Measuring crystal motional parameters with the MiniVNA

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This document is a short manual for a software program to use the MiniVNA for measuring crystal parameters. It is inspired by documents as:
·   "Simplified Tools and Methods for Measuring Crystals" by Jim Kortge, K8IQY
·   "Crystal Motional Parameters A Comparison of Measurement Approaches" by Jack R. Smith K8ZOA (11 June 2006)

Test Fixture

Jim Kortge explains a hardware setup with a crystal oscillator as generator, a test fixture and a level meter. For owners of a MiniVNA really the only thing needed is a decent test fixture. The purpose of the test fixture is to lower the impedance the crystal sees to enhance the measurement resolution. In combination with an attenuator it also serves to get a more reliable impedance value on both sides of the crystal. Ideally a pure resistive impedance lowering attenuator would be best. But this lowers the signal level as well. I found that the MiniVNA suffers from incidental spikes on the readings that get worse at lower signal levels. So I decided to use the following transformer version of the test fixture.
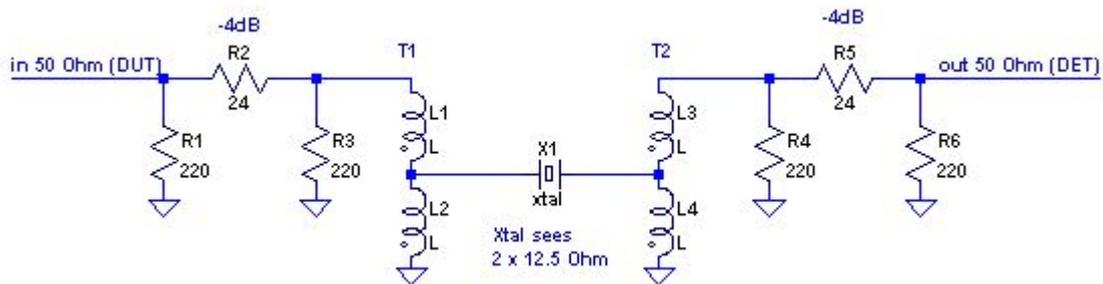
The two sections are shielded from each other in the following manner:
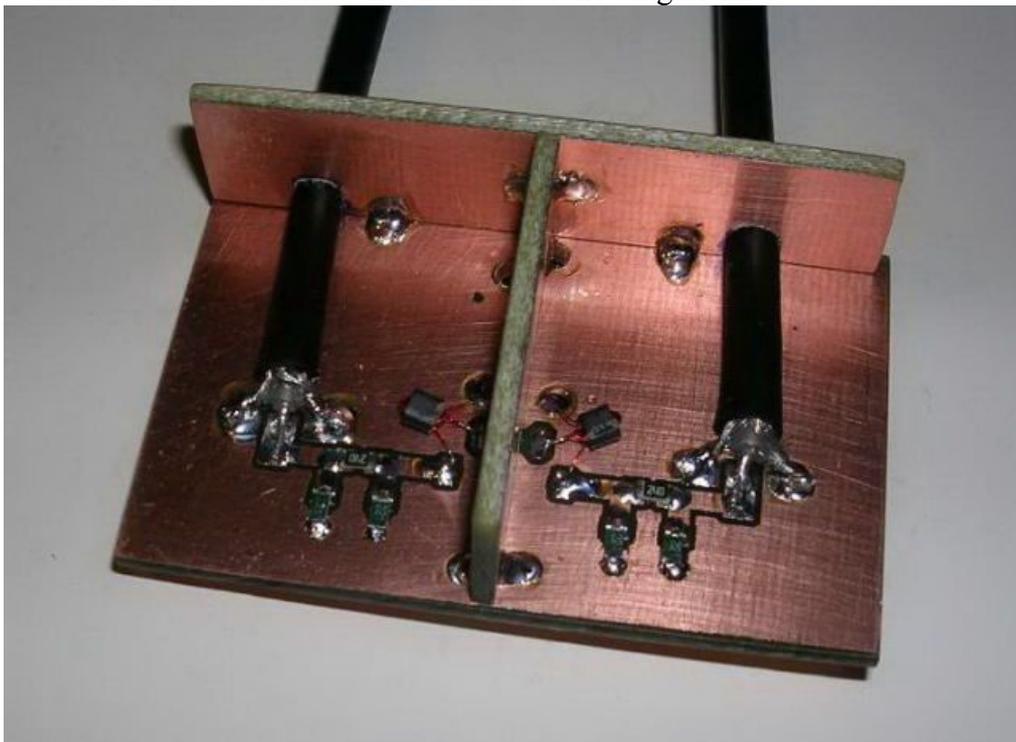
The DET and DUT coax leads are short and enter the fixture through small holes. SMD resistors are used here for the attenuator pads since I also use this fixture to measure crystal overtone frequencies. Note that the software is suited only for fundamental measurements. For overtone operation (above 50 Mhz or so) one needs to compensate the crystal C0 holder capacitance. Else the parasitic C0 clouds the readings to obtain the crystal parameters. I do not know of an easy automated way to do this.

