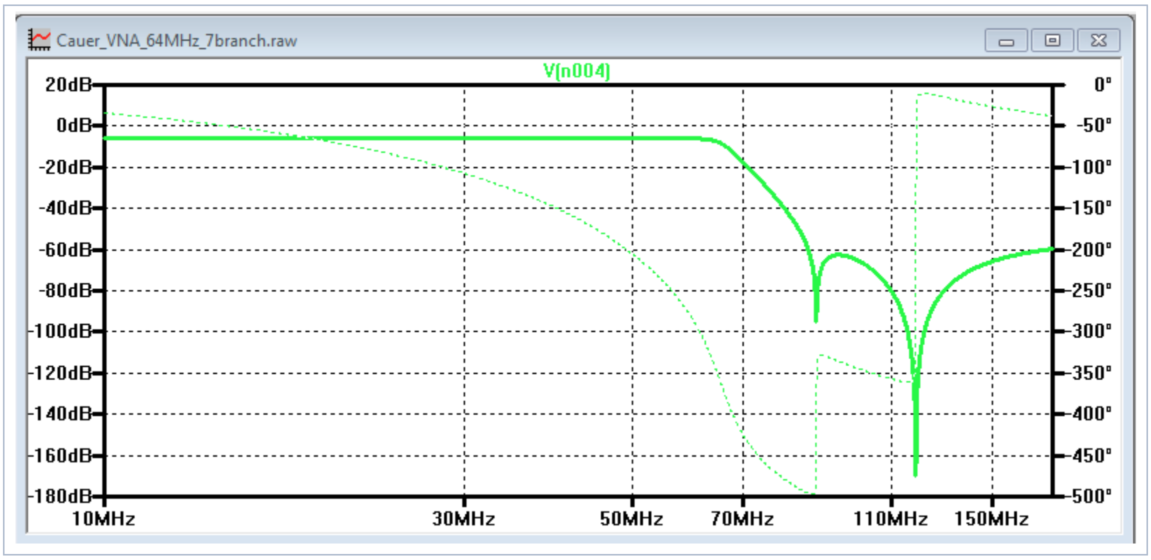
The **-3dB cut off** is at 73 MHz and the **stop frequency** 104 MHz with 75 dB attenuation. At 125 MHz (clock) you have 82 dB attenuation. It **looks like**, that the filter was designed for an AD9851. Because of my mistake (L3 value was wrong) the values are corrected 2015-09-15 with of a hint from Jonti, thanks.

Filter VNA AD9851 from N2PK

This filter comes from the **Vector Network Analyzer** (NVA) project from Paul Kiciak N2PK. It is a 7branch Cauer (elliptic) low pass filter with 50 Ohm input and output impedance. The **LTspice** data file is here for download.



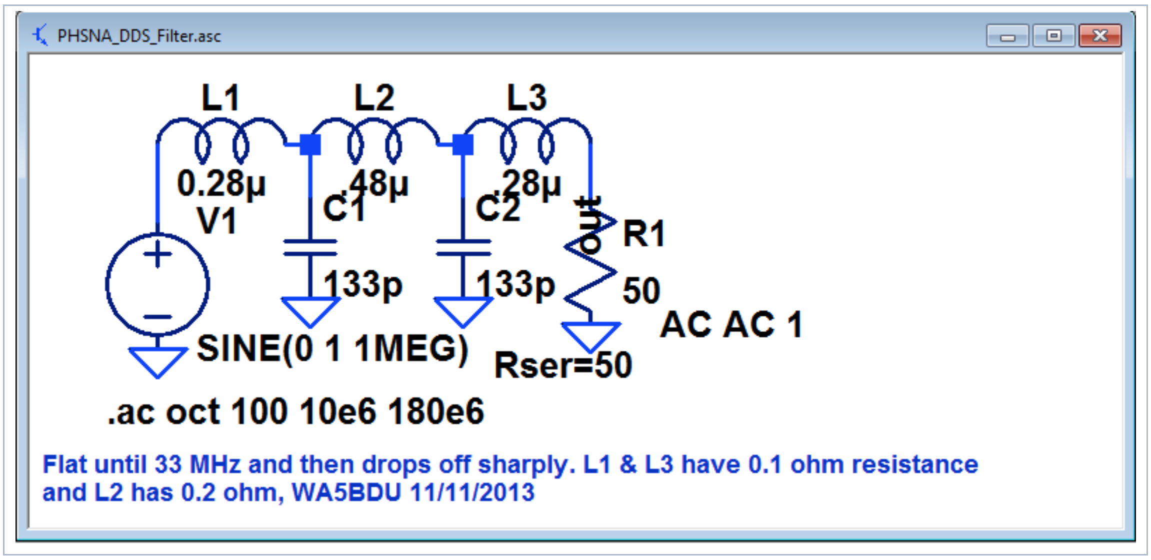
The frequency response is:



