NanoVNA alpha1 kit assembly manual

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EDITS: Refer to end of document for edit notes and credits.

In the beginning

It is a miniature "vector network analyzer" NanoVNA alpha1 kit. Palm size and while the goal is to be able to use it practically. After understanding that toys are under development, Please enjoy the assembly. The software will be announced separately.

Feature

● Palm-sized stand-alone network analyzer
● Draw a graph or a Smith chart on a small LCD (2.4 inches)
● Operate by touch panel or lever switch
● Acquisition and control of measured values via USB

Specification

● Board: 50mm x 68mm x 10mm (not including connector and lever switch)
● Measurement frequency: 0.1 to 300 MHz
● RF output: -13 dBm (up to -9 dBm)
● Measurement range: 70 dB
● Port SWR: <1.1
● Display: 320x240
● USB interface: CDC (serial)
● Power supply: USB 5V 120mA
● Number of scan points: 101 (fixed)
● Display trace: 4, Marker: 4, setting save count: 5

Constitution

![NanoVNA Diagram]
principle

1. Control the clock generator chip Si5351A with I2C and turn off the measurement signal and the local signal (5 kHz generate a square wave (with set)).
2. Apply the measurement signal to the DUT through the resistor bridge to obtain the reflected signal and the passing signal.
3. The measurement signals for comparison and reference are combined and the three signals are convert to obtain a 5kHz IF signal.
4. Take these signals into the MCU at a sampling frequency of 48 kHz with an audio ADC.
5. Reflection coefficient, passage by calculating the ratio of the amplitude of the signal to be measured and the comparison reference signal by signal processing the coefficients are obtained.
6. By changing the frequency above, you can obtain the frequency characteristics of the DUT.
7. Perform calibration processing and display on the LCD in various graph formats.

point

- We use square wave, but triple factor is 3 times = 15kHz even if IF, so separate only fundamental wave component with IF is possible without problems
- A 5 kHz BPF (fourth order vessel) is implemented in the IIR filter block of the TLV320 AIC3204.
- Captured signal to MCU
- Si5351A also generates clock for ADC (8 MHz)
- The MCU clock operates on the internal RC oscillator (LSI) and does not use a crystal. The MCU operates at 48 MHz.
- The frequency can be fine-tuned because VTCTCXO is controlled by DAC

layout drawing

Parts list
## Tools and materials

- Soldering iron, solder, soldering wire, flux, flux cleaner (San Hayato etc.)
- Tweezers (use good quality), loupe (or stereomicroscope)
- Tester, oscilloscope
- USB micro-B cable, PC, USB power supply

## Assembly and test

**Implementation work recommends the following order.**

1. USB connector and power supply
2. Around VCTCXO
3. MCU and CODEC peripheral
4. Analog circuit
5. SMA connector and lever switch
6. LCD

(General) The GND pattern is hard to solder because the area is large and the heat escapes. Time to hit Please make it a little longer.

(1) First, assemble the power supply relationship. USB connector, slide switch SW3, diode D3, regulation Solder the U2 and bypass capacitors C17 and C18. Confirm that there is no short circuit with the tester and USB Connect the power supply to the connector and check that 3.3V is output by the tester. Land patterns such as FB1 Check that about 4.5 V is output. The power supply is either a CVCC power supply or a USB type

It is recommended to use The USB micro-B receptacle has a weak attachment strength to the board, and it is easy to peel off the solder by inserting and removing. It seems better to add a little more solder. Heat moth if the solder can be used, flow the solder also on the back of the receptacle to increase the mounting strength. Meanwhile, the receptacle If solder flows into the inside of the connector, the connector will not stick, especially when using flux please keep in mind.