I assume making everything as small as possible helps to reduce parasitics. For fundamental crystal frequencies this might be a bit overkill. The transformers are bifilar auto transformers on pig nose / two-hole ferrite cores . In my experience these require less wire than toroids and have decent wide band characteristics. Just make sure the impedance is high enough for the required frequency range. Jim Kortge uses 10turns bifilar on a FT37-43 (~30uH). I used 4 turns bifilar on an unknown binocular core to get about the same.

The 3-pin crystal socket is mounted through the pcb on the other side. The section-shield passes right through the middle, with the socket middle pin grounded.

From the top is looks like this. I could have made the leads even shorter.

The software

The math explained in the mentioned documents is incorporated in the software. Several sweeps are done with the MiniVNA in transmission mode. Initially to determine the fundamental frequency, later in increasing detail around the -3dB range . Further additional sweeps are done to filter out the occasional spikes (I am sure you have noticed them yourself...).

The current software version is perhaps not as robust as can be. But it works now and I decided to leave it for a while as it is. It is a single windows .exe and no installation is required. As far as I know there are no unusual dependencies for libraries, dlls, ActiveX controls and such. Just click and run.
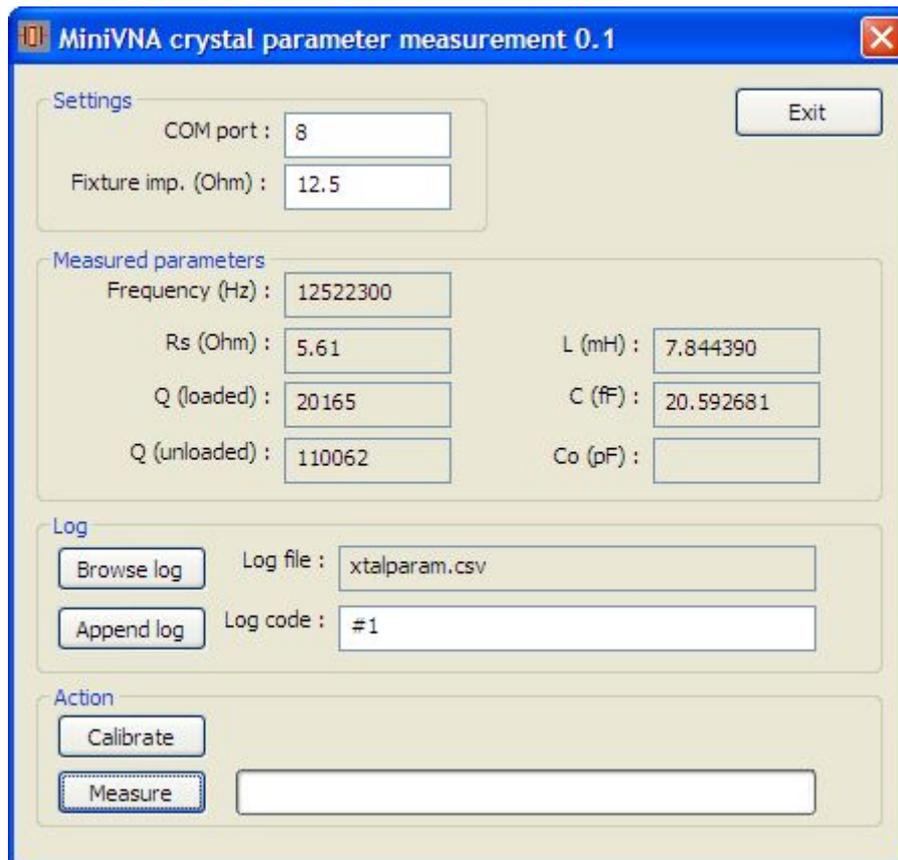

Operation:

1) Enter the COM port number of your miniVNA and the test fixture impedance (what the crystal sees on each side).
2) Before the first run you need to calibrate the test setup once. This step can be repeated at any time. The program will prompt you to short the crystal socket before continuing.
3) Click "Measure" when you have placed a crystal in the fixture. The measured parameters will be updated on the dialog window. Re-measuring the same crystal can be done a bit quicker by holding down the shift-key before clicking. This way the program does not do a full sweep but starts a bit further down in the process.
4) A log entry in a .csv file can be stored by clicking "Append log". A different log file can be selected with "Browse log". The code (e.g. the marker you placed on a crystal) will be stored as a column in the log file as well. The first log after starting the program includes a column header with the meanings of the values. (just so you know, this also happens when appending to an existing file)

Things to know:

- I found that leaving the miniVNA running at the end frequency after a sweep seems to introduce a shift in subsequent measurements. It seems that the crystal heats a little this way. I assume knowing the crystal parameters in maximum detail is primarily important in matching crystals for ladder filters in receivers where signal levels are low. So the miniVNA is left at a safe frequency after a sweep (1 or 2Hz). This gives more consistent readings in subsequent sweeps of the same crystal.
- Try not to touch the crystal with your hands when inserting it into the fixture. Use a pincet / tweezers instead. This avoids heating the crystal with your hands. Also let the crystals acclimatise before making measurements.
- Make sure the crystal socket is of good quality. A few 100 milli Ohm change is clearly visible if the crystal is not making good contact. Perhaps one can stack two sockets and replace the top one when it starts showing signs of wear. Or make it easy to resolder a new one.
- Let the miniVNA run for about 30 minutes before measuring if you really want maximum stability. I have noticed the following warm up drift in mine (generator set to 10MHz):

MiniVNA stability

Y-axis: Offset above 10MHz (Hz), range 190 to 255. X-axis: 0 to 60.
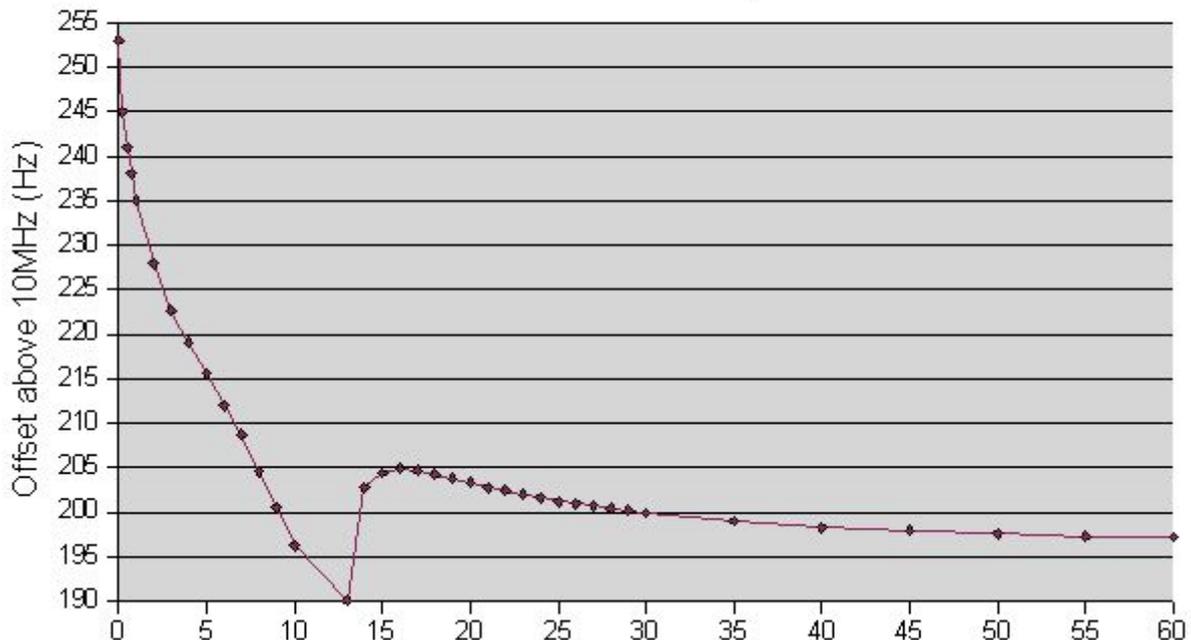
Limitations – future ideas:

- Better error handling. The effects of not placing a crystal, or using the wrong com port may be confusing.
- No frequency calibration yet. You can correct it for now with a spreadsheet calculation if you want.
- No storage of com port number. I guess this could become a nuisance. (fixed in V0.2)
- No storage of calibration. This is done deliberately. Frequent calibration is advisable and it is easy enough to do.
- Math is done with 3 point calculus (max signal, and the -3dB points). I have been looking into Levenberg-Marquardt curve fitting, but the software found so far has not got high enough precision to examine its virtue.
- No C0 parameter measurement yet. This could be done by measuring at 80% of fundamental frequency or 80% of the 3rd overtone. But the required math is not fully clear to me yet. Also a measurement of the parasitic fixture capacitance is needed (easily 0.5 to 1pF).
- The .csv file uses a comma (',') as column separator. Ideally this should be retrieved from the

Regional Settings. Also it is best not to put a comma or quotes in the log code field as this might upset the import into you spreadsheet software.

Related links:

"Simplified Tools and Methods for Measuring Crystals" by Jim Kortge, K8IQY
http://www.k8iqy.com/testequipment/pvxo/Atlanticon2002V1R5.pdf

"Crystal Motional Parameters A Comparison of Measurement Approaches" by Jack R. Smith K8ZOA (11 June 2006)
http://www.cliftonlaboratories.com/Documents/Crystal%20Motional%20Parameters.pdf

Das Grosse Quarzkochbuch / The Crystal Cookbook (in German), Bernd Neubig & Wolfgang Briese (1997)
http://www.qsl.net/dk1ag/buch.html
Have a look at chapter 4 about crystal test fixtures. This one seems to be a industry standard (but has 29.5dB total loss):
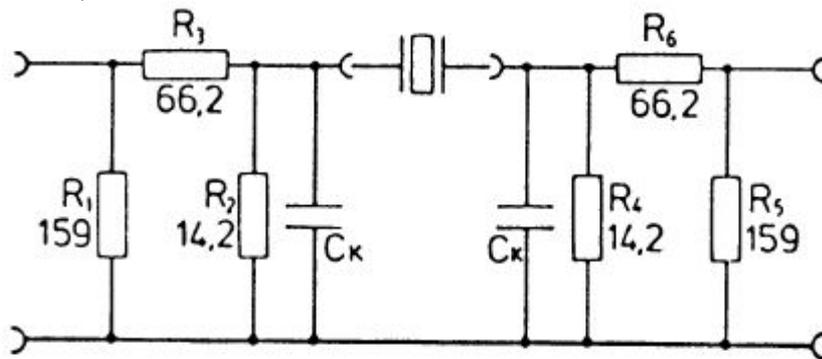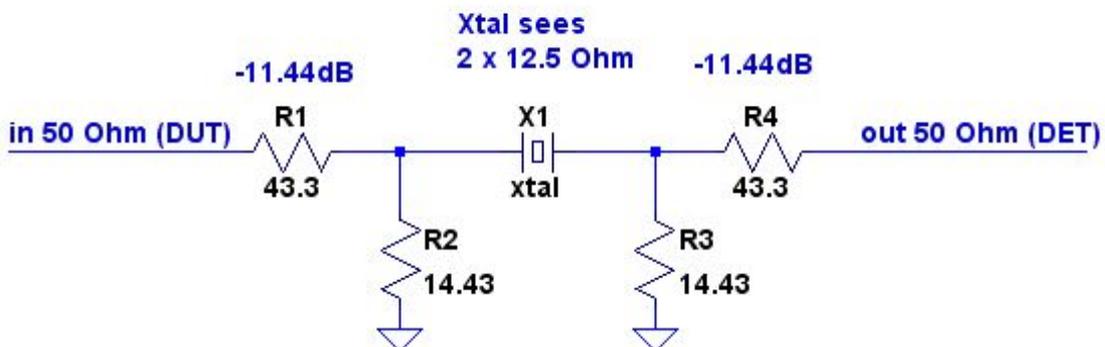

Bild 4.1: Doppel-π-Netzwerk nach (DIN) IEC 444-1

A least-loss (23dB) 50 to 12.5 ohm fixture could be:

It would be interesting to try this once. I am a little concerned my "spike filtering" might not be up to par. But on parasitics it is probably better than a transformer fixture. Anybody wants to try?
Suggestion 15 // 390 = 14.44 and 47 // 560 = 43.36