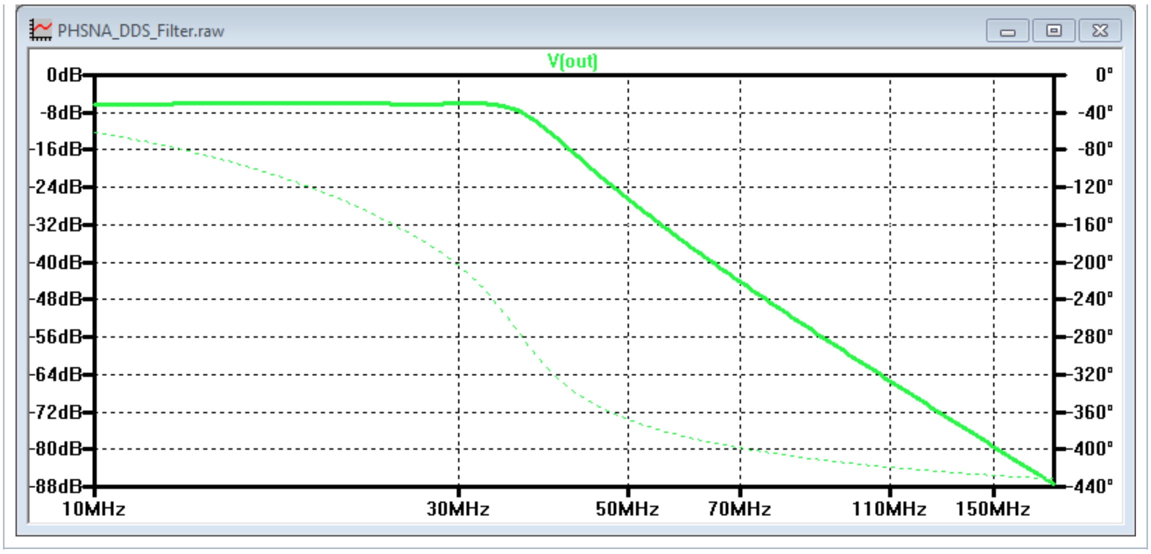
The **-3dB cut off** is at 64 MHz and the **stop frequency** 86 MHz with 67 dB attenuation. At 148.344 MHz (clock) you have 60 dB attenuation.

Filter PHSNA AD9850 from N5IB

This filter comes from the **Poor Hams Scalar Network Analyzer** project (PHSNA) from Jim Giammanco N5IB. It is a 5branch low pass filter with 50 Ohm input and output impedance. The **LTspice** data file is here for download.



The frequency response is:



The **-3dB cut off** is at 36 MHz. At 125 MHz (clock) you have 65 dB attenuation.