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1µF</td>
<td>C17, C18</td>
</tr>
<tr>
<td>100nF</td>
<td>29pcs</td>
</tr>
<tr>
<td>1nF</td>
<td>6pcs</td>
</tr>
<tr>
<td>100pF</td>
<td>3pcs</td>
</tr>
<tr>
<td>12Ω</td>
<td></td>
</tr>
<tr>
<td>22Ω</td>
<td></td>
</tr>
<tr>
<td>27Ω</td>
<td></td>
</tr>
<tr>
<td>39Ω 0.5%</td>
<td></td>
</tr>
<tr>
<td>49.9Ω 0.5%</td>
<td>5pcs</td>
</tr>
<tr>
<td>56Ω 0.1%</td>
<td></td>
</tr>
<tr>
<td>82Ω</td>
<td></td>
</tr>
<tr>
<td>100Ω 0.1%</td>
<td></td>
</tr>
<tr>
<td>150Ω 0.1%</td>
<td></td>
</tr>
<tr>
<td>300Ω 6pcs</td>
<td></td>
</tr>
<tr>
<td>390Ω 0.05%</td>
<td></td>
</tr>
<tr>
<td>470Ω</td>
<td></td>
</tr>
<tr>
<td>1kΩ</td>
<td></td>
</tr>
<tr>
<td>3kΩΩ</td>
<td></td>
</tr>
<tr>
<td>10kΩ 4pcs</td>
<td></td>
</tr>
<tr>
<td>15kΩ 6pcs</td>
<td></td>
</tr>
<tr>
<td>FB 240Ω 3pcs</td>
<td></td>
</tr>
<tr>
<td>BAT54C</td>
<td></td>
</tr>
<tr>
<td>LED</td>
<td></td>
</tr>
<tr>
<td>VCTCXO 26.000MHz</td>
<td>U1</td>
</tr>
<tr>
<td>XC6206P33MR</td>
<td></td>
</tr>
<tr>
<td>Si5351A</td>
<td></td>
</tr>
<tr>
<td>TLV320AIC3204</td>
<td></td>
</tr>
<tr>
<td>STM32F072C8T6</td>
<td></td>
</tr>
<tr>
<td>SA612AD 3pcs</td>
<td></td>
</tr>
</tbody>
</table>
(2) Solder the VTCTCXO. Mounting direction (Photo 1), it is difficult for solder to rotate around the bottom of the pad, metal case. Be careful not to attach solder to the solder. Make sure that there is an output of about 26 MHz 0.8 V pp on the oscilloscope.

(3) Solder the MCU U5, Si5351A U3 and CODEC U4. U4 QFN has some solder on the pad. Because the area on the board side to which iron is applied is narrow, it is easy to work by pre-soldering on the chip side in advance it may be. As a procedure, first of all, let the solder flow from the back side of the chip and remove the solder with the suction line once. Remove the flux, clean it with a flux remover, apply a flux, and attach it to the board. Han At first, align the directions with dots, and then align the four sides accurately (check with a loupe). pin At first, while holding with the set (or finger), it is rough for fixing, so temporary soldering is done. The if I can confirm that it does not shift, I will solder the other side. Fresh solder on the tip With a small amount attached, heat the terminals of the board and chip at the same time. It is OK if solder flows well. 1 Move the tip continuously while supplying solder little by little without trying to finish each pin I will solder the terminal. If the flux is working, surface tension will not cause bridging. After finishing the three sides, finish the side that was tacked on first. If a bridge occurs, apply the flux I will re-sold it. If it does not improve, after sucking the solder with the suction line, apply flux again.

I will finish it. The condition is confirmed with a loupe or a microscope. Finally, from the back side of the board to the bottom pad Pour in the da (it is not necessary because there is almost no heat). Hands on soldering SMD parts such as QFN There is a commentary video that will be helpful for YouTube about the technique. Attach all C and R in the digital section. Do not forget to solder the LED D2 on the back side. Green on the back of the chip The wire is a cathode mark, so point it to the GND side. Since the MCU should operate in this state, check the operation (Please check the power supply short first with a tester). Jumper cable to BOOT0 through hole Plug in (Photo 2), connect the USB cable to the PC, and turn on the power switch. DFU mode if MCU is normal It should start by If using Linux, use the lsusb command or OSX system information to check the recognition status of If you can confirm that DFU is working, in the case of the command line, use the following command to write install dfu-util using package management tools such as apt-get and brew

Please. (A shell script called prog.sh is available for writing)

$ dfu-util -d 0483: df11 -a 0 -s 0x08000000: leave -D build / ch.bin

For Windows, you can download the DFU writing tool from the STM site, so click here