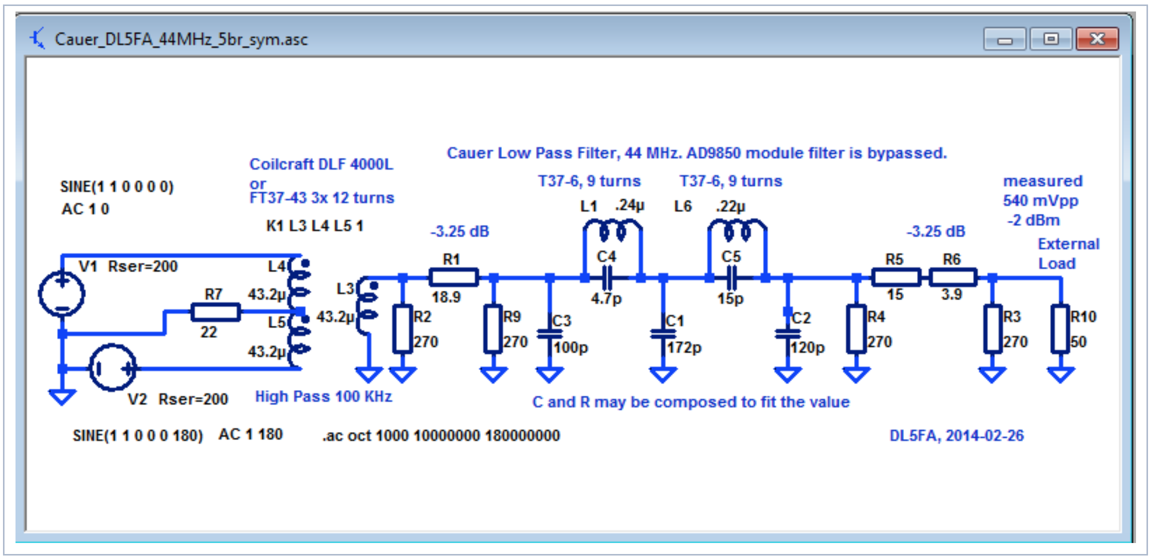
Filter AD9850 from DL5FA

The AD9850 has an complementary analog output. If you use a **push-pull transformer** you will get a 6dB power gain. This filter was designed by myself as a sum of the previous mentioned data. It is a 5branch Cauer (elliptic) low pass filter with 50 Ohm input and output impedance. The filter was designed with **Elsie** and the capacitor values are adjusted to the next E12 series value. Some resistors and capacitors must be combined from 2 values.

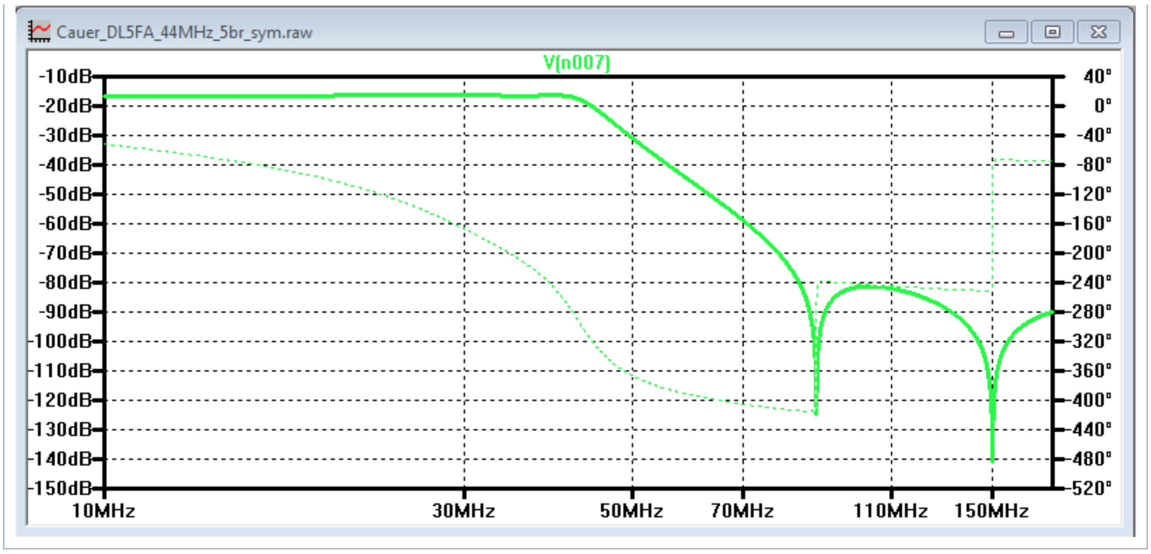
The **22 Ohm resistor** at the transformer was integrated, in order to **improve the amplitude level**. For the **transformer** I could use an already made EMI filter **DLF 4000L** from coilcraft with 4 coils with 28uH each.

The **-3 dB High Pass frequency** of the transformer is about 100 KHz.

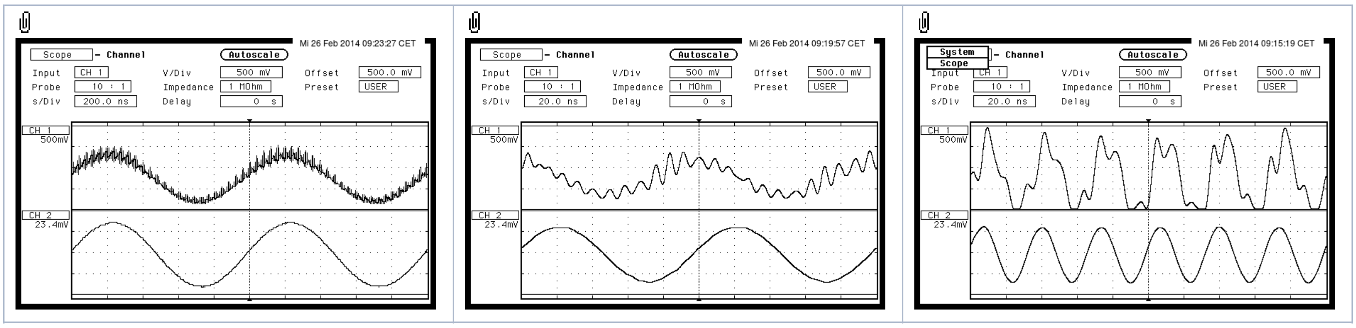
The **LTspice** data file is here for download.