It is also possible to write with ST-Link (2) or OpenOCD etc. using SWD (JTAG) prepared on other boards. It is Please try a convenient method (please tell us the result).
It will be reset after DFU writing is completed. If the jumper BOOT0 is removed after DFU startup, after writing
The factory reset will automatically start the farm. Confirm that it looks as CDC (serial) from PC.
The Make sure that you can connect using the terminal command (screen for Linux or OSX).

```
$ screen /dev/tty.usbmodem401
ChibiOS/RT Shell
ch> help
```
Commands: help exit info echo systime mem threads reset freq offset time dac data dump port
stat gain power gamma scan sweep test touchcal pause resume cal save recall trace marker

ChibiOS/RT Shell
ch>

Check the lighting of the LED. It is normal if the brightness changes periodically (blinks for each scan point, drawing lights up). Furthermore, 8 MHz is output from the MCLK pin in the oscilloscope, and the frequency is set to the C1 and C3 pads.
Check that it is output while switching.

(4) Then, mount the analog part. Three SA612. And bypass capacitors around R, C, and FB.
I will attach it. Finally, solder R and C around the bridge and around the RX port. 390 Ω of R37 and R41
Only use 1005 size. Please note that the chip is smaller than the land. Two in the tester
If you check one of the ports, it should be almost accurate 50Ω each.

In this state, connect to the PC and open the serial console. Output contents of waveform buffer with dump command
I will let you. After repeating several times, if something is seen, it is normal (this data is 5kHz sine wave
1 ms 48 samples for 5 cycles).

```
ch> dump
F045 0000 E03A 0000 DD4E 0000 E8B5 0000 FDC3 0000 13BC 0000 2108 0000 217E 0000
139D 0000 FD9B 0000 E89A 0000 DD48 0000 E049 0000 F067 0000 06FC 0000 1AA9 0000
2351 0000 1D66 0000 0B51 0000 F48C 0000 E288 0000 DCB1 0000 E56D 0000 F929 0000
0FBA 0000 1FC6 0000 22B3 0000 174B 0000 023E 0000 EC45 0000 DE78 0000 DE82 0000
EC63 0000 0264 0000 1766 0000 22B8 0000 1FB7 0000 0F99 0000 F904 0000 E557 0000
DCB0 0000 E29B 0000 F4B0 0000 0B74 0000 1D77 0000 234E 0000 1A92 0000 06D6 0000
```

(5) Solder the SMA connector and lever switch (lever switch is optional).
(6) Attach the flexible board of the LCD. Apply flux to the substrate in advance and align the flexible and LCD position. Let the solder flow to the part where there is a hole in the flexible pattern so that the solder also penetrates the back of the flexible.

The Here we will add a jumper due to a wiring leak on the LCD RESET. 2 using thin wire such as urethane wire. Connect pin #9 and pin #9 and pull up RESET. Weak connection of flexible, LCD for work later. If you lift it by lifting it, the connection may be disconnected. In such cases Kapton tape etc. It is good to reinforce it with a thin tape (Photo 3).

Try turning on the power, a white screen will appear for a moment and then it will be cleared black, and it will be OK if the graph is displayed in about 1.5 seconds.

The Operate the touch or lever and check that the menu can be operated.

Proofreading

You need a calibration kit to use the network analyzer. Self-made using SMA connector. Can be Open, short, load (100Ω // 100Ω = 50Ω) from the left. Measurement of isolation. Needs another load (50Ω terminator). In addition, through adapters and cables are necessary. The If there is an attenuator of around 6 dB or 10 dB, confirmation of passing attenuation, mismatch (incomplete reflection termination) can be used for confirmation. For example, if you connect a 6 dB attenuator and leave the opposite open, the return loss is 12 dB.
In calibration, first determine the reference plane, connect the calibration standard to that position, and measure.

For calibration operation, the type of calibration is determined by which standard is measured before pressing CAL> DONE. (First, there is no need to select the calibration type)

- Through only → Response calibration (pass)
- Response calibration (through) with through and isolation → isolation correction
- Open only (or short only) → response calibration (reflection)
- Open (or short) and load → Response calibration with directionality correction
- Open, short, load → full 1 port calibration (OSL calibration)
- Open, short, load, isolation, through → enhanced response calibration

Through means direct connection between ports, and isolation means both ports closed by load (50Ω)

It is about the state.

**operation**

The basic usage is as follows.