The frequency response is:



The **-3dB cut off** is at 44 MHz and the **stop frequency** 84 MHz with 63 dB attenuation. At 125 MHz (clock) you have 70 dB attenuation.



Have a look to the DDS-Generator output (without on board filter) with a **1-10-30 MHz signal** (upper trace), and after the **Cauer filter** (lower trace) terminated with 50 Ohm, see **pictures** above.

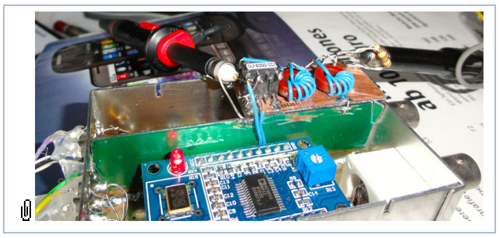
You can see a good part of the signal is from the **125 MHz clock**.

DL5FA test setup

I like to show the **test setup** of the new AD9850 output filter, and how to measure with an 100 MHz oscilloscope (HP1652B). The amplitude at the filter output (50 Ohm load) was:

- 1 MHz - 460 mVpp = 163 mV = -2.8 dBm
- 10 MHz - 416 mVpp = 147 mV = -3.6 dBm
- 30 MHz - 436 mVpp = 154 mV = -3.2 dBm
- 33 MHz - 259 mVpp = 91 mV = -7.7 dBm

The benefit of this design is, you do not need an additional amplifier. For a good conversion table between **Volt-RMS**, **Volt-peak to peak**, **Watt**, and **dBm** look here, or an online dBm calculator.

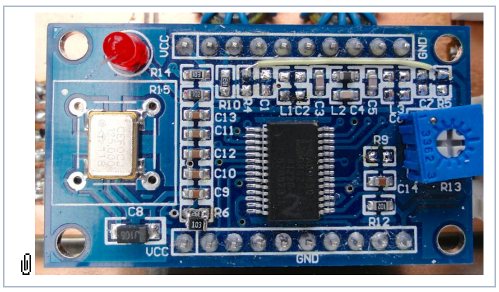


Please see the **pictures** on the right. If you click on the picture it will be **enlarged**. Important is a **short ground connection** of the scope probes. The capacitors and resistors are all 0806 **SMD** parts, in order to keep the setup small.

Frequency degrading at 30 MHz

Surprisingly the output amplitude **degrades above 30 MHz**, even if the filter simulation does not predict that. This is caused by a DDS-Generator typical sin(x)/x amplitude degrading (**Nyquist bandwidth**), which can be up to 4 dB at the upper end of the bandwidth, see at the **Links** for a more detailed explanation.

Module Filter remove



In order to use an alternative output filter for the AD9850 you have to remove the original filter, see the **picture** on the right. The following components have to be removed:

- R4 = 200 Ohm parallel to C1 = 22 pF
- L1 = 470 nH parallel to C2 = 1 pF
- L3 = 390 nH parallel to C6 = 4.7 pF
- R5 = 200 Ohm parallel to C7 = 22 pF
- R9 = 100 Ohm

Add a thin wire from the solder point R4 hot end (IOUT) to R5 hot end (Z_OUT). The cold end is 0 V.