1. Set the frequency range (STIMULUS> START / STOP or CENTER / SPAN)
2. Calibrate (CAL)
3. Select display format and channel (DISPLAY)
4. Save

You can change the display format and channel selection at any time. The order of operation is arbitrary and affects the calibration operation etc.

I will not give.

Changing the frequency setting will reset the calibration status (it will be uncalibrated).

In the initial state (when there is no stored data at 0)

- Scan range 1MHz-300MHz
- Trace 1: LOGMAG CH0 (Reflect)
- Trace 2: SMITH CH0 (Reflect)
- Trace 3: LOGMAG CH1 (Through)
- Trace 4: PHASE CH1 (Through)
- Marker 1: ON
- Not calibrated
It has become.
If you save the setting to SAVE 0, it will be loaded by default at the next startup. Calibration status is also saved.

If calibration is applied, CAL status is displayed. It is hidden when not applied.
C * is in the state where unsaved calibration value is applied (it disappears when the power is turned off). C0 to C4 are 0 to 4 Indicates that the saved calibration value is applied to one of the save locations. Save Unsaved It will change to this state when saved by operation.

The letters below C indicate that the following error terms have been applied.
D: Directivity, R: Reflection Tracking, S: Source Match, T: Transmission Tracking, X: Isolation

Menu
It is possible to operate the menu by the touch panel or lever. Items and functions are provisional and not yet fulfilled
There is also the content of the dress. The feeling of use of the menu is a feeling that both lever and touch are still developing.

<table>
<thead>
<tr>
<th>DISPLAY</th>
<th>FORMAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>o TRACE</td>
<td>o FORMAT</td>
</tr>
<tr>
<td>■ 0</td>
<td>■ LOGMAG</td>
</tr>
<tr>
<td>■ 1</td>
<td>■ PHASE</td>
</tr>
<tr>
<td>■ 2</td>
<td>■ DELAY (not installed)</td>
</tr>
<tr>
<td>■ 3</td>
<td>■ SMITH</td>
</tr>
<tr>
<td></td>
<td>■ SWR</td>
</tr>
</tbody>
</table>
### Known issues

- Do not use LiPo related circuits on the schematic / board. It did not work at 3.7V due to lack of power supply voltage for.
- I was planning to save to the SD card, but due to lack of memory, I am on hold at this point.
- There is no plan to use the LCD side push button (determined as unnecessary).
- The gain of the mixer changes with the power supply voltage, which causes an error (the total reflection amplitude after calibration deviates from 1). Electricity different sources may change the measured value. Use the same stable USB power supply as a countermeasure please.
- After OSL calibration, the unit circle of total internal reflection with delay such as open tip on the tip is shifted downward. (In OSL calibration the upper and lower arcs are shifted downward as a result of combining the OPEN / SHORT / LOAD three points. Response calibration that does not deviate). The cause is ripple due to signal source mismatch (source match). It has improved considerably it has not been resolved enough.
- The display sometimes hangs while operating (the LCD display and the LED do not change). Please turn on the power again please.
- 0 base (other than Marker) and 1 base (Marker) are mixed.

### Document

- **STM32F072C8T6**
- **TLV320AIC3204**
  - [http://m.ti.com/product/jp/tlv320aic3204](http://m.ti.com/product/jp/tlv320aic3204)
    - (Chip register setting)
- **Si5351A**
- SA612AD
- LCD ILI9341
- Applying error correction to Agilent AN1287-3 network analyzer measurement
- Handbook of Microwave Component Measurement with Advanced VNA Techniques,
  Joel P. Dunsmore, John Wiley & Sons 2012

Web / Forum
- http://ttrftech.tumblr.com/kit/nanovna/
- https://github.com/ttrftech/nanovna/

Happy RF Hacking!
  Edy555 at gmail.com

EXTRA:
All references to the NanoVNA on TTRFTECH:  https://ttrf.tk/tags/nanovna/
These pages have excellent original design notes from edy555!!!
Use Google to translate from Japanese to your native language.
https://ttrf.tk/posts/2013-02-12-building-vna-vnwa-using-gnuradio-and-dds-ad9859-1/
https://ttrf.tk/posts/2016-09-11-si5351a-configuration-how-to-and-signal-quality/

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