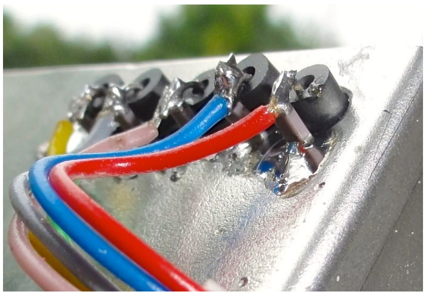
Output level 0 dBm

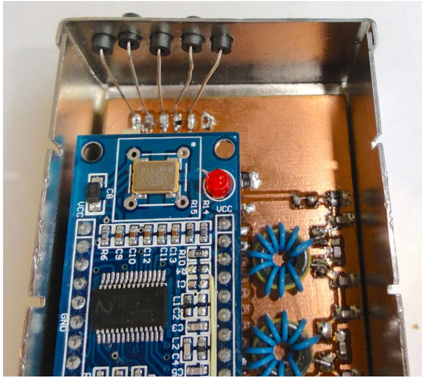
In order to bring the **output level to 0 dBm** (0.63 Vpp at 50 Ohm), you can lower the resistor R6 (lower, left side) from 3k9 to 2k8 by soldering a 10k SMD resistor in parallel, see the **picture** on the right. R6 connects to pin 12 (Rset) of the AD9850 and sets the DAC full-scale output current. The resistor value of 3k9 is good for 10.24 mA. In the data sheet 1k95 = 20.48 mA is also specified, and maximum is 30 mA.

Metal Housing Teko 372

In order to avoid any unwanted RF (Radio Frequeny), the DDS-Generator must be housed in a metal housing. The best fitting housing was a **Teko 372** (WxHxL 50 x 26 x 83 mm, 3,40 EUR at reichelt.de).

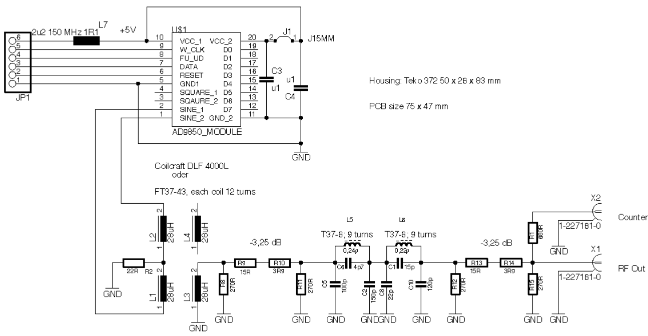
In order to have an easy and cheap **feed through filtering**, SMD1206 capacitors with 1 nF and ferrit damping pearls 3.5 x 5 mm (reichelt.de NPO-G1206 1,0N, DFP 5.0) are used to filter the 4 control signals and the +5 V supply. The spacing was 5 mm, see the **pictures** below.





DDS_Generator PCB

In order to make it easier to place all components onto a PCB (Printed Circuit Board) I developed a PCB with Eagle6. It is a single sided PCB, and all components are soldered on the copper side. The only drilled holes (2.5 mm) are for the BNC plugs, the mounting pins. The mounting pins are cut off at the lower side of the PCB. With those BNC plugs it is easier to test the PCB before mounting in the housing. An **alternative** is to mount BNC plugs in the wall of the housing, and connect by wires.



The **AD9850 module** is connected by 2.54 mm socket stripes (height 8 mm).

Attached are the following files:

- schematic as PDF file for good quality printing
- .eps file for board film printing
- Eagle6 board file
- Eagle6 schematic file

Bill of material:

- The BNC plugs are print versions 50 Ohm (reichelt.de UG 1094W1, 0.94 EUR)
- choke 2u2 in +5 V line (reichelt.de, Fastron SMCC 2,20μ, 0.15 EUR)
- 6-pin connector, 2.54 mm spacing pins (reichelt.de, MPE 087-1-006, 0.15 EUR)
- All SMD resistors and capacitors are 0806 size

Because of a Chinese SMD selection some SMD values must be combined:

- 270R -> 330R parallel 1K5
- R9 + R10 -> 22R parallel 120R
- 120 pF -> 100 pF + 22 pF

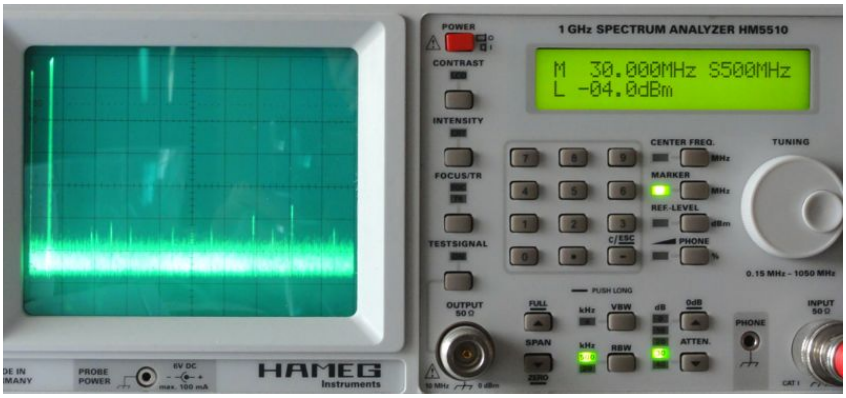
Spectrum Analysis

I had the chance to measure the spectrum of the DDS-Generator with my designed filter. The **spectrum analyzer** was a Hameg HM5510, with an upper frequency limit of 1 GHz. The peak on the left boarder always marks the **0 Hz point**.

The bandwidth of the **sweep filter** is normally set to 500 KHz, as you can see on the front panel.

I had especially a look to a **span** of 200 and 500 MHz, to see if there are any strong unwanted harmonics or other frequencies.

In the **picture** to the right you see a spectrum analysis over a **span** of 500 MHz.

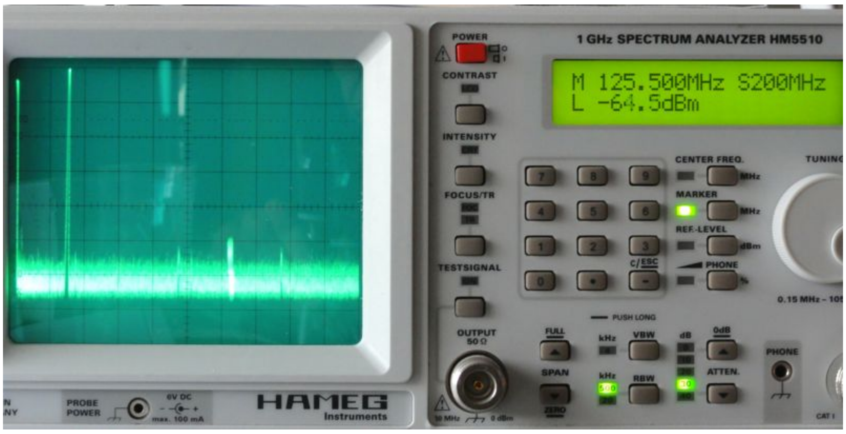


The **oscillator frequency** was 30 MHz, at a level of -4 dBm, as the **Level marker** shows.

The **vertical resolution** of the screen is 10 dB per division.

The **highest peak** I could see was at 400 MHz, with a level of about -45 dB.

The next **picture** to the right shows a spectrum analysis over a **span** of 200 MHz.



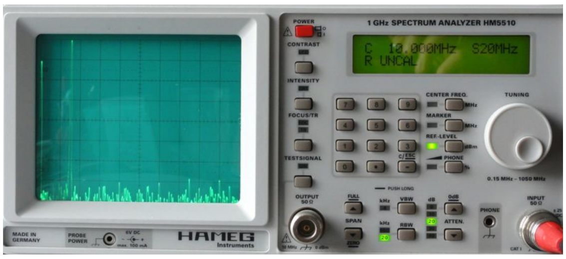
The **oscillator frequency** was 30 MHz, the **Level marker** at 125 MHz (master clock) shows a level of -64 dBm.

The **vertical resolution** of the screen is 10 dB per division.

The **highest peak** I could see was at 125 MHz, the **master clock**, with two mixing products +/- 30 MHz.

I measured also oscillator frequencies of 3, 10 and 24 MHz with similar results, which was expected from the Analog Devices informations.

A **narrow scan** over 20 MHz, with an oscillator frequency of 3 MHz shows a **noise floor** of about -70 dBm, please see the third **picture** on the right (click on the picture to enlarge).



The bandwidth of the **sweep filter** is in this case set to 20 KHz, as you can see on the front panel.

Links

- AD9850 Product Details from Analog Devices
- Design Tools: ADIsimDDS (Direct Digital Synthesis) Frequency and Time domain diagram
- Amidon toroid core calculator from DL5SWB
- Wobbulator project for Rapberry Pi from Tom Herbison
- Vector Network Analyzer (VNA) from Paul Kiciak N2PK
- Poor Hams Scalar Network Analyzer from Jim Giammanco N5IB
- circuit analysis program LTspice, overview
- Elsie, Win32 program for electrical filter design and network analysis
- Nyquist bandwidth
- Vpp - dBm Calculator

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8. ReturnLossBridge
9. StufenAbschwaecher

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